SCHEDULE 1

Train Technical Specification

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1 General 1

1.1 Introduction 2

This specification describes the requirements for four fleets of Trains and supporting Equipment. The Trains are intended for the Piccadilly, Central, Bakerloo and Waterloo & City lines. 1961

Throughout this specification, text in italics is information or advice to assist the reader in understanding the requirements. Text in italics is not requirements. 5927

Where documents and standards are referenced in the requirements, the Manufacturer shall use the specific issue or revision number as listed in the Reference Documents section at the end of the specification. 7074

The Trains and Equipment will be part of an upgraded railway comprising new signalling, control and communication, traction power upgrades, platform edge doors (on some lines) and upgraded maintenance depots. 1963

Each fleet will have the capability of operating in an unattended mode. 1964

1.2 System Description 3

Due to the specific conditions of each line, the final state of the upgraded lines is expected to vary from line to line. The envisaged final states are: 1965

- *Piccadilly line - part attended (South Harrow to Uxbridge) and part unattended (remainder of the line);*
- *Bakerloo line - attended;*
- *Central line - unattended;*
- *Waterloo & City line - unattended.*

There will be a number of migration stages to convert each line to its final state. 1971

All Trains for all lines shall be capable of operating in any migration state. 6943

Where the upgrade of Trains and signalling on a line do not coincide, the Purchaser may initially operate the Trains using manual driving and with train protection provided by trainstops/tripcocks. There will be a data transfer mechanism to and from the Train both to support the operation of the Train in service and for maintenance support. 5998

Once the Train and compatible signalling (as a minimum the ATO/ATP parts of RCS) are in operation, the line will be operated in an attended mode where the Railway Control System (RCS) drives the train and an attending Train Operator carries out specific tasks to ensure safe and efficient operation. The Train Operator's role in opening and closing the doors and starting the Train may be active (doing) or passive (monitoring). 6941

Once platform edge doors have been added and the RCS has the required enhanced functionality of an Operational Control System (OCS) (equivalent to GOA4), the line may be operated in an unattended mode. 6942

The Trains will initially be operated with a cab but later the Trains may be converted to a configuration of internal space which is more appropriate for the latter railway migration stages. The conversion of the cab will entail removal of the cab/saloon partition to offer more space for passenger accommodation. This space will include an operating position with controls and facilities for non-routine operations (e.g. train recovery, infrastructure inspections), movement of the train around the depot and sweeping. 2086

When a line can operate in an unattended condition, this will include maintenance stabling areas and stabling sidings so that Trains can be rapidly entered into and withdrawn from passenger service at the start and end of each traffic day. Manual driving will still be used to transfer Trains into and out of the depot maintenance areas. 1977

The introduction of the new fleets and the necessary inter-running with the existing fleets may require changes in the traction current limit and the regenerated voltage limit. It is expected that these changes will be accommodated through changes to parameters in the traction software, updated locally on the Train, or possibly triggered by messages from the RCS or by messages from the Off-Train Communications (OTC). 3129

1.3 Reliability, Availability, Maintainability and Safety (RAMS) 4

1.3.1 RAMS - General 5029

The Train shall be safe, reliable and fit for the purpose of operating on its intended routes on the LU network wherever and however it is deployed. All safety risks shall be eliminated or demonstrated to be ALARP. 6408

Reference shall be made to BS EN 50126 'Railway Applications. The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS). Part 1: Basic requirements and generic process.' 5786

Reference shall be made to British Standard BS EN 50128:2011 'Railway Applications. Communication, Signalling and Processing 5787

Systems. Software for Railway Control and Protection Systems'.

As far as is reasonably practicable all faults shall be detected and reported by the Train including those within the Train Control and Management System (TCMS), condition monitoring equipment, standby and backup systems. 2717

Backup and standby systems shall be exercised automatically during normal operation to ensure that hidden and dormant failures are revealed. 5780

Deployment of standby or backup systems shall be recorded and reported automatically. 5781

1.3.2 Reliability 8

High levels of reliability are essential to minimise the chance of a Train causing a delay to service or becoming stranded between stations. 1988

No single point failure shall immobilise the Train. Exceptions to this, such as a broken axle, shall be agreed with the Purchaser on a case-by-case basis. 4713

The Train design shall incorporate efficient means of recovery from all foreseeable failure modes. 2480

The Manufacturer shall provide Failures Modes and Effects Criticality Analyses (FMECAs) for the Train and Equipment. An initial FMECA shall be provided as part of the tender submission. 6183

The Manufacturer shall, based on the failures identified in the FMECA, state how each failure is reported, what actions are needed to resolve it, and how quickly those actions can be taken. 6184

Actions to resolve shall include initial actions required whilst the train is in service and remedial activities within the Depot.

The Train diagnostics shall detect and report on all immobilising failures. Exceptions to this, such as a broken axle, shall be agreed with the Purchaser on a case-by-case basis. 6186

The Train diagnostics shall detect and report on all Service Affecting Failures. Exceptions to this, such as a broken axle, shall be agreed with the Purchaser on a case-by-case basis. 6187

All failures diagnosed and reported shall include sufficient information to allow an operator to resolve. 6185

1.3.3 Maintainability 4283

The Purchaser is currently developing the use of a predictive and preventative approach to its asset maintenance. The strategy will be based on assessing current and forecast asset condition. The strategy considers the use of remote asset condition monitoring, noting that the Purchaser has increased potential for condition monitoring as part of its maintenance regime and operational model through the introduction of modern assets with self-monitoring, self-diagnosis and potential for use of real-time data. 1484

LU Standard G0213 'Condition Monitoring' gives guidance as to how this can be applied to the train design process.

The application of predictive condition monitoring can be applied throughout the Train but it is expected to be particularly applicable to doors, air, HVAC, bogies, traction and braking equipment. 4385

The maintenance of the Train shall be developed using British Standards BS ISO 17359:2011 'Condition Monitoring and Diagnostics of Machines - General guidelines'; BS ISO 13379-1:2012 'Condition Monitoring and Diagnostics of Machines - Data Interpretation and Diagnostic Techniques Part 1: General Guidelines' and BS ISO 13374-1:2003 'Condition Monitoring and Diagnostics of Machines - Data Processing, Communication and Presentation - Part 1: General guidelines'. 1485

A RAMS analysis shall be used to determine the optimum maintenance approach to achieve asset performance and whole life cost objectives. This shall assess Train system design and the use of preventative, corrective and condition based asset maintenance strategies based on current and forecast asset condition to determine the most appropriate and effective solution. 5783

The analysis conducted as part of the design shall determine the optimum maintenance strategy for each part of the Train.

Whilst asset condition data may be used to support inspections, the aim should be to move towards eliminating manual inspections. Remote asset condition monitoring can be used to support existing inspections or eliminate manual inspections, and a mixture of manual and automated inspections may be proposed. (e.g. detection of wheel cracks and measurement of thermal condition could be undertaken automatically and eliminate the need to undertake manual wheel inspections.) 1486

The Manufacturer shall define the details of how the maintenance interventions and monitoring supports maintenance and the detection of degradation. This shall include: 1487

- The characteristics within which an asset's condition is determined to be acceptable. These characteristics may be refined as knowledge of the asset increases.
- The method of obtaining data, e.g. through retaining manual inspections, or through the use of monitoring equipment

located either within the train or remote from the Train.

Use shall be made of appropriate and targeted condition monitoring and fault detection systems to enable the identification, recording and reporting of developing defects and deteriorating performance sufficiently early to enable pre-emptive action to avoid an in-service failure and to avoid the need to manually conduct pre-service checks. 3382

An operational concept for condition monitoring shall be developed and agreed with the Purchaser as part of the Train Maintenance Regime. 883

Any particular methodology for configuring logic and rules for generating Notifications, as a result of condition monitoring, shall be agreed with the Purchaser at the design stage. 885

Use of closed algorithms which are not visible to the Purchaser (colloquially known as 'black box software algorithms') is generally unacceptable. 4950

It is recognised that there may be specific situations where closed algorithms need to be used. In such circumstances particular attention should be paid to ensuring that there is sufficient understanding of the output from these algorithms by the Purchaser as well as the ability to configure priorities and filter out low priority Notifications.

1.3.4 Safety Engineering 4282

1.3.4.1 Safety Engineering - General 5782

The safety criticality of Trains and Equipment shall be assessed and identified by using the requirements of the sections titled "Safety Critical Components" and "Hazards and Assessments". 6177

1.3.4.2 Safety Critical Components 6167

The safety criticality of components shall be assessed using a formal documented and auditable process to assign a safety criticality rating. 6168

Components shall be categorised into three groups of safety criticality: 6169

a) Low risk – where failure of the component to perform as designed has no effect on safety;

b) Medium risk – where the consequences of failure are moderate – i.e. where the likelihood of failure is low and impact on the railway of failure is not significant;

c) Critical risk – where failure would or could have a significant impact on the railway.

Failures Modes and Effects Criticality Analysis (FMECA) or an equivalent technique shall be used to give quantified safety criticality assessment to components where the result is not obvious from an 6171 initial overview of a component.

The assessment of safety criticality of a component shall be carried out as stated below unless an equivalent process is used instead. Any equivalent process shall be agreed by the Purchaser before assessment commences. 6172

For each component, the ratings for risk and consequence in the first two tables below shall be combined using the third table to reach a final rating for each item and its consequential position in the low, medium and critical category.

Risk Table:

Risk	Rating	Frequency of failure
High	A	One failure in 12 months or worse
Medium	B	One failure per 10 years or worse, but better than one failure per 12 months
Low	C	Less than one failure per 10 years

Consequence Table:

Consequence	Rating	Examples, in rolling stock context
Major loss	1	Any loss of life or major injuries. Delays to train services in excess of 20 minutes. Damage or faults resulting in a train being withdrawn from service for more than 7 consecutive days.
Serious loss	2	No loss of life but minor injuries. Delays to train service of between 2 and 20 minutes. Damage or fault resulting in cars comprising a unit being out of service for more than two consecutive peak periods, but not more than 7 consecutive days.
Not significant	3	No loss of life, injury or illness. Delays to train services of less than 2 minutes. Damage or faults resulting in cars comprising a unit being withdrawn from traffic for not more than two consecutive peak periods.

Safety Criticality Table:

			Risk		
			High	Medium	Low
			A	B	C
Consequence	Major loss	1			
	Serious loss	2			
	Not Significant	3			

Key	
	Critical risk components
	Medium risk components
	Low risk components

All components shall be considered critical risk until they have been assessed. 6175

All records relating to the assessment of safety critical components shall be recorded in the design documentation for the Train. 6180

1.3.4.3 Hazards and Assessments 2723

The Manufacturer shall assess the Train design to demonstrate that the changes resulting from the Train do not adversely affect the LU Corporate Risk model. 201

The Manufacturer shall contribute information to assist the Purchaser in updating the LU Corporate Risk model as a consequence of the introduction of the Train. 5815

The information for the LU Corporate Risk model shall be supplied by the Manufacturer in a format suitable for import to the Isograph Reliability Workbench software. 5816

The information for the LU Corporate Risk model shall be created by the Manufacturer by taking each of the top event risks and producing fault and event trees for each risk resulting from the introduction of the Train. 5817

The information for the LU Corporate Risk model shall be provided at each formal design review stage and shall be updated thereafter as the design matures. 5818

The hazards associated with the following top event risks shall be explicitly addressed: 2689

- arcing;

- collision between trains;
- collisions other than between trains;
- derailment;
- explosion;
- PTI;
- power failure;
- train fire;
- ventilation.

Controls shall be applied to mitigate the following specific risk events: 2691

- passenger door incident;
- passenger accident;
- structural failure of train component or of car structural member;
- stalled train;
- failure of emergency lighting and ventilation;
- failure of external lights;
- failure of warning horn or whistle;
- communications failure;
- brake failure.

The following systems and components shall also be considered when assessing hazards associated with top event risks: 2694

- those involved in mitigating the risk of platform train interface incidents (including: flooring, doors, door opening and closing systems, Correct Side Door Enable (CSDE), One Person Operation Platform to Train CCTV (OPO CCTV), Passenger Emergency Alarm Brake (PEAB));
- those involved in mitigating the risk of derailment (including: wheels, bogies, bearings, axles, suspension, mountings, brakes, braking systems and controls);
- those involved in mitigating the risk of collision (including: speed systems, propulsion and their control systems, direction control, Electromagnetic Compatibility (EMC), brakes, braking systems and controls, interface with signalling);
- those involved in mitigating the risk of fire (virtually everything);
- those involved in mitigating the risk of arcing (virtually everything but specifically protection);
- those involved in mitigating the risk of ventilation failure;
- software in safety systems;
- communication systems;

- auxiliary systems;
- lighting systems;
- any potential disabling failure
- any other relevant system or serialised component.

Total Failure Rates, taking all failure mechanisms in aggregate, shall not exceed: 2697

- for Vital Components, Vital Systems, and Vital Functions: 1 in 10^9 train kilometres;
- for High Integrity Components, High Integrity Systems and High Integrity Functions: 1 in 10^7 train kilometres.

Vital and High Integrity: An element, system or control and monitoring subsystem that provides essential services on the Train, and that ensures the rolling stock can be operated safely and reliably both in normal service and during degraded modes or emergencies.

Failures for systems, functions or components classified as Vital include: 5968

System, function or component	Failure condition(s) (indicative)
Wheelset integrity	Wheelset failure. Note - subject to approved axle non-destructive test programme.
Wheelset electrical conductivity	Electrical resistance greater than 0.01 ohms between the wheels of an axle when tested statically.
Axle rotation	Locked axle resulting from failure of bearings, gears or motor.
Structural integrity of carbody and bogie	Structural failure of bogie. Structural failure of carbody. Note: - excludes damage due to derailment or collision, within specified crashworthiness criteria. - excludes damage due to incorrect lifting or jacking. - subject to approved axle non-destructive test programme.
Emergency brake	Failure to respond to, e.g. Trainstop/Tripcock, operator vigilance device, loss of ATP permission, loss of train continuity. Traction not inhibited when emergency brake demanded. Loss of emergency brake control.
Traction / Doors Interlocking	Motoring with door not proved closed/locked.
Detrainment system	Failure to deploy.
Underframe equipment	Equipment becomes detached. Note: - equipment to remain securely attached during collision/derailment as far as practicable. - excludes collector shoes. - excludes small components where shown not to present a significant hazard if detached.
Train mobility	Train immobilised as a result of a single failure.
Saloon door opening	Door opens without valid command.
Doors closed interlocks	Door provides false closed/locked indication.
Gangway	Becomes detached or loses integrity. Fouls the gauge.
Inter-car coupling	Cars become separated.

Failures for systems, functions or components classified as High Integrity include: 5967

System, function or component	Failure condition(s) (indicative)
Brake release	Service brake cannot be released from operating position. Emergency brake cannot be released (after resetting initiation condition(s)) from operating position.
Service brake	Failure to apply on demand.
Traction	Failure to move train unassisted.
Overspeed protection (non-ATP)	Failure to limit overspeed, including after tripcock trip.
Control Supply	Loss of control supply, including loss of control supply to individual vital or high integrity functions.
Compressed air supply	Loss of supply (whole train).
Emergency lighting	Failure to provide specified illumination for specified period.
Emergency ventilation	Failure to provide specified emergency ventilation for specified period.
Saloon door operation	Loss of door open/close control, including emergency open.
Saloon door control	Door(s) can open without a valid CSDE signal. Door(s) can open when not adjacent to a useable part of a platform. Door(s) can open at speed.
Radio / deadman alarm	Failure to report loss of vigilance.
Passenger Emergency Alarm	Failure to raise an alarm when operated. Note - excludes talkback facility.
Public Address	Announcements unclear or inaudible.
Headlights, taillights and yellow indicator lights	Failure to illuminate.
State selection	Inconsistent or conflicting states able to be selected on the train leading to maloperation or user confusion.

Any safety isolation, bypass or over-ride features proposed shall be specifically considered under the safety review process with the participation of the users. 2715

The risks associated with the use and misuse of safety isolation, bypass or over-ride features shall be identified and action taken to ensure they are ALARP. 2716

1.3.5 Fault Tolerance and Degraded Operations 3228

The Train shall provide a high level of system resilience and fault tolerance. 3678

Fault tolerance shall be used selectively to support availability. 3225

Fault tolerance shall be used to enable a Train with a defect to continue to operate in service until it can be removed without service disruption. 6128

Fault tolerance shall be used to enable a Train with a defect to continue 6129 to operate in service without demonstrable consequences to the passenger environment.

Loss of redundancy shall be monitored and reported. 3679

Failures in the Train systems shall be automatically resolved by the TCMS sufficiently to enable continued operation of the Train to the depot. Exceptions to this, such as a broken axle, shall be agreed with the Purchaser on a case-by-case basis. 6130

The Train shall be designed to minimise the risk of it becoming stalled and the likelihood of requiring passengers to be evacuated and being required to walk from the Train to the next station. 3665

Design reviews shall demonstrate the use of the following techniques for managing failures: 4949

- Designing out, as far as is practical, the types of fault which can cause a Train to be immobilised;
- Identifying those faults which cannot be designed out, and for each, putting in place a mitigation which limits as far as possible, the time to recover and to rectify the fault;
- For those remaining, for which there is no ready mitigation, putting in place suitable recovery procedures so as to minimise as far as possible any disruption.

Extensive testing of both routine operation (including errors in operation) and a range of fault scenarios shall be undertaken, initially using the TCMS simulator, and then statically and dynamically on an appropriate test track, so as to identify any design defects for which a corrective modification is required. 6944

When switching between redundant systems automatically, spurious fault information shall not be generated. 3226

All defects which can lead to a degraded condition shall be documented with the recommended actions necessary to minimise the consequence. 6199

The following are possible degraded states or conditions when the Train is: 6200

a) Able to remain in passenger use ("Remain"). Some loss of function which does not have a safety implication, i.e. loss of one level of redundancy or a defect which does not affect current service;

b) Able to continue in passenger use for only a limited period ("In service to depot"). Risk of passenger carriage increased but does not exceed the risk of detrainment at given locations; use of procedures to manage risk short-term; fault may worsen with time; item of safety equipment that is only needed when called upon (safety incident) is not working; fault only affects one driving position – can be driven from another driving position in one direction only; defect could seriously *affect journey time or station dwell times; Train could stall if left in service for a long time;*

c) Taken out of service without passengers being conveyed ("Withdraw"). Level of risk inappropriate to the conveyance of passengers or the Train is likely to stall;

d) Not able to operate – requiring rescue ("Sit-down"). Train cannot move under its own control; continuing to operate the Train would exacerbate damage to the Train and or the infrastructure.

1.4 Environmental Information 5

1.4.1 Environment - General 6454

The Train and Equipment shall be designed and manufactured to operate (including start-up and shut down) at full performance under reasonably expected climatic conditions encountered in the operating environment. This shall include changes in environment due to climate change and the consequential extreme weather events. 2099

The Train shall be designed and manufactured to cope with the fluctuations in climatic conditions between open section and tunnel section running that occur throughout the routes over which that Train operates. 2101

Emissions from consumable materials or components used on the Train which are deposited in tunnels or elsewhere on the infrastructure or which become airborne particles shall be controlled so that they do not constitute an unacceptable risk to health. 2103

Unless otherwise stated, the environmental parameters to be used for Train design shall be in accordance with BS EN 50125-1:2014 'Railway Applications. Environmental Conditions for Equipment - Part 1: Rolling Stock and On-Board Equipment'. The Altitude Class shall be A2, Temperature Class T1 and Snow Class S1. 5307

All Train equipment shall be immune to the effects of very high levels of humidity. 5014

The generation of dust shall be minimised by maximising the use of dynamic braking without affecting brake performance. 2104

Waste heat shall be minimised. 6559

Waste heat shall be ducted and directed away from other Train systems and from passengers both on the Train and on platforms. 2105

The heat emitted by the Train and its principal components under a range of different operating conditions shall be declared at tender and confirmed during the design review and type test stages. The 4294 operating conditions shall include motoring, braking, standing at rest after a full service brake and standing at rest after an emergency brake.

The Train performance and function shall not be affected by dust, pollen, seeds and similar airborne particles. 2108

Experience has shown that introducing new trains into existing tunnels results in a significant increase in airborne dust caused by the different aerodynamic performance of the train disturbing longstanding accumulations of settled dust. 2260

The composition of tunnel dust can include the following elements: mostly iron with smaller contributions from calcium, chlorine, sulphur, sodium, silicon, carbon and aluminium. 2337

In April/May 1999, dust monitoring showed the main constituent to be iron, this element accounting for between 38.3% and 52.2% by mass. Silicon, calcium, aluminium and sodium were also present in significant quantities. 2516

In April/May 1999, dust monitoring showed that the total organic carbon content of the samples was between 8.72% and 12.27%. This would have been derived chiefly from clothing and seating fabric, human hair/skin, paper and wood. 2517

In 2008, a report on PM10 particulate concentrations on one of the tube lines indicated that concentrations might typically range between 50 and 300µg/m^3. 2518

In January 2009, measurements on a tube line using a scanning electron microscope indicated that 63% of the dust particles (by number) were less than 1 micron in size, with about 28% between 1-5 microns, about 6.5% between 5-10 microns and with the remainder being greater than 10 microns in size. 2519

There shall be no uncontrolled emission or spillage of fluids under normal operating conditions. 2111

Adhesion improvement aids, windscreen washer, ice prevention and other such fluids shall be dispensed accurately in volume and location. 2112

The traction supply energy consumed by the Train shall be recorded by each propulsion equipment and reported to the RCS. 2436

The traction supply energy recording shall include, for each inter-station section, the energy passed from supply to Train and from Train to supply. 2456

The operation of the Train shall not be adversely affected by the presence of and interaction with the types of litter and debris commonly 2261 encountered on London Underground.

The types of litter encountered on the London Underground include newspapers, batteries, pens, plastic bags, plastic bottles, plastic bottle caps, drinks cans and food wrappings such as polystyrene containers and metallic foil. Debris typically can include coins, mobile phones, hairclips and buttons. 2275

1.4.2 Adhesion Levels and Definitions 1850

Adhesion levels (coefficient of friction) which are either known to occur on the railway or are reasonably foreseeable, and their descriptions, as used elsewhere within this specification, are as follows: 2189

Adhesion Description	***Adhesion Level***	***Description of typical conditions***
Good	*> 0.2*	*Clean, dry rail in TEBD*
Satisfactory	*0.12 – 0.2*	*Steady moderate or heavy rain; "wet rail (steady moderate or heavy rain)" in TEBD*
Adequate	*0.10 – 0.12*	*Steady light or light rain; "wet rail (steady light rain)" in TEBD*
Marginal	*0.08 – 0.10*	*Degraded - Fine rain or drizzle, dew, mist, fog, snow - clean rail, light leaf film contamination*
Poor	*0.06 – 0.08*	*Degraded - Onset of rain, very fine rain or drizzle, dew, mist, fog or snow, light leaf film contamination*
Low	*0.04 – 0.06*	*Tunnel with excessive lubricant, mist, fog, dew, drizzle, onset of light rain (0.05-0.08) Snow, ice (0.02-0.06). Damp, leaf fall contaminated (0.02-0.06) in leaf fall vulnerable areas*
Exceptionally Low	*0.02 - 0.04*	*Snow, ice (0.02-0.06). Damp, leaf fall contaminated (0.02-0.06) in leaf fall vulnerable areas*

The level of adhesion experienced depends on a number of factors and it is not possible to define precise combinations of conditions which will cause a particular level of adhesion. The term Compromised Adhesion is any adhesion level which is not high enough to avoid wheelspin or wheelslip/wheelslide for the applied level of acceleration or braking.

The lines over which the Trains operate suffer from areas of Compromised Adhesion. This includes sustained stretches of leaf film induced exceptionally low adhesion conditions. 3013

However, Compromised Adhesion can occur as a result of contamination and/or moisture. Because such factors can change between trains (e.g. a light shower of rain or the formation of dew), each train needs to be equipped with its own capability to counter such conditions and maintain its performance.

The Train shall have a Compromised Adhesion braking capability such that it can achieve its normal ATO braking performance under damp or wet uncontaminated track conditions.

Under contaminated track conditions, the ATO brake rate may be reduced in line with the output of the Adhesion Management System Condition Assessment Software (AMS CAS).

Contaminated refers to conditions where Compromised Adhesion occurs due to the presence of contaminants which are not purely water based, e.g. leaf film or oil contaminants.

1.5 Design Requirements 6

1.5.1 Design Life 7

The Train shall be designed for a service life of 40 years. 1716

The design life shall apply to each migration state and to all temporary equipment and installations so that the Train can service any migration state for the design life of the Train. 1974

The Manufacturer shall implement an obsolescence management strategy throughout the life of the contract, including the period of service support, in accordance with LU standard S1043 'Obsolescence Management'. 167

Reference shall be made to LU standard G0043 'Obsolescence Management'. 7144

Reference shall be made to British Standard BS EN 62402:2007 'Obsolescence Management - Application Guide'. 5785

The Train shall be designed so that items can be readily replaced as part of an upgrade or refurbishment, to address either ambience or obsolescence. This shall include, but not be limited to: 1747

- saloon interior panels, flooring, draught screens, grab poles and hand rails;
- passenger seats;
- saloon lighting;
- customer information systems – audio and visual;
- Closed Circuit Television (CCTV);
- electronic systems and equipment;
- train control and monitoring systems, including condition monitoring;
- the ability to change software parameters, including by the Purchaser. The extent of parameter modification possible by the Purchaser shall be declared at tender and confirmed during the design review stages;

- the ability to change software platform(s).

1.5.2 Capacity 9

The Manufacturer shall provide the greatest number of seats possible, the largest floor area, the widest doors and sufficient standback depth. 2515

The Stage 4 tender evaluation model capacity evaluation calculation should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with this requirement.

The small diameter of tube tunnels limits the size of the train that can operate in them. The high level of passenger demand, especially in peak times, means that every effort must be made to maximise the volume of usable passenger space in the Train.

1.5.3 Reduced Energy Consumption 10

The Train shall minimise its consumption of energy and its emission of heat in tunnels. 3018

The Stage 4 tender evaluation model energy evaluation calculation should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with this requirement.

1.5.4 Train Mass 14

The Train mass shall be minimised. 3021

There is no explicit weight restriction or maximum axle loading. 3028

The Stage 4 tender evaluation model energy evaluation calculation and the track damage evaluation calculation should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with the requirement to minimise the Train mass. 3026

1.5.5 Software Management 15

The Train Support Software ethernet port interface(s) on the Train shall be directly compatible with an industry standard laptop PC so that bespoke interfacing hardware such as special leads, interface boxes and dongles shall not be required between them. 5150

The Train Support Software used to analyse data from the Train shall enable the data to be presented on paper by a high-resolution colour printer. 4111

Measures shall be taken to ensure that configurable parameters and settings cannot be changed without appropriate authorisation. 4691

Measures shall be taken to ensure that software cannot be uploaded to the Train without appropriate authorisation. 5151

Measures shall be taken to ensure that data logs cannot be deleted without appropriate authorisation. 5152

A risk assessment may be used to assess the risks and determine a satisfactory solution.

1.6 Line Description 18

1.6.1 Piccadilly Line 3041

The Piccadilly Line is a deep level tube line of the London Underground network which runs from Cockfosters in the north of London to Heathrow Airport and Uxbridge in the west of London via the city centre. Part of the upgrade will enable and extend operation to Ealing Broadway. 3043

The Heathrow Airport and Uxbridge lines diverge at Acton Town and there is a loop at Heathrow serving Terminals 1, 2, 3 and 4, and a 2.4km branch from the loop at T1,2,3 to Terminal 5. 3047

The Piccadilly line shares tracks with the District Line between Acton Town and Hanger Lane Junction (between Ealing Common and North Ealing) and the Metropolitan Line between Rayners Lane and Uxbridge. Trains may also operate on the adjacent District Line tracks between Barons Court and Acton Town. 3048

The Piccadilly line operates above ground between Bounds Green and Arnos Grove, Oakwood and Cockfosters, Barons Court and Uxbridge/Hounslow West. The remainder is deep level single bore tube apart from a brief excursion to the surface to cross the River Crane to the east of Hatton Cross. 3049

The Piccadilly line has two dedicated depots at Northfields and Cockfosters and is currently operated by 1973 Tube Stock. The Line is 71km long and serves 53 stations. 3050

The Train for the Piccadilly line shall be compatible with the most onerous track features found on the Piccadilly Line: 1561

Feature	Dimension	Location
Tightest Single Curve (with cant)	64m	Knightsbridge
Tightest Single Curve (without cant)	61m	Down Street / Wood Green
Tightest Reverse Curve (with cant)	93m to 93m	Holborn to Covent Garden WB
Tightest Reverse Curve (without cant)	61m-3m-61m	2 x A switch in tunnels
Tightest Vertical Hog Curve	498m	WB Hammersmith - Ravenscourt Park
Tightest Vertical Sag Curve	500m	WB Acton Town - Ealing Common
Maximum Cant	175mm	WB Bounds Green - Arnos Grove
Steepest gradient	3.33%	Manor House to Finsbury Park

Note 1. The 'A' switch is a standard London Underground switch which has a minimum 61m radius. Two 'A' switches can be used back to back to form a reverse curve with a 3m straight section between the curves.

Note 2. The tightest canted reverse curves are stated however the case of an uncanted reverse curve with a track twist fault equivalent to the maximum value allowed under the track maintenance rules will be the worst case and shall be considered. This maximum value is 1 in 250 measured on a 10m base (reference should be made to LU Standard S1159 'Track - Dimensions and Tolerances').

1.6.2 Central Line 3042

The Central line is a deep level tube line which runs from Epping in Essex to Ealing Broadway and West Ruislip in the west via the city centre. 3051

The lines to Ealing Broadway and West Ruislip diverge at North Acton and there is also a loop at the east end of the line between Leytonstone and Woodford. 3052

The Central line operates above ground between White City and Ealing Broadway/West Ruislip and between Leyton and Epping and between Newbury Park and Roding Valley. The remainder is deep level single bore tube. 3053

The Central line has two depots, at Ruislip (between West Ruislip and Ruislip Gardens) and Hainault and is operated by 1992 Tube Stock. The line is 74km long and serves 49 stations. 3054

The Train for the Central line shall be compatible with the most onerous track features found on the Central Line: 2342

Feature	Dimension	Location
Tightest Single Curve (with cant)	63m	Shepherds Bush to White City WB (Caxton curve)
Tightest Single Curve (without cant)	45m	Marble Arch (crossover route)
Tightest Reverse Curve (with cant)	91m to 88m	Bank
Tightest Reverse Curve (without cant)	61m-3m-61m	2 x A switch in tunnels
Tightest Vertical Hog Curve	325m	Holland Park to Notting Hill Gate
Tightest Vertical Sag Curve	375m	Holland Park to Notting Hill Gate
Maximum Cant	148mm	EB Mile End - Bethnal Green
Steepest gradient	3.80%	Oxford Circus to Tottenham Court Road

Note 1. The 'A' switch is a standard London Underground switch which has a minimum 61m radius. Two 'A' switches can be used back to back to form a reverse curve with a 3m straight section between the curves.

Note 2. The tightest canted reverse curves are stated however the case of an uncanted reverse curve with a track twist fault equivalent to the maximum value allowed under the track maintenance rules will be the worst case and shall be considered. This maximum value is 1 in 250 measured on a 10m base (reference should be made to LU Standard S1159 'Track - Dimensions and Tolerances').

1.6.3 Bakerloo Line 3055

The Bakerloo line is a deep level tube line which runs between Elephant & Castle and Harrow & Wealdstone. 3056

The Bakerloo line operates in deep single bore tunnels between Elephant & Castle and Queen's Park and then above ground on Network Rail track shared with London Overground trains to Harrow & Wealdstone. 3057

The Bakerloo line is 23km long, serves 25 stations and is operated by 1972 MkII Tube Stock. There is one depot at Stonebridge Park. 3058

The Train for the Bakerloo line shall be compatible with the most onerous track features found on the Bakerloo Line: 3059

Feature	Dimension	Location
Tightest Single Curve (with cant)	85m	Piccadilly Circus SB
Tightest Single Curve (without cant)	55m	London Road Depot
Tightest Reverse Curve (with cant)	122m-92m	Regents Park to Oxford Circus SB
Tightest Reverse Curve (without cant)	61m-3m-61m	2 x A switch in tunnels
Tightest Vertical Hog Curve	1600m	Multiple occurrences
Tightest Vertical Sag Curve	1600m	Multiple occurrences
Maximum Cant	158mm	Waterloo - Embankment
Steepest gradient	3.30%	Approach road to London Road Depot

Note 1. The 'A' switch is a standard London Underground switch which has a minimum 61m radius. Two 'A' switches can be used back to back to form a reverse curve with a 3m straight section between the curves.

Note 2. The tightest canted reverse curves are stated however the case of an uncanted reverse curve with a track twist fault equivalent to the maximum value allowed under the track maintenance rules will be the worst case and shall be considered. This maximum value is 1 in 250 measured on a 10m base (reference should be made to LU Standard S1159 'Track - Dimensions and Tolerances').

1.6.4 Waterloo & City Line 3060

The Waterloo & City line is a deep level twin bore tunnel which runs between Waterloo and Bank stations and is operated by 1992 Tube Stock. 3061

The Waterloo & City line is 2.4km long and has a depot at Waterloo. 5788

There is no rail link from the Waterloo & City line to any other line, and single cars are delivered and removed by crane through the roof of the depot. 5789

In Waterloo depot restricted headroom limits the lifting of cars for maintenance to only two at a time. 5790

The Train for the Waterloo & City line shall be compatible with the most onerous track features found on the Waterloo & City line: 3062

Feature	Dimension	Location
Tightest Single Curve (with cant)	50m	Waterloo Depot
Tightest Single Curve (without cant)	61m	Single A Switch
Tightest Reverse Curve (with cant)	97m-174m	Waterloo to Bank EB
Tightest Reverse Curve (without cant)	61m-3m-61m	2 x A switch in tunnels
Tightest Vertical Hog Curve	1600m	Multiple occurrences
Tightest Vertical Sag Curve	1600m	Multiple occurrences
Maximum Cant	116mm	Approx 1.3 Km from Waterloo towards Bank
Steepest gradient	3.40%	

Note 1. The 'A' switch is a standard London Underground switch which has a minimum 61m radius. Two 'A' switches can be used back to back to form a reverse curve with a 3m straight section between the curves.

Note 2. The tightest canted reverse curves are stated however the case of an uncanted reverse curve with a track twist fault equivalent to the maximum value allowed under the track maintenance rules will be the worst case and shall be considered. This maximum value is 1 in 250 measured on a 10m base (reference should be made to LU Standard S1159 'Track - Dimensions and Tolerances').

1.7 Train General Arrangement and Configuration 19

1.7.1 Train Dimensions 2482

Trains for the Bakerloo and Piccadilly lines shall be no longer than 113m measured over body ends. 1978

Trains for the Central line shall be no longer than 134.4m measured over body ends. 1982

Trains for the Waterloo & City line shall be no longer than 70.2m measured over body ends. 1984

1.7.2 Train Configuration 2481

There shall be an open wide gangway between each car. 1980

Each car shall have no fewer than two double-doors per side. 1986

The Train shall be fitted with saloon cooling. 4847

1.7.3 Passenger Loadings 2483

The Tare mass shall be the sum of: 2484

- the car, or train, as appropriate, in operational condition, including full reserves of necessary consumables;
- the Train Operator.

The Full Load mass shall be the sum of: 2488

- any other authorised person accompanying the operator, for whom accommodation has been provided;
- passengers:
  - occupying all fixed seats;
  - standing in the vestibule areas of the saloon, at the rate of 5.6 passengers/m^2 of those floor areas;
  - standing in the inter-car gangway and non-vestibule areas of the saloon, at the rate of 4.2 passengers/m^2 of those floor areas.

The Crush Laden mass shall be the sum of: 2490

- any other authorised person accompanying the Train Operator, for whom accommodation has been provided;
- passengers:
  - occupying all fixed seats;
  - standing in the vestibule areas of the saloon, at the rate of 8 passengers/m^2 of those floor areas;
  - standing in the inter-car gangway and non-vestibule areas of the saloon, at the rate of 6 passengers/m^2 of those floor areas.

The total mass (as it relates to the car, or Train, as appropriate) associated with the Full Load condition shall be the sum of the Full Load mass and the Tare mass. 2491

The total mass (as it relates to the car, or Train, as appropriate) associated with the Crush Laden condition shall be the sum of the Crush Laden mass and the Tare mass. 2492

The mass of the Train Operator and any equipment carried by the Train Operator shall be assumed to be 75kg. 2493

The mass of the person, if any, accompanying the Train Operator and any equipment carried by that person shall be assumed to be 75kg. 2494

The mass of each passenger, including any luggage, shall be assumed to be 75kg. 2495

1.8 General Requirements 4254

All requirements shall be met in all migration states unless specifically stated otherwise. 4689

Requirements have been grouped under headings to aid readability only. All requirements shall have universal application, except where specifically stated otherwise. 4637

The Train shall be safe to use under all operating conditions including when the Train is Powered Off. 5917

Type testing shall be carried out with the Train in each of its available configuration states. Elements most likely to be affected by a change in configuration include Saloon Air Cooling, Saloon lighting, Traction and Braking performance. The Purchaser will decide which tests need not be repeated. 4690

When the time of day is displayed to the user, it shall show the daylight saving time (DST) during the daylight saving period. 5355

There is no requirement for time clocks that are internal to equipment to operate in any particular time system (GMT, BST or UTC etc.) as long as the presentation to the user is the correct local time. For clocks showing time to Train Operators, Maintainers and passengers the daylight saving time will be sufficient. For time showed on logged data and printouts it is suggested that UTC and daylight saving time are both shown so that the data recorded during the time when the clocks change can be shown correctly. 5357

The Train equipment shall automatically insert 29th February in leap years. 4098

The Train shall not suffer performance degradation, below that required by this specification, between Manufacturer defined maintenance intervals. 4464

The Manufacturer may enhance the performance requirements in this specification as necessary to meet this requirement.

All stored energy systems shall: 2074

- include appropriate safety devices;
- exhaust, isolate, discharge, etc. in a safe and timely manner;
- not fail so as to cause hazards to customers and staff;
- have the capability to safely dissipate any stored energy, if appropriate.

The Train and Equipment shall be protected against dust, water and snow ingress and shall provide the required functions and reliability 302 accounting for any residual ingress.

The level of sealing for equipment cases, boxes and enclosures shall be to IP67 in accordance with British Standard BS EN 60529:1992+A2 2013 'Degrees of Protection Provided by Enclosures (IP code)' except where it can be demonstrated to the Purchaser that a lower rating is adequate based on the equipment within and the location of the case, box or enclosure. Allowance shall be made for the degradation of seals over time. 2870

Equipment case sealing shall be designed such that repeated opening and closing of cases shall not affect the integrity of the sealing such that it degrades below standard before the next planned maintenance interval for that seal. 1841

A formal analysis shall be carried out to demonstrate that the design meets the operability requirements of this specification. 4982

Exterior mounted equipment shall not be positioned such that it could be used by staff as hand holds or foot holds when boarding the vehicle. 5094

Materials shall be: 5915

- suited to the environment in which they are required to perform their function;
- resistant to damage from substances in use on or about the railway.

Trains shall be required to operate for 22 hours per day every day of the week throughout the year. 2625

Trains shall be required to operate throughout the night on three consecutive nights each week. This may amount to approximately 90 hours of continuous running. The requirement for 90 hours of continuous running does not apply to the storage and consumption of sand and de-icing fluid for which other requirements in this specification apply. 2626

All parameters specified as being configurable shall be configurable by the Purchaser using the Train Support Software. 7039

1.9 Mock-Ups 25

1.9.1 Saloon Mock-Up 3535

A saloon mock-up is required to be provided to the Purchaser. The saloon mock-up is primarily for the use of the Purchaser however the Manufacturer may use it for demonstrating and validating aspects of the design to the Purchaser. 6152

The saloon mock-up shall be representative of the actual Train in terms of quality of interior and exterior finishes. 3540

The saloon mock-up shall have an exterior and interior which is representative of the proposed final build design. 3541

The length and composition of the saloon mock-up shall be sufficient to support the expected usage and to display the required fixtures and fittings in a representative configuration. 3543

The saloon mock-up shall be able to be configured to represent the saloon under the following operating position configurations: 6142

- with the cab installed;
- with the Saloon Operating Position (SOP) installed.

The saloon mock-up shall be able to be reconfigured between any two operating position configurations within two hours by two people. 6143

When the saloon mock-up is configured to represent the saloon with the cab installed, the mock-up shall include the J-door. 6144

When the saloon mock-up is configured to represent the saloon with the SOP installed, the mock-up shall extend to the end of the Train and include the SOP, the windscreen and the M-door. 6145

The saloon mock-up shall include an open wide gangway, a door vestibule, an area that can be configured to be either a wheelchair position or a multi-purpose area, a full-length seat bay, seats, flooring, windows, grab rails and poles, lighting, draught screens, ventilation grilles, interior trims, signs and labels, advertisements, electronic displays and Passenger Emergency Alarms. 3544

All CIS displays, advertising displays, and door indicator lights both inside and outside of the saloon mock-up, shall be operational and capable of demonstrating the system functionality by displaying a selection of content which is representative of what will be shown on each type of display in passenger service. 6523

It shall be possible to convert the wheelchair position and multi-purpose area of the mock-up to standard seating so that the mock-up can represent all types of saloon interior. The conversion between the different configurations shall take no longer than two hours by two people. 3545

The interior saloon lighting in the saloon mock-up shall be operational and representative of the production light fittings so as to enable measurements of the lighting levels as well as to demonstrate the lighting balance and ambience. Removable blackout covers for all windows shall be provided to facilitate this. 3550

The saloon mock-up shall allow the illuminance levels to be adjusted for individual light sources in order to agree settings. 3800

The passenger seating design and comfort in the saloon mock-up shall be consistent with the finished Train build. 3548

The saloon mock-up shall be sufficiently robust to allow it to be used by the public at publicity events. 3549

The saloon mock-up shall be fully operational when supplied from a UK 230V AC single phase power supply. 3553

1.9.2 Operating Position Mock-Ups 3536

The Manufacturer shall provide, at an early stage in the product development cycle, assurance of the ergonomic design of the operating positions by the construction and demonstration of mock-ups of: 6147

- A complete cab;
- A complete SOP.

The operating position mock-ups shall include seats, functioning internal lighting, indicators, electronic displays and the mechanical controls used to start and stop the Train. 3561

The operating position mock-ups shall be provided sufficiently early in the design cycle to permit comments received to be incorporated in the final design. 5792

1.9.3 Underframe Mock-Ups 3591

The Manufacturer shall construct mock-ups of part or all of the underframe so as to demonstrate that the Train can be maintained in the depot environment. 3592

The underframe mock-ups shall include representative centre pits and side pits as part of the demonstration. 4298

1.9.4 HVAC Mock-Up 6124

Pre-production tests of the saloon HVAC shall include a mock-up of the saloon interior. The saloon interior shall be of sufficient length to include a representative seated portion, vestibule and at least $^{1}/_{3}$rd of the supply air duct length and the return air point. 419

The saloon HVAC interior mock-up shall be used to gain an understanding of the acceptability of: 420

- local airflow patterns and air velocities;

- visual appearance; and
- airflow generated noise.

The saloon HVAC interior mock-up shall be available for Purchaser inspection in the United Kingdom for not less than four weeks duration during which time the Purchaser may wish to make several visits to the installation with several different stakeholders. 421

The saloon HVAC interior mock-up shall include the proposed supply air grilles/diffusers and shall provide supply and return air into the mock-up at airflow rates and temperatures reflective of the design proposal for both heating and cooling. 422

At the saloon HVAC interior mock-up stage, airflow patterns shall be visualised using tell-tale strings and smoke injection. 423

At the saloon HVAC interior mock-up stage, video recordings of the airflow patterns shall be made. 4308

1.10 Human Factors 4617

The design shall be suitable for a user population spanning the 5^{th} percentile female to the 95^{th} percentile male. 4529

Assessments of ergonomics shall give consideration to users outside of the defined user population. *Reasonable adjustments should be made where practicable.* 7065

The anthropometry dataset "Peoplesize 2008 Version 2.02" shall be utilised in the design of the Train. 4530

The anthropometrical data utilised in the design of the Train shall be adjusted for predicted secular growth of the user population over the life of the Train. 4775

There shall be no accessible holes or gaps between fixed or movable panels, fixtures, components or equipment that could cause injury by trapping fingers, hands or any other body parts. 4624

A finger trap shall be as defined in section 4.2.7 of British Standard BS EN 1176 Part 1: 2008 'Playground Equipment and Surfacing. Part 1: General Safety and Test Methods'. 4625

The application of anthropometry data to the Train design shall take into account allowances for typical clothing worn by the user groups. 4627

The design of equipment and processes shall take into account allowances for the clothing, including protective equipment, that could 4531 reasonably be foreseen to be worn by:

- maintainers;
- Train Operators;
- passengers;
- breakdown, emergency and security personnel.

All interactions between passengers and the Train shall be identified and subjected to appropriate analysis and design activities as part of the design development process in compliance with LU standard S1217 'Integration of Human Factors into Systems Development'. 4524

All interactions between maintenance staff and the Train and Equipment shall be identified and subjected to appropriate analysis and design activities as part of the design development process in compliance with LU standard S1217 'Integration of Human Factors into Systems Development'. 4525

All interactions between operational staff and the Train and Equipment shall be identified and subjected to appropriate analysis and design activities as part of the design development process in compliance with LU standard S1217 'Integration of Human Factors into Systems Development'. 6560

All interactions between breakdown, emergency and security personnel and the Train and Equipment shall be identified and subjected to appropriate analysis and design activities as part of the design development process in compliance with LU standard S1217 'Integration of Human Factors into Systems Development'. 4983

Human Factors analysis and design activities shall consider the full life cycle of the Train with reference to: 6088

- all relevant personnel;
- all normal and degraded modes of operation;
- all times of the day and night;
- all climatic conditions.

All user interfaces shall be designed to be compliant with LU standard S1218 'Human Systems Interaction - Dialogues and Notifications' as part of the design development process in compliance with LU standard S1217 'Integration of Human Factors into Systems Development'. 4700

The Manufacturer shall devise a strategy for audible and visual Notifications which shall be agreed with the Purchaser. 825

The Notifications strategy shall provide audible and visual alarms and alerts and transmission of data to the RCS, the OTC and to the on board integrated Train Operator's display screen in a timely manner appropriate to the importance, corrective action necessary and 826 maintenance activity.

Information provided by the Train to operating staff regarding degradation that the Train is undergoing shall recognise the likely stress that operating staff are experiencing. 4964

Human error analysis shall be used during the design development, considering the reasonably expected skill sets, competence and human reliability of maintainers and Train Operators. 5414

The Manufacturer shall demonstrate how the facilities provided have been designed with a view to minimising the potential for customer action or staff error to delay the train service and maximising staff performance in the recovery of a failed Train. 6344

1.11 Rail Vehicle Accessibility Regulations (RVAR) 56

All aspects of the Train design shall fully comply with Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 4384

1.12 Water Ingress and Corrosion Resistance 66

The Train shall be designed and constructed so as to prevent corrosion, including that arising from dissimilar metals and the effects of water, cleaning fluids and graffiti remover. 746

The Train design shall not allow water ingress from weather and train washing into the interior through the carbody sections, seals between components and through any closed door, window or vents. This applies to train washing by the automatic washing plant and by manual processes e.g. high pressure jets. 748

Sealing of the carbody structure shall be to IP56 as defined in British Standard BS EN 60529:1992+A2 2013 'Degrees of Protection Provided by Enclosures (IP code)'. 749

Water flowing from the carbody roof shall not enter the saloon through open doors. 750

Air inlets/outlets and other external orifices on the carbody or equipment shall be self-draining to the exterior. 751

Air inlets/outlets and other external orifices on the carbody or equipment shall prevent undesirable ingress of moisture into 'dry' areas. 4359

Water entering the Train shall not be allowed to form pools but shall drain freely out through the doors. 752

The Manufacturer shall demonstrate how the threat to vehicle longevity through corrosion has been managed. This shall include consideration of penetration of cleaning fluids and other common liquids through floor coverings, joints and abutments in panelling on both the exterior and all interior areas. 3385

1.13 Vandal Resistance (Interior & Exterior) 67

All systems, assemblies, fixtures, fittings, camera housings and controls located within the Train interior shall be resistant to unauthorised access/removal, vandal attack and tampering. 4822

The Manufacturer shall define graffiti removal processes for all material types used inside and outside the Train. 4824

Graffiti removal processes shall consider all materials used on the Train so as to avoid any inadvertent damage to materials in adjacent areas when removing graffiti. 5220

Note - the Purchaser has previously experienced issues with graffiti removal materials and processes causing damage to items such as rubber seals and the bonding of floor coverings including covings.

Passenger windows, door glazing and interior glazed surfaces shall be fitted with replaceable protective films to mitigate damage from scratching. 4825

Surface finishes that have sustained significant damage (e.g. from extensive graffiti) shall be able to be easily replaced or repaired within the normal depot environment (i.e. without the need for specialist areas or equipment). 2503

There shall be no convenient handholds such as would encourage the practise of 'train surfing'. 2454

London Underground considers that all of its trains meet this requirement.

1.14 Surface Finishes 6273

The term 'surface finishes' shall include painted, powder coated, naturally finished or any other surface material finish used on structures, panels, fixtures and fittings on the interior or exterior of the Train. The surface finish requirements detailed in this section do not apply to glass, moquette or flooring materials. 6500

Surface finishes shall show no penetration of the dry film when tested using a 20N counterweight and scratch stylus D in accordance with British Standard BS EN ISO 1518-1:2011 'Paints and varnishes - Determination of scratch resistance - Part 1: Constant-loading method'. 6275

Surface finishes shall not crack or detach from the substrate when tested using a 6mm diameter mandrel in accordance with British Standard BS EN ISO 1519:2011 'Paints and varnishes - Bend test (cylindrical mandrel)'. 6276

Surface finishes shall not exceed adhesion classification 1 when tested in accordance with British Standard BS EN ISO 2409:2013 'Paints and varnishes - Cross-cut test'. 6277

Surface finishes shall not suffer cracking, flaking or detachment from the substrate when tested using a 1kg weight in accordance with British Standard BS EN ISO 6272-1:2011 'Paints and varnishes - Rapid-deformation (impact resistance) tests - Part 1: Falling-weight test, large-area indenter'. 6279

Surface finishes shall not lose a mass of more than 30mg after 500 cycles of testing using a CS10 wheel in accordance with British Standard BS EN ISO 7784-2:2016 'Paints and varnishes - determination of resistance to abrasion - Part 2: Method with abrasive rubber wheels and rotating test specimen'. 6280

Surface finishes shall not soften, swell, blister or suffer from under-film corrosion when subjected to 2000 hours of cycling in accordance with British Standard BS EN ISO 6270-1:2001 'Paints and varnishes - Determination of resistance to humidity - Part 1: Continuous condensation'. 6281

Surface finishes which are used on the exterior of the Train shall not crack, flake, blister, suffer loss of inter-coat adhesion or change in colour (ΔE) greater than 3 units and no gloss reduction greater than 10% when tested in accordance with British Standard BS EN ISO 11507:2007 BS 3900-F16: 2007 'Paints and varnishes - Exposure of coatings to artificial weathering - Exposure to fluorescent UV lamps and water' or when tested in accordance with both BS EN ISO 16474-1:2013 'Paints and varnishes - methods of exposure to laboratory light sources Part 1: General guidance' and BS EN ISO 16474-3:2013 'Paints and varnishes - methods of exposure to laboratory light sources Part 3: Fluorescent UV lamps.' 6282

Surface finishes shall suffer no adverse effects after 24 hours exposure to chemical agents in accordance with British Standard BS EN ISO 2812-4:2007 'Paints and varnishes - Determination of resistance to liquids — Part 4: Spotting methods'. 6283

Surface finishes shall achieve a result of Slight (or better) when tested in accordance with British Standard BS AU 148-15:1969 'Methods of test for motor vehicle paints - Part 15: Resistance to chipping'. 6274

Surface finishes shall be free of defects, corrosion and blistering greater than 2mm from the cut when exposed for 1000 hours in accordance with British Standard BS EN ISO 9227:2012 'Corrosion tests in artificial atmospheres - Salt spray tests'. 6332

Surface finishes shall not exhibit staining, ghosting, colour loss, gloss reduction, softening, swelling or blistering following the application and removal of graffiti a total of 14 times with a 24 hour interval between each application. The graffiti shall be applied in four 25mm wide and 300mm long strips of the painted surface with each section separated by a masked off area no less than 25mm in width. The graffiti application in the first section shall be in the form of aerosol paint and the other three sections shall have black, blue and green coloured pen ink applied evenly over the test sections. The graffiti removal shall be in accordance with the Manufacturer's proposed graffiti removal materials and processes. 6333

The Train exterior shall avoid features which attract dirt or make cleaning on a routine basis difficult to achieve. 2541

The Train exterior shall present a smooth and continuous surface free from protuberances, sharp edges, weld spatter or manufacturing marks. 2542

The Train exterior shall have a ripple free appearance when painted or filmed in high gloss materials. 2543

Undulation on any car exterior surfaces shall not exceed 1mm over 1m length. 2545

Panel joints on the car exterior shall not be visually apparent to an observer with normal eyesight standing 1m from the joint. 2547

Finished welding runs on the car exterior shall be of minimum width, uniform and unobtrusive. 2548

The car exterior shall be hard wearing, durable and suitable for use in the harsh environment of a heavy metro system. 2549

Exterior finishes for equipment below the solebar shall be compatible with the requirements for automatic lineside inspection equipment. 3923

Exterior finishes for equipment below the solebar shall be compatible with the requirements for corrosion resistance. 4708

Colour transitions on the same surface shall have a sharp, clean colour change line. 2546

The Train exterior shall be capable of being fitted with removable film to carry advertising. 3986

Train exterior finishes shall support the application and removal of film to the painted finish without degradation. 3985

1.15 Car Identification 2802

Unique Car Numbers, to be advised by the Purchaser, shall be allocated to and displayed on individual cars. 2804

Car Numbers shall be displayed in a prominent position inside the saloon at both ends of each car. 2806

Car Numbers shall be displayed in a prominent position inside each cab (when fitted). 2808

Car Numbers shall be displayed on the exterior front and rear of the Train. 2809

Car Numbers on the front and rear of the Train shall be coloured Corporate White (NCS S 0500-N) and use a text height of 64mm. 6442

A solid white solid circle, 60mm in diameter, shall be applied after the Car Number on the front of Trains which are fitted with de-icing equipment. 6443

Car Numbers shall be displayed at both ends of each car so as to be visible to maintenance staff working in a pit road underneath that car. 5200

Car Numbers shall be displayed in two positions on both sides of each car (4 positions per car in total), in horizontal alignment with the roundel and blue livery band, between the saloon doors and the end of each car. 6441

Car Numbers on the side of each car on the Train exterior shall use a text height of 80mm and be coloured Corporate Blue (NCS S 3560-R80B). 6440

1.16 Signage & Labelling 148

1.16.1 Signage & Labelling - General 4078

Signage and labelling, used in the context of this section, refers to all information, excluding customer information shown on digital displays, which is provided on the Train to inform passengers, maintenance staff or operational staff about hazards, instructions, rules, and other related information. 4083

1.16.2 Signage & Labelling Information Content 4075

Equipment intended for use by passengers shall be accompanied with signage, using either words or diagrams or both to indicate clearly the function and use of the equipment. 4057

Equipment intended for use by passengers shall be accompanied with signage, using either words or diagrams or both to indicate clearly the method of operation. 4058

The layout and content of all passenger information, safety and warning signage, shall be submitted as part of the preliminary and final design submissions. 4060

Warning signage shall be positioned to protect against injury arising from all hazards associated with any part of the Train. 5161

The Manufacturer shall identify items of equipment that may present hazards, identify the associated hazards and fit warning labels of a nature and location that effectively protect both the knowing and the unwary from those hazards. 5162

DANGER or CAUTION signage shall be used to alert the reader to the possibility of personal injury. 5163

WARNING signage shall be used to alert the reader to the possibility of damage to the equipment. 5164

Labels shall be applied to the sole bar area, and other parts of the underframe as appropriate, to assist maintenance staff and recovery personnel in identifying: 5225

- isolating cocks;
- switches;
- jacking / lifting points;
- axle / wheelset locations (lettering codes).

Signage location, size, type and information content shall be consistent with the need to alert authorised personnel, emergency services and other persons who may have access to the potential hazard. 4074

Signage shall be located in a position which does not create an additional hazard. 5165

Safety signs shall be designed while making reference to Reference Document ATOC Standard AV/ST 9005 'Vehicle Interiors Communication of Safety and Emergency Information'. 4062

Signs shall identify and warn against hazards arising from predictable equipment malfunctions. 4080

Signs shall be fitted in sufficient number in prominent positions to ensure that they are visible from any position from which exposure to the hazard is possible. 4081

Safety signs shall conform to the requirements of British Standard BS ISO 7010:2012+A6:2016 'Graphical Symbols - Safety Colours and Safety Signs - Registered Safety Signs'. 4082

Signage for passengers shall be provided in accordance with section 3.7 and sections 3.11 through to section 3.21 of LU Standard 1-382 'Train Decor Design'. 4092

Signage for staff shall be provided in accordance with section 3.8 of LU Standard 1-382 'Train Decor Design'. 5863

Colours used for signage shall conform to the LU corporate colour scheme as defined in Reference Document 'London Underground Signs Manual'. 5137

Signage design shall be in accordance with the principles detailed in Section 7 of LU Standard S1004 'Signage for Operational Purposes'. 5169

Customer information and signage content shall be consistent with Reference Document 'London Underground Signs Manual'. 6070

Safety signs shall be clearly legible to persons with normal or corrected eyesight at distances in the range 0.4 metre to 1 metre from the sign. 4089

The sign viewing distance requirement shall be met for viewing angles of up to 60° from a normal to the sign, and in all directions. 4090

Safety signs for use on the outside of equipment cases shall use recessed lettering to ensure legibility. 4091

1.16.3 Materials for Signage & Labelling 4068

Adhesive used on signs and labels shall not show or discolour when the label is bonded to glass or any other transparent material. 4063

Adhesive signs and labels shall be securely adhered. 4084

Signs and labels shall be capable of being readily and quickly replaced. 4088

Signs shall be capable of being readily and safely cleaned to ensure continued legibility. 4085

Adhesive labels shall be in accordance with Type 1 General purpose label requirements detailed in British Standard BS 4781:1990 'Specification for pressure-sensitive adhesive plastics labels for permanent use'. 4069

Resistance to colour change of signs and labels shall be demonstrated in accordance with British Standard BS EN 438-2:2005 'High-Pressure 4070

Decorative Laminates (HPL)' clause 27.

Signs and labels shall be made from non-conducting materials. 4071

Signs and labels mounted on the exterior of the Train shall not suffer degradation as a result of regular exposure to train washing and the environment. 4086

Materials used in adhesive signs and labels shall resist unauthorised removal. 4094

1.17 Fire 32

The Train shall be designed to reduce to ALARP the risks to passengers and staff resulting from fire. 1559

Manufacturers shall provide, at the time of tender submission, a Train Fire Strategy. The strategy must consider: 4132

- Managing the risks of fires starting and developing;
- Fire detection and control of spread of fire products;
- The capability of the Train when under attack of fire to reach a place where safe evacuation is possible;
- Evacuation.

The Train shall meet the requirements of LU Standard 1-085 'Fire Safety Performance of Materials'. 1560

In the past it has not always been possible to obtain fully-compliant materials and the Purchaser has granted limited concessions for these non-compliances. The Manufacturer should not assume that any concessions previously granted will be repeated for DTUP.

The Train shall comply with British Standard BS 6853:1999 'Code of Practice for Fire Precautions in the Design and Construction of Passenger Carrying Trains'. 5320

The Train shall comply with British Standard BS EN 50553:2012+A1:2016 'Railway applications - Requirements for running capability in case of fire on board of rolling stock.' 7059

Cables compliant with British Standards BS EN 50306:2002 'Railway Applications. Railway Rolling Stock Cables having special Fire Performance' or British Standard BS EN 50264:2008 'Railway Applications. Railway Rolling Stock Power and Control Cables having special Fire Performance' or British Standard BS EN 50382 'Railway Applications. Railway Rolling Stock High Temperature Power Cables having special Fire Performance' may be used, but compliance with R15 and R16 of British Standard BS EN 45545-2:2013+A1:2015 'Railway Applications. Fire Protection on Railway Vehicles. 5421

Requirements for Fire Behaviour of Materials and Components' shall be demonstrated.

Heating systems shall be designed so that debris cannot collect/form against hot surfaces and give rise to smoke, fumes, smells or constitute a fire risk. 3128

Detectors shall be fitted to the Train for detecting fires in saloon areas of the Train. 710

Detectors shall be fitted to the Train for detecting fires in operator areas of the Train. 6852

Detectors for detecting fire outside the Train shall be fitted to the Train. 4246

Fire detectors shall detect the expected fire products or effects. 4348

The fire detection system response time shall support the overall fire safety design. 711

Upon detection of fire, a notification and CCTV pictures of the affected area shall be provided to the RCS. 712

Reports of detected fires shall include the location of each detector that has been triggered. 4252

On the detection of fire in the saloon, a notification shall be provided to the Train Operator. 713

1.18 Keys & Locks 155

500 Train Mode Selector keys shall be provided. 1503

The Train Mode Selector key shall be a high security type. 1506

The Train Mode Selector assembly shall not require the lock to be removed or disassembled to extract the broken parts of a captive key. 4430

The Train Mode Selector key shall incorporate a hole for attaching a split ring of Ø25mm and Ø3mm cross section, so that it can be attached to a key ring. 1508

The Train Mode Selector key shall not be damaged whilst being carried on the same key ring with J-Door keys and other Train Mode Selector keys. It shall not be damaged when supporting such a set of keys hung from the key fob hole. 5825

Cupboards and compartments shall be secured against unauthorised access. 4768

The emergency equipment shall be accessed via a J-Door key to LU Drawing 100524 'Gedore Operating Key'. 5017

2 Interfaces 131

2.1 Inter-Running 132

Inter-running is the operation of two or more different train types on the same line. 1179

During the delivery phase the new Trains will inter-run with the existing trains until all the existing trains are withdrawn. 1180

On some routes the track is shared and Trains will be inter-running throughout their whole life. 1181

It shall be possible to limit the motoring performance (speed/distance or speed/effort) of the Train to match the performance of the inter-running trains. 1183

The performance curves shall be switchable between two or more pre-programmed settings while the Train is operating in passenger service. 1184

The performance curves shall be selectable between two or more pre-programmed settings depending on the geographical location of the Train. 1185

It shall be possible to mechanically couple a new Train to an existing tube gauge train sufficient for either train to pull or push the other to the end of the line. This may be satisfied either by fitting the Train with a matching outer end coupler or by provision of a portable Interface Coupler (of the Manufacturer's design) suitable for carrying for a distance of at least 1000 metres along the track by no more than two people. 1186

The existing tube gauge train means the predominant passenger service tube stock on the relevant line prior to the introduction of the new Train.

If a portable interface coupler is required to mechanically couple the Train to an existing tube gauge train, then the Manufacturer shall supply a quantity of 0.1 portable Interface Couplers per Train supplied. This shall be on a line-by-line basis and rounded up to the nearest whole number. 4345

If a portable interface coupler is required to mechanically couple the Train to an existing tube gauge train, then the interface coupler shall be proven for strength and the ability of the coupled trains to pass over all track geometry when coupled using the coupler. 5112

There is no requirement for coupling between the new Train and a surface gauge train such as S-Stock and Class 378 trains. 1187

Until the line is fully resignalled, the Train shall not interfere with or suffer interference from the signalling equipment already installed on that line. 1188

Any temporary measures to achieve inter-running signalling compatibility shall be removed by the Manufacturer once the line has been fully resignalled. 1189

For the Piccadilly Line fleet, there is inter-running with S-Stock between Rayners Lane and Uxbridge and between Hammersmith and Hanger Lane Junction. 1190

For the Bakerloo Line fleet, there is inter-running with Class 378 trains and others between Queen's Park and Harrow & Wealdstone. 1191

2.2 Gauging & Dynamics 135

2.2.1 Gauging 1192

Trains for each line will operate exclusively on that line. 4752

The Train shall comply with the kinematic limits for the line or lines over which it is required to pass. LU Standard S1156 'Gauging and Clearances' defines the Structure Profile and Kinematic Limit. The diagrams of interest are C1, C2, C5 and F1. 1194

The Manufacturer shall provide a gauging strategy, initially as part of the tender submission. The strategy must: 4067

- Provide confidence in the deliverability of the tendered Train design in respect of overall dimensions;
- Include details of the proposed method of gauging and the related assumptions;
- Consider the effects of relevant degraded and failure conditions.

For each design submission the Manufacturer shall provide information to form a Gauging Portfolio which shall include the following as a minimum: 5687

- A vehicle diagram, giving an overview of the vehicle concerned (all types of vehicles);
- A vehicle profile summary drawing, identifying the location of the body plan view and cross sectional profiles;
- Vehicle body plan view profiles;
- Vehicle cross sectional profiles;
- Swept envelopes for each significant track configuration and location relevant to the route(s) along which the vehicle will

operate;

- Supporting documentation and evidence.

A detailed description of the required content of the Gauging Portfolio is included in Reference Document NTfL-2344.3.4-LUL-RPT-00011 'Gauging Portfolio Content'.

The vehicle external dimensions shall be maximised within the gauging constraints to enable development of a design with the maximum possible usable internal space. 1198

The height of the stepping surface of the door sill shall be less than 700mm ARL at all times. 1199

The height of the stepping surface of the door sill shall be no lower than 630mm ARL with the Train in the Full Load condition and with the most onerous combination of equipment conditions and tolerances. This requirement applies in the static condition only. 3890

The required sill heights have been determined based upon the future platform heights to ensure that the vertical stepping distances are compliant with the stepping height limits prescribed by RVAR. This has taken into consideration an allowance for rail wear in accordance with LU Track Standards. 1200

The derivation of vehicle swept envelopes and assessments and demonstrations of clearance shall adopt a risk based approach. Factors to be assessed shall be defined by the Manufacturer based on the operating environment and the Train design, and shall include the following: 1201

- The allowable Train speeds;
- Loadings between Tare and Crush;
- Peak cross wind speeds of 100km/h (open sections only);
- The effects of all dimensional tolerances and measuring accuracy (manufacturing and setup) including bodyshell camber and sag, and build tolerances;
- The allowable tolerances between wheel and rail including wear;
- The effects of relevant failure conditions;
- Yaw;
- Wheel to rail conicity in a range 0.05 (maximum) to 0.5 (minimum);
- All reasonably foreseeable co-efficients of friction;
- "10m wavelength" (actually 60 feet) resulting from dipped rail joints where this feature is apparent on the running routes;
- Where there is a significant probability that mandatory limits of wear and maximum tolerances for components, assemblies and systems which influence the dynamic movement of the

vehicle will be exceeded, this shall be taken into account;

- Quasi-static sway arising from steady-state curving forces (cant deficiency and cant excess);
- Dynamic sway in response to short wavelength track cross level tolerance;
- Dynamic sway in response to track irregularities;
- Dynamic vertical suspension displacements in response to track irregularities;
- Static vertical displacements caused by payload variations, wheel wear, and suspension stiffness tolerances, etc.;
- Dynamic vertical deflections of the vehicle body or frame under any conditions of load;
- Vertical and sway displacements associated with likely suspension failure modes and other system failure modes where applicable;
- Geometric throw of individual cars, due to track curvatures in both vertical and horizontal directions;
- Wheel-rail clearance (including flange wear), but not rail wear;
- Component failure;
- Any other relevant variables such as tolerances in vehicle dimensions, mass distributions and wheel loadings, suspension characteristics, and normal variations in vehicle maintenance condition and wear.

The swept envelopes shall be validated by calculations, by comparisons with other vehicles, by testing or by other appropriate means commensurate with the level of risk, complexity and innovation in the vehicle design. 1202

The Train shall have the greatest possible width across door sills. 1776

The Stage 4 tender evaluation model gap filler calculation should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with the vehicle width requirement. 4476

At curved platforms the horizontal platform-to-train stepping gaps are predicted to be outside of acceptable limits. The Purchaser will use passive or active gap fillers on a case by case basis to reduce gaps. Where gaps are large enough to require active (moveable) gap fillers, the Purchaser will be exposed to a performance disbenefit due to the effect on dwell time resulting from the deployment and retraction of the gap fillers. Consequently, the Purchaser wishes to use gap fillers at as few locations as possible. 1777

2.2.2 Dynamics 1203

The dynamic performance of the Train shall ensure the safety of 3827 occupants as far as is practicable under degraded operational modes of suspension and running gear.

The dynamic performance of the Train shall ensure the comfort of occupants as far as is practicable under degraded operational modes of suspension and running gear. 5344

The Train shall resist derailment and roll-over, in compliance with the requirements of Railway Group Standard GM/RT2141 'Resistance of Railway Vehicles to Derailment and Roll-Over'. 2990

The Train shall be designed to accommodate track twist in the most adverse combination of 11‰ (equivalent to 1:90) over the bogie wheelbase and 5‰ (equivalent to 1:200) over the bogie centres. 2997

The wheel unloading shall not exceed 60% of the nominal wheel load when the car negotiates the worst defined track twist in all load conditions, with all suspension parameters at the most disadvantageous limits of the manufacturing tolerance and taking into account increased stiffness due to ageing and temperature effects. 3001

The nominal wheel load is defined as each individual measured wheel load with the car standing on straight and level track. 3006

Wheel unloading tests shall be undertaken on all variants of car types (including adjacent car type combinations for articulated train formations) and bogie types prior to transfer of the first of each type to the LU network, to confirm compliance with the wheel unloading requirement. The test shall be conducted in the most disadvantageous combination of loading and suspension conditions. 4120

The Manufacturer shall demonstrate that the Train has acceptable margins of safety against derailment and overturning. 3828

The design of the bogie, suspension and associated equipment shall be such that the damping values shall remain positive, in plan view, over the full range of: 3916

- equivalent conicity;
- co-efficient of friction;
- speed;
- loading;
- operating conditions;
- maintenance conditions.

The suspension parameters used for the calculation and design of the bogie, suspension and associated equipment, shall be taken at the most disadvantageous limits of their tolerance bands, taking into account manufacturing variations, ageing and temperature effects. 3887

The measured lateral acceleration of the bogie frame above the wheelset shall not exceed $8m/s^2$ for more than six consecutive oscillations between 4Hz and 8Hz. 4119

Acceptability of running characteristics shall be demonstrated in accordance with British Standard BS EN 14363:2016 'Railway applications - Testing for the acceptance of running characteristics of railway vehicles - Testing of running behaviour and stationary tests'. 6419

2.3 Recovery and Rescue 137

The design of the Train shall facilitate re-railing following a derailment and also car and bogie lifting to release trapped persons or objects. 1206

A derailed or otherwise damaged Train shall be capable of being jacked under the bogies to facilitate re-railment. 1207

There shall be jacking pads under each corner of the bogie to facilitate a vertical lift of the bogie. 5114

The jacking pads at the corner of each bogie shall be accessible without the removal of any equipment. 5115

A safe system for the recovery of a stalled Train shall be provided by the Manufacturer. 1208

Instructions and guidance for the movement and recovery of failed, damaged and immobilised Trains shall be provided by the Manufacturer. 1210

Instructions and guidance for the movement and recovery of failed, damaged and immobilised Trains shall include information regarding isolation methods, hazardous materials, lifting, cutting and jacking. 1211

The instructions and guidance for the movement and recovery of failed, damaged and immobilised Trains shall be called the Breakdown Manual. 5116

Jacking pads shall be designed to accept a hydraulic ram jack of 20 ton capacity with a piston head of between 60mm and 76mm diameter. 1205

All jacking pads and lifting points shall be clearly and indelibly labelled. 1212

If lifting straps are provided to link the bogie to the car body for jacking, these shall permit attachment when, due to derailment, the bogie is not level and in line with the car body. 5119

All lifting straps and stock-specific recovery equipment shall be provided by the Manufacturer. 8 sets of 4 straps shall be provided for 5120 each fleet.

This provision is separate from any lifting straps for use by maintenance staff in depots.

A derailed or otherwise damaged Train shall be capable of being recovered from any area of its operation. 1213

A derailed or otherwise damaged Train shall be capable of being raised up onto a wheelskate slid under the wheelset. 1215

Operation of the load release feature, if included with the drawgear, shall not render the drawgear unserviceable for Train recovery purposes. 1216

Trains shall be able to be re-railed after derailment using jacking equipment held by the Emergency Response Unit (ERU). 1204

2.4 Automated Track Monitoring System (ATMS) 138

ATMS is a bespoke LU track condition monitoring system which is being fitted on a small number of trains on each London Underground line. ATMS uses cameras, noise & vibration transducers, data loggers, communication equipment and other associated equipment to inspect the condition of track assets and report anomalies to the track maintenance organisation. 6959

The Purchaser is undertaking a feasibility study to identify the most appropriate solution for automated track monitoring on DTUP lines.

In the event that the equipment needs to be fitted to the Trains then it will be fitted to a small number of Trains on each line and will make use of available space such as that which is occupied by de-icing equipment.

A means shall be provided for ATMS equipment, fitted in the space occupied by de-icing equipment on other Trains, to communicate with the TCMS for the purpose of fault reporting and obtaining information relating to the status of the Train. 6987

A 2.5 kVA 3-phase 400V AC power supply shall be made available for use by ATMS equipment at the locations where de-icing equipment is fitted on de-icing equipped Trains. 7009

There is no requirement to make provision for ATMS on Waterloo & City line Trains. 7089

2.5 Traction Power Supply 140

The Train shall be compatible, without damage, with the traction power supply characteristics defined in LU Standard S1916 'Physical and 1218

Electrical Environment'.

The Train shall be compatible, without damage, with the traction power supply characteristics defined in British Standard BS EN 50163:2004+A1:2007 'Railway Applications. Supply Voltages of Traction Systems'. 1219

The Train shall be compatible with the inverting substations and controlled rectifiers on the line when they are installed as part of the power upgrade. 5327

The Train shall operate correctly over adjacent current rail sections with differing nominal supply voltages. 5305

For instance, where one section is 630V nominal and the next section is 750V nominal, and the reverse.

Operation across current rail sections with differing nominal voltages is to ensure that train operation can continue during the upgrade of the traction supply. The upgrade cannot start until all existing trains have been removed from the line. 5306

The Train shall function over the traction supply voltage range from 450V (maximum) to 1000V (minimum). 5866

The maximum regeneration voltage shall be 1000V in accordance with the requirements of LU Standard 1-122 'Requirements for 750V Traction Power Supplies and Insulation Levels'. 2371

There shall be sufficient traction supply shed receptacles fitted so that all batteries can be charged and any maintenance activities, including testing to prove equipment operation, can be carried out on depot shed roads. 5078

The traction supply shed receptacles fitted to the Train shall be compatible with the depot shed traction supply plug shown in LU Drawing 55612 'General Arrangement of Shed Plug Type 3002'. 4639

Switching of large auxiliary loads simultaneously on multiple Trains shall be avoided to prevent overloading of the power supply at depots and stabling locations. 5876

This may be achieved by introducing a slight random element into pre-programmed switching of significant loads.

2.6 Track and Wheel Rail Interface (WRI) 3945

The Train design, including bogies and WRI mitigation equipment, shall be optimised for the infrastructure, environment, loading and operational profile for each London Underground line individually, to be compatible with, and avoid damage to, the track systems of the route 3963 over which it will operate.

The Manufacturer may propose different designs of bogie and WRI mitigations for Train variants to run on different lines. WRI mitigations may include suspension design, active/passive steering, adhesion modifiers, and other equipment which may need to be optimised for track and environment conditions. 3979

Effects of adverse interaction at the wheel and rail interface shall be minimised under both normal and reasonably foreseeable and credible abnormal operating conditions including, but not limited to: 3938

- wheel and rail (including sliding past signals);
- wheel flats;
- rail burns;
- stalled Trains due to wheel spin;
- derailments;
- mal-operation of track circuits;
- rolling contact fatigue and corrugation;
- thermally initiated squat-like defects resulting from limited creep wheel spin control.

The static wheel load to wheel tread diameter ratio Q/D shall not exceed 0.10, where Q is the static wheel load (kN) in the Full Load condition and D is the fully worn wheel tread diameter (mm). 3941

The P2 force is to be assessed using the formulae and values in Railway Group Standard GM/TT0088 'Permissible Track Forces for Railway Vehicles' clause 6.2. The vehicle parameters should represent passenger loadings as defined below, and new wheels should be considered. 3959

Line	Total passenger loading on the train (tonnes)
Bakerloo Line	60
Piccadilly Line	60
Central Line	68
Waterloo & City Line	34

The maximum normal operating speed to be used in this calculation is 27 m/s. The P2 force calculated in this way shall not exceed 140kN on any wheelset.

The curving performance of the Train shall be simulated by the Manufacturer by carrying out dynamic simulations on a smooth spiral curve. The requirements specified in detail in Reference Document DTP-UIP1973-1.5-RPT-00055 'NTfL Track Damage Assessment Methodology and Guidance' and Reference Document DTP-UIP1973-1.5-RPT-00056 'NTfL Track Damage Assessment Model' defines the inputs, outputs and post-processing methodology. 4755

The whole-train energy dissipation Tγ values shall be calculated in accordance with Reference Document DTP-UIP1973-1.5-RPT-00055 'NTfL Track Damage Assessment Methodology and Guidance' and presented as a function of curve radius.

The Tγ values shall all be less than the corresponding maximum permitted values listed in the table below:

Curve radius band	Max train Tγ (J/m)			
(m)	Piccadilly	Bakerloo	Central	W&C
51 to 60	23000	23000	26286	13143
61 to 70	21000	21000	24000	12000
71 to 80	19000	19000	21714	10857
81 to 90	17250	17250	19714	9857
91 to 100	15500	15500	17714	8857
101 to 110	13750	13750	15714	7857
111 to 120	12250	12250	14000	7000
121 to 130	10750	10750	12286	6143
131 to 140	9750	9750	11143	5571
141 to 150	8750	8750	10000	5000
151 to 160	7900	7900	9029	4514
161 to 170	7150	7150	8171	4086
171 to 180	6400	6400	7314	3657
181 to 190	5800	5800	6629	3314
191 to 200	5300	5300	6057	3029
201 to 210	4900	4900	5600	2800
211 to 220	4600	4600	5257	2629
221 to 230	4350	4350	4971	2486
231 to 240	4100	4100	4686	2343
241 to 250	3900	3900	4457	2229
251 to 260	3750	3750	4286	2143
261 to 270	3650	3650	4171	2086
271 to 280	3550	3550	4057	2029
281 to 290	3450	3450	3943	1971
291 to 300	3350	3350	3829	1914
301 to 320	3250	3250	3714	1857
321 to 340	3150	3150	3600	1800
341 to 360	3050	3050	3486	1743
361 to 380	2950	2950	3371	1686
381 to 400	2850	2850	3257	1629
401 to 420	2750	2750	3143	1571
421 to 440	2650	2650	3029	1514
441 to 460	2550	2550	2914	1457
461 to 480	2450	2450	2800	1400
481 to 500	2400	2400	2743	1371
501 to 550	2300	2300	2629	1314
551 to 600	2200	2200	2514	1257
601 to 650	2100	2100	2400	1200
651 to 700	2000	2000	2286	1143
701 to 800	1850	1850	2114	1057
801 to 900	1650	1650	1886	943
901 to 1000	1450	1450	1657	829
1001 to 1200	1150	1150	1314	657
1201 to 1400	950	950	1086	543
1401 to 1600	750	750	857	429

The calculation from the WRI element of the Stage 4 tender evaluation model should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with the WRI requirements. 3961

2.7 Train Protection 142

The Train shall be fitted with a train protection system, compatible with the associated track-side signalling equipment in place on the routes over which the Train runs. 1266

When commanded by the train protection system, the emergency brake shall apply. 1267

Trainborne signalling equipment shall be appropriately integrated into the Train systems for the function concerned. 1268

The interface between the trainborne signalling protection device and the Train's emergency brake circuits shall have an integrity level of SIL4 given in British Standard BS EN 50129 'Railway Applications - Communication, Signalling and Processing Systems - Safety Related Electronic Systems for Signalling'. 1269

As part of the demonstration of compatibility, the Manufacturer shall refer to the process described in British Standard BS EN 50238-1:2003 "Railway applications — Compatibility between rolling stock and train detection systems". 6195

When a Train is being moved without train protection in force, the maximum speed permitted by the Train shall be 16km/h. 1270

Each individual axle shall be capable of operating track circuits, axle counters and position detectors in both static and dynamic modes. 1271

The Train shall have a minimum load per axle of 5 tonnes if not equipped with tread braking. 1273

The Train shall have a minimum load per axle of 4 tonnes if equipped with tread braking. 1274

The Train shall have a maximum separation of 13.5m between any two adjacent axles in the Train. 1275

The minimum distance between the outermost axles of a Train shall be 13.1m. 1276

The Train shall have a maximum electrical resistance of 0.01 ohms between the wheels of an axle when tested statically. 1277

Rollback protection shall be provided in all forward driving modes to bring the Train to a halt as soon as it has rolled back more than 2m. The distance shall be adjustable in the range 0.5m to 5m in increments of 0.5m or smaller. 1279

When the Train is under the control of the RCS, this function shall be provided by the RCS.

Rollback protection shall be provided in the reverse driving mode to bring the Train to a halt as soon as it has rolled forward more than 2m. The distance shall be adjustable in the range 0.5m to 5m in increments of 0.5m or smaller. 4758

When the Train is under the control of the RCS, this function shall be provided by the RCS.

2.8 Tripcock 5370

A tripcock and associated controls shall be fitted to each end of the Train. 6562

The tripcock arm shall interface with the trainstop which, when raised, is at a height of 76 mm ± 3mm above the running rail datum. 5067

The tripcock arm shall be fitted such that the bottom of the tripcock arm is at a height of 38mm ±2mm above the running rail datum in the Tare condition. 6563

The tripcock arm pocket is defined in LU Standard S1156 'Gauging and Clearances' Diagram F1 - Track Train Interface - New Works and Maintenance - Structure Profile and Kinematic Limit. 5068

The tripcock striking face shall be positioned not more than 3.0m from the front face of the Train end coupler. 5053

The tripcock striking face shall be in front of or adjacent to the leading axle. 7026

This is to prevent nuisance trips caused by the trainstop raising before the tripcock arm has passed over it.

The tripcock shall be compatible with the trainstops defined in LU Standard S1195 'Signalling - Functional Requirements'. 5054

The tripcock shall be compatible with the trainstops defined in LU Standard S2535 'Maintenance of Trainstops'. 7037

The tripcock shall be compatible with the trainstops defined in Railway Group Standard GM/RT2173 'Requirements for the Size of Vehicles and Position of Equipment' and Railway Group Standard GE/RT8018 'Mechanical Trainstop System Interface Requirements' when operating on Network Rail. 5055

The emergency brake shall be applied when the tripcock at the front of the Train is tripped. 5056

The emergency brake shall be applied when the tripcock at the rear of the Train is tripped. 5063

A tripcock reset control shall be fitted in the cab. The tripcock reset control shall be located so that it is not accessible directly from the Train Operator's driving position. 6564

After the tripcock has initiated an emergency brake, the emergency brake shall be retained until the Train has come to a stand and the tripcock reset control has been operated. This shall happen irrespective of the status of the tripcock and the rest of the control system. 5092

When the tripcock has been tripped the maximum speed of the Train shall be limited to 16km/h for three minutes after the tripcock reset control has been operated. 5057

This is traditionally called Speed Control After Tripping (SCAT) and the delay period is known as the Tripcock Time Delay.

If, during the Tripcock Time Delay, the tripcock is tripped and subsequently reset, a new time delay period shall commence, starting from that subsequent reset. 6565

There shall be monitoring of the tripcock reset function so that hidden reset faults are identified. *For example, if a pneumatic reset cylinder is fitted to enable remote resetting, the reset cylinder pressure shall be monitored and any pressure build up identified.* 6312

The Train design shall ensure that it is not possible to defeat the speed control during the Tripcock Time Delay using any sequence of operation of any Train controls. 5058

The Train design shall ensure that it is not possible to cause the Tripcock Time Delay to start using any sequence of operation of any Train controls other than the resetting of the tripcock. 5059

A tripcock isolating switch shall be fitted in the cab. 5091

If a tripcock is isolated, this shall be indicated on the front of the Train by the Yellow Indicator Light which shall flash until the tripcock is no longer isolated. 4853

If a tripcock is isolated, this shall be indicated to the Train Operator within the driving cab. 6566

There shall be an indication to the Train Operator, within the cab, that the Tripcock Time Delay is active. 5060

The tripcock shall withstand repeated tripping by the train stop at 5061
maximum train speed without requiring unplanned maintenance.

The tripcock reset, for leading and rear tripcocks, shall not require the 5062
Train Operator to leave the leading end cab to reset the tripcock.

Without tripping the tripcock, it shall be possible to test all other parts of 6447
the tripcock system.

A changeover control shall be fitted in the cab, to allow an in-service 5052
changeover between tripcock and RCS signalling protection modes.

2.9 RCS Signalling and Train Control (RCS (S&TC)) 143

The Train shall accommodate and interface with the chosen trainborne 1281
RCS (S&TC) equipment.

The specification for RCS (S&TC) equipment here is generic and no 1282
specific product should be inferred. The requirements will be refined as part of the Schedule 26 interfacing work.

Provision shall be made for two axle end tachometers in each end of 1283
the Train for RCS (S&TC). This provision shall include space, mounting and cable routing.

Provision shall be made for four body-mounted radio antennae at each 1284
end of the Train for RCS (S&TC). Provision shall be made to site two of these in the upper left and right front corners of the leading car. Provision shall include space, mounting and cable routing.

Provision shall be made for two accelerometers to be mounted at low 6073
level on the Train centre line in each half of the Train. This provision shall include space, mounting and cable routing.

Provision shall be made for two underframe-mounted antennas at each 1286
end of the Train, one on either side of the Train centre line, for RCS (S&TC). Provision shall include space, mounting and cable routing.

Provision shall be made for two underframe-mounted radar in each end 1287
of the Train for RCS (S&TC). Provision shall include space, mounting and cable routing. These shall be installed to have direct line of sight to the track.

Provision shall be made for RCS (S&TC) electronic equipment on each 1288
end car, with more limited provision in other cars, for associated network equipment.

The space provided for RCS (S&TC) electronic equipment shall allow 1289
the accommodation of 19″ Rack mounts within signalling supplier provided enclosures allowing sufficient cable routing to/from the

enclosure and straightforward maintenance access.

There shall be space for at least 3 rack mounted sets of RCS (S&TC) electronic equipment in each end car. 7031

The rack mounted sets of RCS (S&TC) electronic equipment shall be located close to each other. 7066

Each 19″ rack mount for RCS (S&TC) electronic equipment shall have a depth of at least 450mm and be at least 6U high. 1290

There shall be at least 1U of space for ventilation of RCS (S&TC) electronic equipment above and below each item of rack mounted equipment. 1291

Provision shall be made for a power supply of approximately 1.4kW per Train for the RCS (S&TC) equipment. 1292

Provision shall be made for adequate ventilation and cooling as required by the RCS (S&TC) equipment. 5299

When the Train is stabled, and the traction supply is discharged, the essential parts of the RCS shall remain powered up in order to enable the Train to enter service when the traction supply is restored. 5100

The following items shall be proved before a Train may start in Automatic Train Operation (ATO): 7053

- all exterior doors closed;
- Platform Edge Doors (PEDs) (if applicable) closed;
- two ATO start buttons not held down;
- valid signalling authority;
- no emergency brake applied;
- no PEA unacknowledged.

The Train shall facilitate an operating scenario where automatic initiation of Train movement is enabled on part of the line, but disabled on another part. *This functionality is expected to be provided by the RCS however a changeover switch in the Train is one potential solution. This is a potential mode of operation for the Piccadilly Line at end-state.* 7095

Provision shall be made for stopping accuracy detection equipment at each end of the Train. Depending on the stopping accuracy detection system chosen, sensors or cameras may have to be located on the body end above the sole bar. 6206

2.10 RCS Operational Control System (RCS (OCS)) 144

The RCS (OCS) is responsible for transmitting data between the Train and trackside equipment connected to the control centre and the depot. It carries all the information that is not directly related to signalling and Train control. Examples of OCS data are PEA voice calls, real time CCTV pictures, information on Train and platform edge doors that are locked out of use, Train equipment status, Notifications and maintenance data. 3470

The specification for RCS (OCS) equipment here is generic and no specific product should be inferred. The requirements will be refined as part of the Schedule 26 interfacing work. 1294

The Train shall accommodate and interface with the chosen trainborne RCS (OCS) equipment. 1293

Provision shall be made for two body-mounted radio antennae at each end of the Train for RCS (OCS). Provision shall include space, mounting and cable routing. 1295

Provision shall be made for RCS (OCS) electronic equipment in each end car. 1296

The space provided for RCS (OCS) electronic equipment shall be in the form of one 19″ rack mount which shall have a depth of at least 450mm. 1297

The 19″ rack mount for RCS (OCS) electronic equipment shall be at least 6U high. 1298

There shall be at least 1U of space for RCS (OCS) signalling electronic equipment ventilation above and below each item of rack mounted equipment. 7032

There shall be at least 6U of space for RCS (OCS) electronic equipment in each end car. 1299

Provision shall be made for a power supply of approximately 400W per Train for the RCS (OCS) equipment. 1300

Provision shall be made for adequate ventilation and cooling as required by the RCS (OCS) equipment. 5300

2.11 Platform Edge Doors (PEDs) 145

When PEDs are installed the allowable stopping tolerance will be reduced to ±300mm. 6910

To allow for a station stopping tolerance of ±300mm which will be used with PEDs, each platform edge door aperture will be 600mm wider than the Train passenger door aperture. Platform edge doors will open fully so that, when fully open, no part of the platform edge door obstructs the platform edge door aperture. 3253

The width of a pair of platform edge doors will be wider than the platform edge door aperture so that the outer edge of a closed platform edge door overlaps the fixed PED frame. There will also be a space allowance behind the outer edge of an open platform edge door to accommodate operating mechanism and structure, the dimension of the overlap (platform edge door width minus half of the platform edge door aperture) and an allowance to prevent two platform edge doors from touching each other when fully opened (taking into account platform curvatures). The total allowance for these is 200mm for each leaf. 3254

The minimum spacing of platform edge doors on the platform and Train passenger doors is therefore calculated from the width of the Train passenger door. E.g. for 1600mm Train passenger doors: Door spacing = 2 x (Train passenger door width + stopping tolerance + [platform edge door aperture] + allowance) = 2 x (800+300+[800+300]+200) = 4800mm. A Train passenger door opening of 1600mm will require to be spaced at a minimum PED spacing of 4800mm. Train passenger door openings of 1700mm will require to be spaced at a minimum PED spacing of 5000mm. Train passenger door openings of 1800mm will require to be spaced at a minimum PED spacing of 5200mm. 3255

The Train passenger door width and spacing shall be such that the allowances for PED dimensions and spacing are sufficient to allow the PEDs to open without the outer ends of the platform edge doors touching each other when they are fully open. 3256

The location of the end bodyside passenger doors shall be sufficiently far away from the end of the Train such that the Platform Edge Doors at the extreme ends of the platform can open fully without the outer end of the platform edge door touching the platform end-wall or tail-wall. 3259

For a Train with passenger doors of width other than 1600mm, 1700mm or 1800mm, the maximum distance between first and last door centres shall be scaled using the figures for 1600mm, 1700mm and 1800mm doors. 4518

For a Train with 1600mm wide doors intended for the Piccadilly line, the maximum distance between first and last passenger door centres shall be no more than 101.2m. 4515

For a Train with 1700mm wide doors intended for the Piccadilly line, the maximum distance between first and last passenger door centres shall be no more than 101.0m. 4516

For a Train with 1800mm wide doors intended for the Piccadilly line, the maximum distance between first and last passenger door centres shall be no more than 100.8m. 4517

For a Train with 1600mm wide doors intended for the Central line, the maximum distance between first and last passenger door centres shall be no more than 122.95m. 4505

For a Train with 1700mm wide doors intended for the Central line, the maximum distance between first and last passenger door centres shall be no more than 122.75m. 4687

For a Train with 1800mm wide doors intended for the Central line, the maximum distance between first and last passenger door centres shall be no more than 122.55m. 4688

The platforms on the Bakerloo line are all longer than the Bakerloo line Train and so there is no platform length limit on the position of the Train doors, although the rules for PED compatibility still apply. The width and spacing of the Train passenger doors shall be compatible with the platform edge doors such that the PEDs can be installed on those platforms. 4506

The intended solution for the shortest platform on the Waterloo & City line will be established as part of the Whole Line Option. At this stage, the measurements for the outer end car for the Piccadilly line Train shall be assumed and the Waterloo and City line Train length shall be as stated. The width and spacing of the Train passenger doors shall be compatible with the platform edge doors such that PEDs can be installed on that platform. 4507

As a worked example, a Piccadilly line Train with first to last passenger doorway centres of 101.2m and 1600mm passenger doorway width would exactly fit South Kensington WB platform, which is 106m long: 4502

- *Length from first to last passenger doorway centres: 101.2m (ref 4515).*
- *Length required at each end of platform from centre of passenger doorway based on 1600mm Train passenger door (800mm door leaf) = 2 x (Train passenger door leaf + 300mm) + allowances = 2 x (800 + 300) + 200 = 2400mm*
- *Total length required for first and last platform edge door leaves from centre of door (= 2 x 2400mm) = 4800mm.*
- *Length required for PED installation = 106m*

The spacing of the passenger side doors shall be maintained irrespective of the orientation of the Train. *This is to ensure Train passenger door and platform edge door alignment is maintained when the line geography includes a loop.* 6089

The Train shall (via the OTC) interface with the PTI equipment controller to allow the operation of the Train doors to be coordinated 7058 with the operation of the platform edge doors and with the operation of active (moveable) gap fillers on the platform.

The interface between the Train and the PEDs shall: 6127

- Coordinate the Train doors and the platform edge doors so that they move in unison.
- Enable the platform edge doors to operate when the Train doors are operated by controls on the Train.
- Enable the movements of Train doors and platform edge doors (including any associated gap fillers) to be automatically initiated.
- Ensure that only Train doors that are aligned with the platform edge doors can open.
- Implement platform-specific control of individual Train doors and platform edge doors e.g. Selective Door Operation of Train doors and platform edge doors at a short platform.
- Ensure that where a Train door is out of service, the corresponding platform edge door remains closed;
- Ensure that where a platform edge door is out of service, the corresponding Train door remains closed.

2.12 OPO CCTV 4759

During migration, the safety of the PTI will be managed from within the Train. A track-to-Train CCTV system (OPO CCTV) will transmit CCTV images of the PTI to the Train so they can be displayed to a Train Operator. 1176

The display screens, the power supply and the cabling on the Train facilitating the OPO CCTV system shall be within the Manufacturer's scope. *The rest of this system is not within the Manufacturer's scope.*

The specification for OPO CCTV equipment here is generic and no specific product should be inferred. The requirements will be refined as part of the Schedule 26 interfacing work. 7132

Provision shall be made for four antennas at each end of the Train for OPO CCTV, they shall be located as follows: 2168

- The antennas shall be mounted on the side of the Train below floor level positioned for reception from a transmitter underneath the platform nosing.
- On both sides of each end car there shall be provision for a pair of antennas, the two antennas of a pair shall be separated longitudinally by no less than 5m.
- The outer antenna of each pair shall be as close to the end of the Train as possible.

The space provided for the OPO CCTV receiver shall be in the form of 2169 one 19″ rack mount which is 450mm deep.

The 19″ rack mount for the OPO CCTV receiver shall be at least 2U high. 2171

Provision shall be made for an OPO CCTV receiver in each end car. 2170

Provision shall be made for a power supply of approximately 200W per Train for the OPO CCTV equipment. 2174

All cabling (for both power and data) shall be provided by the Manufacturer as required by the OPO CCTV equipment. 6870

Where the OPO CCTV equipment requires the video signal to be transmitted from one end of the Train to the other, the cable provided by the Manufacturer for this purpose shall be designed and installed to provide a robust, reliable, low-loss transmission of the signal. 7138

To maintain transmission of video from the platform to the Train during the whole of the Train's run-out from the platform, the OPO CCTV equipment is likely to be configured to receive the transmission at the rear of the Train. The through-Train transmission to the display screens at the front of the Train is therefore a critical feature.

Where the OPO CCTV equipment requires the video signal to be transmitted from one end of the Train to the other, the quantity of interconnections in the cable provided by the Manufacturer for this purpose shall be minimised. 7139

Provision shall be made for adequate ventilation and cooling as required by the OPO CCTV equipment. 5301

OPO CCTV images shall be displayed to the Train Operator: 5703

- whilst the Train is stationary at the platform stop position.
- immediately prior to the Train coming to a stand at a platform stop position i.e. within the stopping window of the nominal stopping position.
- during platform departure, until the Train has cleared the platform.

The delay between the output of the OPO CCTV receiver at the front of the Train, and the presentation of the OPO CCTV images on the display screens, shall be less than 15ms. 7141

The latency of the OPO CCTV system must be low so that there can be near 'real-time' interaction with events on the platform.

The Train shall not cause the displayed OPO CCTV images to freeze, showing an image that is no longer real-time. 7136

Any faults in the Manufacturer's scope of supply that could cause the OPO CCTV image to not be a correct likeness of the signal being received by the Train shall result in the OPO CCTV display being blanked. 7137

OPO CCTV images shall not be displayed at stations timetabled as non-stopping. 5704

OPO CCTV images shall not be displayed until the Train speed has reduced below 10km/h. 5867

2.13 Network Rail (Bakerloo line North of Queens Park and Waterloo & City line) 4753

The requirements for compatibility with Network Rail infrastructure on the Bakerloo line north of Queens Park will be established as part of the whole line option. 4754

For information: the Purchaser's S-Stock operates over Network Rail infrastructure to Richmond.

The Trains for the Bakerloo line and the Waterloo & City lines shall be compatible with the Network Rail traction supply used on those routes. 5304

2.14 Train Radio 5683

A TETRA based radio communication system, commonly referred to as Connect Radio, is used by all operational staff and emergency services to communicate throughout the London Underground network. The DTUP Train Radio equipment will be designed to be compatible with existing Connect Radio infrastructure. 5937

The DTUP Train Radio equipment will be "free-issued" by the Purchaser. 5939

Space, power, connectivity and integrated functionality shall be provided in each cab end for Train Radio equipment. The mechanical, electrical and functional interfaces shall be in accordance with Reference Document NTfL-2344.3.4-LUL-RPT-00033 'NTfL Train Radio Interface Definition'. 5932

The Train Radio Control Head shall be integrated with other Train Operator controls in the cab. 5940

The Train shall use visual and audible indications to notify the Train Operator of the presence of an incoming Train Radio call. 5933

Train Radio audio communications shall be integrated with the cab handset, cab loudspeaker, PTT button, radio select button and other associated cab controls and facilities. 5934

2.15 EMC 30

2.15.1 EMC - General 1410

The Train shall comply with Reference Document 2004/108/EC 'The approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC', Reference Document UK SI 2006 No. 3418 'The Electromagnetic Compatibility Regulations 2006' and with Reference Document 2014/30/EU 'The harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)'. 1411

Compliance with the Reference Document DTP-UIP1973-1.4-RPT-00002 'EMC Management Plan' is required. 1412

The Manufacturer shall produce an EMC Control Plan demonstrating compliance with the EMC Management Plan (NTfL Document DTP-UIP1973-1.4-RPT-00002 'EMC Management Plan'). 1413

The EMC Control Plan shall include a strategy for compliance with Reference Document 2013/35/EU 'EMF Directive - The minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC' and the DC and low frequency magnetic field requirements in LU Standard S1222 'Electromagnetic Compatibility (EMC)'. 5326

All Train equipment shall comply with and be tested to LU Standard S1222 'Electromagnetic Compatibility (EMC)' and British Standards BS EN 50121-3-2:2016 'Railway Applications. Electromagnetic Compatibility. Rolling Stock. Apparatus' and BS EN 50155:2007 'Railway Applications. Electronic Equipment Used on Rolling Stock'. 1429

LU Standard S1222 'Electromagnetic Compatibility' section 3.6.2 specifies a psophometric noise limit of 1mV. LU Standard G222 'EMC Best Practice' section 3.10 gives guidance as to how this can be applied to give a current limit for a train. 5328

The whole Train shall comply with British Standard BS EN 50121-3-1:2017 'Railway Applications. Electromagnetic Compatibility. Rolling Stock. Train and Complete Vehicle'. The emission limit shall be reduced by 10dB at 45 – 60MHz (Central line in cab CCTV), 382 – 395MHz (Connect radio) & 855 – 865MHz (station radio public address (PA)). 1430

Appropriate segregation of equipment/cabling shall be designed to ensure compatibility of all Train systems. 1434

An EMC Technical File shall be delivered to the Purchaser showing compliance of the Train to this EMC specification. 1435

2.15.2 Intentional Transmitters 1437

Any transmitter systems used on the Train shall comply with Reference Document 2013/35/EU 'EMF Directive'. 1439

Appropriate segregation distances of any transmitting antenna shall be designed to ensure compatibility with other Train equipment. 1440

2.15.3 EMC Safety Case 1442

The Manufacturer shall support the LU EMC HAZID and hazard management process with the aim of supporting the Train and signalling EMC safety case. 1443

The Manufacturer shall produce a Train conducted interference test plan to demonstrate compliance with LU Standard S1193 'Electromagnetic Compatibility (EMC) with LU Signalling System Assets'. Following the testing, a test report shall be submitted to the Purchaser. 1444

The Manufacturer shall produce an EMC Safety Case for the Train which includes the equipment fitted to only part of the fleet, such as the ATMS equipment and the de-icing equipment. 1445

Compatibility with existing LU signalling shall meet 10^9 MTBWSF and 10^6 MTBRSF limits and comply with LU Standard S1193 'Electromagnetic Compatibility (EMC) with LU Signalling System Assets'. A list of existing LU signalling assets can be found in Reference Document DTP-UIP1973-1.4-RPT-00025 'NTfL Interfaces with LU Signalling Assets'. 1447

The Train shall be compatible with the new Four Lines Modernisation (4LM) signalling. 1449

The Train shall be compatible with the new DTUP signalling. 1509

A safety case for running over the NR signalling on the Bakerloo Line north of Queens Park shall be produced by the Manufacturer. The signalling comprises Reed track circuits and HVI track circuits. See Reference Document NR/SP/SIG/50003 'Methodology for the Demonstration of Compatibility with Double Rail Reed Track Circuits on the DC Railway' for details of Reed Track Circuits and Reference Document NR/GN/SIG/50007 'Methodology for the Demonstration of Compatibility with HVI Track Circuits' for details of HVI Track Circuits. 1510

A safety case for adjacent railways shall be produced (e.g. NR, DLR, Overground, CTRL, Crossrail, etc.) by the Manufacturer. A list of (Non-LU) adjacent signalling interfaces can be found in Reference Document DTP-UIP1973-1.4-RPT-00022 'NTfL Interfaces with Adjacent Signalling Assets'. 1511

Compatibility shall be demonstrated with both a 12 and Pseudo 24 pulse rectified traction supply. 1543

A pseudo 24 pulse rectifier consists of two 12 pulse rectifiers with a 15 degree phase shift connected in parallel. Failure of one rectifier results in a 12 pulse output. Also some 24 pulse rectifiers operate in 12 pulse mode for some of the time. For more detail see Reference Document DTP-UIP1973-1.4-RPT-00026 'NTfL Interfaces with LU Power Assets'. 5330

3 Train Performance 26

3.1 Adhesion Limits 3629

The adhesion demand for any individual wheelset, to support the acceleration and braking demands for the Train, shall not exceed the following values: 2387

Motoring	**Acceleration Rate**	**Adhesion limit**
Achieved acceleration (open)	1.05 m/s/s	0.15
Achieved acceleration (tunnel)	1.2 m/s/s	0.19

		Braking – Design Adhesion Limits	
	Achieved Brake Rate (m/s/s)	No cross blend	With cross blend
Average ATO brake rate - tunnel	1.15	0.14	0.16
Maximum ATO brake rate	1.4	0.16	0.2
Average (normal) ATO brake rate – open	0.6-0.9	0.10	0.16
Average (reduced) ATO brake rate – open	0.3-0.5	0.06	0.06
Maximum service brake rate (manual)	1.15	0.14	0.16
Emergency nominal brake rate	1.4	0.16	N/A

To optimise the use of the dynamic brake, a higher adhesion limit may be utilised during cross blending. In the event of wheelslip being detected, cross blending shall be cancelled and the “No cross blend” limits shall apply. 5793

3.2 Traction Performance 2285

The Train shall be capable of meeting, or exceeding, on dry level tangent track, the speed distance performance curves, as defined in Section 4.1.1 of Reference Document NTfL-2344.3.4-LUL-RPT-00009 'Speed-distance profiles, Interstation Line Geography and run-times'. 5174

The Train shall be capable of operating the duty cycle depicted in the indicative individual inter-station profiles contained within Section 4.1.2 of Reference Document NTfL-2344.3.4-LUL-RPT-00009 'Speed-distance profiles, Interstation Line Geography and run-times'. 6325

The Train shall be capable of operating the duty cycle depicted in the indicative individual inter-station profiles contained within Section 4.1.2 of Reference Document NTfL-2344.3.4-LUL-RPT-00009 'Speed-distance profiles, Interstation Line Geography and run-times' when in the Full Load condition. *It is acknowledged that, owing to the higher* 7100 *load, the Train may not match the speed-distance profiles shown.*

The indicative inter-station profiles shall be met whilst operating with a nominal dwell time (wheel stop to wheel start time) of 30 seconds at each station, including terminal stations. 5794

Station locations, gradients, distances between stations and maximum operating speeds are also contained within Reference Document NTfL-2344.3.4-LUL-RPT-00009 'Speed-distance profiles, Interstation Line Geography and run-times'. 2288

The Train shall sustain the performance requirements for wheel diameters from maximum (new) to minimum (fully worn). 2301

The Train shall be able to achieve and maintain an operating speed of 100km/h on dry level tangent track in the open whilst operating at all loading conditions up to and including Full Load. 3132

The maximum speed of the Train shall not exceed 104km/h. 5012

The maximum acceleration jerk rate shall be $0.75 m/s^3$ for level tangent track. 2256

The achieved acceleration rate on level tangent track shall be within 5% of the demanded rate. 2308

The Train shall initiate motoring above 450V. 2294

The Train shall continue motoring between 400V and 450V, although this may be at reduced performance. 4390

The Train shall not be damaged by traction supply voltages lower than 400V. 4392

The Train shall operate on supplies which have a nominal voltage of 630V DC and 750V DC. The performance defined in this specification shall be delivered at both voltages. 1233

The maximum permitted line current for the Train in motoring shall be 4500A irrespective of the traction supply voltage. 2296

The maximum permitted line current includes an allowance for train auxiliary loads and the Manufacturer may reduce auxiliary loads in motoring to maximise the line current available for traction.

The maximum permitted line current for the Train in braking shall be 6000A irrespective of the traction supply voltage. 4993

The traction system shall not isolate itself when subjected to supply interruptions resulting from ice on the conductor rails and consequential 1157 arcing. This shall work effectively with the rail gap detection system.

3.3 Emergency Braking Performance 3150

The emergency brake shall be used to bring the Train to a halt within a defined distance. 3161

The emergency brake performance shall achieve the stopping distance requirements for the full range of initial adhesion conditions, from "good" to "exceptionally low" adhesion inclusive. It shall be acceptable to achieve this performance with sanding and WSP operating for "marginal" to "exceptionally low" adhesion conditions. 3151

The requirement for "marginal" to "exceptionally low" adhesion conditions need not apply on the Waterloo & City Line Train.

The application jerk rate shall be a maximum of $2.0m/s^3$. 3154

Instantaneous deceleration shall not exceed $1.8m/s^2$ for speeds above 20km/h. Below 20km/h a maximum 10% increase in instantaneous deceleration shall be permitted if required. 3155

The average deceleration, from emergency brake initiation to the Train coming to a stand, on level tangent track, shall not exceed $1.5m/s^2$. 3156

The Train shall be designed to achieve an established deceleration of $1.4m/s^2$ on level tangent track under dry conditions during emergency braking from an initial speed of 80km/h. 3157

The emergency brake system shall be designed such that under adhesion conditions meeting the definition of “good”, “sufficient” or “adequate” ($\mu \geq 0.1$), with all its brake application systems cut-in, the Train will stop within 95% of the Target Emergency Brake Distance (TEBD), defined as follows: 3153

The TEBD for dry rail and wet rail conditions, (defined as “good”, “sufficient” or “adequate”), is defined using the following formulae:

The more stringent (i.e. the lesser distance given by the two formulae) for any speed, load, gradient or rail condition (dry or wet) shall apply.

a) The TEBD under all conditions of load, train formation, line speed and gradient shall be given by:

$D_T = 0.945*(0.417 *Vo + 0.077 *Vo^2/[2*\{a+0.0981*G\}] + 7.82*10^{-7} *Vo^4)$

Where

D_T = Braking distance from the point of brake initiation to rest (in metres)

Vo = Train speed at brake initiation (km/h)

$a = 1.3\ m/s^2$ (dry rail) or $1.1\ m/s^2$ (wet rail - continuous heavy rainfall)

G = Percentage gradient (+ve up, -ve down)

b) The TEBD for a stop commencing from 40 km/h or above shall be given by

$D_T = (0.393 *Vo^2)/(E + G)$

Where D, T, Vo and G are as defined above and

E = minimum acceptable braking efficiency (%) on level track 10.2% (dry rail) or 8.5% (wet rail)

The performance in 'adequate' adhesion conditions shall be attained using the WSP system providing conditioning of the wheel rail interface, without sanding operating.

The emergency brake system shall be designed such that under adhesion conditions meeting the definition of “marginal”, “poor”, "low" or “exceptionally low” ($\mu < 0.1$), with all its brake application systems cut-in, the Train will stop within the distance defined by the following calculation. 3158

This requirement need not apply to the Waterloo & City Line Trains.

The more stringent (i.e. the lesser distance given by the two formulae) for any speed, load, gradient or rail condition shall apply.

Note - This formula is principally intended for stops commencing from a speed of above 40kph

$D_T = 1.1*(0.417 *Vo + 0.077*Vo^2/[2*\{a+0.0981*G\}] + 2* 10^4/Vo^2)$

Note - This formula is principally intended for stops commencing from a speed of below 40kph

$D_T = 1.1*(0.417 *Vo + 0.077*Vo^2/[2*\{a+0.0981*G\}] + 125/Vo/3)$

Where

D_T = Braking distance from the point of brake initiation to rest (in metres)

Vo = Train speed at brake initiation (km/h)

a = Defined nominal deceleration for the adhesion level (see table below)

G = Percentage gradient (+ve up, -ve down)

Adhesion Level (at leading wheelset)	Adhesion Description	Nominal Deceleration (m/s^2) to be used in the above formulae
0.08 - 0.10	Marginal	1.05
0.06 - 0.08	Poor	1.0
0.04 - 0.06	Low	0.75
0.02 - 0.04	Exceptionally Low	0.55

For the purpose of this calculation, brake initiation is, whilst under automatic train protection (ATP), the instant that the safety relays open.

This requirement need not apply to the Waterloo & City Line Trains.

The performance targets shall be attained using the adhesion improving equipment (sanding and WSP systems) operating to improve the wheel rail interface.

3.4 Service Braking Performance 3162

The Service Brake system shall deliver consistent and repeatable braking performance, achieving the demanded braking rate, irrespective of the Train's initial speed, passenger load and braking method (e.g. varying percentages of dynamic and friction braking, 2644 variations in friction as the Train's speed reduces). The avoidance of any discernible variation (increase or decrease) in deceleration (for a constant brake demand) during a stop is essential.

The Service Brake shall be used for all routine Automatic and Manual mode braking requirements. 3165

The Service Brake shall allow control of varying amounts of braking effort for variable durations. 3166

Under dry rail (good) adhesion conditions, the demanded brake performance, for any level of service brake, shall be achieved without any operation or intervention of the WSP and (trainborne) adhesion improving systems. 3169

Under Manual control the service brake shall be delivered between $0.2m/s^2$ and $1.15m/s^2$ on level tangent track. 3170

Under RCS control the service brake shall be delivered between $0.2m/s^2$ and $1.4m/s^2$ on level tangent track. 3171

Over the range of the 'marginal' and 'poor' adhesion band in leaf film contaminated conditions, the Train shall stop within the distance that would be achieved by a constant service brake demand of $0.75m/s^2$ on dry rail level track. 2931

To achieve this requirement it is acceptable to vary the service brake demand across the full range during the stop.

This requirement need not apply to the Waterloo & City Line Trains.

Over the range of the 'marginal' and 'poor' adhesion bands in damp/wet conditions, the Train shall stop within the distance that would be achieved by a constant service brake demand of $0.75m/s^2$ on dry rail level track. 5835

To achieve this requirement it is acceptable to vary the service brake demand across the full range during the stop.

This requirement need not apply to the Waterloo & City Line Trains.

Over the range of the 'low' and 'exceptionally low' adhesion bands in leaf film contaminated conditions, the Train shall stop within the distance that would be achieved by a constant service brake demand of $0.50m/s^2$ on dry rail level track. 5836

To achieve this requirement it is acceptable to vary the service brake demand across the full range during the stop.

This requirement need not apply to the Waterloo & City Line Trains.

Over the range of the 'low' and 'exceptionally low' adhesion bands in damp/wet contaminated conditions, the Train shall stop within the distance that would be achieved by a constant service brake demand of $0.50m/s^2$ on dry rail level track. 5837

To achieve this requirement it is acceptable to vary the service brake demand across the full range during the stop.

This requirement need not apply to the Waterloo & City Line Trains.

The Train shall have a jerk rate under all load conditions of not greater than $0.5m/s^3$ in service braking. 2347

The service brake release rate shall be capable of being increased (from its normal value to ~ $1.0m/s^3$) at low speed so as to ensure that a reduction in brake demand of 50% or more (e.g. from $1.15m/s^2$ to $0.5m/s^2$) at a speed of 5 km/h will result in a reduction in Train deceleration from $1.15m/s^2$ to no more than $0.75m/s^2$ before the Train comes to a stand. 5229

The application and release jerk rates shall be separately adjustable. 5004

The achieved service brake rate for a constant demand under dry rail adhesion conditions on level tangent track shall be within 7.5% of the demanded rate. 3353

The Train shall not suffer from loss of friction due to brake block/disc pads glazing or brake block/disc pad contamination. 6586

There shall be a facility to occasionally use friction only, on all or part of the Train, for a complete stop in order to maintain brake block/disc pad condition. It shall be possible to programme this to occur based on varying times between applications and locations on the line. 6587

For example, this may be on open sections only and every 150th brake application, occurring on half the Train to reduce any potential unusual smells.

The Train design shall be optimised to minimise the potential for metal pick-up in brake blocks or brake disc pads. 4009

Metal pick-up on brake blocks has been encountered on existing modern LU stocks and is thought to be due to a combination of dynamic braking, under wet conditions, with restricted application maintaining the blocks in light contact with the tread for significant periods of time. 4609

The brake effort applied on any bogie shall reflect the bogie load and deceleration demand. The brake effort applied throughout the stop shall not vary from the effort required by more than ±5%. In achieving this requirement, the specified jerk rate limit shall not be exceeded. 3623

During any brake blending at the beginning of a stop, the Train deceleration shall not exceed that demanded nor vary by more than ±10% from the (jerk rate limited) deceleration demanded. 3627

During the transition from dynamic to friction braking, the Train deceleration, for a given demand, shall not vary by more than ±5% from that existing prior to the start of the dynamic brake fade out. 3628

3.5 Parking Brake Performance 3164

In the absence of the energy necessary to apply or maintain other forms of braking, the parking brake shall automatically be applied on a stationary Train before the original brake effort has fallen to a level insufficient to secure the Train. 3179

The parking brake shall be achieved through the use of automatic spring applied, air released brake actuators. 3180

This is referred to as a Spring Applied Parking Brake (SAPB).

When applied following the application (and subsequent release) of the emergency brake, the parking brake performance shall be capable of holding a Crush Laden Train on the steepest applicable gradient indefinitely. 3181

It shall not be possible to disable or manually release the parking brake from any operating position, saloon or under-seat location. 3187

The parking brakes shall be distributed between the Train's axles so as to ensure that, in the event of a Tare Train having to be moved with its parking brake applied, the adhesion required to allow the wheels (on an SAPB applied axle) to rotate rather than slide shall not exceed 0.15. 3189

3.6 Wheelslide Protection (WSP) Performance 3196

The achieved performance shall be in accordance with Reference Document DTP-UIP1973-1.5-RPT-00049 'WSP Performance & Testing Requirements'. This shall, for specific adhesion profiles, assess the performance of: 2868

- stopping distance compared to the Peak Adhesion Seeking Model;
- wheelset lock-up;
- air consumption (if necessary);
- control of WSP Reference Speed.

The WSP system shall achieve the performance requirements over the range of defined adhesion conditions including steady rain, light rain or drizzle, damp rail (no precipitation), oil or grease contaminated rail and leaf contaminated rail. 2757

3.7 Emergency (Fault) Capability 2309

Under all credible failure conditions, sufficient traction and braking facilities shall remain available to enable the Train to be operated out of service or to a depot at the highest safe speed. 2310

With any single traction system component failure a Crush Laden Train positioned wholly on the maximum gradient on the line on which the Train operates, shall be able to start and subsequently be capable of running from any point on the line to a depot assuming a Crush Laden condition and 30s station dwell times. 2313

With any two traction system component failures a Crush Laden Train positioned wholly on the maximum gradient on the line on which the Train operates, shall be able to start and continue to the next station. Once emptied of passengers the Train in Tare condition shall be capable of continuing on the line to a Depot or siding. 2314

With the Train's traction capability supplied from one set of Shoegear, the Train shall be able to start and move a Train in the Full Load condition for a distance of at least 100m up gradients up to and including a maximum of 2.5%, achieving and sustaining a speed of at least 5km/h, without sustaining any damage. 2315

With the Train's traction capability supplied through any one traction power shed receptacle, the Train shall be able to start and move a Train in the Full Load condition for a distance of at least 100m up gradients up to and including a maximum of 2.5%, achieving and sustaining a speed of at least 5km/h, without sustaining any damage. 979

3.8 Recovery Capability 3135

A Tare Train shall be capable of propelling a failed Crush Laden Train over the route and distance to the next station, without sustaining any damage, starting from any position on the line. 3136

A Crush Laden Train shall be capable of propelling a failed Crush Laden Train over the route and distance to the next station, without sustaining any damage, starting from any position on the line. 2318

A Crush Laden Train shall be able to push or pull out another Crush Laden Train on the worst running track incline on the railway, without damage to the Trains or permanent deformation of any elements in the coupling system. 2726

A Tare Train shall be capable of propelling a failed Tare Train to the nearest depot from any location on the line, at any speed up to a minimum of 50km/h, without sustaining damage. 2319

With 50% Spring Applied Parking Brakes (SAPB) applied and 50% 2321 tractive capability unavailable, a Train in a 50% Full Load condition shall be capable of starting on the maximum gradient on the line on which the Train operates, and sustaining movement to the next station without sustaining any damage.

When a SAPB is applied, it shall be possible to recover the Train at no less than 15km/h without damage to the parking brake and without damage to the wheel. 5293

3.9 Self Powered Movement 2349

In the event of an absence of traction power, the Train shall be capable of moving at slow speed for a distance of no less than 200m, with the Train in a Tare condition on level track. 2351

In the event of an absence of traction power, the Train shall be capable of moving at slow speed for a distance of no less than 50m, with the Train in a Crush Laden condition on level track. 5534

The Train shall maintain Train Essential Services during self powered movement. 3631

During self powered movement, the Train shall maintain any train functions which are necessary to ensure that movement will occur. 6585

For example, the compressors may need to operate to allow movement.

Self powered movement shall be enabled by a control at the operating position. 5811

Self powered movement shall be enabled by a command from the RCS. 5812

The Train shall attain a speed of not less than 6km/h during self powered movement on level tangent track. 5535

The Manufacturer shall undertake analysis and testing to define the operating boundaries of self powered movement. This shall be based on a range of combinations of initial battery charge, gradients and passenger load including but not limited to those stated in the self powered performance requirements. The Manufacturer shall determine: 6179

- The initial battery charge required for self powered movement to be enabled under a range of credible gradient/load combinations.
- The extent of self powered movement that can be achieved.
- The state of charge of the battery following self powered movements, detailing:
    - the ability of the battery to deliver some or all of the

emergency support duty immediately after self powered movement;

- the time for the battery to recharge after self powered movement.

This is to enable the Purchaser to refine its recovery plans where self powered movement may be used to recover from failures in service and avoid detrainment of passengers.

3.10 Train Resistance 2324

Train resistance shall be minimised as far as practical, whilst ensuring that other requirements (e.g. bogie dynamic performance) are not compromised. 2325

3.11 Noise, Shock & Vibration and Ride 33

3.11.1 Noise 2882

Unless otherwise specified, all measurements shall be made in accordance with British Standard BS EN ISO 3095:2013 'Acoustics - Railway Applications - Measurement of Noise Emitted by Railbound Vehicles' and British Standard BS EN ISO 3381:2011 'Railway Applications - Acoustics - Measurement of Noise Inside Railbound Vehicles'. 2886

The noise limits specified shall be reduced by 3dB(A) if significant pure tones in the range 200Hz to 4000Hz are present. The significance of pure tone noise in this context shall be assessed using the 'one-third octave' method in Annex C of British Standard BS 4142:2014 'Methods for rating and assessing industrial and commercial sound'. 2889

When the Train is stationary the noise level in the saloon and cab shall not exceed 65dB(A) with all auxiliary equipment operating at its greatest noise output capacity. 2890

The noise levels in the saloon interior at any point along the car centre-line shall be measured at both 1200mm and 1600mm above the floor and not less than 600mm from the end of the saloon. 2893

The noise levels in the cab shall be measured 1000mm above the floor and not less than 200mm from any wall. 2891

The simultaneous operation of all saloon doors on one side of the car (with the audible warnings disabled) without operation of any other auxiliary equipment, shall not produce a noise level inside the car exceeding 75dB(A) measured using the Fast and Impulsive time constant. 2919

When the Train is moving on open sections at the scheduled speed 2898 profile of the railway with all auxiliary systems operating normally and simultaneously, the average inter-station noise levels (Leq) inside the saloon shall not exceed 72dB(A).

When the Train is moving on surface sections at the scheduled speed profile of the railway with all auxiliary systems operating normally and simultaneously, the average inter-station noise levels (Leq) in the cab shall not exceed 70dB(A). 2903

When the Train is moving in tunnel sections with all auxiliary systems operating normally and simultaneously, the average inter-station noise levels (Leq) inside the saloon running at the scheduled speed profile of the railway shall not exceed 78dB(A). 2905

When the Train is moving in tunnel sections with all auxiliary systems operating normally and simultaneously, the average inter-station noise levels (Leq) in the cab shall not exceed 72dB(A). 2906

The inter-station noise levels are typically calculated from test data collected from a limited section of LU track known to be of a good standard. The noise levels at a number of selected positions inside the train are measured on the section of ISO standard compliant track when the train is operated at a range of speeds e.g. 20, 40, 60, 80, 100km/h. A speed versus noise relationship is established and used together with the speed profile of the whole line being assessed to calculate the average noise level for the line. 5416

When the Train is stationary on an open section with all auxiliary systems operating normally and simultaneously, the noise level outside the Train shall not exceed 65dB(A) at any point along the length of the Train on either side. The noise level shall be measured at a position 7.5m horizontally from the centre-line of the track and at any point between 1200mm and 1500mm above the top of the running rail. A second microphone position at a height of 3500mm above the top of the running rail shall be used if significant sound sources are present in the upper part of the car under test. 2910

When the Train is moving on an open section with all auxiliary systems operating normally and simultaneously, the noise level outside the Train shall not exceed 80dB(A) at any speed up to and including 80km/h. The noise limit shall apply at any point 7.5m horizontally from the track centre-line and at any point between 1200mm and 1500mm above the top of the running rail. A second microphone position at a height of 3500mm above the top of the running rail shall be used if significant sound sources are present in the upper part of the car under test. 2915

3.11.2 Shock, Vibration & Ride 2883

The Train overall and its individual sub-systems shall not produce any vibration that is discernible to passengers, whilst the Train is stationary. 2947

All equipment shall comply with the shock and vibration requirements stated in British Standard BS EN 61373:2010 'Railway Applications. Rolling Stock Equipment. Shock and Vibration Tests'. 2525

The vibration levels for standing passengers, determined by the RMS of the root sum-of-squares of the frequency weighted accelerations in the longitudinal, lateral and vertical directions at all positions on the saloon floor, shall not exceed 0.5m/s², measured over the period of any inter-station run when running on track that meets the MT (Maintenance Target) quality level according to the tolerances in LU Standard S1159 'Track – Dimensions and Tolerances'. 2967

The vibration levels for seated passengers and staff, determined by the RMS of the root sum-of-squares of the frequency weighted accelerations in the longitudinal, lateral and vertical directions at all seat positions, shall not exceed 0.5m/s², measured over the period of any inter-station run when running on track that meets the MT (Maintenance Target) quality level according to the tolerances in LU Standard S1159 'Track – Dimensions and Tolerances'. 2969

Whole body vibration measurements shall be carried out in accordance with the current British and EU legislation at all operator and staff seated and standing positions in the Train running at the scheduled speed profile over the full line. The measured levels across the whole line shall be less than the exposure action values. 2971

Vibration measurements and frequency weightings shall be in accordance with British Standards BS ISO 2631-1 'Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration Part 1: General Requirements' and BS ISO 2631-4:2001+A1:2010 'Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration - Guidelines for the Evaluation of the Effects of Vibration and Rotational Motion on Passenger and Crew Comfort in Fixed Guideway Transport Systems' for both passenger and on-train staff exposure. 2966

4 Traction and Braking 28

4.1 Brakes - General 2628

The Train shall be fitted with a friction brake, a regenerative dynamic brake and a rheostatic dynamic brake. 2370

The Train shall be fitted with emergency, service and parking brakes. 3160

A per axle Wheelslide Protection (WSP) system shall be provided, which shall be operable in both emergency and service brake modes. 3622

A sanding system shall be provided, which shall be operable in both emergency and service brake modes. 4482

4.2 Dynamic Braking 2203

Regenerative braking shall be used as a priority during service braking. 2217

The maximum use shall be made of the dynamic brake capability and it shall take precedence over the friction brake throughout the whole range of service brake applications, subject to the defined adhesion limits. 3644

Where the capacity of either the friction brake, the dynamic regenerative brake or the rheostatic brake is insufficient to meet the required performance on its own, then it shall be acceptable for the Train performance to be met using these in combination. However, allowance shall be made for equipment defects and isolations such that the Train performance can continue to be met under all reasonable fault and operating conditions. 2373

In the event that the Train reverts to friction braking as part of WSP at several consecutive station stops, the Train shall be capable of continuing in service using the friction brake, with no degradation in performance or unacceptable wheel temperatures. After each time that the train comes to a halt, the next brake application shall use the electric (dynamic) brake if the level of adhesion is sufficient. Irrespective of the braking method used, the Train shall be able to continue in service and there shall continue to be no adverse effect on both the Train's equipment and the braking performance. 2229

The braking requirements shall be met irrespective of the available line receptivity. 6569

Limitations in line receptivity may be: 1119

- permanent, such as during the inter-running phase when the line voltage is 630V nominal so as to be suitable for the existing trains on the line;

- transient, such as when the Train is passing over one or more rail gaps.

Switching between regenerative, rheostatic and friction braking shall not affect the braking performance and shall not produce any effects discernible to operators or passengers. 3621

It shall be possible to adjust the regenerative voltage limit between 630V DC and 1000V DC. 2372

The regenerative voltage limit shall be switchable between two or more pre-programmed settings, while the Train is operating in passenger service. 6570

The regenerative voltage limit shall be selectable between two or more pre-programmed settings depending on the geographical location of the Train. 5226

The line current limit shall be switchable between two or more pre-programmed settings while the Train is operating in passenger service. 5227

The line current limit shall be selectable between two or more pre-programmed settings depending on the geographical location of the Train. 5228

It shall be possible to adjust the line current limit locally on the Train, via RCS and via the OTC. 6847

It shall be possible to adjust the regenerative voltage limit locally on the Train, via RCS and via the OTC. 6848

4.3 Traction and Braking Control 173

No single failure of the Train control system shall cause an unsafe condition. 2205

The risk of un-demanded movement shall be as low as reasonably practical. 183

Safety devices shall prove that the emergency brake is available on the Train before allowing the Train to move. 6087

No single failure of the Train control shall cause the traction to be disabled. 186

No single failure of the Train control shall cause the braking to be disabled. 5240

The service brake control shall, co-ordinated with the propulsion control, enable a Train to be started on an uphill gradient without any rollback occurring. This shall be achieved in both Automatic and Manual modes of operation. 2667

The Train shall respond to continuously variable traction demands between the minimum and maximum levels. 5951

In the event of loss of the traction supply, the Train shall have the ability to coast as far as possible in order to clear gaps or to reach the next platform, as permitted by the Train protection system. 185

The maximum tractive acceleration rate shall be switchable between two or more pre-programmed settings while the Train is operating in passenger service. 6588

The maximum tractive acceleration rate shall be selectable between two or more pre-programmed settings depending on the geographical location of the Train. 6589

It shall not be possible to change demanded direction whilst the Train is in motion. The Train must come to a halt before any directional change can take effect. 189

The Train shall coast when neither motoring nor braking demands are active. 179

If both motor and braking demands are obtained together, the Train shall not motor. 190

If both forward and reverse demands are obtained together, the Train shall not motor. 191

Any sudden unexpected combination of inputs to equipment shall not lead to damage to the equipment or cause an unsafe condition to arise. 193

In the absence of a load weigh signal, the traction system shall default to the Full Load condition. 985

In the event of a failure to generate, or transmit, a service brake demand, the service brake shall default to a demand of $0.75 m/s^2$ and this shall be load weighed. 2669

In the absence of a load weigh signal, the service brake on that car where the signal is lost shall default to the Full Load condition. 5245

Any automatic isolation of propulsion equipment, upon detection of an internal fault, shall be limited to the affected equipment and shall, wherever possible, avoid the need for maintenance intervention to reset 194 the affected equipment.

The Train shall not be adversely affected by transients on the traction supply, including those generated by the Train or other Trains in the same electrical supply section. 195

The Train shall interrupt a short circuit current of up to 90kA, which is formed by contributions from the local and remote substations. This current is usually interrupted 20ms after the initiation of a fault. 196

The Train shall operate normally with an earth fault of either polarity on the external traction supply. 197

A single pole earth fault of either polarity may be present on the traction supply until corrected, usually 24 hours for the Piccadilly and Central Line. On the Bakerloo Line, north of Queen's Park, and on the Waterloo & City Line the negative rail is bonded to the running rails and so a negative earth fault is always present. 4485

Locked axles shall be automatically detected and advised to the RCS. 2338

The state of all controls, fault-handling devices and the selected Train Protection shall be used by the control system to automatically enable and enforce the best safe behaviour of the Train. Unless higher speeds are permitted by the Train protection control system, the maximum permitted safe speed shall be 16km/h. 794

When the Train is under manual control, the closure of all external side sliding doors shall be followed by a subsequent positive action by the Train Operator before motoring is enabled. 5396

This is typically achieved by requiring the traction brake controller to be in a non-motoring position when the doors closed proving input is received and by restroking the traction brake controller (moving from motoring to non-motoring and back again) if the doors closed proving input is momentarily lost and regained during motoring.

The braking system shall comply with the requirements for an automatic and continuous brake system. 2207

The Traction Brake Controller (TBC) motoring effort demand shall be continuously variable between the first motoring position and the maximum demand position. 5338

The TBC braking effort demand shall be continuously variable between the first service braking position and the full service braking position. 7083

The TBC shall provide motoring demands when operated in a forwards direction and braking demands when operated in a rearwards direction. 5797

The change in demand between increments on the TBC shall be no 5340 more than $0.05m/s^2$.

The TBC design shall ensure that no single action using readily available items shall permit any of the device's safety features to be overridden. 2631

The TBC shall incorporate a vigilance device function which applies the emergency brake in the event of the incapacity or inattention of the Train Operator. *The TBC vigilance device is also commonly known as the deadman's handle.* 5339

In Manual mode, the status (either held or released) of the vigilance device associated with the traction and braking controls in the cab (the TBC vigilance device) shall be used to cause an alarm (the OPO(T) alarm) to be sent to the control centre via the Train Radio as follows: 5261

- Up to 60 seconds after release: no action;
- 60 seconds after being released: a continuing audible alarm shall sound at the operative position and a visual prompt shall be shown to the Train Operator;
- 90 seconds after being released: a message shall be sent to the line control centre, the Yellow Indicator Light at both ends of the Train shall be illuminated.

If the vigilance device status returns to 'held', the OPO(T) alarm timer shall be reset and all alarms and indications shall cease.

Note – the requirement is for the alarm timer sequence to be triggered after the vigilance device has been released. When Manual mode is first selected, the vigilance device will not have been released and the alarm timer sequence should not commence. Once the vigilance device has been held and released for the first time then the alarm timer sequence should commence.

The TBC shall be designed such that there is sufficient resistance to movement to avoid the TBC moving from its selected position due to Train motion and its transmissions. 5341

The TBC shall, if released from the motoring position, spring back into a non-motoring position. 5343

There shall be detents between each of the following positions on the TBC: 5342

- Off & Release and the first motoring position;
- Off & Release and the first service braking position;
- Full service position and emergency position.

In addition to demonstrating its fitness for use, over the defined overhaul interval, testing shall also be conducted to demonstrate the TBC's capability to withstand abuse during normal operation when fitted in a Train. The testing shall include, but not be limited to: 5241

- Being moved rapidly and violently between the two limits of travel;
- Repeated rapid cycling between full motoring and coasting positions;
- Repeated rapid cycling between full braking and coasting positions;
- Repeated rapid cycling of the deadman's device or vigilance system interface;
- Being operated by means of a Train Operator's foot or feet;
- Being wedged into a particular position (e.g. full motoring).

In addition to demonstrating its fitness for use, over the defined overhaul interval, testing shall be conducted to demonstrate the TBC's capability to withstand abuse when being moved around the depot and when being fitted or removed from a Train including: 5796

- Being knocked or dropped while being moved or installed;
- Being carried and manoeuvred by the handle during fitment and removal.

The TBC shall have motoring, Off & Release (coasting), service and emergency braking control functions which are mutually exclusive. Emergency braking shall, when demanded, override all other commands under all conditions. 4985

In Manual mode the status (either held or released) of the vigilance device associated with the traction and braking controls in the SOP shall be used to cause an alarm (the OPO(T) alarm) to be sent to the control centre via the RCS, as follows: 7067

- Up to 60 seconds after release: no action;
- 60 seconds after being released: a continuing audible alarm shall sound at the operative position and a visual prompt shall be shown to the Train Operator;
- 90 seconds after being released: a message shall be sent to the RCS, the Yellow Indicator Light at both ends of the Train shall be illuminated.

If the vigilance device status returns to 'held', the OPO(T) alarm timer shall be reset and all alarms and indications shall cease.

Note – the requirement is for the alarm timer sequence to be triggered after the vigilance device has been released. When Manual mode is first selected, the vigilance device will not have been released and the alarm timer sequence should not commence. Once the vigilance device has been held and released for the first time then the alarm timer sequence should commence.

A failure in either the emergency, service or parking brake shall have minimal effect on the function and performance of the other brake systems. 2218

Loss of the service brake control at the operating position shall result in an emergency brake being applied automatically in place of a service brake demand. 2210

In the event of faults on the Train which would affect the Train's ability to run at full performance, the Train shall inform the RCS and the OTC, such that the RCS can take any remedial measures necessary to cope with the fault. 5242

Faults which lead to a reduced brake availability are an example of this circumstance.

Facilities shall be provided to overcome head end and local faults in the braking system while retaining the maximum of braking capability. 3639

A means shall be provided within the saloon for maintenance and Emergency Response Unit staff to disconnect each individual propulsion control package. 181

It shall be possible to move the Train, at up to full speed, without either mechanical or electrical damage occurring to the propulsion equipment at unpowered (isolated) positions. This may occur until such time as a defective Train is repaired. 2554

It shall be possible to isolate the regenerative brake on a per Train basis without the need for either specialist tools or equipment or the need for a pit road. 2553

A means shall be provided at each driving position for an operator to carry out a static test of the emergency brake system. 6647

The emergency brake test shall confirm the successful brake application of the full Tare emergency brake pressure by each brake equipment. 6649

Feedback shall be provided on the outcome of the emergency brake test. 6648

It shall be possible to complete the emergency brake test with only one car connected to the traction supply. 6651

4.4 Brake Control System Integrity 786

The emergency brake control system shall incorporate a high level of system integrity. This shall be achieved by either two electrically independent hard wired safety circuits or a proven-in-service SIL4 control system accompanied by a suitable safety justification. 787

Where two electrically independent hard wired safety circuits are used these shall be designed so that: 3674

- either circuit shall be able to be used to control the Emergency Brake;
- both circuits shall be Energise to Release;
- each safety circuit shall have dedicated feed and return wires and be switched in both wires by each safety device.

A method shall be provided to prove that the Train is continuous and that the safety devices along the Train are correctly set. This shall be achieved by either a hard wired safety circuit or a proven-in-service SIL4 control system accompanied by a suitable safety justification. 791

Proving that the Train is continuous has traditionally been achieved by using a hard wired circuit, called the Round Train Circuit. 4948

In the event that any safety device in the Train is not correctly set the emergency brake shall be applied, except where it has been bypassed by the positive action of an authorised person. 789

If a hard wired circuit is chosen for the Train continuity circuit, it shall have dedicated feed and return wires and, when de-energised, cut both safety circuits at the operational position. 790

Hardwired safety circuits and Round Train Circuits of this design have been supplied on LU Trains in the past but this has led to significant amounts of wiring. The Manufacturer should propose any alternative equivalent standard product if this can be demonstrated to be beneficial to the overall design. 788

4.5 Wheelspin Control and Rail Squat Defects 2330

Traction shall be controlled so as to minimise the risk of rail damage under Compromised Adhesion conditions. 2331

The traction control system shall detect the onset of wheel spin and control tractive effort to ensure that wheelset and railhead damage does not occur. 2381

Tractive effort shall be reapplied following wheelspin at a rate and to a level to maintain journey times and to maximise available adhesion whilst remaining within defined jerk rate limits of passenger comfort, without wheel/rail damage such as the formation of rail squats. 2382

Rail squats due to modern propulsion equipment wheelspin control are described in the Reference Document 'Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit 0954409712465697', first published December 4, 2012 and Reference Documents 2012-11-92TS-04A 'Traction Requirements to Minimise Thermal Rail Defects' and 2013-03-92TS-06A 'Wheelspin Control - Standard for Rolling Stock'. 3142

Evidence suggests that rail squat defects form when speeds are below

25km/h, predominantly in the 0 to 20km/h range, and arising from the use of high acceleration rates and their reapplication at speed following a demand change from braking to motoring.

The Manufacturer shall demonstrate that their wheelspin control system does not cause rail squat defects to occur. 2334

4.6 Rail Gap Detection 2350

The Train shall be fitted with a gap detection and management system to minimise the production of arcs, shoe wear and electromagnetic interference (EMI) at collector shoes when they pass off a conductor rail ramp by minimising the current passing through the shoe just before the shoe arrives at the ramp. 2357

A compliant solution could be that the leading propulsion equipment detects a rail gap and passes a message to the following propulsion equipments to reduce their load as they approach the gap. It is acknowledged that an arc will be generated by the first traction equipment. 4614

The rail gap detection and management system shall not be falsely triggered when shoe bounce occurs. 2359

The rail gap detection and management system shall not reduce tractive effort when shoe bounce occurs. 4610

The rail gap detection and management system shall not be falsely triggered due to the presence of snow, ice or due to de-icing fluid on the conductor rails. 4015

4.7 Propulsion Equipment Components 2379

Air exhausted from the Train's cooling fans (e.g. brake resistors) shall be directed to avoid discomfort to passengers embarking, disembarking and standing near the Train. 2362

Air exhausted from the Train's cooling fans (e.g. brake resistors) shall not be drawn into the saloon by the HVAC system. 3144

Gearboxes shall incorporate a removable magnetic plug to enable monitoring of ferrous materials within the gearbox, which allows access without the need to drain the gearbox. 2583

Cooling systems shall be designed to ensure that they are not prone to obstruction or blockage and shall be designed to be compatible with the proposed cleaning regime. 2589

Brake resistors shall be designed in accordance with British Standard 1117

BS EN 60322:2001 'Railway Applications. Electric Equipment for Rolling Stock. Rules for Power Resistors of Open Construction' and shall be rated to comply with the full performance specified without exceeding the temperature limits specified.

Brake resistors shall be readily accessible for cleaning. 1118

The Manufacturer shall demonstrate that any litter and debris likely to be in contact with the brake resistor shall not cause short circuits, become trapped, block airflow or cause a fire hazard. 6610

4.8 Emergency Brake Control 2418

The emergency brake shall apply on demand with an integrity equivalent to SIL4 in British Standard BS EN 50129 'Railway Applications - Communication, Signalling and Processing Systems - Safety Related Electronic Systems for Signalling'. 2242

The Emergency Brake shall be controlled by an “Energise to Release” system. 2216

No single fault shall result in the Critical Brake Loss being reached. 2243

Train(s) shall be proven to be complete before the emergency brake can be released. 2201

The emergency brake shall apply when any safety device or input changes to an unsafe position. 4313

The control devices for the emergency brake are likely to include: 2244

- *any TBC moved to the emergency position;*
- *any vigilance device released;*
- *PEAB demand;*
- *any Emergency stop button operated;*
- *cars becoming separated;*
- *train protection (tripcock) emergency demand;*
- *unsafe condition (mainline air is low);*
- *any RCS demanded emergency brake;*
- *any other (emergency) device(s) identified during design.*

The emergency brake application shall be made irrespective of any service brake application which already exists. 2422

Brake forces in emergency braking shall be distributed to ensure that no axle is over-braked by more than 5% of the theoretical force required to decelerate that axle’s dynamic load at the required rate. 2421

This requirement shall be met over the entire Tare-Crush Laden range.

The emergency brake shall apply throughout the Train in response to the de-energisation of its control circuit. 2248

The emergency brake shall be interlocked so that motoring is shut off when an emergency brake application is initiated. 2245

The emergency brake application time (to 90% of the full brake pressure) for a Crush Laden car shall not exceed 1.5 seconds. 6027

4.9 Service Braking Control 2423

The service brake shall be controllable via the traction brake controller (TBC) 2225

The service brake shall be controllable via the RCS to enable automatic operation. 3642

The service brake shall maximise the use of regenerative braking whenever the infrastructure allows, subject to the defined adhesion limits and the maximum permitted line current limit. 2227

The service brake shall maximise the use of rheostatic braking whenever regenerative braking is not available. 3643

In the event of failure of the dynamic brake on one or more axles/bogies, the dynamic brake effort shall be redistributed to other motored bogies to minimise the use of the friction brake. This shall be subject to the defined adhesion limits. 3647

The minimum blend speed shall not be so low as to consequentially affect the response time of any 'Train stationary/brakes applied interlocking' to the RCS (i.e. shall not extend the time taken to confirm that the Train has stopped and the brakes are applied to a level which can hold the Train stationary in the platform). 2228

If the transition from dynamic to friction brake took place at too low a speed, then the friction brake would not have applied prior to the vehicle coming to a stand and this would then delay the 'Train stationary & brakes applied interlocking' signal to the RCS. Dwell time is critical to the Purchaser and so such an additional delay must be avoided. 4399

The Manufacturer shall provide details of wear rates for the friction brake blocks/pads in the event that the dynamic brake is not available. This is to enable the time remaining in service under this condition, for nominal service patterns, to be predicted. 2230

When the service brake is applied, motoring effort shall be shut off. 5319

4.10 Wheelslide Protection (WSP) Control 2426

The WSP system shall be operable in emergency and service braking, including during the brake release phase. 2641

The WSP system shall provide slip/slide control for each wheelset individually (per axle control). 2764

When triggered, the WSP system shall control the wheelsets in limited slip so as to provide a progressive improvement in adhesion, and hence a reduction in wheelslip/wheelslide activity, along the Train. 2766

The WSP system shall be designed and installed so as to ensure that no single failure in the WSP system shall result in a reduction in the emergency brake effort which would cause the Critical Brake Loss to be reached. 2768

The WSP system shall not be triggered as a result of the Train attaining a high level of deceleration (> $2.0m/s^2$) on good adhesion (e.g. emergency brake applied in the tunnel at low speed with cold blocks on an uphill gradient). 2775

The WSP control shall ensure that no single common factor (e.g. speed difference between wheelset and defined maximum rate of deceleration) shall affect multiple axles simultaneously under good adhesion conditions, especially at low speeds. 2780

The WSP system shall ensure that no combination of input signals will cause the WSP control to spuriously energise either the hold or vent dump valve functions, or dynamic brake control equivalent, or prevent the correct operation of the WSP system during braking. 2778

If the WSP system inhibits the dynamic brake from one (or more) traction packages during a service brake stop, then the dynamic brake on the affected vehicle(s) shall remain inhibited until the brakes have been released for a configurable period of time (up to 10s). 2784

The WSP system shall provide protection against the continuous, sustained operation (i.e. continuous energisation) of either the vent or hold valves, or dynamic brake control equivalent. 2781

The WSP system shall not trigger spuriously resulting in the loss of significant brake effort on multiple wheelsets for a sustained period. 5296

The WSP system shall automatically compensate for wheel diameter variations without adversely affecting the WSP performance or causing spurious WSP activity. 5297

The setting of maximum operating limit timers (for vent and hold or dynamic brake control equivalent) shall be determined during performance testing of the system. 2800

The performance of the WSP system shall not be adversely affected by the operation of the sanding system. 2761

WSP system status and fault data shall be provided to the RCS. 2791

Any failure of the brake or WSP system which could compromise the operation of the sanding system shall be identified to the Train Data Recorder (TDR) and the RCS on a real time basis. 2863

4.11 Sanding System 2859

Sanding equipment shall be fitted. 6000

This requirement need not apply to the Waterloo & City Line Trains.

The Train shall be fitted with sanders, unless an alternative solution capable of equivalent performance can be offered, to improve the brake performance in reduced adhesion conditions. 5798

Type testing, including simulation techniques, shall be undertaken to demonstrate the ability of the sanding system to improve the Train's compromised adhesion brake performance whilst minimising the sand usage. 3200

The Manufacturer shall anticipate a period of iterative development work on a simulator and on the test track to determine the right balance of sand dispensing and brake performance. 5356

Type testing of the sanding system shall be co-ordinated and integrated with the testing of the braking and WSP systems in normal and degraded conditions. 4265

The Train shall provide real time information on the sanding system operation and its status to the RCS and the OTC for use by the Adhesion Management System Condition Assessment Software (AMS CAS). 3202

The sanding system shall achieve the demanded brake performance, in both emergency and service braking, under reduced adhesion conditions. 3203

The sanding system shall enable the attainment of open section ATO brake rates and stopping accuracy throughout the year. 3204

Each sander shall be automatically controlled using information from the trainborne systems (e.g. WSP and brake systems) to minimise 3205 delays in response.

The control algorithms for the sander shall be defined by the Manufacturer, based on the operating environment and the Train's design, such as to meet the braking and traction performance under degraded adhesion conditions. 2787

It shall be possible to inhibit the deposition of sand below a configurable speed limit. 3208

The sanding system installation shall ensure the minimum delay between a demand for sand and the deposition of sand at wheel/rail interface. 3209

The sanding system shall provide adequate capacity to support service operation, even under sustained adverse conditions, for an 18 operational hour minimum period before requiring refilling. 3210

The sanding system shall be installed at a sufficient number of positions along the Train to ensure that the braking performance improvement required is achieved. 3211

The sanding control shall avoid the deposition of sand under conditions of high brake demand and only a few axles slipping. It shall ensure the deposition of sand without delay under conditions of low or moderate brake demand and multiple axles slipping. 3214

The system shall allow for individual sander control along the Train to optimise the inhibit, initiation and continuance criteria for each sander installation. 3215

The sand delivery system shall provide unimpeded, consistent delivery of sand to the railhead with minimal loss (e.g. as a result of aerodynamic effects or dispersion by the wheel). 2938

The sanding containment and delivery systems shall operate under the range of environmental conditions with the sand retained and distributed in a useable condition. 2940

The sand reservoir shall be of sufficient capacity to ensure that sand will be available whenever demanded for operation in braking mode. In determining the reservoir capacity, account shall be taken of: 3119

- the mileage operated between replenishments of the reservoir;
- the anticipated maximum demand due to reduced adhesion between replenishments.

Maintenance test facilities for the on-board sanding system shall be provided, to enable individual discharge and system operation to be tested. This shall test as much of the system functionality as practicable and shall permit observation, by the maintainer, of the sand 2937 discharging.

Use of any compressed air to discharge sand shall be minimised and shall not impair the operation of other safety systems on the Train. The failure of any part of the sander pneumatic equipment and installation shall not result in a significant loss of mainline air which would disable the Train. 2948

It shall be possible to vary the sand delivery rate, as required by the sander control algorithm. 2949

There shall be a facility to configure the rates of sand deposition per wheel between 2.0g/metre and 6.0g/metre. 2950

Sand reservoirs shall be sealed to prevent ingress of unwanted contaminants, particularly liquids. 3118

Sand reservoirs shall be designed for ease of access and filling. 4271

The sanding system shall be capable of being refilled at a rate of not less than 20 litres per minute. 5246

The sanding system shall be compatible with sand which meets the following specification: 2963

- The sand shall be uniform and consist of at least 90% by weight hard grains of quartz or siliceous material.
- The clay and other impurities content (for example, pebbles, gravel, pieces of glass, vegetable remains, earth, silt or dust) shall not exceed 2% by weight.
- It is permissible for the remaining materials to be of other mineral content.
- The sand shall, as far as possible, consist of rounded irregular shaped grains; quarry sands are preferable to river or sea sands, to avoid possible salt contamination.
- The maximum proportion of grains of diameter <0.71mm (22 BSS mesh) shall be not more that 5% by weight and the maximum proportion of grains of diameter >2.88mm (5 BSS mesh) shall not be more than 5% by weight. The uniformity coefficient shall be less than 1.5.

The uniformity coefficient (U_C) is a factor for determining the uniformity of, in this case, sand and is a means of determining its resistance to compaction. It is the ratio of D_{60} to D_{10} where D_{60} is the sand diameter at which 60% of the sand weight is finer and D_{10} is the corresponding value at 10% finer, thus:

$$U_C = \frac{D_{60}}{D_{10}}$$

The Manufacturer shall define the sanding data which shall be communicated to the TDR. This shall include but not be limited to: 2957

- WSP activity, identified by wheelset;
- brake cylinder pressures, identified by wheelset;
- Train speed;
- sanding demanded (affected sanders along entire Train identified together with sanding rate for each sander);
- active sand hopper and their locations on the Train.

The sand level (or volume) shall be measured and reported to the RCS on a real time basis. 2941

Warning of low sand levels shall be provided to the RCS on a real time basis. 2942

The estimated remaining sand capacity for each hopper shall be provided to the RCS on a real time basis. 4400

Sanding system and component fault information shall be provided to the RCS. This shall be provided on an individual sanding system basis. 2961

4.12 Brake Supply Reservoir (BSR) 2744

The friction brake system shall include a reserve of energy in the form of air pressure, for each emergency and service brake application system, sufficient to ensure the application of the brakes even in the event of train failures or separation. 2745

The BSR shall be capable of providing, as a minimum, two "Full Load" emergency brake applications whilst charged to the minimum governed main line pressure, and the main line being reduced to atmospheric pressure prior to the brake applications being made. 2746

The BSR shall be capable of providing, as a minimum, one "Crush Laden" emergency brake application whilst charged to the minimum governed main line pressure, and the main line being reduced to atmospheric pressure prior to the brake applications being made. 5298

Each BSR shall be supplied via a BSR check valve to protect the brake system against loss of pressure due to a reduction in main line supply pressure. 2749

4.13 Adhesion Management System Condition Assessment Software (AMS CAS) Interface 2975

To enable operation of the railway under ATO, the Purchaser employs predictive monitoring as part of the Purchaser's adhesion management system. To support this, information will be required from the Train for 2976 *use within the AMS CAS. This is a (off Train) predictive software tool which determines whether conditions are fit to operate in ATO and provides pre-emptive mitigations to the Adhesion Controller for implementation (e.g. ATO traction and braking rates being raised or lowered by the control centre). It shall be used on the Piccadilly, Central and Bakerloo lines.*

The principle is that each Train will automatically upload data to the RCS and the OTC for transmission to the off Train Adhesion Management System so that instances of wheelspin control, WSP activity and sander operation can be used to update the predicted risk level of compromised adhesion and enable the Purchaser to respond to changing conditions.

This information is required on the Piccadilly, Central and Bakerloo Lines. This requirement need not apply to the Waterloo & City Line Trains.

The Train shall provide real time information on the WSP and sanding system condition and usage to the RCS and the OTC for use by the Adhesion Management System Condition Assessment Software Tool (AMS CAS). 1795

Whilst the specific interface and information provided to some extent depends on the implemented solution for the sanding control, the feedback to the AMS CAS shall meet the principles of: 4287

- Providing automatic real time reporting of WSP activity and sander operation (over the Train) to the (off Train) adhesion management system condition assessment software (AMS CAS), via the RCS and OTC.
- Providing the calculation of the estimated sand volume in each sand hopper to the AMS CAS via the RCS and the OTC.
- Automatic uploading of defined data to the AMS CAS via the RCS and OTC whenever the sand hoppers on that Train are refilled.
- Identification and reporting of system failures which could influence the AMS CAS decision making.

Each feedback dataset for the AMS CAS shall include location information, direction of travel, destination of the Train, leading Car Number, time of incident, date of incident and if the Train is in or out of service. 2987

All information shall be transmitted to the RCS and OTC for transmission to the AMS CAS within 10s of their occurrence. 2989

4.14 Brake Friction Blocks and Pads 6077

The details of the constituents of brake friction blocks and pads shall be provided to the Purchaser on demand. 6030

In tunnels, dust from rolling stock remains within the tunnel environment and may present a hazard if the constituents are not *controlled. This requirement is to allow the Purchaser to be aware of and to control the composition of tunnel dust.*

The materials used in brake friction blocks and pads shall be selected such that health risks are managed as low as reasonably practicable. 6031

The materials used in brake friction blocks and pads shall not generate smoke in normal operation. 6032

The materials used in brake friction blocks and pads shall not generate any air-borne fibres or particulates containing any known harmful substances including, but not limited to, the following and their compounds: 6033

- asbestos;
- lead;
- chromium;
- cadmium;
- silica.

Brake blocks fitted to a vehicle in service shall not coat the wheel with material which would increase the wheel to rail electrical resistance by more than 0.02 ohms per wheel. 6034

Brake blocks fitted to a vehicle in service shall not cause electrically-conducting material to be deposited which reduces the resistance across the rail block joints by more than 10 ohms/mm compared to the resistance that would exist with no electrically-conducting material from brake blocks being present. 6035

The friction characteristic of the brake block or brake pad shall be such as to achieve the required friction braking performance over the required range of loads, speeds and brake demands. 6230

The brake blocks or brake pads shall be compatible with the required brake system performance, in dry rail, wet rail and Compromised Adhesion conditions, as defined for the Train. 6239

The static coefficient of friction shall not be less than the dynamic coefficient of friction. 6231

The static coefficient of friction shall not be so high as to prevent a train recovery which is effected by pushing out against applied SAPBs. 6232

The dynamic coefficient of friction shall exhibit the minimum practical variation with braking force, Train speed and temperature (component and ambient) and extent of bedding. 6234

Brake blocks or brake pads shall not lead to noise (squeal) arising 6236 during normal braking operation.

Brake blocks or brake pads shall not be vulnerable to damage due to rough handling in a depot environment (e.g. being dropped into a pit or thrown across from one side of a pit to the other). 6237

Brake blocks or brake pads shall not be damaged by the application of the maximum brake force during the block/pad's initial bedding-in period. 6238

The Train Maintenance Regime shall be compatible with the friction material selected for brake blocks or brake disc pads. 6240

The wheel tread wear due to the brake block shall not exceed the maximum allowed between normal tread re-profiling interval for that wheel type. 6241

Brake blocks or brake pads shall be subject to appropriate agreed type tests to demonstrate their performance and mechanical robustness. 6242

The type testing requirements for any brake block or brake pad shall include, as a minimum, but not be limited to the following: 6243

- Material assessment.
- Dynamometer testing of the friction characteristics, wear rates and interaction with “contaminants” e.g. water, oil, grease, train borne or tack dispensed friction modifiers (solid stick wheel/rail lubricants or other adhesion modifiers) and sand.
- Train testing of emergency, service and parking brake performance, including:
    - Train testing to assess and confirm block wear and interaction with wheels in terms of effects on wheel tread – wear, damage, scoring, pitting etc.;
    - Blocks/pads shall be removed for re-testing on the dynamometer to establish any change in friction characteristic;
    - Assessment of block’s robustness under service conditions;
    - Assessment of block/pad wear and effect on wheel tread.

5 Emergency Equipment 34

5.1 Emergency Equipment - General 35

The following items of emergency equipment shall be available at each end of the Train: 5803

- one fire extinguisher;
- one electromagnetic short circuiting device;
- two shoe paddles;
- six detonators in a detonator box (on the Bakerloo line only);
- one red flag and stick;
- one carry sheet;
- one rail ice scraper;
- one set of Network Rail track circuit clips (on the Bakerloo line and Central line only);
- one set of detrainment steps;
- one detrainment bridge.

The Manufacturer shall be responsible for supplying the following items of emergency equipment: 5889

- fire extinguishers;
- detrainment steps;
- detrainment bridge.

All other emergency equipment listed shall be supplied by the Purchaser on a 'free issue' basis for the Manufacturer to install on each Train.

Unless otherwise specified, each item of emergency equipment shall be accessible by any member of staff, who is located at either end door (M-door) on the Train, within 1 minute, under Tare conditions. 2877

The location of each item of emergency equipment shall be identified unambiguously on an appropriately positioned label / sign. 2878

The emergency equipment label shall show, on a plan view of the Train, at all operating positions, the stowage location of each item of emergency equipment. 4121

The stowage areas for all emergency equipment, unless explicitly stated otherwise, shall be secured with a key to prevent passenger access. 3034

The secured stowage areas for emergency equipment shall be referred to as emergency equipment cupboards.

A means shall be provided to enable a member of staff to easily visually confirm that each item of emergency equipment has not been used or interfered with since its last test or inspection and that it therefore continues to be in a fit condition to be used. 7125

On other London Underground fleets, breakable plastic tamper seals / tags are used to identify when an emergency equipment cupboard or an individual item of emergency equipment has been accessed.

An event shall be reported to RCS when any emergency equipment cupboard is accessed. 4123

Each item of emergency equipment shall be secured to ensure that there is no movement or contact between surfaces which could cause noise (rattles) or wear of components. 3109

5.2 Fire Extinguishers 2899

One fire extinguisher shall be provided at each end of the Train. 2880

Fire extinguishers shall be stowed such that one extinguisher can be accessed by a member of staff, from the M-Door, within 15s. 2879

The fire extinguisher shall be located in each cab (when present). 1553

Fire extinguishers shall not be accessible to passengers. 1551

When no cab is present, fire extinguishers shall be stowed in an emergency equipment cupboard. When positioned in a secured cab, it is acceptable for the fire extinguisher to be stowed in an unsecured bracket with an appropriate tamper seal. 4986

Fire extinguishers shall have a minimum design life of 20 years. 5516

Fire extinguishers shall be of the stored air pressure type. 5518

Fire extinguishers shall have a welded steel body. 5519

Fire extinguishers shall have a 3 litre cylinder capacity. 5520

Fire extinguishers shall be fitted with a hose. 5521

Fire extinguishers shall be fitted with a pressure indication device. 5522

Fire extinguishers shall have a squeeze grip lever operation. 5523

Fire extinguishers shall be water-based and shall have a minimum 5A fire rating. 5524

Fire extinguishers shall be compliant with the requirements of British Standard BS EN 3-7:2004+A1:2007 'Portable Fire Extinguishers. Characteristics, Performance Requirements and Test Methods' for all temperatures between -10°C and +60°C. 1557

All chemical agents used in the extinguishing medium shall be declared to the Purchaser. 5526

Fire extinguishers shall be labelled and coloured in accordance with the requirements of British Standard BS EN 3-7:2004+A1:2007 'Portable Fire Extinguishers. Characteristics, Performance Requirements and Test Methods'. There shall be additional markings as follows: 1558

- 'FOR USE ON ANY TRAIN FIRE'
- 'DO NOT USE ON ANY LIQUID FIRES' (not applicable if the extinguisher has a 'B' rating);
- London Underground roundel;
- BSI Kitemark / CE marking;
- The periodic maintenance requirements of the extinguisher, including provision for the recording of the date of fitting and routine maintenance;
- Manufacturer / LU part number.

5.3 Electromagnetic Short Circuiting Device (SCD) 2901

Electromagnetic SCDs are used by staff to prevent traction current from being inadvertently turned on while people are on track or, in an emergency, to discharge traction current at track level by shorting out the negative and positive conductor rails. 2896

One electromagnetic SCD, as per LU Drawing 2-9562-L53015 Issue B 'Track Shorting Bar Mark 2A Version - Isometric Showing Assembly Details' shall be accommodated in the Emergency Equipment Cupboard at each end of the Train. 2894

5.4 Shoe Paddles 2902

Shoe paddles are used by staff in an emergency to assist with manually isolating conductor shoes from the conductor rails. 2897

Two shoe paddles, as per LU Drawing 31898 'Shoe Paddle', shall be accommodated in the emergency equipment cupboard at each end of the Train. 2895

5.5 Detonators 5712

Detonators provide audible train protection by warning an on-coming train of an obstruction on the track, having been placed on the track by 5713 *trained Purchaser staff.*

Six detonators inside a single detonator box, as per Reference Document NTfL-2344.3.4-LUL-DWG-00001 'Detonator Box Drawings', shall be accommodated within the emergency equipment cupboard at each end of the Train on the Bakerloo line only. 5714

Central line, Piccadilly line and Waterloo & City line Trains shall not carry detonators. 5719

5.6 Flag and Stick 5715

On open track during day light and in lit tunnels the Train Operator or other trained staff may use the red flag and flag stick to display a warning to other trains. 5717

One red flag (20" x 16") and flag stick (24" x 1" diameter) shall be accommodated in the emergency equipment cupboard at each end of the Train. 5722

5.7 Carry Sheet 5723

Staff or passengers or both may use the carry sheet to detrain a casualty or a mobility impaired passenger. 5737

One carry sheet shall be accommodated at each end of the Train either in the emergency equipment cupboard or in another secure location which is not accessible to passengers. The carry sheet will be provided in a green canvas bag with dimensions 18" x 9" x 4". 5738

Note - On some existing LU trains, carry sheets are stored under passenger seats in the saloon.

5.8 Rail Ice Scraper 5900

A rail ice scraper is used by trained staff to clear snow or ice from the surface of the current rails to provide good contact between the train current collector shoes and the current rails. 5892

One rail ice scraper, as per LU Drawing S1860 'Ice Scraper', shall be accommodated in the emergency equipment cupboard at each end of the Train. 5894

5.9 Network Rail Track Circuit Clips 5902

One set of Network Rail track circuit clips (Unipart catalogue number 870/023402) shall be provided in the emergency equipment cupboard at each end of the Trains supplied for the Bakerloo and Central lines. 5898

5.10 Detrainment Systems 36

5.10.1 Detrainment Systems - General 5909

Requirements in this specification for detrainment systems shall apply to both the detrainment steps, which are used for Train to track detrainment via the M-door, and the detrainment bridge, which is used for Train to Train transfer via the M-doors. 3080

The Manufacturer shall provide detailed operational procedures to enable the safe and efficient use of detrainment systems. 2978

Detrainment systems shall enable the evacuation of all passengers (excluding mobility impaired passengers and wheelchair users) in no longer than 60 minutes through a single end, from a Train in a Full Load condition. 3082

The requirement for detrainment systems to support evacuation in no more than 60 minutes, shall be validated by a factory test using able-bodied people, under the most advantageous conditions that maximise the flow of people. 3083

Detrainment systems shall not require the use of tools (other than a key which may be used to unlock the emergency equipment cupboard) to deploy or stow the system. 3084

Detrainment systems shall be re-usable and suitable for use over the design life of the Train. 5188

It shall be possible for a trained member of staff to un-stow and deploy a detrainment system in less than 90s. 3086

It shall be possible for a trained member of staff to remove a detrainment system from its deployed state and to place it in the saloon in under 30s. 3089

It shall be possible for a trained member of staff to re-stow the detrainment system in under 90s. 3090

Appropriate pictograms and text shall be clearly displayed adjacent to or on the detrainment system to illustrate how to safely deploy the mechanism, together with any actions required to open the M-door. 3092

The detrainment system pictograms shall remain visible to the user throughout the deployment or stowage process. 3093

The detrainment system shall be stable when deployed and facilitate safe and rapid detrainment of all passengers. 3095

Any detrainment system surface which passengers step on shall have an anti-slip coating. 3105

The edges of any detrainment system surface which passengers step on shall be clearly highlighted using a highly visible yellow coloured surface (NCS 0080 Y10R or equivalent). 3106

It shall not be possible to close the M-door with any detrainment system in the deployed state. 4987

5.10.2 Detrainment Steps 2875

Removable detrainment steps shall be provided at each end of the Train to enable passengers to leave the Train and walk onto the track. 3107

Reference shall be made to British Standard BS 5395-4:2011 'Code of Practice for the Design of Stairs for Limited Access' in designing the step pitch and rise of steps. 3068

The descent from Train to track level shall be at a constant rate, with the permitted exception of one irregular drop from the lowest tread of the detrainment steps onto the track bed. 3108

The deployed detrainment steps shall, on straight track, maintain a minimum vertical gap of 80mm to the conductor rails when deployed with the maximum possible number of passengers standing on it. 3069

The deployed detrainment steps shall, on the worst case combination of Train tolerances and track vertical curvature, maintain a minimum vertical gap of 10mm to the conductor rails when deployed with the maximum possible number of passengers standing on it. 3070

5.10.3 Detrainment Bridge 2876

A means shall be provided at each end of the Train to facilitate the safe movement of passengers from one Train to another Train through the M-door on each end of the Train when two Trains are closely positioned without being mechanically coupled. 3072

With two Trains positioned, without being mechanically coupled, the horizontal gap between any fixed passenger foothold areas shall be less than 150mm. 3075

If this gap cannot be achieved then a temporary detrainment bridge shall be provided which is deployed to reduce the horizontal gap.

6 Operator Facilities 38

6.1 Operating Position Migration 6623

As part of migration towards greater automation, it shall be possible to convert the Train from having cabs to having Saloon Operating Positions (SOP) which are incorporated within an enlarged saloon area so that more space is released for passenger accommodation. 5970

The design shall allow the cab to be converted to usable passenger space of the same aesthetic standard as the pre-existing saloon, and to be seamlessly integrated with it. 215

Conversion from cab to passenger space shall be possible at any point during the life of the Train at the discretion of the Purchaser. The passenger space shall include the SOP defined in this specification. 217

The conversion from cab to passenger space shall include the removal of the cab side doors. 6893

As part of the conversion of the cab to passenger space, the cab side door apertures shall be discreetly concealed and the overall exterior appearance shall be consistent with Reference Document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6894

During the type testing programme the Manufacturer shall carry out a complete conversion of the outer end cars from cab to SOP configurations. *This is to demonstrate both the conversion processes and compliance with requirements at each stage.* 5804

The conversion from cab to passenger space with an operating position shall, when undertaken in a Purchaser depot, take no longer than two weeks per Train. 4221

The Manufacturer shall provide all the instructions, procedures and training necessary to convert each cab to a passenger space with operating position. 4657

6.2 Cab 4272

A cab shall be provided at both ends of the Train. 213

A cab is an operating position which is segregated from the passenger space on the Train.

The tasks expected to be carried out in the cab throughout the expected migration stages are: 3966

Driven:

- *The Train Operator will drive the Train in accordance with the* *existing lineside signals and the speed limits of the line;*

- *The Train Operator will be responsible for controlling and managing the Train;*
- *The Train Operator will observe the routeway ahead when the Train is approaching a platform and will stop the Train if there is any person on the track or at risk of being struck by the Train;*
- *The Train Operator will observe the PTI during departure and prevent the Train from departing the platform if a passenger is too close to the Train;*
- *The Train Operator will control the passenger doors;*
- *The Train Operator will communicate with customers via the PA facilities;*
- *The Train Operator may assist with problems arising on the Train;*
- *The Train Operator will be in communication with the Line Controller*;
- *The Train Operator will manage passenger emergency alarms (PEAs);*
- *An Instructor Operator will carry out instructional duties.*

Attended:

- *The Train Operator will observe the routeway ahead when the Train is approaching a platform and will stop the Train if there is any person on the track or at risk of being struck by the Train;*
- *The Train Operator may open and close the passenger doors and start the Train;*
- *If the Train Operator does not open and close the passenger doors, the Train Operator may influence the timing of the closing of passenger doors and the timing of departure of the Train in response to events observed at the PTI and on the platform;*
- *The Train Operator will observe the PTI during departure and prevent the Train from departing the platform if a passenger is too close to the Train;*
- *The Train Operator may communicate with customers via the PA facilities;*
- *The Train Operator may assist with problems arising on the Train;*
- *The Train Operator will be in communication with the RC*S;
- *An Instructor Operator will carry out instructional duties.*

Unattended:

- *The Train Operator will be present on special 'sweeper' Trains or to investigate a reported infrastructure issue.*

The cab design and layout shall enable all Train Operators to continuously operate the Train from the seated position. 221

The cab design and layout shall, where practicable, enable operators to operate the Train from a standing position. It is recognised that the physical constraints of the cab may prevent some tall operators (standing) from being able to achieve the required view of the horizon without adopting a poor posture. Where standing operators are able to view the defined sightlines to the horizon the cab design shall enable those operators to operate the Train whilst standing up. 6321

An adjustable footrest to support the lower limbs of a seated operator shall be provided in the cab. 6096

The space occupied by the cab shall be as small as reasonably practicable consistent with the cab meeting all the other requirements in this specification. 4850

The cab shall occupy no more than 2m of car length. 4854

The cab shall incorporate a central clear throughway no less than 650mm wide. 5924

The driving position in the cab shall be located on the left hand side of the M-door (viewed in the direction of travel). 6904

Adjustable sunblinds shall be provided at each window in the cab to allow operators to block dazzle from the sun. 220

The cab shall have a coat hanging space for one coat, using a flush mounted or recessed hook to prevent it snagging on persons passing by. 225

The cab shall have a stowage space for one standard LU Train Operator's bag. The bag dimensions are (d)250mm x (w)280mm x (h)400mm. 3336

The cab shall have a cup holder for each operator, accessible from the seated positions. 3337

Cup holders in the cab shall: 4239

- Accommodate a vessel of constant outside diameter 80mm and height 250mm.
- Accommodate a cup/mug with a single handle.

The location of stowage facilities in the cab shall not result in interference with sightlines. 3338

The location of stowage facilities in the cab shall not restrict access to controls and equipment. 5972

Display screens shall be provided in the cab which: 3340

- are capable of displaying no fewer than eight OPO CCTV video images of the PTI;
- permit interaction with the Train via a touch interface;
- display touch controls (soft keys) and information displays as required to support the Train control and monitoring functions;
- display touch controls (soft keys) and information displays as required to support the interface with RCS;
- display information associated with remote control of Train functions via the OTC;
- display images from the Train-based CCTV systems as required.

The display screens in the cab shall be shared and sub-divided as required, ensuring that images and controls are available for use at the time that they are required and that information from different sources can be shown without having to assign one display to one source. 4245

The dimensions of the display screen area required for displaying OPO CCTV images shall be sufficient to achieve conspicuity of the target of not less than 95%. 5707

For a display screen aspect ratio of 4:3, two images shall be displayed side-by-side cropped at 50% width. Where 3 or 4 images are to be displayed on a screen of this aspect ratio, further cropping and zooming shall occur and the images displayed side-by-side.

For OPO CCTV image display, the viewing angle of the captured target (2 year old British female 825mm tall and 150mm chest depth including clothing) shall be for all viewing positions no less than 54 minutes of arc subtended to the operator’s eye when viewed normal to the plane of the displays, and never less than 42 minutes of arc subtended to the operator’s eye. 5708

OPO CCTV images of the PTI have to achieve conspicuity (probability of detection) of not less than 95% for a 2 year old British female (825mm tall and 150mm chest depth including clothing) throughout the critical area of the defined PTI. The OPO CCTV performance Nomogram in LU Standard G150 'Manual of Good Practice - Telecommunications - OPO CCTV Systems' (and the accompanying explanatory notes) illustrates the relationships between the viewing angle subtended at the observer’s eye, viewing distance, screen size, image height ratio (%C), and conspicuity. 5705

The screens for displaying OPO CCTV images in the cab shall have a resolution of no fewer than 400TVL per picture height. 5709

OPO CCTV images shall be clear under all lighting conditions capable of existing in the cab. 4677

The display screens in the cab shall compensate for variations in ambient lighting conditions. 5247

The display screens in the cab shall have a contrast ratio of no less than 300:1. 5710

The display screens in the cab shall be capable of a luminance of no less than 300cd/m^2. 5711

The display screens in the cab shall be mounted side-by-side or one above the other. 5248

The cab shall have a dedicated HVAC system. 4339

Train Radio equipment (radio control head and ambient microphone) shall be fitted in the cab. 5999

The time shall be displayed in digital 24 hour format (hh:mm:ss) in the cab. 4765

The time display in the cab shall be regularly updated, so that it is always consistent with the Train clock, including alterations for daylight saving. 4767

The cab shall be equipped with a speedometer. 4851

A main line air pressure gauge shall be provided in the cab to indicate the level of pressure in the air supply. The gauge shall be positioned in a clear line of sight from the driving position. 5953

The cab interior panels, fixtures and fittings shall not allow strips of paper with a width greater than or equal to 10mm to be inserted through gaps and junctions. 6508

6.3 Saloon Operating Position (SOP) 4276

When a cab is converted to passenger space, a Saloon Operating Position (SOP) shall be provided to accommodate the controls and facilities which are required for ongoing operation of the Train when the railway system supports a high level of automation. 5971

The provision of equipment at the SOP shall enable non-routine operations (e.g. Train recovery, infrastructure inspections), movement of the Train around the depot and sweeping. 5973

The SOP is an operating position within the saloon which encompasses the operator facilities required when the railway system, operated under

RCS control, supports a high level of automation.

The SOP shall include a control console containing the required controls. 5974

The SOP design shall enable the Train Operator to undertake duties associated with the SOP from either a seated or standing position. 5982

It is envisaged that some tall Train Operators will have to be seated to be able to achieve the required view to the horizon without adopting a poor posture.

A forward facing seat shall be provided for an operator using the SOP. The seat shall: 6306

- Be able to be secured when not in use so that it cannot be used by passengers and cannot be vandalised;
- Be designed and tested to withstand the foreseeable use and abuse load cases.

The control console in the SOP shall support the coupling to and pushing out of a defective Train. 3321

The control console in the SOP shall support manual driving. 4266

The SOP shall be located so as to afford an operator at the controls a view from the front of the Train which offers the defined sightlines. 3344

The control console in the SOP shall be protected against unauthorised use. 3350

The controls of the control console in the SOP shall, when not in use, be concealed behind a locked cover. 4269

The open/closed status of doors/covers of enclosures in the SOP which contain controls shall be reported to the RCS. 3351

Adjustable sunblinds shall be provided for use at the SOP. 4623

Sunblinds provided for use at the SOP shall, when not in use, be concealed behind a secure panel to prevent vandalism. 4231

Separate illumination shall be provided in or around the SOP if the defined saloon lighting is insufficient to adequately illuminate the controls. If appropriate, this lighting shall illuminate automatically when the SOP is in use. 5763

The SOP shall be equipped with a speedometer. 6264

Controls and indications shall be provided in the SOP which shall: 6303

- permit interaction with the Train control and monitoring functions.
- support the interface with RCS.

When any securing cover at the SOP is open, the cover shall: 7184

- not hinder the operator in carrying out their duties;
- not impede access and egress through the M-door;
- not impede activities related to rescue and coupling;
- not impede manual driving;
- not impede sightlines;
- not be capable of causing a nuisance to passengers;
- not be capable of causing a hazard;
- not be susceptible to being damaged.

6.4 Controls 41

6.4.1 Controls in the Cab 4662

A traction brake controller (TBC) for routine manual driving shall be provided in the cab. 6043

Controls and indicators shall be provided in the cab to enable a Train Operator to provide supervisory support when the Train is operating under RCS control, with Automatic Door Closing, but with supervisory tasks undertaken by the Train Operator. The design of these controls and indicators shall be developed as part of the interface with RCS. Examples of the facilities that may be required are as follows: 4001

- An indication or countdown displayed to the Train Operator indicating the time remaining until the Train is due to depart the platform.
- Train Operator to indicate readiness to monitor the PTI during passenger door closing. *This could be achieved via a control at the operating position.*
- Train Operator to indicate that the start of passenger door closing should be delayed. *This could be achieved via a control at the operating position.*
- Train Operator to indicate that they are satisfied with the state of the PTI (i.e. no hazards perceived after the passenger doors have closed) before departure. *This could be achieved via a control at the operating position.*
- Train Operator to indicate that departure should be aborted (PTI hazard perceived). *This could be achieved via a control at the operating position.*
- Train Operator to indicate that departure can be restarted after

it has been aborted. *This could be achieved via a control at the operating position.*

ATO Start buttons shall be provided in the cab. 6630

Controls shall be provided in the cab to enable pictures from train-based CCTV to be selected and viewed on the cab display screen equipment. 4668

Controls for the cab lighting shall be provided in the cab. 4669

Controls for the cab HVAC shall be provided in the cab. 4670

Controls shall be provided in the cab to enter Customer Information System (CIS) data. 4663

Controls for triggering pre-recorded CIS messages shall be provided in the cab. 4666

Controls for selecting the Out Of Service function shall be provided in the cab. 6054

Controls shall be provided in the cab to enable an operator to indicate their presence on-board a Train. 7110

Controls shall be provided in the cab to operate the windscreen wipers, washers and demisters. 4002

Facilities for making live PA announcements shall be provided in the cab. 4665

Controls for operating the whistle shall be provided in the cab. 4674

A keyswitch to unlock the Train mode selector shall be provided in the cab. 4675

A control for selecting forward/reverse direction of travel shall be provided in the cab. 5838

An emergency stop button shall be provided: 4003

- in the cab, at the Train Operator position;
- in the cab, at the Instructor Operator position.

Following an intervention by an operator which has interrupted or overridden RCS command, there shall be an available means for an operator in the cab to positively communicate to the RCS that it can resume control of the Train. 4006

A control shall be provided in the cab for the Hazard Warning function.	2640
Controls shall be provided in the cab for the Yellow Indicator Light.	2708
Controls to Power Off and Power On the Train shall be provided in the cab.	4750
Controls shall be provided in the cab for passenger door opening and passenger door closing.	1959
Controls for re-opening and re-closing passenger doors that have not proven to be closed following a close demand, shall be provided in the cab.	4751
Controls shall be provided in the cab to inhibit the function which closes doors for passenger comfort.	5364
Controls shall be provided in the cab to inhibit a pending Automatic Door Open.	6066
Controls shall be provided in the cab to operate the cab side doors.	6945
Controls shall be provided in the cab to reset a latched emergency brake.	5685
Controls shall be provided in the cab to operate the sleet brushes.	5198
Controls for operating the de-icing system shall be provided in the cab.	5957
Controls shall be provided in the cab to operate the Wrong Direction Move lighting.	5926
There shall be a control in the cab for enabling self powered movement.	5956
Controls shall be provided in the cab to operate the saloon lighting.	6203
A control shall be provided in the cab for resetting the tripcocks.	6329
A control shall be provided in the cab which allows the user to select the Train Radio function.	5955
'Controls' need not be physical buttons or switches but may be available through a touch screen interface (soft keys).	4664

6.4.2 Controls at the Saloon Operating Position (SOP) 4661

Traction and braking controls suitable for infrequent driving of the Train shall be provided in the control console at the SOP. 4848

The design of the traction and braking controls in the SOP shall rigorously address: 6353

- safety issues including fail-safe operation and jamming (intentional or accidental);
- operability and Human Factors issues;
- deliberate abuse and accidental damage cases.

The traction and braking controls in the SOP shall be associated with a vigilance device to apply the emergency brake in the event of the incapacity or inattention of the operator. 6355

Controls shall be provided in the control console at the SOP to vary the level of the saloon lighting in the vicinity of the SOP. 4729

Controls shall be provided in the SOP to enable an operator to indicate their presence on-board the Train. 7111

Controls shall be provided in the control console at the SOP to operate the windscreen wipers, washers and demisters. 6007

Facilities for making live PA announcements shall be provided in the control console at the SOP. 6008

Controls for selecting the Out Of Service function shall be provided in the control console at the SOP. 6056

Controls for operating the whistle shall be provided in the control console at the SOP. 6011

A keyswitch to unlock the Train mode selector shall be provided in the control console at the SOP. 6013

A control for selecting forward/reverse direction of travel shall be provided in the control console at the SOP. 6015

An emergency stop button shall be provided in the control console at the SOP. 6016

Following an intervention by a Train Operator which has interrupted or overridden RCS command, there shall be an available means for a Train Operator at the SOP to positively communicate to the RCS that it can resume control of the Train. 6019

Controls shall be provided in the control console at the SOP for the Hazard Warning function. 6021

Controls shall be provided in the control console at the SOP for the Yellow Indicator Light. 6023

Controls to Power Off and Power On the Train shall be provided in the control console at the SOP. 6041

Controls shall be provided in the control console at the SOP to reset a latched emergency brake. 6045

Controls shall be provided in the control console at the SOP to operate the sleet brushes. 6046

Controls for operating the de-icing system shall be provided in the control console at the SOP. 6048

Controls shall be provided in the control console at the SOP to operate the Wrong Direction Move lighting. 6050

There shall be a control in the control console at the SOP for enabling self powered movement. 6052

Controls shall be provided in the control console at the SOP for passenger door opening and passenger door closing. 6062

Controls shall be provided in the control console at the SOP to inhibit a pending Automatic Door Open. 6311

Controls shall be provided in the SOP to operate the saloon lighting. 6204

6.5 Seating for Operators 42

6.5.1 Cab Seats 6634

Seating shall be provided in the cab for the Train Operator and the Instructor Operator. 5799

Cab seats shall have a level of comfort appropriate to the duration of the operating duty. 247

It shall be possible to independently adjust the height, fore and aft position, back rest angle, seat pan angle, seat pan fore and aft (independent), lumbar support position and armrest height of the cab seats. 4773

The cab seats shall be quickly adjustable so as to enable a safe and comfortable position to be achieved within 10s. 4247

It shall be possible to adjust the cab seats from any position to any other position within 10s. 5884

Armrests of the cab seats shall, if necessary, be moveable such that they do not impede access to the seat. 4248

The cab seats shall not restrict access and egress with the seating in any position. 5952

The cab seats shall permit operation of the Train when the operator chooses to stand for ergonomic, human factor, health and operational reasons. 4250

The cab seats and supporting structure shall withstand the tests identified in this specification without permanent deformation or damage. The detailed test methods shall where applicable be developed based upon the tests in British Standard BS 5459-2:1990 'Performance requirements and tests for office furniture - Part 2: Office Seating'. 4526

The cab seats shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of 2200N applied vertically downwards on to the squab over an area 380mm by 200mm located centrally. The seat shall be adjusted to the most disadvantageous position for the test. 5309

The cab seats shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of ±2000N applied longitudinally relative to the seat over an area of 250 mm wide by 50 mm deep located centrally at the uppermost part of the seat back. Depending on the installation details of the seat it shall be permissible for only the rear acting load to be considered. The seat shall be adjusted to the most disadvantageous position for the test. 5310

The cab seats shall sustain without permanent deformation, for a period of no less than 5 minutes, loads of 2000N applied in the transverse direction relative to the seat, separately to the seat back and to the seat squab. 6253

The cab seats shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of 1700N applied vertically downwards at the end of any armrest. The armrest shall be adjusted to the most disadvantageous position for the test. 5311

The cab seats shall sustain without permanent deformation, for a period of no less than 5 minutes, loads of ±750N applied to the armrest in the transverse direction relative to the seat at the most disadvantageous position on the armrest. 5313

The cab seats shall sustain without failure the repeated application of a 1200N vertical load on the seat squab for 200,000 cycles. 5314

The cab seats shall sustain without failure the repeated application of a 415N longitudinal load on the seat back for 200,000 cycles. 5315

The cab seats shall sustain without failure a fatigue test comprising continuous application of a vertical load of 1200N to the seat and movement of the seat from its forwardmost adjustment point to its rearwardmost adjustment point and back again. This shall be repeated for a number of cycles to be calculated based on the scheduled service life or maintenance interval and a duty cycle comprising 15 crew changes per day. The vertical height adjustment of the seat shall be varied throughout the test. 5316

All adjustment mechanisms of the cab seats shall be subjected to fatigue testing based on the scheduled service life or maintenance interval of the seat or component and a duty cycle comprising 15 crew changes per day. 5317

The cab seat shall withstand without damage the impact force arising from a 130kg operator ‘dropping down’ onto the front edge of the seat from a standing position. 5318

Additional load cases shall be added to the cab seats structural assessment if a review of the particular seat design determines that the seat may reasonably be expected to be subject to use/abuse/misuse load cases that are not taken account of by the prescribed load cases. In particular, where the seat is a folding 'tip-up' design the prescribed loads shall be applied in both the 'deployed' and 'folded' configurations. 4541

A shock and vibration test shall be carried out on the cab seat loaded with a simulated Train Operator weighing 130kg. 6254

The cab seat covering shall allow ventilation and water vapour exchange between the user and the seat. 4542

6.5.2 SOP Seats 6635

The SOP seat and supporting structure shall withstand the tests identified in this specification without permanent deformation or damage. The detailed test methods shall where applicable be developed based upon the tests in British Standard BS 5459-2:1990 'Performance requirements and tests for office furniture - Part 2: Office Seating'. 6636

The SOP seat shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of 2200N applied vertically downwards on to the squab over an area 380mm by 200mm located centrally. The seat shall be adjusted to the most disadvantageous position for the test. 6637

The SOP seat shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of ±2000N applied longitudinally relative to the seat over an area of 250 mm wide by 50 mm deep located centrally at the uppermost part of the seat back. Depending on the installation details of the seat it shall be permissible for only the rear acting load to be considered. The seat shall be adjusted to the most disadvantageous position for the test. 6638

The SOP seat shall sustain without permanent deformation, for a period of no less than 5 minutes, loads of 2000N applied in the transverse direction relative to the seat, separately to the seat back and to the seat squab. 6639

The SOP seat shall sustain without permanent deformation, for a period of no less than 5 minutes, a load of 1700N applied vertically downwards at the end of any armrest. The armrest shall be adjusted to the most disadvantageous position for the test. 6640

The SOP seat shall sustain without permanent deformation, for a period of no less than 5 minutes, loads of ±750N applied to any armrest in the transverse direction relative to the seat at the most disadvantageous position on the armrest. 6641

The SOP seat shall sustain without failure the repeated application of a 1200N vertical load on the seat squab for 200,000 cycles. 6642

The SOP seat shall sustain without failure the repeated application of a 415N longitudinal load on the seat back for 200,000 cycles. 6643

The SOP seat shall withstand without damage the impact force arising from a 130kg operator 'dropping down' onto the front edge of the seat from a standing position. 6644

Additional load cases shall be added to the SOP seat structural assessment if a review of the particular seat design determines that the seat may reasonably be expected to be subject to use/abuse/misuse load cases that are not taken account of by the prescribed load cases. In particular, where the seat is a folding 'tip-up' design the prescribed loads shall be applied in both the 'deployed' and 'folded' configurations. 6645

A shock and vibration test shall be carried out on the SOP seat loaded with a simulated Train Operator weighing 130kg. 6646

6.6 Human Factors for Operators 39

All facilities provided for use by operators shall be designed in accordance with LU Standard S1217 'Integration of Human Factors into Systems Development'. 227

Controls, indicators and labels shall be: 229

- designed and positioned following formal task analyses;
- operable by the intended user population;
- visible in all anticipated natural and artificial lighting conditions.

Controls shall be laid out according to their risk and the consequence of incorrect or inappropriate operation. 230

Facilities for controlling and monitoring the Train shall be designed according to the output of Manufacturer-led task analyses and validated against 'Demanding Scenarios'. 4527

Controls and displays shall be grouped according to their function. 4534

Groups of controls and displays shall be positioned according to their importance, sequence-of-use, frequency-of-use and any interactions they might have with other control and display groups. 4535

Groups of controls and individual controls within each group shall be easily distinguishable from each other. 4536

The operator, positioned in the anticipated operating position, shall have an unrestricted view of all displays and indications which are needed whilst the Train is in motion. 4537

Controls, displays and windscreens shall be free from glare and reflections. 4538

Controls shall provide feedback to the operator. 4539

Operators shall be able to gain adequate support and stability whilst operating the Train. 4540

The contact surfaces of controls that are used for longer than 'momentarily' shall be of materials or finishes of low thermal conductivity. 4544

The size, position and orientation of any display screen at the operating positions shall take into account: 4855

- The size and shape of images to be displayed, alone or in combination, such that the discernibility of the images is sufficient for their intended purpose.
- The range of possible operator eye positions based upon the dimensions of the operators and the available operating positions (including the adjustability thereof).

The Manufacturer shall demonstrate how the facilities provided for the operator reduce the risks associated with Signals Passed at Danger (SPADs) to ALARP. 5944

The Manufacturer shall demonstrate how the facilities provided for the operator reduce the risks associated with the Platform-Train Interface to ALARP. 5947

6.7 Sightlines 43

Windscreens at each operating position shall provide visibility of the routeway ahead to ensure that it is clear for movement of the Train. 219

The view of the routeway ahead shall encompass the track from 5m in front of the Train to the horizon. 4056

The sightlines for tall Train Operators standing up shall be maximised within the constraints of the car body design by keeping the top of the windscreen free from obstructions. 6218

The lateral sightlines shall be maximised within the constraints imposed by the cab structure. Views shall be provided such that the Train can be effectively and safely operated with regard to all relevant scenarios, including: 4055

- The view of the routeway ahead taking into account the effect of track curvature.
- Sighting of lineside stopping markers which can appear on both sides of the track.
- Sighting of a person walking along a path perpendicular to the track (approaching from the left and the right) on a trajectory to cross the track 5m in front of the Train.
- Observation of station platforms (and the track in station areas) for vigilance against persons encroaching onto the track when there is no platform edge barrier.

The operator sightlines from the operating positions shall be compatible with stopping marker 'chevron' signs mounted to the side of, and parallel to, the track. 6905

A 'porthole' window shall be provided in the left hand side of the Train at the operating positions for the purpose of viewing stopping position chevrons appearing on the left hand side of the track (as viewed from the operating position). 6906

The porthole window shall be designed for use by seated Train Operators. 7078

The geometric relationship between the windscreens, the porthole window and the Train Operator eye position shall be such that the parallax error (arising due to variability of eye position) for a Train Operator aligning the Train to a chevron on the left hand side shall be similar to the parallax error on the right hand side. 7077

The Train design shall support the achievement of fast and accurate stopping of the Train at platforms, utilising visual references on the Train (usually the outer edge of the non-driver's side windscreen for chevrons appearing on the right hand side, and the outer edge of the porthole window for chevrons appearing on the left hand side) in alignment with the centre of the chevron sign. 6907

The necessity of good ergonomics prevents the determination of stopping position from being based upon alignment between the chevron sign and the windows in the cab doors because the doors are usually too far rearward.

Chevrons mounted too far forward of the stopping position (such that the chevron can be aligned with the edge of the driver's windscreen) lead to poor stopping accuracy.

6.8 Whistle 63

A whistle shall be provided at each end of the Train. 729

The whistle shall have a 'High' sound level which shall meet the following performance requirements: 730

Whistle Level	Position of Measurements	Distance	Sound pressure level dB(A) at maximum output	Height of test equipment microphone
"High" position on whistle control	along the extension of the centre-line of train at the specified distances from the whistle and front of train	1m	125 minimum. 130 maximum.	Level with whistle
		1m	120 maximum	At any height up to and including 1.6m above rail
		300m	73 minimum	1.6m above rail

The whistle shall have a 'Low' sound level which shall meet the following performance requirements: 4600

Whistle Level	Position of Measurements	Distance	Sound pressure level dB(A) at maximum output	Height of test equipment microphone
"Low" position on whistle control	Along the extension of the centre-line of train at the specified distances from the whistle and front of train	1m	120 maximum.	At any height up to and including 1.6m above rail
		150m	69 minimum	1.6m above rail

The defined whistle sound levels shall be achieved for a minimum period of 5 seconds continuously when activated. 731

The whistle shall emit a combination of frequencies in the range of 1kHz to 2kHz. 732

The whistle shall not generate a noise level in the cab greater than 100dB(A), with all doors closed and the whistle sounding at maximum output. 734

For a pneumatic whistle, the whistle shall be capable of generating a sound pressure level of at least 100dB(A) at a distance of 1m when the air supply is reduced to 50% of the full mainline pressure. This sound level shall be measured at the same height as the whistle. 735

6.9 Windscreen Wipers, Washers and Demisters 64

On all windscreens which are necessarily used by Operators for viewing the way ahead, windscreen wipers and windscreen washers shall be provided. 737

Demisters shall be provided to demist the windscreens (including the M-door glazing) and the porthole window. 7034

Windscreen wipers shall sweep all of the area required for viewing. 738

The windscreen washer fluid tank capacity shall be no less than 20 litres. 741

The windscreen washer fluid tank capacity shall be maximised to reduce the required frequency of refilling. 2821

The windscreen washer filler shall minimise the risk of unauthorised 742 substances being introduced.

The windscreen washer fluid reservoir refilling point shall be conveniently located to support frequent refilling from outside the Train. 2812

Windscreen washer fluid level information shall be made available to the RCS to provide advance warning of low levels. 743

Excessive windscreen washer fluid usage shall be detected by an algorithm with parameters that can be configured by the maintainer. 5377

Excessive windscreen washer fluid usage shall be flagged to the user at the time of it being detected and a record kept of the event. 5378

Windscreen wipers shall be operable at two constant speed levels, 20±5 cycles/minute and 40±5 cycles/minute. 744

Windscreen wipers shall be operable at an Intermittent setting (wipe-wait-wipe-wait...) where there are 14±1 wipe-wait cycles per minute. 5191

Dispensing of windscreen washer fluid shall automatically cause a short period of wiping sufficient to clean and clear the screen. 5376

The windscreen wipers shall automatically return to their 'parked' position when deactivated. 5195

The windscreen wipers in their parked position shall not obscure the necessary sightlines. 5197

The design of the windscreen wiper control shall prevent wipers from being left running when not required. 2872

Demisters shall be provided to clear and/or prevent the formation of condensation and ice. 745

The demisters shall act upon all of the area required for viewing. 4353

Where electric elements are used for demisting these shall be unobtrusive. 739

It shall be possible to control windscreen demisters with a command from the RCS. 3723

Manufacturers may propose automatic rain sensing wipers with automatic variable wiping rate if it can be demonstrated by reference to an established product with proven pedigree that the overall rate of Service Affecting Failures for the wash/wipe system will be no worse than an equivalent manually controlled system. 3705

6.10 Speedometer 6263

The speedometer shall indicate the speed as observed by the speed enforcing mechanism, if any, with a tolerance of ± 2km/h to 40km/h and ± 5% above 40km/h. 6159

The speedometer shall, when accelerating at a rate of up to $\pm 1.5 m/s^2$, indicate the speed with a dynamic accuracy to ±1 km/h above 10 km/h and ±2 km/h below 10 km/h. 6160

The speedometer shall be capable of displaying the Train speed in miles per hour and kilometres per hour. 4859

Selection of the units for display of the Train speed shall be made only by the maintainer. 4861

The units of speed being used by the speedometer shall be clearly displayed. 4860

7 Aesthetic Design 37

7.1 Aesthetic Design - General 6347

The images and additional design information contained in the Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief' should be used for assistance in interpreting and applying the aesthetic design requirements. 6348

Where there is a conflict between aesthetic design requirements and other functional or technical requirements detailed in this Train Technical Specification, then the other requirements detailed in this specification shall take priority. 1908

Any such conflict should be identified by the Manufacturer as part of their Train proposal along with evidence of how the conflict has been resolved while ensuring that the overall aesthetic design intent is maintained.

Any Train design features or components which are not explicitly covered by individual aesthetic design requirements, or are not explicitly shown in the images in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', shall be carefully aesthetically integrated into the design in accordance with the aesthetic design principles detailed in section 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief' and taking design cues from the design vision imagery shown throughout the document. 6368

The general internal appearance of all cars shall be similar and provide a consistent appearance. 2555

The design and installation of the Train interior fittings shall achieve a visually pleasing appearance consistent with a high attention to detail and a high standard of construction. Control (including via the use of a suite of quality standards) of the following parameters shall support this requirement: 6504

- Panel fit – overlapping joints - overlap width and parallelism;
- Panel fit – abutting joints – gap width and parallelism;
- Panel fit – joints – flushness across joint;
- Panel fit – joints and junctions – gap differentials across lines of symmetry;
- Upholstery – pattern matching;
- Upholstery – pattern repetition;
- Flooring – junctions and seals;
- Others as determined by the design.

Any Train exterior surfaces which are visible from inside or outside the 2986

Train, but that are not accessible for cleaning using a train wash facility shall, where possible without affecting the overall aesthetic design, be finished in a colour which minimises the appearance of dirt, e.g. if the inside of a door leaf is visible from inside the car when the door is open then a dark paint finish would help to hide the appearance of dirt and improve the overall ambience.

7.2 Interior Appearance 4370

The colours and finishes used on the interior of the Train shall be as specified in section 4.2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6388

Longitudinal passenger seating shall be visually continuous across adjacent seats. Seats shall be sculpted in shape to provide seating which is both visually inviting and physically comfortable as shown in illustration 6 in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6392

A clear visual distinction shall be preserved between the passenger seat base (seat pan) and seat back with the back appearing to float above the seat as shown in illustration 6 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6395

All seating in the saloon (including at any operating position) shall be upholstered in the DTUP moquette design as defined in section 5 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6396

The top section of passenger seat back shall be upholstered in composition leather or an equivalent hardwearing, wipe-clean material as shown in illustrations 6, 7 and 8 of the Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6413

The moquette on tip-up seats shall wrap over to the underside of the seat cushion to visually align with the top of the wheelchair backboard or bench seat end panel when in the vertical stowed position. The remainder of the underside of the tip-up seats shall use the same material and finish as the bench seat end panel and pediment as shown in illustration 8 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6403

Passenger seat armrests shall have a hard-wearing, metallic, satin finish on their main body and have a hard-wearing coloured insert on their top surface as shown in illustration 5 and 6 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6397

The bench seat end panel and pediment (structure below bench seat) shall be visually integrated such that together they enclose the longitudinal seating, wrapping around smoothly with end panels sweeping seamlessly from the inside vertical to the outside horizontal 6399 surfaces as indicated in illustration 7 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'.

The bench seat end panels and pediments shall be of a hardwearing construction and finish. 6400

A continuous satin metallic edging strip, to match the armrest finish, shall run from the top of the bench seat end panel, down along the side of the first seat and along below the bottom of the seat cushions as shown in illustration 7 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6401

The outside faces of the bench seat end panels shall incorporate a mid-height horizontal bar with a satin metallic finish as shown in illustration 7 and illustration 8 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6402

A TfL Roundel, with a brushed steel or similar unpainted metal finish, as detailed in appendix 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief' shall be fitted on the centre of the seat pediment grille below the central row of seats in each car. The positioning and the sizing of the TfL Roundel shall be in accordance with illustration 20 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', i.e. positioned centrally within the grille section of each seat pediment. 6445

Priority seats shall be visually distinguishable from other seating in the saloon by the use of the LU standard Priority Seat pictogram woven into the moquette back panel of all designated seats as shown in illustration 25 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. This pictogram shall both: 6521

- be centred to the seat back and moquette repeat; and
- deliver a 30-point colour contrast to the surrounding moquette pattern by use of the colours and tones given in the moquette pattern specification as detailed in Section 5 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'.

An LU standard sign/pictogram, as shown in illustration 29 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', shall be shown on the interior car body panels adjacent to each designated Priority Seat. 6522

The inter-car gangway area shall be carefully aesthetically integrated with the rest of saloon design as shown in illustration 9 and illustration 10 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. Protrusions inside of the adjacent panelling and structures shall be minimised to ensure that an unobstructed view is maintained between cars. 6406

Vertical grabpoles shall be angled backwards from base to top away from the car centre, as shown in illustration 10 of Reference document 6404

NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', in order to prevent a stiff rectilinear aesthetic quality. This shall not apply to floor to ceiling grab poles.

Grabpoles shall have naturally finished metallic ends. The remainder of the poles shall be finished in a coloured nylon / polymer (or equivalent) based powder coat to provide a highly durable finish with suitable levels of grip and visual contrast with surrounding features. 6405

The lighting scheme shall include light sources which assist in defining the shape and position of the windows and seats. 6526

The lighting scheme shall include light sources from behind seats which assist in meeting the specified lighting illuminance levels required for seated passengers. The use of multiple light sources is intended to avoid unwanted shadowing from standing passengers and to avoid the need for excessively bright light sources which are further away from the defined illuminance measurement. 6527

Light sources shall be carefully designed in terms of their hierarchy, location and the illuminance levels that are needed to give both the functional and aesthetic requirements of the design. 6528

Light sources shall be carefully integrated within the overall physical design of the door vestibule area, including the ceiling and grab pole positions, so as to create and enhance the nature of the space, and illuminate key passenger touch points such as the grab poles. 6529

The linear nature of the interior saloon space shall be emphasized by the design and position of luminaires that are a holistic part of the ceiling and soffit designs. 6530

The lighting scheme shall provide sufficient illumination to facilitate typical passenger activities such as reading at seated and standing positions and good visibility of passenger information and passenger alarms, etc. whilst ensuring passenger visual comfort by minimising glare and excessive uncomfortable levels of light. 6531

The lighting scheme shall fulfil the basic requirement for safe passenger navigation of the space, including access and egress from the Train. The lighting scheme shall provide adequate illumination for compatibility with CCTV and to ensure a sense of safety within the passenger space. 6532

Draught screens shall be secured and enclosed on three sides by panelling and the structure at the end of the seating. The unsecured exposed edge of the draught screen shall be parallel to adjacent grab pole as shown in illustration 7 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6398

Windows shall be provided in the carbody side which enable platform-side and non-platform-side station names shown in the LU roundel to 1865 be read by seated passengers.

The size, shape and proportion of carbody side windows shall be consistent with illustrations 8, 9 and 10 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6407

Windows shall be provided in the bodyside doors which enable platform-side and non-platform-side station names shown in the LU roundel to be read by passengers standing in the door vestibule area and seated passengers. 1866

Non-digital customer information and signage shall be positioned in a horizontal row above all carbody side windows and below the row of digital screens in the general position shown in illustration 10 and illustration 11 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6410

Digital CIS and advertising screens (VEIDs) shall be positioned in a horizontal row above the non-digital customer information and signage in the general position shown in illustration 11 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. These screens and any associated protective covers, shall be visually integrated with surrounding panelling. 6409

Apart from a kick plate at the base of the door that should be finished in a darker material to match the skirting detail, the interior door skin should visually be of a single, naturally finished metal material. 6437

Internal door visual indicator lights shall be positioned to run vertically along the full height of the inside edge of each door window as shown in illustration 11 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. These indicator lights shall be capable of illuminating and flashing in green and red colours as appropriate to indicate the status of the doors to passengers. 4955

The Passenger Emergency Alarm (PEA) unit design shall be integrated within the Train interior using similar or complimenting colours and finishes to the surrounding panelling, whilst also being visually distinctive such that passengers can easily identify its location and its function as shown in illustration 12 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 675

The PEA unit shall incorporate a means of providing positive visual feedback to users, in the form of aesthetically integrated coloured lights, symbols and/or text, both when the alarm has been activated, and when specific PEA functions such as talkback mode have been enabled in order to prompt the correct user responses. 6412

The flooring shall incorporate a pattern which appears to flow seamlessly throughout carriages comprising of concentric lines radiating around vestibule grab poles and merging into longitudinal lines in corridors creating a roundel shape. The outermost line shall be 6414 of a heavier weight than inner lines to emphasise the roundel feature.

The floor pattern itself is not required to be grooved but grooves may be used where they are required to assist with cleaning or drainage of liquids. 6416

Ceiling panels running the length of each carriage shall reflect the use of lines and the roundel shape in vestibule areas as used on the flooring pattern. The ceiling pattern shall be integrated with air-cooling, light fittings, LED lighting strips and other functions where required. 6417

When the cab is removed, the saloon interior shall be extended to fill the additional space while maintaining the consistent layout and aesthetic appearance of the saloon design. 4626

7.3 Exterior Appearance 4827

The colours and finishes used on the exterior of the Train shall be in accordance with section 4.1 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6387

The profile of the front of the Train shall incorporate a compound curve over the glazed fascia with the centre of the Train protruding further forwards and blending down into the sides and lower running panels. The profile shall be symmetrical about the vertical axis. Reference shall be made to illustration 1 and 2 in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6360

The angled front face of the Train shall sweep smoothly and shall be blended into the larger sides of the Train, particularly the lower section which flows further inward than the upper section as shown in illustrations 1 and 2 in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6363

One of the key aesthetic features of the front and rear of the Train, as shown in illustrations 1 and 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', is a lighting 'halo'. The lighting halo shall consist of an LED lighting strip which follows the outside profile of the carbody around the top and sides of the Train before cutting inside along the bottom of the windscreen glass at an angle towards the M-door. 5762

The lighting halo shall be visually continuous above the M-door unless it can be demonstrated that there is physically insufficient space to fit the halo above the destination display.

The headlight function shall be aesthetically integrated into the lower angled section of the lighting halo and shall meet the performance requirements detailed in this specification. 5764

The upper section of the lighting halo (above the headlight) shall illuminate white and red to match the illumination state of the headlight 5776 and tail light at all times when one end of the Train is a controlling (active) end.

Within the boundary of the lighting halo there shall be a visually continuous black area which shall incorporate the central M-door (from level with the bottom of the headlights upwards), windscreen and door glazing, grabrails and windscreen wipers as shown in illustration 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6365

The M-door grab poles and door handle should blend into the background colour scheme to minimise the visual impact of these features on the front of the Train. 6435

The windscreen glazing edge shall closely follow the profile of the lighting halo on three sides and finish close to the M-door surround on its inside edge as shown in illustration 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6432

All text shown on the exterior of the Train shall use New Johnston Medium typeface as defined in Appendix 1 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6433

All text shown on the exterior of the Train, with the exception of Car Numbers, shall be in sentence case and suitably scaled to complement the exterior design of the Train while meeting RVAR and Train technical specification requirements for visibility and fonts. 6366

All text on the Train exterior, whether it is fixed signage or VEIDs, shall be coloured white with a contrasting black background. 5081

The name of the LU line over which the Train will operate shall be displayed centrally on the M-door using one or two lines of text. 6370

Car Numbers shall be positioned on lower right hand side of the front of the Train as shown in illustration 3 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6371

The Train Number Indicator display shall be positioned centrally on the M-door. 6373

The overall layout of information on the front of the Train shall ensure overall proportionality between each of the individual elements. 6375

A TfL Roundel, with a brushed steel or similar unpainted metal finish, as detailed in appendix 2 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', shall be fitted on the M-door. 6376

Note - This requirement differs from the Roundel shown in the NTfL Design Vision images which show an LU roundel with incorporates Underground text and colour.

The positioning and the sizing of the TfL Roundel on the M-door shall be in accordance with illustration 2 and illustration 3 in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief' i.e. positioned centrally below the window on the M-door against an integrated black background. 6378

A blue livery band shall run horizontally along the length of the side of each car below the saloon windows as shown in illustration 4 and illustration 15 in Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. The height and colour of the livery band shall match the middle section of the roundel. There shall be proportional breaks in the livery band either side of saloon doors (100mm from door) and to accommodate the roundel and Car Numbers on each car. 6383

A London Underground Roundel, as specified in Appendix 3 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief', shall be shown horizontally centrally between the 2 sets of double doors on the body side and vertically in line with the blue livery band on both sides of each car. 6384

External bodyside windows shall have the appearance of multiple individual divided window units. 6389

The lower edge of the door windows shall be at the same height as the lower edge of the bodyside window glazing and the upper edge of the door windows shall finish higher than the bodyside windows in order to allow passengers standing in the vestibule area to view signage on platforms 6391

External door visual indicator lights shall be positioned to run vertically along the full height of the inside edge of each door window as shown in illustration 5 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. These indicator lights shall be capable of illuminating and flashing in colours as appropriate to indicate the status of the doors to passengers. 4954

The windows shall be included in a strongly delineated horizontal feature, proportional in height to the exterior elevations as a whole, and broken only by car doors and car body ends, and this shall be emphasized by the use of colour and materials so as to form a visual black strip as shown in illustration 4 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6393

The horizontal window feature on the car side profile shall be delineated against the carbody livery by the use of a naturally finished metallic trim detail to both the top and bottom of the black window strip. The interior layout of the carbody pillars shall be mirrored on the exterior by a subtle use of a vertical naturally finished metallic trim shown on the black horizontal window strip as shown in illustration 4 of Reference document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 6394

8 Saloon 4829

8.1 Saloon - General Layout 1894

The Train interior design shall present a safe, secure and comfortable environment. 1895

Open wide gangways shall enable passengers to move freely from one end of the Train to the other. 1897

The saloon layout shall optimise seating capacity. 1898

The saloon layout shall optimise standing capacity by making best use of space which is not occupied by seating. 1900

The saloon shall incorporate a central clear throughway from one end of the Train to the other with the minimum dimensions of 1000mm wide and 2000mm high. 1867

The only items of equipment which are permitted to infringe this clear throughway are vertical grabpoles, which may be positioned centrally within the door vestibule area, and the RVAR wheelchair backboard, which has minimum dimensions defined in Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. A reduced vertical height of 1900mm is permitted in the gangway area.

Doorways shall have a minimum clear headroom of 1900mm. 5018

The saloon layout shall incorporate passenger stand back areas adjacent to all passenger doorways. The stand back area design shall ensure that on-board passengers may stand clear either side of the doorway to assist in the flow of passengers out of and into the cars. 2437

The Stage 4 tender evaluation model capacity evaluation calculation should be used to maximise the benefit of conflicting requirements and to demonstrate compliance with the requirements. 4446

All items of furniture and equipment in the saloon shall be designed and positioned to account for the ergonomic needs of passengers, maintainers and operational staff. 4354

Any equipment which is not intended for passenger use and which is located behind interior finishes shall not be visible to passengers. 1851

Any equipment which is not intended for passenger use and which is located behind interior finishes shall not be accessible to passengers. 2136

The lower row of non-digital customer information and signage above 5905 carbody windows shall be fitted with In-Car Line Diagrams, Central London Journey Planners, priority seat information and other fixed customer information notices as specified in section 3.11 through to section 3.21 (inclusive) in LU Standard 1-382 'Train Decor Design'.

Unless otherwise stated, non-digital customer information and signage shall be in the form of durable vinyl labels. 6444

The upper row of digital CIS and advertising VEIDS above carbody windows shall include sufficient CIS information screens to meet customer sightline and legibility requirements, with the remaining space being fitted with the maximum number of digital advertising screens which can be accommodated. 6326

The exact layout of CIS information screens will also be dependent on viewing angles, sightlines and legibility requirements for the information (e.g. RVAR).

Window sills and seat backs, where provided, shall be sloped so as not to be a resting place for primary types of litter encountered on the Underground. 4618

The design of the interior shall incorporate non-static surfaces to help to mitigate the attraction and build-up of dust. 2558

All grilles, covers, panels and luminaires shall either be cleanable in situ or shall be readily removable and replaceable for cleaning. 4549

Spaces shall be eliminated that may be used for the concealment or disposal of items. 2135

Spaces shall be eliminated that are not intended to be used by passengers. 6082

8.2 Wheelchair Spaces 1921

A wheelchair space is an area for a disabled person in a wheelchair which is legislated by Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 1928

Each Train shall be fitted with at least the number of wheelchair spaces required by clause 18 (4) in Part 1 of Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 1967

Wheelchair spaces, and all associated interfaces and signage, shall fully comply with the requirements of Reference document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 1930

Wheelchair spaces shall be clustered together such that the full extents of the door apertures of all of the wheelchair access doorways are contained within a distance which is no longer than 50% of the length of the Train. 1973

Wheelchair spaces shall be positioned symmetrically about the centre of the Train formation such that wheelchair access doorways always line up at the same position on platforms irrespective of the orientation of the Train. 6431

Wheelchair spaces shall be fitted with tip-up seating for use by passengers when they are not occupied by wheelchair users. 1975

Tip-up seats shall not encroach on the defined wheelchair space dimensional requirements when in the stowed position. 4645

Doorways adjacent to wheelchair spaces shall be fitted with a suitable interface to allow a wheelchair manual boarding ramp to be secured to the Train, in accordance with Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010' Part 1 Paragraph 1 (5). 6682

Manual boarding ramps to allow wheelchair access between the Train and platforms which are lower than the Train may be required during migration stages of the programme and on platforms where level access and horizontal stepping distances cannot be fully achieved by infrastructure works alone.

On the Piccadilly line, where some platforms are shared with S-Stock trains and therefore level access to the platform is not possible, the door vestibule area at designated wheelchair positions, including grabpoles and other fixtures, shall be compatible with a portable wheelchair manual boarding ramp which will facilitate the access and egress of wheelchairs from platforms which are higher than the floor level of the Train. The wheelchair manual boarding ramp should be assumed to be 810mm wide and to protrude up to 1000mm into the car. Clearance shall be provided to allow a wheelchair user to manoeuvre a reference wheelchair, as defined in Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010', safely between the ramp and the wheelchair position. 5000

8.3 Multi-Purpose Areas 1923

A multi-purpose area is a space for the safe stowage of luggage, pushchairs, etc. in the saloon. 1956

Each car, except those equipped with an RVAR wheelchair space, shall have at least one multi-purpose area. 1915

Multi-purpose areas shall occupy at least the area that would be occupied by two fixed seats. 1957

Multi-purpose areas shall be located adjacent to, but not be included in, the doorway vestibule area. 1953

Multi-purpose areas shall be fitted with tip-up seating. 1916

8.4 Fixtures and Fittings - General 2033

The design and manufacture of the saloon, and all fixtures and fittings, shall be such as to manage the risk of injury to passengers to a level that is ALARP. 2038

Reference should be made to LU Standard G185 'Interior Crashworthiness and Egress' and Railway Group Standard GM/GN2687 'Guidance on Rail Vehicle Interior Structure and Secondary Structural Elements'. 2041

It shall not be possible for any surfaces, which are accessible to passengers, to exceed a temperature of 50°C. 2160

The joins and junctions between saloon interior panels, fixtures and fittings shall not allow paper travel tickets to be inserted through gaps and junctions where this could result in an accumulation of paper travel tickets becoming a fire hazard. 6507

The interior shall be resistant to scuffing or abrasion damage from contact with wheelchairs, pushchairs, passenger luggage, or other reasonably foreseeable items. 4823

Visible fixings within the saloon interior shall be avoided where possible. Where fastenings are visible, they shall be tamper resistant, aesthetically consistent with the interior design, whilst being robust enough to be undamaged during maintenance activities. 2455

Make-up strips, filler pieces or other similar items are not acceptable. 2557

Secondary retention, in the form of lanyards, shall be incorporated into all saloon interior facing items that are completely above a horizontal plane positioned at a height that is a distance of 0.1m below the top of the saloon body side windows. 2034

This requirement shall include ceiling panels, trim panels, advert panels, electronic displays, lighting, loudspeakers, fan grilles and ventilation grilles. Grab poles and hand rails shall be excluded.

Each secondary retention lanyard shall individually be capable of retaining its connected item falling from its normal position as well as retaining the panel when subjected to normal service accelerations and inertia forces. 2052

Materials that may fracture and reveal sharp edges, potentially injurious 2051 materials, inserts or inlays shall not be used.

Items of furniture and equipment shall remain securely fastened when subjected to the accelerations and inertia forces detailed elsewhere in this specification. 2044

Interior surfaces, which could impact passengers or staff in an accident, shall be free from sharp edges and projections. 2036

Interior surfaces which could impact passengers or staff in an accident shall, where practicable, make use of materials with high energy absorbing features. 2053

Interior panels and ceiling and wall mounted equipment shall, where possible, be fixed directly to the carbody structure. 2050

Interior panels, including fixings and lanyards, shall be adequately supported and shall not resonate, vibrate or emit any noticeable sound in normal service conditions. 2560

Interior panels shall be capable of simple removal and replacement without degradation and with the minimum of disturbance to adjacent areas and flooring. On replacement they shall not require the use of any sealant or other compounds. 2562

Interior surfaces shall be suitable for the application and removal of vinyl film. 4395

On existing fleets, the Purchaser sometimes uses replaceable vinyl film on interior surfaces as an alternative to paint repair following heavy graffiti damage. 4939

Laminates shall comply with all applicable parts of British Standard BS EN 438-2:2005 'High-Pressure Decorative Laminates (HPL)'. 2559

8.5 Handgrips and Grabpoles 1872

Handgrips and grabpoles shall be fitted throughout the Train and shall be positioned such that they encourage passengers to move inside the cars away from the door vestibule areas. 1873

Handgrips and grabpoles shall be positioned such that they enable, under Full Load condition, all passengers to have comfortable and convenient access to at least one fitting. 1874

Handgrips and grabpoles shall not impede passenger flow throughout the Train. 4383

Handgrips and grabpoles shall not impede wheelchair movement 5154 between designated wheelchair spaces and adjacent passenger doorways.

Handgrips and grabpoles shall not contribute to the structural integrity of the car. 2064

Handgrips and grabpoles shall be removable for easy replacement of the coloured sections and the complete item. 2065

Handgrips and grabpoles shall use a nylon / polymer (or equivalent) based powder coating finish on coloured sections. 2066

The finish on handgrips and grabpoles shall be highly resistant to mechanical damage and graffiti and shall be easily cleaned. 6294

Handgrips and grabpoles shall minimise injury to persons thrown against them in the event of rapid deceleration of, or other forces acting on, the car. 2177

Handgrip or grabpole assemblies shall be taken to include all associated attachments, fastenings and welds up to and including the attachment to the carbody structure. 2179

Handgrips and grabpoles shall not, under any of the defined load cases defined for handgrips and grabpoles, exceed the material yield stress or 0.2% proof stress, so as to prevent permanent deformation. 4991

Handgrips and grabpoles shall not, under any of the load cases defined for handgrips and grabpoles, suffer any structural instabilities. 4992

Handgrips and grabpole assemblies shall fully comply with the structural requirements in Section 6.6 of Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures'. 2253

Handgrips and grabpoles, except horizontal rails which are shorter than 1.0m, shall withstand 1700N applied in the most disadvantageous direction. 2265

Horizontal grabpoles, which have rails longer than 1.0m, shall withstand vertical loads of 1700N/m span, applied in the most disadvantageous direction. 2268

Horizontal grabpoles, which have rails longer than 1.0m, shall withstand horizontal loads of 750N/m span applied in the most disadvantageous direction. 2270

Handgrip and grabpole assemblies shall withstand 3400N applied in the most disadvantageous direction without reaching ultimate failure. 2276

8.6 Draught Screens 1868

Glazed draught screens shall be provided at all stand back areas, including adjacent to multi-purpose areas and wheelchair spaces, to give protection from air draughts and the ingress of rain from open doors onto adjacent seats. 1853

Draught screens shall not impede sightlines through from one end of the car to the other. 1870

Draught screens shall not impede wheelchair access to designated spaces. 1871

8.7 Flooring 1931

Flooring throughout the Train interior shall be covered with a hard wearing, durable, resistant surface. 2009

Flooring shall have no gradients exceeding 5%. 2452

Flooring surfaces shall be free from trip hazards. 4619

The slip resistance of flooring materials shall be determined using either the Pendulum Slip test method, as defined in British Standard BS 7976:2002+A1 2013 'Pendulum Testers', or Reference Document 'SATRA Technology Ltd Test Method TM144 (LUL)'. 2004

If flooring material is tested by SATRA Technology Ltd in accordance with Reference Document 'SATRA Technology Ltd Test Method TM144 (LUL)' the coefficient of friction shall not fall below a minimum value of 0.4 for more than a 20mm traverse from the centre of a 100mm trace for all relevant test orientations. 5202

If flooring material is tested in accordance with British Standard BS 7976:2002+A1 2013 'Pendulum Testers', the Pendulum Slip Tester shall be fitted with a "Four-S" contact rubber and shall achieve a PTV≥36 under dry and wet conditions. 5206

Slip resistance testing shall be carried out on representative specimens covering any flooring surface design variations, e.g. profiled and un-profiled sections (if applicable). 5203

Test specimens used for flooring slip resistance testing shall have any surface finishes or polish in place (if applicable) to fully represent service conditions. 5205

Surface profiling of the floor covering may be used where required to aid drainage. 5201

Flooring materials shall remain slip resistant if wet. 2005

The flooring design shall comply with the flooring requirements detailed in Section 8 of Schedule 1 of Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 1932

Dirt traps in flooring shall be avoided and cleaning facilitated by the use of suitable covings or mouldings. 2013

It shall be possible to remove foreign material, such as graffiti or chewing gum, from flooring without damage. 2014

The floor shall be sealed along all edges and joints to prevent ingress of liquid into the sub-floor area. 2015

Note - the Purchaser has had experience of fluid ingress causing problems at flooring joints, sill plates and coving areas and expect particular attention to be paid to these areas in the flooring design.

The Manufacturer shall provide sufficient details of the assembly / installation process for flooring on the Train to demonstrate that the processes recommended by the flooring Manufacturer will be implemented in full. 6675

There shall be no access to any equipment or services by lifting interior floor panels or floor covering. 2026

8.8 Door Sills 3258

Door sills shall be fitted at all passenger doorways. 2020

Door sills shall provide a threshold between the floor covering inside the car and the outermost edge of the car on which passengers can step. 5252

Door sills shall extend outside each doorway, within gauging limits, to minimise platform to Train stepping distances. 5249

Door sills shall have a durable and slip resistant stainless steel (or equivalent) finish. 5251

Door sills shall allow water drainage from inside the car. 2021

8.9 Passenger Seating 49

8.9.1 Passenger Seating - General 2121

Passenger seats with a longitudinal orientation shall be fitted throughout the saloon. 1884

The construction of seats shall be such that in the event of any type of failure occurring when the Train is in normal passenger service there shall be no component that could penetrate the seat cover and cause injury to a passenger. 2399

Where seats fail due to abuse they shall fail such that the risk of injury to the person causing the abuse and to subsequent users is managed ALARP. 2400

It shall be demonstrated that Passenger seats provide adequate comfort for the intended user population and for the expected passenger journey times. 5208

All seats shall have a clear space of at least 300mm in front of the seat (measured from the front edge of the seat cushion). The space shall be clear across the full height and width of the seat. 1886

The first fixed seat on both sides of each saloon double doorway shall be assigned as a Priority Seat. This shall exclude positions where there is a tip-up seat fitted between the first fixed seat and the doorway. 1933

Requirements for Priority Seats are detailed in Reference Document "The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 4941

Tip-up seats shall only be used in defined Wheelchair Spaces and Multi-Purpose areas. 6259

When not in use tip-up seats shall automatically return to the stowed vertical position. 4640

Tip-up seats shall return to the stowed position in a controlled manner which prevents the potential for passenger injury. 4642

On recent Purchaser train fleets, tip-up seats incorporate a damping mechanism to meet this requirement.

Tip-up seats shall be suitable for passengers to 'perch' on when in the stowed position. 4646

Passenger seats shall be resistant to vandal damage using a knife or sharp blade. 2127

8.9.2 Seat Dimensions 2122

Each seat shall be at least 495mm wide. This dimension includes half of the armrest on either side of the seat. For seats without armrests, an equivalent space shall be provided. 2067

The cushioned area of a passenger seat base shall be at least 450mm wide. 2443

Each seat shall be at least 410mm deep at the base of the seat. 2068

8.9.3 Seat Armrests 2444

All passenger seats, excluding tip-up seats, shall be fitted with an armrest between any two seats. 2446

Each armrest shall be at least 45mm wide. 4994

In the event of armrest failure, no parts shall remain that could cause injury. 2401

8.9.4 Seat Maintenance Access 2124

Seating units shall be interchangeable to minimise spares stock holdings. 2069

The seat cushions and squabs including cover shall be secured to prevent unauthorised removal. 2098

If access below seats is required for maintenance or operational purposes, seats shall be capable of being raised, secured in the raised position and closed by one person. 2106

If access below seats is required for maintenance or operational purposes, seats shall be automatically retained in the raised position and shall close in a controlled, safe manner. 4999

Seats that are capable of being raised shall be locked in the down position with a slam type lock. 2107

Seat locks shall be opened by the female end of a J-door key as detailed in LU Drawing 100524 'Gedore Operating Key'. 2109

The gap between the seat riser and seat cushion shall be no greater than 3mm at any point when the seat is secured. 2114

8.9.5 Seating Upholstery 2125

All passenger seats, including tip-up seats, shall be cushioned and shall be finished with a moquette fabric both on the seat base and the seat back. 2440

The passenger seat moquette material specification shall be in accordance with Reference Document RSE/CTS/008 'Specification for Moquette', except where there are conflicting requirements in this specification. 2130

The passenger seat moquette shall have an abrasion resistance of no less than 80,000 rubs when tested in accordance with the Martindale method defined in British Standard BS EN ISO 12947:1998 'Textiles - Determination of Abrasion Resistance of Fabrics by the Martindale Method'. 5210

The passenger seat moquette shall have a burst strength of no less than 1300kN/m² when tested in accordance with British Standard BS EN ISO 13938-1:1999 'Textiles — Bursting properties of fabrics — Part 1: Hydraulic method for determination of bursting strength and bursting distension'. 5213

8.9.6 Structural Requirements for Seats 2278

Structural requirements for passenger seating shall fully comply with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', with additions and amendments as noted in this specification. 2279

The Manufacturer shall demonstrate that all fixed and tip-up passenger seats and supporting structures shall withstand all of the passenger seating load cases defined in this specification, applied individually, without permanent deformation or damage. 2283

All fixed passenger seats and supporting structures shall withstand a vertical load of 2000N applied downwards over an area of 380mm wide by 200mm deep located centrally on the seat cushion. This load application shall be sustained for 5 minutes. 2417

Tip-up seats and supporting structures shall withstand a vertical load of 2000N applied vertically downwards at any position on the front edge of a deployed seat. 4629

Tip-up seats and supporting structures shall withstand a vertical load of 2000N applied vertically downwards centrally on top of an undeployed tip-up seat. 4636

Tip-up seats, supporting structures and deployment mechanisms shall be subject to fatigue assessment to demonstrate the design life of the seat (including deploying and returning to vertical). Testing shall be 4650 based on Manufacturer maintenance intervals and expected passenger usage.

Fatigue load cases for tip-up seats used shall be proposed by the Manufacturer taking account of predicted tip-up seat usage by the target user population and equipment attachment loads in Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures'. 5215

In the case of multiple seats being contained on a single structure, all individual load cases shall be applied simultaneously on each seat. 2412

If additional fatigue analysis of seats is deemed necessary, British Standard BS EN 61373:2010 'Railway Applications. Rolling Stock Equipment. Shock and Vibration Tests' or equipment attachment loads in Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures' should be used. 2282

8.9.7 Structural Requirements for Seat Armrests 2413

Seat armrests shall comply with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', with additions and amendments as noted in this specification. 2415

Seat armrests shall withstand a static proof load of +1700N, sustained for 5 minutes, applied in the vertically downwards direction at the free end of the armrest. 2394

Seat armrests shall withstand a static proof load of ±1500N applied in the transverse direction (relative to the seat) at the free end of the armrest. 2407

9 Interior Lighting 52

9.1 Interior Lighting - General 444

Interior lighting shall be provided which delivers uniform illumination throughout the Train. 5537

The interior lighting shall be designed to minimise glare. 6319

The interior lighting shall ensure that there are no shadowing effects inside the Train. 6320

All interior lighting shall be provided using LED or equivalent low energy, high efficiency, low maintenance light sources. 445

Interior lighting shall not flicker, flash, pulse or fade. 474

The colour appearance, colour rendering and glare of the lighting shall comply with the requirements of British Standard BS EN 13272:2012 'Railway Applications - Electrical Lighting for Rolling Stock in Public Transport Systems'. 447

The lighting shall allow all of the interior to be clearly visible under normal and emergency lighting conditions in all environments. 449

It shall be possible to change the source of illumination with the lighting supply switched on without exposing staff to the danger of electric shocks. 1544

Light fittings shall be designed to be robust and resistant to vandalism while providing easy access to enable replacement of sources of illumination. 1534

Saloon lighting correlated colour temperature shall be nominally 3000^{o}K. 3702

9.2 Lighting Control 1609

Consideration should be given to the use of Constant Light Output technology to ensure a consistent level of light output throughout the lifetime of the lighting components. 5744

Saloon lighting levels shall be controlled to reduce energy consumption when the Train is out of service and not required for maintenance, cleaning or operational tasks. 459

Controls shall be provided at the operating positions so that 6161 maintenance and cleaning staff (including litter pickers) can switch the saloon lighting on and off.

Saloon lighting will be subject to automatic control by the RCS/OTC for energy efficiency.

The status of the saloon lighting shall be reported to the RCS. 6162

Saloon lighting levels near the SOP shall be adjustable locally to a reduced set level to mitigate the impact of reflections in the windscreen when manual driving. 460

9.3 Lighting Circuit Configuration 467

A single point failure shall not result in the loss of more than 50% of saloon lighting in any car. 468

The loss of the main lighting shall not result in the loss of emergency lighting and vice versa. 4414

The main and emergency lighting shall be arranged to ensure that the operation of any protection or control device does not affect all of the lights on a car. 469

The emergency lighting on each car shall be arranged such that any single failure does not result in one area of the car being in darkness. 472

The main lighting on each car shall be arranged such that any single failure does not result in one area of the car being in darkness. 5872

9.4 Luminaires 498

Luminaires shall generally comply with British Standard BS EN 60598 'Luminaires' except where there is conflict with the requirements of this specification. 499

Luminaires shall be designed to be robust. 5741

Luminaires shall be sealed to prevent the ingress of all dust and liquids. 500

Broken luminaires shall not result in shards. 5002

Luminaires and associated drivers shall be designed to be easy to access for maintenance. 5742

Low level door threshold lighting shall be provided which illuminates the edge of the floor along the doorway entrance. 5873

Low level door threshold lighting shall be positioned inside the Train near to floor level at both sides of each passenger doorway. 1647

Low level door threshold lighting shall illuminate the threshold when the door is not closed. 7035

Low level door threshold lighting shall be designed in such a way as to avoid any glare to passengers and CCTV cameras on the platform. 3741

LED luminaires and lamps shall be guaranteed for colour stability of three or fewer MacAdam ellipses for their required lifetime. 5747

All light sources shall have a Colour Rendering Index (CRI) greater than Ra80. 5748

LED light sources shall have a minimum lumen maintenance of L80 for at least 3 years' service. Lumen maintenance shall be measured using the test method defined in Reference Document IES LM 80-08: 'Measuring Lumen Maintenance of LED Light Sources'. 5749

9.5 Normal Lighting Performance 477

Normal lighting in the saloon shall be the combination of the main lighting and the emergency lighting. 6662

The normal lighting illuminance level shall be not less than 350 lux at each individual saloon seating position. 478

Illuminance shall be measured with the light meter held at an angle of 45º above the centre of the seat front edge, at a height of 1000mm above the car floor.

Note - This test case simulates the lighting level for a seated passenger reading a newspaper.

The normal lighting illuminance level shall be not less than 350 lux at each saloon standing measurement position. 479

Illuminance shall be measured with a light meter at an angle of 45º at a height of 1500mm above the car floor at 1m intervals along the longitudinal centre line of the entire Train, including the gangways. The sensitive part of the meter shall be facing the mid-point of the car.

Note - This test case simulates the lighting level for a standing passenger reading a newspaper.

Uniformity of illuminance in normal lighting conditions, when calculated from saloon seated position measurements, shall be not less than 0.5. 480

Uniformity of illuminance in normal lighting conditions, when calculated from saloon standing position measurements, shall be not less than 0.5. 481

The saloon normal lighting shall ensure that the areas detailed below are sufficiently illuminated and free from any shadowing effect: 3727

- seating;
- grab rails/poles;
- flooring;
- Passenger Emergency Alarm (PEA);
- passenger door threshold area;
- non-backlit customer information;
- signage;
- non-backlit advertising (if fitted).

Interior lighting characteristics and performance shall be in accordance with British Standard BS EN 13272:2012 'Railway Applications - Electrical Lighting for Rolling Stock in Public Transport Systems', except where that standard conflicts with the requirements of this specification. 3731

9.6 Emergency Lighting Performance 482

Emergency lighting provides illumination levels required to ensure passenger safety when normal lighting is not available. 483

Emergency lighting shall form part of the normal lighting within the car under normal operating conditions. 4415

Emergency lighting shall enable safe passenger detrainment. 484

Emergency lighting shall continue to provide a minimum of 2 hours lighting in the event of loss of auxiliary supply. 485

Emergency lighting illuminance level shall be not less than 50 lux measured at any seating positions with the light meter (reading pane) held at an angle of 45º above the centre of the seat front edge, at a height of 1000mm above the car floor. 486

Note - This test case simulates the lighting level for a seated passenger reading a newspaper.

Emergency lighting illuminance level shall be not less than 50 lux measured, with the light meter facing directly upwards, at floor level on the longitudinal centreline of the car, including the enclosed inter-car gangways and the cab area. 487

Emergency lighting illuminance level shall be not less than 50 lux measured at any passenger alarm position or at any exit signage. 488

Emergency lighting illuminance level shall be not less than 50 lux 489 measured at the centre line of each saloon passenger door at floor level without the use of the low level door threshold lighting.

Uniformity of illuminance in emergency lighting conditions, when calculated from all measurements taken, shall be no less than 0.25. 490

In the event of failure of one of the emergency light circuits then the remaining emergency light circuits (assuming no main lighting is available) shall provide a reasonable uniformity of lighting. 491

Some of the emergency lights in each car shall contain an independent battery which shall keep that light illuminated for at least 3 hours following the loss of emergency lighting. 494

Illuminance levels for the independent battery powered back-up lighting shall be sufficient to enable passengers to: 495

- see each other and staff;
- enable emergency first aid to be administered;
- enable emergency evacuation.

9.7 Cab Lighting 1520

Lighting in the cab area (when fitted) shall comply with all interior lighting requirements detailed in this specification except where they conflict with the additional requirements in this cab lighting section. 5263

Cab lighting shall comply with the requirements of Railway Group Standard GM/RT2176 'Air Quality and Lighting Environment for Traincrew Inside Railway Vehicles'. 1608

Cab lighting shall provide illumination of controls in the cab. 6072

Sufficient illumination of cab controls shall be provided to allow the Train Operator to safely and efficiently operate the Train with the cab lighting turned off. 6663

A control shall be provided to allow the Train Operator to set the cab lighting to at least two different lighting levels and off. 1575

Cab lighting shall be illuminated at all times, except when cab has been made a controlling cab, in which case the state of the cab lighting shall be in accordance with the cab lighting control setting. 1570

Uniformity of illuminance for lighting in the cab area shall be no less than 0.5. 1601

No single failure shall result in the loss of all cab lighting. 1524

Cab lighting shall be appropriate for safely de-training passengers through the end M-door. 1526

Cab lighting shall remain illuminated for at least 2 hours in the event of loss of auxiliary supplies. 1573

No single fault shall result in the minimum required cab lighting illumination for emergency evacuation not being achieved. 4553

9.8 Lighting Design Validation 503

Saloon lighting requirements shall be validated for both the scenario with a cab being present and without a cab being present. 5003

Saloon lighting shall meet the specified performance criteria with all digital screens and door visual indications turned off. 6266

Test conditions for the validation of lighting requirements shall be as defined in British Standard BS EN 13272:2012 'Railway Applications - Electrical Lighting for Rolling Stock in Public Transport Systems' except where test conditions are detailed in this technical specification. 504

10 Exterior Lighting 60

10.1 Exterior Lighting - General 2496

Exterior lighting on the Train is required to: 2529

- *illuminate the route ahead;*
- *make the Train visible to all railway users;*
- *provide indications to staff and customers;*
- *illuminate the area in front of the Train, e.g. for passenger detrainment.*

The performance requirements of the tail light, Yellow Indicator Light and detrainment lights can be satisfied using discrete light units rather than being satisfied by the lighting halo. 5778

All exterior lighting assemblies shall be rated to IP66, as defined in British Standard BS EN 60529:1992+A2 2013 'Degrees of Protection Provided by Enclosures (IP code)'. 2565

All exterior lighting shall use LED or low energy equivalent light sources. 2566

All exterior lighting shall be scratch and impact resistant and resistant to damage arising from dirt and graffiti removal. 2567

Cleaning shall not affect beam settings. 2569

10.2 Headlight 2530

Each end of the Train shall be fitted with two headlight arrays. 2579

Headlights shall illuminate the route ahead. 2577

Headlights shall be turned on at one end of the Train when RCS selects that end of the Train to be the leading (controlling) end. 4705

Headlights shall be turned on at that end of the Train when the local mode switch is set to Manual mode. 4706

Headlights shall be automatically turned off when the local mode switch is set to Automatic and the RCS has not selected that end of the Train to be the leading (controlling) end. 2650

Headlights shall be turned off at that end of the Train when the local mode switch is set to Train Secure mode. 4707

Headlights shall be automatically turned off when the detrainment lights are illuminated. 5874

Headlights shall use a white light source. 2584

Headlights shall have a clear lens. 2585

Each headlight shall be provided with a means of finely adjusting the beam alignment. 2598

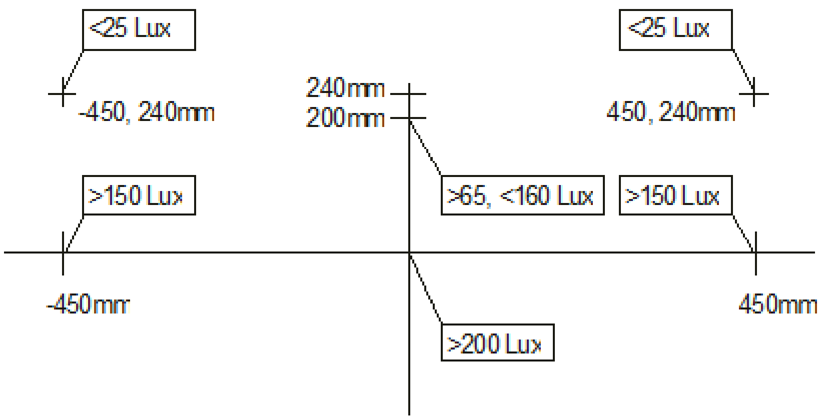
Headlights shall be located between the solebar and the car waist line, with their horizontal centrelines between 1000mm and 1750mm above rail level. 2599

Both headlights shall be mounted symmetrically at the same height. 2618

Both headlights shall be mounted with a minimum lateral separation of 1300mm between their vertical centre-lines. 2619

The beam pattern of the headlights shall be elliptical with a flattened top. 2602

The headlight illumination levels at key points on a surface perpendicular to the beam centre-line at a distance of 5m in front of a single headlight shall be as shown below: 2603



The headlight illuminance at points across the beam pattern horizontal centre-line shall be maintained as high as possible so as to provide illumination of the side of the track. 2611

The headlight illuminance at points more than 240mm above the beam pattern horizontal centre-line shall be as low as possible so as to minimise the level of glare at the eyes of on-coming Train Operators 2612 and passengers standing on platforms.

The headlight illuminance at points more than 450mm to either side of the beam pattern vertical centreline, shall be as low as possible so as to minimise the level of glare at the eyes of on-coming Train Operators and passengers standing on platforms. 2613

Each headlight beam shall be inclined downwards so that the beam pattern horizontal centre-line strikes the running rails 40m ±4m in front of the Train whilst on straight level track. 2614

Each headlight beam shall not deviate laterally from straight track. 2615

The vertical and horizontal adjustment resolution of the headlights shall be such as to easily achieve an accuracy consistent with the performance requirements defined in this specification. 2646

The range of adjustment of the headlights shall be a minimum of 2° greater than the installation tolerance to allow for future re-alignment. 2648

The headlight beam alignment shall be unaffected by shock and vibration during normal service and shall not require routine adjustment. 2649

Headlights shall be fed from a power supply independent of the availability of the traction power supply. 2616

No single point failure shall result in the loss of both headlights. 2617

A Hazard Warning function shall be provided which causes the headlights to flash. 2841

It shall be possible to control the headlight Hazard Warning function via a trigger from the RCS interface. 2635

The position of the headlight Hazard Warning control shall be logged by the Train Data Recorder. 2643

When activated for hazard warning, both headlights shall flash alternately at 40 ±4 cycles per minute. 2632

When activated for hazard warning, the mark : space ratio should be 1:1 and each headlight should alternate between fully on and fully off. 2633

When activated for hazard warning, headlights shall flash simultaneously at both ends of the Train. 2637

The Hazard Warning headlight function shall be independent of Train 2634 state and the availability of the traction supply.

10.3 Tail Light 2537

Two tail lights shall be provided at each end of the Train. 2572

Both tail lights shall illuminate at all times except when the headlights are illuminated at that end of the Train unless the Wrong Direction Move lighting control has been operated, in which case both the tail lights shall remain illuminated at the same time as the headlights being illuminated. 2674

Tail lights shall remain illuminated when the Train is Powered Off. 2675

Tail light illumination shall not be dependent on the availability of the traction supply. 2702

Tail lights shall be mounted at the same height with their horizontal centre-lines a minimum of 1500mm above rail level. 2651

Tail lights shall have a minimum lateral separation of 1300mm between their vertical centrelines. 2652

Tail lights shall be clearly visible from a distance of 300m in daylight conditions. 2653

Tail lights shall have an output of Signal red, Colour Class B as defined in British Standard BS 1376:1974 'Specification for Colours of Light Signals'. 2654

Tail lights shall have a beam pattern which shall be circular with a viewing angle of at least 15°. 2655

Tail lights shall have an illuminance of greater than 6.5 lux on a surface perpendicular to, and on, the beam centre-line, at a distance of 2m from the tail light. 2656

A single point failure shall not result in the loss of both tail lights. 2659

If the Train battery is not located on the end car then the tail light shall contain a local backup power supply which shall have sufficient capacity to maintain the illumination of both tail lights for a minimum of 2 hours after the loss of supplies to that car. 2673

10.4 Yellow Indicator Light 2581

A Yellow Indicator Light shall be provided at each end of the Train. 2707

The Yellow Indicator Light shall be separate from the tail light. 2718

The Yellow Indicator Light shall be identical in performance to the tail light, except that the colour shall be Signal Yellow, colour class B, as defined in British Standard BS 1376:1974 'Specification for Colours of Light Signals'. 2748

The Yellow Indicator Light shall be fed from a power source independent of the availability of the traction power supply. 2772

The Yellow Indicator Light status shall be either On, Off or Flashing. 4519

The status of the Yellow Indicator Light shall be reported to the RCS. 2792

Activation of the Yellow Indicator Light control at any operating position shall cause the Yellow Indicator light at both end cars to illuminate continuously. 2801

It shall be possible to automatically control the Yellow Indicator Light status via TCMS logic. 2709

It shall be possible to remotely control the Yellow Indicator Light status via the RCS interface. 2774

The Yellow Indicator Light shall illuminate continuously at both ends of the Train when Train Secure mode is selected. 2797

The Yellow Indicator Light shall illuminate continuously at both ends of the Train when an OPO(T) deadman alarm is sent and, when the alarm is cancelled, the light shall be extinguished. 5260

Illumination of the Yellow Indicator Light from a second Train when two Trains are coupled together shall not be possible. 2799

The Yellow Indicator Light shall be arranged to automatically flash at both ends of the Train when the Train is in Restricted Manual mode. 2711

There shall be a visual indication at each operating position showing the status of the Yellow Indicator Lights. 2790

10.5 Detrainment Lighting 2531

Detrainment lighting shall be provided at each Train outer end door (M-door) to support the safe evacuation of passengers from the Train down to track level via the detrainment steps and from Train to Train via the detrainment bridge. 2811

Detrainment lighting shall be sufficient to illuminate the surface onto which the passengers will step. 2795

Detrainment lighting shall be sufficient to illuminate the handrails on the outside of the Train which may be used in the detrainment process. 2824

Detrainment lighting shall be sufficient to illuminate the track to a distance of 5m beyond the end of the detrainment system. 2825

The illumination provided by detrainment lighting shall minimise the shadows impairing the view of detraining passengers. 2813

The illumination provided by detrainment lighting shall minimise the glare directed at those assisting detrainment from the Train. 2830

The illumination of the surfaces on which passengers will step during a Train to Train or Train to track detrainment shall be a minimum of 100lux. 2826

The illumination by the detrainment lighting of a horizontal surface, at the level of the top of the negative rail, over an area protruding forward from the bottom edge of the detrainment system by 2m and being 1m wide, shall not be less than 50lux. 2827

The illumination by the detrainment lighting of a horizontal surface, at the level of the top of the negative rail, over an area projecting forward which starts 2m from the bottom edge of the detrainment system and extends to 3m and is 1m wide shall not be less than 25lux. 2828

Detrainment lights shall be fed from a source independent of the availability of the traction power supply. 2829

The activation of the detrainment lights shall turn the hazard warning lights off at that end of the Train. 2833

Detrainment lights shall automatically illuminate at one end of the Train whilst the local M-door is open and extinguish when the local M-door is closed. 2834

Detrainment lights shall automatically illuminate at one end of the Train when Train Secure mode is selected at that end. 5875

11 CCTV 53

11.1 CCTV - General 506

A CCTV system shall be provided, which captures, presents and records for later use, colour video images captured from strategically positioned cameras throughout the Train for the purpose of safety and security as well as supporting operational procedures. 5126

The CCTV system includes both forward and rear facing CCTV (FFCCTV) and internal CCTV coverage. 509

The CCTV system shall incorporate IP compatible digital video recorder(s) for time-lapse and real-time video recordings. 507

The CCTV system shall incorporate vandal resistant, IP compatible CCTV cameras. 5121

The CCTV system shall be active and shall record at all times when the Train is powered on. 510

CCTV camera lenses shall avoid internal reflections, optical distortions and chromatic aberration. 578

CCTV camera installations shall be sealed to a minimum of IP65 as defined in British Standard BS EN 60529:1992+A2 2013 'Degrees of Protection Provided by Enclosures (IP code)'. 580

11.2 Internal CCTV Coverage 515

CCTV surveillance equipment shall be installed throughout the passenger saloon. 516

CCTV cameras shall provide a clear unobscured view of each saloon door and the area around it. These images shall be of suitable quality to observe passengers boarding and alighting, door faults and door passenger incidents. 520

CCTV cameras shall provide a clear unobscured view of the area around all PEA units to observe passenger activity in that area. 521

CCTV cameras shall provide a clear unobscured view to observe passenger activity in the inter-car gangway area. 522

CCTV cameras shall provide a clear unobscured view to observe passenger activity in the area around detrainment doors at either end of the Train. 523

CCTV cameras shall provide an overall coverage of at least 90% of the volume of space in the passenger saloon area (including gangways). 517

CCTV cameras shall provide a clear unobscured view to observe the driving position when the driving position is within the passenger saloon (i.e. the SOP). 3693

Any CCTV coverage "blind spot" shall not exceed the space occupied by a single seated or standing passenger. 5216

All CCTV cameras shall be positioned to give the best possible view of each area specified above when the Train is in the Full Load condition. 5005

11.3 Forward and Rear Facing CCTV (FFCCTV) 4429

The outer ends of each Train shall be fitted with forward and rear facing colour CCTV (FFCCTV) cameras compliant with Railway Group Standard GM/GN2606 'Guidance on the Fitment and Functionality of Forward and Rear Facing Cameras on Rolling Stock'. (Note that conditional requirements defined within GM/GN2606 shall be considered to be mandated except where they conflict with the requirements of this specification.) 714

The Train shall be fitted with FFCCTV recording equipment compliant with Railway Group Standard GM/GN2606 'Guidance on the Fitment and Functionality of Forward and Rear Facing Cameras on Rolling Stock'. (Note that conditional requirements defined within GM/GN2606 shall be considered to be mandated except where they conflict with the requirements of this specification.) 4685

There shall be a long-range FFCCTV camera targeted at a distant point in front of the Train. 715

The long-range FFCCTV camera and lens assembly shall be capable of capturing images that include, at a minimum, the viewing envelope for a seated Train Operator as defined elsewhere in this specification. The point of focus and depth of field should be consistent with these sighting requirements. 716

There shall be a short-range FFCCTV camera targeted at the area directly in front of the Train. 717

The short-range FFCCTV camera and lens assembly shall be capable of capturing images that include views of: 6352

- the coupler;
- the deployed detrainment device and associated detrainment activities;
- persons boarding or alighting via the M-door;
- the area between the rails from the front of the Train to 5m in

front of the Train at track level.

A means shall be provided to automatically keep all FFCCTV camera views clear and free from dirt, smears, moisture (inside and outside) and other obstructions. 5006

The FFCCTV function shall be fully integrated with, and meet the performance and functional requirements of, the main CCTV system. 718

It shall be possible to view live images from the FFCCTV cameras on display screens in the cab when selected. 6268

It shall be possible to view live images from the FFCCTV cameras via the RCS when requested. 6269

Images from all FFCCTV cameras shall be recorded at all times irrespective of the direction of movement of the Train. 721

11.4 CCTV Observation Live 526

The CCTV system shall allow the Train Operator to select individually, or to scroll automatically through, all camera locations on the Train and to view live camera images in real time. 527

The CCTV system shall allow the Train Operator to switch between train-based CCTV camera views and OPO CCTV views (when OPO CCTV views are available). 6520

The CCTV system shall allow staff remote from the Train, via the RCS interface, to select individually, or to scroll automatically through, all camera locations on the Train and to view live camera images in real time. 4259

The CCTV system shall be configurable by the Purchaser such that it is possible to suppress the presentation of CCTV images on the display screens in the cab based on whether the Train is moving or stationary. 7128

The initial setting of the CCTV system shall be such that CCTV images are not shown on display screens in the cab when the Train is moving. 7036

The CCTV system shall be configurable by the Purchaser such that CCTV controls (user interactions) in the cab can be temporarily disabled based on whether the Train is moving or stationary. 6705

This is intended to give operational flexibility in the event that staff are on board the Train but not involved in driving the Train and monitoring the PTI.

The initial setting of the CCTV system shall be such that CCTV controls in the cab are functional only when the Train is stationary. 528

The CCTV system shall allow a member of staff, to connect a laptop at any one of the ethernet ports on the Train to select individually, or to scroll automatically through, all camera locations on the Train and to view live camera images in real time. 4420

When a PEA is operated the CCTV images showing the area in the vicinity of the activated PEA shall be packaged and made available to the RCS for remote viewing. 530

When a PEA is operated the CCTV images showing the area in the vicinity of the activated PEA shall be packaged and made available to view on the display screens in the cab. 5959

When a second or subsequent PEA is operated, the CCTV images showing the area in the vicinity of the new active PEA shall be packaged and made available to be viewed on the display screens in the cab. 6691

If more than one PEA related CCTV image is available to be viewed on the display screens, any new CCTV image shall be queued and then displayed on the display screen when the Train Operator manually selects to view the new available CCTV image. 7045

If more than one PEA related CCTV image is available to be viewed on the display screens, any new CCTV image shall be queued and then displayed on the display screen when PEA talkback is initiated to the PEA associated with the new CCTV image. 7046

If more than one PEA related CCTV image is available to be viewed on the display screens, any new CCTV image shall be queued and then displayed on the display screen automatically when the PEA associated with the previously displayed CCTV images has been cleared. 7047

Any Notification which has been categorised for presentation to the Train Operator, and which is associated with a specific location in the saloon, shall be accompanied by real time CCTV image(s) showing the area in the vicinity of the event being presented to the Train Operator. 531

Any Notification which has been categorised for presentation to the RCS, and which is associated with a specific location in the saloon, shall be accompanied by real time CCTV image(s) showing the area in the vicinity of the event being packaged and made available to the RCS for onward real time transmission to the control centre. 532

CCTV images shall continue to be shown on the display screen(s) in the cab until either: 6692

- the Train Operator manually selects a different image; or
- the Train Operator manually selects to turn off the CCTV image; or
- the Train Operator manually selects to change the view to OPO

CCTV or other display screen functions; or

- a higher priority CCTV image is automatically triggered; or
- the Train moves causing the saloon CCTV images to be inhibited; or
- a configurable time (initially set at 5 minutes) has passed since the last active Notification or PEA has cleared or since the last Train Operator interaction with the CCTV controls.

A function shall be provided to allow a user to replay and view the most recent 5 minutes of recorded images from any specific selected CCTV camera using the display screens. 5265

FFCCTV images from the non-controlling end of the Train shall be made available at the controlling cab, when Manual mode is selected in the reverse direction. 719

11.5 CCTV Video Recording/Storage 533

Recording and retrieval of CCTV recordings shall provide a secure and auditable trail of evidence that satisfies the requirements of evidential continuity to prove that the data has not been tampered with in any way. 723

The CCTV system shall have on-board storage capacity to store images from all cameras for at least 7 full service days. This storage capacity shall be calculated based on normal video recording quality and shall not include where higher quality recording is required e.g. due to passenger emergency alarm activations. 536

The activation of a PEA shall cause the passenger talkback audio transmissions to be recorded by the CCTV system in time sync with associated video recordings. 537

The video storage system shall be such that no single point failure shall result in the loss of stored video data. 5124

Each CCTV image shall be recorded on two, physically separate, removable storage devices to mitigate loss of recorded images. 534

At least one set of the recordings from each CCTV camera shall be stored on a recording device which is located a distance of no less than 1 car length from that camera. 539

All CCTV recordings shall be identified with metadata including the Car Number, camera location, date and time for each image. 4436

Time stamping of CCTV images shall be accurate to +/-1s of the on-board TCMS reference time. 540

The video storage system shall provide a comprehensive searching facility that enables review of recorded video by criteria including, but not limited to: 542

- time;
- date;
- camera reference;
- Notifications which are associated with a specific location in the saloon.

CCTV recordings shall be made available to the RCS for high-speed remote retrieval of the data at any time. 545

CCTV recordings shall be made available to the OTC for high-speed remote retrieval of the data. 6856

CCTV recordings shall be able to be manually retrieved by a user by connecting a laptop at any one of the ethernet ports on the Train, via a standard interface. 546

CCTV storage media shall be manually removable from the Train using hands wearing standard leather welder's gauntlets. 547

The Manufacturer shall provide 2 sets of equipment per depot to view and copy CCTV recordings directly from CCTV storage media following its removal from the Train. 4686

CCTV recordings shall not be adversely affected by video retrieval or archiving operations. 549

It shall be possible to extract still frames from both live images and time-lapsed CCTV recordings. 5123

11.6 CCTV System Performance 1455

The CCTV system shall be capable of capturing, live streaming, displaying and recording high definition quality video images (1920 x 1080p or better). 551

CCTV images from all CCTV cameras in the affected car, starting 10 minutes before the time when a PEA is operated and ending 10 minutes after the PEA has been reset, shall be recorded at a frame rate of 25 frames per second (fps). 538

FFCCTV images shall be recorded at 25fps at all times when the Train is in motion. 6271

FFCCTV images shall be recorded at 6fps at all times when the Train is 6871 stationary and powered on.

Live CCTV images provided to the Train Operator CCTV HMI or the RCS interface for onward transmission, shall be at a frame rate of 25fps. 553

CCTV images which are not explicitly covered by separate requirements, shall be recorded at a frame rate of 6fps. 554

CCTV views shall be encoded and streamed via the ITU-T H.264 compression standard detailed in Reference Document ITU-T H.264 'Implementers Guide for H.264: "Advanced Video Coding for Generic Audiovisual Services"'. 556

CCTV recordings shall be in open-standard replayable formats. 558

CCTV recordings shall be viewable using codecs found in standard PC operating systems. 559

Monitoring / viewings of live and recorded images shall not interfere with the continuous recording of images. 563

Saloon CCTV shall automatically accommodate varying light conditions that are likely to occur within the saloon without affecting compliance with specific image requirements detailed in this specification. 564

This requirement is intended to cover Normal and Emergency lighting levels, external natural light, lighting in tunnels and station lighting. It is not intended to apply in the extreme scenario of loss of all lighting in the saloon.

CCTV system displayed resolution (on any trainborne display equipment) shall be measured end-to end using British Standard BS EN 62676-4:2015 'Video surveillance systems for use in security applications Part 4: Application guidelines' test methodology such that the minimum resolution shall be 750TVL. 565

12 Customer Information System (CIS) 54

12.1 CIS - General 1638

The term CIS will be used to describe the integrated audible and visual communications systems on the Train. 588

CIS functions to be provided on the Train shall include: 589

- Public Address;
- Visual customer information (internal and external);
- Train Number information;
- Audible customer information;
- Cab to cab communication;
- Digital advertising.

Automated customer information shall be delivered in both audio and visual form. 616

The term Audio & Visual Information (AVI) is used in this specification to refer to the automated messaging component of the CIS. 5736

All CIS AVI shall be provided at the time appropriate to both the purpose and the user. 617

All CIS AVI shall be capable of being triggered or suppressed by stimuli external to the Train (i.e. the RCS, the OTC and Train Radio). 618

All CIS AVI shall be capable of being triggered or suppressed by the Train Operator. 3546

It shall be possible to vary CIS AVI content according to time of day, day of week and location of Train. 619

It shall be possible to vary CIS AVI content on (up to 99) special dates, e.g. bank holidays, which shall be configurable by the Purchaser. 1802

The CIS shall be capable of generating new AVI message content in real time using inputs from the RCS, the OTC and Train Radio. 1707

The CIS AVI shall be capable of providing passengers with the following information: 1758

- Train Destination information;
- direction of travel;
- principal intermediate stations between current location and

destination;

- the next station and the interchanges at the next station;
- the doors which will be isolated on the outer end cars because of a short platform at the next station;
- the doors which will be isolated as a result of a failure of the train door or the corresponding PED;
- a moving display of Train's current location against a map of its route with a clear indication of the direction of travel;
- real time updates about relevant service disruptions;
- automatic announcements when a Train is auto reversing or stabling;
- "mind the gap" warning message at platforms where the PTI gap is greater than a set dimension;
- automatic passenger re-assurance type messages when Trains are being held due to the activation of one or more PEA alarms on that Train;
- advice and information on safety and emergency related procedures specific to the Train;
- when the Train is scheduled to skip a platform;
- predicted arrival times for key stations on the current Train route;
- extended station dwell times.

The CIS shall include at least 20% spare capacity to allow for future upgrades and enhancements to content and functionality. 6024

12.2 CIS Train Operator Facilities 592

Facilities shall be provided to permit a Train Operator, at any operating position, to communicate directly with passengers by means of live audible PA announcements. 593

Facilities shall be provided in the cab for a Train Operator to communicate with the passengers by selecting from a list of up to 99 pre-defined AVI messages, chosen from a message library, which shall then be queued and played to passengers. 594

The Train Operator interface shall allow a Train Operator to manually enter data which shall include, as a minimum: Train Destination code (up to 4 digit number), Train Number (3 digit number), crew ID (up to 8 digit number), etc. 1791

It shall be obvious to the Train Operator which CIS function is selected and in operation at all times. 595

The Train Operator shall be provided with a means of monitoring the 596

Train Number and the Train Destination information being displayed by the CIS on a Train. This shall be available either automatically or under the control of the Train Operator.

Controls for CIS functions shall be positioned within comfortable reach of the Train Operator. 597

Controls for CIS functions shall be arranged such that each function can be selected without confusion. 6670

There shall be a handset which supports clear two-way audible communication as required by any CIS and Train Radio functions. 1779

The handset and controls shall be positioned and coloured to minimise confusion and reduce the risk of the wrong communication function being used. 598

The handset assembly shall be robust and able to withstand vandal attack. 599

The handset shall include a physical switch or button to activate the microphone. This actuator shall be referred to as the “press-to-talk” (PTT) switch. 600

Replacing the handset on its cradle shall terminate the selected audio communication function. 601

Selecting a new handset communication function shall terminate any previously active handset communication function. 6671

A clear indication shall be provided to the Train Operator to identify when a handset is not stowed correctly. 5007

Handset leads/cables shall not present a snagging or tripping hazard. 602

Cabs shall be fitted with one or more loudspeakers which are capable of sounding Notifications and voice communications associated with Train Radio, cab to cab and PA. 1739

Each cab loudspeaker shall deliver a minimum differential between the loudspeaker volume and ambient noise. 226

The speech volume from the cab loudspeaker shall be independent of the facility selected and consistent irrespective of the audio source. 1740

There shall be a means for the Train Operator to control the speech volume from the cab loudspeaker(s). 1741

It shall not be possible for the Train Operator to reduce the nominal sound pressure level of the cab loudspeaker below 65dB(A) measured at head height at the Train Operators position. 1742

The Train Operator shall be provided with a facility to view all currently active Real Time Disruption (RTD) data and any other off-train CIS inputs at any time. 1735

This facility allows the Train Operator to ensure that any manual PA announcements do not repeat or contradict other information that is being given to passengers.

12.3 CIS Off-Train Inputs 603

It shall be possible to change the CIS Train Destination information via the RCS and via the OTC. 604

It shall be possible to change the Train Number via the RCS and via the OTC. 4455

It shall be possible to communicate directly with the passengers at any time by means of live audible PA announcements via the RCS interface and via the Train Radio. This shall be known as Remote PA. 606

Positive confirmation of the currently set Train Number and CIS Train Destination shall be made available to the RCS, OTC and Train Radio at all times. 605

The CIS shall modify any routine passenger information content to incorporate coded triggers, received via the RCS, via the Train Radio and via the OTC, for pre-defined AVI messages which are stored in an AVI library on the Train. 4440

The CIS shall modify any routine passenger information content in accordance with RTD input data provided via the RCS. 1699

The CIS shall modify any routine passenger information content in accordance with RTD input data provided via the Train Radio. 5960

The CIS shall modify any routine passenger information content in accordance with RTD input data provided via the OTC. 6867

The CIS shall modify any routine passenger information content to incorporate audio files containing new audible announcements received via the RCS and via the OTC. 1794

The CIS shall modify any routine passenger information content to incorporate new visual message content in the form of free text received via the RCS and via the OTC. 6667

The CIS shall use metadata associated with each off-train CIS input to determine the priority of a new CIS information input received relative to other CIS information content and to use that priority information to determine which pieces of information are broadcast to passengers at a specific time and location. 6688

Higher priority customer information components shall always be delivered at the expense of lower priority customer information components when the time window available to play a particular set of CIS messages is less than the time required to deliver all of the available CIS message content for that specific location. This may result in new information received via external CIS inputs not being played at a particular location. 6946

The time window which is available to play a particular set of CIS messages shall be constrained by dwell times at platforms, interstation run-times and configurable limits set by the CIS to avoid excessively long audible announcements. 6949

The CIS shall automatically modify routine message content to avoid broadcasting conflicting information following off-train inputs. 6948

Any remote CIS triggers and new content received via the RCS, via the OTC and via the Train Radio shall be integrated into the CIS AVI script for the Train in real time such that all messages are delivered to passengers at the appropriate time and location. 6669

The CIS shall support the sending and receiving of audible communications via the Train Radio. 5961

The CIS shall report to the RCS and to the OTC any situation where the current set CIS Route is not consistent with the current location of the Train as determined from train location information. 610

The CIS shall use Train location information to trigger location specific customer information messages. 611

It shall be possible for Remote PA and AVI messages to be directed to any one of the following: 5417

- the whole Train;
- specific selected car or cars;
- locally in the vicinity of specified doorways (including the M-door).

The status of CIS commands received from the RCS and the OTC, including Remote PA, RTD, message triggers, text triggers, etc., shall be reported back to the RCS and to the OTC from each Train. 3539

The status of inputs shall be reported as either:

- Accepted (put into queue or ready to dispatch message);

- Triggered (message content is being delivered to passengers);
- Completed (message content fully delivered to passengers);
- Not Completed (compatibility error, communication error or some other fault resulting in the requested information not being broadcast to passengers in the requested location).

It shall be possible to upload a new CIS database remotely via the RCS and via the OTC. 4703

It shall be possible to select which CIS database is the Active database via a trigger from the RCS. 624

It shall be possible to select which CIS database is the Active database via a trigger from the OTC. 6950

It shall be possible to select which CIS database is the Active database via a trigger from the Train Radio. 5962

12.4 Public Address (PA) 612

The audible communication system shall be considered a "sound system for emergency purposes" and shall comply with the requirements of British Standard BS EN 60849:1998 'Sound Systems for Emergency Purposes', except for requirement 4.1h) (“attention-drawing signal”) which shall be ignored. 613

The public address (PA) function shall be considered to be the main emergency communication channel and shall therefore have priority over any conflicting communication selection. 6672

In the event of a request for both Remote PA and a local on-train control position PA, the most recent request shall be granted. 1719

In the event of conflict between any PA function and automated audible information to passengers, the automated information shall be silenced and PA shall take priority. 4438

12.5 Cab to Cab 45

A facility, to be known as Cab-to-Cab, shall be provided to permit communications in full duplex mode between all operating positions on a Train. 250

Cab-to-Cab shall provide communications in full duplex mode between all operating positions on two Trains when coupled together. 251

Cab-to-Cab shall provide telephone conference type call communication between all operating positions on two coupled Trains. 6122

Once a call between two positions is established, further positions selecting this function shall be connected directly to the existing call.

Cab-to-Cab shall make use of suitable audible Notifications and calling tones which sound at all connected operating positions. 4555

Cab-to-Cab conversations shall normally be via the handsets fitted at each operating position such that conversations are private and cannot be overheard by passengers. 5869

A hands-free Cab-to-Cab function shall be provided which, when selected, allows a Train Operator to participate in a Cab-to-Cab conversation without physically holding the handset. 6300

Cab-to-Cab shall be functional at all times when a Train is powered up irrespective of the Train mode selected. 253

12.6 CIS Databases 621

The CIS shall make use of information databases containing: 622

- a complete suite of pre-defined message audio files / synthetic voice parameters;
- a complete suite of pre-defined message visual/graphic data files;
- a configuration file which controls the information content triggers, locations, timing logic, default volumes and brightness, for all CIS functions;
- RTD and remote message handling logic.

Each CIS database shall include information content for all permitted routes over which that Train can operate. 5010

The CIS shall hold a minimum of two databases at any one time on each Train, one of which shall be set as being the Active database. 623

It shall be possible to select which database is the Active database locally by connecting a device (e.g. laptop), to a single ethernet port on each Train. 626

It shall be possible to upload a new database locally by connecting a device (e.g. laptop), to a single ethernet port on each Train. 4704

The process of loading a new database locally shall take no more than 5 minutes per Train for a single member of staff. 627

12.7 CIS Edit Tool 628

CIS Edit Tool support software functionality shall be provided which will allow the Purchaser to edit and create new CIS database releases / versions using a standard operating system platform. 629

The CIS Edit Tool shall allow the Purchaser to edit and create new AVI message content including: 6561

- audio content (composition, tone, voice, inclinations, volume, content, etc.);
- visual content (graphics, colours, text content, fonts, style, backgrounds, layout, etc.);
- metadata (triggers, locations, timing logic, default volumes, brightness, etc.).

The CIS Edit Tool function shall perform comprehensive error checking of database changes such that it is not possible to create new content or a new database with any unresolved errors. 1690

Error checking associated with the CIS Edit Tool function shall include: 1691

- software compatibility checks;
- file format checking;
- cross reference checking;
- spelling (UK English).

12.8 CIS Simulation Tool 1682

CIS Simulation Tool support software functionality shall be provided which can be used to fully validate new CIS databases without the need for on-train testing. 630

The CIS Simulation Tool function shall allow users to simulate all possible combinations of: 1684

- routes;
- location triggers;
- timing parameters;
- dwell times;
- inter-station run times;
- real time disruption message triggers;
- real time disruption message handling logic;
- configurable data parameters.

The CIS Simulation Tool shall have an output which allows the user to clearly see the content and timings of all visual and audible message content in order to easily validate a new database. 1688

The CIS Simulation Tool shall provide a graphical output which clearly highlights key results from each simulation. 1689

The detail of the CIS Simulation Tool output shall be developed in conjunction with the Purchaser and shall include reporting of any errors, any messages which are cut short and any messages which are not completed in required timeframes. 4461

The CIS Simulation Tool shall allow the user to select and listen to any audible messages to check content. 1692

The CIS Simulation Tool shall support outputting of test summary results to a standard file format e.g. Excel. 1687

12.9 Audible Customer Information 631

Audible announcements shall be clearly and consistently audible by passengers with normal hearing ability throughout each saloon. 632

The CIS shall be capable of delivering the routine audio journey information as detailed in Reference Document NTfL-2344.3.4-LUL-PLN-00003 'Routine CIS Audio Information Concept Structure'. 1757

Automated Voice Announcements (AVA) for automated information shall generally be made in a neutral female voice. 3648

Automated Voice Announcements (AVA) for safety warning type automated announcements shall be made in a neutral male voice. 5397

The voice intonations and continuity in the AVA shall make all announcements sound like natural speech. 3649

All audible and visual announcements shall be made using plain English (UK) language. 3650

The CIS shall compose coherent, human like audio messages, in real time, based on routine message content combined with real time disruption information, using voice synthesis or equivalent technologies. 5398

The generated voice to be used for CIS audio announcements shall not sound robotic and shall be acceptable to the Purchaser. 3687

It shall be possible for the Purchaser to configure the CIS to use pre-recorded (WAV or equivalent format) audio files containing human voice recordings as an alternative to synthetic audio for specific message content. 7133

It shall be possible to make targeted audible announcements to only an 3867 area in the vicinity of a specific passenger door.

It shall be possible to automatically trigger audible announcements to only an area in the vicinity of a specific passenger door when that door has reported a status which could result in a service delay. 5928

The Purchaser anticipates that this function may be useful to prompt passengers to stand clear of the doors when the door has reported an obstacle being detected or the door is not proved closed following a door close demand or a door is repeatedly pushed against the pushback spring.

It shall be possible to make targeted audible announcements to a single car only. 5303

It shall be possible to automatically trigger specific audible and visual announcements as part of the passenger door closing sequence, prior to the door closing audible warning commencing, at specific locations, following delayed platform dwell times and in very busy Trains. e.g. "Please stand clear of the closing doors". 4745

It shall be possible to use TCMS events to automatically trigger audible and visual announcements. 7076

This function will be used to trigger appropriate automated announcements which are relevant to customers on a Train when TCMS has knowledge of specific local events which affect their journey. Examples may include:

- *PEA activated;*
- *obstacle detection;*
- *detrainment detection;*
- *input from the RCS (S&TC) equipment to indicate a relevant status (e.g. 'Hold', 'Code Red', 'Code Amber', 'inaccurate stop', 'jog');*
- *Restricted Manual mode or a reverse mode selected;*
- *door obstacle detection;*
- *door loss of pilot light; and*
- *fire detection.*

Automated audible announcements shall be timed to coincide with the display of the equivalent visual information throughout the Train. 6877

12.10 CIS Acoustic Performance 1753

Loudspeaker installations shall be designed to optimise acoustic performance, whilst protecting the loudspeakers from pressure pulses, condensate and tunnel dust. 1751

Any acoustic requirements which are for the PA system shall apply to all audible announcements in the saloon irrespective of whether those announcements are made using a live human voice, voice synthesis or pre-recorded audio. 5294

Ambient listening microphones shall be used to maintain the measured noise levels, from saloon loudspeakers, a minimum of 6dB(A) and a maximum of 10dB(A) above the ambient noise level, on a per car basis. 4778

When the Train is operating normally between stationary (with doors closed) and full line speed, the PA system output shall provide a STI-PA higher than 0.6. 4777

With the Train in a platform on tunnel sections and with the doors open the Speech Transmission Index (STI-PA) figure shall not fall below 0.5 when measured at a height of 1600mm above floor at a distance of 1000mm onto the platform with a platform background noise (voice babble) level of 62dB(A). The system design shall take account of different ambient noise conditions. 4787

When the Train is in a platform on open sections and with the doors open audible announcements shall not cause undue disturbance to railway neighbours. This shall be achieved by: 4788

- ensuring that the PA volume is related to ambient noise;
- the use of directional speakers to minimise noise overspill;
- speaker installation design, e.g. ensuring speakers are not directed at door openings.

The noise level used for a specific automated announcement shall be set when the message begins and shall not change during a message. 3806

The average sound pressure level capability of the CIS shall be not less than 90dB(A) measured at any point in the car at a height of 1600mm above saloon floor level. 4798

An upper limit on the average sound pressure level shall be set at 95dB(A) with a short duration peak limit of 100dB. 4799

It shall be possible to adjust the PA output during commissioning trials to ensure passenger comfort needs whilst retaining speech intelligibility. 4791

Audible announcements shall be matched in volume between live audible public address messages and automated announcements. 634

When the audible communication system is not making announcements, there shall be no audible sound, including sounds outside of the normal human hearing frequency range but which may affect dogs, from any loudspeaker. 635

The total harmonic distortion from the CIS shall be less than 1% with the PA function selected, the Train stationary and all auxiliaries running. 4800

This shall be measured as detailed in British Standard BS EN 60268-3:2013 'Sound System Equipment - Amplifiers' at a source e.m.f. equivalent to that required to produce a saloon sound pressure level of 90 dB. The measurement shall be repeated at an e.m.f. equivalent to 65 dB. The source e.m.f. shall be applied at the microphone position at one end of the Train and the distortion measured at a loudspeaker position at the other end of the Train.

Audible announcements shall continue to be audible from all saloon locations following any single point failure. 1746

Microphones shall be appropriately specified to ensure that the target noise source is clearly understood by the target recipient under the most adverse conditions. 1726

The CIS shall be equipped with automatic gain control which: 4795

- compensates for varying voice power of handset users;
- prevents any part of the CIS acoustic system reaching its distortion limit in the event that the voice level exceeds the normal maximum.

Inter and intra car synchronisation of audible content shall be better than 10ms to avoid noticeable distortion. 1749

The acoustic frequency response, from the handset microphone (or RCS interface) to the saloon loudspeakers, shall be flat to within 3dB over the frequency range 300Hz to 6000Hz. 4774

Sound system measurements shall be made in accordance British Standard BS EN 60268-16:2011 'Sound System Equipment - Objective Rating of Speech Intelligibility by Speech Transmission Index', except where there are conflicts with the requirements in this specification. 4794

Acoustic modelling shall be used to demonstrate compliance with CIS acoustic performance and to assess the environmental impact using the method described in LU Standard G148 'Management of Noise due to Public Address Systems'. 4789

Unless explicitly stated otherwise, in-Train measurements shall be taken at all seated positions and at a height of 1600mm above the floor at all points along the centre line of the car and in accordance with Railway Group Standard GM/RC2533 'Recommendations for Communication of Emergency and Safety Information'. 4792

12.11 Visual Customer Information 637

CIS displays will be referred to as Visual Electronic Information Displays (VEIDs). 4465

VEIDs shall comply with information viewing requirements detailed in Reference Document 'The Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010'. 1815

Text used on CIS VEIDs, external and internal passenger facing signage or labelling shall be in a font from the New Johnston font set as described in Appendix 1 of Reference Document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief' or, where not specified, New Johnston Medium font, using both upper and lower case letters (sentence case). 649

Text on VEIDs shall not compress lower case font descenders. 4469

All VEIDs shall be of sufficient size to accommodate, without scrolling, all possible Train Destination information in full. 644

Visual customer information shall be synchronised such that all similar types of displays show the same information at the same time, e.g. External Front Displays, External Side Displays, internal VEIDs, etc. 5015

Internal and external VEIDs, including any protective glass or covers, shall be designed to avoid reflections. 5016

Internal CIS VEIDs shall make use of LED or OLED backlit, LCD, TFT or equivalent low energy consumption equipment, to convey visual electronic information to customers throughout the saloon. 638

The number, size and location of internal CIS VEIDs shall be such that the visual information content can be read by a normally sighted person within the height range of a 5th percentile female to a 95th percentile male: 639

- whose view is not obstructed by another passenger;
- under artificial and natural lighting (including sunlight);
- from all seated and all standing positions in the saloon.

The viewing requirement for internal CIS VEIDs shall also be met, for standing passengers only, when the number of passengers in the saloon equates to Full Load. 640

Internal VEIDs shall provide information which is consistent with information displayed on the External VEIDs. 641

The CIS shall display visual information on Internal VEIDs which is 642 consistent with the LU concept detailed in Reference Document NTfL-2344.3.4-LUL-RPT-00007 'NTfL Customer Information System (CIS) Visual Display Content Style Guide' Issue 2. This style guide is an example only to be used for the purpose of equipment design and specification. The final detailed CIS visual display content shall be developed between the Purchaser and the Manufacturer during the Train design.

External CIS VEIDs shall make use of LED dot-matrix, or equivalent low energy consumption technology to convey visual electronic information to customers and staff on platforms and at track level. 5080

The name of the line and the destination and routeing of the Train shall be displayed externally on the front and rear of the Train and externally on the sides of each car. 3653

Abbreviations shall not be used for any Train Destination names shown on External VEIDs. 3657

The Train Destination is generally the name of the final station at which a particular service Train has been routed and is due to terminate. It should be assumed any station on the line over which a Train will operate in passenger service can potentially be set as the destination station. For stations on the west end of the Piccadilly line and on the east end of the Central line, where there is more than one possible route for a Train to reach a particular destination station, additional information is required to be included in the Train Destination text which is shown on VEIDs to inform passengers. 6429

The longest Train Destination names which are currently required to be shown on CIS VEIDs on the lines over which the new Trains will operate include "Hainault via Newbury Park", "Hainault via Woodford" and "Tottenham Court Road" on the Central Line, "Heathrow Terminals 123 & 5" and "King's Cross St. Pancras" on the Piccadilly line and "Harrow & Wealdstone" on the Bakerloo line.

External VEIDs shall be capable of being read by a normally sighted person on the outside of the Train in all expected lighting conditions including bright sunlight and artificial lighting (e.g. platform lighting) and darkness (<5 lux). 645

External VEIDs shall function when the Train is powered up. 648

External VEIDs shall be fitted on each end of the Train. These are known as the External Front Display and Train Number Indicator. 643

The External Front Display and Train Number Indicator shall be capable of being read by a normally sighted person on the outside of the Train at any distance between 1m and 30m and at any angle up to 45° in the horizontal plane on each side of the centre-line of the Train. 3661

The vertical viewing angle of the External Front Display and Train Number Indicator shall be considered adequate, provided the viewing 647 requirements, detailed above, are met for all normally sighted people within the height range of a 5th percentile female to a 95th percentile male, standing both at track level and at platform level.

The Train Destination shall be shown on the External Front Display which shall be located centrally above the M-door. 3654

The display area size on the External Front Display shall be maximised to support the display of unabbreviated Train Destination names (text) in full. 6428

A Train Number Indicator VEID shall be fitted at each end of the Train. 4718

The Train Number Indicator shall display the Train Number which has been set either by the RCS or manually on the Train. 4719

A Train Number Indicator shall show the same number, in the range 000 to 999, at both ends of the Train within 2s of a new number being selected. 4720

External VEIDs shall be fitted on each side of each car at a height which facilitates unobstructed sightlines for passengers standing on platforms. These are known as the External Side Display. 2165

The External Side Displays shall display the following information: 5877

- Name of the line;
- Train Destination;
- Train Number (leading and trailing cars only);
- Next station name (all cars excluding the leading and trailing cars);

Each of these pieces of information shall be shown as static text (not scrolling) and alternated in sequence with each item displayed for a configurable time of between 1 and 5 seconds. This time shall be initially set at 2 seconds.

Text on the External Front Displays and External Side Displays shall be centred. 3655

12.12 Real Time Disruption (RTD) Information 650

RTD, in the context of this specification, refers to any event which has occurred somewhere on the LU or TfL networks, or adjacent networks, which could potentially impact on passengers' journeys. The Purchaser aims to make passengers aware of such events in a co-ordinated way such that information is always provided only at relevant locations as defined by the Purchaser. 1703

When information is available, the following events warrant a message being given out to customers via RTD functionality: 3658

- *current service disruptions on any London Underground line;*
- *current service disruptions on other modes within the London area;*
- *current station or facility closures on the London Underground network;*
- *current station or facility closures on other modes within the London area;*
- *current security alerts or other major events in specific areas of London;*
- *the expected time of recovery.*

The CIS shall be capable of modifying all routine passenger AVI content in response to RTD event data received via the RCS. 651

The CIS shall be capable of modifying all routine passenger AVI content in response to RTD event data received via the OTC. 6954

The CIS shall be capable of modifying all routine passenger AVI content in response to RTD event data received via the Train Radio. 5963

RTD event information received on the Train is expected to be in the form of coded data which will be generated at the service control centre and will include: 5878

- *information on specific message content which passengers need to be told about in the form of visual and audible announcements;*
- *location information to tell the CIS the location codes for where this information should be announced;*
- *message priority information to assist the CIS with deciding whether it has time to transmit certain information at the expense of not having time to play other information to passengers.*

A system which follows this approach is currently successfully used by London Underground on the Victoria line.

RTD events shall result in additional AVI content being automatically added to routine AVI messaging at defined locations. 1701

RTD events shall result in components of the routine AVI messages being automatically inhibited to avoid conflicting information. e.g. the CIS shall not say "Change here for the Central line" followed by "The Central line is suspended". 1704

Where RTD causes routine message content to change in length (i.e. the time required to deliver that information) the CIS shall automatically modify the start time trigger for AVI messages, as required, to avoid 1705 messages over-running (e.g. the Next Station message still playing when the doors open) or playing at the wrong times or locations.

It shall be possible to configure the maximum number of RTD events which can be played on a per location basis. 1706

The CIS shall be capable of automatically generating a message, to be known as the Delay Message, if a Train is stationary for a configurable time (default 30s). This message shall use available RTD information to give passengers an apology and an accurate explanation for the delay. 3659

The Delay Message shall use available RTD information and any other information available from the RCS, OTC, TCMS and Train Radio to give passengers an apology and an accurate explanation for the delay. 6555

When the Train is at a platform with the passenger doors open, the Delay Message shall include alternative travel options. 3660

The Delay Message shall be repeated continuously after a configurable time (default 90s), each time giving the most accurate reason for the delay possible from available RTD information, until the Train is moving again. 3662

12.13 CIS Diagnostics 1710

The CIS shall have a system test facility to enable one maintainer to manually check the health of all CIS equipment including displays, handsets, microphones, loudspeakers and PEA units whilst making a single journey walking through the Train. 1712

Once started the CIS system test shall run until completion unless it is manually cancelled by the maintainer via the operating position controls or any of the network access ports on the Train. 4480

The CIS shall maintain a detailed service log which shall record, with time and location stamps, all CIS outputs, all triggers, all errors, and any other CIS service information which could be of use for fault diagnostic or passenger service report investigation purposes. 1831

The CIS data log shall record no less than 15 full days of service information, without overwriting. 1832

It shall be possible to retrieve the CIS data log from a Train remotely via the RCS and via the OTC. 1833

It shall be possible to retrieve the CIS data log locally by connecting a suitable device containing the correct software, to an ethernet port on the Train. 1834

12.14 Digital Advertising 3981

Digital advertising equipment shall be fitted throughout the Train and shall include: 5880

- VEIDs;
- equipment to receive advertising content updates via Wi-Fi (e.g. at stations, depots or sidings);
- control equipment;
- RCS interface;
- OTC interface.

Digital advertising VEIDs shall be positioned alongside customer information displays on the upper row of information above all seats as shown in Reference Document NTfL-2344.3.4-LUL-RPT-00027 'NTfL Aesthetic Design Brief'. 653

Digital advertising VEIDs shall be of sufficient size to show adverts with a minimum display area of 564mm x 240mm (landscape) or a larger display area which maintains the same scaled proportions. 6208

The screen space available for digital advertising on the Train shall be optimised to maximise the Purchaser's potential commercial revenue. 6092

The digital advertising system shall be capable of displaying static, full colour, advertising content. 4273

The digital advertising system shall be capable of displaying dynamic video advertising content. 4274

The digital advertising system shall be capable of displaying content with high definition (minimum 1080p) image resolution. 6209

The digital advertising system shall be capable of displaying location-specific advertising content. 5347

The digital advertising system shall support advertising content being modified via data transmissions received via a secure Wi-Fi transmission. 4277

The digital advertising system shall support advertising content being modified locally by physically connecting to the trainborne hardware and loading new data. 4612

The digital advertising system shall detect and report faults with the playing of advertising content. 6210

When a fault is detected with advertising content, or when no 6211 advertising content is present, the digital advertising system shall default to displaying a predefined default screen which will contain a TfL defined corporate passenger message.

The digital advertising system shall support the categorisation of advertising content into different priority levels. e.g. high priority, medium priority, low priority. 6244

When a fault which prevents digital advertising content being displayed on any part of the Train is detected, the digital advertising system shall reconfigure the usage of the advertising screens within the Train to ensure that higher priority content is always shown before lower priority content. 6212

This is required to mitigate loss of commercial advertising revenue over non-revenue TfL advertising content.

It shall be possible for the Purchaser to configure the following parameters in the digital advertising system using a Digital Advertising Edit Tool: 4475

- advertising content;
- triggers for specific adverts (time, location, date, day of week);
- advert sequence;
- advert duration;
- brightness;
- contrast;
- content priority category;
- content of default screen;
- content of the predefined safety information shown on digital advertising VEIDs.

The digital advertising system shall synchronise advertising content on all screens in one car such that both: 6093

- all VEIDs can show the same or related content for a larger campaign;
- all VEIDs can show different unrelated content but shall refresh the content simultaneously.

Digital advertising VEIDs shall be designed and suitably illuminated to prevent glare or reflection. 6213

Digital advertising equipment shall be modular in design and use standard off the shelf equipment where possible to ensure that it can easily be replaced and/or upgraded throughout the life of the Train. 6214

13 Passenger Emergency Alarm (PEA) 55

13.1 PEA - General 2147

The Train shall be fitted with Passenger Emergency Alarms (PEAs) to allow passengers and on-board staff to contact a person who is in a position to take appropriate action in the event of an emergency. 662

It shall be possible for the Purchaser to configure the PEA function by selecting one of two modes for use on the fleet: 5046

- Train Operator PEA Handling mode - where associated Notifications, talkback and clearing functions are managed on the Train via the PEA HMI;
- RCS PEA Handling mode - where associated Notifications, talkback and clearing functions are managed remotely via the RCS.

The Train shall automatically switch between PEA Handling modes based on the geographic location of the Train. 7090

It shall be possible for the Purchaser to configure the geographic locations where each PEA Handling mode will apply via a local update on the Train. 7091

It shall be possible for the Purchaser to configure the geographic locations where each PEA Handling mode will apply via the RCS and via the OTC. 7092

When Train Operator PEA Handling mode is selected, a Notification shall be provided to the RCS to alert staff automatically when a PEA is being managed on the Train. 5148

When Train Operator PEA Handling mode is selected, the audio from any PEA talkback conversation shall be transmitted to the control centre via the RCS. 7062

When RCS PEA Handling mode is selected, a Notification shall be provided to the RCS to alert staff when any PEA is active. This Notification shall include PEA location information and shall be accompanied by any other relevant Train status information which may assist with the handling of the PEA (e.g. fire detection, derailment detection, etc.) 6350

When RCS PEA Handling mode is selected, a Notification shall be provided at all driving positions to inform a Train Operator when any PEA is active on that Train. 5149

PEAs shall be actuated using handles or pushbuttons. 665

PEA actuators shall be coloured Corporate Red (NCS S 1085-Y80R). 5086

PEAs shall include a protective cover so that they are not susceptible to inadvertent or unwanted operation. 673

It shall be possible to open the PEA protective cover with a single hand with limited manual dexterity in a single action. 674

The Manufacturer may provide more than one PEA unit design variant due to the different specific requirements which apply for the usability of PEAs at wheelchair positions. 679

13.2 PEA Locations 1322

One PEA shall be provided at each RVAR wheelchair position. 669

Wheelchair PEAs shall be placed within reach of a person in a reference wheelchair. 671

One PEA shall be provided at each door vestibule. 666

Vestibule PEAs shall be on the right hand side of the passenger doorway when looking out from inside the Train. 4483

Vestibule PEAs shall be located on alternating sides along the Train. 4484

A PEA shall be provided on the right hand side of each J-door (when the cab is present). 6084

A PEA shall be provided at each M-door when the M-door is part of the saloon area. 4738

PEA actuators, other than those fitted at Wheelchair positions, shall be at a height of 1500mm to 1600mm above the floor. 677

13.3 PEA Functionality General 5070

PEAs shall be momentary operation devices which do not mechanically latch and shall not require local resetting. 682

PEA activations shall be cleared, one at a time, by the operator using a control at the PEA HMI or at the service control centre via the RCS. 5085

Clearing a PEA shall de-activate the PEA event such that all visual and audible indications in the saloon and at the operating position are reset, the talkback conversation is ended and the emergency brake application (if any) resulting from the PEA activation is released. 6699

Positive feedback shall be provided to the operator, either via the PEA HMI or at the service control centre via the RCS as appropriate, when a PEA has successfully been cleared. 6327

PEAs shall provide the user (passenger) with positive audible feedback in the form of a PEA Alarm which shall sound when a PEA has been activated. 6112

The PEA Alarm shall only sound in the area in the vicinity of the activated PEA. 6114

The PEA Alarm shall cease when the PEA is acknowledged by the operator either at the PEA HMI or at the service control centre. 6113

PEAs shall provide the user (passenger) with positive visual feedback when a PEA has been activated. 6078

The PEA activation visual feedback shall remain active/illuminated until the PEA is cleared. 6115

PEAs shall provide the user (passenger) with positive visual feedback that the operator has received and acknowledged the PEA activation. This feedback shall remain active/illuminated until the PEA is cleared. 683

PEAs shall provide the user with a visual indication when the two-way communication via the talkback facility has been made active by the operator either via the PEA HMI or the service control centre HMI. This indication shall be extinguished when the operator de-selects talkback. 684

Wheelchair PEAs shall provide users with identical communication functionality to that provided at other PEA positions. 670

Wheelchair PEAs shall be operable by the palm of the hand exerting a force not exceeding 30N. 672

The Wheelchair PEA protective cover shall not immediately close and exert a force on the back of the user's hand while operating the PEA. 4486

13.4 PEA Talkback 687

PEAs shall incorporate a Talkback function which can facilitate clear, simultaneous two-way audio communication between a person who has operated the PEA and an operator in the cab or the RCS during all normal service operating conditions. 688

A PEA activation shall result in only the PEA microphone and loudspeakers in the vicinity of that PEA being activated. 689

The acoustic frequency response from the talkback microphone to the 690 operating position handset and loudspeakers shall be optimised for speech intelligibility over a frequency range of 300 Hz to 3400 Hz.

When Remote PA is active (i.e. Remote communication to passengers from the control centre), any talkback communication shall be inhibited until the Remote PA has been terminated. 696

When PEA talkback is active, the audio components of all CIS AVI messages shall be cancelled immediately and any new CIS AVI messages shall be inhibited in the car with the active PEA, only until the talkback communication has been terminated. 697

13.5 PEA Brake (PEAB) 698

An emergency brake shall be applied when a PEA is activated on a Train when that Train is departing a platform and any part of the Train is still within station limits. This is referred to as a PEA Brake (PEAB). 4503

An emergency brake shall be applied when a PEA is activated on a Train when that Train is stationary at a platform. This is referred to as a PEA Brake (PEAB). 7040

The PEAB shall not be applied when a PEA is activated on a Train arriving in a platform. 700

The PEAB shall not be applied when a PEA is activated when the Train is between stations and no part of the Train is within the platform area. 7041

It shall be possible for the Purchaser to modify the PEAB logic at a future date so that the brake is not applied when a PEA is operated either at all platforms or at specific platform locations. 2138

It shall be possible for the Purchaser to modify the PEAB logic at a future date to change the size and position of the PEAB application zone. 4504

The mechanism for providing the PEAB function shall have an appropriate integrity which is suitable for this safety function. 4532

The safety integrity of the PEAB function shall also be applied to the mechanism for making changes to the PEAB parameters as defined above. 4533

It shall not be possible for the Train to depart from a station when there are any unacknowledged PEAs on that Train. 5075

The PEAB shall be released when all active PEAs on that Train have been cleared. 6331

13.6 PEA HMI 2141

A facility shall be provided in the cab to allow a Train Operator to select to listen-in to any PEA talkback conversation, using the handset or cab loudspeaker, when a PEA on that Train is being handled by the RCS. This shall be known as the PEA Listen-In function. 6557

When the PEA Listen-In function is active, it shall not be possible for the Train Operator to be heard by the participants of the PEA talkback conversation. 6558

It is anticipated that audio communication between the Train Operator and the Control Centre (RCS) will always be via the Train Radio.

A facility shall be provided to visually indicate to the Train Operator the location on the Train of all activated PEAs. 704

The following PEA HMI functions shall only be functional when the Train is in Train Operator PEA Handling mode: 5147

- PEA audible alarm;
- PEA acknowledge control;
- PEA talkback;
- PEA clear control.

A distinctive PEA audible alarm shall sound in the cab whenever a PEA is activated and the Train is in Train Operator PEA Handling mode. 702

A facility shall be provided in the cab to allow the Train Operator to acknowledge a new active PEA one at a time. 5088

The PEA cab alarm shall be muted (sound at a reduced volume) when the PEA acknowledge function is operated. 703

A muted PEA cab alarm shall return to its original volume level in the event of a second or subsequent PEA being activated in another saloon before the first PEA is cleared. 5047

The PEA cab alarm shall silence only when all PEAs have been cleared. 5048

The PEA cab alarm shall mute temporarily when PEA talkback is in use. 5049

It shall be possible for the Train Operator to put a PEA talkback conversation on hold temporarily and to use other cab communication functions (e.g. Train Radio) before re-activating the talkback conversation. 5089

It shall be possible for the Train Operator to acknowledge a PEA without activating the talkback facility. 5064

Where more than one PEA is activated before the Train Operator acknowledges the first one, the alarms shall be stored in a queue, displayed in chronological order, and selectable individually by the Train Operator. 705

When the cab handset is in use for another function, PEA talkback audio shall sound through the cab loudspeaker. 5072

A talkback conversation shall be automatically terminated when the Train Operator in the cab replaces the handset onto its cradle. 5073

A talkback conversation shall be automatically terminated when the Train Operator in the cab selects another communication function which involves the handset. 5074

A facility shall be provided for the Train Operator to clear any active PEAs, one by one, from the cab once they are satisfied that it is safe to move the Train. 5087

13.7 External PEA Status Indication 701

A PEA status indication light shall be fitted on both sides of each car. 708

The PEA status indication shall illuminate on both sides of each car when a PEA in that car is active and shall extinguish only when all PEAs in that car are cleared. 6261

The PEA status indication shall function at all times when the Train is powered on, irrespective of the Train mode selected or Train location. 709

It shall be possible to distinguish the illuminated PEA status indication in all normal lighting conditions. 2843

The PEA status indication shall be coloured white. 2844

The PEA status indication shall remain functional until loadshed following loss of auxiliary supply. 2845

The PEA status indication shall be clearly visible, when the passenger doors are in any position, to a person standing adjacent to the side of the Train when on straight track, at either end of the Train, on station platforms or at the trackside. 4723

The PEA status of each car shall be made available to the RCS and the OTC. 7023

This is to assist platform staff who may not be able to see the external

PEA status indications when the PEDs are installed.

14 Heating, Ventilation and Cooling (HVAC) 51

14.1 HVAC Environment 3304

The average below ground environmental conditions (Design conditions) to be used when determining the cooling and heating capacity are 30^{o}C and 45% relative humidity in summer and 20^{o}C and 40% relative humidity in winter. 294

The average below ground environmental conditions relate to both an average over the tunnel or platform cross sectional area and an average over a repeating pattern of train movements. 295

The outside environmental parameters contained in British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters' Annex E for the relevant (UK) climatic zones shall be taken as the design conditions for saloon HVAC heating and cooling, except that the summer dry bulb temperature shall be taken as 29^{o}C (rather than 28^{o}C) and the winter dry bulb temperature shall be taken as -1^{o}C (rather than -10^{o}C). 296

The outside environmental parameters contained in British Standard BS EN 14813-1:2006+A1:2010 'Railway Applications. Air Conditioning for Driving Cabs. Comfort Parameters' Annex D for the relevant (UK) climatic zones shall be taken as the design conditions for cab HVAC heating and cooling, except that the summer dry bulb temperature shall be taken as 29^{o}C (rather than 28^{o}C) and the winter dry bulb temperature shall be taken as -1^{o}C (rather than -10^{o}C). 235

The Manufacturer shall account for the spatial and temporal deviation from the average environmental conditions when the Train is stopped in tunnels and at platforms. 297

Air intake temperatures for below car condensers may be warmer than the average below ground environmental conditions. The arrangement of undercar equipment shall be optimised to limit the thermal interaction between the systems. 299

14.2 HVAC - General 5334

Condensate from the HVAC systems shall be routed to avoid nuisance to passengers and staff and to avoid all rails. 5230

There shall be no piping of refrigerant between cars. 255

The maximum heating and cooling capacities shall be determined from the normal operations cases rather than the pre-cooling or pre-heating cases. 289

The HVAC systems shall have a Stabled mode. In Stabled mode the setpoint temperature shall be optimised for energy saving and frost protection. The setpoint temperature for Stabled mode shall be separate for cab HVAC and saloon HVAC and shall be configurable by the Purchaser. 4319

The initial temperature setpoints for HVAC Stabled mode shall be agreed with the Purchaser. 286

The HVAC systems shall switch between Stabled and Normal mode operation when commanded to do so by the RCS. 260

The HVAC systems shall switch between Stabled and Normal mode operation when commanded to do so by the OTC. 7022

The HVAC systems on a train may be switched out of Stabled mode in advance of the Train being required for service so that pre-heating or pre-cooling can occur. 4945

The Manufacturer shall provide heating and cooling performance test data (cab and saloon) sufficient to define configurable switching parameters for the RCS and OTC control of Stabled/Normal mode selection. 5333

The Train shall be able to switch the HVAC systems between Stabled and Normal mode by algorithms that consider internal and external temperatures, time of day, Train usage (e.g. stabled or in use) and pre-heating / pre-cooling performance such that the interior is at a comfortable temperature at the times that they are required for operational use, and energy is used efficiently. 5332

To improve clarity this Specification discusses heating, cooling, ventilation and control as sub-systems. There is no requirement for the heating, cooling, ventilation and control sub-systems to be physically separate or discrete. 264

Detrimental cycling between heating and cooling modes shall not occur for any design condition. 3127

Data important to the understanding of the HVAC systems performance and maintenance shall be monitored and recorded. 382

Refrigerants shall comply with British Standard BS EN 378:2016 'Refrigerating systems and heat pumps - Safety and environmental requirements'. 333

Refrigerants shall comply with European Standard Regulation (EU) No. 517/2014 'Fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006'. 6197

Refrigerants shall be proven safe and effective in use in below-ground and above-ground railway applications. 6422

Refrigerants shall be a non-flammable gas at ambient temperature and atmospheric pressure and at the temperatures and pressures to which they may be exposed in the event of leakage. 334

Refrigerants shall have a low toxicity. 6421

Refrigerant units shall be located in a safe place, away from arcing risk areas and be labelled to indicate the presence of primary refrigerant. 2113

Refrigerant shall be chosen to maximise the ability of the systems to operate when the Train is stopped in tunnels with elevated temperatures around the condenser. 335

Leakage from the refrigerant circuit shall be limited to the greatest extent practicable. 336

If non-brazed joints are used in the refrigerant circuit they shall be accessible for testing using a portable leakage detector. 6874

If non-brazed joints are used in the refrigerant circuit it shall be possible to easily maintain the non-brazed joints over the life of the system to minimise the potential for leakage. 6875

14.3 Saloon HVAC 3276

14.3.1 Saloon HVAC Modes 1318

Each saloon HVAC system shall operate in Normal, Emergency, Stalled, Stabled and Off modes. 258

The saloon HVAC shall be able to be turned off in response to commands from the RCS and commands from the OTC. 4812

Off mode applies to the situation when the saloon HVAC system has been switched to a non-operational condition. 259

The saloon HVAC shall have a Stalled mode which shall be used during a stalled train event to prevent the HVAC causing high localised temperatures around the Train and subsequent loss of cooling due to 'tripping'. 5813

The saloon HVAC Stalled mode shall be used based upon the detection, by the Train control system, of a stalled train situation. This shall use robust logic that avoids false detections. 4288

During stalled mode the saloon interior temperatures shall not be directly controlled and the cooling shall be stopped after a configurable time delay. 280

The saloon HVAC system shall provide fresh air ventilation at the maximum rate during stalled mode. 281

Emergency mode applies when the output from the auxiliary converter has been lost. 4808

Normal mode applies to situations when the saloon HVAC system is not in Emergency, Stalled, Stabled or Off modes. 263

The status of the saloon HVAC system shall be reported to the RCS. 6163

14.3.2 Saloon HVAC Performance 265

The saloon HVAC system shall provide interior environmental conditions in accordance with British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters' for Category B vehicles except where modified in this Specification. 267

The saloon HVAC cooling function shall maintain average saloon temperatures at a maximum of 26^{o}C with a passenger loading of all seats occupied and 2 standing passengers per m^2 over the entire floor area including the inter-car gangway when operating both inside and outside the tunnels at the design conditions given in this specification. 271

The saloon HVAC system coefficient of performance in cooling mode at the design interior and exterior conditions shall be greater than 2.2. 275

The saloon HVAC system coefficient of performance shall be defined as the saloon HVAC system's total cooling out (in kW) divided by the saloon HVAC system's coincident power intake, including for fans, compressors, controls and other power consuming devices. 6251

When operating in tunnels, the electrical power demand of the saloon HVAC system during cooling and normal ventilation mode shall be less than 65kW per train on the Piccadilly line at the design outside environmental conditions and loading. If this constraint is reached the Manufacturer shall advise the Purchaser of the predicted saloon interior conditions that would result at this maximum power consumption and also what power would be required to meet the specified interior saloon conditions. The Purchaser will instruct the Manufacturer whether to curtail the cooling capacity to within the cited power constraint or whether the constraint will be waived. The Manufacturer shall act upon this instruction. 276

The cooling power constraint is to ensure co-ordination with the associated infrastructure cooling provision. If other features of the Train 278 *design are more efficient than the baseline assumptions made by the Purchaser, the Purchaser may have freedom to accept greater power consumption from the saloon HVAC system.*

For the Bakerloo, Central and Waterloo & City Lines, a proportional saloon HVAC power constraint to that imposed for the Piccadilly Line shall be exercised by scaling up or down the HVAC provision by the difference in the length of Train supplied for each of these lines as compared to that supplied for the Piccadilly Line. 5415

By comparison of maximum allowable train lengths, the Purchaser expects this to result in constraints of 65kW on the Bakerloo Line, 77kW on the Central Line and 40kW on the Waterloo & City Line.

The saloon HVAC cooling function shall be capable of operating without failure when the condenser air intake temperature is 45°C. 292

The saloon heating shall be capable of operating without failure when the outside air temperature is -15°C. 3311

The saloon heating shall be capable of maintaining the saloon temperatures in a Tare Train operating at the maximum line speed. 270

The Manufacturer shall perform a numerical analysis to predict the temperatures around a stopped Train at a platform when determining the nature and disposition of the undercar equipment and location of any air intakes or exhausts. 298

The Manufacturer shall perform a numerical analysis to predict the temperatures around a stopped Train in a tunnel when determining the nature and disposition of the undercar equipment and location of any air intakes or exhausts. 4290

The numerical analyses of temperatures around stopped Trains shall be performed using computational fluid dynamics and shall account for at least the following factors: transient conditions; a representative and agreed typical platform geometry and the presence of any platform edge doors; the heat rejection and airflow patterns from other undercar equipment such as braking resistor grids, cab HVAC and traction packages; and residual airflow from train piston effect. 300

An investigation carried out on behalf of the Purchaser determined that it would be advantageous to fit brake resistor units that are capable of always discharging heat towards the platform bore wall and never towards the platform. This arrangement would be expected to achieve a reduction in temperatures under the Train (more favourable for condenser air intake) and less potential for hot air to enter cars through the open doors. 3859

The Manufacturer shall demonstrate that they have taken advantages of opportunities (such as optimising the location of equipment based on the results of CFD analysis) to minimise any negative interactions 301 between the saloon HVAC system and other elements of the Train.

14.3.3 Saloon HVAC Energy Efficiency 305

The saloon HVAC shall have multi-speed compressors and condenser fans and associated capacity control. 306

Methods of capacity control to closely match the heating and cooling output to the demand shall be provided. 307

The saloon HVAC system shall provide cooling using ventilation only (free cooling) when outside ambient conditions and the prevailing cooling demands permit. 308

Other energy efficiency measures shall be individually and jointly appraised as part of a whole-life cost analysis for the saloon HVAC. These shall include, but not be limited to multi-speed evaporator fans and micro channel heat exchangers. 309

Where the whole-life cost analysis indicates a favourable case the energy efficiency measure or combination of measures shall be adopted. 310

The saloon HVAC system shall be capable of providing increased cooling output during Train braking in cases where energy would otherwise be flowing to any braking resistor. 311

The functionality delivering increased cooling output during vehicle braking shall be operationally tested on the first Train and the control characteristics refined by the Manufacturer. If the resulting performance is deemed by the Purchaser to be reasonable the functionality shall be enabled on subsequent Trains. 312

It shall be possible for the Purchaser, via a configuration setting, to disable and enable the functionality delivering increased cooling output during Train braking. 4291

With respect to the increased cooling output during braking functionality, the cooling output shall not be increased above the maximum design cooling output of the system for the summer design condition. 313

14.3.4 Air Leakage 315

The heating and cooling loads shall take into account the forced ventilation and air leakage. 322

The leakage area between the saloon and outside environments shall not exceed $0.011m^2$ per linear metre of Train averaged over the full 319 length of the Train.

For determination of the heating/cooling loads, the Manufacturer shall calculate the air leakage into and out of the Train when operating inside and outside of tunnels and when at the platform dwells, and shall account for the piston pressure differentials particular to LU tunnels. 320

The air leakage area between the saloon and the outside of the Train shall be proven to be within the defined limit by testing of the first production vehicle and at least two further production vehicles randomly selected by the Purchaser at approximately 33% and 66% of the fleet delivery. 316

The air leakage testing shall comprise the pressurisation of the Train and measurement of the air leakage. The principles shall be as outlined in British Standard BS EN 13829:2001 'Thermal Performance of Buildings - Determination of Air Permeability of Buildings - Fan Pressurization Method' but adapted to suit the Train application. 317

The air leakage test shall account for Method B in accordance with British Standard BS EN 13829:2001 'Thermal Performance of Buildings - Determination of Air Permeability of Buildings - Fan Pressurization Method' (i.e. all adjustable openings closed and remaining intentional openings sealed). The test results shall be normalised to provide a calculated total leakage area rather than a maximum leakage rate. 318

14.3.5 Heat Transfer Coefficient 323

The heat transfer coefficient (k) shall be that given in British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters' for Category B vehicles. 324

The Train roof heat transfer coefficient and roof reflective properties shall be optimised to minimise the effects of solar heat gain. 3584

The Manufacturer may submit a concession against the heat transfer coefficient if there is a case for reducing whole-life costs by optimisation of the amount of thermal insulation applied to the car body. 325

The air leakage may be excluded from the heat transfer coefficient as defined in British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters' and calculated separately as described in these requirements. 326

Thermal insulation shall be provided to prevent significant heat sources on the underframe from causing localised heating of the saloon floor. 327

14.3.6 Air Distribution 340

All cooled air shall be introduced into the saloon through supply points higher than 1.6m above floor level. 341

Cooled air shall be introduced in both the seated areas and standing vestibule areas in proportion to the calculated location specific cooling demand at design conditions. 342

All HVAC components shall minimise the potential for dust to collect within the ductwork and equipment casings. 343

Corrugated ductwork and flexible ductwork which provide recesses for dust to collect within shall not be used. 344

A numerical analysis shall be performed to understand and optimise the airflow distribution within the saloon. 345

The numerical analysis of airflow distribution within the saloon shall be conducted using computational fluid dynamics and shall account for at least the following situations and factors: 346

- Trains within tunnels and at platforms;
- the nose to tail pressure gradient and associated air infiltration that prevails when trains operate in LU's tunnels; the operation and non-operation of the outside air ventilation system;
- seated and standing passengers;
- heating and cooling; and open and closed doors.

A numerical analysis shall be performed to understand and optimise the HVAC ductwork and equipment casing arrangement and airflows. 347

The numerical analysis of airflows in ductwork and equipment casings shall be conducted using computational fluid dynamics and shall account for at least the following situations and factors: 348

- changes in direction;
- areas of high airflow shearing and circulating patterns and the associated propensity for dust to settle in these areas;
- fan system effects and installation factors.

Cooling air shall be filtered to at least a G3 performance class according to British Standard BS EN 779:2012 'Particulate Air Filters for General Ventilation - Determination of the Filtration Performance' before passing across the evaporator coils. 349

Ventilation air introduced by mechanical fans shall be filtered to at least a G2 performance class according to British Standard BS EN 779:2012 'Particulate Air Filters for General Ventilation - Determination of the 350

Filtration Performance'.

Not greater than 30% of the heating capacity shall be provided through supply points higher than 1.6m above floor level unless it can be demonstrated by means of a physical mock-up that a greater proportion of high level heating does not cause a significant difference in thermal comfort. 330

The air diffused through supply points higher than 1.6m above floor level onto standing passengers shall not be greater than 45°C. 331

The air speed measured at any point in the saloon shall be no greater than 2.5m/s. 5199

It is recognised that the maximum air velocity criterion given in British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters' may be difficult to comply with for measurement points close to the air outlets within the saloon. Any air velocities exceeding the criterion shall be shown to be acceptable, by means of demonstration using a mock-up, that the air velocities are not likely to give discomfort to a representative sample of test subjects. 6876

14.3.7 Ventilation 352

Forced normal and forced emergency ventilation shall be provided. 354

The ventilation may be forced supply air and passive relief, forced exhaust air and passive intake or both forced intake and exhaust. 355

The normal and emergency ventilation may be provided by a common fan system. 356

Air intakes for normal and emergency ventilation of the saloon shall not be taken from the car underside. 357

Outside air shall be provided at a rate not less than that described in British Standard BS EN 14750-1:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters'. 359

The normal ventilation airflow rate shall be regulated to closely match the supply to the demand. 360

If CO2 sensing is used to regulate the normal ventilation airflow rate, the concentration of carbon dioxide in the saloon shall be maintained to less than 2000 parts per million at an occupancy of all seated and four passengers per square metre standing. 361

If the calculated airflow from air leakage is sufficient to meet the normal ventilation requirements, the cooling and heating calculations may assume that the forced normal ventilation is switched off in preference for 'natural' ventilation from infiltration. 362

Forced emergency ventilation shall be provided at the required air flow rate for a minimum of 2 hours when the output from the auxiliary converter has been lost. 4550

Forced emergency ventilation shall provide outside air at a rate of not less than $9m^3$/h per passenger based on the Crush Laden capacity. 365

It will be acceptable to separate the emergency ventilation control from the general saloon HVAC system control in recognition of the higher reliability demands of the emergency ventilation. 372

14.3.8 Saloon HVAC Control 369

A neutral zone control shall be provided between heating and cooling functions to avoid simultaneous operation of both functions or frequent heating in one car and cooling in the adjacent. 273

Heating and cooling shall be separated from each other and inhibited upon reaching the boundary of the neutral zone. The neutral zone shall initially be set at Tic 19°C and 21°C. The set points for the neutral zone shall be adjustable based on operational experience to maximise thermal comfort and minimise energy usage. 274

The saloon heating and cooling shall be regulated in accordance with the following rules: 373

- At Tem less than 1°C the Tic shall be set at Tem + 18°C;
- At Tem between 1°C and 12°C Tic shall be set at 19°C;
- At Tem above 12°C Tic shall be prescribed by the relationship of Tic = (0.4 x Tem) + 14.

(Tem = mean exterior temperature, Tic = interior temperature setting)

The saloon temperature regulation curve shall be easily reconfigurable by the Purchaser. 374

The interior temperature set point shall not be susceptible to short term fluctuations due to sudden changes in external temperature resulting from, for example, transition from surface to tunnel. 375

The control sub system shall regulate the output of the saloon HVAC system to allow reduced performance as the condensing pressure approaches the operational limits of the equipment. 376

Configurable parameters shall be capable of being set on a per HVAC unit, per Train and per fleet basis (to avoid the need to change each 378

HVAC unit individually).

When smoke/fire is detected inside the saloon, the saloon cooling and heating in the area of the detection shall cease and the fresh air ventilation in the area of the detection shall operate at the normal ventilation rate. 379

When smoke/fire is detected outside the Train, the saloon fresh air ventilation shall be stopped in all cars for a period of time. 380

After smoke/fire detection, the saloon HVAC shall return to its normal operating mode when the smoke concentration has diminished. 4551

The alteration of the saloon HVAC operation, for longer than 10 minutes, due to smoke/fire detection shall depend on the detection of a sustained presence of fire products at a hazardous level. 4552

Alteration of the saloon HVAC operation due to smoke/fire detection, for longer than 10 minutes shall be subject to a safety risk review to evaluate the failure modes that could lead to a prolonged loss of fresh air ventilation. 5814

Cooling shall be capable of being switched on and off on a location basis in response to commands from the RCS and commands from the OTC. 4807

14.3.9 Monitoring and Diagnostics 381

The Train shall use a heat strain algorithm to predict the time before the onset of passenger heat strain in each car during a stalled train event. 391

The evaluation for the potential for passenger heat strain shall be based on the Wet Bulb Globe Temperature (WBGT) described in British Standard BS EN 27243:1994 / ISO 7243:1989 'Hot Environments - Estimation of the Heat Stress on Working Man, based on the WBGT-index (Wet Bulb Globe Temperature)'. 392

A Heat Strain Warning shall be raised and passed to the RCS if the WBGT in any car exceeds 29°C. 5403

A Heat Strain Alarm shall be raised and passed to the RCS if the WBGT in any car exceeds 33°C. 5405

A Heat Strain Warning relates to the potential for heat strain within healthy persons if the thermal conditions were to persist for more than one hour. A Heat Strain Alarm relates to the potential for heat strain within healthy persons within one hour. 5408

The trigger points for the heat strain warning and heat strain alarm shall be able to be configured by the maintainer. 6661

The WBGT calculation shall adopt a calibrated carriage air temperature as a proxy for car globe temperature. 5409

The Manufacturer shall measure globe and air temperatures during the environmental chamber tests and develop the required calibration factors for the WBGT calculation. 5410

At least two calibration factors for the WBGT calculation shall be developed including one for in-tunnel conditions and one for external conditions with a simulated solar heat load. 5411

The WBGT calculation shall utilise wet bulb temperature values derived from the relative humidity measured on the Train. 5412

The thermal conditions utilised in the WBGT calculation shall be the rolling average of up to 10 minutes of the preceding air temperature and relative humidity. 5413

14.3.10 Reliability 395

The saloon HVAC system shall incorporate measures to result in gradual degradation of cooling output in the event of component failures. 397

The MTBF (all failures) for the saloon HVAC system shall be not less than 20,000 hours per HVAC unit. 398

The MTBF of failures associated with the refrigeration system of each saloon HVAC unit shall not be less than 150,000 hours. This shall include any component that would necessitate partial or full evacuation and recovery of the refrigerant for preventative or corrective maintenance. 399

During fault conditions the saloon HVAC system shall revert to failure states that maximise passenger thermal safety and comfort in each car. 283

14.3.11 Maintainability 402

To the greatest extent practicable, corrective maintenance shall be possible using accessible line replaceable units that can be changed without the need to remove the entire HVAC unit from the underside of the Train. 403

The compressor shall be replaceable without having to remove the HVAC unit from the Train and without the need for unbrazing and brazing. 405

It is anticipated that the condenser coil cleaning process can be integrated into the automatic train wash facility, therefore specific requirements are provided to safeguard this capability. 4803

Condenser coil cleaning shall be capable of being completed from the side of a slowly moving Train without the prior removal of any components, covers or casings. 4804

The surface of the condenser coils shall be orientated towards the side(s) of the car. 4805

The direction of airflow through the condenser coils shall result in any contamination occurring to the outward facing surface so that it can be easily cleaned. 4806

14.3.12 Testing 414

The HVAC test requirements given in this specification shall not be taken to be an exhaustive list. 418

The test regime shall include tests on a single saloon HVAC unit of the submitted final design at the earliest opportunity (risk reduction measure). These tests shall demonstrate that the proposed unit provides the specified performance and functions and delivers the performance and features designed at the design stage. 425

The test regime shall include software and functional tests on a single saloon HVAC unit. Inputs from sensors and devices shall be simulated and the ability of the unit to transition between the different operating modes and functions shall be verified. 428

The test regime shall include software and functional tests on a single saloon HVAC unit. The ability to efficiently regulate output and shut down in response to unsafe conditions shall be verified. 4309

The saloon HVAC test regime shall include airflow measurements on a single unit. The airflow delivery of the supply air fan shall be recorded with a simulated resistance equivalent to the calculated resistance of the main supply and return air ductwork. The airflow delivery of the condenser air fan shall be recorded. 429

Cooling and heating capacity tests shall be conducted on a single HVAC unit placed in an environmental chamber capable of simulating the calculated saloon cooling sensible and latent heating and cooling demand and the design summer conditions at the condenser. 430

The single HVAC unit environmental chamber tests shall verify the cooling capacity, power usage and the ability to operate at the extreme condenser air intake condition. 4312

The saloon HVAC test regime shall include shock and vibration tests on a single unit: The tests shall demonstrate the ability of the saloon HVAC system to withstand the environmental vibration experienced on the railway. Vibration tests shall be carried out in accordance with British Standard BS EN 61373:2010 'Railway Applications. Rolling Stock Equipment. Shock and Vibration Tests'. These shall include functional tests as per the Standard Clause 6.3.2 and shall as a minimum demonstrate operation in cooling mode for at least 15 minutes before, during and after the test for each axis of vibration during normal vibration. 432

The saloon HVAC test regime shall include a water carryover test on a single unit: The test shall evaluate the performance and external tightness against rain, dust, snow and other contaminations and internal tightness against condensation water. The test shall verify the ability to prevent rainwater from filtering into the unit (external tightness); to prevent condensation water from evacuating (internal tightness) and to internal flooding. 433

The saloon HVAC test regime shall include a TL2 test in accordance with British Standard BS EN 14750-2:2006 'Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 2: Type tests' shall be conducted to verify the comfort parameters and the performance of the system. 436

The saloon HVAC test regime shall include tests with a completed Train operating over the intended line areas to verify the system performs in accordance with the requirements of the specification and to the Manufacturer’s specification and design intent. 441

14.4 Cab HVAC 40

The cab shall be equipped with heating, ventilation and cooling to maintain a safe and comfortable working environment for the Train Operator. 3115

The cab HVAC system shall be independent of the saloon HVAC system. 231

The cab HVAC system shall conform to the requirements of British Standards BS EN 14813-1:2006+A1:2010 'Railway Applications. Air Conditioning for Driving Cabs. Comfort Parameters' and BS EN 14813-2:2006+A1:2010 'Railway Applications. Air Conditioning for Driving Cabs. Type Tests', except where modified in this specification. 232

The driving cab shall be considered to be 'Category A' in accordance with the definition and requirements defined within British Standard BS EN 14813-1:2006+A1:2010 'Railway Applications. Air Conditioning for Driving Cabs. Comfort Parameters'. Exceptions to this shall be: 234

- the heat transfer coefficient (k) which shall be less than or equal to $3.5W/m^2K$ as per 'Category B'.

- the air speed which shall meet the requirements for 'Category B'.

The cab HVAC system shall be able to cater for two personnel within the cab. 236

The cab HVAC system shall allow the operator to select the cab interior set-point temperature between +17°C to +24°C selectable in 1°C stages. 237

The selected set-point temperature for the cab HVAC shall be maintained within ±1°C. 3063

The cab HVAC system shall allow the operator to select between high and low fan speeds. 239

The high fan speed selection shall deliver an airflow rate that includes no less than 60m^3/h of outside air. 3044

The low fan speed selection shall deliver an airflow rate that includes no less than 40m^3/h of outside air. 3045

The outside airflow rate is expected to maintain a maximum carbon dioxide level in the cab less than 1,000ppm, commensurate with operator expectations. 3046

The cab HVAC system shall allow the operator to turn off the heating and cooling functions whilst maintaining the outside air provision. 240

The cab HVAC system shall include a personal vent that allows the operator to direct and control an airflow that is directed towards their upper torso and head (when seated). 242

Ventilation outlets other than the personal vent shall be arranged to avoid directly exposing the operator to the airflow. 243

The outside air provision to the cab shall be capable of being maintained for a period of not less than two hours in the event of loss of output from the auxiliary converter. 244

The cab HVAC system shall be tested to level TL2 in accordance with British Standard BS EN 14813-2:2006+A1:2010 'Railway Applications. Air Conditioning for Driving Cabs. Type Tests.' 246

The cab cooling capability shall take account of expected solar gain on open sections and elevated ambient air temperatures within the tunnels. 3120

The Manufacturer shall demonstrate that all opportunities (such as 3316 optimising the location of equipment based on the results of CFD analysis) have been taken advantage of to minimise any negative interactions between the cab HVAC system and other elements of the Train design.

The cab HVAC cooling function shall be capable of operating without failure when the condenser air intake temperature is 45°C. 3317

The cab HVAC heating function shall be capable of operating without failure when the outside air temperature is -15°C. 3318

When smoke/fire is detected outside the Train, the cab fresh air ventilation shall cease. 4813

After smoke/fire detection, the cab HVAC shall return to its normal operating mode when the smoke concentration has diminished. 4815

The alteration of the cab HVAC operation, for longer than 10 minutes, due to smoke/fire detection shall depend on the detection of a sustained presence of fire products at a hazardous level. 4816

15 Train Control and Management (TCMS) 68

15.1 Train Control and Management - General 795

The term Train Control and Management System (TCMS) is used to describe the collection of distributed equipment within a common operating environment, working co-operatively to deliver trainwide control, monitoring, recording and reporting functionality according to the requirements stated throughout this specification. 796

Where requirements in this specification state that data is to be provided to the RCS, the data shall also, where appropriate: 6136

- be used to generate Notifications and status information for staff on board the Train;
- be used to generate Notifications and status information for operational or maintenance staff;
- be provided to the Off-Train Communications (OTC);
- be made available to the RCS (S&TC) so that RCS (S&TC) can function when fitted;
- be made available to the RCS (OCS) so that RCS (OCS) can function when fitted.

Information may need to be provided to assist the Train Operator while the Train is being operated in Manual mode or Automatic mode where RCS (OCS) is not available. When the Train is in unattended mode of operation, controlled via RCS (S&TC) and RCS (OCS), the information will be used at the service control centre where decisions will be made.

The content and relative priority of any data, including Notifications, shall be designed to support a safe and efficient railway. 6131

The content and relative priority of any data, including Notifications, shall be reassessed for each migration state to ensure that they continue to be appropriate to support a safe and efficient railway. 6132

Where RCS control and monitoring functions are required, then these shall be built into the initial Train design to support subsequent migration states. 6133

Examples include allowing for inputs to and memory capacity of the TDR, power required from the batteries to support retention of RCS equipment and control functions needed for switching equipment on and off to support energy conservation.

Where RCS control functions are required, then the majority of these functions shall also be provided by the Off-Train Communications and OTC Data Tools. For example, the OTC and OTC Data Tool shall control consumers to minimise energy consumption. 6708

Where RCS data functions are required, then all of these functions shall also be built into the functionality for the OTC and shall be viewed and analysed from the OTC Data Tool. 6710

There shall be provision for a limited number of high priority fault events to be passed to the RCS (S&TC) equipment so that some real-time information can be sent to the service control centre. 6709

The Train Control and Management System shall: 797

- provide appropriate signals to all items of equipment on the Train so that the Train functions correctly and consistently;
- monitor the status and health of Train systems so that fault and event information and advice is provided to the on-board Train Operator/maintainer;
- monitor the health of Train systems so that fault information and advice is provided to the RCS and the OTC;
- store data for later retrieval for failure and incident investigation;
- record vital data in a Train Data Recorder for incident investigations;
- support any predictive and condition based maintenance;
- respond to faults and apply mitigations to the Train so as to minimise the consequences of the fault.

Using the position of the Train's controls and the selected Train mode, the Train shall automatically limit its function and performance so that the safety risk of potentially substandard conditions continues to be ALARP. 798

The display screen(s) in the cab shall be used to enable the user to interact with the TCMS. 3675

The TCMS shall collate system status data and fault data, both current and historical. 835

The TCMS shall interface with the trainborne RCS to enable control and data to be passed to/from the RCS. 841

The TCMS shall interface with the trainborne OTC to enable control and data to be passed to/from the OTC. 6747

The TCMS shall interface with the trainborne RCS to enable the downloading of data from the Train to the RCS at the wayside. 4033

The TCMS shall interface with the trainborne OTC to enable the downloading of data from the Train to the OTC at the wayside. 6625

The TCMS shall allow the downloading of data via the ethernet port. 5888

System status data shall be clear and unambiguous to assist operators undertaking maintenance diagnostic activity. 836

Ethernet ports shall be provided throughout the Train, including in the cab, and shall: 4709

- enable access to all systems' data;
- be concealed;
- be readily accessible;
- be physically secured to prevent unauthorised access.

A TCMS Data Analysis Tool shall be provided for the retrieval, processing and analysis of the TCMS data. 3126

The TCMS Data Analysis Tool shall, using a standard laptop computer, allow a user to: 6673

- retrieve data for off-board review and storage on secure digital media;
- search for and view data filtered and sorted by any combination of date, time, location and event (historical or on-line);
- scroll through data;
- edit Notification message and system status text;
- upload revised Notifications and system status text to the Train.

The TCMS shall provide a high level of configurability to enable the Purchaser to be able to change the TCMS functionality and parameters. 4442

It shall be possible to make configuration changes, securely, to a fleet of Trains with a single command. 6674

It shall be possible to update software remotely via the RCS and via the OTC. 5273

This requirement shall be assessed for applicability to individual Train systems and it is acknowledged that some safety application software may be omitted from the scope.

An Out of Service function shall be provided which, when activated, shall result in: 4453

- appropriate audio and visual CIS information being automatically broadcast throughout the saloon;
- 'Not in Service' text being displayed in place of the Train Destination text on both the External Front Display and the External Side Displays.

- all normal journey CIS AVI content being inhibited;
- passenger doors being protected from being accidentally manually opened;
- automatic door opening being inhibited.

The Train shall report to the RCS when the Out of Service function has been selected. 5964

It shall be possible to select the Out of Service function on any Train via the RCS. 4454

15.2 Train Modes 70

The Train shall have the following operating modes: Shutdown, Restricted Manual, Inter, Protected Manual, Attended Automatic, Unattended Automatic and Train Secure. 770

Where the term 'Manual mode' is used, this shall be taken as applying to Restricted Manual, Protected Manual and Inter modes, unless otherwise stated. Where the term 'Automatic mode' is used, this shall be taken as applying to Attended Automatic and Unattended Automatic, unless otherwise stated. 7142

The Train Operator shall be able to select the operating mode using controls provided in the cab and the SOP. 7115

The Train Operator shall be able to quickly and easily determine which operating mode is selected. 7116

The Train mode selector shall be secured with a Train mode selector key which shall be held captive in some of the Train mode selector positions. 6621

Attended Automatic mode: In this mode the RCS shall control the Train, supported by a Train Operator who carries out duties on the Train such as managing the platform-train interface, using the controls in the cab. Key features of this mode are: 4017

- The RCS shall have control over Train movement in either direction;
- The RCS shall have control over Train systems;
- The cab braking and traction controls shall be inoperative;
- The Train Mode Selector key shall be captive in the Train mode selector;
- Automatic Door Opening and Automatic Door Closing shall be available, depending on the selected configuration.

Unattended Automatic mode: In this mode the RCS shall control the Train. Key features of this mode are: 7117

- The RCS shall have control over Train movement in either direction;
- The RCS shall have control over Train systems;
- The cab and control console braking and traction controls shall be inoperative;
- The Train Mode Selector key shall not be captive in the Train mode selector.

Protected Manual mode: In this mode the Train shall be controlled by a Train Operator, using the driving controls in the cab and at the SOP. Key features of this mode are: 4018

- Manual driving of the Train shall be enabled when signalling protection from RCS (ATP) is available;
- Manual driving of the Train shall be enabled when Tripcock protection is selected;
- The cab and control console braking and traction controls shall be operative;
- The Train mode selector key shall be captive in the Train mode selector;
- Automatic Door Opening and Automatic Door Closing shall be available, depending on the selected configuration.

Restricted Manual mode: In this mode the Train shall be controlled by a Train Operator. There is no movement intervention by the RCS and the maximum operating speed of 16km/h shall be enforced by the Train's systems. Key features of this mode are: 7118

- Movement of the Train in forward and reverse directions shall be available;
- The cab and control console braking and traction controls shall be operative;
- The Train mode selector key shall be captive in the Train mode selector;
- Automatic Door Opening and Automatic Door Closing shall not be available.

Inter mode: This mode shall be similar to Restricted Manual except that the Train shall not be able to traction. Key features of this mode are: 7119

- The cab and control console traction controls shall not be operative;
- The cab and control console braking controls shall be operative;
- The Train mode selector key shall be captive in the Train mode selector.

Train Secure mode: This mode shall be selected in the cab and at the SOP to ensure that the Train cannot be moved. Key features of this mode are: 4019

- The RCS shall not have control over Train movement;
- The cab and control console braking and traction controls shall be inoperative;
- The emergency brakes shall be applied;
- All other control facilities shall be available;
- The Train mode selector key shall not be captive in the Train mode selector.

Shutdown mode: This mode shall be selected in the cab and at the SOP when the Train is not in service. Key features of this mode are: 6590

- The driving controls are inoperative;
- The brakes are applied;
- The RCS shall not have control over Train movement;
- The tail lights shall be on;
- The Train mode selector key shall not be captive in the Train mode selector.

In Protected Manual mode the Train speed shall be unlimited, up to the signalling protection limit. 2328

Both forward and reverse directions of travel shall be selectable at the controlling driving position in Restricted Manual mode. 4260

In Manual mode full tractive effort shall be available. 3141

In Restricted Manual mode, where the demand and/or location would otherwise lead to the Train's speed exceeding 16km/h, the Train shall automatically regulate the speed at a maximum of 16km/h. 6952

For example, on downhill gradients or where the Train Operator calls for full tractive effort when Manual mode is selected.

Controls at driving positions, other than the position in use, shall be rendered inoperative, except for those designed to be operative at any time. Those designed to remain operative shall include, but not be limited to: 754

- Emergency brake activation and reset mechanism;
- Controls for the whistle;
- Controls that enable communication between two driving positions on the same Train;
- Windscreen Wiper;
- Windscreen Demister;

- Cab lighting controls.

Any attempt to make more than one driving position active, under control of either RCS or via the use of the on board controls, shall have no damaging effect on the Train. 192

There shall be an indication in the cab and at the Saloon Operating Position control console which shows the mode selected at the other end of the Train. 4403

The information displays and indicators that shall be active at an operating position when the operating position at the other end of the Train is enabled shall include, but not be limited to: 6156

- The indicator which shows which mode is selected at the other end of the Train;
- The speedometer;
- Any screen displaying status and monitoring information.

There shall be a Train Power Off control. 771

The Train Power Off control shall, when operated, select the Train Powered Off state. 6099

The Train Power Off control shall operate only in Shutdown mode. 4681

When the Train is Powered Off, the Power On control shall be illuminated. 6681

There shall be a Train Power On control to switch on the Train. 4682

The Train Power On control shall operate only in Shutdown mode. 4683

In Manual mode any equipment which had previously been switched by the RCS or by the OTC in to an energy saving mode shall be switched to normal operation. 3274

In the event that Automatic mode is selected at one cab or SOP and the second cab or SOP is placed in a Manual mode, then the cab or SOP with Manual mode selected shall be the controlling position. 4747

In the event that Manual mode is selected at one cab or SOP and the second cab or SOP is placed in Train Secure Mode, then the cab or SOP with Train Secure mode shall be the controlling position. 4728

In the event that Automatic mode is selected at one cab or SOP and the second is placed in Train Secure Mode, then Train Secure mode at the recently selected cab shall be the controlling mode. 4748

In the event that Manual mode is selected at one cab or SOP and the second is then placed in Manual mode, then the cab or SOP at the originally selected cab shall be retained active. 4749

In the event that Attended Automatic mode is selected at one cab and the second is placed in Unattended Automatic mode, then Attended Automatic mode at the first cab shall be retained active. 7122

The status of the operating mode selected shall be made available to the RCS. 7123

No unwanted transitory states shall occur when transitioning between each Train mode. 772

The Train shall respond to commands from any functioning trainborne RCS, irrespective of its location on the Train. 775

The Train shall enable an operator to indicate their presence on-board a Train. 7109

15.3 Train Control - Design 753

The Train shall be fitted with an IP based Ethernet network. 3323

For traction, brake and door commands, the total system response time from initiation to commencement of demanded action shall be not greater than 200ms. 175

For commands other than traction, brake and door commands, the total system response time from initiation to commencement of demanded action shall be not greater than 2s. 176

The time taken to display status and diagnostic information on the Train shall be not greater than 2s. 5264

The time taken to provide status and diagnostic information to the on board RCS equipment for onwards transmission shall be not greater than 2s after the triggering event. 6190

The time taken to provide status and diagnostic information to the on board OTC equipment for onwards transmission shall be not greater than 2s after the triggering event. 6618

Under all credible failure conditions, sufficient traction and braking facilities shall remain available to enable the Train to be operated out of service or to a depot at the maximum safest speed appropriate to the state of the Train. 758

The Train and subsystems shall not be confused by being Railed. 759

The Train and subsystems shall not be confused by being Gapped.	7044
When a Train is Railed, supplies shall be distributed sufficiently along the Train to enable it to be moved fully on to the electrified rails without any shed traction supply plug being inserted in to a shed receptacle.	6606
The Train shall respond uniformly and consistently to its controls.	760
Single point failures in the Train Control and Management system shall not immobilise the Train.	763
Single point failures in the Train Control and Management system shall not cause unsafe events to occur.	3918
Single point failures in the Train Control and Management system shall be reported to the RCS.	3919
Fault handling shall limit the operation of the Train such that unsafe conditions cannot arise when fault handling devices such as bypass and isolating switches and isolating cocks are operated, locally or remotely.	764
Loss of services or supplies in or to the control system shall not result in an unsafe condition.	765
All electrical, hydraulic, pneumatic and other systems, including wiring, shall as far as reasonably practicable fail to a defined safe condition, in the event of a defect, failure or an emergency.	6028
False feed defects and false earth defects on vital electrical circuits shall be detected and isolated and reported to the Maintainer. They shall also be reported to the RCS/Train Operator if the defect might compromise the safety of the Train.	6257
Failures on the Train shall as far as possible be automatically resolved by TCMS sufficiently to enable continued operation of the Train to depot, without intervention from either RCS or a manual action on the Train.	6137
Where the safety analysis identifies that a positive intervention is necessary to carry out fault isolations, rather than the Train carrying out such isolations automatically, then facilities shall be provided on the Train to enable an operator to carry out the positive intervention.	6680
Facilities provided for recovery from failures shall be operable remotely from the RCS.	4280
Where the safety analysis identifies that a positive intervention is necessary to carry out fault isolations, rather than the Train carrying out such isolations automatically, then facilities shall be provided on the	862

Train to allow the RCS to remotely control fault handling to recover from service failures. (e.g. control of cut-out and bypass switches, isolating cocks and other fault handling/rectification controls identified during reliability reviews).

Safety devices and functions that protect the Train shall be proved in the correct position before the emergency brake can be released. 767

Safety devices and functions that protect the Train shall prove that the emergency brake is available before allowing the Train to move. 4346

For functions which have the potential to create emergency brake requests (except demands made via the Traction Brake Controller), the following shall apply: 5111

- The emergency brake command shall be latched so that the brake is applied continuously;
- It shall not be possible to reset the emergency brake until the system has recovered the capability to stop again.
- It shall not be possible to reset the latch until the Train has come to a halt;
- It shall be possible to reset the latch using controls at the Train Operator's position;
- It shall be possible to reset the latch remotely using the RCS;
- There shall be an indication to the user carrying out the reset to confirm to them which latch the user is about to reset.

For multiple demands occurring at the same time, each demand shall require a separate action from the operator on the Train or at the service control centre to enact the reset.

The RCS (S&TC) equipment shall remain powered up, irrespective of the Train mode. 3295

All time clocks in all train subsystems shall be synchronised with each other. 832

The time clocks fitted on the Train shall be synchronised with the external time source from the RCS. 5354

The time clocks fitted on the Train shall be synchronised with a time source provided externally from the train via the OTC. 6619

The RCS time source shall take precedence over the alternative off train time source via the OTC, when both are available. 6620

The onboard TCMS time clock shall maintain time to an accuracy of better than ±1s per day. 3927

The TCMS shall be synchronised with the external time source with an accuracy of ±1s. 4989

The TCMS shall record energy consumption data provided by all of the onboard energy measurement systems. 851

The TCMS shall identify any isolation devices which are not in their correct operating position. 896

Correct operating position relates to the normal default position for the device.

The TCMS shall identify any individual MCBs which are not in their correct operating position. 4990

The TCMS shall monitor and record performance parameters, e.g. door open/close time, compressor charge time. 853

Configurable system parameter versions, software versions, hardware serial numbers and hardware modification status for all electronic line replaceable units (LRU) shall be reported to RCS. 854

The TCMS shall provide 20% spare capacity for an expansion of its capability, in terms of both spare input and output signals, its memory and its processing capability. 3685

The time for the Train to change between Powered Off state and any other state shall be no more than 120s, not including the time taken for the compressors to charge the pneumatic supply or the HVAC to stabilise temperatures. 961

The time to reconfigure the Train when moving between each Train mode shall be not more than 2s. 3315

15.4 Diagnostics and Monitoring 808

The RCS shall be provided with useful and timely warnings and diagnostic information to assist in operating the Train in the manner which is most safe, efficient and reliable. 809

The RCS shall be provided with useful and timely warnings and diagnostic information to inform of rectifiable faults. 4034

The RCS shall be provided with useful and timely warnings and diagnostic information to inform of faults and failures which require withdrawal of the Train from service. 4714

The RCS shall be provided with useful and timely warnings and diagnostic information to manage faults and failures so as to minimise 4035 the impact of disruptions on the service.

The RCS shall be provided with useful and timely warnings and diagnostic information to support the effective maintenance of the Trains. 4036

The Train Operator shall be provided with useful and timely warnings and diagnostic information to assist in operating the Train in the manner which is most safe, efficient and reliable. 5820

The Train Operator shall be provided with useful and timely warnings and diagnostic information to inform of rectifiable faults. 5821

The Train Operator shall be provided with useful and timely warnings and diagnostic information to inform of faults and failures which require withdrawal of the Train from service. 5822

The Train Operator shall be provided with useful and timely warnings and diagnostic information to manage faults and failures so as to minimise the impact of disruptions on the service. 5823

The monitoring shall provide early identification of potential faults that may affect the overall reliability of the railway and faults where the mean time to repair may be comparatively long or the maintenance tasks intensive. 4692

The Manufacturer shall propose monitoring and diagnostics with a supporting analysis of the trade-off between the ability to detect incipient faults and the added capital cost, complexity and associated maintenance demands of the system needed to achieve this. 4693

The diagnostics data shall be stored in non-volatile memory. 4695

The RCS and the OTC shall be provided with information relating to the status of the passenger environment. The information shall include: 3302

- saloon temperature;
- relative humidity;
- CO_2 (or equivalent);
- passenger affecting faults (e.g. lighting/HVAC defective);
- status of load shedding;
- PEA status.

The RCS and the OTC shall be provided with information to allow a decision to be made on whether or not a push-out will be successful. 3298

The RCS and the OTC shall be provided with information confirming that the Train is complete. 3301

The RCS and the OTC shall be provided with information on the number of cars/Trains in the formation and their unique identity. 3299

The RCS and the OTC shall be provided with information regarding the condition and testing of the Train and its suitability for entering and remaining in service. 811

The RCS and the OTC shall be provided with information regarding the Train's perceived status of the traction power supply. 6707

The TCMS shall be used to predict components which are near to causing a service failure. In addition, this information shall be used to assess asset condition and to monitor long term deterioration of asset condition. 3297

Vital systems on the Train should not be compromised by a failure of the monitoring system. 810

Monitoring of asset condition shall be incapable of causing failure of the asset being monitored. 889

Where redundancy is adopted and used, the condition of the redundant system shall be logged and reported. 4232

The monitoring system shall not issue continuous reminders of matters about which operators are aware. 814

The monitoring system shall not report faults to users where that information cannot be used to take action. 6106

The monitoring system output shall accurately reflect the condition of the Train, when actions have been incorrectly carried out. 4725

The monitoring system shall not be susceptible to spurious messages caused by spikes or transients on monitoring inputs. 816

The monitoring system shall not be susceptible to spurious messages during changes of inputs between one state and the next. 817

The monitoring system shall report only a root cause failure and appropriately filter the failures caused by it. 818

The monitoring system shall automatically update information displayed as it changes, without requiring operator intervention to do so. 819

Where an operator action is appropriate, the monitoring system shall diagnose the problem and propose a solution. 820

The course(s) of action shall be appropriate for the operator to undertake, taking into account the confines of the Train and its environment, e.g. that access to external controls or equipment in a tube tunnel is neither possible nor permissible and that the Train may be Crush Laden with passengers impeding access to underseat and saloon equipment.

The monitoring system shall, where the problem has more than one solution, present them one at a time, in order of preference. 821

The monitoring system shall, following any operator action, review its diagnosis and present revised information if appropriate. 6100

Any revised actions offered to the operator shall not result in circular instruction paths.

It shall be possible to clear fault events without the need to reactivate the control position which was selected at the time of the original triggering of the event. 3346

The monitoring system shall, when a fault clears, remove the Notification without Train Operator intervention, but retain it in the log. 822

The Train Operator shall be provided with Notifications and information at the operating position. 824

The TCMS shall allow maintainers to view and record real time data from any system without affecting the vehicle operation. 902

The RCS shall be provided with sufficient Train status and diagnostic information to enable a person in the service control centre to be aware of, and respond to, relevant events on the Train. 3684

The RCS shall be provided with sufficient Train status and diagnostic information to enable a person in the service control centre to cross-check the Train's diagnosis and determine whether the Train is fit to move and at what level of performance. 6101

The state of all controls and fault-handling devices in response to diagnostic advice shall be used to obtain the best available operation of the Train so as to minimise the effects of the failure on the Train and the operation of the railway. 6102

This shall apply following actions, either by a Train Operator/RCS or maintainer, or as carried automatically by the Train.

The TCMS shall monitor and record Train distance travelled for the purpose of operational and maintenance planning and report it to the RCS. 838

The design shall allow the Notification (audio and visual) category, message text and supporting information text to be modified by the Purchaser, as configurable data, without full regression testing of the software. 830

All recorded TCMS events shall have date, time, position (on train), and other associated data sets which provide sufficient information to enable an accurate reconstruction of the sequence of events and actions associated with that event. This supporting information shall be configurable. 831

The monitoring system storage capacity shall be sufficient to allow data from 15 days in normal service to be retained on the Train. 833

All data, raw and processed, shall be made available to the Purchaser via the RCS and the OTC. 3425

All data, raw and processed, shall be made available to the Purchaser via the on-train diagnostics ethernet ports. 3426

The location of the access ports in the cab shall be positioned to enable access without interfering with Train Operator duties. 5180

15.5 Train Control and Management System - Simulator 855

The Manufacturer shall construct, demonstrate and use a representative TCMS simulator to validate and verify the Train Control and Management System using a complete Train set of TCMS equipment and Train sub-system equipment. 856

The Manufacturer shall use the TCMS simulator as a test and development tool. The simulator shall trigger all control functions and Notifications logged or used by the TCMS. 857

15.6 Passenger Load Weighing Data 87

Passenger load data, on a per bogie, per car and whole Train basis, shall be provided to the RCS on a real time basis. 982

The load weigh output signal shall change to within 5% of the actual passenger load within 10s of the completion of the change in static load. 983

The hysteresis of the load weigh system shall be consistent with the requirements of the traction and braking system. 984

Failures of the load weigh system shall be logged and reported to the RCS. 2681

15.7 Train Data Recorder (TDR) 74

The Train Data Recorder (TDR) is often referred to as an On Train 5274

Monitoring Recorder (OTMR) or an On Board Driving Data Recorder (ODDR).

Each TDR shall record signals which support an incident investigation into an unsafe or irregular operation or function of the train, based on a systematic analysis of the overall Train system and its interfaces. 4447

These signals shall include, but not be limited to:

- Position of all Train Operator controls and indicators;
- Status of all safety devices;
- Time, speed, distance and direction of travel;
- Status of all door circuits and controls;
- Status of traction, braking, WSP, sanding systems;
- Status of whistle;
- Status of HVAC;
- Status of fire/smoke detection;
- Status of Hazard Warning Light;
- Tripcock;
- Tripcock time delay;
- Tripcock reset control operation;
- OTC related functions;
- RCS (S&TC);
- RCS (OCS).

TDRs fitted to existing LU Rolling Stock record the following signals: 905

- *Vehicle identification;*
- *Time of day and date;*
- *Status of Train Continuity ("Round Train Circuit") circuit;*
- *Train secure circuit status;*
- *Operation of Start buttons;*
- *Operating mode (i.e. Manual mode, Automatic mode, Train Secure mode);*
- *Master Control Switch position;*
- *Forward or reverse selected (both A & D);*
- *Train Speed being used for Protection and being shown on the Speedometer;*
- *Independent Train Speed (e.g. trailer car axle wheel rotation) accurate to within ±2.5%;*
- *Cumulative Distance travelled from Power On accurate to within ±2.5%;*

- *Direction of travel;*
- *The ATP interfaces with the Train's Emergency Brake system to enforce position and speed restrictions and the ATO interfaces with the Train's TCMS to provide control of normal Train movement. Each ATP control unit should interface to each Train Data Recorder. Train Operator, or other user, interactions with train protection, control and warning systems such as ATP/ATO data including Maximum Safe Speed, Target Speed and Movement Authority , in cab signalling systems;*
- *State of any Protection which applies emergency brake e.g. ATP tripped;*
- *State of ATP cut out switch (if fitted);*
- *Status of the tripcock isolating switch;*
- *Status of the tripcock reset control;*
- *Status of the tripcock;*
- *Emergency brake demand status from tripcock.*
- *Braking demanded (or equivalent);*
- *Brake effort demanded by ATP and Brake controller position when driving manually;*
- *WSP activity (per wheelset);*
- *Sanding equipment operation - location and rate;*
- *Brake cylinder pressure;*
- *Status and operation of Train radio systems;*
- *Status and operation of obstacle detection systems;*
- *Status and operation of air cooling systems;*
- *Emergency brake demand status from on board safety systems;*
- *Traction demanded (or equivalent);*
- *Traction effort demanded by ATP and the Traction controller position when driving manually;*
- *Train location (As a minimum last station passed. More precise location to be used if information is available);*
- *Selection of doors open (each side recorded independently);*
- *Operation of the in-cab saloon doors close buttons (each side recorded independently);*
- *Doors close demand (each side recorded independently);*
- *Door signal circuit status;*
- *Deadman's handle position;*
- *Passenger emergency alarm operated;*
- *Whistle actuation demand (and quiet/loud if applicable);*
- *Rollback operated or triggered;*

- *Rollback reset operated;*
- *All cut out, selection, emergency and override pushbuttons and switches including but not limited to Yellow Indicator light, CSDE override, PEAB override, rollback cut-out and all others which are accessible to the Train Operator or enabled remotely via the RCS;*
- *Operator identity e.g. crew identification read from other on-vehicle system;*
- *Status of fire detection;*
- *Safety Brake Circuit A/B selected;*
- *Data available from TCMS;*
- *Detrainment door status.*

A TDR shall be fitted at each end of the Train. 906

Each TDR shall record in all Train modes. 907

Each TDR shall record all of the data that is available to the TDR, irrespective of its position relative to the controlling end. 4054

TDRs shall be located in such a position so as to minimise the risk of damage in the event of collision. They shall not be mounted forward of the leading bogie. 910

The TDR shall be located such that the download facility can be easily accessed by authorised personnel without the need for special keys or tools. 911

It shall be possible for an authorised person only, on a Train in passenger serviceable condition, to remove the TDR in its entirety and replace it with another in not more than 10 minutes. 912

It shall be possible for an authorised person only, on a Train in passenger serviceable condition, to remove the TDR secure storage and replace it with another, in not more than 10 minutes. 4095

The TDR shall comply with the crash protection requirements of British Standard BS EN 62625-1:2013 'Electronic railway equipment - On board driving data recording system. Part 1: System specification' in accordance with Table 1 Parameter values FA-SA-PA-CA-IA-HA-MA. 915

The TDR equipment and its installation shall meet the requirements of British Standard BS EN 60529:1992+A2 2013 'Degrees of Protection Provided by Enclosures (IP code)' using the environmental protection rating IP55. 916

The TDR shall have sufficient non-volatile memory capacity to store the records of at least 15 days of the Train operating in normal passenger 917 service.

The disconnection or loss of external power to the TDR shall not affect the integrity of data which has already been recorded. 6624

Data logged in the monitoring equipment shall be made available to support incident investigation. 903

The TDR shall incorporate its own real time clock. 918

The TDR real time clock shall record the year, month, date, hours, minutes and seconds. 6103

The TDR real time clock shall be regularly and automatically corrected such that it is consistent with the time source within ±1 second. 904

The TDR real time clock shall have an accuracy of ±2s per month. 3305

The TDR real time clock shall continue to run for not less than 30 days, in the event of the external power being removed. 3306

The TDR time shall not synchronise in response to an external time signal whilst the Train is operational. 5107

It shall be possible to view TDR inputs on a real time basis to enable testing of those inputs. 4724

It shall be possible to rename each input in the TDR, for update and tagging purposes. 919

The TDR shall require a password to allow changes to its configuration, including input names. 5109

Configuration of the TDR shall be possible by uploading from a portable electronic device or industry standard laptop PC. 4099

Configuration data for the TDR shall include, but not be limited to: 4100

- the current date (year, month, date);
- current time (hours, minutes, seconds);
- car number;
- channel names.

There shall be capacity to add a further 15% recorded channels (rounded up to the nearest whole number) to the TDR with analogue and digital channels provided in proportion to those already installed. 920

The secure storage in the TDR shall, in the normal operating environment of the TDR, retain its stored data for an unlimited time, with external power being applied. 921

The TDR secure storage shall, in the normal operating environment of the TDR, retain its stored data for at least 3 months, without external power being applied. 4102

The TDR secure storage shall, if external power is restored during this 3 month period, not lose the data held. 4103

Batteries shall not be used in the TDR secure storage to retain data. 922

Downloading of recorded data from the TDR shall be possible by physical unlocking and removal of the secure storage. 923

Downloading of recorded data from the TDR shall be possible, with the secure storage still in the TDR (both installed and off the Train), to a portable electronic device. 4104

Downloading of recorded data from the TDR shall be possible, with the secure storage still in the TDR (both installed and off the Train), to an industry standard laptop PC. 4105

A typical means of manually downloading the TDR would be via a standard modern industry protocol, such as by USB memory stick or similar high speed serial data link. 924

Downloading of recorded data from the TDR shall be possible, remotely on a real-time basis to the RCS and to the OTC for in-service monitoring. 4108

Download of data from the TDR shall not damage, delete or otherwise affect data held in the secure storage. 925

In the event of the TDR being damaged to the extent that data cannot be downloaded in-situ, it shall be possible for the secure storage to be retrieved without loss of that data; or the facility to retrieve that data. 926

The application of an electrical surge or transient from the Train to any TDR input shall not, even if the input circuit itself is damaged, damage the memory storage device or corrupt data. 927

The connection between the Train circuits and the TDR shall be as direct as practicable to ensure data integrity and shall not compromise the control system of the Train in any way during either normal or fault conditions. 928

Risk assessment, FMECA and FTA shall be used to demonstrate that the TDR does not import unacceptable risk into the Train by affecting 929 the circuits it is monitoring.

The TDR shall be separate from all other on-board database and fault storage equipment. 930

The TDR shall be operative and recording whenever the Train is in any Train mode and commence routine recording within 15s of power-up. 931

The TDR shall self-test upon power-up. 932

The TDR shall continuously monitor its status after power-up. 3308

The TDR shall report its self-test and its status to the RCS. 3309

The TDR shall display its status, in a position visible to a maintainer, when installed in its operating position. 6104

The status of the TDR shall be displayed to the Train Operator. 6105

The TDR shall continue to operate using the standby battery of the Train for at least 2 hours after the loss of traction supply or until the functions being monitored cease to be available on the car, whichever is the sooner. 933

The status of a changed input shall be recorded into the TDR secure storage and shall consist of each trigger event and the date and time of the trigger event, with a time resolution of no greater than 100ms. 934

For analogue values, the size of the absolute or relative change in the value that triggers a record in the TDR memory shall be configurable. 936

The software used to analyse the TDR data shall allow retrieval and analysis of recorded data. 939

The file name of the extracted TDR data shall include the Car Number, the date and the time. 5110

The software used to analyse the TDR data shall present data in a tabular and graphical form as directed by the user. 940

Each data set shall include the TDR software version, configuration data version, date and time of data download, Car Number and TDR serial or other identification number. 4110

The software used to analyse TDR data shall provide a printout of the state of all inputs between specified dates and times. 941

The software used to analyse TDR data shall provide graphs of user- 942 selected inputs against time, distance and speed, from any specified origin.

The software used to analyse TDR data shall provide printouts showing all input states before and after a user-selected trigger event. 943

The software used to analyse TDR data shall provide printouts showing all occurrences of a user-selected input changing state. Available datums shall be time, distance or speed. 944

The software used to analyse TDR data shall provide printouts showing all occurrences of a user-selected sequence or combination of events. 945

The software used to analyse TDR data shall provide a means to store the contents, or part of the contents, of a TDR secure storage on another medium for archiving and later analysis. 946

The software used to analyse TDR data shall provide real time viewing of the inputs, in graphical and tabular form. 948

The software used to analyse TDR data shall provide selection of sub-sets of data. 949

The software used to analyse the TDR data shall be version controlled and suitably tested to ensure that data is represented accurately. 950

Facilities shall be provided to the Purchaser to retrieve and analyse the TDR recorded data. Provision shall include any necessary connecting cables, card readers, keys, special tools. 951

An agreed number of sets of facilities necessary to enable retrieval and analysis of TDR data shall be delivered to the Purchaser before the first TDR is installed on a Train. 952

15.8 Railway Control System (RCS) Control Interfaces 840

Whilst in both Unattended Automatic mode and Shutdown mode, the Train shall respond to control inputs from the RCS to switch off unnecessary consumers, so as to minimise noise and maximise energy efficiency when the Train is stabled and not required for service. Specific interface requirements shall be fully developed by the Manufacturer and agreed by the Purchaser as part of the design review process. 3339

The Train shall switch on and switch off normal saloon lighting in response to a command from the RCS. 3267

The Train shall switch on and switch off emergency saloon lighting in 4698 response to a command from the RCS.

The Train shall switch on and switch off all CIS VEIDs in response to a command from the RCS. 3269

The Train shall control the Saloon HVAC in response to a command from the RCS. 3270

The Train shall switch on and switch off the compressors in response to a command from the RCS. 3271

The Train shall switch on and switch off the auxiliary converters in response to a command from the RCS. 3272

The Train shall switch on and switch off exterior lighting (e.g. headlights, tail lights) in response to a command from the RCS. 3268

The Train shall control the windscreen demister in response to a command from the RCS. 4711

The Train shall monitor the battery charge and override the RCS control of the Auxiliary Converter if the battery voltage falls below the limit required for emergency standby duty. 3273

The Train shall monitor the battery charge and override the OTC control of the Auxiliary Converter if the battery voltage falls below the limit required for emergency standby duty. 7042

The interface with the RCS shall be of sufficient integrity to ensure that equipment is not switched off when it should be operating. 4443

The interface with the OTC shall be of sufficient integrity to ensure that equipment is not switched off when it should be operating. 7043

In the event of conflicting control signals or signal combinations that are not permitted or valid then the Train shall default to a safe condition. 187

The Train shall respond to a single command to prepare for service from the RCS by turning on all consumers (if it is safe to do so) which were turned off in response to a previous command from RCS. 6861

The Train shall provide feedback that the prepare for service command from the RCS has been received and actioned. 6862

The Train shall respond to a single command from the RCS to shut down unnecessary consumers. 6863

The Train shall provide feedback that the input to shut down unnecessary consumers from the RCS has been received and 6864 actioned.

The status of the Train modes shall be reported to the RCS. 783

The Train shall provide to the RCS status information pertaining to the presence / absence of an operator on the Train. 7112

This status will be used by the RCS to ensure that the Train is supervised during sweeping.

The commencement of Power Off shall be reported to the RCS. 4712

The completion of Power On shall be reported to the RCS. 6616

Information shall be shared between trainborne systems and allocated between off-train systems so as to minimise or eliminate duplication of data transmitted between Train and trackside. 879

15.9 Off-Train Communications (OTC) Control Interfaces 6817

Whilst in Unattended Automatic mode and Shutdown mode, the Train shall respond to control inputs from the OTC to switch off unnecessary consumers, so as to minimise noise and maximise energy efficiency when the Train is stabled and not required for service. 6818

The Train shall switch on and switch off normal saloon lighting in response to a command from the OTC. 6819

The Train shall switch on and switch off all CIS VEIDs in response to a command from the OTC. 6821

The Train shall control the Saloon HVAC in response to a command from the OTC. 6823

The Train shall switch on and switch off the Compressors in response to a command from the OTC. 6824

The Train shall switch on and switch off the Auxiliary Converters in response to a command from the OTC. 6825

The Train shall monitor the battery charge and override the OTC control of the Auxiliary Converter if the battery charge falls below that limit required for emergency standby duty. 6830

The Train shall respond to commands from any functioning trainborne OTC, irrespective of its location on the Train. 6831

The interface with the OTC shall be of high integrity to ensure that 6833 equipment is not switched off when not required.

In the event of conflicting control signals or signal combinations that are not permitted or valid from the OTC then the Train shall default to a safe condition. 6834

The Train shall respond to a single command to prepare for service input from the OTC by turning on all consumers (if it is safe to do so) which were turned off in response to a previous command from OTC. 6858

The Train shall provide feedback that the prepare for service input from the OTC has been received and actioned. 6860

The Train shall respond to a single command from the OTC to shut down unnecessary consumers. 6859

The Train shall provide feedback that the shut down unnecessary consumers input from the OTC has been received and actioned. 6865

The status of the Train modes shall be reported to the OTC. 6835

The commencement of Power Off shall be reported to the OTC. 6836

The completion of Power On shall be reported to the OTC. 6837

15.10 Off-Train Communications (OTC) 6448

15.10.1 OTC - General 6896

The Manufacturer shall provide Off-Train Communications (OTC) equipment to transfer data to and from Trains whilst in service and whilst stabled in the depot and sidings. 6626

In general, there are various types of data to be transferred: 6676

- *High integrity information which has to be communicated to or from the Train, at every station and at some depot locations, before the Train doors can open;*
- *High integrity information which has to be communicated to or from the Train at stations with PEDs to coordinate Train door operation with PED operation;*
- *Control functions which may take place at stations but more typically occurs at depot locations;*
- *Notifications and status data which may be downloaded immediately or some time after it is created, potentially in a depot after the Train has stabled;*
- *TDR, CCTV and software data which may be transferred at depot locations after the Train has stabled.*

These functions do not have to be implemented by one system but they shall be collectively known as Off-Train Communications (OTC).

15.10.2 OTC - Platform-Specific Functions 6592

The OTC shall support the correct operation of the Train passenger doors and PEDs. 6607

The OTC shall support the correct operation of the Train passenger doors and PEDs at locations where the Train may reverse in the platform. 7069

The OTC shall support the correct operation of the Train passenger doors and PEDs when the same operational cab is shut down and then opened up again during the station stop. 7080

The OTC shall support the correct operation of the Train passenger doors and PEDs when the operational cab changes from one end of the Train to the other during the station stop. 7081

The OTC shall ensure that only the doors on the side(s) of the Train which is (are) adjacent to the platform are enabled. 6598

This is known as Correct Side Door Enable (CSDE).

When the Train is correctly berthed at a platform which has a useable length which is too short to accommodate all of the passenger doors, the rear-most passenger doorway of the Train shall be inhibited from opening. The OTC shall ensure that only the doors which are aligned with a useable part of the platform are enabled. 6599

This is known as Selective Door Opening (SDO).

The OTC shall ensure that the doors shall be enabled only when the Train has stopped at any point within a zone which is 2.8m in length and which is centred on the nominal stopping position, such that the stopping window extends from a point 1.4m short of the nominal stopping position to a point 1.4m forward of the nominal stopping position. 7124

This will ensure that the following railway system needs can both be met:

- *That the requirement to permit only the doors which are aligned with a useable part of the platform to be enabled, will be able to be met with minimal use of SDO.*
- *That there is a stopping window sufficiently large to prevent service disruption occurring as a result of underrun or overrun of the nominal stopping position.*

SDO shall be used at Queensway Platform 2 on the Central Line. SDO shall be used at other platforms should any additional locations requiring it be identified. 6601

It shall be possible to perform a maintenance test (in the depots) of the end to end door control, including all of the Train doors, e.g. by simulating the CSDE and SDO inputs. 6895

Any Equipment to perform a maintenance test (in the depots) of all of the platform specific functions and the Train doors shall be provided. 6604

The open/closed status and open/closed enabled status of the doors and PEDs shall be reported to the RCS. 6605

The Train doors shall be enabled no more than 250ms after the Train has stopped at the correct stopping point. 6608

The Train doors shall be enabled only after any requirement to inhibit individual door(s) has been established. 6609

In order to enable passenger doors within the specified time, it is likely that communication across the interface boundaries (PEDs and gap fillers), to establish which doors to enable, will need to be established before the train comes to rest. 7070

At locations where the transmission of data is available to the Train when it is moving, this transmission shall occur when the Train is moving at any speed, up to and including the maximum speed of the Train. 6613

A Train shall receive only the data which is intended for that Train. 6615

The cross-reading of platform-specific data from adjacent platforms is a particular safety hazard that shall be eliminated. 6850

A Train shall not receive any transmission intended for another Train. 6738

The Off-Train Communications shall co-exist with the Correct Side Door Enable (CSDE) systems currently in use on the DTUP lines. 6656

The Train shall not depart the platform until the PEDs are reported closed and locked, any gap fillers have retracted and no obstructions are detected between the Train and the PEDs. 6740

15.10.3 OTC - Data Transfer Functions 6741

The data transferred to and from the Train via the OTC shall include, but not be limited to: 6450

- condition based monitoring and trending data;
- Notifications of Train fault event data;
- attribute data associated with Train fault events;

- status of onboard isolations;
- test status and results;
- software status of equipment;
- hardware status of equipment;
- equipment count data from individual control equipment (e.g. operational counts, operating hours, distance run);
- information displayed to the Train Operator for individual Trains;
- passenger load weigh data;
- saloon environment measurements;
- TDR data;
- CCTV data;
- software updates;
- control functions;
- time synchronisation;
- PEA status;
- rough ride detection data;
- CIS database;
- digital advertising;
- location data;
- surface/tunnel area data;
- equipment status information;
- all other data identified by the Purchaser during the design & test process as being useful to assist in the use of the Train.

The term attribute data refers to any supporting data which assists in identifying why an event has been generated, e.g. Train speed, ambient temperature, saloon temperature, mileage, tractive effort.

Train data via the OTC shall be grouped, prioritised and scheduled for transfer based on its criticality, intended use and the Train's location. 6497

For example, low priority condition monitoring data may be downloaded only in depot areas, whereas higher priority fault information may be downloaded at the next available opportunity.

If multiple transmission paths are available for data transfer via the OTC (e.g. WLAN, GSM), it shall be possible to configure which data is sent via which path. 6501

When the Train is in platform, siding and depot areas, data shall be made available via the OTC so that the Train can control functions that are dependent on specific geographic location or on surface or tunnel location. 6600

A time synchronisation signal shall be provided to the Train via the OTC. 6628

When the transfer between the Train and the trackside OTC equipment is intermittent, faulty or unavailable, data yet to be transmitted shall be retained on the Train and it shall be accessible to the Purchaser. 6492

OTC data transfer errors shall be detected and appropriate action taken to protect data and report on failures (e.g. retrying data transfer, on-train data buffering, on-train data storage, fault logs and Notifications). 6576

The OTC shall provide 20% spare capacity to allow for future data volume growth (e.g. for condition based monitoring, fault event data, attribute data, RCS data), resulting from developments to the Train monitoring and analysis implemented during service introduction and to support reliability improvements. 6496

It shall be possible to configure the OTC to pass raw and processed data to related Purchaser services such as the AMS CAS, maintenance management tools (e.g. Ellipse) or to the RCS. 6512

15.10.4 OTC - Installation 6742

The Manufacturer shall supply the train-borne equipment, the infrastructure-borne Equipment for each location, and sufficient computer hardware and software necessary to fulfil the requirements for the Off-Train Communications installation. 6744

The Purchaser shall determine the nominal stopping position at each platform. 6849

The Manufacturer shall provide any infrastructure-borne OTC Equipment elements to the Purchaser for installation on the infrastructure by the Purchaser or a third party appointed by the Purchaser. 6693

The infrastructure-borne OTC Equipment shall comprise generic hardware which shall be able to be installed via a generic installation methodology which is suitable for all locations and requires the minimum of location specific tailoring of the hardware. 6657

The infrastructure-borne OTC Equipment elements supplied by the Manufacturer shall each be pre-mounted on a fixing plate that can be fixed to a generic mounting interface (e.g. Unistrut or similar). 7134

The design of the infrastructure-borne OTC Equipment(s) fixing plate(s) shall include provision for strain relief and grounding of cabling connections to the Equipment where appropriate. 7135

It shall be possible to install any infrastructure-borne OTC Equipment 6653 within the Manufacturer's scope of supply within a maximum time of 3 hours per platform.

All infrastructure-borne OTC Equipment installed on or around platforms shall be replaceable within 30 minutes. 6654

15.10.5 OTC - Data Tool 6517

The OTC Data Tool shall be provided by the Manufacturer. 6519

The OTC Data Tool shall be available to users via a web-based interface. 6456

The OTC Data Tool shall: 6451

- enable maintenance staff to conduct the prescribed maintenance regime, including supporting routine maintenance tasks, prediction and avoidance of failures, trend analysis, post-failure interventions, maintenance optimisation and service performance analysis;
- inform operators at the service control centre so as to manage Trains whilst they are operating in service;
- enable operators to control the turning on and off of consumers on Trains, so as to minimise noise and maximise energy efficiency;
- enable operators to carry out other control functions stated elsewhere in this specification.

The OTC Data Tool shall be used to facilitate sending software updates to the Train via the OTC. 6629

It shall be possible to request the transmission of TDR data from the Train via the OTC. 6506

It shall be possible to upload a new CIS database to the Train remotely via the OTC. 6857

It shall be possible to request the transmission of CCTV data from the Train via the OTC. 6855

Each user of the OTC Data Tool shall have their own account with a unique password. 6457

For each user account, an administrator shall be able to determine which facilities and functions are available to each user. 6633

The Purchaser's administrative staff shall have control of access rights for the Purchaser's staff. 6464

It shall be possible for at least 20 users to simultaneously access and use any of the functions of the OTC Data Tool without affecting the tool's response. 6462

The OTC Data Tool shall provide immediate access to historic data to assist in analysing trends and patterns of events and reports. 6516

The OTC Data Tool shall allow the use of fleet data from any time period within the life of the stock for producing queries and reports. 6465

It shall be possible to export the results of an OTC Data Tool query to a report. 6846

The naming convention for exported files shall be automatically generated in a logical format (based on the search criteria) and shall also be adjustable by the user. 6470

For example, the file name of an extracted fault data file may include the Car Number, the date and the time span of the search.

The OTC Data Tool shall automatically identify and report any Trains which are not reporting their status, fault events or other system information. 6518

The data provided to, and accessed from, the OTC Data Tool shall include: 6458

- condition based monitoring and trending data;
- Notifications of train fault event data;
- attribute data associated with Train fault events;
- status of onboard isolations;
- test status and results;
- software status of equipment;
- hardware status of equipment;
- equipment count data from individual control equipment (e.g. operational counts, operating hours, distance run);
- information displayed to the Train Operator for individual Trains;
- passenger load weigh information;
- saloon environment measurements;
- TDR data;
- CCTV data;
- software updates;
- information displayed on the Train Operator's display screen for individual Trains;
- access to enable control functions;

- equipment status information;
- all other data identified by the Purchaser during the design & test process as being useful to assist in the use of the Train.

It shall be possible to use the OTC Data Tool to apply additional rules to generate reports and Notifications. 6459

Such reports and Notifications may, for example, form part of the condition trend analysis. The purpose of this is to avoid the build-up of problems leading to SAFs or reducing Train redundancy, whilst not directly causing a SAF to occur. Such logic shall also be applicable to faults which do not directly lead to a SAF. Such as: any event occurring more than X times in a journey; event active for more than X minutes; event active and specific Train location; cumulative duration of greater than Y minutes; more than X individual events.

The OTC Data Tool shall have the ability to generate customised reports and Notifications and to send them to specified users via text message. 6477

The OTC Data Tool shall have the ability to generate customised reports and Notifications and to send them to specified users via email. 6632

It shall be possible to use the OTC Data Tool to search for and extract Train fault event data based on, but not limited to, combinations of the following: 6472

- a specific Train or a group of Trains;
- one or more individual car type(s) in a Train formation;
- one or more selectable periods of time (e.g. days, weeks or months);
- all or a combination of fault codes;
- all faults for one or more particular systems (based on fault numbers or free text or combinations of such criteria);
- one or more geographical locations where faults occurred;
- all faults of a particular priority.

It shall be possible for the Purchaser to test new rules used to generate reports and data against historical and current real time data, prior to their release, to prove that they work correctly, without affecting the existing proven reporting functions. 6460

Results exported from the OTC Data Tool, which are greater than the capacity of the intended application into which they are being exported, shall be split-up into manageable sized data-sets. 6461

The OTC Data Tool shall include standard graphs of event count, including but not limited to the following filtering: 6482

- by date;

- by event count by fault;
- by event counts for one or more assets by sub-systems;
- by event count by assets.

Predefined maintenance reports within the OTC Data Tool shall be provided and shall typically include: 6473

- Asset number;
- Fault code;
- Severity;
- Description;
- Start date;
- End date;
- Duration;
- Location;
- Fault text;
- Associated attribute data for events.

It shall be possible to search, extract, view and graph the following Train data attributes: 6474

- condition based monitoring and trending data;
- train fault event data;
- attribute data associated with Train faults;
- status of onboard isolations;
- test status and results;
- software status of equipment;
- hardware status of equipment;
- equipment count data from individual control equipment (e.g. operational counts, operating hours, daily and cumulative Train mileage);
- all other data identified during the design & test process as being consistent with meeting the intent of this requirement;
- passenger load weigh information;
- saloon environment measurements.

The Purchaser shall have access to the logic used to define any Notifications, so as to support their understanding as maintainer. 6475

The OTC Data Tool shall include a high level fleet overview screen where each Train and its status with regard to important faults is displayed. It shall be possible to directly access greater detail for each individual Train from this screen. 6476

It shall be possible for users to be able to set up reports to run automatically at pre-set times or time intervals using the OTC Data Tool. 6478

The OTC Data Tool shall record and report on any automatic and manual tests, including passes, failures and outstanding tests. 6479

The OTC Data Tool shall present selected data in a tabular and graphical form as directed by the user. This can be via a selection of pre-defined templates and customised reports. 6480

The OTC Data Tool shall be capable of generating graphs from any user selected recorded information. 6481

The OTC Data Tool shall allow users to save customised search criteria and graphical output for their use only. 6484

The OTC Data Tool shall allow users to save customised search criteria and graphical output for use by other users. 6485

The OTC Data Tool shall allow users to create new search criteria and graphical output by editing existing search criteria. 6486

The OTC Data Tool shall allow users to set up any search criteria and graphical output to run automatically at pre-set times or time intervals. 6487

The OTC Data Tool shall allow users to save customised reports for their use only. 6488

The OTC Data Tool shall allow users to save customised reports for use between users. 6489

The OTC Data Tool shall allow users to be able to create new reports by editing existing search criteria. 6490

The OTC Data Tool shall allow users access to trigger, individually, each of the Train control functions which can be controlled via the OTC. 6840

The OTC Data Tool shall allow users access to turn on all of the control functions, for each Train, which can be controlled via the OTC. 6841

This shall be used to prepare a Train for service and control sleet brushes and de-icing whilst the Train is in service.

The OTC Data Tool shall log which User has initiated any control functions on which Trains, such as to switch on and switch off Train consumers or to control the CIS VEIDs. 6868

Feedback shall be provided via the OTC Data Tool on the success of 6842 each control trigger and the response of the Train.

The OTC Data Tool shall provide the facility to display the status of each item of equipment, which is controlled via the OTC, for each Train. 6843

The OTC Data Tool shall provide a summary screen showing whether each Train has received the command to prepare for service and whether each Train is now ready for service. 6844

It shall be possible to apply logic which means that these control functions are only applied when the Train is situated in specific agreed locations. 6845

16 Mechanical 78

16.1 Structural Requirements 1329

16.1.1 Structural Requirements - General 4340

The structural requirements for all aspects of the Train design shall be in accordance with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', except where specific more demanding criteria are set-out elsewhere in this specification. 988

Although Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures' does permit the use of load cases derived from test, service or simulation data to support or to replace the loads specified (if technically justified), the defined loads should be regarded as minimum loads suitable for the LU environment. It is highly unlikely that reducing loads below those defined will be satisfactory in practice. 989

The Train shall provide a strong, mass efficient structure to provide the maximum practical protection to both passengers and staff in the event of an accident (collision or derailment). 990

The Train design shall meet all requirements over the full range of variations in condition that are likely to be experienced, including: 3892

- design tolerances for suspension characteristics, including ageing of components;
- loading conditions;
- maintenance tolerances that affect dynamic behaviour;
- wear and degradation of material, components and systems.

Structural integrity shall be maintained throughout the defined life of the Train whilst ensuring that weight and material usage is optimised. 991

Calculations shall be undertaken to demonstrate compliance with all structural requirements. 4315

All relevant loads shall be assessed to ensure that structures designed are fit for purpose. The loads specified are the minimum loads against which designs shall be assessed, but are not to be used as the definitive design load cases. Where necessary, the loads specified shall be enhanced, and additional load cases devised. 965

All items of Train-mounted equipment shall remain securely attached under normal operating conditions and as far as is practicable, during collisions or derailments. 2510

The effect of all mounting holes and brackets, access holes and other 4112 stress concentrating features shall be assessed.

Materials selected for structural components shall be ductile within the expected temperature range in the LU operating environment. 5258

Welding shall be managed, executed and verified in accordance with British Standard BS EN 15085:2007 'Welding of railway vehicles and components'. 6736

16.1.2 Fatigue Strength - General 4317

The fatigue design life for structures or substructures, bogie structures or substructures, equipment attached to bodies, bogies or axles, and body to bogie connections, shall be determined and shall be at least equal to the design life of the Train. 962

The fatigue strength of bolted, riveted or welded structures of steel shall be assessed using British Standard BS 7608:2014+A1:2015 'Guide to Fatigue Design and Assessment of Steel Products' with a 2.3% probability of failure. 963

The fatigue strength of bolted, riveted or welded structures of aluminium shall be assessed using British Standard BS 8118-1:1991 'Structural Use of Aluminium. Code of Practice for Design' with a 2.3% probability of failure. 964

Equipment attachments shall withstand fatigue loading in accordance with British Standard BS EN 12663-1:2010+A1:2014 'Railway Applications - Structural Requirements of Railway Vehicle Bodies' 6.7.3. Longitudinal equipment inertia accelerations of at least $\pm 0.2g$ for 10^7 cycles (BS EN 12663-1:2010+A1:2014 Table 18) shall apply. 966

Fatigue strength shall be demonstrated using a cumulative damage approach. Partial fatigue damages shall be calculated for each of the fatigue load cases. The damages assessed for each case shall be added and the total damage for all load cases shall not exceed unity. 4101

16.1.3 Proof Strength - General 4318

The stress levels induced in the structures or substructures, bogie structures or substructures, equipment attached to bodies, bogies or axles, and body to bogie connections, as a result of each load case (whether that load case is defined in this specification or by the Manufacturer) shall be determined. 5181

The stress levels induced as a result of each load case shall, individually, not exceed the material yield stress or 0.2% proof stress so as to prevent any permanent deformations. 3810

The proof load cases defined in this specification shall not cause any 3811 structural instabilities.

The load cases defined in this specification shall not result in any slippage or movement of joints or interfaces between components or fixings. 5870

Proof strength calculations shall use an Uncertainty Factor S1 of 1.15, regardless of whether it is intended to test the structure. 995

16.1.4 Failure Mitigation - General 4320

Equipment and mountings shall be designed to take into account the consequences of failure. 2526

The risk of failure of equipment and mountings shall be reduced, where appropriate, by measures such as: 2528

- the over-design of mountings and attachments;
- the use of fasteners incorporating high strain energy;
- the provision of:
    - emergency or secondary restraints;
    - alternative load paths.

Secondary security / retention shall be used for the mounting of equipment where the loss of integrity of such mountings might lead to injury to persons. This shall not be achieved by redundancy, using parallel load paths. 4802

Any secondary retention system shall be demonstrably capable of retaining displaced equipment in a safe condition between routine maintenance inspections. 4310

16.2 Bogies and Suspension 79

16.2.1 Bogies - General 3788

The term bogie shall be taken to mean the bogie frame and all equipment mounted on it. 3863

Bogies for the Piccadilly line Train shall not have active steering. 5517

The Piccadilly line will be the first line upgraded. The Purchaser considers that the development risk of an actively steered bogie is greater than the benefit that might be obtained on the Piccadilly line.

As far as is practicable, bogies shall remain attached to carbodies during a derailment or collision. 3791

No part of the bogie frame shall touch any part of the carbody under any conditions of loading, both dynamically and statically. This shall take into account the full range of suspension movements including suspension failure conditions. 3897

The bogie shall enable routine (manual and automated) inspections (including of the structure), component replacement and component adjustments to be undertaken whilst the bogies are under the car by personnel working either from pits or alongside the car at rail level. 3898

Assessment of derailment risks on some existing LU fleets has resulted in designs deliberately preventing larger components such as traction motors being removable with the bogie in situ. 4951

It shall be possible to disconnect wheelsets from the bogie allowing the bogie to be lifted both alone, and with the carbody, to leave the wheelset as a free standing assembly. 3905

Wheelsets shall be held captive to the bogie without the need to fit additional restraints at the time of lifting. 3907

All bogies shall have provision for safe lifting of complete bogies using overhead slings and shackles, with no need for adjustment of bogie components afterwards. The bogies shall also have means for safe towing of bogies or complete vehicles via the bogies, using slings and shackles, without damage to the bogies and without hazard to personnel. Lifting eyes or holes shall be sized to fit standard slings and shackles appropriate to the load being lifted. 3906

It shall be possible to adjust bogie height to compensate for wheel wear, spring settlement and creep, without disconnection or complete removal of the carbody from the bogie. 3901

Machined datum points shall be provided to enable accurate checks to be made on bogie height settings and bogie frame squareness. 3903

The procedures for bogie height and car height calibration shall be compatible with the Manufacturer's stated specification for maintenance road geometry. 5269

Bogie frames shall be designed to avoid undesirable responses excited by bogie dynamics, and in particular those associated with the vibration of large mass equipment such as traction motors. 4347

16.2.2 Bogies - Structural Requirements 3832

The bogie frame shall withstand, without failure, all loads encountered in service. 3789

The bogie frame shall withstand, without failure, all loads encountered 3790 during foreseeable failure conditions including minor derailments and equipment failure.

A minor derailment, for the purpose of this requirement, shall be considered to be a derailment where the primary additional loading arises from the geometric deflections associated with one or more wheels leaving the rails and coming to rest on the track bed or associated components.

The bogie shall achieve its specified design life without rebuilding, repair or strengthening of any structural members. 3866

The bogie requirements detailed in this specification have been developed in accordance with British Standard BS EN 13749:2011 'Railway Applications - Wheelsets and Bogies - Method of Specifying the Structural Requirements of Bogie Frames'. Any additional requirements developed by the Manufacturer shall also be in accordance with BS EN 13749:2011. 3793

Bogie movement shall not cause strain to the carbody structure or to the interconnecting pipes, hoses and cables so as to reduce the life of the carbody, life of the services or impair the function of the services. 3895

Connecting pipes, cables and hoses between fixed points on the bogie, and equipment affixed to the bogie, and the adjacent carbody shall be located and secured such that there is no chafing, stress and strain on these connections. 3896

The following are the minimum bogie proof load cases to be assessed: 3812

- Vertical symmetric loads – The mass associated with the Crush Laden condition applied vertically in equal parts at the secondary suspension points plus the sprung mass of the bogie, reacted at the primary suspension. A dynamic factor of 1.5 shall be applied.
- Lateral loads – A load of 10kN + W/3 per axle applied laterally at the carbody centre of mass and reacted at the track. W is the vertical axle load in kN in the Crush Laden condition. The mass associated with the Crush Laden condition plus the sprung mass of the bogie shall be applied concurrently.
- Curving – Lozenging loads induced as a result of curving in the Crush Laden condition assuming all wheels are just slipping. The wheel/rail coefficient of friction shall be taken as 0.6. The mass associated with the Crush Laden condition plus the sprung mass of the bogie shall be applied vertically, concurrently.
- Track twist – Loads induced by the application of a track twist of 1:50 over the wheelbase of the bogie. The mass associated with the Crush Laden condition plus the sprung mass of the bogie shall be applied vertically, concurrently.
- Emergency braking – 1.5 times the loads induced as a result of an emergency brake application, including all forces induced by the brake assemblies themselves, including snatch effects. The

mass associated with the Crush Laden condition plus the sprung mass of the bogie shall be applied vertically, concurrently.

- Reaction of motor loads – 1.5 times the maximum loads induced onto the bogie frame resulting from motoring or dynamic braking in the Crush Laden condition. This shall include the effects of flashover and other relevant traction or braking failure conditions.
- Equipment inertia loads – equipment attached to the bogie frame shall be subject to the forces arising from the application of the accelerations in Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', with the exception of the vertical acceleration, which shall be taken as ±20g regardless of location.
- Jacking – The bogie shall be capable of withstanding the loads associated with jacking the bogie and half the Tare mass at the designated jacking points. A load factor of 2 shall be applied to the jacking loads.
- Craning – The bogie shall be capable of withstanding the loads associated with craning the bogie complete with all its equipment and wheelsets. A load factor of 2 shall be applied to the craning loads.

The following are the minimum bogie fatigue load cases to be assessed: 3821

- Vertical – A load of ±35% of the sum of the Tare mass and 25% of the Crush Laden mass shall be applied vertically at the secondary suspension points and reacted at the primary suspension for 10 million cycles.
- Lateral – A load of ±15% of the sum of the Tare mass and 25% of the Crush Laden mass shall be applied laterally at the carbody centre of mass plus ±50% of the bogie sprung weight applied in-phase laterally at the bogie centre of mass for 10 million cycles.
- Curving – Lozenging loads as indicated in the force table below shall be applied for the equivalent of 5 million km of Train running. The lozenging forces defined by this table act at the wheel treads along a line parallel to the bogie sideframe in equal and opposite directions on either side of the bogie. The resultant couple is balanced by lateral forces at the wheelsets.

Lozenging Force Range (kN)	Mid Range (kN)	Applied Cycles (cycles/km)
0-10	5	4700
10-20	15	130
20-30	25	14
30-40	35	3.3
40-50	45	1.1
50-60	55	0.45
60-70	65	0.21
70-80	75	0.11
80-90	85	0.06

- Twist – Track twist as indicated in the track twist table below shall be applied over the wheel base of the bogie for the equivalent number of km for the specified design life of the Train. The track twist figures defined by this table are total included angles of one rail relative to the other when viewed from across the track (i.e. a track twist range).

Track Twist (mrad)	Class Mid Point (mrad)	Applied Cycles (cycles/km)
0-4	2	1000
4-8	6	150
8-12	10	50
12-16	14	10
16-20	18	5
20-24	22	1
24-28	26	0.2

- Passenger loading/unloading case – The loads arising from passenger loading/unloading shall be applied in accordance with the table below:

% of Crush Load	Million Cycles
0 to 33 to 0	1.5
0 to 50 to 0	0.75
0 to 66 to 0	0.45
0 to 83 to 0	0.18
0 to 100 to 0	0.12

- Braking - The forces arising from using the friction brakes to decelerate the complete car at 1.4m/s². These forces shall be applied for 3 million cycles with the passenger load spectrum defined in the passenger loading/unloading table above.

- Motor torque – The peak motor torque applied once in motoring and once in braking per typical inter-station run shall be taken as one cycle. These forces shall be applied for 3 million cycles with the passenger load spectrum defined in the passenger loading/unloading table above.

- Equipment Inertia loads – Equipment mounted on the bogie shall be subject to the forces arising from the application of the accelerations defined in Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', with the exception of the vertical acceleration, which shall be taken as ±10g regardless of location. These accelerations shall be taken as acting simultaneously, in-phase to give the most disadvantageous combination for 10 million cycles. In cases where the equipment mass is large relative to the bogie frame itself, suitably conservative load cases may be derived by other means, including tests and calculations.

- Damper bracket – The load equivalent to ±1.3 times the damper blow-off setting shall be applied for 10 million cycles.

- Body to bogie connections – Appropriate loads arising from other body to bogie connections including (if fitted) anti-roll bars, lateral bump stops, etc. shall be applied to the bogie frame.

Axlebox-mounted equipment shall accommodate the following accelerations: 6701

Acceleration	Axlebox Mounted Equipment
Maximum vertical	50g
Root Mean Squared (RMS) Vertical	8g
Maximum Lateral	20g
RMS Lateral	3g
Maximum Longitudinal	5g

Detailed calculations, including a finite element analysis, shall be carried out to demonstrate that the strength of the bogie frame is adequate for all load inputs, including, but not limited to, the proof and fatigue load cases. The design and location of all pipework and cable cleating shall be established prior to undertaking structural analysis so that the effect of all mounting holes and brackets is realistically assessed. 3894

The bogie frame structure shall be tested statically to demonstrate compliance with the proof load cases and fatigue load cases. 4321

For the bogie frame static test, strain gauges shall be placed in any area where the calculated stress level is greater than 80% of the yield stress or the 0.2% proof stress of the material, in any area where the calculated damage is greater than 0.75, and in other locations determined either by the Purchaser or by the Manufacturer. 4322

Additional static loads shall be applied to enable the stresses arising from the fatigue loads to be derived. 4323

Accelerated fatigue life testing shall be undertaken upon successful completion of bogie frame static testing. 5965

Accelerated fatigue life testing shall incorporate all fatigue load cases. The number of cycles may be reduced to a minimum of 25% of those used for calculation and static test providing that the loads are factored up in a suitably conservative manner. 4326

The bogie frame, and any other components, used for the purpose of conducting the accelerated fatigue life testing shall not be used on a service Train or for static testing. 4327

On completion of testing any bogie used for accelerated fatigue life testing, which is not scrapped, shall be clearly identified such that it cannot be mistaken for a bogie which is fit for service. 5843

The bogie frame, and any other components, used for the purpose of conducting the bogie frame static test, shall not be used for the 5175 accelerated fatigue life test.

Bogie track testing shall be carried out to assess the life of the bogie frame on the London Underground line that the vehicle will ultimately operate on. 6059

Bogie track testing shall use either simulated (i.e. using weights to simulate passenger loading) or actual in-service fatigue data. 4328

New bogies shall not be run on the LU system until the defined bogie static testing has been successfully completed. 6026

For the bogie frame track test, strain gauges shall be placed in any area which has a fatigue damage of greater than 0.75 as calculated against the load cases used for fatigue assessment, and in any other locations at the discretion of either the Manufacturer or the Purchaser. 4329

For the bogie frame track test, the strain gauged bogie shall be run on track which has characteristics typical of the line on which the bogies will run in passenger service, for a distance of not less than 160km in both Tare and Crush Laden conditions. 4330

The time based strain signals from the bogie frame track test shall be subjected to a cycle counting technique and the results will be used to assess the fatigue damage. 4331

The bogie track test may be performed concurrently with the accelerated fatigue life test specified. 4332

A static bogie swing test shall be undertaken to demonstrate adequate clearance between carbody and bogie. Adequate allowance shall be made for tolerances and failure conditions. 4335

16.2.3 Suspension 4333

The suspension system characteristics shall give a low transmissibility of vibration to the bogie. 3868

The suspension system characteristics shall give a low transmissibility of vibration to the carbody. 3869

The suspension system characteristics shall minimise both impact and vibration noise. 3870

The bogies and the equipment mounted on them shall be designed to avoid undesirable responses excited by bogie dynamics. 3871

The suspension system characteristics shall be selected so as to avoid resonance between the various elements of the car system, including 3872 the carbody.

The suspension system characteristics shall ensure a frequency separation sufficient to avoid coupling between the bogie bounce and carbody vertical bending frequencies. The target shall be a 3Hz separation. 3873

The suspension system must ensure that the car height remains within the vertical height tolerance specified, considering the most disadvantageous limits of all relevant tolerance bands and taking into account manufacturing variations, ageing and temperature effects, wear, etc. 3875

The Train and its suspension shall be designed so that it does not impart excessive dynamic forces into the track under credible failure modes. 3889

Primary suspension components located on the axlebox shall be made captive for the safety of maintenance and recovery staff. 3900

Secondary air suspension shall not be fitted. 3874

16.2.4 Adhesion Modifiers 80

The Purchaser currently primarily uses track mounted grease based lubricators, supplemented by trainborne lubrication (solid stick lubricants) on some lines. 3015

The Purchaser is working towards the replacement of the track based lubricators with Train mounted lubrication system(s) as the primary means of wheel/rail lubrication, with the intention of phasing out track mounted units. 3016

A lubrication system shall be fitted to manage friction at the wheel rail interface (WRI). 3017

The WRI lubrication system shall minimise the need for track based lubrication. 6573

The WRI lubrication system may be a combination of solid and spray based lubricators. 5381

The WRI lubrication system shall target a 0.35 coefficient of friction between the wheel tread and the top of rail. 4115

The WRI lubrication system shall consistently provide between 0.25 and 0.35 coefficient of friction between the wheel tread and the top of rail. 7048

The WRI lubrication system shall deliver a coefficient of friction no higher than 0.10 between the wheel and the rail at the wheel flange to gauge corner. 3667

The WRI lubrication system shall deliver a coefficient of friction no higher than 0.10 between the wheel and the rail at the wheel flange to the face of the rail. 6684

The WRI lubrication system shall deliver a coefficient of friction no higher than 0.10 between the wheel and the rail at the wheel back of flange to check rail. 4114

There shall be space provided at each wheel location to enable the fitting of solid stick lubrication and friction modifier dispensers to enable the relocation of dispensers, or fitting of additional dispensers, along the Train to optimise the performance. 3020

The WRI lubrication system shall provide consistent lubrication to the wheels so that wheel wear rates throughout the Train are not irregular. 5839

The capacity of the consumables for the WRI lubrication system shall be maximised in order to maximise refilling intervals. 4731

LU has experience of fitting solid stick lubrication dispensers, spread evenly along the Train on both wheels of individual axles at 30% of positions. 3030

The WRI equipment shall incorporate any adjustment features necessary to enable correct positioning of the dispensed material at: 3032

- initial set-up on the vehicles;
- after wheel turning;
- after replacement.

The lubrication dispensing system shall not require adjustment between wheel turning intervals. 5382

The lubrication dispensing system shall continue to accurately dispense lubricant between wheel turning intervals. 5383

Any spray based lubrication system shall be controllable so that it can be isolated by depot based maintenance staff. 5384

It shall be possible to adjust the dispensing rate of the spray based lubrication during system development and in light of service experience. 5385

It shall be possible to adjust the geographic locations where the spray based lubricant is dispensed. 5386

It shall be possible to adjust the geographic locations where the spray based lubricant dispenses via a local update on the Train. 5387

It shall be possible to adjust the geographic locations where the spray based lubricant dispenses via RCS and via the OTC. 6685

The trainborne lubrication system shall not adversely affect the performance of the traction, braking and signalling requirements of the Train in all conditions. 5388

The trainborne lubrication system shall be compatible with any other trainborne dispensed materials. (e.g. sand). 5389

The Manufacturer shall implement a comprehensive wheel wear data collection and monitoring program during the testing, service introduction and warranty period to demonstrate the effectiveness and stability of the lubrication at the wheel-rail interface. 5390

The Purchaser will be carrying out a comprehensive rail data collection and monitoring program to demonstrate the effectiveness and stability of the lubrication at the wheel-rail interface (e.g. wheel and rail profiles and rates of change, noise, ride comfort and rail condition). The information provided by the Manufacturer will be an essential part of this process.

The Manufacturer shall collaborate with the Purchaser to develop a jointly agreed migration strategy for the introduction of the new Train and the removal of track based lubrication. 5391

The lubrication system shall avoid irregular wear patterns of the wheel which cannot be managed by the application of the wheel maintenance regime. 5392

Examples of such defects include double hollow treads.

The lubrication system shall not require removal when wheel turning takes place. 5393

A method shall be provided to protect nozzles from swarf contamination during wheel turning. 5394

16.2.5 Lifeguards 3814

All leading bogies shall be fitted with lifeguards in accordance with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures'. 3820

16.2.6 Obstacle Detection 82

Obstacle detection shall be provided, at each end of the Train, to reduce detrimental consequences to passengers and property from 967 collisions with obstacles on the track.

Obstacle detection shall apply the emergency brake when it detects an obstacle on the track in front of the Train. 968

The specification of obstacles to be detected shall be defined by a specific task analysis or safety risk assessment and agreed with the Purchaser. 969

Detection of an obstacle shall be reported to the RCS. 971

There shall be a method to bypass the emergency brake application caused by application of the obstacle detection, which shall be accessible to the maintainer. The obstacle detection part of the system design shall still operate and any obstacle detections shall be reported, even when this bypass has been selected. 6686

16.2.7 Derailment Detection 5021

Derailment detection shall be fitted to all axles on the first two bogies at each end of the Train. 5022

Detection of a derailment shall cause the emergency brakes to apply. 5024

Detection of a derailment shall be reported to the RCS. 5025

There shall be a method to bypass the emergency brake application caused by derailment detection, which shall be accessible to the maintainer. The derailment detection part of the system design shall still operate and any derailment detections shall be reported, even when this bypass has been selected. 6687

16.2.8 Rough Ride Detection (RRD) 6938

Rough Ride Detection (RRD) functionality is used to detect and report serious track defects. When a Train is exposed to track accelerations which are above defined threshold levels Notifications will be sent to the RCS and OTC. RRD data from all Trains will be analysed by the RCS and the OTC to identify substandard track conditions. 6912

RRD transducers shall be fitted to the first bogie at each end of the Train. 6911

A single vertical RRD accelerometer shall be fitted on one axlebox and both a vertical and a lateral RRD accelerometer shall be fitted on the axlebox on the opposite end of the same axle (3 axlebox RRD accelerometers in total per RRD equipped bogie). 6915

A tri-axial accelerometer shall be fitted near to both the leading and 6917 trailing extremities of the bogie, one on each side, diagonally opposite each other on the bogie structure (2 tri-axial RRD accelerometers in total per RRD equipped bogie).

The technical characteristics of each RRD accelerometer shall ensure that the transducers accurately reflect the true vibrations of the axlebox and bogie resulting from track inputs. 7103

The mounting arrangement for RRD accelerometers shall ensure that the transducers accurately reflect the true vibrations of the axlebox and bogie resulting from track inputs. 6916

Signals from all RRD accelerometers shall be: 6919

- appropriately conditioned;
- sampled at a rate that will adequately reflect the frequency ranges which need to be detected;
- processed using an A to D converter that has suitable resolution and dynamic range;
- speed corrected (i.e. normalised to compensate for Train speed). This may take the form of a correction factor such as a X Log10 (V/V0) relationship (where V is the train speed and V0 a reference speed);
- cropped such that data captured below a lower cut-off Train speed is discarded for calculation purposes. The cut-off speed shall be configurable for each transducer channel independently whether speed corrected or uncorrected;
- stored with Train speed, time and location inputs.

The RRD shall sample the processed RRD data from all RRD accelerometers at a minimum sampling frequency of 40 ms. Each data sample shall contain both average (r.m.s.) and peak values within the discrete sampling time period expressed in terms of acceleration in m/s^2. 6920

It shall be possible for the Purchaser to configure RRD data filtering for individual data channels to band limit the signal. 6921

Both speed corrected and non-speed corrected RRD data shall be calculated. 6924

The RRD shall provide, for each of the bogie mounted RRD tri-axial accelerometers, a vector sum of the outputs from the three directions (X, Y & Z). (Summated output = Square root of X squared plus Y squared plus Z squared). 6925

The RRD shall provide, for each of the bogie mounted RRD tri-axial accelerometers, a root mean quad vector sum value. 6976

The processed data values from each RRD transducer, as well as the calculated vector sums, shall be compared to a set of defined (configurable) threshold values and if these thresholds are exceeded a Notification shall be sent to the service control centre via the RCS and the OTC. 6929

The RRD detection thresholds will be set by the Purchaser. 6956

The RRD shall provide a number of different configurable threshold values for each signal which can be combined to determine the appropriate Notification which is required to indicate different levels of severity of rough ride. 6930

The vibration level thresholds at which the Train reports RRD exceedances shall be configurable by the Purchaser. 6913

The Notifications for each rough ride severity level shall contain sufficient information to allow appropriate action to be taken by the Purchaser's operational and maintenance staff including but not limited to: 6931

- category (severity) of trigger;
- vibration value calculated;
- threshold level breached;
- position of measurement on the Train;
- Train identification;
- Train location;
- time.

The RRD shall be able to automatically detect and report any significant wheel defects on the measurement wheelset that may unduly affect the RRD performance. 6934

RRD log files recording all aspects of the behaviour of the RRD function shall be available for fault investigation and system diagnostics. These log files shall be stored locally on the Train, in readable plain text format, for a minimum period of 15 days and shall be available for manual download to a portable device via a secure access port. 6936

It shall be possible for Purchaser staff to locally connect to the Train via a secure ethernet port interface in order to: 6926

- view and modify RRD configuration settings;
- view and download RRD log files.

It shall be possible to download RRD log files via the RCS. 6928

It shall be possible to download RRD log files via the OTC. 6927

The OTC Data Tool shall be used to process multiple RRD Notifications and inputs from all Trains at the service control centre. 6958

Replacement of RRD transducers shall have no detrimental effect on the RRD function and performance. The system shall automatically pick-up the transducer characteristics and compensate for differences in transducer sensitivities. *This could be achieved using transducers with TEDS (Transducer Electronic Data Sheets) or equivalent.* 6933

16.2.9 Shoegear 83

16.2.9.1 Shoegear - General 3750

The term Shoegear is used by London Underground to describe the part of the traction system which picks up traction current from the top contact conductor rails. 3571

The Shoegear installation on a single bogie shall comprise two positive Shoegear, one each side, and one negative Shoegear, centrally located. 3590

Shoegear shall be fitted on the outer end bogies. 5173

The Shoegear shall, under failure conditions, have failure modes such that the risks of the following are reduced to ALARP: 3565

- Derailment;
- Injuries and damage due to displaced conductor rail;
- Detached parts;
- Arcing;
- Damage to the Train.

The Train shall detect when any individual collector shoe is missing and this shall be reported to RCS. 3582

Shoegear shall be sufficient in number and positioned along the Train length to ensure that the risk of gapping is minimised for the conductor rail installation. 3585

The contact forces between the Shoegear and the current rails shall be minimised consistent with both the electrical performance required and the objective of minimising both electrical and mechanical wear of the shoes and the current rails. 3568

16.2.9.2 Shoegear - Electrical Requirements 3751

Shoegear shall maintain good electrical contact with the traction supply, when the Train is stationary and in motion, to minimise arcing. 975

The connections between collector shoes on different bogies shall not cause current rail section gaps to be bridged. The minimum infrastructure current rail section gap length is 14m. 972

Shoegear and cabling shall operate within its thermal design both when all shoes are present and also when any one shoe is missing. 974

Shoegear shall be prevented from becoming live when the Train is provided with traction power via a shed receptacle lead. 3586

The overall current collection equipment provided on the Train shall be thermally rated to enable the Train to operate normally (i.e. sustain its normal performance) with one shoe missing. 3588

Shoegear assemblies shall be capable of handling all envisaged peak currents for all credible durations. 3593

Shoegear shall not be damaged by fault currents on the Train. The predicted worst case fault conditions are contained in LU Standard 1-124 'Low Voltage AC and DC Power Supply Parameters, Characteristics and Performance Requirements' clause 3.1.5. 3769

Shoegear shall be compliant with the test cycle defined in British Standard BS EN 50123-2:2003 'Railway Applications - Fixed Installations - DC Switchgear', Table 3, Duty 1. 3771

The design and installation of Shoegear assemblies shall ensure that the risk of inadvertent electrical contact by a person with any live component is ALARP. This requirement also applies to passengers falling between Train and platform who could come into contact with the Shoegear. 3597

A flexible shunt connection on the Shoegear shall ensure that no current passes through any of the moveable joints within the Shoegear. 3758

The connections at both ends of the Shoegear flexible connection shall not cause fretting or damage that may lead to premature failure of the component. 3761

The construction of the Shoegear flexible connection shall not let it sag or behave in an uncontrolled manner that may lead it to infringe the gauge, fail to meet the creepage and clearance requirements or become damaged. 3762

Provided the Shoegear flexible connection is physically located within the shoegear equipment assembly, so that there is no credible risk of contacting it without having contacted any of the surrounding electrified metal components, then there is no requirement for the flexible connection to be insulated. Insulating the flexible component may compromise its flexibility and result in an increased risk of overheating. 3763

16.2.9.3 Shoegear - Mechanical Requirements 3752

The shoegear mechanical requirements are intended to ensure that Shoegear are strong enough to withstand normal service loads but not so strong that they will damage any rail, rail support, sleeper or any other part of the railway infrastructure and that they do not excessively wear conductor rails.. 3600

The Shoegear shall incorporate a frangible link that allows the collector shoe to break off in a controlled manner, without causing damage to the remaining Shoegear, other trainborne equipment or infrastructure. 976

LU Standard S1164 'Conductor Rail – Dimensions and Tolerances' contains details of conductor rail dimensional tolerances which shall be used in defining design load cases for the Shoegear. 3604

Collector shoes shall have a tapered face at both ends and along both sides. 5184

The Shoegear frangible link shall withstand normal service loads resulting from continuous operation over the worst track conditions without breakage. 3572

The Shoegear frangible link shall not suffer fatigue failure prior to planned component replacement as part of normal Shoegear maintenance. 5234

The Shoegear frangible link shall not fail when subjected to 500,000 impacts with a 5^{o} (to the horizontal) conductor rail ramp at an impact speed of 15m/s. 3747

The Shoegear frangible link shall not fail when subjected to 50,000 impacts with a 5mm vertical discontinuity (square edged) at an impact speed of 15m/s. The first 10,000 impacts shall be with a shoe in the “as new” condition, the next 30,000 impacts with the shoe 50% worn and the final 10,000 impacts shall be with a fully worn shoe. 3748

The Shoegear frangible link shall not be damaged by bending moments or lateral forces resulting from contact with a conductor rail ramp and also running on conductor rail where the outer edge of the base surface of the shoe is the contact point. 5182

The Shoegear shall withstand, without damage, the forces likely to be encountered when passing over ice adhering to the conductor rail surface. 3579

The Shoegear frangible link shall break at the lowest input energy compatible with the service performance requirement detailed above. 5233

The Shoegear frangible link shall break in the event of striking a fixed obstacle, or a freely moveable obstacle giving rise to the force 3573 equivalent to an obstacle of mass of 10kg struck at full Train speed.

The Shoegear frangible link shall break in the event of the shoe running off the top and onto the side of a conductor rail. 3574

The Shoegear frangible link shall break at lateral / vertical inputs lower than would be required to turn over conductor rail. 3575

The mass which becomes detached in the event of a frangible link breakage shall be kept to a minimum. 5235

On breakage of the Shoegear frangible link the shoe shall detach completely from the Train. 3576

On breakage of the Shoegear frangible link, it shall not be possible for the remaining parts of the Shoegear to make electrical contact or physical contact with any other part of the Train or track infrastructure. 3577

On breakage of the Shoegear frangible link, it shall not be possible for the remaining parts of the Shoegear to infringe the swept envelope. 3578

On breakage of the Shoegear frangible link, the Shoegear which remains shall be undamaged and fully operational once components designed to break and detach have been replaced. 5237

Shoegear shall accommodate the following proof accelerations: 3580

Acceleration	Bogie Mounted Shoegear	Axlebox Mounted Shoegear
Maximum vertical	20g	50g
Root Mean Squared (RMS) Vertical	8g	8g
Maximum Lateral	3g	20g
RMS Lateral	3g	3g
Maximum Longitudinal	5g	5g

The collector shoe and frangible link parts of the Shoegear shall withstand the accelerations below, which shall be taken as acting in phase, to give the most disadvantageous combination, for 125,000 cycles. 3746

Acceleration	Bogie Mounted Shoegear	Axlebox Mounted Shoegear
Maximum vertical	20g	50g
Root Mean Squared (RMS) Vertical	8g	8g
Maximum Lateral	3g	20g
RMS Lateral	3g	3g
Maximum Longitudinal	5g	5g

The following clearances shall be provided with the Train in the Tare condition: 3601

Negative collector shoe (free hanging) to running rail level	25mm (+0, -2)
Axle related positive collector shoe (free hanging) to running rail level	58mm (+0, -2)
Bogie frame related positive collector shoe (free hanging) to running rail level. NB This assumes primary suspension less than 26mm, and it is expected that frame related shoe will not be possible with greater primary suspension movement.	63mm (+0, -2)

16.2.9.4 Shoegear - Isolation 3753

The Shoegear shall have a facility to provide full electrical and mechanical isolation between the Shoegear and current rails to safely disconnect a car from the electrical traction supply. 978

The Shoegear isolation facility shall be provided within the Shoegear mechanism or shall require the use of only one hand tool to operate it. 3772

It shall be possible for a single person to manually lift and secure the Shoegear in the raised position. 3595

It is considered acceptable to use a mechanical aid to achieve this.

When raised, any collector shoe shall be more than 153mm above the running rail under worst case conditions. 3596

16.2.9.5 Shoegear - Maintenance 3773

A wear indication shall be provided on each collector shoe which shall clearly indicate whether or not the shoe is capable of continuing in service, under normal operating conditions, until the next planned maintenance examination. 3774

It shall be possible to visually inspect and replace the maintainable components of the Shoegear from a pit without requiring the removal of adjacent equipment. 3778

A collector shoe vertical height adjustment mechanism shall be provided to compensate for the maximum wheel radial wear and for collector shoe wear. 3782

The shoegear adjustment mechanism shall be completely independent of the Shoegear mounting. 3783

The shoegear adjustment mechanism shall maintain the shoe parallel to the conductor rail along its length. 3784

It shall be possible to easily adjust collector shoe height and secure in position. 3599

The collector shoe height adjustment mechanism shall be designed so that shoes do not move out of adjustment as a result of dynamic inputs during normal service. 3779

It shall be possible to gauge the height of the collector shoe using the running rail as a reference. 3781

It shall be possible to change the consumable part of the Shoegear without disturbing the flexible electrical shunt connection. 3785

16.2.10 Brake Equipment 84

There shall be no features which permit snow and ice to accumulate on or around brake equipment such that a reduction in the braking effort is caused. 2432

There shall be no features which permit snow and ice to accumulate on or around brake equipment such that a delay in brake application is caused. 2431

The brake block force shall be high enough to avoid gross loss of block friction due to the presence of water between the block and wheel in wet weather. 2710

The SAPB shall be fitted with a manual release mechanism to permit the SAPB to be disengaged for block/pad changing. This release mechanism shall not require the removal of adjacent equipment to access it. 2727

The manual release mechanism for the SAPB shall provide a clear indication to a maintainer in a depot pit road as to whether an SAPB actuator is in an ‘operative’ or 'released' state. 2728

It shall not be possible manually to release an SAPB without first discharging the air supply to the spring actuator sufficiently to cause the actuator to apply. 2729

The manual release mechanism shall automatically reset on the admission of air into the SAPB actuator. The SAPB shall fully release and the manual release shall reset when the SAPB cylinder pressure is greater than the air brake cylinder pressure required to meet the defined parking brake performance. 2730

The slack adjuster shall take up excessive clearance during brake application and release cycles and shall take up the maximum clearance (i.e. new block fitted but fully retracted) in the minimum number of applications. 2734

Slack adjuster function shall not be adversely affected by deflection of the bogie primary suspension and, under the worst case conditions, the friction brake clearance with the brake released shall not be less than 1mm. 2735

Uneven block/pad wear shall not occur. 2736

The slack adjuster mechanism shall incorporate a facility to enable the rapid retraction and extension of the brake cylinder push rod and thus enable brake blocks to be changed quickly. 2737

The Friction Braking Pair shall accept and dissipate the full braking energy arising from the defined braking duty without any adverse effect on the Friction Braking Pair components or a change in the Friction Braking Pair friction characteristics. 2753

The impact of contaminants such as oil, grease and adhesion modifiers, on the friction brake characteristic shall be minimised. 2752

16.2.11 Wheelsets 86

16.2.11.1 Wheelsets - General 4342

Wheelsets shall be in accordance with British Standard BS EN 13260:2009+A1:2010 'Railway Applications - Wheelsets and Bogies - Wheelsets - Product Requirements', BS EN 13103:2009+A2:2012 'Railway Applications - Wheelsets and Bogies - Non powered Axles - Design Method', BS EN 13104:2009+A2:2012 'Railway Applications — Wheelsets and Bogies — Powered Axles — Design Method', and BS 8535:2011 'Railway Applications - Wheelsets and Bogies - Powered and Non-Powered Axles with Inboard Bearings - Design Method' as applicable with additional requirements detailed in this specification. 4293

Wheelsets and their component parts shall be designed to have an infinite fatigue life. 3483

Wheelsets and their component parts shall fulfil all the fatigue load requirements for bogies. 3488

Wheelsets shall use the LT5 wheel profile, as defined on LU Drawing 92667 'LT5 Wheel Profile'. 3476

The factors to be taken into account when calculating the wheelset fatigue life shall include, but are not limited to: 3479

- the full range of dimensional variations of the wheelset components throughout their life (e.g. wear and turning effects);
- mechanical loads input from the track and the car;
- mechanical loads produced by traction, braking, and other

axle-mounted and axlebox-mounted components and loads imposed from transmission components;

- additional force inputs due to the effects of predictable tread defects. (e.g. wheel flats, cavities, pitting, crazing or spalling and RCF);
- torsional vibrations;
- centripetal force effects;
- the interference fit effects of the wheel and any other component secured to the axle by an interference fit;
- stress concentrating mechanisms (e.g. surface finish, geometry, holes);
- residual stresses, whether a result of manufacture or mode of operation;
- impact damage from ballast;
- corrosion damage;
- thermal effects of the fit of the wheel and any other component secured to the axle by interference fit that is subject to a significant rise in temperature;
- thermal effects produced by friction brake components;
- thermal effects of pushing a Train with SAPBs applied.

The wheel back to back dimension shall be 1358mm for outside bearing wheelsets or 1356mm for inside bearing wheelsets. 3494

The axial run-out of the inside face of the wheel when measured on the flange back face of the wheel at a point 60mm below the flange tip shall be within 0.5mm. 3495

Ultrasonic testing of axles shall be carried out in accordance with British Standards BS EN 13260:2009+A1:2010 'Railway Applications - Wheelsets and Bogies - Wheelsets - Product Requirements' Clause F3.2 or BS 5892-8:2012 'Railway Rolling Stock Materials. Part 8: Railway Applications - Wheelsets and Bogies - Powered and Non-Powered Wheelsets with Inboard Bearings - Product Requirements' Clause D3.2. 3497

The axle design shall incorporate sufficient protection to prevent detriment to the axle due to corrosion, impact from flying debris including ballast, and handling during maintenance and storage in accordance with British Standard BS EN 13261:2009+A1:2010 'Railway Applications - Wheelsets and Bogies - Axles - Product Requirements', Table 11 Class 3. 3500

All axles shall have any exposed portions of axle between the road wheels protected from possible electrical burning during service using axle wrapping, or an equivalent solution. 3502

Axle wrapping, and equivalent axle protection solutions, shall be firmly secured with no loose ends, fraying etc. 3504

Any final coating, wrapping or fastening on an axle shall be painted with grey gloss paint. The axle number shall be clearly stencilled on the finished axle in 50mm high white numerals. 3505

The axle protection solution which is used on modern LU fleets consists of the following typical protection application process: 7131

- *a coat of suitable corrosion resistant (red oxide or epoxy based) primer paint is applied to all exposed portions of the axles between the wheel bosses on the fully assembled wheelset and allowed to dry thoroughly;*
- *the axle is wrapped with self adhesive glass cloth tape which has been cut to the required length and having a suitable width to ensure a generous lap joint;*
- *the glass cloth tape is secured firmly using suitable cable ties or tape;*
- *the 'axle wrapping' is finally coated with a suitable epoxy based paint (i.e. which is resistant to fire, heat, abrasion and corrosion).*

This 'axle wrapping' type of axle protection, when used with an appropriate inspection regime to identify and assess mechanical damage, is considered to meet the axle protection requirements of this specification.

The maximum permitted diameter differential between wheels on the same wheelset shall be no more than 5mm. 5186

The permitted wheelset diameter differentials shall be declared at the tender stage. 4667

16.2.11.2 Wheelsets - Axles 3516

Axles, and all associated testing and validation of axles, shall be in accordance with Category 2 of British Standard BS EN 13261:2009+A1:2010 'Railway Applications - Wheelsets and Bogies - Axles - Product Requirements' with additional specific requirements as detailed below. 3507

Axlebox bearings shall be compliant to British Standard BS EN 12080:2007+A1:2010 Railway applications - Axleboxes — Rolling bearings. 6116

Axlebox lubricating greases shall be compliant to British Standard BS EN 12081:2007+A1:2010 Railway applications - Axleboxes - Lubricating greases. 6117

Axleboxes shall be subjected to a rig test and a field test in accordance 6118 with British Standard BS EN 12082:2007+A1:2010 Railway applications - Axleboxes - Performance testing.

Axles shall be manufactured from Grade EA1T steel. Alternative steel grades may also be acceptable subject to the Manufacturer demonstrating, to the satisfaction of the Purchaser, that the alternative material has equivalent, or better, structural performance for the specific application. 3509

Axle markings and axle serial numbers shall be cold stamped on opposite ends of each axle. The finish and position of markings shall be compatible with the use of ultrasonic test equipment. 3510

16.2.11.3 Wheelsets - Wheels 3517

Wheels, and all associated testing and validation of axles, shall be in accordance with Category 2 of British Standard BS EN 13262:2004+A2:2011 with additional specific requirements as detailed below. 3518

Wheels shall be manufactured from Grade ER9 steel. Alternative steel grades may also be acceptable subject to the Manufacturer demonstrating, to the satisfaction of the Purchaser, that the alternative material has equivalent, or better, structural performance for the specific application. 3519

Wheel markings shall be in accordance with British Standard BS EN 13262:2004+A2:2011, Clause 3.10, with the following additional marks applied: 3520

- The letter 'U' (to indicate that an ultrasonic test has been carried out);
- The wheel serial number as allocated by the Purchaser;
- All stampings shall be 10 mm high;
- The wheel serial number shall be stamped on the outside face of the wheel on the radius between the wheel boss and the web.

16.3 Carbody 88

16.3.1 Carbody Structural Performance 1333

16.3.1.1 Carbody Structural Performance - General 5912

The carbody shall meet the requirements of Category P-III in British Standard BS EN 12663-1:2010+A1:2014 'Railway Applications - Structural Requirements of Railway Vehicle Bodies', with specific modifications and additional requirements as detailed in this specification. 997

The natural modes of vibration of the carbody, in all operating conditions, shall be separated sufficiently, or otherwise decoupled, from the suspension frequencies, so as to avoid the occurrence of undesirable resonances. 998

The carbody structure shall be sufficiently rigid to ensure consistent door operation over the range of passenger loadings. 999

In order that carbody structures can cope with the full range of variations and uncertainties in car condition that are likely to be experienced throughout the life of the car, account shall be taken of all influential factors including: 2502

- tolerances in car dimensions and masses;
- loading variations and asymmetries;
- normal variations in car maintenance and condition.

The following carbody structural tests shall be carried out: 4116

- In order to validate the calculations, and to demonstrate the ability of the carbody to withstand the loads likely to be encountered, the car body structure shall be tested statically to demonstrate compliance with the defined proof load cases and fatigue load cases;
- Strain gauges shall be placed in any area where the calculated stress level is greater than 80% of the yield stress or the 0.2% proof stress of the material, wherever the calculated fatigue damage exceeds 0.75, and in other locations determined either by the Purchaser or by the Manufacturer;
- Additional static loads shall be applied to enable the stresses arising from the fatigue loads to be derived;
- Partial fatigue damages shall be calculated for each of the fatigue load cases;
- The damages assessed for each case shall be added and the total damage for all the load cases shall not exceed unity;
- Modal parameters shall be measured.

The life of the carbody shall be assessed by using simulated or actual in-service fatigue data: 4117

- Strain gauges shall be placed in any area which has a calculated fatigue damage of greater than 0.75, and in any other locations at the discretion of the Manufacturer or the Purchaser;
- The strain gauged car body shall be run on track which has characteristics typical of the line on which the cars will run in passenger service, for a distance of not less than 160km in both Tare and Crush Laden conditions;
- The time based strain signals so acquired will be subjected to a cycle counting technique and the results will be used to assess the fatigue damage.

Detailed calculations, including a finite element analysis, shall be carried out to demonstrate that the strength of the carbody is adequate for all load inputs, including, but not limited to, the proof and fatigue load cases. The design and location of all fittings shall be established prior to undertaking such a structural analysis so that the effect of all mounting holes and brackets is realistically assessed. 4113

The carbody used for structural testing shall not be used in a production Train unless it can be proven that the carbody is fit for the full design life. 5031

16.3.1.2 Carbody Proof Strength 1335

The compressive force at buffer level (British Standard BS EN 12663-1:2010+A1:2014 'Railway Applications - Structural Requirements of Railway Vehicle Bodies' Table 2) shall be 1000kN. 1001

The tensile force in the coupler area (British Standard BS EN 12663-1:2010+A1:2014 'Railway Applications - Structural Requirements of Railway Vehicle Bodies' Table 5 and Table 12) shall be 200kN. This load shall also be applied in compression as an additional load case. 1002

A load case shall simulate the carbody twist condition corresponding to the derailment of one bogie with the other remaining on flat track: 1003

- The derailed bogie shall have its secondary suspension acting in its most disadvantageous condition;
- There shall be a vertical difference of 130mm in wheel height between the wheels on one side of the derailed bogie (at rest on sleepers) and the opposite wheels (lodged on a rail);
- The carbody shall be in Crush Laden condition plus a 15% dynamic increment.

The carbody shall support the total weight of a motored bogie when that load is reacted at the carbody trailing end secondary suspension point and the leading end cab anti-climb position. 1004

16.3.1.3 Carbody Fatigue Strength 1336

Carbody fatigue strength shall be demonstrated using a cumulative damage approach. Partial fatigue damages shall be calculated for each of the following fatigue load cases: 1006

- 100 million cycles of stress fluctuating at ±10% of the vertical stresses for the loading condition of all seated passengers, with no standing passengers;
- 10 million cycles of stress fluctuating at ±10% of the vertical stress for the Crush Laden condition;
- 1 million cycles of stress fluctuations caused by a lateral acceleration of ±0.1g for the loading condition of all seated passengers, with no standing passengers;

- 2 million cycles of stress fluctuations caused by passenger loading/unloading comprising the following load ranges:

Passenger load range	Cycles x 10^6
33% Crush Laden	1.00
50% Crush Laden	0.50
66% Crush Laden	0.30
83% Crush Laden	0.12
100% Crush Laden	0.08

- Stress cycles induced from track twist (twist range is the amount over a 10m base, by which one point of the four is out of plane with the other three) with the 10m track twist spectrum detailed below:

Twist Range (mm)	Cycles/km
10	600.0
15	22.0
25	8.0
35	3.0
50	2.0
70	1.5
100	0.2

The damages assessed for each case shall be added and the total damage for all load cases shall not exceed unity.

16.3.2 Crashworthiness 1337

The carbody shall provide effective and comprehensive protection of the Train Operator and passengers with a train-wide crashworthiness approach. This shall include elements such as collapse zones that will absorb energy in a controlled and predictable manner, while maintaining suitably low decelerations so as to avoid unnecessary injury. 2339

The collision scenarios against which assessments of crashworthiness shall be made are contained within this specification. The methods and criteria for demonstrating achievement of the crashworthiness performance objectives shall be in accordance with British Standard BS EN 15227:2008+A1:2010 'Railway Applications. Crashworthiness Requirements for Railway Vehicle Bodies'. 1008

In the event of a collision, the carbody design shall be such that deformation of the end section of the car occurs before other parts of the carbody are damaged. 2255

As far as is practicable, body structures shall not collapse in an uncontrolled manner as a result of high longitudinal loads encountered during rough couples and collisions. 2264

In respect of a rough couple between one Crush Laden Train travelling at 3km/h and a similar but stationary Crush Laden Train with its brakes applied and a wheel to rail coefficient of friction of 0.3, the coupling systems shall not sustain any damage or loss of serviceability. 2269

The collision mass to be used in this scenario shall be calculated in accordance with British Standard BS EN 15227:2008+A1:2010 'Railway Applications. Crashworthiness Requirements for Railway Vehicle Bodies' - the design mass in working order plus the mass of 50% of seated passengers.

In respect of a collision between one Crush Laden Train travelling at 10km/h and a similar but stationary Crush Laden Train with its brakes applied and a wheel to rail coefficient of friction of 0.3, the carbody structure (and local wiring and pipework) shall not sustain any damage, though operation of the energy absorption feature of couplers and anti-climb features may occur. 2271

The collision mass to be used in this scenario shall be calculated in accordance with British Standard BS EN 15227:2008+A1:2010 'Railway Applications. Crashworthiness Requirements for Railway Vehicle Bodies' - the design mass in working order plus the mass of 50% of seated passengers.

In respect of a collision between one Crush Laden Train travelling at 16km/h and a similar but stationary Crush Laden Train with its brakes applied and a wheel to rail coefficient of friction of 0.3, the passenger survival space shall remain intact. 6098

The collision mass to be used in this scenario shall be calculated in accordance with British Standard BS EN 15227:2008+A1:2010 'Railway Applications. Crashworthiness Requirements for Railway Vehicle Bodies' - the design mass in working order plus the mass of 50% of seated passengers.

Energy absorption elements which, having been put to use, are unserviceable shall be able to be clearly and easily identified as such. 5256

The energy released during a collision giving an impact force in excess of 1MN shall be absorbed by gradual collapse of the carbody, occurring at the car end. 2280

Structural collapse of the main passenger compartment of the carbody shall not occur until collision impact forces greater than 2.5 MN are encountered. 2281

At both ends of every car, a means of override prevention shall be fitted, to prevent one car from riding up over the adjoining car. 2336

In the event of a derailment or collision, cars in a Train shall remain coupled. 992

In the event of a derailment or collision, cars in a Train shall resist jack-knifing as far as is reasonably practicable. 2211

In the event of a derailment or collision, cars in a Train shall be designed such that the risk of injury to passengers and operators due to structural failure is ALARP. 2212

In the event of a derailment or collision, cars in a Train shall maintain as far as practicable the integrity of the occupied compartments. 2213

The Train shall be capable of engaging with train arrestors compatible with the Train. 4014

16.3.3 Underframe 2119

Measures shall be employed to protect against the undesirable consequences of impact damage to the underframe and underframe mounted equipment caused by projectiles, in particular detached conductor shoes and flying ballast. Such measures may include, but not be limited to: 2120

- locating vulnerable equipment or components in naturally protected locations;
- provision of guards or deflectors;
- design of equipment casings and covers to withstand expected impact forces.

The layout and design of underframe equipment shall be demonstrated to provide the required access to inspect, maintain and replace equipment in accordance with the Train Maintenance Regime for both routine and casualty maintenance. 2167

Underfloor equipment cases, components and services shall be designed to minimise the accumulation of dirt, litter, dust, oil, grease and other contaminants thrown up from the track and wheels. 2608

Forced-ventilated equipment shall not be adversely affected by ingress of snow (of whatever type), dust, debris or fibrous material. 2677

16.3.4 Carbody Mounted Equipment and Fittings 90

Footholds shall be provided on the front of the train to enable staff entry and exit into and out of the Train through the M-Door from the track. 4763

Steps shall be provided to enable access and egress between ground level and the Train via the cab side doors. 6897

Steps and footholds shall have anti-slip surfaces. 5922

Steps and footholds shall allow water to drain away. 5923

If steps are not clearly visible to the user when the user is preparing to use the steps, the area above the steps shall be marked to indicate the position and width of the step. 6898

Steps, if recessed, shall be marked so as to be distinct from the surrounding area. 6899

Ergonomic incompatibility between recessed steps and the user is a particular issue that shall be avoided. 6900

Vertical handrails shall be provided on the exterior of the Train on both sides of the M-door. 1859

Handrails, for both hands, shall be provided for use with the steps leading to the cab side doors. 6901

There shall be a bracket for attaching a "Train Not To Be Moved" sign. The bracket shall be located at an accessible height from track level at both extreme ends of the Train on diagonally opposite corners such that the sign is visible from the side of the Train. 3924

In order to avoid undesirable responses, the fundamental modes of vibration of items of equipment on their mountings and in all operation conditions, shall be: 2594

- separated sufficiently, from the modes of vibration of the car body structure and suspension; or
- otherwise decoupled from the modes of vibration of the carbody structure and suspension.

Where a cover has the ability to go out of gauge in a failed condition, a secondary restraining device shall be fitted to restrain the cover within the gauge. 2592

16.3.5 Glazing 91

Fixed windows shall be provided in the carbody bodysides, in the passenger doors and in the cab side doors. 2441

Windscreens and windows shall meet the requirements of Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures'. 2161

The windscreen optical properties shall comply with the specification in Railway Group Standard GM/RT2161 'Requirements for Driving Cabs of Railway Vehicles'. 6423

Two interchangeable versions of the windscreen shall be provided: 3444

- A version fitted with anti-spall layers for use during migration states where a Train Operator will be seated behind the glass.

- A version fitted with an anti-shatter film but not an anti-spall layer available for use after migration as a spare part when there will not be a Train Operator seated behind the glass. *The intention is to mitigate the risk of scratch-graffiti damage to the windscreen.*

If glass is used for internal fittings located above the level of the tops of car windows or luminaires (located anywhere), laminated glass to British Standard BS 857:1967 'Specification for Safety Glass for Land Transport' shall be used. 2162

Draught screens shall be made using laminated glass as defined by British Standard BS 857:1967 'Specification for Safety Glass for Land Transport'. 2032

Glass shall not be used in any application where it is intended to be broken to gain access to emergency controls or equipment. 2163

All glass in operator and passenger areas, including draught screens, saloon door windows and bodyside windows, shall have any exposed edges adequately protected. 2464

All glass in passenger facing areas, including draught screens, saloon door windows and bodyside windows, shall be strong enough to withstand passengers leaning against it and shall support and contain passengers during normal operation of the Train. 2465

If glass is used to protect digital screens in the saloon, it shall be suitably treated to prevent reflections and glare. 6307

The doorleaf glazing shall be designed and installed such that the transition from the inner face of the doorleaf to the inner face of the glazing minimises the risk of limb trapping when the door is in motion, both opening and closing. 3447

There have been instances where a person holding a handhold in the area of the door standback has suffered injury due to their elbow being caught on the door window frame as the door opens. 3449

It shall be possible to replace the glazing in bodyside windows and doors wholly from inside the saloon. 4559

Bodyside windows and all door windows shall not use adhesive bonding as the primary fixing method for the glazing. 5071

The glazing (including any applied film) in the saloon bodyside windows and passenger doors shall have low reflectance of visible light. 6425

The glazing (including any applied film) in the saloon bodyside windows and passenger doors shall have visible light transmittance of no less than 45%. 6426

The colour of the glazing (including any applied film) in the saloon bodyside windows and passenger doors shall be of a neutral appearance. 6427

16.4 Inter-Car Gangways 92

Open wide inter-car gangways shall be fitted between all cars. 1453

Gangways shall be in accordance with British Standard BS EN 16286-1:2013, 'Railway Applications - Gangway Systems between Vehicles - Part 1: Main Applications', except where conflicting or additional requirements are detailed in this specification. 4360

The gangway vertical clearway, as defined in British Standard BS EN 16286-1:2013, 'Railway Applications - Gangway Systems between Vehicles - Part 1: Main Applications' Figure 1, shall be no less than 1900mm. 4358

The gangway width, as defined in British Standard BS EN 16286-1:2013, 'Railway Applications - Gangway Systems between Vehicles - Part 1: Main Applications' Figure 1, shall follow the profile of the interior saloon carbody side panels at all positions above the level of the top of the passenger seating. 4350

The horizontal clearway in the gangway area, as defined in British Standard BS EN 16286-1:2013, 'Railway Applications - Gangway Systems between Vehicles - Part 1: Main Applications' Figure 1, shall be no less than the minimum width between opposite longitudinal seating and shall maintain a minimum 1000mm width for the full 1900mm vertical clearway. 4356

The inter-car gangway shall comply with the structural requirements detailed in Group Railway Standard GM/RT2100 'Requirements for Rail Vehicle Structures' Part 5. 1384

The inter-car gangway shall be capable of resisting, without significant deflection, a horizontal loading of 3.0 kN/m^2 over any part of its surface. 6081

Inter-car gangway movement shall not cause strain to the carbody structure or to the interconnecting pipes, hoses and cables so as to reduce the life of the carbody, life of the services or impair the function of the services. 6700

The exterior profile of the inter-car gangway shall prevent a passenger falling into the gap between the inter-car connection and the platform. 1385

The exterior profile of the inter-car gangway shall consistently follow the profile of the carbody and shall not be more than 50mm inside the adjacent carbody profile. 6080

The inter-car gangway shall minimise the ingress and accumulation of tunnel dust. 1387

It is anticipated that a means of allowing liquids to drain freely from below the floor in the gangway area may be needed.

The inter-car gangway shall be resistant to noise ingress to ensure compliance with the saloon noise requirements as defined elsewhere in this specification. 1388

The inter-car gangway shall provide a comfortable, secure platform for passengers standing within it and for passengers walking through it. 1389

The inter-car gangway shall not present a trapping hazard during normal operation. The criteria used to define what constitutes a trapping hazard shall be as defined in section 4.2.7 of British Standard BS EN 1176 Part 1:2008 'Playground Equipment and Surfacing Part 1: General Safety Requirements and Test Methods'. 1390

The inter-car gangway shall be resistant to graffiti, resistant to cuts and abrasions from knives and sharp blades and be easy to clean and repair. 1391

To allow passengers to safely stand in the gangway areas suitable handgrips, grabpoles and other handholds shall be provided equivalent to those provided in the adjacent saloon areas. 1395

No passenger seating shall be fitted in the inter-car gangway area. 6322

16.5 Couplers 95

16.5.1 Coupling Trains for Rescue 96

Couplers shall be provided on both ends of the Train to allow coupling of trains for rescue purposes. 4022

Coupling systems between trains shall be capable of transmitting safely all the forces that may arise during train recovery. 2699

The coupling system shall not limit the options for train rescues to either push-out or pull-out. 6357

A rescuing Train shall couple to a defective Train and make the correct mechanical, pneumatic and electrical connections to enable safe movement of the defective Train by the rescuing Train. This shall include, where permitted by the underlying defect, control of the brakes 2725 on the defective Train by the rescuing Train. This shall include, where permitted by the underlying defect, control of the brakes on the rescuing Train from the defective Train.

A safe method of coupling and uncoupling Trains of the same type for push-outs and pull-outs, which requires only one person who remains on board the Train or Trains, shall be provided by the Manufacturer. This shall be effective when the Trains are positioned at any horizontal or vertical curve found on the routes on which the Train operates, for any combination of loading and degraded conditions. 1209

The gathering range of the Train end couplers shall be sufficient to permit one Train to couple to another Train at all locations on the routeway (including points & crossings, sidings and depot tracks) over which the Train operates. 4020

A means shall be provided of visually confirming, from the operating position, that any securing devices on the Train end coupler are positively engaged. 2713

The Train shall report its coupled/uncoupled status to the RCS. 6438

Mechanical coupling between Trains shall be in accordance with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures' Part 8. 2770

16.5.2 Inter-Vehicle Coupling 2688

Drawgear and couplings shall be resilient to controlled shocks (i.e. buffing loads), in order to allow the Train to behave as a single mass. 2690

Drawgear and couplings shall resist parting of cars. 2692

Drawgear and couplings shall resist overturning of cars. 2693

Coupling systems between cars in a Train shall be capable of transmitting safely all the forces that may arise during normal operation and Train recovery. 2696

The operational scenarios that shall be considered for coupling loading design shall be defined by the Manufacturer based on the operating environment and the Train's design, and shall include the following: 2698

- Peak traction and braking rates;
- Buffing and drawing;
- Coupling and un-coupling;
- Any track horizontal and vertical curves, and reverse (horizontal) curves on which the Train may operate;
- Any speed up to the maximum operational speed and at the

maximum carbody twist which can occur, taking into consideration design tolerances and maximum track twist.

A failed coupling shall be supported and retained within the permitted gauge of the Train. 2773

16.6 De-Icing and Sleet Brushes 119

De-icing equipment shall be fitted on the Piccadilly, Central and Bakerloo Line fleets. 5189

At least 30% of each Train fleet shall be fitted with de-icing fluid tanks and dispensing equipment. 1158

The de-icing fluid capacity shall be at least 900 litres per Train. 1160

There shall be three de-icing dispensing units, one for the negative rail and one for each of the positive rails. 1161

The de-icing system shall have a dispensing rate adjustable between 0.5ml/m and 3.0ml/m. 1163

The de-icing system shall dispense 1.2 millilitres nominal of de-icing fluid onto every metre of each conductor rail. 1162

The de-icing system shall have a fixed dispensation rate of 14ml/sec for depot and siding areas only. This shall be selectable by maintenance staff. 5239

The positive conductor rail can be present on either side of the Train. A means of detecting the presence of the positive conductor rail shall be provided and the control system shall dispense de-icing fluid only to that side. 5190

Re-filling of the de-icing tank shall be possible from either side of the Train. 1164

The de-icing system shall be capable of being refilled at a rate of not less than 450 litres per minute. 4450

It shall be possible to drain the de-icing fluid from the tank. 1165

The de-icing system shall be able to accommodate and dispense the de-icing fluid which is Ethylene Glycol and Water in equal parts and which may contain mineral and metallic contaminants in suspension. 1166

The de-icing system shall be able to accommodate and dispense the de-icing fluid known as Magic Ice Stop. 1167

The de-icing system shall be able to accommodate and dispense the de-icing fluid known as Killfrost Rail. 6358

Fluid loss and leakage during re-filling, conveyance on the Train and dispensing from the de-icing tank shall be reduced to as low as reasonably practical. 1168

A dial gauge indicator shall be fitted on either side of the Train to indicate to a maintainer filling the tank the amount of fluid in the de-icing tank. 1169

The fluid level within each de-icing tank shall be reported to the RCS. 1171

The de-icing fluid shall dispense when commanded by the RCS and by the OTC. 1172

The de-icing fluid shall dispense when commanded by the Train Operator. 5193

The vehicle shall not be compromised due to corrosion, mechanical damage or electrical leakage currents related to the de-icing equipment. 2597

The de-icing fluid shall not dispense when the Train is in a tunnel. 1173

The de-icing fluid shall not dispense when the Train is stationary. 2600

Sleet brushes shall be fitted in advance of the outer end positive and negative Shoegear at each end of all Trains on the Piccadilly, Central and Bakerloo lines. 1174

The sleet brush shall be effective in removing snow and frost from the conductor rails over the full Train speed range. 4192

The application and retraction of the sleet brushes shall be controlled by the RCS and by the OTC. 3931

The application and retraction of the sleet brushes shall be controlled by a Train Operator on the Train. 5807

Sleet brushes shall retract when the Train enters a tunnel. 7113

Sleet brushes shall only be deployed at the leading end of the Train. 5808

The application and retraction of the sleet brushes shall be reported to the RCS. 6866

17 Pneumatics 97

17.1 Pneumatics - General 101

The main line air system shall incorporate protection devices to prevent loss of main line air in the event of failure. 2145

To aid recovery the main line air system shall incorporate isolation devices to enable division of the air system in the event of a problem causing loss of main line air. 5351

Failures in the air supply system shall be automatically resolved by TCMS sufficiently to enable continued operation of the Train to depot. 5352

The configuration and layout of equipment shall ensure that the air supply shall be available when only one end car is connected to the traction power supply to permit movement of a Train to enter service. 2080

It is envisaged that any credible Train design meeting the fault tolerance requirements will have at least two compressors. 2083

The configuration and layout of equipment shall ensure that the air system is able to recharge with only the collector shoes of the end car in contact with the conductor rails and with no shed leads connected. 5379

Reservoirs used on any brake supply shall be fitted with drain plugs and not drain cocks. 2091

Isolating cocks and their labels shall be visible under normal and emergency lighting conditions and shall be clearly labelled with the function of the cock and whether “open” or “closed”. 2092

All isolating cocks shall operate through a nominal angle of 90^{o}. 6695

The pneumatic system design, installation and component selection shall minimise the risk of Train immobilisation resulting from failures. 2094

LU’s experience is that unnecessarily high risks of main line bursts are due to vulnerable components on the underframe, poor flexible hose installation, unsuitable flexible hose design or construction, insufficiently robust pipe work, pipe work connections not readily accessible, pipe fittings not secure or vulnerable to deterioration and inadequate redundancy in overall system design. 2095

The main line air pressure control shall cause the compressors to start if WSP activity exceeds a defined level, even if the main line air pressure is within its normal limits, so as to minimise the depletion of the main air pressure as a result of sustained WSP activity and 2097 resulting sander operation.

An air dryer with a bulk pre-separator shall be used at each compressor. 2102

There shall be a means to check the correct operation of any air pressure monitoring devices whilst the air supply system is fully charged. 2110

The main line connection between adjacent cars shall be arranged such that the failure of an individual inter-car hose connection shall not prevent the continued operation of that Train in passenger service. 2142

One way of achieving resilience of inter-car pneumatic connections is by the installation of flow cut off valves (FCOVs) on each car with duplicated inter vehicle hoses between the FCOVs. 2143

Pipe fittings and pipework of fixed pipework shall require no routine maintenance over the design life of the Train. 2187

A routine stand up pressure test shall be carried to demonstrate that the air leakage from each Train is consistent with the anticipated air leakage allowed for in the duty cycle calculation of the air supply system. 5349

Type tests on both the test track and the line over which the Train is to operate shall demonstrate that the actual air consumption is no more than that for which the air supply system was designed. 5350

17.2 Compressor 98

The time to fully charge the Train's air system, from a fully discharged state, shall not exceed 15 minutes. 2152

The time to re-charge the main line air system between its normal lower and upper limits (i.e. under automatic control) with no air being demanded shall not exceed 1 minute. 2153

In normal use, the duty cycle of each compressor shall be no more than 40%. 5348

'Normal use' in this requirement refers to the operation of the compressor when the air demand on the Train is as predicted by regular service pattern usage, i.e. when the compressor control is working as per design, there are no equipment or control faults, Train is working to the timetable and so routine braking is taking place, there is no excessive (out of maintenance limit) air leakage and there is no excessive WSP activity due to low and exceptionally low adhesion.

Any single compressor failure shall not require a duty cycle of more than 80% from the remaining functional compressors, to support the air 6255 demands needed for the Train operating in service.

17.3 Compressed Air Storage 100

The size and quantity of main line reservoirs could be kept to a minimum by distributing the air storage volume over a wide area e.g. through use of large diameter pipework. 2129

Reservoirs shall meet the requirements of British Standard BS EN 286-3:1995 'Simple unfired pressure vessels designed to contain air or nitrogen. Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock'. 2158

Reservoirs shall be protected against corrosion to last the design life of the Train. 5380

18 Electrical 102

18.1 Electrical - General 103

All work shall comply with British Standard BS EN 50343:2014 'Railway Applications - Rolling Stock - Rules for Installation of Cabling'. 5103

All work shall comply with the requirements of British Standard BS EN 50153:2014 'Railway applications. Rolling stock. Protective provisions relating to electrical hazards'. 6193

All electronic equipment shall comply with British Standard BS EN 50155:2007 'Railway applications. Electronic equipment used on rolling stock'**.** 5128

All equipment shall comply with the requirements of British Standard BS EN 50124-1:2001+A2:2005 'Railway Applications. Insulation Coordination. Basic Requirements. Clearances and Creepage Distances for all Electrical and Electronic Equipment'. 1842

All equipment shall comply with the requirements of British Standard BS EN 50124-2:2001 (Incorporating corrigendum May 2010) 'Railway applications. Insulation coordination. Part 2: Overvoltages and related protection'. 6192

The Train shall comply with British Standard 'BS EN 60077 Railway applications. Electric equipment for rolling stock. All parts.' 7060

Electronic equipment shall, where possible, be naturally cooled with heat sink fins located on the outside of the case. 1011

For each heat sink which could become fouled or contaminated due to dust or dirt, there shall be a method in the maintenance manual for assessing condition and for cleaning it. 5084

Where it is essential that forced cooling is employed then the design shall ensure that airborne contaminants such as dust shall not impair the cooling function. 4299

Cooling systems for electrical equipment exposed to tunnel air, including braking resistor grids, shall be designed to minimise the potential for dust to collect within the enclosures and casings. 4459

A numerical analysis shall be performed to understand and optimise the airflow distribution associated with electrical equipment cooling systems. 5131

The numerical analysis of airflow distribution around electrical equipment cooling systems shall be conducted using computational 5132 fluid dynamics and shall account for at least the following situations and factors:

- rolling stock within tunnels and at platforms;
- moving and stopped Trains;
- part-load operation of any cooling fans.

The Train shall be capable of being powered from depot traction power supplies via shed receptacles on the Train. 1012

There shall be an indication to the Train Operator at the driving position when any attempt is made to move the Train with a shed supply lead connected to the Train. 1015

There shall be an indication to the Train Operator whenever a shed plug is inserted and the traction power supply is detected at any Shoegear. 981

All equipment, cables, connectors and terminations carrying traction power supply voltages shall be located below the vehicle floor. 1017

Connectors shall lock in position when fully mated. It shall be evident to the person making the connection that the lock has been achieved and that the connector is fully mated. 1018

All pins and sockets used to pass low voltage signals (5V or lower) shall be gold plated. 1019

All pins and sockets used to pass low current signals (5mA or lower) shall be gold plated. 5369

The fixed end of any connector, which is normally unconnected (e.g. a test point), shall be sealed with a cover such as either a dust cap secured by a flexible link or a lid held closed by a spring. 1020

Vehicle wiring shall not connect directly onto the terminals of Line Replaceable Units. 1021

Vehicle wiring shall not connect directly onto relay, contactor or switch terminals. 6853

An intermediate terminal panel or similar means shall be used such that damage to cable ends during component replacement shall not require the replacement of wiring in conduits, behind panels or under floors. 6854

To enable future upgrades and modifications, the Manufacturer shall install at least 10% additional Train wiring in all the looms. This spare wiring shall not be used for any purpose by the Manufacturer without the agreement of the Purchaser. 6164

Spare cables shall be terminated and labelled. 6165

All electrical and cabling installations shall be free from swarf. 6343

Relays and contactors in safety critical circuits shall be mounted such that in the event of a `heavy collision', (a rapid deceleration of the Train not greater than 5g), their contacts shall not momentarily change state enabling possible unsafe conditions to occur. 1022

Electrical connections to switches, relays, contactors and terminal blocks shall be by either ring crimps, spade crimps or cage clamps. 1023

Switch fixings shall either be tamper proof or be designed so that they are not accessible from the front panel to passengers or unauthorised staff. 1024

Rotary switches shall operate correctly when rotated through 360^{o} and shall have no end stop. 1025

All cable terminations (i.e. ends of cables) shall be made using crimp terminals or cage clamps. 1026

Protective devices protecting circuits operating at different voltages shall be segregated and grouped and clearly labelled. 1027

Devices protecting equipment operating at traction power supply voltages shall be installed in their own enclosure. 1028

Circuit-breakers shall be used to protect auxiliary and control circuits except where an alternative would better allow the Train to meet the overall requirements. 1029

In all electrical equipment, including wiring, limits shall be defined for transients, surges, induced voltage and induced electromagnetic interference. 6336

In the event that transients, surges, induced voltages or induced electromagnetic interference exceed the defined limits, the Train shall remain in a safe condition. 6337

The negative pole of the control supply shall be electrically bonded to the carbody structure. 1030

All uninsulated metal parts not intended to be part of a live circuit shall be bonded to the carbody. The only exception is metalwork of equipment required to be secondary insulated. 6338

The carbody underframe shall be connected to the carbody underframe of an adjacent permanently coupled vehicle by two physically separate 6339 bonds connected in parallel.

The carbody shall be electrically bonded to each bogie via two bonds, one fitted to each bogie side frame. 6340

One axle-box on each wheelset shall be electrically bonded to the bogie. 6341

The Train shall be protected in the event of reverse polarity connection to the LU traction power supply using the shed receptacle. 1031

The Train shall be capable of being safely connected to and disconnected from the shed supply. The table below details the required safety controls for the connecting of shed supplies to the car: 1032

	Shed Plug Position and Change Over (C/O) System Condition		
	'Shed'	**'Off'**	**'Track'**
Collector Shoes:	Isolated from shed receptacle	Isolated from shed receptacle	Connected to car circuitry.
Train Shed Receptacle Socket	Connected to car circuitry	Isolated from car circuitry.	No exposed live conductors.
Traction / Brakes: (Traction Supply present on the collector shoes of any car of the half train connected to the shed supply)	Traction inhibited Emergency Brakes applied	Traction inhibited Emergency Brakes applied	Unrestricted
Traction / Brakes: (Traction Supply absent on the collector shoes of all cars of the half train connected to the shed supply)	As demanded by TBC but with acceleration and top speed limited to ensure safe and controlled movement while the lead is attached to the train.	Unrestricted	Unrestricted
Restrictions: Lid Position	Unrestricted	Unrestricted	Lid closed and locked.
Restrictions: Shed Plug insertion/removal	Not possible	Possible – this is the only position for inserting or removing the shed plug	Not possible
Restrictions: Other selectable switch positions	Can Select 'Off' only	Can select 'Track' without a shed lead connected, or 'Shed'.	Can select 'Off' only.

The Train shall be capable of being readily connected to and disconnected from the shed supply by one person. 4613

Combined tests of alternating current motors and control systems fed from an indirect converter shall be undertaken in accordance with British Standard BS EN 61377:2016 'Railway applications. Rolling stock. Combined test method for traction systems'. 6109

The Manufacturer shall provide all cabling on the Train irrespective of whether or not the equipment is in the Manufacturer's scope of supply. 7075

18.2 Earth Faults 4968

The Train shall be able to operate with a single pole earth fault, of either polarity, intermittently or continuously present on the traction power supply. 1034

Single pole earth faults on the Train shall be detected and isolated with minimal impact on the operation of the Train. 1035

In the event of an earth fault occurring on a protected device on the Train, the defective system shall be automatically isolated from the traction power supply. 1036

In the event of a pole-to-pole circuit fault in the protected power cabling on the Train, the defective system shall be automatically isolated from the traction power supply. 1037

Earth faults in the low voltage control circuits and supplies shall be detected and isolated. 6198

On each car one earth point shall be designated and labelled as the "Main Car Earth". 1038

All earth points which are not the main car earth shall be referenced to the main car earth. 6342

On cars with stand-by batteries the "Main Car Earth" point shall be the point at which the hardwired voltage return is bonded to the car body. 1039

18.3 Arc Protection & Unprotected Wiring 4969

LU Standard G183 'Guidelines for the Engineering of Underfloor Arc and Thermal Protection Requirements' contains useful reference information to which the Manufacturer shall refer and which the Manufacturer shall apply to the design. Note that the warning statements on page 2 of G183 shall be disregarded. 1040

The risk from arcs shall be managed by ensuring that the probability of arc initiation is managed as low as reasonably practicable. 1041

The risk from arcs shall be managed by ensuring that the duration of any arc is managed as low as reasonably practicable. 1042

The risk from arcs shall be managed by ensuring that the size of any arc is managed as low as reasonably practicable. 1043

The risk from arcs shall be managed by ensuring that if an arc is initiated it shall be contained so as to limit as far as reasonably practicable its severity both to the Train and passengers. 1044

The risk from arcs shall be managed by ensuring that if an arc is initiated the release of smoke, fumes and toxic products is limited as far as reasonably practicable. 1045

The risk from arcs shall be managed by ensuring that if an arc is initiated it is extinguished safely and rapidly. 1046

The risk from arcs shall be managed by ensuring that under body arc barriers and thermal protection are fitted. 1047

The Train shall be fitted with comprehensive arc protection to remove the risk of a sustained arc or resultant fire. 1048

Unprotected circuits shall be confined to the underframe and wherever possible protected against mechanical damage. Where it is mechanically unprotected it shall be routed where damage is unlikely and be of a robust construction suitable and appropriate for its location and duty. 1051

Conductors in unprotected circuits shall have a creepage and clearance distance to earth or to other conductors of not less than 300mm. 1052

Unprotected circuits shall be protected from the risk of damage and arcing. 1053

Unprotected circuits shall be run in locations which afford the greatest practical protection against potential thermal or UV damage. 1054

Cables between cars shall be electrically protected. 1033

In the event of a power arc occurring in the unprotected circuit, the resulting arc shall be contained and self-extinguishing. 1055

The number of electrical connections in unprotected circuits on the under frame shall be reduced to as few as reasonably practical. 1056

Unprotected circuits shall be as short as reasonably practicable. 1057

The risk of a trainborne fault, in the unprotected power circuits, resulting in a self-maintaining power arc shall not be greater than once in 10^7 hours per Train (equivalent to once per millennium per Train). 1059

The exposure of people to live collector shoes and to conductor cabling from the shoes to electrical equipment shall be reduced as low as reasonably practicable. 6182

Arc barrier installations shall not be vulnerable to damage during routine or casualty maintenance activities, particularly when separating the carbody from its bogies. 1060

18.4 Cable Installation 4970

Cable identifications and numbering shall be consistent and used throughout the Train. 1066

Cable identifications shall be yellow in colour and the lettering shall be black. 1067

Cable identification lettering shall be permanent. 1068

Cable identification lettering shall not smudge and shall not be removed by rubbing. 4343

Cable identification lettering shall be unaffected by the cleaning fluids and processes that are recommended by the Manufacturer as part of the Train Maintenance Regime. 4344

The cable identification system used shall distinguish between Train and car wiring. 1069

Colour coding shall not form part of the cable identification system. 1070

The identification of all safety cables and wires shall carry the prefix "S". 1071

18.5 Auxiliary Supplies 110

18.5.1 Auxiliary Supplies - General 4831

All batteries in the Train shall be recharged when only one shed supply lead is connected to the Train. 1072

While the Train is crossing conductor rail gaps the loads fed directly 1078 from the traction supply shall suspend operation until the supply is restored.

While the Train is crossing conductor rail gaps the auxiliary converter module shall return to its original state within 3 seconds of the traction supply being restored. 1080

The traction power supply is routinely subjected to interruptions which occur whilst traversing current conductor rail gaps, during shoe bounce etc. 4494

The Train shall not be adversely affected by traction power supply interruptions. 5095

The Train shall not be damaged by traction power supply interruptions. 5096

Traction supply interruptions shall not interfere with the operation of the Train. 5097

Traction supply interruptions shall not falsely trigger the load shedding sequence. 5098

Traction supply interruptions shall not falsely trigger signalling interference protection devices. 5099

A “Supply On” indicator shall be provided at each operating position on the Train. 6154

The “Supply On” indicator shall illuminate when at least one auxiliary converter is operating. 6155

To enable future upgrades and modifications, the auxiliary converter shall have at least 10% additional capacity. The additional traction supply current required for this shall not be included in the line current limit. This spare capacity shall not be used for any purpose by the Manufacturer. 6166

18.5.2 Load Shedding 111

The Train shall have a load shedding hierarchy to preserve the battery charge for as long as possible following loss of output from the Train's auxiliary converters. 4490

The load shedding sequence shall commence automatically following loss of output from the auxiliary converters. 4492

The Train equipment shall function correctly in response to its supply being disconnected during any load shedding sequence, incorporating controlled shut down and start up sequences. 4493

Load shedding shall take precedence over any RCS triggers to turn on equipment. 4495

Load shedding shall take precedence over any OTC triggers to turn on equipment. 6838

The time at which load shedding shall commence (after the loss of traction power) shall be configurable from 20s to maximum of 2 minutes. 4496

Load shedding shall initially be set to commence 20s after the loss of traction power. 5374

The term Train Essential Services is used to describe those systems which are considered necessary to be maintained to ensure the safety of passengers and enable the Train to be restarted following the perturbation (e.g. loss of traction power supply, Train fault). 4491

All non-essential services shall (after the initial configurable time) be switched off in a controlled manner. These shall include, but not be limited to: 4497

- Main saloon lighting;
- Digital advertising;
- some CIS VEIDs in each car;
- PEA indicator status;
- Compressor air dryer;
- CCTV display screen/OPO platform CCTV system;
- HVAC functions except emergency ventilation;
- the system which identifies the Train Operator to the RCS.

The Train Essential Services shall be retained for a minimum of 2 hours. These shall include, but not be limited to: 4498

- Train data recorders;
- Passenger Emergency Alarm communication facility to Train Operator and RCS;
- Some CIS VEIDs in each car;
- Cab to cab communications;
- Public address;
- Train number indicator display;
- Doors open and close functions and door closed proving circuits;
- Yellow Indicator Light, headlights, tail lights, detrainment lights, emergency saloon lights and cab lights;
- CCTV recording and transmission to the RCS;

- Emergency ventilation;
- RCS:
- OTC;
- Sufficient control functionality to enable Train to be powered-up if traction supply returns;
- Sufficient control functionality to enable self powered movement;
- Fire detection;
- M-door locking and lock status detection;
- Monitoring;
- Train Radio.

In the event of the batteries becoming discharged and the low voltage monitor being tripped, the remaining Train circuits shall be load shed except for the tail lights which shall be retained for 24 hours. 4499

When the traction supply is reinstated, following load shedding, the Train shall automatically return to its condition prior to load shedding, without any intervention or command. 6219

18.6 Battery 118

18.6.1 Battery Capacity 3607

Batteries shall be provided. 1130

Without any use of self powered movement, the batteries shall supply the Train Essential Services for a minimum period of two hours in the event of loss of the traction supply. 3606

The batteries shall supply the Train Essential Services and the self powered movement capability. 4139

It is acknowledged that the use of self powered movement may reduce the 2 hour Train Essential Services capacity.

Batteries shall provide an uninterruptible control supply in support of the output from the auxiliary converter(s). 3608

In the event of the batteries becoming discharged and the low voltage monitor being tripped, sufficient charge shall be retained in the batteries to re-initialise battery charging once the traction supply has been restored. 3610

The battery shall have adequate capacity to undertake three restarts after the battery low voltage monitor has tripped. 3614

The battery capacity calculation shall be based on meeting the performance throughout the entire service life of the battery. 3609

Battery capacity sufficient to supply the Train Essential Services for two hours shall still be available after the Train has been powered off for 72 hours. 3615

The remaining battery charge, expressed as a percentage of the battery capacity, shall be reported to the RCS and the OTC. 6697

Batteries shall provide sufficient power to support continuous use of the tail lights when the Train is Powered Off for a minimum period of one week. 1086

The battery capacity shall be sufficient to provide the RCS with a standby power supply for at least 54 hours of traction current unavailability. The power consumption of the essential RCS standby supply shall be 50W. 5827

The standby power supply should be enough to ensure positional and other essential data is retained which is required to ensure the Train does not need to relocate or re-register to allow automatic driving following resumption of traction power supply.

18.6.2 Battery System Design 3611

The battery installation shall be designed to prevent polarity reversal. 1135

Protection shall be provided to prevent deep discharging which adversely affects the life of the batteries. 1139

A fully discharged battery shall achieve 50% of its rated capacity within 3 hours when charged by the Train auxiliary supply. 1140

The production of battery gas shall be negligible and shall not at any time constitute a safety hazard. The battery shall be ventilated to atmosphere. 1141

Gases from batteries shall be prevented from directly entering the Train interior. 3617

The battery shall be located beneath the car floor fire barrier. 1142

It shall be possible to isolate the battery for maintenance purposes. 1143

All cell block connections shall be insulated or protected such that no live terminals are exposed when the battery is accessed. 3612

The Manufacturer shall detail how the condition of the individual cells of 5105 the battery can be checked and replaced.

The Manufacturer shall state how the risk of individual cells overheating is managed so as to avoid the risk of fire. 5106

Batteries shall comply with the safety requirements contained in British Standard BS EN 50272 parts 1, 2 and 3 'Safety Requirements for Secondary Batteries and Battery Installations'. 1149

Batteries and battery installations shall comply with British Standard BS EN 50547:2013 'Railway Applications - Batteries for Auxiliary Power Supply Systems'. 1148

19 Doors 120

19.1 Doors - General 121

A safe, efficient and reliable means of access to and egress from a Train for passengers and operators shall be provided under all: 1613

- normal operating conditions;
- emergency operating conditions.

The risks to passengers and staff associated with the use of doors shall be demonstrated to be ALARP. 1628

The replication of existing door systems shall not automatically be assumed as demonstrating risks to be ALARP. 1630

All relevant human factors shall be taken into account in the design of all access and egress systems. 1615

Doors (including components thereof and any equipment mounted on doors) shall not: 1619

- infringe the clear door openings of the Train when fully open;
- present a trip hazard.

Doors shall be able to be maintained by a single maintainer, including: 1651

- mechanical set-up and geometry checking;
- adjustment of switches and sensors;
- confirmation that the doorway is fit for service.

It shall be possible to remove and refit doorleaf mating seals without dismounting the doorleaves. 2873

The door system shall detect and report status and condition information for each doorway. 1643

The status (e.g. Open, Closed, Obstructed, 'Out-Of-Service', etc.) of each door shall be displayed to the Train Operator and available to the RCS. 1937

The door system shall be capable of comprehensive self-monitoring to provide failure detection, fault diagnosis and performance information to the TCMS for onward transmission to the RCS. The data shall be sufficient to provide: 1901

- information and advice for managing in-service faults;
- door system health status information thus reducing need to conduct checks and functional tests as part of routine

maintenance;

- information about deteriorating performance and developing problems;
- information to assist with incident investigation including alleged Door Irregularities;
- information pertaining to the frequency of use of obstruction detection features.

The design of side sliding doors and their guidance systems shall manage as low as reasonably practicable the risk of doors opening or becoming detached in the event of the car colliding with: 2040

- another train;
- fixed infrastructure;
- obstructions (e.g. trees).

Structural strength of exterior doors shall be in accordance with Railway Group Standard GM/RT2100 'Requirements for Rail Vehicle Structures', and in addition passenger doors shall: 2035

- be capable of withstanding a force of $7kN/m^2$ applied to the whole inside face of the door leaf when mounted in the top and bottom door guides;
- under type test conditions remain firmly held by the top and bottom door guides under this load for 5 minutes.

The door leaf guidance shall not be susceptible to becoming obstructed through build-up of foreign objects such as dust, debris, ice and snow. 4032

The door leaf guidance shall not be susceptible to becoming obstructed due to entry of commonly encountered types of litter and debris into any door guidance channel. 5828

19.2 Doors Closed Proving 1875

A system shall be provided to detect when all exterior doors are closed and locked. 1880

The door control system shall incorporate means of accurately and reliably detecting that all doors are closed utilising “energised when proven closed” logic. 1614

The Train shall not motor unless the exterior doors are proven to be closed and locked. 1935

The Train shall stop motoring should any exterior door open or be enabled to open. 1617

The doors closed proving circuit and its regulation of the traction control shall be hard wired. 6158

Two blue Train doors closed visual indications shall be provided. 1665

The Train doors closed indications shall be incorporated into the two passenger door close buttons located at each operating position. 4744

During the closing stroke, a sliding passenger doorleaf shall only be detected as closed when it is within 6-8mm of its fully closed position. 2000

During the opening stroke, a sliding passenger doorleaf shall be detected as open when it has opened to a distance of no more than 4mm wider than the 'closed detected' position. 2001

During the closing stroke, a sliding cab side doorleaf shall only be detected as closed when it is within 20-25mm of its fully closed position. 6884

During the opening stroke, a sliding cab side doorleaf shall be detected as open when it has opened to a distance of up to 10mm more than the 'closed detected' position. 6885

The Train shall report the status of the doors closed and locked proving to the RCS. 4701

19.3 Passenger Doors 122

19.3.1 Passenger Doors - General 4980

Power-operated doors shall be provided on both sides of the Train to enable passenger access to and egress from the Train via the platform in both normal and degraded conditions. 1626

Passenger doorways shall comprise double sliding leaves only. Single leaf doorways shall not be permitted. 1627

Under normal operating conditions the bodyside passenger doors shall be the only method of access and egress. 4409

The internal layout of the Train, especially near to the doors, shall aid passenger flow into and out of the Train. 4411

In normal operation and in the event of failure, door systems shall reduce safety risks to ALARP, in particular the following: 1632

- a Train moving with one or more doors not fully closed;
- a Train moving with people or objects trapped in a door, when

the door is not fully closed;

- a Train moving with people or objects trapped between two doors, when the doors are closed;
- a door opening or partially opening when a Train is:
  - in motion;
  - not correctly aligned with:
    - a station platform;
    - where provided, PEDs.
- a door opening or closing on a passenger so as to cause injury.

When demonstrating that door system safety risks are reduced ALARP, issues that may be considered include the trapping and dragging of passengers, their clothes and their possessions; the impact of moving doors on passengers; the crushing of passengers by closing doors; opening of doors on the non-platform side; opening of doors whilst in motion; any un-commanded opening or closing of doors and opening of doors when not correctly berthed. 1634

Means shall be provided to encourage passengers to not obstruct the doors while closing, to minimise delays caused by obstructed doors and to protect people and objects struck or trapped by the doors. Measures to achieve these objectives shall be defined by the Manufacturer based on the operating environment and the Train design, and shall include: 1653

- increasing or decreasing the door operating force through the stroke;
- re-opening the door several times partially or fully when obstructed;
- stalling the door at any position such that movement by passengers is not possible;
- sounding alarms local to the door before movement and during obstruction;
- illuminating indicators local to the door before movement and during obstruction;
- making automated announcements.

Passenger doors shall open only when: 1648

- commanded correctly;
- on the correct side adjacent to the platform;
- correctly aligned with the platform infrastructure e.g. PEDs;
- the Train is stationary.

A means shall be provided for a member of operational staff to determine the status of each passenger door on arrival at the door. 1801

Passenger doors shall be identified as follows: 1861

- first on left hand side to be nominated ‘A door’;
- first on right hand side ‘B door’;
- second on left hand side ‘C door’;
- second on right hand side ‘D door’;
- and so on, treated on the basis of individual door leaves repeated in following cars in the Train.

Each pair of passenger doors shall be locked in the closed position. 1910

Whilst locked, it shall not be possible to open the passenger doors beyond the pushback distance. 6698

The passenger doors shall not open against the pushback mechanism during peak acceleration and braking rates on the most adverse gradient. 5346

The door system test programme shall include the use of a rig to test the door system behaviour from an early stage in the design cycle. 1929

The door system rig test programme shall be agreed with the Purchaser and shall include activities to simulate foreseeable real-world passenger interactions and to seek to identify unforeseen failure modes. 4421

The door system rig test programme shall include reliability testing to validate against failure of performance. Failure in this instance shall be defined as any closing time in excess of 2.5 seconds and any opening time in excess of 2.0 seconds. This should include demonstration of B10 reliability to 1 million door cycles (one cycle being door open and door close) to a confidence level of 50%. Testing should be conducted at nominal environmental conditions. 6690

The passenger door opening and closing times shall be configurable in ranges from the lowest values that can be acceptably achieved up to a maximum value of 10 seconds. 3745

The lowest configurable value for the passenger door closing time shall be minimised within the constraints of other competing requirements (e.g. impact forces) and in any case shall not be greater than 2.5 seconds. The time shall commence when the door starts to move and complete when the door is fully closed. 2028

The lowest configurable value for the passenger door opening time shall be minimised and not greater than 2.0 seconds. The time shall commence when the door starts to move and complete when the door is fully open. 2029

Minimisation of door open and close times is to allow the Purchaser to optimise the platform dwell times. 3744

The requirements for limiting passenger door impact forces shall be achieved throughout the configurable range of door opening and closing times. 5171

The passenger door distance-time operating profiles shall be configurable to enable movement consistent with PEDs. 4743

All door system timing parameters such as opening/closing times and audible/visual warnings (including all delays and offsets associated with these) shall be easily configurable by the maintainer within a range appropriate to each parameter in increments of 0.05s. 3357

Mechanical devices to manually lock doors 'out-of-service' shall not be provided. *It is expected that the doors will be locked 'out-of-service' using a "door not allowed to open" command or an electrical cut-out or similar.* 3755

The passenger doors shall resist becoming stalled when a plastic bottle top is placed on the floor between the door leaves. 4029

19.3.2 Door Control 1610

The passenger door control system shall be designed such that the risk of injury to passengers and operators is ALARP. 1637

Passenger doors on each side of the Train shall be: 1662

- controlled independently;
- controlled by systems separated from each other throughout the Train.

Passenger doors shall be individually controllable to allow per-doorway control to manage multiple scenarios. The scenarios shall include: 1926

- Inhibition of individual door(s) operation to allow a Train to continue in service with a Train door defect;
- Inhibition of individual door(s) operation to support continuation of service where the doorway is adjacent to a defective (non-opening) PED;
- Inhibition of individual door(s) operation to compensate for short platforms;
- Inhibition of individual door(s) operation to avoid clash with platform mounted infrastructure associated with existing stock. This scenario is associated with migration;
- Open and close of individual door(s). This could be used to release persons detected between Train and PED and to

routinely enable staff access and egress from the Train.

- Inhibition of door operation on the leading door(s) to deal with an overrun of the platform stopping position.

Inhibition of individual passenger door(s) operation shall occur automatically and shall not require the Train Operator to make any door selections. 6533

The passenger door control system shall interface with the OTC so that doors are correctly and safely selected to operate and that they operate in conjunction with the platform edge doors. 6126

The Purchaser shall be able to configure the passenger doors to either Operator Open where door open/release commands result in the doors releasing and opening, or Passenger Open where the door open/release commands result in the doors releasing and being available to be individually opened by passengers using doorleaf mounted pushbuttons. 6068

The Train passenger doors shall be controlled as part of an integrated control system featuring the Train (including OTC), RCS and PED control equipment. The interactions shall be developed fully as part of interface design works. 7084

The design shall allow:

- Automatic Door Opening;
- Automatic Door Closing;
- initiation of door opening by the Train Operator;
- initiation of door closing by the Train Operator.

Automatic Door Opening shall be able to be configured to be enabled or disabled. 7085

Automatic Door Closing shall be able to be configured to be enabled or disabled. 7086

The Train shall facilitate an operating scenario where Automatic Door Opening is enabled on part of the line, but disabled on another part. *This is a potential mode of operation for the Piccadilly Line at end-state.* 7087

The Train shall facilitate an operating scenario where Automatic Door Closing is enabled on part of the line, but disabled on another part. *This is a potential mode of operation for the Piccadilly Line at end-state.* 7088

The release of the passenger doors by an operator in the Train shall require the operation of two separate buttons simultaneously. 5525

When the passenger doors are released, the corresponding door open buttons at the operating positions shall be illuminated. 6071

Following a passenger door close demand it shall be possible to fully re-open and re-close all doors not proved closed. 4449

The passenger door re-open and re-close function shall respond to commands from the RCS and from the Train Operator. 4451

The passenger door re-open and re-close function shall be able to be triggered via a configurable time delay. 6704

There shall be a facility for a Train Operator to inhibit Automatic Door Open to avoid opening the Train doors at a platform. 5954

A passenger door emergency open function shall be provided. 1913

The passenger door emergency open function shall be selectable via a rotary switch. When set to 'Normal', the opening of the passenger doors shall require confirmation of the platform side and the train being stationary. When set to 'Emergency' the passenger doors shall be able to be opened irrespective of platform side and Train speed. 6188

When the passenger door emergency open function is used means shall be provided to minimise the risk to ALARP of the doors opening on the wrong side. 6215

The Train shall not be able to move when door emergency open is selected. 6189

The emergency brake shall apply when door emergency open is selected. 7052

There shall be a facility for a configurable time delay between a door open demand and the start of the movement. This time delay is to achieve synchronisation with PEDs. 1960

There shall be a facility for a configurable time delay between a passenger door close demand and the start of the door movement. This time delay is to achieve synchronisation with PEDs and is in addition to the delay associated with the door closing audible warning. 1962

Operator controls for the passenger doors on each side of the Train shall be separated and positioned such as to be closest to the side of the Train on which they control the doors. 1663

The passenger doors shall be protected against being accidentally opened when the Out of Service function has been selected. 4981

The Purchaser's experience is that Train Operators sometimes become habituated to normal operations and this can lead to unintended consequences when operating 'abnormally' such as Out of Service. Accidentally opening the doors when a train is being removed from service (but comes to rest at a platform en-route) can exacerbate the *delay to service.*

A facility shall be provided to permit staff to detrain passengers while ensuring no-one else can board the Train, which shall: 1783

- close the passenger doors on that side of the car, when operated;
- be accessible from the platform and the saloon;
- be located at a consistent position on each car;
- operate without delay;
- be robust against inadvertent or malicious use by passengers.

Emergency door access controls shall be provided on the outside of each car on each side which shall: 1790

- enable the emergency services to enter the Train;
- enable staff to enter the Train (including in an emergency) from the platform if RCS faults prevent remote operation of the doors;
- be accessible from the platform by reaching through the aperture of an open platform edge door;
- function under all degraded conditions of the Train and power supply;
- open/release the adjacent set of double doors, when operated;
- open/release the wheelchair access door on any cars where wheelchair access doors are present;
- when the power supply is healthy, automatically power open the adjacent doorway or allow the adjacent doorway to be powered open using a control locally at that doorway;
- resist inadvertent operation from accidental contact by passengers and their luggage;
- return to its original position when released;
- require no key or tools to operate it;
- be operable by the target user population;
- be located and labelled so as to be visible to persons who may require its use in an emergency.

It shall be possible to access and operate no less than one emergency door access control on the side of each car via a PED aperture. This requirement shall be met for all positions of the Train within the normal stopping position window (+/-300mm from nominal stopping position). 6202

It is anticipated that this will require fitting one emergency door access control per doorway.

It shall be possible to evacuate all passengers (excluding mobility impaired passengers and wheelchair users) from a Train in no longer than 90 seconds through those side doors to the platform that are 6090 operated by the emergency door access controls. This test shall be carried out by able bodied staff, in the factory, under the most advantageous conditions that maximise the flow of people.

It shall be possible for staff to open/close the end set(s) of passenger doors to enter/leave the Train. The facilities to be provided for this purpose shall: 3632

- include open and close controls, conveniently located inside the Train near to the doors;
- include open and close controls, conveniently located outside the Train near to the doors;
- minimise the risk of unauthorised use.

A means shall be provided for staff to open and close each individual passenger door from within the saloon. This facility shall be conveniently accessible for instant use and shall function irrespective of whether or not the doors are powered. 3957

Passenger doors shall close for passenger comfort 45s after opening. This timing parameter shall be configurable by the Purchaser. *This feature is for passenger comfort and thermal efficiency during extended platform dwells.* 1806

Doors that have closed for passenger comfort shall be able to be reopened by passengers on demand as long as the doors are still authorised to be open. 5359

Doors that are closing for passenger comfort shall be able to be reopened by passengers on demand as long as the doors are still authorised to be open. 5366

Doors that have closed for passenger comfort and then have been reopened by a passenger shall subsequently automatically close 15s after the passenger reopen command. This timing pattern shall be repeated for any further passenger reopen commands during the station stop. 5368

Doors that are closing for passenger comfort shall have associated audible and visual indications that are distinct from the audible and visual indications used at other times. The indications shall avoid conveying a message that the Train is preparing to depart. 5360

Doors that are closing for passenger comfort shall do so at a slow speed and shall immediately re-open fully (at normal speed) when an obstruction is detected. 5361

It shall be possible to inhibit the function which closes doors for passenger comfort. The inhibit shall be for all of the passenger doors on a Train and shall be able to be applied at any time during a station stop. The inhibit shall stay active until the end of the station stop. 5362

Inhibiting of the function which closes doors for passenger comfort shall be possible by an operator on board the Train. 5363

Inhibiting of the function which closes doors for passenger comfort shall be possible remotely via the RCS. 5367

Door closing for passenger comfort shall not occur on any door when there is an active PEA anywhere on the Train. 6591

Passenger operated door open buttons shall be provided to enable passengers to reopen doors that have closed for passenger comfort, or to open doors that have been released (i.e. Passenger Open selected). On the exterior, each doorleaf shall have a door open pushbutton located close to the centreline of the doorway. On the interior, one doorleaf shall have a door open pushbutton located close to the centreline of the doorway. 1805

Passenger operated door open buttons shall, when pressed and held down before the doors are enabled, cause the doors to open as soon as they are enabled without having to release and re-press the button after the doors are enabled. 5921

Controls provided for use only by staff shall be protected against use by passengers. 5160

19.3.3 Audible and Visual Indications 1938

Both external sides of each car shall be fitted with an outside door indicator light (ODIL) which shall illuminate when: 1792

- one or more doorways of the car are not closed;
- one or more doorways of the car are closed but released.

ODILs shall be clearly visible, when the passenger doors are in any position, to a person standing adjacent to the side of the Train when on straight track, at either end of the Train, on station platforms (without PEDs) or at the trackside. 1793

ODILs shall have an amber coloured light and have their state readily discernible in all natural and artificial lighting conditions. 4458

Each passenger doorway shall be fitted with an audible warning device which shall emit warning sounds which can be heard inside and outside the vehicle adjacent to the doorway. 4971

The door system shall sound an audible warning prior to the closing of the passenger doors. The warning shall be configurable, with an initial setting of 3.0 seconds. The characteristics of the warning shall be consistent with door close warnings on existing LU trains. 2003

The door closing audible warning shall be a pulsed single tone at a rate of 6 pulses/s, with a frequency of 1500±100hz and a sound pressure level configurable between $60dBL_{Aeq,T}$ and $70dBL_{Aeq,T}$ measured outside the train 1.5m from the door, aligned with the doorway centreline, at 1.5m above floor level. 3798

The door system shall include an audible warning during the opening of the passenger doors. 2011

The door opening audible warning shall be distinctly different from the door closing audible warning. 3801

The door opening audible warning shall have a sound pressure level configurable between $58dBL_{Aeq,T}$ and $68dBL_{Aeq,T}$ measured inside the Train, on the longitudinal centreline, aligned with the doorway centreline, at 1.5m above floor level. 3802

The sound pressure level (SPL) of the door audible warnings shall be easily configurable at the commissioning stage and throughout the life of the Train. This shall facilitate: 4972

- Initial setting of the SPL to ensure warnings are sufficiently audible at all stations (taking into account station acoustic properties and ambient noise).
- Initial setting of the SPL to ensure warnings do not constitute a nuisance to passengers on board the Train or to the neighbours of the railway.
- Alterations, if required, to continue to achieve the above when Platform Edge Doors are introduced.

Provision shall be made to optimise (at the testing and commissioning stage) the ratio of door audible warnings SPLs apparent inside the Train with those apparent outside the Train. 4973

External visual indications shall be provided at all passenger doorways and shall be highly visible to passengers approaching the doorway from the platform. 2007

External visual indications at the doorways shall inform passengers on the platform that the doors are opening or are open. 4974

External visual indications at the doorways shall warn passengers on the platform that the doors are preparing to close or are closing and that it is not advisable to attempt boarding. 4975

External visual indications at the doorways shall inform staff and passengers on the platform when the door has not closed and locked within a configurable time after a close command. 4976

Internal visual indications at the doorways shall inform passengers in 4746 the door vestibule that the doors are open or are opening.

Internal visual indications at the doorways shall inform passengers in the door vestibule that the doors are preparing to close or are closing. 4977

Internal visual indications at the doorways shall inform staff and passengers in the saloon when the door has not closed and locked within a configurable time after a close command. 4978

Internal visual indications at the doorways shall inform passengers in the saloon that the door will not open at the next station. 4979

Internal visual indications at the doorways shall inform passengers in the saloon that the door will not open at the current station. 5829

The duration of the passenger door audible and visual indications shall be configurable (independently). 1958

Audible announcements shall be made in the vicinity of passenger doors that are cut-out or inhibited to encourage passengers to move to another doorway. 4830

When passenger doors are obstructed, audible and visual indications shall be employed to draw attention of persons inside and outside the Train to the obstructed doorway. Options to be considered include flashing the door threshold lights, making automated announcements, sounding a specific audible alert, flashing the ODIL, and flashing the internal and external visual indications. 2008

19.3.4 Obstruction Management and Anti-Dragging 1992

The features required for detection and management of obstructions are intended to deter passengers from obstructing the doors and to reduce the chances of any attempts to obstruct being successful, whilst not causing any injury. 1995

Doors shall operate in a manner such that the safety risk of objects and passengers becoming trapped is managed ALARP. 1649

Doors shall maximise the opportunity for objects and passengers to be released when trapped. 4416

When inserted between the passenger doorleaves up to a height of 450mm from the treadplate, an 11mm diameter bar shall be detected and prevent the Train from moving. 4417

In the event of a passenger door contacting an obstacle during the closing stroke, the following sequence of actions shall occur at that doorway: 1993

- the door shall stop, reverse direction and re-open a distance of 50 mm per doorleaf;
- the door shall pause for a time of 0.5 s and then attempt to re-close;
- if an obstacle is again detected, this cycle shall be repeated a further 2 times.

If after 3 attempts the door is still obstructed then the following sequence of actions shall occur:

- the door shall stop and remain in its current location and apply a clamping force not exceeding 150 N and not less than 100 N;
- if an attempt is made to push the door open, the door shall respond with a clamping force of up to 400 N in order to resist the attempt to open the door. This raised clamping force shall be maintained for at least 2 minutes;
- if the obstacle is cleared during this sequence, the door shall close normally and lock. If the obstacle has still not cleared at the expiry of 2 minutes (minimum) the door may become free to be moved by hand but shall not power open or close without further command;
- once the door is free to move it shall be possible to command the door to close by issuing a close command only.

All of the parameters and behaviour, including timings, forces and distances, comprising the passenger door obstruction detection sequence defined shall be configurable and shall be alterable by the Purchaser. 4463

Where passenger doors have failed to close after a configurable time period, saloon CCTV images of the affected door vestibule(s) shall be made available to the RCS and to the cab displays. 4462

On heavily loaded trains, passengers will squeeze into the vestibule and be very close to the doors when they close. Therefore there is a risk of them initially getting loose clothing trapped in the doors which they will then attempt to extract. This is most common in winter. This can be particularly problematic when passengers still cannot release their clothing at the next station due to the platform side alternating from one side to the other at each station. 1997

A passenger door pushback facility shall be provided which will allow one doorleaf of each pair to be reopened up to 115mm from the fully closed position. The forces shall be no more than 120-140N at 3mm stroke and 227-253N at 110mm stroke. 1998

The pushback facility shall provide opportunity for trapped items to be released and it shall lead to de-energisation of the traction-door interlock and loss of doors closed indication if the door is forced open further than the interlock switch break point. 6260

On release of the doorleaf at any point within the pushback travel the doorleaf shall return to the fully closed position within 2 seconds. 5183

It shall be possible for passengers on board the Train to self-release trapped items from between closed door leaves at any time without affecting the operation of the Train. Typical trapped items to be released are newspapers, bag straps and folds of material e.g. coat tails and sleeves. 1996

The passenger door seals shall allow a piece of double thickness canvas, to LU Drawing 76340 'Canvas Sheet and Pull Through Test', to be pulled through the door edge seals at right angles to the door leaf and at all heights between floor level and 1.2 m ± 0.25 m with the doors closed with a force no more than 90N. This requirement represents a pull through of passenger clothing. 5779

The impact forces throughout the passenger door closing stroke shall comply with the 'higher force level' of British Standard BS EN 14752:2015 'Railway Applications - Bodyside Entrance Systems for Rolling Stock'. 3823

19.4 Cab/Saloon Interconnecting Door 124

A door designated J-door shall be provided in the partition between the cab (when fitted) and the saloon. 1667

The J-door shall enable staff access and egress between the cab and saloon. 3934

The J-door shall enable controlled passenger movement from the saloon to the cab (and vice versa) for emergency evacuation. 3933

The J-door shall provide security against unauthorised access to the cab. 3935

The open/closed status of the J-door shall be monitored and made available to the RCS. 5185

J-Doors shall not be capable of being jammed shut: 1622

- in normal operation;
- as a result of any reasonably foreseeable collision.

The J-door throughway shall be as large as reasonably practicable and in any event not less than 650mm wide and not less than 1815mm high. 1668

The J-door shall be fitted with a slam lock. 1669

The J-door shall be hinged on the left-hand side, when viewed from the saloon side. 3937

The J-door shall hinge open into the saloon. 3939

The J-door shall be capable of being opened from the cab side by the use of a plain handle. 3940

The J-door shall be capable of being opened from the saloon side by an authorised person using the female end of a standard J-door key. 3943

The J-door shall be capable of being opened from the saloon side by any person after removing a sacrificial covering over the door handle. The covering shall be designed to discourage unauthorised access. 3946

A security viewer shall be provided to allow the operator to view the area in the vicinity of the J-door on the saloon side, from the cab. 1855

The J-door shall be capable of withstanding the following loading, applied separately: 2043

- 2kN over any area measuring 50mm by 50mm;
- 7kN over the whole area of the door.

Fluids shall be prevented from passing underneath the J-door from the saloon into the cab. 2384

19.5 Emergency Access and Detrainment Door 125

A door designated M-door shall be provided in both outer ends of the Train to enable: 1672

- access and egress between the car and the track under:
  - normal operation;
  - where infrastructure conditions require, emergency conditions.
- passenger egress to the track, in the event of an emergency;
- containment of passengers within the Train when there is no cab.

The M-door throughway shall be as large as reasonably practicable and in any event not less than 650mm wide and not less than 1815mm high. 1673

The M-door shall open into the cab and not impede the J-door. 1674

The M-door hinge shall be positioned such that when the door is opened the door forms a barrier between the operating position and the 5345 door aperture.

The M-door shall be leak-proof and draught-proof. 4466

The M-door shall be operable manually under all conditions from: 4467

- the exterior of the car from track level;
- the doorway of an assisting train.

M-Doors shall not be capable of being jammed shut: 4742

- in normal operation;
- as a result of any reasonably foreseeable collision.

The M-door shall be capable of withstanding impacts from reasonably expected projectiles and small branches from fallen trees. 4468

In the early migration states, the M-door will be accessible only to the operator and later it will be a part of the saloon and therefore it will be accessible to passengers. 4253

The M-door at the front end of the Train shall not be locked when the Train is in Shutdown, Manual mode and Train Secure mode. 4262

The M-door at the rear end of the Train shall be securely locked shut when the Train is in Manual mode and Train Secure mode. 5899

The M-door at the rear end of the Train shall not be locked shut when the Train is in Shutdown mode. 6851

The M-doors shall be securely locked shut when the Train is in Automatic mode. 3925

The M-door shall be capable of being opened from the inside by staff and passengers when the door is unlocked. 3930

The M-door shall always be capable of being opened (even if it is locked) from the outside without the use of tools or keys. 5801

The M-door shall be capable of being unlocked in response to a command from the RCS. 3928

The M-door shall default to unlocked when the RCS reports all communication with the trackside is lost and the Train speed is zero. Implementation of this requirement shall avoid unnecessary unlocking due to intermittent short-duration loss of RCS communication. 4267

The Manufacturer shall undertake a safety assessment which considers the failure modes associated with the M-door locking and the 4261 hazards associated with passengers being trapped on a train.

The open/closed status of the M-door shall be monitored and the output made available to the RCS. 3949

Changes of open/closed status of the M-door which occur whilst the Train to RCS communication is lost shall be reported to the RCS immediately when Train to RCS communication is restored. 6262

The locked/unlocked status of the M-door shall be monitored and the output made available to the RCS. 3952

When Restricted Manual mode is selected it shall be possible for the operator to drive the Train with the local M-door open. 4258

When Automatic mode is selected the Train shall not be able to traction when either M-door is open. 5958

19.6 Cab Side Doors 6879

Power operated access doors shall be provided on both sides of the cab. 6880

The cab side doors shall be able to be operated by hand when no power supply is available. 6881

The cab side door controls shall be able to be operated from platform level and from track level. 6903

The time taken for a sliding cab side door to open shall be not less than 3.0 seconds and not greater than 3.5 seconds. 6882

The time taken for a sliding cab side door to close shall be not less than 3.5 seconds and not greater than 4.0 seconds. 6883

The cab side door controls shall minimise the risk of unauthorised access to the Train. 6888

It shall not be possible to gain access, via the external cab side door controls, to any cab of a Train on which a cab is in an operational mode. 6891

Each cab side door shall be controlled independently. 6902

There shall be a cab side door close pushbutton on the outside of the Train adjacent to each cab side door. 7054

There shall be a cab side door open keyswitch on the outside of the Train adjacent to each cab side door which shall be operated by the female end of a J-door key (LU Drawing 100524 'Gedore Operating Key'). 7055

External cab side door controls shall not be illuminated. 7056

An operator at the controlling operating position shall be made aware of the status of the cab side doors in the rear cab. 6886

The status of the cab side doors shall be reported to the RCS. 6887

There shall be a facility available in the controlling cab to close the cab side doors in the rear cab. This facility shall be available when the position of the rear cab side door is preventing the Train from entering service. The use of the facility shall cause an audible alert to be sounded in the rear cab. 6890

20 Train Driving Simulator 5702

The term 'train driving simulator' used within this document embraces all on-Train equipment (and associated functionality) used for the monitoring and control of Train movements and for communication with the railway control organisation and with customers. 5546

Each Train driving simulator shall comprise a full cab mock-up providing a realistic simulation of the driving experience - 5643

- the cab layout;
- the view through the windows;
- the feel and response to operation of all controls;
- a fully immersive, accurate simulation of the cab environment and railway functionality.

Each Train driving simulator shall be designed and built to address the following training needs: 5644

- general driving skills;
- use of cab controls and instruments;
- observation of and compliance with the demands of the signalling system;
- response to various signals;
- application of brakes;
- remedial action to equipment failures;
- safety aspects of driving, including recognition of, and reaction to, notifications (i.e. alarms and alerts);
- communication with the railway control organisation and with customers;
- driving under normal, abnormal, degraded and emergency conditions.

Each Train driving simulator shall be provided with a separate trainer station that allows for interaction with the trainee in the Train driving simulators and for the setting-up, monitoring and administration of various scenarios. 5646

Each Train driving simulator shall provide simulation options for open sections of line, to reflect operation in conditions of low adhesion, sun, fog, snow, rain and dull weather. 5845

Each Train driving simulator shall provide simulation options for tunnel sections to reflect operation in normal and dusty conditions, with and without tunnel lighting. 5846

Each Train driving simulator shall be a true representation of the Train 5847 cab with fully functioning operator interfaces offering identical tactile feel and appearance to the actual equipment in a new Train cab.

The view through each cab window of each Train driving simulator shall be represented by life size, lifelike, dynamic images, synchronised to simulated Train speed and replicating all parts of the DTUP infrastructure (including the depots) over which the Train will travel. 5848

The view presented through each cab window of each Train driving simulator shall contain dynamic representations of features relevant to the driving experience including, but not limited to: 5849

- all operational signs, notices and markers boards;
- all signals and related equipment;
- all platform / train loading conditions;
- removable and/or moving events and features (e.g. obstruction on the track).

Each Train driving simulator shall provide a surround sound system with adjustable volume, giving realistic simulation of the audio environment of the driving cab, synchronised to simulated Train location, speed and infrastructure performance, covering the full frequency spectrum of the Train noise. 5850

Each Train driving simulator shall accurately reflect Train performance characteristics in all modes of operation. 5851

Each Train driving simulator shall simulate all operational modes available on the Train including, but not limited to, Shutdown, Restricted Manual, Inter, Protected Manual, Attended Automatic, Unattended Automatic, Train Secure and Power On and Power Off. 5852

Each Train driving simulator shall provide a means of emulating the Train's response to Train Operator actions throughout the Train. 5853

A facility shall be provided with each Train driving simulator to enable training on all aspects associated with the operation of the detrainment systems. 5854

Each detrainment training facility could be either fully integrated with its associated Train driving simulator or provided as a separate training rig.

Each Train driving simulator shall provide a facility to simulate the coupling of two Trains together and the push/pull-out of a Train (using relevant CCTV etc.). 5855

The Manufacturer shall provide equipment in the training room to allow real-time observation of the trainee experience in relation to the associated Train driving simulator(s), including (as a minimum): 5856

- CCTV video of the cab interior from which to observe trainee actions;

- a facility to hear all trainee communications with the trainer's workstation and vice versa;
- Computer Generated Image (CGI) view of the road ahead as seen by the trainee;
- CGI graphical representation of driving cab controls indicating controlling positions / settings; and
- CGI image of all trainee interfaces within the cab and associated trainee actions throughout the Train showing trainee stimulus and response.

The Purchaser will provide a training room with seating for up to 12 trainee operators who will be observing training sessions in the train driving simulator.

Where two Train driving simulators are co-located, in addition to each trainer station controlling its associated simulator, one of the trainer stations shall be capable of simultaneously controlling both simulators. 5857

Each Train driving simulator trainer station shall provide: 5858

- full control of all elements of the Train driving simulator;
- a facility for the trainer to communicate with the trainee during scenarios;
- a facility for the trainer to play the role of customer or a member of the railway control organisation and communicate as such with the trainee during scenarios;
- a mute control and on/off facility positioned within the training room for the audio link from the simulator to the training room and a mute control and on/off facility positioned at the trainer workstation for the audio link from the simulator to the trainer workstation;
- CGI image of the active training scenario showing progress against the scenario and highlighting upcoming scenario events;
- a facility to make real-time modifications to the live scenario during training sessions;
- a facility to simulate all operator-facing fault and failure conditions and allow trainees to undertake the actions required to rectify such conditions;
- a facility to select environmental conditions for scenario runs including, but not limited to: day, night, rain, fog, snow, ice, varying adhesion conditions;
- a facility to put event markers (via a trainer station push button) to time-stamp any point in a training session for later replay for de-briefing;
- real-time synchronised audio and video recording of training sessions;
- audio and video playback of training sessions for trainee

session de-briefing;

- a facility to “fast forward" and "rewind” audio and video playback to trainer flagged event markers;
- automated real-time report generation and printouts of trainee performance against each training scenario on both train operation technique and defect handling;
- off-line facility for trainers to create, copy, edit and save training scenarios;
- off-line facility to create, modify, copy and edit training report templates for the automated report generation system.

Each Train driving simulator shall be designed so as to ensure that scenarios can be run with Trains changing their direction of travel at a terminal station, depot or other location as required, without the need to shut-down or re-start the Simulator. 5859

Each Train driving simulator shall be able to operate independently in the event that linked simulators are not being used or are being maintained. 5860

Each Train driving simulator shall be capable of being operated for 16 hours per day, seven days per week. 5647

The Manufacturer shall provide all necessary support in relation to both the user operation of the system and in relation to equipping the Purchaser's personnel with the knowledge and skill required to author scenario content changes. 5648

The Manufacturer shall provide training on the train driving simulator to include, but not be limited to; 5649

- simulator start-up and shut-down;
- running simulator scenarios;
- editing and creating scenarios, including the use of Purchaser scripts;
- evaluating the performance of Train Operators;
- printing reports;
- operation and use of all peripheral equipment;
- periodic database maintenance activities;
- simulator diagnostic testing and fault isolation in all operational areas of the simulator;
- simulator regular maintenance;
- identification and completion of remedial actions to the computer system, peripheral components and simulator cabin hardware;
- all other aspects pertinent to the operation of the train driving

simulator not included in the above.

The Manufacturer shall provide confirmation of the interface requirements for each Train driving simulator, including: 6439

- space;
- access;
- electrical supply requirements.

21 Maintenance 153

21.1 Maintenance - General 1624

The Manufacturer shall carry out maintainability analyses during all phases of the project to ensure compliance with the maintenance requirements. Any actions arising from the analyses shall be fed back into the design by an auditable process. 3367

The Manufacturer shall conduct maintenance demonstrations to prove that the maintenance timings and processes (including tooling) defined are achievable and useable. 3363

The Manufacturer shall define wheel condition and wheel profile maintenance and monitoring, including measurement techniques, record keeping and trend analysis. 5400

The Manufacturer shall work with the Purchaser to develop the specification for equipment to be installed in the depot, by the Purchaser, in order to enable the Purchaser to maintain the Trains in line with the Train Maintenance Regime (TMR) and ensure that the depot plant interface is achievable. This shall include, but not be limited to: 5401

- Train/car lifting;
- equipment drop capability;
- any cleaning facility requirements;
- facilities for the replenishment of consumables;
- exterior equipment access platforms, e.g. door maintenance (access);
- any condition monitoring data analysis/trend analysis facilities;
- interpretation of downloaded Train data;
- a level road for measurement and adjustment;
- integration of any Special Tools which are provided by the Manufacturer;
- interface plates, arms and jigs for refit and removal of Train equipment;
- any other depot changes or Equipment identified by the Manufacturer pertaining to the TMR.

Isolation devices shall be provided to support effective maintenance. 4286

Any adjustment facilities shall have sufficient tolerance to allow setting of the equipment across the range of tolerances without any difficulty. 1546

If actions are required to set-up Train equipment, it shall be possible to 3392 readily access all of the items which require adjustment or test and the procedure shall be simple and straightforward without the need for 'trial and error'.

The design shall minimise the opportunity for errors during routine maintenance and Part replacement activities. Error proofing devices shall be designed in to the Train and where applicable, gauges, jigs or alignment devices shall be provided to confirm correct set up. 1550

The Manufacturer shall provide automatic lineside inspection equipment where this can reduce the whole life cost of the Train (e.g. checking the condition of panels, fastenings). 3432

The Manufacturer shall provide the automatic lineside inspection equipment to the Purchaser for installation on the infrastructure by the Purchaser or a third party appointed by the Purchaser. 7063

The Manufacturer shall supply any trainborne equipment, the ground-based Equipment for each location, and sufficient computer hardware and software necessary to fulfil the requirements for the automatic lineside inspection equipment. 7064

It shall be possible to configure the automatic lineside inspection equipment to pass raw and processed data to related Purchaser services such as the Purchaser's maintenance management tools (e.g. Ellipse). 7129

The Train's equipment arrangement shall be compatible with automatic lineside inspection equipment where this has been derived to be the optimum maintenance approach both when the asset is initially introduced and by making reasonable assumptions about future lineside inspection equipment which may be implemented. 2684

Automatic lineside inspection equipment will be defined and used, for example, to measure collector shoe wear, shoe gauging, brake block/pad wear, wheel condition and to check the condition of underframe equipment fixings. 2685

The Train shall be capable of being lifted as a complete Train with or without bogies and without detrimental effect on the inter-car coupling or gangway. Facilities to remove equipment from the Train, including alternatives to a full Train lift, shall be proposed by the Manufacturer. 1744

Parts and their packaging shall be designed such that spares shall not be damaged during handling or storage. 1472

Where access panels require removal for access to items of equipment, their removal shall not disturb the integrity of any water and dust ingress seals. 1839

Types of visually similar but functionally different Parts shall be 3362 designed so that it is not possible to fit one type in place of another type.

All identical items of equipment and all identical Parts shall be fully interchangeable. 3394

A single method of cascading data to any systems affected by a change in wheel diameter data shall be provided. 3396

Any captive parts (e.g. threaded inserts) of fixings shall withstand the number of required operations throughout the life of the stock or be designed to enable effective repair and replacement within the maintenance plan. 3421

The Train overall and its individual sub-systems shall be designed and, where necessary, maintenance instructions shall be produced, in order to prevent acts or omissions during maintenance from causing vibration to be induced. 2953

It shall be possible to update software locally via an ethernet port. 4702

Connections and ports, which are not usually connected in service, shall be protected by a cover to prevent accidental damage or misuse. 3407

21.2 Train Maintenance Regime (TMR) 3440

A Train Maintenance Regime (TMR) shall be delivered to support: 1564

- achievement of the design life;
- achievement of the reliability targets;
- sufficient availability;
- maintenance of the aesthetic condition;
- cleanliness;
- maintenance of asset condition;
- safe operation

of the Trains and Equipment.

The TMR shall be established by a structured analysis of: 1563

- service requirements;
- operating environment;
- Train and Equipment design;
- maintenance facilities;
- historical data (where available);
- industry best practice.

The TMR shall declare the operational context, philosophy, maintenance procedures and tests, how required standards are to be achieved and how the maintenance regime supports the safety case. 3358

The Train Maintenance Plan (TMP), part of the TMR, shall comprise a series of maintenance activities structured to follow the maintenance levels outlined in the TMR, with defined intervals and tolerances on intervals, after which the Train needs to be withdrawn from service. 3355

The Purchaser traditionally specified Daily Train Preparation and other specific maintenance intervals and activities. These requirements are no longer prescribed; any specific requirements would be those which emerge during the Train design. 1536

There shall be no nightly or 24 hourly train preparation, inspection or testing by the maintainer. 2527

The TMR shall include details of any safety inspection checks, the purpose of these being to ensure that external equipment is secure and undamaged. Such checks shall make effective use of the automatic lineside inspection equipment to minimise the use of physical inspections. 3581

Any testing or inspection that is required to be carried out at an interval of less than 7 days shall be fully automatic requiring no action by the maintainer. This does not apply to cleaning and litter picking. 2623

Routine inspection and testing of Short-Circuiting Devices shall be in accordance with LU Standard S1926 'Design, Manufacture, Testing and Maintenance of Short-Circuiting Devices'. 4934

The TMR shall show how the maintenance activities can be arranged to enable the greatest service availability to be achieved. 4998

The design of the Train and Equipment, including all its systems and Parts, shall ensure that routine maintenance requirements and whole life costs are minimised. 3110

The Train and Equipment design and TMR shall enable the Purchaser to substantially reduce the cost of maintenance by the use of innovative techniques such as automated testing and inspection, elimination of repetitive inspection by maintainers and enabling automation of manual tasks. 3112

Maintenance requirements should be assessed using the Stage 4 tender evaluation model calculation. 3111

21.3 Design for Depot Facilities 1501

The Train shall be designed for maintenance generally within the 1303 existing depots. The Purchaser expects to make changes where these are proposed by the Manufacturer so as to support the TMR. It is not proposed to make general changes such as the replacement of the current pitted and side pitted roads with swimming pool roads. It is acknowledged that significant depot infrastructure changes such as fitting new lifting facilities will be needed, either to replace existing facilities which are unsuitable, or where no facilities exist.

The current depot layout and facilities are described in Reference Document NTfL-2344.3.4-LUL-RPT-00047 'Depot Potential Developments'. A number of potential depot changes which have been assessed by the Purchaser have also been included within this document. 1641

The Manufacturer shall propose any changes needed to depot facilities, e.g. equipment drop or lift facilities. Such proposals shall be supported by a rationale for how these changes support an effective TMR. 1636

The Manufacturer shall define the interface and equipment required for filling the sand reservoirs. 2936

The Depot Facilities evaluation calculation from the Stage 4 tender evaluation model shall be used to maximise the benefit of conflicting requirements and to demonstrate compliance with the requirements. 4234

21.4 Design for Access and Ease of Maintenance 1661

It shall be possible to access Parts for repair, overhaul and test with a minimum of dismantling and disturbance to other parts. As far as reasonably practicable, access to items that need to be routinely removed shall not be restricted by other Parts that would need to be removed or adjusted to enable the actual maintenance activity to commence. 1545

The number and type of fixings shall be chosen to enable the shortest removal and replacement times commensurate with safety and security. 1474

It shall be possible to easily identify that any fixings are not correctly fastened. 6025

Blind fixings shall not be used on key structural underframe Parts. 5177

Common lengths and grades of fixings shall be used to reduce spares holdings and staff errors. 5178

Spring washers and split pins shall be avoided. 5179

The time and cost of removing panels and equipment for access shall be listed in the Stage 4 tender evaluation model calculation. 4235

Part removal and replacement shall be assessed in terms of manual handling to ensure that the activity can be undertaken by the target user population. 1465

To support the easy reassembly of equipment, alignment pegs shall be used where applicable. 4512

Any Part modularisation shall be determined so as to minimise whole life costs, thus giving effective stock holding, reduce replacement cycle times and not impact on reliability. 1713

Removal and refitting of equipment shall be demonstrated to meet good HF & HSE principles. 1478

Where a Part is of a size, weight, and within a reach envelope, that together result in a reasonable expectation that removal of that Part should be accomplishable by a single maintainer, the design of fixings, supports and attachments shall meet that expectation. 4545

Where sub-assemblies of Parts are unsuitable for lifting by one person, then a means shall be provided to allow lifting/lowering by suitable lifting equipment (e.g. slings or chain tackles or lifting tables). Where lifting eyes or lugs are required to effect safe lifting, but cannot be accommodated permanently due to space constraints, then tapped holes for screwed lifting eyes may be provided as an alternative, in which case the holes shall be used for no other purpose. 2568

Handles or handholds shall be provided on Parts whenever their omission would lead to difficulty during removal or replacement. 4547

Where individual modules or Parts cannot be removed/refitted by a single person, they shall be arranged such that they can be easily manoeuvred into and out of position with the aid of lifting/lowering equipment, taking full account of the location of the equipment, depot facilities and access limitations. 1519

Where connectors of the same type and form are in close proximity, a means of preventing wrong connection shall be employed. 168

The free half of a connector pair shall be adequately robust to resist damage where there is a possibility of dropping the connector, with cable attached, onto a hard surface. 169

Labels shall be fitted adjacent to all relays and contactors and/or a diagram of the devices shall be securely attached to the inside of the enclosure cover, depicting the name or function and contact arrangement for each device. 170

It shall be possible for labels on equipment and for identifying diagrams on covers and enclosures to be replaced as part of a modification to the vehicle during its life. 171

The Train shall be capable of having its wheels turned using an underfloor wheel lathe. 3374

It shall be possible to carry out any bogie or carbody height adjustment required after wheel turning without having to lift the cars. 5732

This is to ensure that Trains do not need to be shunted to other depot locations after wheel turning for ride height adjustment.

The processes for removing large items of equipment shall be compatible with the depot layout (e.g. pit, fork lift truck, space between roads). 3377

The Train shall be designed so as to ensure that damage caused by passenger action and vandalism can be repaired quickly. This shall be facilitated by having a robust and rugged interior, design features which make it quick and easy for authorised staff to replace items and tamper proof fixings and fastenings. 3378

Examples of damage and vandalism, which shall be repairable between peak service intervals, shall include, but not be limited to:

- window replacement;
- interior panel replacement;
- saloon CCTV or customer information displays replacement;
- seats and arm rests replacement and repair;
- removal of graffiti.

All luminaires shall be secured by tamper proof fasteners but these shall be easily replaceable using simple hand tools. 4699

Areas of the Train with the highest stresses shall be readily accessible for effective inspection. The total time taken to access and reinstate the area, not including the time for inspection, shall be less than 1 hour per car. 3379

The design shall ensure that it is practical to undertake visual inspections of hidden areas of the carbody structure to check for signs of damage or deterioration. 3423

Consumable replenishments shall be carried out without the removal or disturbance of other Parts or equipment. 3372

The conduct of routine maintenance to check or adjust Parts shall not require the mounting arrangement of that component to be disturbed or the component's security to be compromised (e.g. shoegear height adjustment shall not require the shoegear mounting to be disturbed). 3381

21.5 Line Replaceable Units (LRU) 3401

An LRU is defined as a Part which can be replaced as part of first line maintenance to rectify faults. This could be an item which is a sub-component of another assembly, which itself could be changed out. 4351

LRUs shall wherever possible utilise standard fixings, seals and connections to facilitate their removal and fitment. 3402

Pneumatic commissioning chokes shall be retained on the Train and not be removable as part of any LRU. 2798

Non-traction voltage electrical connections to LRUs shall be via multi-pin connectors. 3406

LRUs shall be designed so that any levers, control handles, switches or other devices shall sustain no damage whilst the LRU is not mounted on the Train. 3408

LRUs weighing more than 20kg shall be provided with feet or flats to provide adequate stability to prevent rolling when placed on the workshop floor or work-bench. 3409

LRUs shall be provided with an identification label indicating key parameters, including where appropriate description, type, where used, setting, version, modification status, part number, unique serial number. 3410

When the LRU is installed on the Train in the final position, the identification label shall be visible to the maintainer without the need to dismantle or remove other equipment. 6181

All labelling shall remain legible for the whole life of the Part, including overhaul processes and cleaning. 4843

All Train Parts used in all simulators shall be uniquely identified in the same manner as Train Parts fitted to Trains. 1723

LRUs shall be provided with industry standard electronic identification and tracking tags (e.g. RFID tagging). 3411

The LRU identification tags shall be permanently attached and shall not be degraded by the operating environment. 5865

LRU identification tags shall be capable of being recorded in situ by using a handheld self powered reader with download capability. 1722

21.6 Consumables 3412

Consumables which are designed to wear out shall achieve their design wear rate. 3415

Consumables that wear shall either provide a clear (visual) indication that they require replacement or be installed such that the automatic lineside inspection equipment can identify the extent of the wear. 3417

All Consumables shall have sufficient life to last until at least the next planned consumable intervention. 3414

For Consumables that are dispensed there shall be monitoring and reporting to indicate when replenishment is required. 3418

There shall be monitoring and reporting to detect failures which cause an excessive rate of consumption of Consumables. 3570

21.7 Cleaning 1489

The Manufacturer shall define all cleaning for the Train. This shall include tools, materials and processes. 1493

All parts of the Train shall be designed for ease of cleaning without excessive dismantling. 4236

The design of the Train shall facilitate the cleaning of the interior and exterior of the Train in order to: 1490

- preserve the aesthetic appearance;
- control the risk of infestation;
- control the risk of health problems for staff and passengers;
- control the potential fire hazard posed by accumulated waste.

The Train shall be resistant to damage that can be caused by: 1491

- use of the recommended cleaning materials;
- cleaning processes;
- graffiti and gum removal processes employed.

Examples of graffiti shall include, but not be limited to, damage caused by the use of leather dye, spray paint, marker pens.

The cleaning products and processes proposed shall be such that their use is not a risk to the public or staff and residues are not left such as to cause harm to these people or to the environment. 1492

The cleaning processes shall minimise the volume of water and cleaning consumables used. 4995

The Train shall not be harmed by repeated applications of cleaning techniques. 4238

The interior shall be designed so that all surfaces are easily cleaned. 3386

The interior finish of the Train shall be resistant to the materials and techniques proposed for the removal of graffiti. 5156

The interior finish of the Train shall not show any graffiti residue following the Manufacturer approved cleaning process. 5158

The exterior shall be designed so that all surfaces are easily cleaned. 5155

The carbody exterior finish shall not suffer damage or deterioration as a result of regular, routine cleaning (e.g. by means of a washing plant and hand washing with a brush). 2500

The cleaning processes shall not have an adverse effect on peripheral items which may be exposed to the cleaning agents and process by their proximity. 1734

The Manufacturer shall demonstrate that any filters required can be either automatically purged of debris in a controlled manner or be readily and quickly checked and cleaned or replaced. 1728

21.8 Maintenance Testing & Fault Finding 1566

The Train and Equipment shall, where practicable, include automated post-maintenance testing. 4428

It shall be possible to command automated tests remotely via the RCS and via the OTC. 3430

It shall be possible to manually trigger automatic tests via the RCS and via the OTC. 5270

It shall be possible to manually trigger automatic tests locally on the Train. 5271

Where automated testing is instigated, it shall not contribute to loss of performance or cause in service failures to occur. 1697

The TCMS shall record and report to RCS automatically initiated system self tests which have not been performed, failed to complete, failed the test or passed the test, along with details of any test results. 3348

The TCMS shall record and report to RCS maintainer initiated system self tests which have not been performed, failed to complete, failed the test or passed the test, along with details of any test results. 900

Equipment shall not be isolated due to a failure to complete an 901 automatic test within a particular time limit, unless there is a demonstrable safety risk.

The results of routine testing, associated with fitness for service, shall be transmitted to the RCS. 1316

A means of accessing service performance and fault information from all electronic control units shall be provided. This shall be accessible via the RCS and the OTC and directly from the item of equipment. 3399

The Manufacturer shall define and provide any test points required for maintenance diagnostics and testing and emergency recovery. 2739

Test points shall be provided for checking the state of pneumatic, electrical and electronic signals. 3398

Test points shall be easily accessible and shall be grouped in a logical manner. 3397

All test points fitted shall be protected from damage and the ingress of debris. 2740

All pneumatic test points fitted shall, where fitted with quick release connections, be fitted with removable protection chokes, so that the system to which it is connected will not be affected by failure of the test point. 2741

The Train and Equipment shall have in-built self-test facilities. 1711

The Train self-test facilities shall confirm the operational status of sub-systems and equipment prior to entry into service and also on demand. 5127

If a safety analysis shows that testing is required to assure continuing safety, such testing shall be automatically triggered and reported. 897

Systems not routinely exercised during normal passenger service (e.g. remote brake release, Yellow Indicator light, redundant systems) shall be subjected to routine tests at appropriate intervals. 3436

21.9 Special Tools & Non-Standard Tools 156

Non-Standard or Special Tools include Non-Standard tooling, gauges, fixtures, test and diagnostic equipment. 3736

Non-Standard tools are commercially available tools which are not included in the standard tools list. 3738

Special Tools are tools which have been developed specifically for 3739 *maintaining the Train and Equipment.*

The use of either Non-Standard or Special Tools shall be minimised. The use of Standard Maintenance Tools is preferred. 1513

The list of current Standard Maintenance Tools is identified in Reference Document DTP-UIP1973-1.5-RPT-00048 'Depot Standard Tooling List'. The Manufacturer shall use this as a representative list of tooling and shall, as far as possible, choose tooling from this list for maintenance of the Train. Specific items may be replaced on a like for like basis. Where additional Non-Standard and/or Special tools are required for maintenance, they shall be shown to improve the efficiency of carrying out the maintenance task. 1512

Special Tools shall be provided with industry standard electronic identification and tracking tags (e.g. RFID tagging). 6583

Special Tool identification tags shall be capable of being recorded in situ by using a handheld self powered reader with download capability. 6584

21.10 Train Wiring Search Tool 5484

A computer based facility shall be provided to allow tracing of wiring for repair and fault finding purposes. 5464

The search criteria within the train wiring search tool shall allow whole or part systems to be traced on a Train or individual car basis. 5508

Search criteria within the train wiring search tool shall allow wire identification/number, connector reference, looms, pin, sockets, input and outputs to particular LRUs to be traced. 7020

The output from the train wiring search tool shall include, but not be limited to the following information on: 5509

- connector identification number(s);
- loom number(s);
- wire identification number(s);
- wire type(s);
- schematic reference number;
- wiring location(s);
- connector type(s).

Redundant and spare wiring shall be identified and searchable within the train wiring search tool. 5510

22 Reference Documents 3953

22.1 DTUP Documents 4125

DTP-UIP1973-1.4-RPT-00002 Issue 3 4190
EMC Management Plan

DTP-UIP1973-1.4-RPT-00022 Issue 1 4178
NTfL Interfaces with Adjacent Signalling Assets

DTP-UIP1973-1.4-RPT-00025 Issue 3 4191
NTfL Interfaces with LU Signalling Assets

DTP-UIP1973-1.4-RPT-00026 Issue 2 5331
NTfL Interfaces with LU Power Assets

DTP-UIP1973-1.5-RPT-00048 Issue 1 3967
Depot Standard Tooling List

DTP-UIP1973-1.5-RPT-00049 Issue 1 3969
WSP Performance & Testing Requirements

DTP-UIP1973-1.5-RPT-00055 Issue 2 4756
NTfL Track Damage Assessment Methodology and Guidance

DTP-UIP1973-1.5-RPT-00056 Issue 1 4757
NTfL Track Damage Assessment Model

NTfL-2344.3.4-LUL-DWG-00001 Issue 1 5890
Detonator Box Drawings

NTfL-2344.3.4-LUL-RPT-00009 Issue 1 5751
Speed-distance profiles, Interstation Line Geography and run-times

NTfL-2344.3.4-LUL-RPT-00047 Issue 1 3970
Depot Potential Developments

NTfL-2344.3.4-LUL-PLN-00003 Issue 1 5404
Routine CIS Audio Information Concept Structure

NTfL-2344.3.4-LUL-RPT-00007 Issue 2 5407
NTfL Customer Information System (CIS) Visual Display Content Style

Guide

NTfL-2344.3.4-LUL-RPT-00011 Issue 2 5688

Gauging Portfolio Content

NTfL-2344.3.4-LUL-RPT-00027 Issue 1 6346

NTfL Aesthetic Design Brief

NTfL-2344.3.4-LUL-RPT-00033 Issue 1 6735

NTfL Train Radio Interface Definition

22.2 LU Drawings 4786

Drawing 31898 Issue H 4189

Shoe Paddle

Drawing 55612 Issue A 4643

General Arrangement of Shed Plug Type 3002

Drawing 76340 Issue B 5862

Canvas Sheet and Pull Through Test

Drawing 92667 Issue A 4195

LT5 Wheel Profile

Drawing 100524 Issue A 4194

Gedore Operating Key

Drawing 2-9562-L53015 Issue B 4835

Track Shorting Bar Mark 2A Version - Isometric Showing Assembly Details

Drawing S1860 Issue C 6572

Ice Scraper

22.3 LU Standards 4783

1-085 A4 4197

Fire Safety Performance of Materials

1-122 A1 4005

Requirements for 750V Traction Power Supplies and Insulation Levels

1-124 A1 5740

Low Voltage AC and DC Power Supply Parameters, Characteristics and Performance Requirements

1-382 A6 4199

Train Decor Design

G0043 A3 3977

Obsolescence Management

G0213 A2 5805

Condition Monitoring

G148 A4 4790

Management of Noise due to Public Address Systems

G150 A1 5706

Manual of Good Practice - Telecommunications - OPO CCTV Systems

G183 A2 5104

Guidelines for the Engineering of Underfloor Arc and Thermal Protection Requirements

G185 A2 4200

Interior Crashworthiness and Egress

G222 A3 5329

EMC Best Practice

S1004 A11 5170

Signage for Operational Purposes

S1043 A1 7145

Obsolescence Management

S1156 A9 4204

Gauging and Clearances

S1159 A4 7072

Track - Dimensions and Tolerances

S1164 A3 4198

Conductor Rail – Dimensions and Tolerances

S1193 A3 4849

Electromagnetic Compatibility (EMC) with LU Signalling System Assets

S1195 A6 5824

Signalling - Functional Requirements

S1217 A2 5009

Integration of Human Factors into Systems Development

S1218 A2 5224

Human Systems Interaction - Dialogues and Notifications

S1222 A3 4207

Electromagnetic Compatibility (EMC)

S1916 A1 4208

Physical and Electrical Environment of the System

S1926 A1 4959

Design, Manufacture, Testing and Maintenance of Short-Circuiting Devices

S2535 A7 7038

Maintenance of Trainstops

22.4 British and European Standards 4127

BS EN 3-7:2004+A1:2007 4124

Portable Fire Extinguishers. Characteristics, Performance Requirements and Test Methods

BS AU 148-15:1969 6293

Methods of test for motor vehicle paints - Part 15: Resistance to chipping

BS EN 286-3:1995 4156

Simple unfired pressure vessels designed to contain air or nitrogen. Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

BS EN 378:2016 (all parts) 4157

Refrigerating Systems and Heat Pumps - Safety and Environmental Requirements

BS EN 438-2:2005 4158

High-Pressure Decorative Laminates (HPL)

BS EN 779:2012 4172

Particulate Air Filters for General Ventilation - Determination of the Filtration Performance

BS 857:1967 4143

Specification for Safety Glass for Land Transport

BS EN 1176 Part 1:2008 4145

Playground Equipment and Surfacing Part 1: General Safety Requirements and Test Methods

BS 1376:1974 4137

Specification for Colours of Light Signals

BS EN ISO 1518-1:2011 6285

Paints and varnishes - Determination of scratch resistance - Part 1: Constant-loading method

BS EN ISO 1519:2011 6286

Paints and varnishes - Bend test (cylindrical mandrel)

BS EN ISO 2409:2013 6287

Paints and varnishes - Cross-cut test

BS ISO 2631-1:1997 4176

Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration Part 1: General Requirements

BS ISO 2631-4:2001+A1:2010 4837

Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration - Guidelines for the Evaluation of the Effects of Vibration and Rotational Motion on Passenger and Crew Comfort in Fixed Guideway Transport Systems

BS EN ISO 2812-4:2007 6292

Paints and varnishes -Determination of resistance to liquids - Part 4: Spotting methods

BS EN ISO 3095:2013 4173

Acoustics - Railway Applications - Measurement of Noise Emitted by Railbound Vehicles

BS EN ISO 3381:2011 4174

Railway Applications - Acoustics - Measurement of Noise Inside Railbound Vehicles

BS 4142:2014 6869

Methods for rating and assessing industrial and commercial sound

BS 4781:1990 5754

Specification for Pressure-Sensitive Adhesive Plastics Labels for Permanent Use

BS 5395-4:2011 4138

Code of Practice for the Design of Stairs for Limited Access

BS 5459-2:1990 5755

Performance Requirements and Tests for Office Furniture - Part 2: Office Seating

Note - Although this British Standard has been superseded, the old version is still deliberately referenced for the purpose of seat structural testing as the relevant requirements are not all contained in the current version.

BS 5892-8:2012 5756

Railway Rolling Stock Materials. Part 8: Railway Applications - Wheelsets and Bogies - Powered and Non-Powered Wheelsets with Inboard Bearings - Product Requirements

BS EN ISO 6270-1:2001 6290

Paints and varnishes - Determination of resistance to humidity - Part 1: Continuous condensation

BS EN ISO 6272-1:2011 6288

Paints and varnishes - Rapid-deformation (impact resistance) tests - Part 1: Falling-weight test, large-area indenter

BS 6853:1999 4140

Code of Practice for Fire Precautions in the Design and Construction of Passenger Carrying Trains

Note - Although this British Standard has been superseded, this version is still deliberately used for the purpose of this specification.

BS ISO 7010:2012+A6:2016 5757

Graphical Symbols - Safety Colours and Safety Signs - Registered Safety Signs

BS 7608:2014+A1:2015 4141

Guide to Fatigue Design and Assessment of Steel Products

BS EN ISO 7784-2:2016 6289

Paints and varnishes - determination of resistance to abrasion - Part 2: Method with abrasive rubber wheels and rotating test specimen

BS 7976:2002+A1 2013 (all parts) 5207

Pendulum Testers

BS 8118-1:1991 4142

Structural Use of Aluminium. Code of practice for design

BS 8535:2011 5931

Railway Applications - Wheelsets and Bogies - Powered and Non-Powered Axles with Inboard Bearings - Design Method

BS EN ISO 9227:2012 7073

Corrosion tests in artificial atmospheres - Salt spray tests

BS EN ISO 11507:2007 BS 3900-F16: 2007 6291

Paints and varnishes -Exposure of coatings to artificial weathering - Exposure to fluorescent UV lamps and water

BS EN 12080:2007+A1:2010 6119

Railway applications - Axleboxes — Rolling bearings

BS EN 12081:2007+A1:2010 4146

Railway Applications - Axleboxes - Lubricating Greases

BS EN 12082:2007+A1:2010 6120

Railway applications - Axleboxes - Performance testing

BS EN 12663-1:2010+A1:2014 4147

Railway Applications - Structural Requirements of Railway Vehicle Bodies

BS EN ISO 12947: 1998 (all parts) 5212

Textiles — Determination of Abrasion Resistance of Fabrics by the

Martindale Method

BS EN 13103:2009+A2:2012 5919

Railway Applications - Wheelsets and Bogies - Non powered Axles - Design Method

BS EN 13104:2009+A2:2012 5920

Railway Applications - Wheelsets and Bogies - Powered Axles - Design Method

BS EN 13260:2009+A1:2010 5758

Railway Applications - Wheelsets and Bogies - Wheelsets - Product Requirements

BS EN 13261:2009+A1:2010 4148

Railway Applications - Wheelsets and Bogies - Axles - Product Requirements

BS EN 13262:2004+A2:2011 5765

Railway Applications - Wheelsets and Bogies - Wheels - Product Requirements

BS EN 13272:2012 4149

Railway Applications - Electrical Lighting for Rolling Stock in Public Transport Systems

BS ISO 13374-1:2003 5810

Condition Monitoring and Diagnostics of Machines - Data Processing, Communication and Presentation - Part 1: General Guidelines

BS ISO 13379-1:2012 5809

Condition Monitoring and Diagnostics of Machines - Data Interpretation and Diagnostic Techniques Part 1: General Guidelines

BS EN 13749:2011 4150

Railway Applications - Wheelsets and Bogies - Method of Specifying the Structural Requirements of Bogie Frames

BS EN 13829:2001 4151

Thermal Performance of Buildings - Determination of Air Permeability of Buildings - Fan Pressurization Method

BS EN ISO 13938-1:1999 6141

Textiles — Bursting properties of fabrics — Part 1: Hydraulic method for determination of bursting strength and bursting distension

BS EN 14363:2016 6420

Railway applications - Testing for the acceptance of running characteristics of railway vehicles - Testing of running behaviour and stationary tests

BS EN 14750-1:2006 4152

Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 1: Comfort Parameters

BS EN 14750-2:2006 4175

Railway Applications - Air Conditioning for Urban and Suburban Rolling Stock - Part 2: Type Tests

BS EN 14752:2015 4212

Railway Applications - Bodyside Entrance Systems for Rolling Stock

BS EN 14813-1:2006+A1:2010 4153

Railway Applications. Air Conditioning for Driving Cabs. Comfort Parameters

BS EN 14813-2:2006+A1:2010 4154

Railway Applications. Air Conditioning for Driving Cabs. Type Tests

BS EN 15085:2007 (all parts) 6737

Welding of railway vehicles and components

BS EN 15227:2008+A1:2010 4155

Railway Applications. Crashworthiness Requirements for Railway Vehicle Bodies

BS EN 16286-1:2013 5262

Railway Applications - Gangway Systems between Vehicles - Part 1: Main Applications

BS EN ISO 16474-1:2013 7101

Paints and varnishes - Methods of Exposure to Laboratory Light Sources Part 1: General guidance

BS EN ISO 16474-3:2013 7102

Paints and varnishes - Methods of Exposure to Laboratory Light Sources Part 3: Fluorescent UV lamps

BS ISO 17359:2011 5766

Condition Monitoring and Diagnostics of Machines - General Guidelines

BS EN 27243:1994 / ISO 7243:1989 5402

Hot Environments - Estimation of the Heat Stress on Working Man, based on the *WBGT*-index (wet bulb globe temperature)

BS EN 45545-2:2013+A1:2015 5767

Railway Applications. Fire Protection on Railway Vehicles. Requirements for Fire Behaviour of Materials and Components

BS EN 50121-3-1:2017 5145

Railway Applications. Electromagnetic Compatibility. Rolling Stock. Train and Complete Vehicle

BS EN 50121-3-2:2016 4182

Railway Applications. Electromagnetic Compatibility. Rolling Stock. Apparatus

BS EN 50123-2:2003 4159

Railway Applications - Fixed Installations - DC Switchgear

BS EN 50124-1:2001+A2:2005 4160

Railway Applications. Insulation Coordination. Basic Requirements. Clearances and Creepage Distances for all Electrical and Electronic Equipment

BS EN 50124-2:2001 (Incorporating corrigendum May 2010) 6191

Railway Applications - Insulation coordination — Part 2: Overvoltages and related protection

BS EN 50125-1:2014 5308

Railway Applications. Environmental Conditions for Equipment - Part 1: Rolling Stock and On-Board Equipment

BS EN 50126-1:1999 (Incorporating corrigenda May 2006 and May 2010) 4161

Railway Applications. The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS). Part 1: Basic requirements and generic process

BS EN 50128:2011 4162

Railway Applications. Communication, Signalling and Processing Systems. Software for Railway Control and Protection Systems

BS EN 50129:2003 (Incorporating corrigendum May 2010) 5422

Railway Applications - Communication, Signalling and Processing Systems - Safety Related Electronic Systems for Signalling

BS EN 50153:2014 6194

Railway applications - Rolling stock - Protective provisions relating to electrical hazards

BS EN 50155:2007 4183

Railway Applications. Electronic Equipment used on Rolling Stock

BS EN 50163:2004+A1:2007 4164

Railway Applications. Supply Voltages of Traction Systems

BS EN 50238-1:2003 6196

Railway applications — Compatibility between rolling stock and train detection systems

BS EN 50264:2008 (all parts) 5419

Railway Applications. Railway Rolling Stock Power and Control Cables having Special Fire Performance

BS EN 50272 parts 1, 2 and 3 4165

Safety Requirements for Secondary Batteries and Battery Installations

BS EN 50306:2002 (all parts) 5418

Railway Applications. Railway Rolling Stock Cables having Special Fire Performance

BS EN 50343:2014 5102

Railway Applications - Rolling Stock - Rules for Installation of Cabling

BS EN 50382:2008+A1 2013 (all parts) 5420

Railway Applications. Railway Rolling Stock High Temperature Power Cables having Special Fire Performance

BS EN 50547:2013 4167

Railway Applications - Batteries for Auxiliary Power Supply Systems

BS EN 50553:2012+A1:2016 6058

Railway applications - Requirements for running capability in case of fire on board of rolling stock

BS EN 60268-3:2013 4817

Sound System Equipment – Amplifiers

BS EN 60268-16:2011 4814

Sound System Equipment - Objective Rating of Speech Intelligibility by Speech Transmission Index

BS EN 60322:2001 4168

Railway Applications. Electric Equipment for Rolling Stock. Rules for Power Resistors of Open Construction

BS EN 60529:1992+A2 2013 4097

Degrees of Protection Provided by Enclosures (IP code)

BS EN 60598 (all parts) 4169

Luminaires

BS EN 60077 (all parts) 6650

Railway applications. Electric equipment for rolling stock

BS EN 60849:1998 4170

Sound Systems for Emergency Purposes

BS EN 61373:2010 4171

Railway Applications. Rolling Stock Equipment. Shock and Vibration Tests

BS EN 61377:2016 6111

Railway applications. Rolling stock. Combined test method for traction systems

BS EN 62402:2007 5358

Obsolescence Management - Application Guide

BS EN 62625-1:2013 6622

Electronic railway equipment - On board driving data recording system. Part 1: System specification

BS EN 62676-4:2015 4163

Video surveillance systems for use in security applications Part 4: Application guidelines

22.5 Railway Group Standards 4129

GE/RT8018 Issue 2 5769

Mechanical Trainstop System Interface Requirements

GM/GN2606 Issue 1 4214

Guidance on the Fitment and Functionality of Forward and Rear Facing Cameras on Rolling Stock

GM/GN2687 Issue 1 4386

Guidance on Rail Vehicle Interior Structure and Secondary Structural Elements

GM/RC2533 Issue 1 4811

Recommendations for Communication of Emergency and Safety Information

GM/RT2100 Issue 5 4216

Requirements for Rail Vehicle Structures

GM/RT2141 Issue 3 4217

Resistance of Railway Vehicles to Derailment and Roll-Over

GM/RT2161 Issue 1 5771

Requirements for Driving Cabs of Railway Vehicles

GM/RT2173 Issue 1 5770

Requirements for the Size of Vehicles and Position of Equipment

GM/RT2176 Issue 1 4215

Air Quality and Lighting Environment for Traincrew Inside Railway Vehicles

GM/TT0088 Issue 1 4810

Permissible Track Forces for Railway Vehicles

22.6 Other Documents 4130

2012-11-92TS-04A 3974

Traction Requirements to Minimise Thermal Rail Defects

2013-03-92TS-06A 7068

Wheelspin Control - Standard for Rolling Stock

ATOC Standard AV/ST 9005 4135

Vehicle Interiors Communication of Safety and Emergency Information

Directive 2004/108/EC 4179

The approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC

Directive 2013/35/EU 4180

The minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

Directive 2014/30/EU 5768

The harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)

IES LM 80-08 6207

Measuring Lumen Maintenance of LED Light Sources

Illuminating Engineering Society (IES)

ISBN: 978-0-87995-227-3

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Implementers Guide for H.264: “Advanced Video Coding for Generic Audiovisual Services”

London Underground Signs Manual Issue 4 6069

Regulation (EC) No. 842/2006 4210

Fluorinated greenhouse gases

NR/GN/SIG/50007 Issue 1 5772

Methodology for the Demonstration of Compatibility with HVI Track Circuits

23 Definitions 4620

Adhesion Management System Condition Assessment Software 4895

LU predictive software tool which determines how the railway will be operated, dependant on predicted adhesion and recommends pre-emptive mitigations to the adhesion controller for implementation.

Automatic Door Close(ing) 7126

The passenger doors are closed as a consequence of a demand by the system, and not by an operator on the Train.

Automatic Door Open(ing) 7127

The passenger doors are released, or released and opened, as a consequence of a demand generated by the system, and not by an operator on the Train.

Car Number 5930

The Car Number is a unique 5 digit number which is permanently assigned to each individual Car (carriage) on the Train. The Car Number is displayed in key locations both inside and outside the car and is used by both staff and passengers to identify and report equipment locations, defects, faults, maintenance activities, etc.

Car Numbers are allocated by the Purchaser. The first 2 digits are usually used to identify the car type / position in the Train formation and the final 3 digits are usually assigned to the Train unit. Each Train consists of 2 units for the purpose of car numbering such that each end car (cab end) in the fleet will have a unique final 3 numbers.

Chevron sign 6908

A type of signage provided on the track side at station platforms to enable a Train Operator to align the train with the required stopping position. A template design for such a board is shown in drawing 7-01411-030 in LU Standard S1004 'Signage For Operational Purposes'.

Compromised Adhesion 4881

Compromised adhesion is any adhesion level which is not high enough to avoid wheelspin or wheelslip/wheelslide for the applied level of acceleration or braking.

Consumables 3413

Consumables are any substance or component which needs to be replaced or replenished on a regular routine basis (e.g. lubricants, windscreen wash, brake blocks, current collector shoes, wheel rail interface lubricant, HVAC fluids and gases, greases and oils, de-icing fluid).

Correct Side Door Enable 4923

A system for ensuring that only the side of doors adjacent to and correctly aligned with a platform can be opened.

Critical Brake Loss 4893

Critical Brake Loss is defined as the point at which the number of actuators' worth of friction brake effort lost results in an extension of the emergency braking distance, such that the TEBD exceeds 110%.

Cross Blending 6571

Cross blending is the use of surplus dynamic brake capability from motored cars to reduce the friction brake used on other cars.

Demanding Scenarios 4898

Demanding scenarios are a series of operational scenarios which can be used to demonstrate that the Train design is fit for purpose i.e. that the design can fulfil the tasks which would be required of it in any operational scenario.

Door Irregularity 5231

A Door Irregularity is the occurrence of one or more of the following:

- One or more power-operated doors coming open on a Train without the relevant door controls being operated, and no outside door valve operated.
- The Train can be driven with one or more doors open when the Train doors interlocks are in the normal 'cut-in' position.
- A doors closed visual remains illuminated when one or more doors are open.

An allegation of a Door Irregularity will result in the Train being removed from service for a formal investigation to take place.

Friction Braking Pair 4919

The friction braking pair comprises either brake blocks operating on the running wheels or brake disc pads operating against brake discs

Gapped 6611

A vehicle or Train that has stalled due to its current collector shoes having become isolated from the conductor rails.

Instructor Operator 6314

A person accompanying a Train Operator for training and assessment purposes.

Line Replaceable Unit 7108

An LRU is defined as a Part which can be replaced as part of first line maintenance to rectify faults. This could be an item which is a sub-component of another assembly, which itself could be changed out.

LU Corporate Risk model 6176

The LU corporate quantified risk assessment (LU QRA) model assesses the risk from major hazards with the potential to cause fatality to customers and other members of the public.

Notification 6683

A Notification is a system response in which information is raised via an alarm or an alert and provided to one or more of the Purchaser's staff in accordance with LU standard S1218 'Human Systems Interaction - Dialogues and Notifications'. The alarm or alert will provide the supporting information to partially or fully mitigate the impact of the conditions leading to the raising of that alert or the alarm.

Off-Train Communications 6743

This is the collective name for all of the data transfer to/from the Train which does not pass through the RCS or the Train Radio.

Out of Service 6702

The Out of Service function is used to trigger specific customer information content and to inhibit door controls when a Train is not in passenger service. Out of Service mode is selected either via a manual control at the operating position or via the RCS when a Train is being, or has been, removed from passenger service or is being used as a non-passenger carrying test train.

Peak Adhesion Seeking Model 4878

This refers to the Braking Performance, which is theoretically achievable during a low or poor adhesion stop, if the maximum adhesion level available through the adhesion profile (against percentage wheelslip and distance from braking initiation) could be used. This shall be used as a reference basis during the simulation testing for the assessment of WSP performance under low or poor adhesion conditions.

Powered Off 6614

Descriptive of a state of a Train when:

(a) the Train is not in service;

(b) the auxiliary converters are switched off;

(c) the battery supply is isolated and feeding the tail lights only;

(d) the driving controls are inoperative.

Protected circuit 1050

Components and wiring protected by over current devices fitted to the Train.

Railed 6612

A Train positioned on a non-electrified depot shed road with the leading car (or the first car with shoe gear) only standing outside the shed on electrified rails. The car with the shoegear on the current rails is powered. Other cars may or may not have shed leads inserted.

Saloon 6356

The Saloon is the whole of the passenger space inside the train and includes all seated areas, vestibule areas, gangway areas, etc. in the whole Train.

Self powered movement 4882

This is the capability, in the event of loss of traction current, for the Train to be equipped with sufficient stored energy, in the form of battery capacity, to move at slow speed. It is intended to be used to un-gap a gapped Train or to move the Train within the Depot maintenance areas where traction current rails are not provided.

Shutdown 6617

Descriptive of a state of a Train when:

- the driving controls are inoperative;
- the brakes are applied.

Sweeping 4900

After a period of non-operation of a unattended (driverless) railway it is required to prove that the routeway is clear through the use of a 'sweeper' Train (in normal passenger service) which has a Train Operator on-board viewing the routeway, poised to stop the Train should it be necessary.

Task Analysis 4899

A collaborative activity to gain an understanding of the different tasks and activities that a user has to carry out to complete the defined duties effectively and safely.

Train Essential Services 4920

This describes those systems which are considered necessary to be maintained to ensure the safety of passengers and enable the Train to be restarted following perturbations such as loss of traction power supply, train fault.

Train Number 5929

The Train Number is a 3 digit number which is assigned to a specific operational train path which is defined in a train service timetable. Any train may be assigned to run on a numbered train path on any given day i.e. it is not linked with the asset number / Car Number. The Train number is set on a specific train either via information from the RCS, or by a Train Operator manually entering the Train Number. The Train Number is then displayed on the Train Number Indicator on the front and rear of the train and on the External VEID on the side of the end cars only. The Train Number is also sometimes referred to as the train running number or the set number.

Train Operator 6313

The Train Operator is a person driving the Train and/or undertaking tasks contributing to the safe and efficient running of the Train.

Train Support Software 4868

Collective term for off-train software used to update train software and parameters, download and interpret recorded Train data or to interface with the Train in other ways.

Unprotected circuit 1049

The components and wiring between the collector shoes and the first over current protection device.

Vestibule 5684

The vestibule is an area of the saloon for passenger access, egress, standing and circulation. The vestibules are bounded on two sides by the boundaries of the passenger doors and standback areas, and on the other two sides by the boundaries of the seating areas.

Wheelslide 6664

A condition under braking when the wheelset stops rotating whilst the Train is moving.

Wheelslip 6665

A condition under braking when the wheelset rotates slower than the corresponding Train speed, but continues to rotate.

Wheelspin 6666

A condition under acceleration when the wheelset rotates faster than the corresponding Train speed.

WSP Reference Speed 4877

The signal generated and/or used by the WSP system to determine the current Train speed.

24 Abbreviations 4863

4LM	Four Lines Modernisation	5325
AC	Alternating Current	5286
ALARP	As Low As Reasonably Practicable	4888
AMS CAS	Adhesion Management System Condition Assessment Software	4896
ARL	Above Rail Level	4925
ATMS	Automated Track Monitoring System	4926
ATO	Automatic Train Operation	4873
ATP	Automatic Train Protection	5280
AVA	Automated Voice Announcer	4912
AVI	Audio and Visual Information	4908
BSR	Brake Supply Reservoir	5281
BSI	British Standards Institute	7146
BST	British Summer Time	7147
CCTV	Closed Circuit Television	4904
CE	Conformité Européene (European Conformity)	7148
CFD	Computational Fluid Dynamics	7149
CGI	Computer Generated Imagery	7150
CIS	Customer Information System	4907
CRI	Colour Rendering Index	7151
CSDE	Correct Side Door Enable	4922
CTRL	Channel Tunnel Rail Link	4886

DST	Daylight Saving Time	5371
DTUP	Deep Tube Upgrade Programme	7152
DC	Direct Current	5287
DLR	Docklands Light Railway	4885
EB	Eastbound	7165
EMC	Electromagnetic Compatibility	5136
EMF	Electromagnetic Fields	5322
EMI	Electromagnetic Interference	4889
ERU	Emergency Response Unit	7153
EU	European Union	7154
FCOV	Flow Cut-Off Valve	7155
FFCCTV	Forward and Rear Facing CCTV	4932
FMECA	Failures Modes and Effects Criticality Analysis	7156
FTA	Fault Tree Analysis	7157
GOA	Grade of Automation - BS EN 62290	4864
GMT	Greenwich Mean Time	5373
GSM	Global System for Mobile communications	7017
HAZID	Hazard Identification	5321
HF	Human Factors	5135
HMI	Human Machine Interface	4928
HSE	Health, Safety and Environment	7158
HVAC	Heating, Ventilation and Cooling	4988

HVI	High Voltage Impulse	7106
IP	Ingress Protection	5284
ISO	International Organisation for Standardisation	7159
LCD	Liquid Crystal Display	7160
LED	Light Emitting Diode	7161
LRU	Line Replaceable Unit	4931
LU	London Underground	7162
MCB	Miniature Circuit Breaker	7163
MT	Maintenance Target	7164
MTBF	Mean Time Between Failures	5129
MTBRSF	Mean Time Between Right Side Failures	5323
MTBWSF	Mean Time Between Wrong Side Failures	5324
NCS	Natural Colour System	7105
NR	Network Rail	4884
OCS	Operational Control System	5253
ODDR	On Board Driving Data Recorder	7166
ODIL	Outside Door Indicator Light	4921
OLED	Organic Light Emitting Diode	7167
OPO CCTV	One Person Operation Platform to Train CCTV	5288
OPO(T)	One Person Operation (Tube)	6149
OTC	Off-Train Communications	6878
OTMR	On-Train Monitoring Recorder	7168

PA	Public Address (system)	4906
PC	Personnel Computer	5283
PEA	Passenger Emergency Alarm	4909
PEAB	Passenger Emergency Alarm Brake	4913
PED	Platform Edge (screen) Door. The abbreviation may apply to an individual single leaf or double leaf door unit or a complete system, depending upon the usage context.	4866
PTI	Platform Train Interface	4887
PTT	Press to Talk	4910
PTV	Pendulum Test Value	7104
RAMS	Reliability, Availability, Maintainability and Safety	7169
RCF	Rolling Contact Fatigue	7170
RCS	Railway Control System	4865
RFID	Radio Frequency Identification	7171
RRD	Rough Ride Detection	7019
RTD	Real Time Disruption	4911
RVAR	Rail Vehicle Accessibility Regulations	4901
S&TC	Signalling and Train Control	7061
SAF	Service Affecting Failure	7172
SAPB	Spring Applied Parking Brake	4874
SATRA	Shoe and Allied Trades Research Association	4902
SB	Southbound	7173
SCAT	Speed Control After Tripping	7174

SDO	Selective Door Opening	7175
SCD	Short Circuiting Device	4897
SIL	Safety Integrity Level	4927
SOP	Saloon Operating Position	6086
SPAD	Signal Passed At Danger	7176
SPL	Sound Pressure Level	7177
STI-PA	Speech Transmission Index for Public Address systems	5013
TEBD	Target Emergency Braking Distance	4876
TEDS	Transducer Electronic Data Sheets	7178
TBC	Traction Brake Controller	4892
TCMS	Train Control and Management System	4867
TDR	Train Data Recorder	4929
TfL	Transport for London	7179
TFT	Thin Film Transistor	7180
TMR	Train Maintenance Regime	5276
TMP	Train Maintenance Plan	5292
UTC	Coordinated Universal Time	5372
UK	United Kingdom	5285
USB	Universal Serial Bus	7183
UV	Ultra Violet	7181
VEID	Visual Electronic Information Display	5134
WB	Westbound	7182

WBGT	Wet Bulb Globe Temperature	7071
WLAN	Wireless Local Area Network	4916
WRI	Wheel Rail Interface	5221
WSP	Wheel Slide Protection	4875