Transport for London

London Underground Limited

Central Line Programme
Tunnel Cleaning Unit – Technical Specification <UIP Code>
CTL-PVEC3017-BCV-SPC-00002

Tunnel Cleaning Unit

Technical Requirements Specification (TRS)

		Signature	Date
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Approved by	I confirm that this deliverable meets the requirements of the relevant PMF Product Description and that all consultation comments have been addressed to the satisfaction of consultees. Alan Wilson Project Manager	[redacted]	25th Oct 2010

Document History

Revision	Date	Summary of changes
A1	04.05.10	Issue for Tender
A2	21.10.10	Issue for Contract

CONTENTS

1 Purpose

1.1 The purpose of this specification is to define the engineering requirements for a Tunnel Cleaning Unit (TCU) which will be combined with an LU Motive Power Unit (MPU) to form a Tunnel Cleaning Train (TCT). This formation is required to remove dust and litter from the track bed, tunnel walls (including wall mounted cables and equipment) and tunnel ceilings of London Underground's Deep Tube and Sub-Surface Network.

2 Scope

2.1 This specification details the engineering requirements for the design, test, production, supply and commissioning of a Tunnel Cleaning Unit (TCU).

2.2 The TCT will comprise the TCU and the Motive Power Unit (MPU) consisting of four LU Tube Stock cars, which will be used to provide motive power to and from the work site, two cars being attached to each end of the TCU.

2.3 The Supplier is required to provide a new build Tunnel Cleaning Unit (TCU) of one or more cars which will contain the tunnel cleaning equipment and slow-speed motive power for use during cleaning when on site. The slow-speed motive power shall be sufficiently sized to be able to move the full train including the MPU when cleaning.

2.4 The auxiliary power supply to operate the cleaning equipment shall be procured and fitted to the TCU by the Supplier.

2.5 London Underground will assume the role of System Integrator for the overall TCT and the TCU Supplier will be required to support LU.

2.6 The LU supplied MPU will consist of four Tube Stock motor cars, coupled in two pairs with one pair connected either side of the new tunnel cleaning unit – supporting information for the MPU is provided in Appendix 3 to this specification.

2.7 The Supplier shall specify and identify all TCU interfaces/ equipment which will need to be installed on the LU vehicles for controlling the operation and monitoring of the cleaning equipment.

3 Definitions

3.1 Appendix 2 contains definitions of terms which may be used in this Technical Specification.

4 Design Concept

The purpose of this section is to outline how the Purchaser currently envisages the Tunnel Cleaning Train (TCT). This is not a stipulation on the supplier, simply an explanation of the existing vision for the project. This is provided to aid the supplier with their reading of this specification. The details of this proposal will be developed to take account of specific features of the vehicles proposed.

Formation: The Purchaser will provide four motor cars of 1972 Tube Stock (72TS) to act as a Motive Power Unit (MPU). The 72TS are retired passenger vehicles from the Victoria Line. They have all axles motored, providing adequate tractive effort for pulling other cars.

The 72TS cars have LU-standard wedgelock couplers in between the middle cars, allowing them to couple to each other, or to the suppliers TCU as required. Two of the 72TS cars will be positioned either end of the suppliers Tunnel Cleaning Unit (TCU) allowing it to be driven in either direction. The TCT will be formed by coupling the TCU between the four MPU cars.

Motive Power Unit: The Motive Power Unit will be modified for the new application. The purchaser will free-issue couplers, sector bars and buffers which will be compatible with those fitted to the MPU to enable it to interface mechanically to the TCU. Jumpers will be provided by the Purchaser to enable electrical control, electrical power and digital/communications signals to be sent between the MPU and TCU and between the individual cars of the MPU as required. Power for the TCU will be provided through jumpers from the MPUs and derived from the traction supply.

Tunnel Cleaning Unit: The TCU will consist of one or more cars installed with equipment to effectively disturb dust and litter, then collect it once disturbed for safe disposal away from the railway. It will not interface directly with the traction supply and will not be required to operate independently of the MPU.

Slow Speed Drive:
The TCU must be able to propel itself and the MPU at a precisely controlled slow speed which is optimised for tunnel cleaning. The functionality to drive at a set speed must be provided on the

TCU itself as the 72TS cars forming the MPU cannot be driven at slow speed for prolonged periods and do not have sufficiently controllable traction/braking to hold a set speed to the required accuracy.

Due to operational restrictions the MPU cannot decouple from the TCU while on site, so the TCU must be able to operate at the required speed with the MPU attached. To cover gaps in the power supply (e.g. over points & crossings) the TCU must be able to continue motoring for a short duration with the traction supply removed.

The purchaser has a preference for hydraulic drives, due to their favourable EMC characteristics and their ability to operate at low speeds on varying gradients without risk of overheat or stalling. Experience has shown that a hydraulic drive would be less prone to obsolescence than a similar electrical system. Electrical drive methods are not prohibited; however suppliers are required to justify the selection of an electrical drive over a hydraulic drive.

Cleaning: The TCU will effectively remove all dust and litter which could be disturbed by the passage of service trains. It must do this without damage to the railway, for example disturbance of the ballast or impact on wayside assets.

Operational Modes:
The purchaser envisages three operational modes on the railway, the exact details will be agreed during the design phase. In all modes there will be two staff on the TCT, a train operator and a cleaning operator. These staff will both be able to perform either role.

1. **Transit** - when the train is in transit the TCU is dormant. Its braking, through-control and communication systems will be live but all other functions are isolated. The lead cab of the MCU will drive to site using conventional traction and braking systems.
2. **Cleaning** - when the train reaches site the direction is selected. The leading cab is set to ‘cleaning’ mode. This activates the Cleaning Console in the trailing car of the other MPU, and activates the Vigilance devices in both cars (on the cleaning console of the trailing car and in the cab of the lead car). The Cleaning Operator now uses the Cleaning Control Console to operate the TCU. In this state, all systems on the TCU are active. The cleaning equipment extracts the maximum dust with the minimum operator intervention. The slow speed drive responds to speed commands from the operator and reports set/actual speed.
3. **Dead End Siding** – under degraded or emergency conditions it may be necessary to stable the TCT in a ‘dead end’ (blind) siding. It is assumed that there is no way to provide

a throughway for staff to pass through the TCU in a tube tunnel. In such sidings there is no means for an operator in the dead end to leave the vehicle once it is secured. In order to stable the train in this way the TCT will stop in a platform. The 'dead end' operator will be transferred to the other cab and the vehicle will be driven from the trailing cab using the CCTV system. This will be done using either the slow speed drive or the main drive, as appropriate. In this mode the cleaning equipment will be locked out.

Unloading: Once the TCT returns to a depot the TCU must be unloaded of all collected dust and rubbish. The Purchaser requires the maximum flexibility in the provision of unloading arrangements as the TCT may be required to stable in any LU depot, not only its primary maintenance location.

Health, Safety and Environment: The main hazards identified by the Purchaser are as follows:

- Derailment
- Collision with a stabled train
- Runaway
- Stalled trains
- Damage to Infrastructure
- Dust explosion or fire
- Noise
- Environmental incident (uncontrolled release)
- Operators exposed to dust

5 Operational Concept

The purpose of this section is to outline in greater detail how it is currently envisaged the TCT (including the TCU) would be operated and to detail the relevant requirements/deliverables. The details of this process will be developed to take account of specific features of the vehicles proposed.

5.1 The train will be manned by a minimum of two persons both of whom can act either as a train operator or as the cleaning operator.

5.2 The train operator would be located in the leading cab while the cleaning operator would be located in the rear vehicle of the train. In order to support bi-directional working during a shift, both persons could undertake both roles during the course of a cleaning shift.

5.3 The TCT will have a home base at which heavy maintenance will be undertaken.

5.4 There will be a number of depots at which TCT can be unloaded and routine (non heavy) or casualty maintenance undertaken. The TCT may temporarily stable in any LU depot.

5.5 For each line, there will be identified locations at which the TCT will be stabled during the day so as to minimise the distance to be travelled to/from site.

5.6 The TCT shall have three primary modes of operation

- Transit (i.e. travel to/from site at up to line speed)
- Cleaning (i.e. restricted to slow speed drive operation only)
- Dead End Siding (i.e. slow speed driving from the trailing cab with the lead cab unoccupied)

5.7 In transit mode the train operator shall drive the train to site using the normal traction and braking controls. The cleaning equipment operator shall travel in the rear cab / car of the train; he/she will be able to apply the brake if required.

5.8 A mode selector switch will be fitted in each MPU cab; it shall have four positions “Off”, “Transit”, “Cleaning” and “Dead End Siding”. When “cleaning” is selected in the active cab an indicator shall illuminate at both cleaning operator’s consoles and in the cab of the second “outer DM” car to indicate the selected mode of operation.

5.9 The slow speed drive shall only be enabled if the mode selector switch in the active cab is in “Cleaning” or “Dead End Siding” mode. In “Cleaning” mode, the lead cab shall control the MPU (i.e. emergency brake and vigilance), and the rear cab shall control the cleaning and slow speed drive.

5.10 It shall be possible to reverse the TCT into a dead end tunnel where there is no driver access or egress at the blind end of the tunnel. A “Dead End Siding” mode is provided to meet this requirement. In this mode the active cab shall control the MPU, the slow speed drive and CCTV systems. The cleaning system itself shall be isolated. This allows the TCT to reverse into a siding without an operator in the rear cab.

5.11 Once on site, with cleaning mode selected, the cleaning operator shall control the slow speed drive and the tunnel cleaning equipment from the cleaning control console in rear vehicle to optimise cleaning performance.

5.12 In cleaning mode both leading cab and cleaning console shall have vigilance devices active; failure by either train or cleaning operators to operate the vigilance devices shall result in the slow speed drive halting the TCT and an audible alarm sounding.

5.13 The following is a table of the expected operating control conditions. For clarity, the "leading" cab is the first cab to pass a defined point in the intended direction of travel, the trailing cab is the second cab to pass that same point.

Control Conditions				
Activity	**Leading Cab**	**Leading Cleaning Console**	**Trailing Cleaning Console**	**Trailing Cab**
Travelling to and from Work Site	Active	Not Active	Not Active	Not Active
Slow Speed Forward Direction	Controls Starting, Emergency Brake and Vigilance	Not Active	Slow Speed Control and Vigilance	Not Active
Cleaning, Slow Speed Forward Direction	Start, Emergency Brake and Vigilance	Not Active	Slow Speed Control and Cleaning Control. Vigilance	Not Active
Slow Speed Reverse Direction	Not Active	Not Active	Slow Speed Control and Vigilance	Start, Emergency Brake and Vigilance
Dead End Siding	Not Active	Not Active	Slow Speed starting, Slow Speed Control, main drive active CCTV, Cleaning system cut out.	Emergency Brake, Vigilance.

5.14 When the Cleaning equipment is started, the collection equipment shall activate, and prove activated, before any means of forcibly disturbing dust/litter is activated. This is to avoid a failure of the collection equipment leading to a cloud of dust which cannot be captured.

5.15 In the event of the dust/litter capture equipment failing any separate means of disturbing dust/litter shall automatically be isolated. This is to avoid a failure leading to a cloud of dust which cannot be captured.

5.16 The TCU shall be designed to allow the tunnel cleaning equipment to be operated or supervised remotely by a single person who shall be seated or standing at an operating position in one of the 72TS driving motor cars.

5.17 The TCT shall be supplied with communications cab to cab and between the tunnel cleaning control area and the active cab, where applicable. The design of the TCU shall facilitate this provision.

5.18 Following a number of shifts, the TCU will require emptying. This will necessitate moving to the nearest equipped depot on that line and removing the dust and rubbish collected.

5.19 If the slow speed drive or cleaning equipment inadvertently shuts down for what ever reason it shall not automatically restart, but will require a conscious action to re-engage it. The cleaning operator shall be notified of the requirement.

6 General Requirements

6.1 The effect of the tunnel cleaning capability shall be:

- to remove all dust and debris that could be disturbed by the passage of trains
- to remove accumulations of dust and debris that could cause or contribute to equipment failures
- to remove accumulations of dust and debris that could result in the break out of fires
- to reduce the residual particulate matter content of the tunnel air, thereby improving the environment for both passengers and staff
- to remove dust and debris from the railway, including station platform faces, to improve customer satisfaction
- to remove dust and debris from the railway and thus improve the image of both London and London Underground

6.2 Tunnel cleaning shall comply with Standard 1-166 - Cleaning of the Track Environment. The performance shall be measured against the Criteria specified in Appendix 9 of this document.

6.3 The TCU is to be self-propelled, operate in both directions, on defined routes of London Underground's rail network and shall deliver the required cleaning performance.

6.4 The TCU shall be safe to use under all operating conditions and environmental conditions found on London Underground.

6.5 The TCU shall not cause damage or interference to any neighbours in the course of travelling or working anywhere on the LUL network

6.6 The TCU shall not cause damage or interference to any assets in the course of travelling or working anywhere on the LUL network

6.7 The Purchaser will be responsible for the management of the integration of the TCU with the MPU vehicles supplied by the Purchaser and the Supplier will support all integration activities. The Purchaser will be responsible for the conversion of the MPU vehicles.

6.8 The Supplier shall detail all standards to which its vehicle complies and demonstrate how these standards ensure that the vehicle is suitable for use on the London Underground network. It is expected that the vehicle will comply with all Standards listed in Appendix 1 or equivalent, and any relevant European Standards, British Standards, International Standards and associated codes of practice as are required for the Supplier to perform the Scope of Work in accordance with Good Engineering Practice.

6.9 The TCU shall have a minimum usable life of not less than 25 years covering an annual distance of not less than 15,000 km travelling to /from work sites and not less than 2,500 km whilst undertaking cleaning duties.

6.10 The tunnel cleaning system on the TCU shall utilise cleaning equipment and techniques identical to or derived from those which have a proven record of reliable and effective operation in similar metro environments.

6.11 The TCU shall be built from new and the Purchaser shall have full access to as-built drawings, supporting calculations and component specifications, including drawings / IPR for all special tools and jigs.

6.12 Environment

6.12.1 The TCU shall operate satisfactorily in the environment in which it will be operating as specified in E6161 as detailed in Appendix 1.

6.12.2 The Supplier shall demonstrate compliance with requirements 6.12.1 by:

- Previous experience of equipment in a similar environment or
- Successfully completing a comprehensive programme of functional tests in a climatic chamber simulating all specified weather conditions expected up until product end of life.

7 Cleaning Requirements

7.1 General cleaning requirements

7.1.1 The TCU shall clean with the traction supply live, though it will not directly draw power from this supply unless by prior agreement with the Purchaser. If necessary, the traction supply will be collected by the MPU and distributed to the TCU. Information on the traction supply characteristics are provided in G6381.

7.1.2 The required standard of cleaning shall be achieved without the use of water, solvents or other fluids which could short circuit, earth, or otherwise interfere with signalling circuits or damage the railway.

7.1.3 Within stations the track bed and the platform structure between the nosing stones and the track bed shall be cleared of litter and dust by the TCT.

7.1.4 The TCU shall be capable of accepting upgrades to the cleaning equipment/system

7.1.5 Whilst cleaning, the heat input to the tunnels shall be minimised as far as possible whilst meeting the defined cleaning performance

7.1.6 The cleaning performance shall be maintained over the range of deep tube tunnel diameters / dimensions as defined in the gauge information (see section 15 – Route Availability).

7.1.7 Cleaning performance shall be maintained until waste storage is full and be unaffected by track cant or gradient.

7.1.8 The design and operation of the TCU shall be such as to maximise the removal of dust and refuse from the tunnels

7.1.9 The process for disturbing and removing dust and refuse from the tunnels shall ensure that there is minimal disturbance of the air at either end of the TCU thereby ensuring unrestricted vision both ahead and behind from the cabs of the TCT.

7.1.10 The TCU shall not cause dust to be dispersed onto station platforms whilst operating in cleaning mode.

7.1.11 The TCU shall not cause dust to be dispersed onto station platforms whilst travelling to/from site

7.1.12 Whilst travelling to/from site, any moveable components of the TCU shall remain secured within the defined gauge. Any failure of power or control systems shall result in movable components returning immediately to a position within the most restrictive tube tunnel gauge.

7.1.13 The cleaning equipment shall be capable of being directed or switched off, when cleaning in slow speed drive and when stationary.

7.1.14 Selectable zones: LU defines the tunnel zones as follows. The TCU must be able to select each zone for independent cleaning.

Fig 1 - Photograph of typical tunnel section

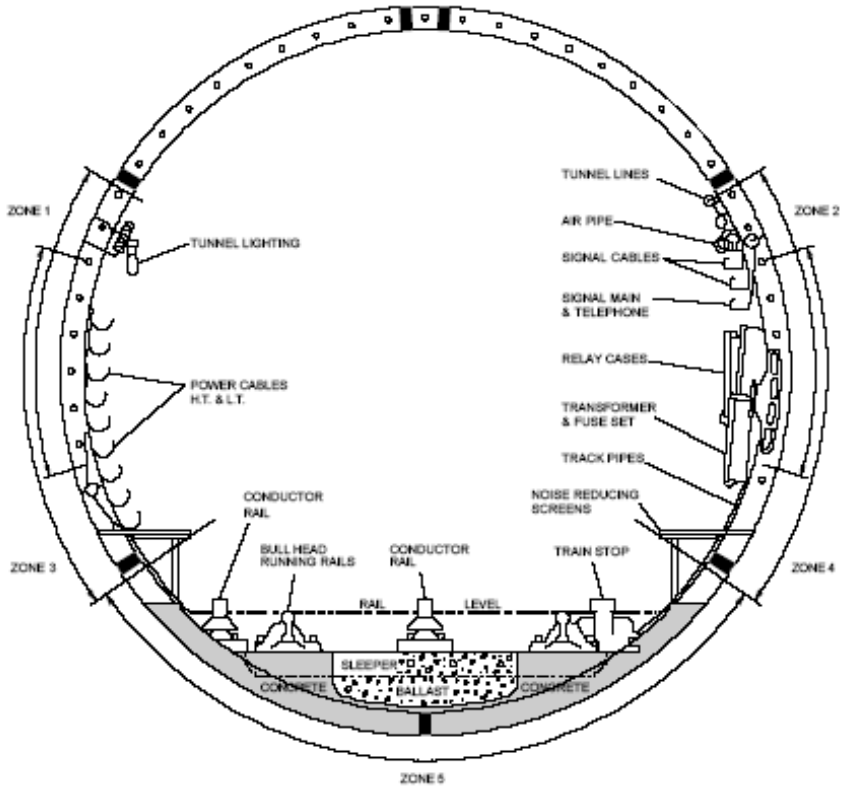

Fig – 2: Diagram explaining tube section zones

a.) Tunnel Roof (zone Zero)

b.) Zones 1, 2, 3 & 4 includes

- The surface of the full circumference of tube section running tunnels (not including Zone Zero).
- The surfaces of the casings of trackside equipment within the tunnels, spaces behind equipment and trackside panels.
- The surfaces of tunnel lines, air pipes, signal cables, track pipes, power cables and tunnel lighting.
- The casings of signals and the surfaces of trackside signs.
- The upper and lower surfaces of noise reducing screens.

c.) Zone 5

- The whole area of the track, it is a requirement that as much dust as possible is removed from the ballast.

Note: When in a platform zones 0-4 are to be isolated.

7.1.15 Obstruction Avoidance: Where relevant the TCU shall be capable of automatically adjusting the position of any movable cleaning equipment to avoid damaging equipment such as tunnel telephones, signals, warning signs, etc fixed to tunnel walls and train stops, track lubricators etc. fixed to the track bed. Adjustment shall be possible dynamically whilst the equipment is operational and the TCT is travelling at any cleaning mode speed. The CCTV system shall provide advance visibility of such items to the cleaning operator.

7.1.16 Cleaning Equipment: The TCU shall be designed for ease of access to cleaning equipment for maintenance and fault diagnosis.

7.1.17 At the relevant stage in the project design phase the Supplier is to provide the Purchaser with a detailed air flow analysis of the vacuum/pressure systems to demonstrate that the air shall flow smoothly with no debris build up in any part of the system under operating conditions.

7.1.18 Within the tender return the Supplier shall state the maximum air flow speed, suction pressure and air flow volume of their proposed equipment.

7.2 Deep tube cleaning requirements

7.2.1 The TCU shall be capable of cleaning:

- Track bed, tunnel walls and tunnel ceiling (360 degree cleaning);
- Cable runs and tunnel mounted equipment;

7.2.2 The TCT shall be able to “deep clean” 305 km of deep tube tunnel in a maximum of 800 hours of cleaning time, (see Appendix 2 for the definition of deep clean).

7.3 The TCT shall be able to “routine clean” 305 km of deep tube tunnel in a maximum of 200 hours of cleaning time, (see Appendix 2 for the definition of routine clean).

7.4 Cut and cover TCT cleaning requirements

7.4.1 The TCT shall be capable of cleaning the track bed (4 foot) and tunnel walls up to 400 mm from the outside of both running rails, up to a height of 2m of the sub surface tunnels to the same standard as required for the deep tube tunnels.

7.5 Tunnel air quality post clean

7.5.1 Atmospheric dust levels shall be no worse after cleaning than prior to cleaning. If this is not achievable the Supplier is to specify the time elapsed after completion of a cleaning run when the respirable dust levels will be no worse than before the tunnel cleaning took place. Typical dust composition and combustibility information from recent analysis on the Victoria Line are contained in two 4-Rail reports, see Appendix 1. Analysis of the respirable dust has revealed that:

- 80% of the dust is made up of iron;
- Pm10 size is < 10 µg/m3 with a mean of 7 µg/m3;
- Pm2.5 4mg/m3 respirable particles averaged over an 8 hour period.
- Sample measurements indicate that 42.9% of the dust particles (by number) were less than 1 micron in size, with about 41.9% between 1-5 microns, about 11.5% between 5-10 microns and with the remainder (3.7%) being greater than 10 microns in size. Note however that these figures may be skewed by the equipment used to collect the sample.

8 Waste Management

8.1 Waste Storage Capacity

8.1.1 The Supplier shall confirm the maximum dust and refuse storage capacity of the unit. As a minimum the unit shall be able to store:

- Dust – 10 Tonnes
- Refuse – 4 Tonnes

8.1.2 The TCU shall provide the maximum practical waste capacity within the permitted length of the TCU, commensurate with the maximum axle weight specified and required cleaning performance.

8.1.3 The Supplier shall specify the maximum storage capacity per compartment and the number of compartments for material collected.

8.1.4 The TCU cleaning console shall provide the cleaning operator with an indication of the remaining storage capacity of the TCT during cleaning operations. The TCU shall provide similar indications externally to maintenance staff at the waste removal locations. As a minimum the TCT shall provide quarter, half, three quarters and full indicators for both the dust and refuse collection systems.

8.2 Waste removal

8.2.1 The TCU shall be equipped with flashing amber lights to be used only when the removal of collected dust and refuse rubbish is in progress.

8.2.2 The Supplier shall propose costed solutions for

- On vehicle separation of waste prior to disposal
- Off vehicle separation of waste

8.2.3 The Supplier shall provide costed proposals for depot handling facilities at the locations defined by the Purchaser to enable collected waste to be removed from the TCU and the TCU restored to an operational condition in a time not exceeding 1 hour. If this cannot be achieved the Supplier shall state the time taken to unload the full capacity of waste from the train. Note: The Purchaser will define the depot locations based on the detail of the Suppliers' proposal.

8.2.4 The waste handling facilities shall ensure that waste collected remains contained during its removal from the train and subsequent transportation and shall be compliant with environmental regulations.

8.2.5 The TCU shall be fitted with illumination that will enable the safe removal of waste in environments with low or poor light levels.

8.2.6 The Supplier shall provide the facilities required for removal of waste at:

- The base operating depot
- Satellite stabling location.

8.2.7 The Supplier shall ensure that the storage and subsequent handling during discharge and transfer of the material collected avoids hazards arising.

8.2.8 Waste shall be collected on the TCU in waste containers capable of mechanical handling by fork lift truck or crane. Removal of the containers by any means shall not result in dust being released, regardless of the amount of dust held at the time.

8.2.9 The Supplier may propose another industry established process using road vehicles adjacent to the TCT. The containers shall be accessible from above, and from both sides of the TCT. Access shall be restricted to authorised personnel via body-side doors. The Supplier shall declare at Tender Stage the available methods of waste removal from the TCT and its subsequent disposal, with a cost for each.

8.2.10 The Supplier shall declare at Tender Stage the number of waste containers proposed in the TCT to achieve the cleaning rate, together with the time taken to remove a full container and replace it with an empty container.

8.2.11 The containers shall be designed to prevent spillage of contents whilst being removed and transported.

9 Interface Requirements – Tunnel Cleaning Unit to Motive Power Units

9.1 The TCU shall be fitted with a 'Wedgelock' auto coupler, sector bar and buffer arrangement at each end which will be free-issued by the purchaser. The Supplier shall install the coupler, sector bar and buffer in a way which is mechanically and pneumatically compatible with the MPU provided by LU. Drawings relating to 72TS auto coupler, sector bar and buffer arrangements are provided for reference in Appendix 1.

9.2 The auto coupler and buffer arrangement fitted at each end of the TCU shall comply with the applicable sections of the following standards:

- E6741 A3 – Semi-permanent couplers
- E6742 A3 – Wedge lock couplers

9.3 For the free-issue auto-couplers to work satisfactorily the TCU car lengths, bogie centres, coupler pivot points and end throws should be compatible with the operational limitations of the free-issue auto-couplers. The Purchaser and the Supplier will agree TCU car lengths and end throws during the design phase.

9.4 The electrical interface between the MPU and the TCU shall be by multi-core jumpers and configured such that the TCU can be marshalled either way round between the two motive power units. Where provided the contacts in the free-issue auto-couplers shall not be used.

9.5 The jumpers shall be constructed in a manner appropriate for the application using industry standard components, and shall have a connector at both ends. The connectors shall meet the requirements of E6482.

9.6 The MPU at both ends of the TCU shall be capable of operating in multiple through the use of Train Wires which run the length of the train formation.

9.7 The Auxiliary Power Supply functions shall be in separate jumpers to the jumpers carrying the through-train control circuitry (Train Wires) necessary for the operation of the MPU.

9.8 As a minimum the following jumper arrangements shall be provided by the Supplier.

- Two multi-core jumpers sufficient to enable the two 72TS units to operate in multiple. This will also necessitate train wires throughout the TCU. At least 30 Ways will be needed in each jumper. The connections between the motive power units and the tunnel cleaning unit shall be by multi-core inter-car jumpers, as described in 9.4 above – the Purchaser will define the connection arrangement
- A jumper (or jumpers) containing the protected positive and negative poles of the Traction Supply (note – this item to be priced separately);
- A jumper (or jumpers) containing wires for the control of: a) the auxiliary converter, b) the cleaning equipment, c) the slow speed traction equipment and d) any monitoring of the previous items.
- A jumper (or jumpers) containing wires for the CCTV system and other digital communications which may be susceptible to interference.

9.9 Not used.

9.10 In addition to the above, any AC consumer shall be capable of being fed from either Auxiliary Power Unit.

9.11 If the Traction Supply (630V DC) is used for the Slow Speed Drive, the electrical interfaces for the Traction Supply from the motive power vehicles to the slow speed drive equipment shall be kept separate from the auxiliary power and any control, monitoring and warning functions associated with the motoring and braking functions of the slow speed drive and tunnel cleaning equipment itself.

9.12 The Supplier shall supply the following information to the Purchaser:

- Power requirements for the slow speed drive equipment;
- Control requirements for the slow speed drive equipment;
- Power requirements for the tunnel cleaning equipment;
- Control requirements for the tunnel cleaning equipment;
- Monitoring requirements for the tunnel cleaning equipment;
- Monitoring requirements for the slow speed drive equipment.

9.13 The Supplier shall provide the following operational interface requirements:

- Remote cameras and lighting to enable entry into dead end sidings from rear cab control

9.14 The tunnel cleaning unit shall be capable of coupling either way round to the pair of motive power units.

10 Rolling Stock requirements

10.1 General RS Requirements

10.1.1 The Supplier shall, where applicable, comply and shall assist the Purchaser in complying with the London Underground standard 1-538 Assurance.

10.1.2 The TCT shall be marked with identification numbers and any other legends for equipment and components to be advised by the Purchaser.

10.1.3 The TCT shall be provided with appropriate operator accessible isolation facilities so that any single failure shall not prevent the train being able to move from a tube tunnel.

10.1.4 The TCU shall be capable of travelling at speeds of up to 80 kph while travelling to or from site in all payload conditions from tare to fully laden.

10.1.5 Where Standard 1-180 is referred to the Supplier should refer to Appendix 6 which contains a compliance table which identifies applicable clauses together with any comments to aid interpretation.

10.2 RS slow speed motive power

10.2.1 The slow speed drive is required to propel the complete tunnel cleaning formation (i.e. the TCU and the 4 motive power cars) at a steady slow speed to be selected by the cleaning operator in order to deliver the most effective cleaning capability.

10.2.2 The slow speed drive shall be capable of automatically maintaining any set speed over the range of track gradients which will be experienced (up to and including 1 in 30) in tare or loaded condition without the need for the friction brake to be applied.

10.2.3 The slow speed drive shall be installed so as to ensure that in achieving the above performance the adhesion required at any axle does not exceed 0.2.

10.2.4 The slow speed drive shall be powered and controlled so as to ensure that slow speed drive is not lost in the event of an individual motive power car (or pair of cars) becoming

"gapped". If the power for the slow speed drive is derived from the Traction Supply this shall be provided from both of the motive power units. The TCU shall switch between MPUs depending on the availability of traction supply. It shall not be possible, under any circumstances, for the shoes on the MPUs at both ends of the train to be electrically connected together through the traction supply cables.

10.2.5 The TCU shall have the capability to be self-propelled by traction battery or other means over 100 metres on level track in tare or loaded condition so as to guard against being gapped and therefore unable to draw power from the traction supply.

10.2.6 The TCT shall be capable of operating continuously at all defined (slow) speeds whilst in "cleaning" mode.

10.2.7 It shall be possible to adjust the required slow speed to achieve the optimum practical cleaning effectiveness - over the suggested range of between 1 and 10 kph in 0.5 kph increments – the Supplier shall submit costed proposals for acceptance as part of their tender return.

10.2.8 The Slow Speed Drive shall automatically maintain the speed selected by the cleaning operator. Set and actual speeds are to be displayed to the cleaning operator. The supplier is to indicate the accuracy of their equipment (i.e. +/- 0.25 kph).

10.2.9 The continuous rating capability of the slow speed drive at any speed shall be greater than the time required to fill the storage capacity of the TCU.

10.2.10 A low acceleration and low jerk rate shall be maintained during on site tunnel cleaning operations by the slow speed drive equipment.

10.2.11 The control of the slow speed drive shall meet the principle requirements of LU Standard RSE-ST-00101 (traction control standard) as follows:

- Electrical drive – RSE-ST-00101 applicable, RSE-ST-00102 applicable also;
- Other drives e.g. hydraulic – RSE-ST-00101 Section 9 applicable only.

10.2.12 Wherever possible, equipment within the slow speed drive shall not be force ventilated.

10.2.13 The slow speed drive equipment shall not be susceptible to damage due to the ingress of water, snow and contaminant particles which could be present in the ambient air throughout the year.

10.2.14 In order to minimise the un-sprung mass, the final drive arrangement shall minimise as far as possible the mass borne directly by the axle.

10.2.15 If a hydraulic drive is used, means shall be provided to detect fluid loss and warn the operators. A comprehensive filtering system shall also be provided. The drive shall be designed to be maintainable over the 25 year life of the vehicle, including strategic spares to mitigate any obsolescence issues.

10.3 RS Electrical and Systems

10.3.1 Auxiliary and Control Supplies Requirements

10.3.1.1 The MPU shall derive electrical power from the traction supply. This power will be supplied to the TCU in a form to be agreed between the parties for driving the tunnel cleaning equipment, the control and monitoring of the slow speed drive equipment cleaning equipment and for the control and monitoring of the tunnel cleaning equipment.

10.3.1.2 The control and monitoring supply shall be DC and shall have a backup battery to provide continuity of supply when the converter switches off over gaps in the conductor rails.

10.3.1.3 The Auxiliary Supply will be a 4-wire (3-phase and neutral) 400/230V 50Hz system where the neutral is bonded to the main car earth. The supply will be capable of powering the entire tunnel cleaning equipment on the TCU, including the slow speed drive if this does not derive its own supply directly from the Traction Supply, together with providing the 'control supply' described in 10.3.1.1 above.

10.3.1.4 The Supplier shall ensure that the converter outputs are galvanically isolated from the Traction Supply from which they are derived. The Auxiliary Supply will be derived from the Traction Supply through auxiliary converters. Two or more auxiliary converters shall be provided so that the failure of one will not leave TCU without power for cleaning power or movement on the slow speed drive.

10.3.1.5 The Auxiliary Supply shall feed a battery charger whose output is used to float-charge the local stand-by battery and to provide the Control Supply as described in 10.3.1.1 above.

10.3.1.6 The Control Supply voltage shall be at an industry-standard value (for example 96V nominal is currently used, with a float-charge level of 110V) but must be matched to the

battery charging characteristics. The negative pole of the battery shall be bonded to the car body and all returns shall be hard wired. A Low-Voltage Cut-out system shall be fitted to ensure that the battery is not damaged by over-discharge and that there is always sufficient charge left to re-start the Converter when traction supply is available.

10.3.1.7 The Auxiliary Converters will not be capable of operating whilst the train is travelling to and from the site to be cleaned. The Supplier shall ensure that this power supply is not required for the TCU to operate to and from site safely.

10.3.1.8 The legacy motive power vehicles provide their own Control Supply and will also provide the Traction Supply to power the Auxiliary Supply converter for the cleaning equipment. The Traction Supply will be provided to the Tunnel Cleaning Unit by both motive power units, so the TCU shall have connections for this at both ends.

10.3.1.9 Not used.

10.3.1.10 Any equipment on the tunnel cleaning unit required to function when the formation is travelling under the control of either motive power unit (e.g. service brake equipment) shall interface with the -52V Control Supply derived from the motive power units. Information on this Control Supply is contained in G6381.

10.3.2 Electrical systems - general

10.3.2.1 The design of the electrical systems and the wiring installation shall be in accordance with LU Rolling Stock Standards RSE/STD/024 Pts.1, 5 & 6; and E6487. All controls, switches, relays, etc. shall meet railway industry-recognised standards and be fit for purpose.

10.3.2.2 If using the traction supply the TCU shall be capable of working on and handling variations in, the traction supply. The traction supply is nominally 630V pole-to-pole (+420V to earth and -210V to earth) however there are future upgrades to parts of the network to 750V. Maximum voltage encountered when other stocks are braking regeneratively is 900V. Under fault conditions, either pole can rise to the full supply voltage.

10.4 RS Equipment Enclosure Sealing

10.4.1 Equipment enclosures shall be designed to the IP 65 degree of protection as a minimum. Enclosures containing equipment requiring vent paths to the atmosphere (which shall be designed to restrict ingress of dust and moisture to an acceptable level)

are excluded from this clause. All equipment should be contained in IP65 enclosures as defined in BS60529. TL 2-054

10.4.2 In order to protect against the degradation of case sealing with time, the equipment within cases shall assume an equipment case enclosure protection rating of IP 55.

10.4.3 The Supplier shall demonstrate by practical means that equipment enclosures prevent ingress of tunnel dust. Where this is not achieved the Supplier shall demonstrate by test that tunnel dust contamination has no adverse effect on component and system performance or life.

10.4.4 The Supplier shall ensure that suction and ventilation ducts are arranged to prevent the ingress of water as a result of the following as a minimum:

- Train washing and heavy rain conditions
- Condensate and ice formation
- Snow, sleet and hail stones

10.4.5 The Supplier shall ensure that any moisture in the ducts can drain away without adversely affecting the performance of the equipment housed in or connected to the ducts.

10.4.6 The Purchaser has had previous experience of clogging of filters with the fibrous matter present in its dusty environment and the need to incorporate filters shall be minimised. The Supplier shall demonstrate that if filters are required to be fitted to TCU equipment they are located as far away from the cleaning heads as practicable and be designed to permit normal equipment operation with a high degree of contamination. They shall be either automatically purged of debris in a controlled manner or shall warn the Operator of degraded operation and be capable of being quickly checked as part of routine inspection to determine if they are clogged or partially clogged. The filters shall be such that they can be easily and quickly cleaned by a procedure which causes no adverse effect to the equipment and does not present an environmental hazard to the maintenance personnel. The Supplier shall propose a means of achieving these requirements at the design stage and demonstrate as part of maintainability demonstration. Filters shall not require cleaning or changing more frequently than 3 monthly intervals.

10.5 RS Structural requirements

10.5.1 The TCU structural design life shall be 25 years and the cleaning equipment within the train is to be designed for a 25 year life covering an annual distance of not less than 15,000 km travelling to /from work sites and not less than 2,500 km whilst undertaking cleaning duties. The Supplier is to specify the life time interventions to achieve or exceed the design life.

10.5.2 The TCU shall meet the structural requirements contained in LU Standard 1-180 Standard for Rolling Stock section 3.10, as explained in Appendix 6.

10.6 RS Mechanical

10.6.1 Mass of the TCT:

- The (empty) mass of the TCU shall be minimised as far as possible.
- The (empty) mass of the TCU shall not exceed 45 tonnes (i.e. excluding mass of collected dust and rubbish)
- The fully laden mass of the TCU shall not exceed 75 tonnes.

10.6.2 The Length of the TCU shall be minimised as far as possible subject to clause 9.3 and shall not exceed 45 metres over the free-issue coupler faces. The Supplier shall advise if a small increase in the required lengths would provide a significant benefit.

10.6.3 Each vehicle within the TCU shall be carried on a minimum of 4 axles.

10.6.4 TCU equipment security shall comply with E6302 – Rolling Stock Equipment Security.

10.6.5 All materials used in the construction of the TCU shall comply with the applicable sections of LU Standard 1-180 Standard for Rolling Stock section 3.9.

10.6.6 Painting systems used on the TCU shall comply with E6241.

10.6.7 The TCU shall be compatible with the cleaning materials defined in G6162.

10.6.8 It is assumed that there is no practicable way to provide a throughway for operators to move through the TCU while in the tunnel. If the supplier is able to provide such a feature they are to provide a price for it within the tender return, and clearly specify the effect on the cleaning/storage and other performance requirements in this specification.

10.7 Wheel / rail interface requirements

10.7.1 The TCU shall be designed to run on LU track. LU Track is defined, and max design cases for horizontal and vertical curvature are listed section 15 of this specification.

10.7.2 The TCT must comply with Wheel Rail Interface requirements set out in LU Standard 1-180 Standard for Rolling Stock section 3.2.5.

10.7.3 The mass and un-sprung mass of the vehicle shall be kept to a minimum to prevent track wear.

10.7.4 Wheel diameter scrap size shall be greater than 650mm to avoid high rail stresses.

10.7.5 Lowest LU targeted friction coefficient on the rail surface is 0.2. The TCU traction and braking shall be at least designed as to not cause wheel slide under braking or wheel burns during traction at this friction level.

10.7.6 The TCU wheel profile shall be LT5.

10.7.7 Maximum axle load of TCU shall not to exceed 16 Tonnes.

10.8 Emergency Response Unit requirements

10.8.1 The TCU shall be able to be re-railed after derailment using jacking equipment held by the LU Emergency Response Unit. The Supplier shall define a process and equipment required for re-railing the TCU.

10.8.2 The rail cars which comprise the TCU shall be capable of being lifted by depot jacks by the same or different under body jacking points.

10.8.3 The Supplier shall provide adequate warning information on the vehicle and in the training material as to the location of any hazardous materials.

10.9 RS Brakes and Pneumatics

10.9.1 Emergency and Service Brake System

10.9.2 The MPU brake equipment comprises an electro pneumatic (EP) service brake and a direct release automatic air brake for emergency brake duties. Mercury retardation control is provided as part of the brake control system. This is used to prevent excessive deceleration.

10.9.3 The TCU shall be equipped with an automatic air brake (with diaphragm triple valves) and an EP brake for normal service use. All braking system components shall be capable of withstanding an air pressure equal to 8 bar without any detrimental effect to any component. The use of nylon for any pipe work within the brake system is prohibited.

10.9.4 EP Brake units (including diaphragm triple valves, application, holding and blow down valves, brake release valve, EP Brake Isolating Cock and EP brake heater) will be recovered from legacy LU cars, overhauled and will be free issued to the Supplier for use on the TCU vehicles.

10.9.5 Where possible the brake units for the TCU shall be fitted on the outer ends of the cleaning consist in order to enable the train crew to access them in the confines of a tube tunnel if there is a need (emergency or failure) to isolate the brakes on the TCU when the train is in use.

10.9.6 Depending on the number of vehicles/bogies in the TCU it should be possible to use 2 brake control units to control all the brakes on the TCU. The exact details will be agreed with the brakes engineer once the final configuration of the TCU has been determined.

10.9.7 The automatic air brake shall require auxiliary reservoirs (one per brake unit) to be fitted on the TCU to provide the dedicated compressed air supply for the emergency brake.

10.9.8 The auxiliary reservoirs (one per brake unit) to be supplied and fitted by the Supplier on the TCU shall have sufficient capacity to attain an equalised pressure (between the reservoir and the associated brake actuators) of 3.5 bar, with an additional 20% capacity for leakage.

10.9.9 The brake actuator shall require no routine maintenance between vehicle overhauls. It shall have means of automatically maintaining brake block/pad to wheel/disc clearances to an agreed value (slack adjuster function).

10.9.10 The layout of all pipe work and pneumatic components shall be such that low points in the system do not occur and condensation traps are avoided.

10.9.11 The layout of all pipe work and pneumatic components shall ensure that air cannot pass from the main line into the train line under any circumstances.

10.9.12 Brake cylinder pressure gauges shall be provided and are to be visible from both sides of the TCU and from the end (so as to be visible from the MPU).

10.9.13 Test points shall be provided for maintainers to check the state of the main line, train line and brake cylinder pressures on the TCU. These to be labelled, grouped and sealed when not in use.

10.9.14 Brake Application Equipment

10.9.14.1 The TCU shall be equipped with friction brakes sufficient to enable its mass to be decelerated at a rate of 1.2 m/s2, on level tangent track, when supplied with a brake pressure of nominally 2.5 bar.

10.9.14.2 The brake actuators shall be sized such that, with the same brake cylinder pressure supplied to each axle's actuators, the adhesion demand at any axle on the TCU does not exceed 0.15 when decelerating the TCU at a rate of 1.2 m/s2.

10.9.14.3 Either tread or disc brakes are be considered acceptable for the cleaning consist. The legacy vehicles use tread brakes with composition brake blocks (type 697) supplied by TMD. Use of these brake blocks on the TCU would be acceptable.

10.9.14.4 Emergency devices shall be fitted to each corner of the TCU cars to provide a means of applying the emergency brake. When activated these devices shall result in the rapid discharge of the train line thereby causing the emergency brakes to apply.

10.9.14.5 Air reservoirs shall comply with BS EN 286-3 (steel pressure vessels for use on railway rolling stock).

10.9.14.6 It shall be possible to check all components of the brake system for wear while in situ on the vehicle.

10.9.15 Brake Performance

10.9.15.1 The braking performance of the TCU needs to provide a sufficient performance so that, in conjunction with the legacy motive power vehicles, the whole train (TCT) meets the emergency brake performance required for operation on the London Underground network.

10.9.15.2 For emergency braking, the braking equipment on the TCU shall provide a braking effort to decelerate its own mass at a braking rate of 1.5m/s2.

10.9.15.3 The emergency brake cylinder pressure shall attain 90% of the pressure required to achieve this brake rate within a time of 1.5 – 2.0 seconds.

10.9.15.4 For normal (line speed) service braking, the braking equipment on the TCU shall provide the braking effort to decelerate its own crush laden mass at a braking rate of up to 1.15 m/s2.

10.9.15.5 The brake cylinder pressure, required to achieve a braking rate of 1.15 m/s2, shall be attained within the range of 2.0 – 3.5 seconds. The application time shall be set to match that of the legacy motive power vehicles. (This is achieved by adjusting the application choke in the brake unit). The brake release time, from a brake demand of 1.15 m/s2 shall be in the range 3.5 – 4.5 seconds and shall be set to match that of the legacy motive power vehicles. (This is achieved by adjusting the release choke in the brake unit). (Note – it may be decided to set the brake application time on the TCU slightly longer than that of the motive power vehicles and the release time on the TCU slightly shorter so as to bias the service braking effort onto the motive power vehicles.)

10.9.16 Slow Speed Drive Brake Control

10.9.16.1 If the requirement in 10.2.2 cannot be delivered then the Supplier shall indicate whether there is a need for the TCU to have control of the brake system during slow speed operation. If required, an interface will be provided whereby the slow speed control could operate the application and holding wires of the EP brake system and, if necessary, this could be limited to some of the vehicles so as to reduce the effectiveness.

10.9.17 Parking Brake

10.9.17.1 The MPU vehicles are each fitted with a manually operated hand brake. The TCU shall be equipped with a spring applied parking brake (SAPB) system which shall be capable of holding its own mass, fully laden, on a 1 in 30 gradient (with no air brake assistance).

10.9.17.2 The SAPB system on the TCU shall be capable of being applied by the train operator from either motive power formation (e.g. via electrically operated EP valves) and shall apply automatically when neither motive power unit is “opened up” – i.e. has an operational cab. When a cab is opened up, the SAPBs on the TCU shall automatically release unless the SAPB “apply” control in either motive power formation has been operated. An indication showing whether the SAPBs are applied or released shall be fitted in the each driving cab of both motive power formations.

10.9.17.3 There shall be a means to mechanically release the SAPB after discharging the air pressure to enable routine maintenance activities to be undertaken safely. The position

of the mechanical release shall clearly indicate the status of the SAPB (i.e. 'Active' or 'Released').

11 Noise

11.1 The overall requirements of the train including the motor cars and the tunnel cleaning unit shall comply with the noise requirements of Standard 1-180 set out in paragraphs: 3.2.9.1 and 3.2.9.3 – 3.2.9.8 inclusive (note that the requirement set out in paragraph 3.2.9.2 relating to the rail condition on which pass-by noise levels shall be measured shall not apply. Instead the rail shall be compliant to the conditions set out in BS EN ISO 3381:2005 "Railway applications – Acoustics – Measurement of Noise inside Railbound Vehicles"). The specified levels of noise for the saloon shall be ignored. Instead, the noise limits specified for the cab in these paragraphs shall also apply to the saloon area of the vehicle.

11.2 The Supplier shall work with London Underground to ensure that noise generated by the tunnel cleaning unit does not compromise meeting the overall requirements for the train as set out in the paragraphs listed above. To this end, the Supplier shall provide design details and evidence of measurements, as necessary, during the development of the vehicle for use in determining and controlling noise emission and imission levels. It is expected that during the development of the vehicle specific constraints on the acceptable noise levels for sub-elements of the tunnel cleaning unit will be determined and the Supplier will be responsible for ensuring that such requirements are met. This includes components supplied through sub-Suppliers.

12 Train Protection and Signalling Compatibility

12.1 LU will manage the train protection and signalling compatibility issues as part of the development of the MPUs.

13 EMC

13.1 EMC requirements for the TCT are set out in Appendix 4.

14 Fire Performance

14.1 All materials incorporated in the Supplier's Equipment shall comply with LU Standard 1-085 'Fire Performance of Materials'. Guidance notes are provided in Appendix 5 of this

specification on the application of this standard. All materials on the train, when exposed to fire shall not emit toxic fumes.

14.2 The Supplier shall comply with the requirements of prEN45545 – 2009, Railway applications – Fire protection on railway vehicles Operation Category 4 / Design Category N, and DIN 5510 Preventative fire protection in railway vehicles Protection level 4, despite the fact that these standards are intended for passenger rolling stock.

14.3 The TCT shall be fitted with fire systems that comply with the ARGE Directive – Fire Prevention in Rolling Stock.

14.4 Not used.

14.5 Not used.

14.6 The TCU shall be provided with an automatic fire suppression system compatible with operation in a deep tube environment.

14.7 The TCU shall be provided with a comprehensive, automatic fire system which provides accurate detection and suppression of any fires in any part of the tunnel cleaning equipment.

14.8 The automatic fire suppression system (controlled by the fire detection system) shall not adversely affect collected dust within the cleaning and collection system when operated.

14.9 Because the TCT will be operating in deep level, single bore tube tunnels with members of staff in vehicles located either side of the TCU a very high level of integrity, effectiveness and reliability in the detection and suppression of fire events is required.

14.10 No single failure in either the fire detection or suppression system shall prevent its operation.

14.11 Warnings and indications from the fire detection and suppression system shall trigger a “primary alarm” at both cleaning operator consoles.

14.12 In the event of a “fire detected” event, the system shall automatically cause the tunnel cleaning system to shut down. Note: If possible the means of disturbing the dust and litter should be shut down before the means of collecting it, to avoid a dust plume which will hinder escape and rescue attempts.

14.13 In the event of a “fire detected” event in the waste collection or storage areas, then, in addition to the operation of the fire suppression system, the affected container(s) shall be isolated so as minimise the spread of smoke.

14.14 Following automatic isolation, it shall not be possible to reset the tunnel cleaning equipment until a thorough inspection of the suspect area has been undertaken (e.g. need reset switch adjacent to each TCU compartment).

14.15 The fire suppression method shall be such that its operation shall not present an unacceptable risk to the train crew on the motive power units.

14.16 The fire suppression method shall be such that, after operation, the tunnel cleaning equipment shall be capable of operation following appropriate cleaning (assuming no significant fire damage).

14.17 The operation of the fire suppression system shall not cause significant damage to the cleaning equipment, necessitating extensive dismantling and replacement (assuming no significant fire damage).

14.18 The operation of the fire suppression system shall not prevent the subsequent discharge of collected waste matter (assuming no significant fire damage).

14.19 The fire detection and suppression system shall provide status and health indications to the cleaning operator.

14.20 It shall be possible for the cleaning operator to be able view, via CCTV, the interior of all TCU vehicles in the event of a fire detection warning being triggered.

14.21 The fire detection and suppression systems, including their monitoring, shall be included within the required RAMS analysis.

15 Route Availability

The gauging requirement for the Tunnel Cleaning Train has been focused on the profiles used for the tube tunnels. The structure profile for sub-surface tunnels has been included to allow consideration to be given for cleaning low level structures in these areas. The type of vehicle which may be used to carry the tunnel cleaning equipment has also been divided to widen the choice. When the Tunnel Cleaning Train is in working mode, the permitted swept envelope has been enlarged, to allow design engineers to maximise the efficiency of the dust collection system. Refer to LU Gauging and Clearance standard 1-156 for definitions and diagrams.

15.1 Deep level tube tunnels.

15.1.1 For a vehicle with a rigid outer skin which defines its profile.

15.1.1.1 The Kinematic envelope of the vehicle must lie within the kinematic limit (KL) of diagram G1 as defined in the LUL Gauging and Clearance standard 1-156.

15.1.1.2 The swept envelope of the vehicle must remain within the KL of diagram G1 (enlarged for curvature) for the minimum track radii specified below.

15.1.1.3 A computer model which is acceptable to The Client must be used to demonstrate compliance of the vehicle profile with the KL defined in diagram G1.

15.1.1.4 At low level, the vehicle must comply with diagram F1 of the Gauging and Clearance standard 1-156.

15.1.1.5 The profile for non-insulated components shown on diagram F1 must not be infringed by any part of the vehicle in its lowest condition, or when the vehicle travels over track junctions and cross-overs.

15.1.2 Not applicable.

15.1.2.1 Not applicable.

15.1.2.2 Not applicable.

15.1.2.3 Not applicable.

15.1.2.4 Not applicable.

15.2 Cut-and cover type sub-surface tunnels

15.2.1 The Structure profile as defined in Diagram E2 of the LUL Gauging and Clearance standard 1-156 is included for guidance in the design of the low level cleaning facility in sub-surface tunnels.

15.3 At the work site

15.3.1 The profile of the Tunnel Cleaning Unit in its working mode may be enlarged beyond the Structure Profile applicable to the tunnel, provided that any element which is extended is designed to either automatically retract before impact, or deflect without damage to it or the impacted structure.

15.3.2 If the extended element is designed to retract, it must return to its original profile and be reported as “correctly stowed” to the train operator. The retraction must be automated but must also have a manual facility accessible to the Train Operator in a tunnel environment. The retracted element may be designed to return automatically to its working design position, or may signal its retracted status for manual reinstatement.

15.3.3 If the infringing element is designed to deflect, the deflection force at maximum working speed must not cause any damage to the structure. Snagging must not be possible.

15.3.4 The deflected element must return to its design position when the obstruction is cleared.

15.3.5 Retraction and deflection must apply in both directions of travel.

15.3.6 Any cleaning equipment which, when deployed, is outside the Kinematic Envelope shall be proven to be correctly stowed within gauge before full speed performance can be enabled.

15.3.7 Any cleaning equipment which, when deployed, is outside the Kinematic Envelope shall automatically stow within gauge in the event of a power loss from the MCU.

15.3.8 Any cleaning equipment which is able to be deployed outside the Kinematic Envelope shall be securely held within gauge without power from the MCU.

15.3.9 The existing track data are as specified in Standard E8404 Track Geometry and condition Standards. The Supplier shall incorporate the most onerous requirements specified within E8404.

15.3.10 Minimum curve Radii

The TCU shall be designed to operate on the following worse case track dimensions:
Basic Track Dimensions:
Minimum depot curve radius = 46m, minimum operating curve radius = 61m, minimum vertical curve radius = 400m.
The most severe reverse curve definition is defined as:

Location on curve (m)	Curvature (1/m)	Radius (m)
0	-0.01587	-63
6.25	-0.01587	-63
15.25	0	0
18.75	0	0
22.75	0.00893	112
27	0.00893	112

16 Human Factors / Operational Requirements

16.1 General

16.1.1 The work carried out on this project shall comply with 1-217 – integration of Human Factors into system integration

16.1.2 Where the Supplier provides operational facing equipment that affects train control then the supplier will support the Purchaser in its responsibility to comply with the Standard for Rolling Stock 1-180, Clause 3.13, whilst considering the content of G-182 – Ergonomic considerations for the design and development of a rolling stock operators cab

16.1.3 Where interfaces are provided for control of tunnel cleaning equipment these should comply with LU standard 1-218 Universal Computer Interaction

16.1.4 The end users impacted upon by the introduction of the new systems shall be considered. This should include, but is not limited to:

- The tunnel cleaning equipment operators
- The maintainer of the new assets

16.1.5 All interfaces, whether they are computer or machine, shall to be usable by all potential end users within the 5th to 95th percentile anthropometric range for the life of the equipment.

16.1.6 The Purchaser will be responsible for the overall integration of this equipment into the cab and other refurbishment, overhaul or additional systems required in the cab / car to run on different LU lines. All equipment provided should be suitable and operable within the cab environment.

16.1.7 All interfaces shall be designed to enable the operator to carry out the various tasks in a timely and error free manner.

16.1.8 The operational workload when using the new interfaces should be such that it fits within the capabilities of the end user.

16.1.9 Human Factors and Workplace Task Analysis shall be used to determine the optimal design and location of all controls and isolations.

16.1.10 Maintenance of the new systems should be carried out in a manner that is safe, error free and able to be carried out in a timely manner.

16.1.11 The HMI hardware installation shall seek to avoid adversely affecting access to, or functionality of, existing train controls.

16.1.12 Information displayed on any HMI displays shall be clearly visible in both tunnel and bright outdoor lighting conditions. Displays should be designed with anti-reflective surfaces.

16.1.13 The displays and controls used on the HMI must be robust, durable and suitable for use in the London Underground environment.

16.1.14 All isolation devices that are required to be used with the tunnel cleaning system shall be accessible to the operator in a tube tunnel and be clearly identified and labelled so that their operation is clear and unambiguous to the operator.

16.1.15 To assist them in the quick, safe and economical operation of the tunnel cleaning equipment, a simple and effective HMI shall be provided which:

- Before or prior to entry into service: gives information regarding the status and health of the tunnel cleaning equipment (including any formal train prep work if applicable)
- In service: gives relevant and timely information regarding the state of the tunnel cleaning equipment and its related systems;
- Filters the data so that only faults which the operators can rectify or which require them to take appropriate action are reported;
- Does not issue continuous reminders of matters about which operators are aware;
- Confirms, within an acceptable time period, that actions have been correctly carried out;
- Is not susceptible to spurious messages caused by spikes or transients on monitoring inputs;
- Reports only a primary failure and not the failures caused by it;
- Automatically updates information displayed as it changes, without requiring operator intervention to do so;
- Where operator action is practicable, diagnoses the problem and proposes a solution;
- Where the problem has more than one solution, presents them one at a time, in order of preference;

- When a fault clears, removes it from the display without operator intervention, but retains it in the log.

16.1.16 An equipment management system (EMS) shall be provided for the tunnel cleaning system for the following purposes:

16.1.17 The EMS shall provide appropriate signals to all items of equipment so that the tunnel cleaning system functions correctly;

16.1.18 The EMS shall monitor system performance and provide timely warnings at all operating positions and actions when sub-optimal performance of any system is detected.

16.1.19 The EMS shall automatically shut the system down under circumstances which could lead to a hazardous condition. For example, any failure in a system designed to capture dust shall automatically cause any system designed to disturb dust to shut down. The reason for any such automatic shutdown shall be flagged to the cleaning operator by the EMS.

16.1.20 The EMS shall provide the nature, location and action required to remedy all equipment failures.

16.1.21 The EMS shall store information for later retrieval for failure and incident investigation;

16.1.22 The state of all controls and fault-handling devices shall be used by the control system to enable automatically and enforce the best safe behaviour of the tunnel cleaning system.

16.1.23 Loss of services or supplies in or to the control system shall not result in an unsafe condition.

16.1.24 The cleaning operator shall be provided with:

- Useful and timely warnings and diagnostic information to assist in operating the system in the manner which is most safe, efficient and reliable;
- Information about rectifiable faults or of failures that require the tunnel cleaning equipment to be shut down and withdrawal of the train from service

16.1.25 Delays in transmitting all other commands, or in displaying information following a failure, shall not be greater than 2 seconds.

16.1.26 The tunnel cleaning system shall not be confused by railing or gapping.

16.1.27 Single point failures in the control and monitoring system shall:

- Not immobilise the train or cause unsafe events to occur;
- Be self-revealing to the operator.

16.1.28 Faults about which the operator is unable to take action shall not be reported, unless the operator has specifically selected to display status information.

16.1.29 Diagnostic and rectification information shall include advice on a suitable remedy. The course(s) of action shall be appropriate for the operator to undertake, taking into account the confines of the train and its environment. In addition to the normal driver display this should also consider a maintenance accessible log to assist with fault diagnosis which should provide a much more detailed level of failure data.

16.1.30 TCT shall be provided with CCTV so that the cleaning controller can view both ahead and behind the TCT.

16.1.31 All routine cleaning functions shall be fully automatic without the need for Equipment Operator intervention. All cleaning locations and the track ahead shall be monitored by CCTV with the pictures displayed on screens located at the operator position. The Equipment Operator shall be able to view all cleaning locations around the TCT from either cab / car together with appropriate intervention controls. This shall include illumination deployed to rear of the TCT to enable the Equipment Operator to view the cleaned areas to ensure the cleaning operation has not dislodged any equipment. The Supplier shall propose at Tender Stage how many cameras are required to achieve full coverage and what method is proposed to prevent lens contamination**.**

16.1.32 In addition to the train operating lights fitted to the exterior of the 72TS cabs the Supplier shall supply and fit supplementary lights to the two 72TS cabs to provide all round illumination for the forward and rearward facing CCTV cameras. These lights shall only be enabled when the TCT is in cleaning mode. The lights shall be LED or long life equivalent.

16.2 Audible Warnings

16.2.1 The Train Operator and Tunnel Cleaning Operator shall be provided with audible and visual alarms as appropriate. A strategy for audible and visual alarms & information shall be devised for the TCT in accordance with the Standard for Rolling Stock 1-180

Clause 3.14.4.5. The Supplier will comply with this clause with regards to the Tunnel Cleaning Operator and support The Purchaser as appropriate for the Train Operator.

16.2.2 The alarms strategy shall consider but not be limited to alarms for heat, oxygen and dust levels.

16.2.3 The Supplier shall demonstrate all the audible alarms, including those commanded by free issue equipment, in the interior mock-up [See Section 16.4]; together with any associated visual alarms at Preliminary Design. Volume levels shall take account of ambient noise levels prevailing whilst in tunnel; at grade; at cleaning operating speeds; up to line speed and stationary.

16.3 Interior Mock Up

16.3.1 A full size mock-up of TCU control panel shall be supplied by the Supplier to validate the proposed Interior design and confirm all Anthropometric, Human Factors, Task Analysis and visibility requirements are achieved.

16.3.2 The mock up shall include all controls, indications and monitors and shall be used to verify spatial relationships and all ergonomic criteria. Fully functioning TCU Equipment Operator seats shall be fitted.

16.3.3 The mock-up shall be made available at the Supplier's premises and be accepted by the Supply Manager before Concept Design is submitted for acceptance. It shall be located to permit access by the Supply Manager, Operations Representatives and other interested parties. It shall also be capable of dismantling, transporting and re-assembling within the Purchasers premises at no cost to the Purchaser.

16.3.4 The Supplier shall note that as a result of nominated representatives examining the mock-up changes may be required to achieve acceptance.

17 Disposal / decommissioning

17.1 The Supplier shall, as part of the Design Submission Process, provide details of all equipment and materials, their ability to be recycled and the methods to be used for disposal.

18 RAMS strategy

18.1 Clauses 18 to 21 describe in full the requirements to be compliant with respect to RAMS.

18.2 The Supplier shall adopt a systems approach to reliability, availability, maintainability and safety (RAMS) as described in the following:

- LU standards (principally 1-538 Assurance, 1-526 The Assessment and Management of Health, Safety and Environmental Risk and 1-521 Safety Decision Making);
- Industry good practice, including the Yellow Book Engineering Safety Management - Volumes 1 & 2 - Fundamentals and Guidance, Issue 4, RSSB;
- BS EN 50126 Railway Applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)

18.3 Preliminary plans shall show how the Supplier's RAMS management processes will integrate to deliver safety within the Scope of Work.

19 Reliability

19.1 The fundamental requirement is that the train should complete the full scope of work of each tunnel cleaning shift in the allotted time and not have any adverse effect on the scheduled operation of the railway.

19.2 A shift is defined as starting when the train leaves its depot/berth travels to the cleaning site where it performs its duties up until it returns to depot or berths on completion of its defined run.

19.3 Reliability, other than for Rolling Stock purposes, where 1-180 applies, may be considered as the percentage of required cleaning duties which the TCU begins, cleans and completes. For the Slow Speed Drive, auxiliaries and Cleaning System, the reliability shall be 99.9%.

19.4 The Supplier shall undertake a Reliability analysis, as defined in LUL Standard for Rolling Stock 1-180, giving reliability targets for each of the sub-systems supplied under the Contract. Note: this requirement only applies to the Rolling Stock system itself (structure, brakes, wheel sets), as covered by 1-180. It does not apply to the cleaning system or slow speed drive.

19.5 The Rolling Stock Reliability data shall be given as distance-based failure rates. To permit this form of presentation, assumptions as to 'frequency of demand' type events shall be agreed with the Purchaser, and documented.

19.6 Where calculations are derived from time-based source data, e.g. MTBF (Mean Time Between Failures), the combination of these into service distance-based failure rates shall be performed consistently, regardless of equipment source of supply, using an apportionment method. Where calculations are based on frequency-related data, the Supplier shall use a consistent and documented method, acceptable to the Purchaser, to relate such data to the duty cycle and service-distance-based failure rates.

19.7 Presentation of Rolling Stock reliability data as event probabilities is not acceptable, however presentation of Slow Speed Drive and Cleaning System reliability data as event probabilities is acceptable.

20 Availability

20.1 There will be a total of 250 EH shifts available for use by the TCU each year. The TCU shall achieve an availability such that it is available for use on not less that 240 of these (96%) when maintained in accord with the maintenance manual. Availability is defined as the number of required shifts of work that the TCU is in a fit state to begin.

21 Maintainability

21.1 The Supplier shall comply with the Standard for Rolling Stock 1-180, Clause 3.3 Condition and Maintenance as noted in the attached compliance table in Appendix 6. The supplier shall use E6603 and E6831 as guidance in the production of all maintenance documentation. Standards referred to in these standards need not be consulted.

21.2 The Supplier shall demonstrate, to the Purchaser's satisfaction, adequate consideration of the maintenance aspects and implications of the Scope of Work, and how they will be supported including:

- Routine maintenance and servicing intervals
- Labour, materials, down time and facilities required for each maintenance interval.
- Fault finding guides, training, diagnostic equipment and spare parts.

21.3 The Supplier shall demonstrate that all maintenance tasks are capable of being performed safely with negligible risks of unsafe working practices and that the possibility of errors during maintenance has been designed out as far as is practicable.

21.4 The Supplier shall demonstrate that the required maintainability performance has been achieved. Trial replacement and assembly procedures shall be demonstrated on site at Ruislip depot during the trial operation phase.

21.5 The requirement for use of special tools, which shall include non-Standard tooling, gauges, fixtures, test and diagnostic equipment, to maintain the TCT shall be minimised.

21.6 Where required the Supplier shall recommend and provide specialised tools, test, fault finding and handling equipment for maintenance and overhaul. The Supplier shall also supply the Supplier's name, address and all applicable reference or part numbers to the Purchaser.

21.7 The Supplier shall supply manufacturing drawings for any tooling items which cannot be purchased off-the-shelf.

21.8 The Supplier shall confirm at Tender Stage that all wheels can be fully turned in situ using an under floor wheel lathe and all related suspension and speed signal adjustments can be made with the TCT railed.

21.9 The TCT shall be capable of being lifted with or without bogies using lifting jacks or cranes.

21.10 The TCT shall be capable of external cleaning using existing tube gauge train washers.

21.11 The Supplier shall propose at Tender Stage how all cleaning equipment can be automatically self-cleaned and the resulting waste safely removed from the TCT.

21.12 The Supplier shall propose and define the list of Line Replaceable Units (LRU's). The Supplier shall declare at Tender Stage what LRU's are not capable of being exchanged without lifting or access to a pit.

21.13 The Supplier shall recommend to the Purchaser the initial quantity of spares stock holding levels for all equipment and components supplied under the Agreement required to maintain the TCT.

21.14 It shall be possible to replenish all consumables and undertake fault finding at remote stabling locations with appropriate portable maintenance and test equipment.

22 Safety

22.1 The TCT shall be safe, reliable and fit for purpose operating on the LU network. The Supplier shall comply with the Standard for Rolling Stock 1-180 Section 3.4 as noted in the attached compliance table in Appendix 6. Assessment of the supplied goods in the context of this standard is to be based on the expected duty cycle and normal usage

expected. It is accepted that the low annual kilometreage of the TCT (compared with a passenger train) may make demonstration of compliance with the numeric targets in the Rolling Stock Standard 1-180 Clause 3.4.5.5 difficult. If this is the case, and the Supplier considers the assessed performance is acceptable, the Supplier shall provide an argument in support of this to enable a concession to be considered.

22.2 The TCT supplier shall provide for the TCU and support the Purchaser in providing for the TCT safety justifications for the new equipment in accordance with the general requirements expressed in 18.2.

22.3 This safety justification shall include identification and analysis of credible functional and physical safety hazards applicable:

- During stabling of the TCT on LU infrastructure;
- When the TCT is moving between a stabling location and a work site;
- When cleaning at the worksite;
- During maintenance, inspection and testing;

The analysis shall consider hazards to Operators, Maintainers, Staff on stations, Passengers, Track Workers.

22.4 The analysis shall cover safety under normal operation, with external stimuli and in the presence of credible fault conditions. The analysis shall also cover the potential affect of the TCT on other railway assets, either directly or via electro-magnetic interference. The safety justification shall provide assurance that the residual functional and physical safety risk associated with the TCT is tolerable and has been reduced as low as reasonably practicable (ALARP).

23 Identification and traceability

23.1 All major sub-systems and components shall be uniquely and traceably identifiable, including to material sources.

23.2 The Supplier shall identify any other components of a critical nature for which traceability will be provided.

24 TCU documentation

24.1 The Supplier of the TCU shall supply documentation to support the TCU throughout its life in broad compliance with the requirements set out in the Standard for Rolling Stock 1-180 Section 3.5 as noted in the attached compliance table in Appendix 6.

24.2 The Supplier shall provide As-built drawings, associated reports and calculations, performance modelling results and Type and Routine Test results, Radiographic/NDT Data, Asset Identification, Performance Data and Specifications; all in accordance with the specified requirements. As-built drawings shall comply with the requirements of LUL Manual MR-M-17 CAD Specification Manual, and standard 1-037 Computer Aided Design Data. Any 3-D modelling developed shall be provided in native format and in a format compatible with the Bentley Micro-station V8.

24.3 All documentation shall reference the physical components of the TCT in accordance with the requirements of LUL Standard 1-187.

24.4 The Supplier shall provide a detailed submission plan of all Maintenance Documentation. The maintenance manuals including process instructions will be submitted in support of the Detail Design Submission.

24.5 The final issue of the Maintenance Documentation shall be delivered not later than the delivery of the TCU to the Purchaser to be used to demonstrate maintenance processes during the Trial Operations.

24.6 All software/ hardware critical to the whole life operation of the TCT shall be placed in escrow.

24.7 The Supplier shall provide an asset record for all equipment supplied. These records shall include equipment description, serial number, location of installation, test records and history of repair / replacement prior to Hand Over. Details of the record content and format of the system proposed shall be agreed with the Supply Manager.

25 Design and Validation Process

25.1 General

25.1.1 The design and validation process shall generally be carried out in accordance with 1-180 Clauses 3.4.2 and 3.4.3 as modified in the table in Appendix 6.

25.1.2 To minimise project risk and gain confidence that the design will meet requirements the Supplier shall facilitate the acceptance process by holding design reviews at key stages of the design process, and providing the required documentary evidence as detailed in the following sections.

25.1.3 The Supplier shall provide a plan of all design and validation reviews to be held and provide the meeting schedule and agendas to the Purchaser at least five business days before each review meeting.

25.1.4 All Reviews shall be single gateway reviews. If necessary each review may be held over a number of consecutive days.

25.1.5 The reviews shall be minuted by the Supplier such that the minutes, once agreed and issued to all parties, and all actions closed to the satisfaction of the Purchaser, will form the agreed platform for project progression to the subsequent stage.

25.1.6 The Supplier shall prepare the submissions for each review stage by preparing the documentation relevant to that stage. The documents required for each stage are described in Table 2 in Appendix 8. These shall be submitted to the Purchaser not less than 10 Business Days prior to the respective review date. Each submission shall include a clear explanation of the scope of the submission for that stage.

25.1.7 The design and validation review process for the TCU and its commissioning within the TCT is made up of 8 sequential reviews as indicted in the following table:

Project Stage	**Project Activity**	**Review**	**Assurance Deliverable**
Design	Concept Design	1. Systems Requirements Review	
		2. Concept Design Review	Agreement In Principle
	Detail Design	3. Intermediate Design Review	
		4. Final Design Review	Letter Of No Objection
Delivery	Build	5. Preliminary Test Readiness Review	
	FAT	6. Physical & Functional Configuration Audit Review	Consent To Test (depot)
	Commission & test TCT	7. Test Readiness Review	Consent To Test (Railway)
		8. Trial Operations Review	Consent To Operate

25.2 Design Review Process

25.2.1 Design Review is conducted in two parts as follows:-

25.2.2 Concept Design - Concept Design Validation is carried out in two stages, System Requirements Review (SRR) and Concept Design Review (CDR). The successful completion of both the SRR and the CDR results in a Concept Design Submission (CDS) being submitted by the Supplier, resulting in an Approval in Principle (AIP) issued by the Purchaser.

25.2.3 Detail Design– Detail Design is carried out in two stages, Intermediate Design Review (IDR) and Final Design Review (FDR). The successful completion of both the IDR and FDR results in a Compliance Submission being submitted by the Supplier, resulting in a Letter of no Objection (LONO) issued by the Purchaser.

25.2.4 Concept Design

The two stages of Concept Design Review are as follows:

25.2.5 System Requirements Review (SRR)

25.2.5.1 The purpose of the SRR is to confirm to the Purchasers' satisfaction the adequacy of the Supplier's efforts in translating the Technical Specification into a suite of design requirement documents and engineering plans.

25.2.6 Concept Design Review (CDR)

25.2.6.1 The purpose of the Concept Design Review stage is to confirm to the Purchasers' satisfaction that the developing concept design satisfies the system requirements and that the optimum engineering design option has been selected.

25.2.6.2 Following on from the successful completion of all outstanding actions raised during the CDR the Supplier shall submit a Concept Design Submission (CDS) in accordance with the LU standard 1-538, Assurance.

25.3 Detail Design

The two stages of Detail Design Review are as follows:

25.3.1 Intermediate Design Review (IDR)

25.3.1.1 The IDR shall be conducted to evaluate the initial design concepts developed to meet the requirements of the Technical Specification, together with the engineering processes and analysis that underpins them.

25.3.1.2 The purpose of the IDR is to confirm to the Purchasers' satisfaction that the detailed design aligns with the concept design and meets system requirements. This will include the identification of any changes necessary to the detailed design in advance of committing to absolutes.

25.3.2 Final Design Review (FDR)

25.3.2.1 The FDR shall be conducted to evaluate the design that has been developed. The purpose of the FDR is to provide the Purchaser with confidence that the detailed design will support delivery of the Purchasers intended business objectives.

25.3.2.2 The Supplier's submissions shall provide sufficient information to demonstrate to the Purchasers satisfaction that the proposed TCU will to meet the requirements of the contract, and that the TCU will be fit for purpose.

25.3.2.3 This will be achieved by proving that the design can be built, operated and maintained; that it is compliant with standards and that it has been produced by the approach set out in the appropriate safety and engineering cases and plans. The FDR shall also demonstrate that inter disciplinary co-ordination has been considered and the emerging discipline design solutions work together to deliver the system requirements.

25.3.2.4 Following on from the successful completion of all outstanding actions raised during the FDR the Supplier shall submit a Compliance Submission in accordance with the LU Standard 1-538, Assurance.

25.4 Validation Sequence and Validation Reviews

Validation Reviews shall be conducted to support the 'Acceptance' Stages of the project as defined in the Goods Information Section 3.1 Clause 3. For the avoidance of doubt 'Acceptance Stages' are as follows:

1) Acceptance

2) Acceptance for Service

3) Completion

The Validation Reviews shall be conducted in the following sequence:

- Preliminary Test Readiness Review (PTRR).
- Physical and Functional Configuration Audit Review (PFCAR).
- Test Readiness Review (TRR).
- Trial Operations Review (TOR).

25.4.1 Preliminary Test Readiness Review

25.4.1.1 The entry criterion for this review is a completed FDR as described in Clause 25.3.2for which all actions has been closed to the satisfaction of the Purchaser.

25.4.1.2 The PTRR enables the Factory Acceptance Tests (FAT) to be carried out at the Suppliers facilities. Successful completion of the FAT shall be followed by the PFCAR.

25.4.2 Physical and Functional Configuration Audit Review (PFCAR)

25.4.2.1 The entry criterion for this review is a completed FAT and the submission of the Physical and Functional Configuration Audits with all actions closed to the satisfaction of the Purchaser.

25.4.2.2 The PFCAR is a review of the pre-delivery documentation and activities to be carried out at the Suppliers facilities. The successful completion of the PFCAR supports Acceptance and Delivery as described in the Goods Information Section 3.1 Clause 3.

25.4.2.3 In addition to the above and prior to delivery the Supplier will support the Purchaser with the preparation of a Consent to Test (Depot) in accordance with LU Assurance Standard 1-538, in order that the commissioning of the TCU can commence on arrival and to enable the integration and functional testing of the TCU with the MPU in the depot.

25.4.3 Test Readiness Review

25.4.3.1 Before the TRR the Supplier shall deliver the TCU to site, commission the TCU, then assist the Purchaser in connecting the TCU to the MPU and with the integration of the vehicle to form the TCT.

25.4.3.2 The entry criterion for this review is a completed PFCAR and delivery of the TCU in accordance with the Goods Information Section 3.1 Clause 3, followed by TCU commissioning and it's integration with the MPU including testing.

25.4.3.3 The Test Readiness Review shall be held after the integration of the TCT and MPU. It shall ensure that all approvals and consents are in place to allow the dynamic Functional and Performance Testing (F&PT) to commence on the railway. The Supplier shall provide the required evidence to support progression to the F&PT stage of testing on the operational railway.

25.4.3.4 The Supplier shall support the Purchaser in the preparation of a Consent to Test (Railway) Submission. The Consent to Test (Railway) Submission shall specify the F&PT to be carried out on the Operational Railway as specified in LU Standard Assurance 1-538.

25.4.4 Trial Operations Review (TOR)

25.4.4.1 The entry criterion for the TOR is the completion of F&PT for which all actions have been closed to the satisfaction of the Purchaser, and the achievement of Acceptance for Service in accordance with the Goods Information Section 3.1 Clause 3.

25.4.4.2 The supplier shall support the Purchaser in the preparation of a Consent to Trial Operations Submission for the Trial Operation to be carried out as specified in LU Standard Assurance 1-538.

25.4.4.3 The conclusion of the TOR shall be a single gateway review minuted by the Purchaser such that the minutes, once agreed and issued to all parties, and all actions closed, will form the agreed platform for project progression into Trial Operations of the TCT following the route mapped out in the Consent to Trial Operations.

Appendix 1 – Reference documents

Number	Issue no.	Issue Date	Description
LU Cat 1 standards			
1-037	A1	Oct 2007	CAD data
1-085	A2	Dec 2008	Fire safety performance of materials
1-156	A4	Feb 2009	Gauging and Clearances requirements
1-166	A1	Oct 2007	Cleaning of track environment
1-180	A2	Feb 2008	Standard for Rolling Stock
1-187	A1	June 2008	Index of components for rolling stock
1-193	A2	Feb 2009	EMC with LU Signalling Systems Assets
1-217	A1	Oct 2007	Integration of Human Factors into Systems Development
1-218	A1	Oct 2007	Universal Human Computer Interaction
1-222	A1	Oct 2007	Electromagnetic Compatibility
1-521	3	Dec 2008	Safety decision making
1-526	3	Jun 2009	The assessment and management of health, safety and environmental risk
1-538	A4	Jun 2009	Assurance
G-182	A1	Oct 2007	Ergonomic considerations for the design and development of a rolling stock operator's cab
G-222	A1	Oct 2007	Manual of EMC best practice
LU Cat 2 standards			
E6161	A3	Aug 2000	Rolling Stock Railway Environment Applicable clauses are: 1.1 – 1.4, 2.2, 5, 6, 7, 8.1 – 8.4, 9.2, 10.1, 10.33(?), 10.32, 12
E6241	A2	Aug 2000	Rolling Stock coating systems
E6302	A2	Aug 2000	RS equipment security
E6482	A2	Aug 2000	Rolling stock multipole connectors
E6487	A2	Aug 2000	Crimped terminations for use on Rolling Stock
E6603	A2	Aug 2000	Rolling Stock maintenance documentation
E6741	A3	Aug 2000	Passenger RS semi-permanent couplers, drawbars & draftgear
E6742	A3	Aug 2000	Passenger rolling stock auto-couplers

Number	Issue no.	Issue Date	Description
E6831	A3	Oct 2000	Train Maintenance Regimes
E7053	A2	Nov 2000	Signalling requirements for the acceptance of Rolling Stock
E8404	A4	May 2007	Track geometry and condition standards
G6162	A2	Aug 2000	Cleaning materials for use on rolling stock - general
G6381	A2	Aug 2000	Rolling stock electrical supplies
RSE/STD/024 Pt 1 RSE/STD/024 Pt 5 RSE/STD/024 Pt 6	B B D	Sep 2000 Sep 2000 Sep 2000	Part 1 – Electrical Design Part 2 – Wiring Practice Part 6 – Cables for use on Rolling Stock
RSE-ST-00101	A2	June 2006	General requirements for traction equipment
RSE-ST-00102	A2	Nov 2006	Traction motors and line fed auxiliary machines
MR-M-17	A6	Jan 2006	CAD specification manual
S&CSE-ST 0062	A3	Mar 2008	Maximum allowable levels of electromagnetic interference in safety signalling equipment
BS / EN / ISO standards			
BS 60529			Ingress Protection
BS EN 50126			Systems Approach to Reliability, Maintainability, Availability and Safety (RAMS)
BS 6853: 1999			Code of practice for fire precautions in the design and construction of passenger carrying trains
BS5306			Code of practice for fire detection and alarm systems for buildings
BS5839 (BS ISO 14520)			Fire extinguishing installations
BS EN ISO 3381:2005			Railway applications – Acoustics – Measurement of Noise Inside Railbound Vehicles
BS 476 Parts 6 & 7			Fire performance
BS EN 286-3			steel pressure vessels for use on railway

Number	Issue no.	Issue Date	Description
			rolling stock
BS EN 50238			Railway applications – Compatibility between rolling stock and train detection systems
Other references			
Yellow Book 3	4		Engineering Safety Management Volumes 1 & 2 Fundamentals & Guidance
DD CEN TS 45545: 2009			Railway applications — Fire protection on railway vehicles. This Standard is in draft form, but should be used as a guide
Report			4-Rail – Analysis of dust sample from Victoria Line
Report			4-Rail – Combustibility of dust sample from Victoria Line
RT/E/C 50001			Methodology for demonstration of electrical compatibility between rolling stock and infrastructure
RT/E/C 50002– RT/E/C50017			Methodologies for demonstrating compliance with various types of Track Circuits
RT/E/C50018			Methodology for determination of interaction with neighbouring railways
UK EMC Regs SI 2006 / 3418			UK Electromagnetic Compatibility Regulations
LU Drawings			
83147	A		Relationships between auto couplers and end car buffers
45142	D		Arrangement of auto-coupler
46468 sheet 1 & 2	D		Arrangement of buffers
50364	A		Arrangement & details of auto-coupler carrier
50400 sheet 1		Sept 1973	Arrangement of under-frame UNDM car
50402 sheet 3		Sept 1973	Arrangement of under-frame UNDM car

Number	Issue no.	Issue Date	Description
50412		May 1972	Head stock details – auto end
50413	A		Arrangement of auto-coupler carrier
50414		April 1973	Longitude details – seat riser
50415		April 1973	Longitude details
50423		June 1972	Sector bar auto end – UNDM car

Appendix 2 – Definitions

Term	Definition
TCU	Tunnel Cleaning Unit
TCT	Tunnel Cleaning Train
MPU	Motive Power Unit
Train Operator	The TCT operator in the front cab of the train driving the train
Cleaning Operator	The TCT operator in the rear vehicle of the train operating the cleaning equipment
IPR	Intellectual Property Rights
IP	Ingress Protection
LT5	London Transport preferred wheel profile
EP	Electro-Pneumatic
SAPB	Spring Applied Parking Brake
HMI	Human Machine Interface
EMS	Equipment Management System
CCTV	Closed Circuit Television
LED	Light Emitting Diode
RAMS	Reliability Availability Maintainability Safety
MTBF	Mean Time Between Failures
EH	Engineering Hours
LRU	Line Replaceable Unit
HAZIDS / HAZOPS	Hazard Identification Study / Hazards and Operability Study
FMECA	Failure Modes Effects and Criticality Analysis
FTA / ETA	Fault Tree Analysis / Event Tree Analysis
CAD	Computer Aided Design
SRR	Systems Requirements Review
CDR	Concept Design Review
IDR	Intermediate Design Review
FDR	Final Design Review
PTRR	Preliminary Test Readiness Review
P&FCAR	Physical and Functional Configuration Audit Review
TRR	Test Readiness Review

TOR	Trial Operations Review
DM	Driving Motor
EMC	Electromagnetic Compatibility
WSF	Wrong Side Failure
LU	London Underground
DoC	Declaration of Conformity
UK	United Kingdom
MTBWSF	Mean Time Between Wrong Side Failures
CONNECT radio	LU universal radio system
MDBF	Mean Distance Between Failures
DLR	Docklands Light Railway
Deep Clean	Deep cleaning is defined as the initial cleaning of the Tunnels. The majority of the tunnels have not been cleaned for several years and it is therefore expected that the dust and waste collected will be much greater per kilometre than on subsequent cleaning cycles. It is envisaged that the deep cleaning will be undertaken at very slow speed and require multiple passes over a section of tunnel in order to achieve the standard of cleanliness required.
Routine clean	Routine Clean: Once the deep clean has been undertaken, a programme of regular cleaning, at intervals of nominally 12 months will be instigated. "Routine Cleaning" is defined as the cleaning undertaken on a tunnel which has been cleaned by the TCT within the previous 15 months. It is envisaged that routine cleaning will be undertaken at a slightly higher speed than that required for deep cleaning and will require fewer passes (ideally only one pass) over a section of tunnel in order to achieve the standard of cleanliness required.

Appendix 3 – Supporting Information

Motive Power Cars - 1972 TS Driving Motor Cars

LU will provide four Tube Stock motor cars, coupled in two pairs with one pair connected either side of the new tunnel cleaning unit. The physical, mechanical and electrical interfaces between the Tube Stock motor cars and the TCU to enable the basic train functionality are specified in this technical specification (e.g. travelling to/from site). This permits the following functionality:

- The Tube Stock motor cars can be upgraded or replaced as required by LU with other standard LU stocks
- Other LU stocks can recover the vehicles as needed
- The Tube Stock motor cars remain able to couple to each other and other LU vehicles at both ends if necessary
- The interface defined by LU will allow both Tube Stock motor units to co-act, with regards to signalling, traction and braking.

The motive power for the TCT will be provided by four 1972 TS DM cars. These will be coupled back to back in two pairs, with one pair at either end of the TCU. The outer car of each pair will provide a driving cab, the cleaning equipment operator control console and accommodation for up to 3 people. The inner car of each pair will need to be provided with an air compressor and main reservoir (to provide the compressed air for the existing train systems), two motor alternators and associated control equipment for provide the local Control Supply and battery charging.

The length of these vehicles is 16.1 metres; when coupled back to back there will be a small inter car gap; when coupled to the cleaning consist there will again need to be an inter vehicle gap.

As a guide the tare mass of each vehicle is 31 tonnes; however there will be a need to install a compressor, main reservoir, two motor alternators and associated control equipment on the inner car of each pair.

Each pair of DM cars will therefore be 62 tonnes, plus any additional equipment which has to be fitted. Allowing 1.2 tonne for the air compressor, reservoir, mounting frames, control equipment etc and 0.75 tonne for each motor alternator, control equipment and fuse box results in a 2 car mass of 65 tonnes as a guide. This mass will be further increased by the installation of the control and monitoring equipment for the tunnel cleaning equipment (which will be fitted in the outer car of each pair)

Each driving motor car is fitted with two pairs of 300 V DC traction motors wired in permanent series, one pair per bogie.

The existing axle loads are as follows

A axle	B axle	C axle	D axle
8.05 tonnes	8.01 tonnes	7.42 tonnes	7.42 tonnes

Each DM car is fitted with current collection shoegear on each bogie. Thus each pair of DM cars will have 4 bogies, each fitted with current collection shoegear. The existing shoegear is not compatible with use on the Central Line and will be replaced with new shoegear rated for TCT operation.

Appendix 4 – EMC Requirements

1.0 EMC SAFETY CASE DOCUMENTATION

An EMC safety case for the Slow Speed Traction Propulsion System, Tunnel Cleaning Equipment and Auxiliary Power Supplies are required.

Formation	Requirement
Cleaning formation and auxiliary power supply either diesel or 630 V and slow speed motive power for use during cleaning	Need only consider Engineering Hours operation. Compliance with BS EN 50121-3-1 and BS EN 50121-3-2 specifications and LU specifications, in particular the Wrong Side Failure requirements in S&CSE-ST0062, which specifies allowable levels. Since the signalling is not used to protect the train whilst cleaning it is only necessary to demonstrate that signalling is unaffected by conducted interference i.e. no damage or mal operation occurs. It will be necessary to demonstrate to neighbouring railways that inference does not interfere with their systems, this is particularly so where the 630 V is used as the power source since there are points of direct coupling and locations where tracks run in parallel where coupling could occur either through conducted, capacitive or inductive mechanisms.

1.1. Engineer Hours Operation

For cleaning operation the signalling is not used to protect the Tunnel Cleaning Train, therefore it is only necessary to demonstrate that the signalling and communications systems will not be damaged or malfunction by the operation of the Tunnel Cleaning Train in cleaning mode. To demonstrate this it will be necessary to comply with the Wrong Side Failure (WSF) conducted inference limits detailed in S&CSE ST0062 and the requirements of BS EN 50121 suite of specifications and the other specifications detailed latter in this document. This means that a full Safety Case need not be produced for LU signalling infrastructure since the fail safe operation of the signalling not necessary when cleaning is undertaken in Engineering Hours. Nevertheless it will be necessary to provide assurance that when the Tunnel Cleaning Train is operating the Supplier's equipment will not give rise to levels of EMI that causes the infrastructure equipment to be damaged or to malfunction. Assurance will also be required so that faults which may occur with the Suppliers equipment will not give rise to high levels of interference that would damage infrastructure equipment or cause it to malfunction. The level of rigour required for Normal and Fault this analysis will be agreed with the LU but will less than that normally required for a Full EMC Safety Case.

The Engineering Hours concept does not apply to other railways consequently it will be necessary to demonstrate that the operation of the cleaning equipment does not pose a hazard to those railways which are directly coupled to LU lines or which run in close proximity. In the first instance the approach shall be to try and establish that the train would not interfere with the track circuit if it was to run over it, i.e. that the coupling factor between the LU lines and the third party lines is 1. If this demonstration is not possible then the most sensitive location(s) shall be identified and the coupling factor deduced, this factor shall then be applied throughout for the type of track circuit being considered. To do this the vulnerable areas will need to be located, installed

equipment on those railways identified, coupling factors derived and allowable interference levels calculated: assistance will be provided by LU in identifying the most sensitive locations but calculation of the coupling factor(s) will be the responsibility of the supplier The Supplier should note that approval will need to be obtained by them from neighbouring railways and that they will require a Safety Case submission that takes account of fault conditions as described later in this document.

1.3 Safety Case

This safety case will be called the EMC Safety Case and will be produced by the Supplier.

The EMC Safety Case will demonstrate compliance with the relevant standards and safety requirements; it will contain necessary supporting technical documentation. It is necessary for the Supplier to provide the documentary evidence showing that those electrical, mechanical and operational considerations have been taken into account and considered and that all hazards are ALARP. The results/outputs of HazIDs, Hazops, fault trees, failure analysis, test plans, test results, calculations etc must be provided and referenced within the EMC Safety Case. The information supplied shall take the form of reports and be suitable for Safety Case purposes. The documents must be forwarded to LU for review as soon as they become available i.e. prior to completion and submission of the EMC Safety Case.

The Supplier is required to support LU in the submission of the EMC Safety Case to internal and external approval/review panels by making available documents etc and suitable resources, who may be required to attend safety review panels.

EMC Safety Case may be subject to independent assessment. The Supplier shall make information and personnel freely available for the independent assessment if required.

The Supplier shall demonstrate that all the EMC aspects have been considered and that use of the TCT will not increase the existing EMC risk to the railway. The Supplier shall also demonstrate that the equipment does not generate magnetic fields, radiated electro magnetic fields and conducted interference that could affect the correct operation of other equipment or be injurious to persons. All coupling mechanisms shall be considered e.g. inductive, capacitive, radiated and conducted. The following interfaces shall be considered. Consideration shall be given to failures that normally occur on the infrastructure and which could increase susceptibility.

- Signalling equipment on route
- Neighbouring Railways, including other London Underground lines
- Neighbours other than railways

The Supplier shall note that the present system supply voltage is a nominal 630V DC but that this will increase to a nominal 750V DC in accordance with BS EN 50163:2004.

2.0 SPECIFIC REQUIREMENTS

The route to achieving EMC compliance with both the LU environment and that of neighbouring parties, whilst meeting the requirements of the EMC Directive and the UK EMC Regulations is as follows.

The basic concept of EMC requirements is safe operation and demonstrable compliance with the appropriate legal and industry standards.

2.1. Principal Legal Requirements

All supplied electrical and electronic equipment shall comply with the EMC Directive 2004/108/EC (implemented by the UK Electromagnetic Compatibility Regulations 2006, SI 2006/3418).
The essential requirements of the EMC Directive state that equipment shall:

- Not cause electromagnetic interference under normal operating and failure conditions.
- Operate correctly, without degradation of performance or function in its intended electromagnetic environment, under normal operating and failure conditions.

2.2. LU Requirements

The Category 1 LU EMC standard, 1-222, defines EMC requirements for equipment to be installed within the London Underground environment to ensure that LU meets the requirements of the European EMC Directive, the corresponding UK Regulations and applicable railway standards. This is supported by a Manual of EMC Best Practice, G-222.

Standard 1-193 A1 defines the requirements for achieving EMC with LU signalling system assets, and also calls up S&CSE-ST0062-A3: Maximum allowable levels of electromagnetic interference in safety signalling equipment

Note: S&CSE-ST0062-A3 contains some textual errors and, which are as follows:

- Attachment 10.9 - Top table heading should read "Maximum amplitude at receiver input (maximum receiver sensitivity)"
- Attachment 10.10 - Bottom table, second column should read "Maximum amplitude in the current rail (maximum receiver sensitivity)"
- Attachment 10.12 - Bottom table. Units should be A, not mA.

Note

There are a number of systems on the LU network which are not addressed in S&CSE-ST0062-A3: the following levels should be used in corresponding assessments.

- The Jubilee Line SELTRAC system has a susceptibility limit of 1 mA at 36kHz and 56kHz.
- The Jubilee Line Platform Docking Loops operate at 84kHz.
- A TI 21 Version for which the compatibility requirements of RT/E/C 50008 shall be applied
- Axle counters for which the compatibility requirements of RT/E/C 5011 shall be applied
- The existing Victoria Line track circuit receiver has a susceptibility level of 308mA in the band 110Hz to 140Hz (The receiver is known as the Code Acceptance Unit - CAU).
- The Victoria Line track circuits will be replaced in a few years by FS2550 track circuits. The limits are as per the table below.

Maximum Permitted Levels of FSK Interference – WSF

Frequency range, f (Hz)	Traction rail current	Receiver Input Current (mA)	Minimum duration (mS)	Modulation (Hz)	Comments
< 200	10,000 A	N/A	N/A	N/A	
200 - 800	1,000 A	N/A	N/A	N/A	
800 - 2000	100 A	N/A	N/A	N/A	
2000 - 3580	10 A	N/A	N/A	N/A	
3580 - 6500	252 mA #	4	405	80	Near band
3810 - 3870 5730 - 5790	162 mA #	2.2	405	80	Proving tone alias
6500 - 9,000	3.0 A	N/A	N/A	N/A	
9000 - 100,000	10 A	N/A	N/A	N/A	

Measurement in a sample of 22.5 Hz with a Hanning window function

Maximum Permitted Levels of FSK Interference - RSF

Frequency range, f (Hz)	Traction rail current	Receiver Input Current (mA)	Minimum duration (mS)	Modulation (Hz)	Comments
< 200	10,000 A	N/A	N/A	N/A	
200 - 800	1,000 A	N/A	N/A	N/A	
800 - 2000	100 A	N/A	N/A	N/A	
2000 - 3580	10 A	N/A	N/A	N/A	
3580 - 6500	252 mA #	4	190	None required	Near band
3810 - 3870	162 mA #	2.2	190	None required	
5730 - 5790	162 mA #	2.2	190	None required	Proving tone alias
6500 - 9,000	3.0 A	N/A	N/A	N/A	
9000 - 100,000	10 A	N/A	N/A	N/A	

Measurement in a sample of 22.5 Hz with a Hanning window function

The LU EMC standards further stipulate that new or modified rolling stock be compliant with BS EN 50121-3-1: Railway applications, Electromagnetic compatibility, Rolling stock, Train and complete vehicle.

Equipment will need to be CE marked for the environment in which it is intended to operate. Documented evidence such as Declarations of Conformity (DoCs) will be required to demonstrate compliance.

Equipment must adhere to the requirement stipulated by the UK EMC Regulations that apparatus shall be constructed in such a way that it has an adequate level of immunity in its intended electromagnetic environment.

2.3. EMC Strategy

The Supplier must produce an EMC Strategy document, defining how they intend to achieve EMC. The Strategy document must be submitted to LU for review as part of the tender process.

The Supplier shall demonstrate that the neither the train (if part of the Contract) nor the cleaning equipments generates magnetic fields, RFI or conducted interference at a level that could affect the correct operation of existing equipment. Consideration shall be given to:

- Equipment on route, principally (though not exclusively) signalling assets.
- Interfaces with neighbouring railways (LU or other third parties)
- Neighbours other than railways
- Compatibility with other trains operating on the LU Network

All coupling mechanisms shall be considered e.g. conductive, inductive, capacitive, and radiated. Consideration shall be given to failures that normally occur on the infrastructure and which could increase susceptibility (see earlier sections for applicability).

The Strategy document must present a breakdown of activities to be undertaken in order to achieve EMC, and detail how the outputs of these activities will be compiled within the final EMC Technical Documentation. Further details on EMC testing requirements, EM Interfaces and risk assessment requirements are detailed below.

2.4. EMC Testing

Radiated emissions testing must be undertaken in accordance with BS EN 50121-3-1, ensuring that all auxiliary circuits are active; however the frequency range for the tests shall be extended below the 9 kHz stipulated in BS EN 50121-3-1 to enable the measurement of low frequency magnetic field emissions down to 10Hz.

Testing of the train mounted equipment shall be undertaken in accordance with EN50121-3-2.

Conducted emissions measurements shall also be undertaken to determine whether the train or the cleaning equipment will introduce any additional threat of EMI by this mechanism. The current drawn by the train and the cleaning equipment is to be measured over the frequency range from dc to a maximum frequency of 80 kHz.
The contributions of other parts of the railway system (e.g. substations, signalling) and of the external environment (e.g. power lines, industrial sites, radio and television transmitters) to the emissions measurements must be taken into account.

2.5. Compatibility with the Signalling Systems

Specification S&CSE-ST0062-A3 contains details of the operating frequency, modulation rates and defines the maximum current in the current rail, running rail or receiver; these levels relate to normal infrastructure conditions. The Supplier's attention is drawn to the fact that both common mode currents and differential mode interfering currents need to be considered.

The Supplier shall consider Wrong Side failure modes associated with the track circuits and the data transmission system and must demonstrate the Mean Time Between Wrong Side Failure (MTBWSF) is not less than 10^6 hours per train.

Compatibility with other non railway neighbours will be demonstrated by means of compliance with BS EN 50121-3-1. However to ensure compatibility with the CONNECT radio system, which have been deployed across the LU network, the BS EN 50121-3-1 emissions limits will be lowered by a further 10dB for radio operating frequencies including the CONNECT radio system.

Note: The MTBWSF target for a Full Train Safety Case is 10^9 hours. However given that the equipment is only to be used in engineering hours and that the train speeds are low when cleaning, a lower requirement of 10^6 hours has been allocated. Third party acceptance of boundary safety cases may demand the use of the higher 10^9 hours value.

2.6. Risk Assessment

The Supplier must ensure that all EMC aspects are considered as part of the overall Project Risk Assessment.

The Supplier shall conduct an EMC Hazard Identification in conjunction with LU experts from all relevant disciplines. A Hazard Log is to be produced, along with a list of actions, to be agreed by LU, which will lead to the Hazard Log entries being closed out.

During the Hazard Closeout process, compliance with LU safety targets or design standards will be demonstrated using quantitative methods where applicable. Where no quantitative targets or applicable standards exist, a qualitative assessment will be used to demonstrate that the risk is tolerable, for instance by using conventional schemes such as severity-frequency matrices.

The Supplier will produce Hazard Closeout documents which will demonstrate that all the EMC aspects have been considered and that the train and its equipment will not increase the existing EMC risk to the railway and its neighbours.

2.7. Responsibilities and Deliverables

The Supplier shall produce an EMC Strategy (as detailed above) and an EMC Control Plan
The Supplier will be responsible for:

- Performing a Hazard Identification (HazID).
- Performing conducted emissions, radiated emissions and magnetic field tests.
- Producing Hazard Closeout documents and supplying all relevant supporting documents e.g. test reports, fault tree analysis to demonstrate compliance with MTBF targets.
- Providing the necessary supporting documentation including maintenance documentation to support the safe operation of the trains.

The Supplier shall provide EMC Technical Documentation for input into the Safety Case, which will demonstrate compliance with the relevant standards and safety requirements. The results/outputs of HazIDs, Hazops, and fault tree and failure analysis must be collated within the Technical Documentation, along with Test Plans, Test Results and EMC DoCs. However, constituent documents must be forwarded to LU for review as soon as they become available i.e. prior to submission of the EMC Technical Documentation in its entirety.

The information supplied shall be suitable for Safety Case purposes and may be subject to independent assessment. The Supplier shall make information and personnel freely available for independent review if required.

With respect to establishing EMC, LU will:

- Provide the Supplier with a list of all relevant standards and supply copies of any documents not in the public domain
- Provide information on relevant infrastructure systems and boundaries in accordance with the requirements of section 1.1.
- Define Safety Requirements and Safety Targets as input to design. Where additional and possibly vulnerable infrastructure systems are suspected which are not covered by the above, LU will perform suitable assessment to identify these issues
- Provide technical information as input to the design, and to the Hazard Identification and Hazard Closeout processes.

2.8. EMC Control Plan

Once the EMC Strategy has been agreed, the Supplier must produce a detailed EMC Control Plan in accordance with the guidelines contained in G-222 describing the processes to achieve EMC. The Plan shall incorporate an assessment of the EM environment of the intended operating route, taking into account assets both on route and interfaces e.g. neighbouring LU lines, Network Rail lines. The nature and severity of any EMC issues anticipated or encountered, together with appropriate counter-measures, shall be included within the Plan.

Organisational responsibilities with respect to EMC shall be provided including the name and contact details for a single point of contact.

The Plan shall make adequate provision for undertaking and witnessing of any test programme required to demonstrate compliance.

The Plan shall take due account, where appropriate, of other asset replacement programmes, e.g. station refurbishments, signalling upgrades, and the consequences for maintaining EMC throughout their respective migration paths and on final deployment. It shall also identify measures to achieve EMC at interfaces with infrastructure owned or managed by other parties such as (but not limited to) Network Rail, DLR, public and rail industry power transmission and distribution networks.

The effects of failure modes, in relation to the train and the cleaning equipment and the operational infrastructure, with regard to EMC shall also be considered and mitigated appropriately.

Details of key milestones inclusive of target dates shall be presented.

2.9. Quality Control

The Supplier shall ensure that quality control is maintained throughout the project lifecycle, and shall take cognisance of the need to maintain documented records for the lifetime of the asset.

With respect to EMC, an audit trail must exist for all aspects of design, test and implementation. The Supplier shall employ a traceable document management system, and maintain configuration control of drawings, prototypes, equipments under test and embedded software (where applicable).

3.0 STANDARDS AND REFERENCE DOCUMENTS

Please note the documents cited below are additional to the relevant RSE/STD/024 series, but do not represent an exhaustive list; reference must be made to the latest revisions of the standards.

3.1. Regulatory

1. EU EMC Directive 2004/108/EC
2. UK Electromagnetic Compatibility Regulations, S.I. 2006/3418

3.2. Railway Euro norm (also invoked by EMC Standard 1-222, noted below)

3. BS EN 50121-1: 2006, Railway applications - Electromagnetic Compatibility, Part 1: General
4. BS EN 50121-2: 2006, Railway applications - Electromagnetic Compatibility, Part 2: Emission of the whole Railway to the outside world.
5. BS EN 50121-3-1: 2006, Railway applications - Electromagnetic Compatibility, Part 3-1: Rolling Stock - Train and complete vehicle.
6. BS EN 50121-3-2: 2006, Railway applications - Electromagnetic Compatibility, Part 3-2: Rolling Stock - Apparatus.
7. BS EN 50121-4: 2006, Railway applications - Electromagnetic Compatibility, Part 4: Standard for the Emission and Immunity of the Signalling and Telecommunications apparatus.
8. BS EN 50121-5: 2006, Railway applications Electromagnetic Compatibility, Part 5: Fixed power supply installations (and various EN 61000 documents cited therein).
9. BS EN 50238: Railway applications – Compatibility between rolling stock and train detection systems

3.3. LU Asset Modification and EMC Standards and related documents

10. 1-538 Assurance
11. 1-521 (formerly 2-05101-101) Safety Decision Making
12. 1-222 (formerly 2-01018-001, E1027) Standard – Electromagnetic Compatibility
13. G-222 (formerly 5-01018-001, M1027) EMC Manual of Good Practice

3.4. LU Signalling Systems Compatibility

14. E7053 Signalling requirements for the acceptance of Rolling Stock
15. 1-193 (formerly 2-01016-001) EMC with LU Signalling System Assets
16. S&CSE-ST0062 Maximum allowable levels of electromagnetic interference in safety signalling equipment

3.5. Network Rail

17. RT/E/C 50001Methodology for demonstration of electrical compatibility between rolling stock and infrastructure
18. RT/E/C50002 – RT/E/C50017 Methodologies for demonstrating compliance with various types of Track Circuits.
19. RT/E/C 50018 Methodology for determination of interaction with neighbouring railways

3.6. Human Field Exposure

20. EU Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)
21. NRPB Statement on Restrictions on Human Exposure to Static and Time Varying Electromagnetic Fields and Radiation, Volume 4 No 5 1993

Appendix 5 – Fire performance requirements of materials

London Underground fire performance requirements are defined in LU Standard 1-085 'Fire Safety Performance of Materials'. For rolling stock this Standard refers to BS 6853: 1999 'Code of practice for fire precautions in the design and construction of passenger carrying vehicles'. Although BS 6853 specifically refers to passenger carrying vehicles, LU Standard 1-085 covers the use of engineering trains (ref. paragraph 2.2). Hence, BS 6853 is also applicable to the Tunnel Cleaning Train. However Clause 6.8 in the main body of the Technical Specification allows equivalent or relevant European Standards such as prEN 45545 ; 2009 and DIN5510 to be substituted for BS 6853 and BS 476 subject to the conditions set out in Clause 14.2.
Also attached below is a table of required compliance against LU Fire Performance of Materials Standard 1-085.

The fire performance requirement is that materials should be assessed against three parameters:
1) Combustibility or flammability ref. BS 476 Parts 6 and 7,
2) Smoke emission (tests as outlined in BS 6853),
3) Toxic fume emission (tests as outlined in BS 6853).

The type of testing depends upon the type of configuration of the component e.g. horizontal surface or vertical surface. Testing to BS 476 also depends upon the nature of the components and is generally applicable to, for example, painted wall finishes. For certain components, referred to as non-listed items in the Standard, alternative tests such as temperature index or oxygen index are required.

The testing of materials may be carried out at any appropriate accredited test house e.g. Bodycote Warrington Fire (recently renamed as Exova) and BRE Global (Building Research Establishment). However, BS 6853 does allow for the small scale use of potentially non-compliant materials under a minor usage clause (ref. Section 6.1) in which 100 g or less of material (interiors) or 400 g or less of material (exteriors) is unclassified with respect to fire performance. The separation of materials needs to be taken into account in considering the grouping of materials. If there is a separation of 0.5 m for a horizontal prone or vertical surface and a separation of 0.2 m for a horizontal supine surface between any two minor usage materials, then they may be considered on an individual basis. If such a separation is not achieved, then their masses and areas should be added and they should be considered as a single material.

Many materials have previously been assessed and found compliant with LU Standard 1-085. Examples of compliant materials are given below:
1) Various paints system supplied by manufacturers such as 3M Scotchkote.
2) Composite materials such as Pheniclad, a UK manufactured polyester resin type composite.
3) Some adhesives e.g. anerobic which are deemed compliant on the basis of 'Minor Use'.

A materials advisory service is provided within London Underground by two qualified material technologists (Derek McGovern & Sam Sambasivan). Information can be

provided on which particular products are compliant. Advice can be given on how tests can be conducted.

Appendix 5 – Compliance table; commentary on 1-085 A2 applicability

All comments are in the context of the supply of the Tunnel Cleaning Unit unless specifically to support LU's responsibilities

Section of 1-085				Applicability
1				LU to apply a concession against the use of 1-085 unless otherwise clarified below
1.1				Use of appropriate international standards
1.2				Applicable
2.1				LU to apply a concession against the use of 1-085 unless otherwise clarified below
	2.1(a)			Use of appropriate international standards
	2.1(b)			Use of appropriate international standards
	2.1(c)			Use of appropriate international standards
2.2				
	2.2(a)			Not Applicable
	2.2(b)			LU to apply a concession against the use of 1-085
	2.2(c)			Not Applicable
	2.2(d)			Not Applicable
	2.2(e)			Not Applicable
2.3				Noted
2.4				Noted
3.1				
	3.1.1			Applicable
	3.1.2			Applicable
3.2	3.2.1			LU to apply a concession against the use of BS 6853
	3.2.2			Applicable
	3.2.3			
		3.2.3.1		Applicable
		3.2.3.2.		Applicable
	3.2.4	3.2.4.1		LU to apply a concession against the use of BS 6853
		3.2.4.2.		LU to apply a concession against the use of BS 6853
		3.2.4.3.		LU to apply a concession against the use of BS 6853
3.3				Not Applicable
3.4				Not Applicable
3.5				Applicable
4				Applicable as described
5.1				Not Applicable
5.2				Applicable as modified above.
6				Noted with the TCU Technical Specification in addition to the modification made above taking precedence.

Appendix 6 – Compliance table; commentary on 1-180 A2 applicability

All comments are in the context of the supply of the Tunnel Cleaning Unit unless specifically to support LU's responsibilities

Section of 1-180				Applicability
3.2.5				**Wheel rail interface**
3.2.5				Applicable
3.3				
3.3.1	3.3.1.1			Applicable
	3.3.1.2			Not Applicable
	3.3.1.3			Not Applicable
	3.3.1.4			Applicable, however 1-036 is not available E1140A2 should be used for guidance.
3.3.2	3.3.2.1			Not Applicable
	3.3.2.2			Not Applicable
3.3.3	3.3.3.1			Suppliers will comply with the training requirements specified in the General Specification to address these clauses
	3.3.3.2			Suppliers will comply with the training requirements specified in the General Specification to address these clauses
3.3.4	3.3.4.1			Applicable with the exception of item d)
	3.3.4.2			Applicable
	3.3.4.3			Applicable
	3.3.4.4			Applicable with the exception of item e) which the supplier will support LU in achieving compliance
	3.3.4.5			Not Applicable
	3.3.4.6			Not Applicable
	3.3.4.7			Not Applicable
	3.3.4.8			Applicable
	3.3.4.9			Not Applicable
	3.3.4.10			Not applicable however the supplier shall support LU in this requirement
	3.3.4.11			Applicable
	3.3.4.12			Applicable
3.3.5	3.3.5.1			Applicable with the exception of item h) which the supplier will support LU in its production
	3.3.5.2			Applicable
3.3.6	3.3.6.1			Applicable in the context of the supplied goods to support LU's overarching Tunnel Cleaning Train Maintenance Plan
		a		Applicable
		b)	I)	Table 3 to be modified to suit the supplier deliverable.
		b)	II)	Applicable
		b)	III)	Applicable
		b)	IV)	Applicable if appropriate
		b)	V)	Not Applicable
	3.3.6.2			Applicable

Section of 1-180				Applicability
	3.3.6.3			Applicable
	3.3.6.4			Applicable
	3.3.6.5			Not Applicable
3.3.7	3.3.7.1			Not Applicable
	3.3.7.2			Not Applicable
3.3.8	3.3.8.1			Applicable the supplier will support LU in providing the details so that MAC's of the TCU can be derived as part of the TCT MAC
	3.3.8.2			Applicable the supplier will support LU in providing the details so that MAC's of the TCU can be derived as part of the TCT MAC
	3.3.8.3			Applicable the supplier will support LU in providing the details so that MAC's of the TCU can be derived as part of the TCT MAC
3.3.9	3.3.9.1			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.2			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.3			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.4			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.5			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.6			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
	3.3.9.7			Not Applicable however the supplier will support LU's overarching TCT Maintenance Plan in terms of the supplied goods by the provision of details as appropriate
3.3.10	3.3.10.1			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.10.2			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.10.3			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable

Section of 1-180				Applicability
3.3.11	3.3.11.1			Applicable
	3.3.11.2			Applicable
3.3.12	3.3.12.1			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.12.2			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.12.3			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.12.4			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.12.5			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
	3.3.12.6			Not Applicable however the supplier will support LU in terms of compliance with these clauses with respect to the supplied goods by the provision of details as applicable
3.3.13	3.3.13.1			Applicable as adapted in clause 13.3.13.2
	3.3.13.2			Applicable note a modified Table 5 specific to the critical systems of the Tunnel Cleaning Unit is found as Table XXXX in Clause 22 of the Technical Specification
3.4				**Safety and Reliability**
3.4.1	3.4.1.1			Applicable. Note 1-506 should read 1-526
	3.4.1.2			Applicable
3.4.2	3.4.2.1			Applicable
	3.4.2.2			Applicable
	3.4.2.3			Applicable
	3.4.2.4			Applicable. In the Context of the Supplied goods.
	3.4.2.5			Applicable
	3.4.2.6			Applicable
	3.4.2.7			Applicable
3.4.3	3.4.3.1			Applicable
	3.4.3.2			Applicable
	3.4.3.3			Applicable
	3.4.3.4			Applicable
	3.4.3.5			Applicable
	3.4.3.6			Applicable
3.4.4	3.4.4.1			Applicable. Note 1-506 should read 1-526
	3.4.4.2			Applicable.
	3.4.4.3			Applicable In the Context of the Supplied goods.
	3.4.4.4			Applicable
	3.4.4.5			Applicable Note there shall be an appropriate independent reviewer covering the whole of the TCT

Section of 1-180				Applicability
				scope
	3.4.4.6			Applicable
	3.4.4.7			Applicable
3.4.5	3.4.5.1			Applicable with appropriate assessment to made in the Context of the supplied goods.
	3.4.5.2			Applicable with Hazards associated with appropriate Top Event Risks in accordance with the Context of the supplied goods
	3.4.5.3			Applicable with Hazards controls associated with appropriate Top Event Risks in accordance with the Context of the supplied goods
	3.4.5.4			Applicable and as Appropriate in accordance with the context of the supplied goods
	3.4.5.5			Applicable in accordance with Clause 18.1 of the technical specification
	3.4.5.6			Applicable, note a modified Table 5 specific to the critical systems of the Tunnel Cleaning Unit is found as Table XXXX in Clause 22 of the Technical Specification
	3.4.5.7			Applicable
	3.4.5.8			Applicable
3.4.6				The supplier will carry out the assessment of safety critical components as described in the context of the supplied goods in order to support LU in its role as the system Integrator
	3.4.6.1			Applicable
	3.4.6.2			Applicable
	3.4.6.3			Applicable
	3.4.6.4			Applicable
	3.4.6.5			Applicable
	3.4.6.6			Applicable
	3.4.6.7			Applicable
	3.4.6.8			Applicable
3.4.7	3.4.7.1			Applicable
	3.4.7.2			Applicable
	3.4.7.3			Applicable
3.4.8	3.4.8.1			Applicable
	3.4.8.2			Applicable
3.4.9	3.4.9.1			Applicable
	3.4.9.2			A more detailed description relevant to the duties of the supplied goods is included in Clause 18.???
	3.4.9.3			Applicable
	3.4.9.4			Applicable. Note appropriate assessment to be made in the Context of the supplied goods
	3.4.9.5			Applicable
	3.4.9.6			Applicable
	3.4.9.7			Applicable with appropriate actions to be made in the Context of the supplied goods
3.4.10	3.4.10.1			Applicable
	3.4.10.2			Applicable as appropriate to suit the context of the delivered good, Clause ??? Of the technical specification refers

Section of 1-180				Applicability
	3.4.10.3			Applicable
	3.4.10.4			Applicable
3.5				**Whole Life Documentation** All clauses are to be complied with in accordance with the context for the supply of the Tunnel Cleaning Unit and all TCT interfaces
3.5.1	3.5.1.1			Applicable
	3.5.1.2			Applicable
	3.5.1.3			Applicable
3.5.2	3.5.2.1	a		Applicable
		b		Applicable
		c		Applicable items I & V only
	3.5.2.2			Applicable
	3.5.2.3			Applicable
	3.5.2.4			Applicable
	3.5.2.5			Applicable, however 1-036 is not available E1140A2 should be used for guidance.
	3.5.2.6			Applicable the Supplier to support LU
3.5.3	3.5.3.1			Applicable
	3.5.3.2			Applicable
	3.5.3.3			Applicable
	3.5.3.4			Applicable the Supplier to support LU in maintaining up-to-date maintenance documentation
3.5.4	3.5.4.1			Applicable
	3.5.4.2			Applicable if as part of the supplied goods a Tunnel Cleaning Unit Training Simulator is provided
	3.5.4.3			Not Applicable
3.5.5	3.5.5.1			Applicable in the context as described in Clause 3.4 above
	3.5.5.2			Applicable in the context as described in Clause 3.4 above
	3.5.5.3			Applicable in the context as described in Clause 3.4 above
	3.5.5.4			Applicable in the context as described in Clause 3.4 above. Note 1-036 is not available E1140A2 should be used for guidance
	3.5.5.5			Applicable the supplier will support LU in providing the details so that MAC's of the TCU can be derived as part of the TCT MAC
3.8				**Services and supplies**
3.8				Applicable with the exception of clauses 3.8.7 and 3.8.9 only
3.10				Structures
3.10.1	3.10.1.1			Not applicable
	3.10.1.2			Not applicable
	3.10.1.3	a		Applicable
		b		The TCU should provide at least the same protection against jack-knifing and over-riding as the other vehicles in the TCT.
		c		The possibility of injury to operators shall be minimised in the event of a structural failure.
3.10.2	3.10.2.1	a		Applicable

Section of 1-180				Applicability
		b		Full load shall be taken as typical dust and refuse payload. Note that 'full load' is not subsequently used for structural calculations.
		c		Crush load shall be taken as maximum dust and refuse payload.
	3.10.2.2	a		Applicable
		b	I	Applicable
			II	Applicable
			III	Not applicable
		c		Not applicable
	3.10.2.3			Applicable
3.10.3				Applicable
3.10.4	3.10.4.1			Not applicable
	3.10.4.2	a		Not applicable
		b		Applicable
	3.10.4.3			Not applicable
	3.10.4.4			Not applicable
	3.10.4.5			Applicable
	3.10.4.6			Applicable
	3.10.4.7			Not applicable
	3.10.4.8			Not applicable
3.10.5				Applicable
3.10.6				Applicable. Note that fatigue load cases should be treated as single stress range equivalents of variable amplitude spectrums that contain some cycles above the non-propagating stress range.
3.10.7	3.10.7.1			Note that there are two complimentary requirements given in this sub-section. The requirement that 'the proof and fatigue loads given in 3.10.8 and 3.10.9 respectively […] shall not be used as the definitive design load cases' remains applicable. The requirement that those proof and fatigue loads are the minimum loads shall be interpreted as 'The proof and fatigue load cases given in 3.10.8 and 3.10.9 represent the minimum number of load cases' that define the load environment. The loads themselves may be factored to account for the reduced distance the TCU will travel over its design life.
	3.10.7.2			Applicable
	3.10.7.3			BS EN 12663 load cases are split into categories that presume certain vehicle characteristics such as suspension type. It is therefore appropriate to categorise the vehicle when the determining attributes have been specified.
3.10.8	3.10.8.1			Applicable
	3.10.8.2			Applicable
	3.10.8.3			Applicable
	3.10.8.4			Applicable
	3.10.8.5			The car body shall support the weight of the heaviest TCU bogie when reacted at the trailing end secondary suspension point and the leading end headstock position.
3.10.9				Where compliance to alternative car body fatigue

Section of 1-180				Applicability
				load cases has already been demonstrated, it may be sufficient to demonstrate equivalence between those and the following load cases with agreement from the Project Engineer.
	3.10.9.1			Applicable
	3.10.9.2			Applicable
	3.10.9.3	a		This load case may be factored by taking 13% of the stated number of cycles. The loading condition of '20% of crush load' shall be used instead of 'all seated passengers'. It should be noted that the load case assumes a suspension system that achieves compliance with section 3.10.31 'Ride Comfort' of standard 1-180. In the event that this is not achieved, the car body load cases shall be accordingly factored to account for the increased vibration transmission through the secondary suspension.
		b		This load case may be factored by taking 13% of the stated number of cycles. It should be noted that the load case assumes a suspension system that achieves compliance with section 3.10.31 'Ride Comfort' of standard 1-180. In the event that this is not achieved, the car body load cases shall be accordingly factored to account for the increased vibration transmission through the secondary suspension.
		c		This load case may be factored by taking 13% of the stated number of cycles. The loading condition of '20% of crush load' shall be used instead of 'all seated passengers'. It should be noted that the load case assumes a suspension system that achieves compliance with section 3.10.31 'Ride Comfort' of standard 1-180. In the event that this is not achieved, the car body load cases shall be accordingly factored to account for the increased vibration transmission through the secondary suspension.
		d		This load case shall be replaced by an equivalent payload loading/unloading scenario based on the operational requirements of the TCU.
		e		Applicable
3.10.10				Applicable
3.10.11	3.10.11.1			Not Applicable
	3.10.11.2			Applicable
	3.10.11.3			Scenarios to be considered shall be rough couple during re-form of the TCT, rough couple of the TCT with another LUL train, collision of the TCT with another LUL train, and collision into a buffer stop. The position of the TCU within the train shall be taken into account.
	3.10.11.4			Applicable
	3.10.11.5			Applicable
	3.10.11.6			Not applicable
3.10.12				The TCU shall provide, as a minimum, the same level of protection as the other vehicles in the TCT.
3.10.13				Applicable

Section of 1-180				Applicability
3.10.14				Not applicable
3.10.15				Not applicable
3.10.16				In the event that handgrips or grab poles are provided for operator access, they shall comply with the stated load cases.
3.10.17				Not applicable
3.10.18				Not applicable
3.10.19	3.10.19.1			Applicable
	3.10.19.2			Applicable
	3.10.19.3	a		Note that there are two complimentary requirements given in this sub-section. The requirement that 'the proof and fatigue loads given in 3.10.20 and 3.10.21 […] shall not be used as the definitive design load cases' remains applicable. The requirement that those proof and fatigue loads are the minimum loads shall be interpreted as 'The proof and fatigue load cases given in 3.10.20 and 3.10.21 represent the minimum number of load cases' that define the load environment. The loads themselves may be factored to account for the reduced distance the TCU will travel over its design life.
		b		Applicable
	3.10.19.4			Applicable
3.10.20	3.10.20.1			Applicable. Crush laden mass shall be derived in accordance with 3.10.2.2 a) I) and 3.10.2.1 c) subject to the interpretation provided above.
	3.10.20.2	a		Applicable
		b		Applicable
		c		Applicable
		d		Applicable
		e		Applicable
		f		Not applicable
		g		Applicable
		h		Applicable
		j		Applicable – half the crush laden mass shall be applied
		k		Applicable
3.10.21	3.10.21.1			Applicable
	3.10.21.2	a		Applicable. Crush laden mass shall be derived in accordance with 3.10.2.2 a) I) and 3.10.2.1 c) subject to the interpretation provided above. This load case may be factored by taking 13% of the stated number of cycles.
		b		Applicable. Crush laden mass shall be derived in accordance with 3.10.2.2 a) I) and 3.10.2.1 c) subject to the interpretation provided above. This load case may be factored by taking 13% of the stated number of cycles.
		c		Applicable. The load case shall be applied for the equivalent of 700000 km.
		d		Applicable. The load case shall be applied for the equivalent of 700000 km.
		e		This load case shall be replaced by an equivalent

Section of 1-180				Applicability
				payload loading/unloading scenario based on the operational requirements of the TCU.
		f		Applicable. Deceleration rate shall be 1.15m/s^2 The total number of cycles shall be reduced to 390000.
		g		Not applicable.
		h		This load case may be factored by taking 13% of the stated number of cycles.
		j		This load case may be factored by taking 13% of the stated number of cycles.
		k		Applicable
3.10.22				Not applicable
3.10.23				Applicable
3.10.24				Not applicable
3.10.25	3.10.25.1			Not applicable
	3.10.25.2	a		Applicable
		b		Applicable
		c		Not applicable
		d		Applicable
3.10.26				Applicable
3.10.27				Not applicable (unless air suspension is fitted)
3.10.28				Applicable
3.10.29				Applicable
3.10.30				Applicable
3.10.31				Not applicable
3.10.32				Applicable
3.10.33				Applicable
3.10.34				Applicable although Section 6.1 of BS EN 12663:2000 *Structural requirements of railway vehicle bodies* and section 9.2.1 of BS EN 13749:2005 *Methods of specifying structural requirements of bogie frames* may be considered when deciding the extent of any new test schedule.

Appendix 7 – Extracts from 1-180 A2

1-180 3.4.5.6

Failures for systems, functions or components in Table 1 below shall be classified accordingly.

System, function or component	Classification	Requirement
Wheelset integrity	Vital	Subject to approved axle non-destructive test programme.
Wheelset electrical conductivity	Vital	Per-Car track shunting resistance not to exceed maximum permissible value, refer to section 3.2.5.2.
Axle rotation	Vital	Not to lock under failure of bearings, gears or motor.
Structural integrity of car body and bogie	Vital	Subject to approved non-destructive test programme Excludes damage due to derailment or collision, within specified crashworthiness criteria Excludes damage due to incorrect lifting or jacking.
Emergency brake	Vital	Includes failure to respond to trainstop, Operator vigilance device, emergency brake control, loss of ATP permission, loss of train continuity (however caused) and inhibition of traction by emergency brake application.
Evacuation system???	Vital	Not to suffer any blockage, subject to regular deployment testing of permanently installed evacuation aids.
Under frame equipment security	Vital	See Section 3.10.5. Excludes collector shoes. Excludes other small components where shown not to present a significant hazard if detached.
Train mobility	Vital	Train unable to move, even with assisting train, as a result of a single failure.
Doors closed interlocks	Vital	Not to give false 'closed' signal.
Brake release	High Integrity	Ability to release both service and emergency brakes from cab (after resetting initiation condition(s) in the case of emergency brake application).
Service brake	High Integrity	Including hard wired control circuitry.
Traction	High Integrity	Ability of train to move unassisted. Includes hard wired control circuitry.
Vehicle coupling	High Integrity	Includes Auto-coupler uncouple control.
Control Supply	High Integrity	Loss of supply to other High Integrity users.
Compressed air supply	High Integrity	Total supply loss (whole train).
Head, tail and calling-on lights	High Integrity	Excluding filament bulbs.
State selection	High Integrity	Sets and maintains correct train state including inter-cab interlocking functions.

Table 1 - Classification of Vital and High Integrity functions

Appendix 8 – Table 2 Design Assurance Submissions

ID	Submission	Description
SRR	**System Requirements Review**	*This review shall be conducted to evaluate the initial design concepts developed to meet the requirements of the Technical Specification, together with the engineering processes and analysis that underpins them.*
SRR1	Engineering plan	The Engineering Plan form the basis for all review submissions and shall include: • Specifications - A list of the specifications to be produced for the procurement of sub-contract equipment. • Plans - A list of Plans to be prepared included in SRR • Design Schedule - A Design Schedule that lists the drawings to be produced. • Weight Schedule - Detailing the weight control programme. • Calculations - A list of calculations to be carried out. • Software - A list of software to be produced. • Design Reviews - A list of both the internal and customer focussed design reviews to be carried out. • Test Schedule - A list of the tests to be undertaken as defined in Goods Information Section 3.1, Clause 2. • Submittals - A list of all information required to be prepared and provided to the Company shall be made. • Configurable Items List (CIL) - A list of equipment e.g. LRU etc, which is traceable during all stages of manufacture and for which its modification status shall be maintained. This list will become the New Asset List CDR16
SRR2	Product specification	The product specification shall be a specification that describes the technical solution in terms of the initial design concepts and describing how they meet the relevant clauses of this Technical Specification. It shall contain the criteria by which the solution can be judged to be compliant and acceptable for service operation. The product specification shall define the scope of supply which shall list all the major items of equipment that make up the product and indicate the organisation supplying the equipment. The scope of supply should be expanded to include all components such that it can be developed into a parts list during the design phase. The scope of supply will form the basis for the Configurable Items List and the Weight Schedule.
SRR3	Systems Engineering Management Plan	The Systems Engineering Management Plan (SEMP) identifies the system engineering processes, controls and programme of work for the project and how these aspects will be managed. The SEMP shall ensure that an auditable process is followed to manage the design and application of the whole system as distinct from the individual parts or sub-systems and to reduce the risk that arises from the integration of systems. The SEMP shall include the following six elements SRR4 –SRR9
SRR4	Interface Management	The Interface Management Plan (IMP) shall describe how the operational and technical interfaces

	Plan	identified will be managed and controlled and define how: • Interface requirements will be identified, • Interface risks will be resolved, controlled or mitigated.
SRR5	Configuration Management Plan	The configuration management plan shall expand on the configuration list in the engineering plan. Configuration Management Plan (CMP) shall track Technical and Operational Requirements changes, and assess the impact of the changes, against configuration baselines through each phase of the project lifecycle. It shall ensure that the whole life maintenance information is tracked and maintained ready for handover. The content of the CMP can be subsumed within the SEMP.
SRR6	RAM Plan	The RAM Plan shall define the RAM activities required and how those activities will be managed throughout the project lifecycle, to ensure that the project is capable of meeting the RAM requirements Clauses 18, 19 and 21 of the Goods information Technical Specification Section 3.2 refer The content of the RAM Plan can be subsumed within the SEMP;
SRR7	EMC Control Plan	EMC Control Plan .....has the meaning as specified in Section 3.2 Appendix 4 Clause 2.8 of th The content of the EMC Plan can be subsumed within the SEMP
SRR8	Human Factors Integration Plan	Human Factors Integration Plan (HFIP) shall demonstrate that human factors have been taken into consideration and confirm the activities to be undertaken to ensure compliance with standards and integration, (LUL Category 1 Standard 1-217 'Integration of Human Factors into Systems Development'. The content of the HFIP can be subsumed within the SEMP.
SRR9	Requirements Management Plan	shall define the requirements management activities, document the requirements and control changes to the requirements. The content of this Plan can be subsumed within the SEMP
SRR10	Operational Readiness Plan	Operational Readiness Plan shall plan the actions required to demonstrate that new or modified assets are ready to be brought into operational use.
SRR11	Production Plan	The production plan shall provide evidence that the items listed below have been considered. For SRR, the production plan shall demonstrate that basic manufacturing considerations have been made and that production engineering is incorporated throughout the design. • Production planning • Facilities allocation • Incorporation of producibility-orientated changes • Identification and fabrication of tools/equipment • Procurement of long lead items • Routine testing
SRR12	Verification and Validation Plan	Verification & Validation Plan (V&VP) shall ensure that assets or systems are fit for service and meets the requirements by: • Demonstrating that the deliverables for each stage of the project meets the system requirements of that stage (Verification);

		• Demonstrating that the system at any step of its development and after its installation meets the user requirement (Validation); • Collection of the evidence via the production of a Verification & Validation Report The content of the V&VP can be subsumed within the SEMP;
SRR13	PEP	Shall act as the central reference document for managing the project which aligns the various plans and describes the approach to be adopted to satisfy the requirements
SRR14	PAP	Shall detail the assurance strategy, based on the technical, safety and operational risks ensuring that safety and performance will be maintained on the railway as a result of the change or changes brought about by the project – both in terms of the final delivery and during the build phase. It shall also describe the risk based assurance framework for all engineering activities (temporary, permanent or enabling works) to be undertaken by a project and the timescales associated with them;
SRR15	Risk Management Strategy / Plan	is a strategy/plan to develop a programme level Risk Management Strategy/Plan to manage risks on the programme and to the wider organisation.
SRR16	Risk Register	risk register is where all relevant information relating to identified risks on the project is recorded (Section 1 - Forms of Tender Appendix 1.9);
SRR17	Inspection & Testing Strategy/Plan	shall define the activities, arrangements and management that must be put in place for a successful inspection and testing programme that will confirm that the product(s), component(s), asset(s) or system(s) perform as designed and as planned as described in Section 3.1 Clause 2 of the Goods Information;
CDR	**Concept Design Review**	*This review shall be conducted to evaluate the detailed concepts developed to meet the requirements of this Technical Specification. The Supplier's submissions shall provide sufficient information to demonstrate that the proposed TCU is likely to meet the requirements of the Technical Specification, and that it will be fit for purpose.*
CDR1	Conceptual Design Statement	Conceptual Design Statement (CDS) defines the starting point for a design and to demonstrate how the design will satisfy project requirements, (LUL Category 1 Standard 1-538 Assurance, section 3.16 refers).
CDR2	Concept drawings / models & schematics	Drawings and/or models shall provide sufficient detail to enable the concept designs to be understood and to support the Conceptual Design Statement. They shall cover all aspects of the design.
CDR3	Weight Schedule	Updated from the SRR Engineering Plan / Product Specification
CDR4	Scoping calculations	Scoping calculations shall support the Conceptual Design Statement and shall cover all aspects of the design including: cleaning performance, structural, dynamic, braking, traction, electrical power requirements.
CDR5	Agreed Interface Definition Document	Agreed Interface Definition Document (AIDD) shall describe the design implementation and testing decisions that ensure both sides of an interface agree the technical and operational interfaces;
CDR6	Configuration Control Document	Updating and developing the Configuration Management Plan. The content of the CMP Plan can be subsumed within the SEMP;

CDR7	Updated RAMS Plan	Reliability, Availability & Maintainability shall each be developed updated further for this design stage in the RAM Plan Clauses 18, 19 and 20 of the Goods information Technical Specification Section 3.2 refer. The content of the RAM Plan can be subsumed within the SEMP;
CDR8	Engineering Safety Management Plan	Shall define the strategy and processes to be used by the project team and shall explain the safety roles, responsibilities and by when engineering safety management activities must be completed; Clause 22 of the Goods information Technical Specification Section 3.2 refers.
CDR9	EMC Technical File (1st draft)	Is the collation of appropriate documentation that shall be evidenced to show that the project has satisfied the EMC requirements;
CDR10	Initial HF Study	Developed from the HFIP this includes the following : • Operating Principles including Day In The Life the TCU • Control Unit Mock-up review report to accompany the mock-up
CDR11	Human Factors Task Analysis	Human Factors Task Analysis shall document an agreed baseline analysis of existing operational and maintenance tasks to determine the effects the project will have on future operational and maintenance tasks as described in the Operational Concept. This will be used in the Training Needs Analysis, workload analysis and other deliverables stated in the Human Factors Integration Plan (HFIP).
CDR12	Updated Verification and Validation Plan	Updated of SRR12 Verification and Validation Plan including a Technical Compliance Matrix
CDR13	Inspection & Testing Strategy/Plan	Shall be updated to include or develop further the • Sub-system FAT Schedule; • TCU FAT Schedule; • Commissioning Type Test Schedule; • Trial Operations Test Schedule • EMC Test Plan
CDR14	Asset Commissioning and Handover Plan (ACHP)	Shall outline the people; roles; processes; information; deliverables and timescales which are required for the handover of the new or altered assets from the project to delivery into service.
CDR15	The Interface Requirements Specification (IRS)	Shall ensure that all interfaces identified in the Interface Management Plan are collated, rationalised, apportioned and communicated to provide the basis for the control and management of all interfaces as follows: • Definition of the interface between two or more sub-systems; Information necessary for all parties to initiate work packages to develop the interfaces.
CDR16	New Asset List	the asset listing shall be updated and finalise at project completion to enable the LU Asset Data Management Function (ADMF) team to register the asset data into the Ellipse asset register and builds on the list that includes Line Replaceable Units captured on SRR1
CDR17	Engineering Safety Hazard Log	shall record, manage and support the analysis of identified hazards

IDR	**Intermediate Design Review**	*This review shall be conducted to evaluate the detailed design developed to meet the requirements of the Technical Specification. The Supplier's submissions shall provide sufficient information to demonstrate that the proposed TCU will meet the requirements of this Technical Specification and that it will be fit for purpose.*
IDR1	Detail Drawings and Schematics	These follow on from CDR2, 3 & 4 and are updates, developments or new Design Drawings & Calculations needed to support the design that fulfils the System Requirement Specification (SRS) at the IDR stage for the project
IDR2	Updated Weight Schedule	
IDR3	Carbody structural analysis report	
IDR4	Bogie structural analysis report	
IDR5	Dynamic analysis report	
IDR6	Braking calculations	
IDR7	Traction calculations	
IDR8	Updated Agreed Interface Definition Documents	Update of CDR5
IDR9	Updated configuration control document	Update of CDR6 to keep up with the progress of the developing design
IDR10	RAM Report	Update of CDR7 with detailed Reliability, Availability and Maintainability reports against the progress of the developing design
IDR11	Human factors Report	Update of CDR10 to report the progress of the developing design
IDR12	Training Needs Analysis	Training Needs Analysis shall identify where there are skills, knowledge and attribute gaps between existing roles and the new roles that will be introduced to the current job holders as a result of the project; which is part of human factors design for the system. Training requirements are as described in Section 3.1 Clause 1 of the Goods Information; It shall include outputs from CDR11
IDR13	Physical Configuration Audit Specification	The Physical Build Audit Specification shall describe the terms of engagement for the Physical Configuration Audit. *The Physical Configuration Audit will consist of a technical examination of the Supplier's developed hardware/ software to verify that the hardware/ software 'as built' conforms to the technical documentation that defines it*
IDR14	Functional Configuration Audit Specification	Functional Build Audit Specification shall describe the terms of engagement for the Functional Configuration Audit. *The Functional Configuration audit is to validate that the development of the Supplier's hardware complies with the Technical Specification and that all previous testing has been completed successfully and is fully documented.*
IDR15	Sub-system FAT specification	The sub-system Factory Acceptance Tests shall Include but not be limited to: • Cleaning Module Test Specification;

		• Carbody static test specification; • Bogie static test specification; • Bogie accelerated life test specification; • Suspension component test specification; • Traction component test specification; • Build (Electrical) test specification; • EMC Test Specification
IDR16	Obsolescence Mitigation Plan	is used to minimise the costs of obsolescence and achieve the optimal sustainability of performance, maintainability and safety throughout the whole-life of the asset or assets: To clearly identify the roles and responsibilities of those who are involved in the maintenance of the asset(s) as specified in Section 3.2 Clause 20 of the Goods Information;
IDR17	Vehicle Log Book Specification	the structure and content of the vehicle log book is required at this stage. the Vehicle Log Book is where the detailed compliance, build and test record of the TCU provided in support of the TCU sale in order to comply with the Acceptance Clauses specified in Section 3.1 Clause 3.7.4 of the Goods Information;
IDR18	Engineering Safety Report	The output of the works included with the Engineering Safety Management Plan for the IDR Stage
IDR 19	EMC Technical File	Update of CDR 9
IDR20	Training Plan	Training Plan shall describe the detailed aspects of the training delivery for the project in accordance with the training requirements described in Section 3.1 Clause 1 of the Goods Information; this follows the TNA at IDR
IDR21	Updated Verification and Validation Plan	Update of CDR12
FDR	**Final Design Review**	***This review shall be conducted to evaluate the final detailed design developed to meet the requirements of the Technical Specification. The Supplier's submissions shall provide sufficient information to demonstrate that the proposed TCU will meet the requirements of this Technical Specification and that it will be fit for purpose.***
FDR1	Compliance Statement	Compliance Submission / Declaration shall be submitted to declare that the design is complete, meets the technical, safety and operational requirements and complies with the required standards. (LUL Category 1 Standard 1-538 Assurance, section 3.18)
FDR2	Production drawing pack	These follow on from IDR1, 2, 3, 4, 5, 6 & 7 and are updates, developments or new Design Drawings & Calculations needed to support the design that fulfils the System Requirement Specification (SRS) at the FDR stage for the project
FDR3	Finalised weight schedule	
FDR4	Electrical (power requirements) confirmed	
FDR5	Finalised Agreed Interface Definition Documents	Update of IDR8

FDR6	Updated configuration control document	Update of IDR9 to keep up with the progress of the developing design
FDR7	RAM report	Update of IDR10 including detailed Reliability, Availability and Maintainability reports against the progress of the developing design
FDR8	Engineering Safety Report	Update of IDR20
FDR9	Maintenance Manual	is defined as all necessary documentation, periodicity and maintenance requirements that the project needs to deliver; to ensure that maintainers are able to correctly and safely maintain the new or modified asset(s) and those assets remain serviceable and are safe to operate throughout their life.
FDR10	EMC Technical file (compliance draft)	Update of IDR 21
FDR11	Training Plan	update of IDR20
FDR12	Operations manual	is defined as all necessary documentation and operator requirements that the project needs to deliver: to ensure that operators are able to correctly and safely operate those new or modified asset(s).
FDR13	Training Materials	Training Materials are the materials provided in order that the trainers can effectively train all the end users or personnel that require training as described in Section 3.1 Clause 1 of the Goods Information;
FDR14	System FAT Specifications	The system Factory Acceptance Tests shall Include but not be limited to: • Cleaning system test specification; • Traction system test specification; • Brake system test specification; • Wheel unloading test specification; • X factor test specification; • Sway test specification; • Bogie slew test specification; • Coupling slew test specification; • Build control static test specification; • EMC Test Specification
FDR15	Updated Verification and Validation Plan	Update of IDR21
PTRR	**Preliminary Test Readiness Review**	***This review shall be conducted to evaluate the as built condition and function of the TCU sub-systems to give confidence that the TCU will meet all physical and functional requirements in the Technical Specification.***

PTRR1	As built drawings	shall record the „as built version of an asset after all testing, commissioning and snagging is complete as specified in Section 3.2 Clause 24.2 of the Goods Information;
PTRR2	Carbody static test comparison report	shall detail the results of tests carried out to verify, or otherwise, that the works are compliant with standards and meet the project requirements
PTRR3	Bogie static test comparison report	shall detail the results of tests carried out to verify, or otherwise, that the works are compliant with standards and meet the project requirements
PTRR4	Updated configuration control document	Update of FDR6
PTRR5	Sub-system FAT reports	shall detail the results of tests carried out to verify, or otherwise, that the works are compliant with standards and meet the project requirements for the following: • Cleaning Module Test report; • Carbody static test report; • Bogie static test report; • Bogie accelerated life test report; • Suspension component test report; • Traction component test report; • Build (Electrical) test report;
PTTR6	V&V Report	Update of FDR15 and confirmation that all of the requirements to be validated at this stage. have been verified
PFCAR	**Physical and Functional Configuration Audit Review**	***This review shall be conducted to evaluate the as built condition and function of the TCU to establish that it meets all physical and functional requirements in the Technical Specification and establish that the TCU can be accepted as fit for delivery to LU and fit to undergo depot testing.***
PFCAR1	Functional configuration audit report	Detailed report of the Functional Configuration of the TCU specified in IDR 14
PFCAR 2	Vehicle Log book	The Vehicle Log Book is to be populated and is where the detailed compliance, build and test record of the TCU provided in support of the TCU sale in order to comply with the Acceptance Clauses specified in Section 3.1 Clause 3.7.4 of the Goods Information;
PFCAR 3	Physical configuration audit report	Detailed report of the Physical Configuration of the TCU specified in IDR 13
PFCAR 4	Weight report	Confirmation and validation of FDR3
PFCAR 5	Dynamic comparison report	A report giving detailed comparison between track test results and test results / analysis.
PFCAR 6	Training log	Training Log has the meaning as specified in Section 3.1 Clause 1 of the Goods Information;

PFCAR 7	Systems FAT reports	Shall detail the results of tests carried out to verify, or otherwise, that the works are compliant with standards and meet the project requirements Including: • Cleaning system test report; • Traction system test report; • Brake system test report; • Wheel unloading test report; • X factor test report; • Sway test report; • Bogie slew test report; • Coupling slew test report; • Build control static test report; • EMC Test Report
PFCAR 8	As Built Drawings	Update of PTTR 1
PFCAR 9	Test Certificate.....	Shall provide a serviceability record, with applicable information and details of a product component, asset or system after a successful test.
PFCAR 10	V&V Report	Update of PTTR6 and confirmation that all of the requirements to be validated at this stage have been verified
PFCAR 11	Asset Commissioning & Handover Log (ACHL)	Is the comprehensive reference log containing all documentation required by LU (Asset Performance) to accept the new and altered assets into maintenance and operational service;
PFCAR 12	Method Statement	Shall describe the safe method of working by which specific construction (and other) works will be undertaken. Delivery and testing shall require method statements which shall include the following; personnel and responsibilities, access, facilities and equipment availability
PFCAR 13	TCU Commissioning Test Specification	Is the test specification that defines the scope of the reformation and commissioning tests to be carried out On-site.
PFCAR 14	Integration Test Specification	The Supplier shall assist the purchaser in the production of the Integration Test specification. The Integration test Specification defines the scope of the TCU and MPU tests to be carried out On-site.
PFCAR 15	Functional and Performance (F&P) Test Specification	The Supplier shall assist the purchaser in the production of the F&P Test specification. The F&P test Specification defines the scope of the TCT type tests to be carried out On-site.
TRR	**Test Readiness Review**	***This review shall be conducted to evaluate the results of static and depot based testing to establish that the TCU / TCT is fit to undertake dynamic testing on the operational railway.***
TRR1	Updated Log book	Update of PFCAR2

TRR2	Updated Training log	Update of PFCAR6
TRR3	Test Report	Arising from: Commissioning Type Test specification
TRR4	EMC Safety Case	has the meaning as specified in Section 3.2 Appendix 4 Clause 2.8 of the Goods Information;
TRR5	V&V Report	Update of PFCAR10 and confirmation that all of the requirements to be validated at this stage. have been verified
TOR	**Trial Operations Review**	***This review shall be conducted to evaluate the results of dynamic testing on the operational railway to establish that the TCU / TCT is fit to undertake trial operations on the operational railway.***
TOR1	Updated Log book	Update of TRR1
TOR2	Car body track test comparison report	A report giving detailed comparison carbody track test results with carbody static test result and finite element analysis.
TOR3	Bogie track test comparison report	A report giving detailed comparison bogie track test results with bogie static test result and finite element analysis.
TOR4	Maintenance demonstration specification	Specifies the validation criteria to be demonstrated during the trial operation phase which will culminate in a Maintenance Demonstration Report.
TOR5	EMC Safety Case	Update of TRR4
TOR6	Finalised Training Materials	Update of FDR13
TOR7	Finalised Training Log	Update of TRR2
TOR8	Final Verification and Validation Report	Update of TRR5 and confirmation that all of the requirements to be validated at this stage. have been verified
TOR9	Trial Operations Test Specification	Describes that which is to trialled during the trial operation period culminating in a report.
TOR10	Operational Readiness Report	the actions identified and carried out in accordance with the Operational Readiness Plan shall be evidence through the production of an Operational Readiness Report; This shall include the finalised RAMS reports.

Appendix 9 - Tunnel Cleaning Train Cleaning Performance Criteria

1. Scope

1.1 This Tunnel Cleaning Performance Criteria defines the required quality of cleanliness for specified areas of the track, track surrounds, tunnels, and other track areas for which London Underground Limited is responsible to ensure compliance with statutory legislation on completion of tunnel cleaning using the Tunnel Cleaning Train.

1.2 The performance criteria are to be used in conjunction with LU standard 1-166 for cleanliness in relation to the following sections of track:

a) Tube and sub-surface sections;

b) Open sections.

2. Definitions

Sub-surface section - section of railway just below ground level constructed as 'cut and cover' with short lengths in open cut,

Tube section - section of railway in small gauge bored and lined tunnels of single or multiple configuration,

Void - vertical gap between the underside of the sleeper and the ballast or between other rail support components.

Platform invert - void beneath platform slab with controlled entry if a confined space;

Station grounds - the track at stations between tunnel headwalls in tube section and between the ends of platforms elsewhere.

3. Introduction

General

3.1 Determination of the dust level of an asset and its variation within that asset is not a precise exercise and categorisation on inspection will be based to some extent on individual subjective judgement.

Category	General cleanliness
CG1	Area may be dirty to the touch No detectable difference between the cleanliness of ledges and segment walls Bolt threads clearly visible Minimal dust on cables No excess materials present No debris or refuse
CG2	Not more than 1 mm of dust in several places Dust visible in several areas but cable colour identifiable Bolt threads on the whole clearly visible No excess materials present No debris

Table 1 Categories of general cleanliness

4. Cleanliness quality

4.1 Categories of general cleanliness with regard to dust, debris and other loose material are given in table 1.

4.2 Categories of cleanliness with regard to fluff are given in table 2.

Category	Amount of fluff
CF1	No fluff present
CF2	Fluff detectable at various points
CF3	Thin layer of fluff but structure clearly visible

Table 2 Category of fluff cleanliness

4.3 Categories of cleanliness regarding litter in tunnels are given in table 3. The amounts are for each track kilometre.

Category	Amount of litter
CL1	None
CL2	1 hand full

Table 3 Category of litter cleanliness

4.4 The minimum required standards of cleanliness for the various sections after passage of the TCT are as given in table 4.

4.5 Crossover, step plate and dead end tunnels which form part of the operational railway shall meet the standards of cleanliness shown in table 4 for tube section tunnels.

Area	Minimum standard of cleanliness		
	General	Fluff	Litter
Tube section - running tunnel			
Tunnel walls above and behind equipment	CG2	CF1	CL2
Surfaces of track equipment, air pipes, track pipes, cables and lighting	CG2	CF1	CL2
External surfaces of signals and signs	CG2	CF1	CL1
Upper and lower surfaces of noise reducing screens, behind trackside panels and wall mounted cabinets	CG2	CF2	CL2
Surface of the track	CG1	CF1	CL2
Running rails	CG1	CF1	CL2
Conductor rail insulators and insulator pedestals	CG1	CF1	CL1
Voids under the track	CG2	CF2	CL2
Tube section - station grounds and fifty metres of running tunnel at exit end			
Tunnel walls above and behind equipment	CG2	CF2	CL1
Surfaces of track equipment, air pipes, track pipes, cables and lighting	CG2	CF2	CL2
Surface of the track	CG1	CF2	CL2
Running rails	CG1	CF2	CL1
Conductor rail insulators and insulator pedestals	CG1	CF2	CL1
Suicide pits, secondary concrete, paper traps	CG1	CF2	CL1
External surfaces of signals and signs	CG1	CF1	CL1
Track equipment and signs in station grounds	CG1	CF1	CL1
Sub-surface section			
Surface of track including track cess to the boundary	CG2	CF3	CL1
Surfaces of track equipment, pipes, lines and cables	CG2	CF2	CL1
External surfaces of signals and signs	CG1	CF1	CL1
Track equipment and signs in station grounds	CG1	CF1	CL1

Table 4 Minimum standard of cleanliness and inspection frequency

4.6 After cleaning, all cleaned areas shall meet categories defined in Table 4.

4.7 Cleaning quality to be achieved is illustrated in Standard Cleaning of the Track Environment 1-166

5. Inspections

5.1 Following the Performance testing a report shall be prepared recording at least the following information:

a) Name of asset;

b) Structure number (if any);

c) BRS code;

d) Location;

e) Amount of dust on cables, ledges, floors, walls and signalling and other equipment;

f) Amount of fluff present;

g) Amount of litter present;

h) Amount and nature of any excess materials present.

6. Asset data

Track and tunnel cleanliness condition report

Line		Station		
Asset type *				Cleaning required
Asset location				Yes ☐
Asset number		BRS ref.		No ☐
Inspection Contract No.		Inspection date		

	Cables	Ledges	Floors	Walls
Category of dust present *				
Category of fluff present *				
Category of litter present *				
Nature of excess material				
Amount of excess material				

* See below for designations

Any other comments to be recorded on reverse

Category	Amount of dirt and dust
CG1	Area may be dirty to the touch No detectable difference between the cleanliness of ledges and segment walls Bolt threads clearly visible No visible dust on cables No excess materials present No debris or refuse
CG2	Not more than 1 mm of dust in several places Dust visible in several areas but cable colour identifiable Bolt threads on the whole clearly visible No excess materials present No debris

Category	Amount of fluff
CF1	No fluff present
CF2	Fluff detectable at various points

Category	Amount of litter
CL1	None
CL2	1 hand full

Asset type
Tube section - running tunnel - station
Sub-surface - running tunnel - station