

Category 1 Standard

S1172

On Track Machines – Design and Acceptance

*This standard should be complied with as soon as possible and shall be complied with in full by **1 January 2016**.*

*This standard together with three other A2 Versions of Plant standards S1171, S1173 and S1174 replace the existing A1 Plant standards which will remain in place until **1 January 2016**.*

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Contents

1	Purpose	5
2	Scope	5
2.1	Types of Plant	5
2.2	Engineering Requirements	5
2.3	Area of Application	5
2.4	Plant Ownership	5
3	Compliance with International, European and UK Railway Industry Standards	6
4	Classification & Terminology – On-Track Machines	6
5	Acceptance	7
6	Requirements – Part 1 – Design – General	8
7	Part 1a – Requirements for Running (BS EN 14033 Part 1)	8
7.1	Design – Requirements for Running	8
7.2	Machine Categorisation (4)	8
7.2.1	Categories (4.1)	8
7.2.2	Type examination and categories (4.2)	8
7.3	Gauge (5)	8
7.3.1	General Rules (5.1)	8
7.3.2	Stowing of movable machine parts in transport position (5.2)	9
7.4	Frame (6)	10
7.4.1	Principal Dimensions (6.1)	10
7.4.2	Design of the Machine frame (Structure) (6.2)	10
7.4.3	Lifting and Jacking Points (6.3)	11
7.4.4	Stowage points for transport on boats (6.4)	12
7.5	Running Gear (7)	12
7.5.1	General (7.1)	12
7.5.2	Wheel Diameter (7.2)	12
7.5.3	Static Axle Loading (7.3)	12
7.5.4	Wheel Profile (7.4)	12
7.5.5	Shape and Dimensions of the Axles and Wheelsets (7.5)	12
7.5.6	Axle Arrangements and Axle Loads (7.6)	12
7.5.7	Design for Longitudinal Compressive Forces (7.7)	13
7.5.8	Lifeguards (7.8)	13
7.6	Traction System (Not covered in BS EN 14033)	13
7.7	Running Safety (8)	14
7.7.1	Running Tests (8.1)	14
7.7.2	Running Safety on Twisted Track (8.2)	14
7.7.3	Running simulation (8.3)	14
7.8	Brakes (9)	14
7.9	Buffing and Drawgear (10)	15
7.9.1	Couplings (10.1)	15
7.9.2	Buffers (10.2)	16
7.9.3	Interaction Forces between the Machine and Coupled Vehicles (10.3)	16
7.9.4	Space to be Kept Free at the End of the Machine (10.4)	16
7.9.5	Buffer Handrail (10.5)	16
7.9.6	Shunter's Step (10.6)	16
7.10	Operation of Track Circuits, Axle Counters, Treadles for Level Crossings, Hot Box Detectors and Unreleased Brake Detectors (11)	17
7.10.1	Operation of Track Circuits (11.1)	17
7.10.2	Operation of Axle Counters and Treadles for Level Crossings (11.2)	17
7.10.3	Operation of Hot Axle Box and Unreleased Brake Detectors (11.3)	18
7.11	Running Safety Equipment (12)	18
7.11.1	Indication Equipment (12.1)	19
7.11.2	Data Recorder (12.2)	19
7.12	Warning Equipment and Lights (13)	19
7.12.1	Warning Horns (13.1)	19
7.12.2	Lamp Brackets and Marker lights (13.2)	20
7.13	Driver's Cabs and Driving Position (14)	20
7.13.1	General (14.1)	20
7.13.2	Access to Cab (14.2)	21
7.13.3	Interior of Cab (14.3)	22
7.13.4	Heating, Cooling and Ventilation (14.4)	22

7.13.5	Internal Lighting (14.5)	23
7.13.6	Area of Visibility (14.6) (See 9.2.11 for visibility in Travelling and Working Modes)	23
7.13.7	Driver's Desks (14.7)	23
7.13.8	Controls and Indicators (14.8)	23
7.13.9	Driver's and Assistant's Seats (14.9)	23
7.13.10	Equipment and Controls (14.10)	23
7.14	Design for Rescue Purposes. (Not Covered by BS EN 14033-1)	23
7.14.1	General	23
7.15	Safety Design Features (15)	24
7.15.1	Electrical Protection Measures (15.1)	24
7.15.2	Mechanical Protection Measures (15.2)	24
7.15.3	Fire Protection (15.3)	24
7.15.4	Electromagnetic Compatibility (15.4)	24
7.16	Environmental Protection (16)	25
7.16.1	General (16.1)	25
7.16.2	Carriage and Storage of Fuel and Oil (16.2)	25
7.16.3	Tanks and Equipment (16.3)	25
7.16.4	Power Equipment (16.4)	25
7.17	Machine Marking (17)	26
7.17.1	Lettering on the Machine (17.1)	26
7.17.2	Machine Number (17.2)	27
7.17.3	Details of the Railway Infrastructure Where the Machine is Allowed to Run (17.3)	27
7.18	Machine data and maintenance book (18)	27
7.18.1	Maintenance Schedule (18.1)	27
7.18.2	Maintenance Manual (18.2)	27
8	Part 1b – Requirements for Working (BS EN 14033 Part 2)	28
8.1	Design - Requirements for Working	28
8.2	Field of Use of Machines (4)	28
8.3	Specific railway requirements and/or measures (5)	28
8.3.1	Interaction with the infrastructure (5.1)	28
8.3.2	Stability and safety against derailment (5.2)	29
8.3.3	Working Limit Contour (5.3)	30
8.3.4	Working Places (5.4)	32
8.3.5	Access to Places of Work (5.5)	32
8.3.6	Influences on the Environment (5.6)	32
8.3.7	Electromagnetic Compatibility (5.7)	33
8.3.8	Protection from Risks due to Electric Traction Equipment (5.8)	33
8.3.9	Protection from the Risk of Fire (5.9)	33
8.3.10	Lighting for Work (5.10)	34
8.3.11	Visibility of Machines (5.11)	34
8.3.12	Braking (5.12)	35
8.3.13	Warning Systems (5.13)	36
8.3.14	Recovery Conditions (5.14)	37
8.4	Verification of the conformity to the requirements and/or particular safety measures (6)	37
8.5	User Information (7)	37
8.5.1	General (7.1)	38
8.5.2	Warning signs and pictograms (7.2)	39
8.6	Marking and numbering of machines (8)	39
8.6.1	Machine marking (8.1)	39
8.6.2	Service number of the machine (8.2)	39
9	Part 1c –General Safety Requirements (BS EN 14033 Part 3)	40
9.1	Design – General Safety Requirements	40
9.2	General safety requirements and/or protective measures (5)	40
9.2.1	General (5.1)	40
9.2.2	Access to working places (5.2)	40
9.2.3	Ergonomics (5.3)	40
9.2.4	Requirements for working cabs (5.4)	40
9.2.5	Operator's seats (5.5)	41
9.2.6	Edges and Corners (5.6)	41
9.2.7	Pipes and hoses (5.7)	41
9.2.8	Communications between work positions (5.8)	41
9.2.9	Stability and measures preventing derailment (5.9)	42
9.2.10	Visibility of working tools and working areas (5.10)	42
9.2.11	Visibility of the track ahead of the machine in the direction of movement (5.11) (See 7.13.6 for visibility in Running Mode).	42

9.2.12	Emergency devices (5.12)	42
9.2.13	Hazards associated with high working places and their access (5.13)	43
9.2.14	Moving parts and materials (5.14)	43
9.2.15	Operator's controls and indicators (5.15)	43
9.2.16	Thermal Hazards (5.16)	44
9.2.17	Electrical hazards (5.17)	44
9.2.18	Machine safety requirements related to electromagnetic compatibility (5.18)	47
9.2.19	Emissions of gas and particles (5.19)	47
9.2.20	Pressurised systems (5.20)	48
9.2.21	Fuel tanks and hydraulic tanks (5.21)	50
9.2.22	Noise reduction (5.22)	51
9.2.23	Vibration (5.23)	51
9.2.24	Protection from the risk of lasers (Not included in BS EN 14033)	51
9.2.25	Protection from the risks of fire (5.24)	52
9.2.26	Braking Systems (5.25)	53
9.2.27	Lighting (5.26)	53
9.2.28	Warning systems (5.27)	53
9.2.29	Maintenance (5.28)	53
9.2.30	Safe handling (5.29)	54
9.3	Additional safety requirements and/or measures for specific machine functions (6)	54
9.3.1	Conveyors (6.1)	54
9.3.2	Rail handling devices (6.2)	54
9.3.3	Portal cranes mounted on railbound Machines (6.3)	54
9.3.4	Cranes and lifting devices fixed on the Machine (6.4)	54
9.3.5	Transport of loads by crane (6.5)	54
9.3.6	Elevating work platforms (6.6)	54
9.4	Verification of the conformity to the safety requirements and/or particular safety measures (7)	54
9.5	Information for use (8)	55
9.5.1	Instruction handbook (8.1)	55
9.5.2	Warning signs and written warnings (8.2)	55
10	Part 2 – Engineering Acceptance - Assessment of Conformity	56
10.1	General Requirements for Engineering Acceptance	56
10.2	Engineering Acceptance – Conformity with Legislation	56
10.3	Engineering Acceptance - Verification of Conformity with Standards	56
10.3.4	Visual check	56
10.3.5	Measurement	56
10.3.6	Functional test	56
10.3.7	Load test	57
10.3.8	Specific verification/measurements and other controls	57
10.4	Verification of Compliance with Specified Requirements	57
11	References	58
11.1	References	58
11.1.1	Statutory documents	58
11.1.2	British Standards	58
11.1.3	Other national standards	60
11.1.4	Industry codes of practice	61
11.1.5	TfL company documents	61
11.1.6	Other	61
11.2	Abbreviations	61
11.3	Definitions	62
11.4	Person accountable for the document	65
11.5	Document history	65
12	Attachments	65
12.1	Attachment 1 – LU Track Geometry	66
12.1.1	Track Geometry – Overview	66
12.1.2	Design Geometry	66
12.1.3	Track Maintenance Geometry	67
12.2	Attachment 2 – Emergency Equipment	68
12.3	Attachment 3 – LU Track Geometry	69
12.4	Attachment 4 – LU Environment	70
12.4.1	Weather/Ambient Conditions	70
12.5	Attachment 5 – Tunnel Dust	71
12.6	Attachment 6 – Conformity Checklist	72

1 Purpose

- 1.1 This Standard is one of four Standards which together define the requirements for the design, construction, acceptance, use and maintenance of portable and transportable plant intended for use on the LU Infrastructure.
- 1.2 The range of plant covered by the four Standards is sub-divided into groups with similar attributes and requirements. Details of the groups and definitions used for the various categories of plant, collectively referred to as 'Plant', are shown in Attachment 1 of LU Standard S1171.
- 1.3 The purpose of this standard is to define the **engineering requirements for On-Track Machines** and the requirement for verification of conformity with these engineering requirements.
- 1.4 The requirements for the Acceptance, Use and Maintenance of all Plant including On-Track Machines are set out in LU Standard S1171.
- 1.5 The engineering requirements and the requirements for the verification of conformity for On-Track Plant and for Non-Railborne Plant are set out in standards S1173 and S1174 respectively.
- 1.6 The requirements set out in this Standard are intended to control the risks associated with the engineering aspects of On Track Machines. The risks to be controlled are those which have the potential to affect safety, the train service, the environment and the Company's business, finances and reputation
- 1.7 This Standard replaces S1172 A1.

2 Scope

2.1 Types of Plant

- 2.1.1 This Standard defines the engineering requirements for all Plant classified as On-Track Machines in accordance with Section 4 of this standard and intended for use on the LU Infrastructure.

2.2 Engineering Requirements

- 2.2.1 The scope of the engineering requirements for On-Track Machines covered by this standard includes, design, construction and operating/maintenance instructions together with the requirements for demonstrating conformity.
- 2.2.2 The scope of this standard does not include the design or performance requirements for the working function of On-Track Machines. The expectation is that performance requirements such as quality and rate of output will be set out in the Technical Requirement Specifications used for the acquisition of the Machine.

2.3 Area of Application

- 2.3.1 The requirements set out in this standard apply to all On-Track Machines that are placed on any running lines or within any sidings or depots forming part of the LU Infrastructure, as defined in Section 11.2 of this standard, including Possessions or other temporary worksites established in any of these areas.

2.4 Machine Ownership and Period of Deployment.

- 2.4.1 This standard applies to all Machines within the scope defined in 2.1, irrespective of ownership or the length of time that the Machines are to be deployed.

3 Compliance with International, European and UK Railway Industry Standards

- 3.1 This Standard is based on the European Standard BS EN 14033 Parts 1,2 and 3, Railbound Construction and Maintenance Machines, and mandates compliance with the appropriate elements of this standard, defining any exceptions and any additional requirements that are necessary as a result of the special operating arrangements, infrastructure and environment of the LU Railway.
- 3.2 To simplify use and to facilitate cross referencing, this Standard uses the same structure and subject headings as the BS ENs and provides the relevant BS EN paragraph number in parentheses against each subject heading
- 3.3 Where this Standard mandates compliance with a clause in one of the three Parts of BS EN 14033 and this clause references a requirement in another Part of BS EN 14033, any exceptions or additions recorded by LU in respect of the referenced clause in the other Part of BS EN 14033 shall apply.
- 3.4 Where compliance is required with other London Underground, National, European or International Standards or Guidance Documents the relevant document and specific requirement will be quoted or referenced in this Standard.
- 3.5 The references to other Standards and related Guidance Documents made in this Standard will normally be restricted to the primary document although compliance is required with all secondary documents referenced by the Primary document unless non-compliance is instructed or formally agreed by LU.
- 3.6 Where no specific issue or version is quoted for the Standards and Guidance Documents referenced in this Standard, the latest authorised version of each referenced Standard or Guidance Document must be used.
- 3.7 The primary Standards and Guidance Documents referenced in this Standard are listed in Section 11.1 References.

4 Classification & Terminology – On-Track Machines

- 4.1 This Standard uses classifications, terms and definitions for the various types of On-Track Machine which are based on UK National and European Standards. These are set out in Table 1 of BS EN 14033-1.

GN001 - Category 1,2 and 3 Machines are not relevant when considering the LU Infrastructure as Engineer's Trains are not permitted to reach speeds above 100km/h.

- 4.2 The principal characteristic of all On-Track Machines is that they are approved to travel during Traffic Hours (i.e. outside of Possession) either self propelled or as part of a Train.
- 4.3 All On-Track Machines are required to be capable of operating the track circuits associated with the LU signalling systems (see section 7.10.1 of this Standard).

- 4.4 On-Track Machines approved to operate self propelled outside of Possession (Cat.4&6 Machines) shall be approved to interface with the signalling system(s) for the parts of the Railway where they have Route Availability.
- 4.5 Cat 5 and Cat 7 Machines are not required to interface with signalling systems other than operating conventional track circuits. Therefore outside of Possession they must always be coupled within a Train or to another On-Track Machine which is equipped to interface with the signalling system(s) installed on the routes to be travelled.
- 4.6 Demountable modules associated with On-Track Machines shall be required to comply with all relevant parts of this standard if one or more of the following apply:-
- a) It has been manufactured or modified to suit the particular On-Track Machine or type of On-Track Machine.
 - b) It is used to carry personnel during Running or Travelling.
 - c) It is positioned on the On-Track Machine by other than gravity twist locks.
 - d) It has electrical, pneumatic or hydraulic connections to the On-Track Machine.
 - e) It is connected to the On-Track Machine by twist locks and is used for lifting any load.
 - f) It is connected to the On-Track Machine by twist locks and has moveable components which are able to exceed the gauge profile of the On-Track Machine.

5 Acceptance

- 5.1 The requirements for the Acceptance of all Plant intended for use on the LU Infrastructure including On-Track Machines are set out in LU Standard S1171.
- 5.2 The requirements for the verification of the conformity of On-Track Machines with the requirements of this standard are included as Section 10 of this document.

Requirements for Running

Requirements – Part 1 – Design

6 Requirements – Part 1 – Design – General

- 6.1 The requirements set out in this Standard are the minimum acceptable requirements and apply to all On-Track Machines intended for normal use on the LU Infrastructure, irrespective of the ownership of the Machine or the length of time that the Machine is to be on the LU Infrastructure.

GN002 - The reference to 'normal use' in paragraph 6.1 means any approved use which is not designated as a test or trial.
Where the use of On-Track Machines are to be restricted to test or trial use only full compliance with the design requirements set out in this Standard may not be necessary.
Details of the requirements for Acceptance for trial purposes are contained in Part 2 of Standard S1171.

GN003 - Where On-Track Machines are designed or adapted specifically for use on the LU Infrastructure it may be beneficial for specific features to be provided that are additional to the requirements set out in this Standard. The requirement for these specific features will be defined in the Technical Requirements Specification used for the procurement of the Machine or the modification. The Technical Requirement Specifications for On-Track Machines cannot define requirements that conflict with those set out in this Standard unless such conflicts are authorised by an approved Concession.

GN004 - On-Track Machines that are required to run on Network Rail infrastructure must comply with the Interoperability The Railway (Interoperability) Regulations 2011 and other NR specific design requirements that are not covered by this standard.

7 Part 1a – Requirements for Running (BS EN 14033 Part 1)

7.1 Design – Requirements for Running

- 7.1.1 On-Track Machines that are intended for use on the LU Infrastructure shall comply with the requirements for Running as set out in BS EN 14033-1:2011, subject to the exceptions and additions specified below.

7.2 Machine Categorisation (4)

7.2.1 Categories (4.1)

The requirements set out in paragraph 4.1 shall be complied with subject to the addition of the following exceptions or additions:-

- a) Some of the requirements set out in this Standard only apply to certain Categories of On-Track Machine. The conformity check lists included as Attachment 6 show the applicability of clauses to each Category of On-Track Machine which may be considered for use on the LU Network.

7.2.2 Type examination and categories (4.2)

The requirements set out in paragraph 4.2 shall apply.

7.3 Gauge (5)

7.3.1 General Rules (5.1)

The requirements set out in paragraph 5.1 shall be replaced with the following:-

Requirements for Running

a) Gauge – Dimensions – Running

- i. On-Track Machines shall be designed to comply with the LU gauging requirements defined in Standard S1156 for the parts of the Network over which they are intended to travel.
- ii. On-Track Machines that are intended to carry materials or equipment which, due to their nature cannot reliably be positioned with the degree of accuracy required by the principles of kinematic gauging, shall be constructed and assessed to the relevant maximum Load Gauge as defined in drawing G2 in attachment 4 of LU Standard S1156.

GN005 - The application of kinematic gauging principles in the design of On-Track Machines is preferred as this allows the optimum use of available space for the Machine's profile. However, the use of kinematic gauging requires the profile of the Machine to comply with very small dimensional tolerances and this can be a problem where On-Track Machines are used to carry materials or equipment unless they are either fully enclosed within the structure of the Machine or of known dimensions and secured accurately and securely into a fixed position. In cases where it is not possible to guarantee, to the level of accuracy required for kinematic gauging, the position of loads or equipment carried on On-Track Machines, it is necessary to work instead to the relevant Loading Gauge which provides increased tolerance in terms of load positioning and therefore improved confidence that the necessary clearances will be achieved at all times.

- iii. For existing On-Track Machines where the information required to enable kinematic gauging is unavailable and its acquisition is either impracticable or un-affordable, it is acceptable for the machine to be assessed against the appropriate Load Gauge. The following gauging information shall be provided for each type or design of On-Track Machine:
 - Static Profile
 - Axle/Bogie centre spacings and carbody overhangs (for calculating centre and end throws)
 - Dynamic (Kinematic) Profile (see iv to vi below)
 - Swept Envelope (see v and vi below)
- iv. The determination of the Kinematic Profile of the Machine shall take account of the cumulative effect of the influencing factors including speed, track geometry etc., using a probabilistic approach to achieve a credible outcome.
- v. The methods to be used to predict and to verify the Kinematic Profile and Swept Envelope of the Machine shall be agreed with LU and any software used for this purpose shall be approved by LU.
- vi. Information regarding the characteristics of the Machine used in the determination of the Kinematic Profile and Swept Envelope shall be provided to LU as part of the technical information requirements set out in Section 9.5.1.2 of this Standard.

7.3.2 Stowing of movable machine parts in transport position (5.2)

The requirements set out in paragraph 5.2 shall be complied with subject to the following exceptions or additions:

Requirements for Running

a) Gauge – Retention of Components – General

- i. All component parts of On-Track Machines shall be securely attached to prevent their unintentional displacement or detachment when travelling or working. Particular attention shall be given to the security of components that, if displaced or detached, could cause derailment of the On-Track Machine or other rolling stock encountering the displaced component.
- ii. Equipment and mountings shall be designed to take into account the consequences of failure.
- iii. The risk of failure of equipment and mountings shall be reduced, where appropriate, by measures such as:
 - the over-design of mountings and attachments;
 - the use of fasteners employing high strain energy;
 - the provision of:
 - emergency or secondary restraints;
 - alternative load paths.
- iv. Where a cover has the ability to go out of gauge in a failed condition, a secondary restraining device shall be fitted to maintain the cover within the gauge.

b) Gauge – Retention of Components – Working Parts

- i. When an On-Track Machine is in the Running Mode, any equipment designed to move outside the Kinematic Limit when working shall be stowed in a position within the Kinematic Limit and retained in this position in the event of accidental operation.
- ii. Locking devices used to secure components in their stowed position shall not solely rely upon a power source to retain the locking function.
- iii. The engagement and release of the locking mechanisms shall preferably be designed for operation from a safe position within the Machine. Where this is not possible the controls for operating the locking mechanisms must be located in a position which minimises the risk to the operator.
- iv. The state of engagement of the locking mechanisms must be clearly visible to staff inspecting the On-Track Machine from track level.
- v. For self propelled On-Track Machines, where the required state of engagement of the locks cannot be guaranteed at all times, the locks must be visible, either directly or by other acceptable means, from all driving positions on the Machine.

7.4 Frame (6)

7.4.1 Principal Dimensions (6.1)

The requirements set out in paragraph 6.1 shall apply.

7.4.2 Design of the Machine frame (Structure) (6.2)

The requirements set out in paragraph 6.2 shall apply subject to the following exceptions or additions:-

- a) Where Machines are fitted with driving cabs they shall meet the requirements of BS EN 12663-1:2010 clause 6.2.3 and for Table 6 and Table 7 only, shall be considered as

Requirements for Running

category L (not category F-I or F-II which BS EN 14033 clause 6.2 specifies for the other load cases).

- b) The dynamic frame strength (fatigue) of On-Track Machines shall comply with BS EN 12663-1:2010, clause 6.6.
- c) Attachments to the On-Track Machine frame, including bogie attachments, shall comply with BS EN 12663-1:2010, clauses 6.5.2 and 6.7.
- d) Bogies and axlebox equipment shall comply with BS EN 13749:2011 clause 4. Axleboxes and equipment fitted to non-bogied On-Track Machines shall also comply with BS EN 13749:2011 clause 4. The validation of these requirements shall comply with BS EN 13749:2011 clause 6.2.
- e) For On-Track Machines that include a bogie frame, the integrity of the structure of the bogie frame, all attached equipment and body to bogie connection shall be demonstrated using one of the methods set out in BS EN 13749:2011 clause 6.2.
- f) In the application of the load cases referred to in BS EN 13749:2011, the exceptional payload shall be taken as the fully laden condition.
- g) The hypothesis taken to evaluate the loads due to bogie running (formula and coefficients) set out in BS EN 13749:2011 Annex C, shall be stated in the technical documentation (see BS EN 14033-1:2011, Annex I).
- h) The design of the Machine's frame and other structural elements shall make provision for the additional loads and stresses associated with the Machine's working mode. These include but are not limited to:-
 - Vibration
 - Repeated deflections
 - Variations of masses
 - Asymmetries in payload
 - Any sort of additional payload imposed by use in working mode.
- i) All forward facing surfaces, excluding windscreens, of areas of On-Track Machines intended to be occupied by people shall have sufficient impact strength to resist penetration of a sharp cornered hollow steel cube having sides of 70mm to 75mm and a mass of 0.9 kg and travelling at twice the maximum running speed of the Machine.
- j) Roofs, including any glass panels forming part of the roofover areas intended to be occupied by people shall resist the penetration, into the On-Track Machine, of a concrete cube weighing 100kg dropped from a height of 3.0m above the roof. The cube shall be dropped so that a flat surface hits the roof.

7.4.3 Lifting and Jacking Points (6.3)

The requirements of paragraph 6.3 shall apply subject to the following exceptions or additions:-

- a) The positioning of Lifting and Jacking points which may be used during emergency re-railing of the Machine, shall take account of the presence of the two conductor rails installed on the LU Network, and the very restricted access available in single bore tube tunnels.

Requirements for Running

- b) Brackets used for re-railing shall either conform to the options given in EN 16404:2014 or, if different to those choices, the brackets shall be carried on the On-Track Machine.

7.4.4 Stowage points for transport on boats (6.4)

The requirements set out in paragraph 6.4 shall apply.

7.5 Running Gear (7)

7.5.1 General (7.1)

Table B1 is not applicable to London Underground.

- a) The running gear shall be able to negotiate the horizontal and vertical curves shown in Attachment 1.

7.5.2 Wheel Diameter (7.2)

The requirements of paragraph 7.2 shall be replaced with the following:-

- a) The preferred minimum, fully worn, wheel diameter for On-Track Machines is 650 mm.
- b) Wheel diameters of less than 650mm will only be accepted where evidence is provided to demonstrate that the Machine under consideration, fitted with these wheels, will be able to safely traverse all LU crossing configurations without derailment or damage.
- c) The minimum worn diameter shall not be smaller than 330 mm.

7.5.3 Static Axle Loading (7.3)

The requirements set out in paragraph 7.3 shall apply.

7.5.4 Wheel Profile (7.4)

The requirements of paragraph 7.4 shall be replaced with the following:-

- a) The rail wheel used on On-Track Machines intended for use on the LU Infrastructure should preferably have LT5 profiles although other profiles will be accepted provided their satisfactory performance in the proposed application is demonstrated to the satisfaction of LU.

7.5.5 Shape and Dimensions of the Axles and Wheelsets (7.5)

The requirements set out in paragraph 7.5 shall apply subject to the following exceptions or additions:-

- a) For vehicles operating solely on LU controlled infrastructure, the back to back dimension shall be $1359 \text{ mm} \pm 1$ when measured under static conditions.
- b) For any other vehicle operating over LUL tracks the back to back dimension shall be as specified in 'a' above or in Railway Group Standard GM/RT2466 Issue 3.

7.5.6 Axle Arrangements and Axle Loads (7.6)

The requirements set out in paragraph 7.6 shall apply subject to the following exceptions or additions:-

- a) The stresses generated on bridges and at the approach to bridges by On Track Machines in Running Mode shall not exceed the limits defined in Appendix 7 Clause 7.5 LU Civil Engineering Standard S1051.
- b) The compatibility of vehicle weights and underline bridges for vehicles intended to be used on Network Rail infrastructure shall be assessed in accordance with Railway Group Standard GE/RT8006 Issue 2.
- c) The largest overhang shall not exceed 3226mm

Requirements for Running

GN006 - Requirements b and c are UK National Requirements quoted in BS EN 14033-1 Annex B

7.5.7 Design for Longitudinal Compressive Forces (7.7)

The requirements set out in paragraph 7.7 shall apply.

7.5.8 Lifeguards (7.8)

The requirements set out in paragraph 7.8 shall apply

7.6 Traction System (Not covered in BS EN 14033)

7.6.1 On-Track Machines must be capable of travelling safely on the LU Infrastructure at all speeds up to 50 mph (80 kph) either self-propelled or in train formation.

GN007 - As the performance of LU's passenger trains is increased it will become desirable for self propelled OTMs to be capable of acceleration and braking performance which is compatible with the passenger stock. Specific requirements for traction performance and any additional requirements for braking performance will be set out in the Technical Requirements Specification for the Machine(s) concerned.

7.6.2 Traction drive systems shall be capable of moving the On-Track Machine in both tare and fully laden conditions, independently of any external assistance, in a smooth and progressive manner between 'creep' and 'full' speed, without wheel spin, in normal adhesion conditions ($\mu = 0.1$) on level track.

7.6.3 Traction drive systems shall be arranged such that identical performance is obtainable in each direction.

7.6.4 No single point failure shall result in the unintentional movement of the On-Track Machine.

7.6.5 Traction drive systems designed for multiple working, where the leading On-Track Machine operates the system in a connected trailing On-Track Machine, shall be matched to comply with 7.6.2 above.

7.6.6 A method shall be provided to identify the direction of travel selected for On-Track Machines operated from revolving superstructures.

7.6.7 On-Track Machines capable of being towed in train formation which require the drive system to be manually disengaged shall have an external indicator to show whether the drive system is engaged or not. The drive system shall be lockable in both the engaged and disengaged positions.

7.6.8 For On-Track Machines that have separate drive arrangements in Running, Travelling and/or Working modes, it shall be possible to control the changeover from the Running driving position(s).

7.6.9 All control systems designed to control the movement of the On-Track Machine shall meet the requirements of BS EN ISO 13849-1:2008, Table 3. The combined effect of correct use by an operator and the machine control system shall be to achieve a performance level of:-

- Unrequested movement - at least level 'c'
- Changeover of controls – at least level 'c'
- Emergency cut of power – at least level 'd'

Requirements for Running

- Correct direction of movement – at least level ‘c’

GN008 - The validation of the the safety functions and categories defined in 7.6.9 above is set out in BS EN ISO 13849-2:2008.

GN009 - Software within systems should be validated as set out in BS EN ISO 13849-1:2008 clause 4.6. Software and electro-technical solutions should be validated as set out in the BS EN ISO 61508 series of standards.

GN010 - To demonstrate compliance with 7.6.9 above, the manufacturer should have completed an analysis, for example, using failure modes and effects analysis (FMEA) failure modes, effects and criticality analysis (FMECA) safety integrity level (SIL) or decision tree which could also be supported by physical testing as appropriate.

7.6.10 Diesel engines used to supply traction power shall comply with the requirements of section 7.16.4 of this standard.

7.7 Running Safety (8)

7.7.1 Running Tests (8.1)

The requirements of paragraph 8.1 shall apply.

7.7.2 Running Safety on Twisted Track (8.2)

The requirements of paragraph 8.2 shall be replaced with the following:-

- a) The wheel unloading shall not exceed 60% of the nominal wheel load, defined as each individual measured wheel load with the Machine standing on straight and level track, when the vehicle negotiates the track twist defined below in all load conditions and:-
 - i. with the suspension inflated and deflated (if air suspension is used).
 - ii. with all suspension parameters at the most disadvantageous limits of the manufacturing tolerance and
 - iii. taking into account increased stiffness due to ageing and temperature effects.
- b) For bogie vehicles, the track twist shall be the most adverse combination of 1:75 over the bogie wheelbase and 1:200 over the bogie centres.
- c) For non-bogied vehicles, the track twist shall be the most adverse combination of 1:75 over the first 2m between the wheelsets, and 1:200 over the remainder of the distance.

7.7.3 Running simulation (8.3)

The requirements of paragraph 8.3 shall apply subject to the following exceptions or additions:-

- a) Where the running behaviour and derailment resistance of the On-Track Machine are to be demonstrated by computer simulation the models and inputs used shall be approved by LU.
- b) Tests shall be carried out on the first vehicle of each type to demonstrate compliance with the requirements for wheel unloading (See 7.7.2 above).

7.8 Brakes (9)

The requirements of Section 9 shall be replaced with the following:-

Requirements for Running

- a) The design and performance of the braking systems of On-Track Machines which are intended for use on the LU Network shall comply with the minimum requirements, appropriate for the relevant LU Engineer's Vehicle Category of the On-Track Machine, as set out in Parts 0, 1, 2, 3, 5, 10, 21, 22, and 30 of LU Standard RSE-STD-039.

GN011 - LU Standard RSE/STD/039 uses a categorisation system for Engineer's Vehicles (including OTMs) which is different from the categorisation system used in BS EN 14033.

GN012 - The design and performance of braking systems of On-Track Machines which are purpose built for LU may, if deemed appropriate, be required to comply with the additional requirements for braking system design and performance, appropriate for the category of the On-Track Machine, as set out in Parts 11, 12, 13 and 15 of LU Standard RSE-STD-039.

GN013 - Any requirement for purpose built machines to exceed the minimum braking requirements defined in this Standard will be included in a Technical Requirements Specification.

- b) The braking control system shall meet the requirements of BS EN ISO 13849-1:2008. The combined effect of correct use by an operator, the control system, the operating system and the safety system shall be to achieve a performance level of at least 'd' as defined in Table 3 of BS EN ISO 13849-1:2008.
- c) The Common Safety Method can be used as an alternative to BS EN ISO 13849-1:2008 as the means of assessing the safety integrity of the braking control system.

GN014 - The validation of the safety functions and categories in 7.8 (b) is set out in BS EN ISO 13849-2:2008.

GN015 - Software within systems should be validated as set out in BS EN ISO 13849-1:2008 clause 4.6. Software and electro-technical solutions should be validated as set out in the BS EN ISO 61508 series of standards.

7.9 Buffing and Drawgear (10)

7.9.1 Couplings (10.1)

The requirements of paragraph 10.1 shall apply subject to the following exceptions or additions:-

- a) The ends of On-Track Machines shall be provided with a coupling facility designed either for normal use and emergency recovery or designed solely for emergency recovery. The coupling facility shall be designed to transmit, safely and without significant permanent deformation, all sustained and shock loads that may arise between Machine and any coupled rail vehicle associated with:-
- Coupling and uncoupling.
 - Traction and braking
 - Traversing curved track
 - Vertical changes in alignment
 - Shock loads caused by play and flexibility in the coupling system.
- b) The design of the coupling system shall ensure that it is possible to determine that it is positively engaged, either by direct observation or by a suitable system of indication.

Requirements for Running

- c) The design of the couplings and buffers shall together ensure that the vehicle, individually or in a train consist when and where permitted, is able to safely negotiate track incorporating the most extreme combinations of curves and other geometric characteristics defined in Attachment 1.
- d) Where the coupling system of an On-Track Machine is unable to accommodate the track geometric conditions set out in Attachment 1, the limitations shall be declared as part of the Acceptance process and recorded in the Instruction Handbook.
- e) Systems that control the operation of the coupling or uncoupling system shall be protected from reasonably foreseeable interference that could result in the system's inadvertent or malicious operation.
- f) The design of the coupling system shall allow manual uncoupling when the systems normally required for uncoupling are unavailable.
- g) If vehicles of an On-Track Machine are permanently coupled together, the coupling system between the vehicles shall be designed to withstand forces greater than the couplings and buffers (if fitted) at the ends of the Machine.
- h) The design of the coupling system shall ensure that it is unnecessary for personnel to be positioned between the Machine and a coupling/uncoupling rail vehicle at any time while either the Machine or the rail vehicle is unsecured and free to move.
- i) The design of tow bars intended for normal or emergency use shall be approved by the LU Head of Rolling Stock Engineering (see also paragraphs 7.14 and 8.3.14.1 of this Standard).

7.9.2 Buffers (10.2)

The requirements of paragraph 10.2 shall apply subject to the following exceptions or additions:-

- a) The design of the couplings and buffers shall together ensure that the vehicle, individually or in a train consist when and where permitted, is able to safely negotiate the curves defined in Attachment 1.

7.9.3 Interaction Forces between the Machine and Coupled Vehicles (10.3)

The requirements set out in paragraph 10.3 shall apply.

7.9.4 Space to be Kept Free at the End of the Machine (10.4)

The requirements set out in paragraph 10.4 shall apply.

7.9.5 Buffer Handrail (10.5)

The requirements of paragraph 10.5 shall apply subject to the following exceptions or additions:-

- a) Buffer handrails are not required by LU.

7.9.6 Shunter's Step (10.6)

The requirements of paragraph 10.6 shall apply subject to the following exceptions or additions:-

- a) Shunter's steps are not required by LU.

Requirements for Running

7.10 Operation of Track Circuits, Axle Counters, Treadles for Level Crossings, Hot Box Detectors and Unreleased Brake Detectors (11)

7.10.1 Operation of Track Circuits (11.1)

The requirements of paragraph 11.1 shall be replaced with the following:-

- a) On-Track Machines shall be capable of reliably operating track circuits in both static and dynamic modes.
- b) All On-Track Machines shall have:-
 - i. A minimum of two axles.
 - ii. A minimum axle load of 4 tonnes.
 - iii. A maximum separation of 13.5m between:-
 - Any two adjacent axles fitted to the Machine.
 - The two adjacent axles of the Machine and any coupled rail vehicle intended to travel with the Machine outside of Protection (ie. In Traffic Hours).
 - iv. A maximum electrical resistance of 0.01Ω between the wheels of an axle.

GN016 - The electrical resistance between the wheels of an axle is a function of the design and construction of the wheelset and should not be confused with the shunt resistance.

- c) On-Track Machines intended to operate as independent, self propelled, units outside of Protection shall have:-
 - i. A minimum of four axles
 - ii. A minimum axle load of 5 tonnes unless meeting the requirements of 'iii' below.
 - iii. A minimum axle load of 4 tonnes if equipped with tread braking or an approved tread scrubbing system on each rail wheel.
 - iv. An axle configuration that ensures that at least two axles of the Machine are in contact with a single track circuit at all times.

GN017 - The maximum length of undetected track permitted in clause 3.3.2.2 of LU Standard S2505 A3 is a total of 9 metres at the interface between adjacent tuned track circuits, being 4.5 metres within the boundary of each track circuit. This means that a conventional bogie mounted Machine, with a 2 metres axle centre spacing on each bogie, would require the outermost axles of the Machine to be separated by at least 13.5 metres in order to comply with the requirements of 7.9.1.c iv above.

GN018 - On-Track Machines which do not comply with the axle configuration requirements set out in 7.9.1.c above may be accepted for use on the LU controlled infrastructure subject to restrictions to their route access.

7.10.2 Operation of Axle Counters and Treadles for Level Crossings (11.2)

The requirements of paragraph 11.2 shall apply subject to the following exceptions or additions:-

Requirements for Running

- a) The sensitive zone according to EN 50238:2003, Figure A.22, shall be kept free of all components, with the exception of the tripcock operating lever, if a tripcock is fitted.

7.10.3 Operation of Hot Axle Box and Unreleased Brake Detectors (11.3)

The requirements of paragraph 11.3 shall apply subject to the following exceptions or additions:-

- a) The detection zones are defined in GE/RT8014 Issue 2.

GN019 - London Underground infrastructure does not currently have hot axle-box detectors or unreleased brake detectors, but On-Track Machines may be required to run on Network Rail infrastructure.

7.11 Running Safety Equipment (12)

The requirements of paragraph 12 shall be replaced with the following:-

- a) Train safety systems shall be fitted in accordance with GM/RT2185 Issue 2.
- b) On-Track Machines intended for self propulsion outside of Possession (Cat 4&6 Machines) shall be equipped to interface with the signalling system(s) installed on those parts of the LU Railway where Route Availability for the Machine is required. Details of the signalling systems are obtainable from LU.
- c) Where a Category 4 or 6 Machine is required to run independently over track fitted with a conventional fixed block signalling system, the Machine must be fitted with LU approved tripcocks. The tripcock shall:-
- i. be compatible with the train stops defined in:
 - LU Standard S1195 and
 - GE/RT8018 where the Rolling stock is required to run on NR managed infrastructure.
 - ii. apply the emergency brake when tripped;
 - iii. invoke speed control that ensures that train speed cannot exceed 16 km/h (10mph) for three minutes after the tripcock is manually reset. It shall not be possible to:
 - defeat the three minute delay using any sequence of operation of any controls;
 - initiate the three minute delay using any sequence of operation of any controls other than the resetting of the tripcock.
 - iv. have a “tripcock delay” indicator at the operator’s position which illuminates when the tripcock is reset and extinguishes at the end of the three minute delay.
 - v. be capable of withstanding interaction with the train stop up to maximum Machine speed;
 - vi. not require the operator to leave the driving position to reset the tripcock;
- d) The train protection system shall comply with the requirements of RSE/STD/039 Part 20.
- e) Train borne signalling equipment shall be appropriately integrated into the train systems for the function concerned.

Requirements for Running

- f) The interface between the train borne signalling protection device and the Machine's train safety circuits shall have an integrity level not less than SIL4 (Safety Integrity Level) given in BS EN 50126.
- g) When a Machine is in Running Mode without train protection in force, the maximum speed permitted by the Machine shall be 16km/h.
- h) On-Track Machines which are self propelled in Traffic Hours must be equipped with radio and telephone communication systems complying with LU requirements and enabling verbal communication between the Machines' crew and the staff controlling the Railway Operations. The availability of this communication equipment at all times must be guaranteed and this shall be achieved where necessary by the provision of an appropriate level of redundancy (see also paragraph 9.2.8 of this Standard).

GN020 - This requirement may be satisfied by the provision of sufficient portable CONNECT radios.

- i) Provision shall be made in each driving cabin of OTMs for accommodating the emergency Equipment listed in Attachment 2. This replaces the equipment listed for United Kingdom Network Rail in Table J.1 of BS EN 14033-1:2011.
- j) The emergency equipment shall be accessible by the Operator from the driving position within 1 minute without the use of special tools or any tool not carried on the Machine. A standard key common to other LU Rolling Stock shall be used to operate locked cupboards and compartments.
- k) The emergency equipment shall be stored in locked cupboards or compartments in the driving cab. Any cupboards or compartments used for the stowage of emergency equipment shall be dust free and sealed to the minimum requirement as BS EN 60529: 1992 section IP55.
- l) Additional Emergency Equipment shall be installed when the requirement is identified by an appropriate risk assessment.
- m) A label shall describe the stowage location of all emergency equipment and shall depict the emergency equipment on a plan view.

7.11.1 Indication Equipment (12.1)

The requirements of paragraph 12.1 shall be replaced with the following:-

- a) There are no specific requirements for indication equipment on Machines intended for use on the LU Infrastructure.

7.11.2 Data Recorder (12.2)

The requirements set out in paragraph 12.2 shall apply subject to the following exceptions or additions:-

- a) Self propelled On-Track Machines shall be fitted with an on-train monitoring recorder meeting the requirements of GM/RT2472.

7.12 Warning Equipment and Lights (13)

7.12.1 Warning Horns (13.1)

The requirements of paragraph 13.1 shall be replaced with the following:-

Requirements for Running

- a) Self propelled On-Track Machines shall be equipped with a minimum of two electric horns for use in the Running Mode and operable from each driving position.
- b) The warning horns shall meet the requirements of GM/RT2484 Issue 2.

7.12.2 Lamp Brackets and Marker lights (13.2)

7.12.2.1 Lamp Brackets (13.2.1)

The requirements of paragraph 13.2.1 shall be replaced with the following:-

- a) On-Track Machines which may be stabled on the Railway shall be fitted with mounting brackets to allow the attachment of stabling lights. The design of these brackets shall comply with BS EN 14033-1:2011 Annex B and their location shall allow the lights to be mounted at the same height with their horizontal centre-lines at least 1500mm above rail level, with a minimum lateral separation of 1300mm between their vertical centre-lines.

7.12.2.2 Arrangement of Marker Lights (13.2.2)

The requirements of paragraph 13.2.2 shall be replaced with the following:-

- a) On-Track Machines intended to run independently outside of Protection (Category 4 & 6 Machines) shall be fitted with headlights complying with the requirements of LU Standard 1-180, issue A4, section 3.1.5. The headlights shall be fitted to each end of machines comprised of a single vehicle and for machines comprised of more than one vehicle at each end that could lead when in Running mode.

GN021 - In addition to providing the driver with visibility of the track ahead during the hours of darkness, headlights are required to improve the visibility of On-Track Machines to personnel at track level at all times. The requirement for yellow ends of the Machine (see section 8.3.11) is for the same purpose.

- b) On-Track Machines which are approved to operate self-propelled in Traffic Hours shall be fitted with two tail lights at each end which comply with LU Rolling Stock Standard 1-180 issue A4, section 3.1.6.1.
- c) The circuits supplying tail lights shall be configured to ensure that the lights can only be illuminated on one end at any one time and that failure of one or more lamps does not prevent the continuing operation of any remaining serviceable lamps.

7.12.2.3 Light Characteristics (13.2.3)

The requirements set out in paragraph 13.2.3 shall apply.

7.12.2.4 Additional Devices (13.2.4)

The requirements set out in paragraph 13.2.4 shall apply.

- a) The frequency of the flashing lights shall be 0.7 Hz.

7.12.2.5 Light Switching Arrangements (13.2.5)

The requirements set out in paragraph 13.2.5 shall apply.

7.13 Driver's Cabs and Driving Position (14)

7.13.1 General (14.1)

The requirements set out in paragraph 14.1 shall apply subject to the following exceptions or conditions:-

- a) The drivers cabin(s) of self propelled On-Track Machines shall be designed to accommodate as a minimum the driver and a second person.

Requirements for Running

7.13.2 Access to Cab (14.2)

7.13.2.1 General (14.2.1)

The requirements of paragraph 14.2.1 shall apply subject to the following exceptions or additions:-

- a) Where staff may be required to enter or leave On-Track Machines in tube tunnels, provision shall be made for safe access and egress at each end of the Machine, taking account of the presence of a negative conductor rail.
- b) The positioning of access/egress points for On-Track Machines shall minimise the risks to staff arising from slips, contact with live conductor rails and contact with moving vehicles on adjacent lines.
- c) Where On-Track Machines are designed to Run in LU tube tunnels, and where the design of the Machine permits, an emergency walkway shall be provided to allow detained passengers to pass safely through the length of the Machine.

7.13.2.2 Steps, Handrails, Platforms and Railings (14.2.2)

The requirements of paragraph 14.2.2 shall apply subject to the following exceptions or additions:-

(See also paragraph 9.2.2.3 of this Standard).

- a) Steps and handrails shall be provided where required to facilitate safe and easy access to and egress from On-Track Machines. Steps must be designed to provide a slip free surface of appropriate dimensions and incorporating a backing plate where necessary to prevent feet accidentally passing over the tread.
- b) Where On-Track Machines are intended for use in close proximity to operating railway lines, or on worksites where road or rail vehicles may pass close to the Machine, the access and egress points shall be provided with suitable barriers and warnings to safeguard staff using the Machine.
- c) Machines intended for use on the LU controlled infrastructure do not require protective roofs over accessible areas but where these are not provided the Machine shall display warning notices stating that 'This Machine must not be operated or maintained under a live catenary'.

GN022 - LU does not have an overhead catenary on any part of its Network.

- d) Where protective roofs are provided these shall comply with the requirements of Railway Industry Standard RIS-1530-PLT Issue 4, section 5.17.

7.13.2.3 Doors (14.2.3)

The requirements set out in paragraph 14.2.3 shall apply subject to the following exceptions or additions:-

- a) External doors and their mountings fitted to On-Track Machines shall withstand the following separate proof load cases without significant permanent deformation or loss of normal function:-
 - i. A concentrated perpendicular load of 2.5 kN applied over an area of 0.1m x 0.1m, acting from within the Machine. The door structure shall be capable of withstanding this load at any position on the surface of the door.
 - ii. An external surface pressure of 2.5 kPa.

Requirements for Running

- iii. The inner surface pressure load of 2.5 kPa, applied over the internal surface of the door, plus a concentrated perpendicular load, acting from within the Machine, of 0.8 kN applied over an area of 0.1m x 0.1m. The structure shall be capable of withstanding the concentrated load at any position on the surface of the door.
- b) The external doors for use by personnel for access and egress directly from and to the track shall withstand, as an ultimate load case, a sustained pressure of 3 kPa over its internal surface. It is permissible for the door and associated components not to remain operational after the application of this load.

7.13.3 Interior of Cab (14.3)

7.13.3.1 Driver's Position (14.3.1)

The requirements set out in paragraph 14.3.1 shall apply.

7.13.3.2 Additional Seats (14.3.2)

The requirements set out in paragraph 14.3.2 shall apply.

7.13.3.3 Layout of Driver's Cabs (14.3.3)

The requirements set out in paragraph 14.3.3 shall apply.

7.13.3.4 Windscreens (14.3.4)

The requirements set out in paragraph 14.3.4 shall apply.

7.13.3.5 Noise Levels (Not covered in BS EN 14033)

- a) The maximum noise level in the cab during Running or Travelling shall comply with the Conventional Rail Noise TSI (CR NOI TSI).
- b) The acoustic characteristics of the driving cabs shall be such that exploding detonators, as specified in BR 0640A, can be heard inside the cab at any permitted Running/Travelling speed and are readily distinguishable from background noise.

7.13.3.6 Side Windows (14.3.5)

The requirements of paragraph 14.3.5 shall apply subject to the following exceptions or additions:-

- a) Due to very restricted clearances on LU, the use of opening side windows for this purpose is not permitted.
- b) Safety glass used in side windows shall be either laminated or toughened glass.

7.13.4 Heating, Cooling and Ventilation (14.4)

The requirements of paragraph 14.4 shall apply subject to the following exceptions or additions:-

- a) The Cab cooling and ventilation arrangements must be suitable for use in all of the LU environments where the Machine is intended to travel and/or work.

GN023 - Air temperatures in Sub-Surface tunnels may be as high as 32°C and in Tube tunnels as high as 35°C with very limited ventilation in many locations. (see Attachment 4)

GN024 - Dust in tunnels can build up in poorly designed ventilation systems creating nuisance and fire risk. (see Attachment 5).

Requirements for Running

7.13.5 Internal Lighting (14.5)

The requirements set out in paragraph 14.5 shall apply.

7.13.6 Area of Visibility (14.6) (See 9.2.11 for visibility in Travelling and Working Modes)

The requirements set out in paragraph 14.6 shall be replaced with the following:-

- a) The operator shall be able to view the routeway ahead, to ensure that it is clear for movement of the Machine. This shall be possible from all normal operating positions and shall permit the operator to view the track from 5m forward of the Machine front (or 5.3m for Machines without buffers) to the horizon.

7.13.7 Driver's Desks (14.7)

The requirements set out in paragraph 14.7 shall apply.

7.13.8 Controls and Indicators (14.8)

The requirements set out in paragraph 14.8 shall apply subject to the following exceptions or additions:-

- a) On-Track Machines, capable of being towed in train formation, which require the drive system to be manually disengaged shall have an external indicator to show whether the drive system is engaged or not. The drive system shall be lockable in both engaged and disengaged positions.
- b) On-Track Machines that have separate drive arrangements in Running, Travelling and / or Working Modes shall have the changeover controlled from the Running/Travelling driving position(s).

7.13.9 Driver's and Assistant's Seats (14.9)

The requirements set out in paragraph 14.9 shall apply.

(See also paragraph 9.2.5 of this Standard).

7.13.10 Equipment and Controls (14.10)

7.13.10.1 Minimum Equipment Necessary for the Driving of the Machine (14.10.1)

The requirements of paragraph 14.10.1 shall apply.

7.13.10.2 Equipment Necessary for Monitoring of the Machine (14.10.2)

The requirements set out in paragraph 14.10.2 shall apply.

7.13.10.3 Arrangements of Instruments for the Driver's Assistant (14.10.3)

The requirements set out in paragraph 14.10.3 shall apply.

7.13.10.4 Miscellaneous Accessories (14.10.4)

The requirements set out in paragraph 14.10.4 shall apply.

7.14 Design for Rescue Purposes. (Not Covered by BS EN 14033-1)

7.14.1 General

- 7.14.1.1 To enable the safe removal of the Machine clear of the line, failed On-Track Machines shall be capable of being coupled to a locomotive or other rail vehicle fitted with a drawhook that complies with BS EN 15566;2009+A1:2010 clause 5.2.

Requirements for Running

- 7.14.1.2 It shall be possible (where not prevented by damage to the brake system) to release and apply the brakes of the combined train when the assisted On-Track Machine is coupled to the assisting locomotive or rail vehicle. The brake system shall be designed to automatically apply the brakes in the event of the combined train parting.
- 7.14.1.3 Where the On-Track Machine is designed to be recovered by use of an emergency tow bar, then the emergency tow bar shall be:-
- Of a design approved by the LU Head of Rolling Stock Engineering.
 - Carried on the Machine
 - Designed to be fitted by one person
 - Capable of accepting the forces and movements involved in the recovery of the On-Track Machine, without significant permanent deformation or damage.
- 7.14.1.4 Where the design of the On-Track Machine requires the use of special brake hoses for recovery, then the special brake hoses shall be:-
- Carried on the Machine
 - Designed to be fitted by one person
- 7.14.1.5 The design of On-Track Machines shall include provision for the stowage of working equipment following failure of the main power source as specified in clause 8.3.14.2 of this Standard.
- 7.14.1.6 The procedure for emergency recovery of the Machine, including the use of a tow bar, shall be included in the Instruction Handbook (see also clause 8.5.1.2.12).

7.15 Safety Design Features (15)

7.15.1 Electrical Protection Measures (15.1)

The requirements of paragraph 15.1 shall apply subject to the following exceptions or additions:-

- a) Particular attention shall be given to those components which are sited near to the current rails. All components within the electrical exclusion zones in LU Standard S1156 diagram F1 shall be electrically insulated.

7.15.2 Mechanical Protection Measures (15.2)

The requirements of paragraph 15.2 shall apply subject to the following exceptions or additions:-

- a) LU's particular requirements for mechanical protection measures are set out in Section 7.3.2 of this Standard.

7.15.3 Fire Protection (15.3)

The requirements of paragraph 15.3 shall apply.

(See also Sections 8.3.9 and 9.2.25 of this Standard)

7.15.4 Electromagnetic Compatibility (15.4)

The requirements of paragraph 15.4 shall apply subject to the following exceptions or additions:-

- a) On-Track Machines shall also comply with LU Standards S1222 Electromagnetic Compatibility (EMC) and S1193 EMC with LU Signalling System Assets.