

Category 1 Standard

S1180 Standard for Rolling Stock

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1 Purpose

- 1.1 The purpose of this standard is to define the requirements, documentation and processes for the operation of rolling stock on the London Underground Limited (LU) network, in order to demonstrate that the trains and their systems are safe and that all residual risks are As Low as Reasonably Practicable (ALARP).
- 1.2 This Standard exists to define:
- a) the top level requirements for the use of trains in the LU environment, ensuring that they are fit for purpose, and minimise the risks to the system, staff, passengers, members of the public and the environment;
 - b) the performance requirements of the train under normal and degraded operating conditions, so that emergency recovery procedures are used as rarely as possible, and operators are supplied with appropriate information to ensure timely recovery of trains from defects;
 - c) the general standard of equipment to be provided on passenger trains, including the resistance to vandalism of all types;
 - d) the operating systems and interfaces appropriate for the infrastructure in which the trains operate including the visibility from and the visual external appearance of the train.

2 Scope

- 2.1 The extent of the application of this standard is as follows:
- a) new trains supplied to LU for operation by LU or its agents over LU infrastructure shall comply with this standard in its entirety;
 - b) new trains supplied to LU for operation by LU or its agents over LU and Network Rail (NR) infrastructure shall comply with this standard in its entirety and with Railway Group Standard (RGS) GM/RT2452;
 - c) existing trains operated by LU or its agents over LU infrastructure shall comply with this standard as far as reasonably practicable;
 - d) existing trains operated by LU or its agents over LU and NR infrastructure shall comply with this standard as far as reasonably practicable (refer to the Standards Code in the PPP contract) and with RGS GM/RT2452;
 - e) new trains and existing trains certified as fit for NR infrastructure operated by a Train Operating Company (TOC) over LU infrastructure shall comply insofar as these do not conflict with RGSs with, for example, the requirements for gauge, route availability (mass, axle loads, length, etc) radio communications, braking and train protection;
 - f) trains which previously have been operated by a TOC over NR infrastructure, supplied for operation by LU or its agents over LU infrastructure, shall comply with this standard, as far as reasonably practicable;
 - g) trains which previously have been operated by a TOC over NR infrastructure, supplied for operation by LU or its agents over LU and NR infrastructure shall comply with this standard as far as reasonably practicable and with RGSs where appropriate;
 - h) new and existing non-passenger trains and vehicles shall comply with this standard where appropriate.
- 2.2 Existing trains, operating as described in c) and d) above which are modified shall:
- a) comply with this standard, as regards the modification and;
 - b) comply with this standard as far as reasonably practicable, as regards other items revealed by or related to the modification.



Note: Compliance with the requirements of this standard does not in itself ensure compliance with the requirements of the contract or deliver a train that is fit for purpose.

- 2.3 This Standard applies to all new rolling stock in its entirety and to existing rolling stock so far as is deemed reasonably practicable. When existing rolling stock is modified then it will be deemed to come within the scope and the degree of compliance shall be reassessed for reasonableness.

Note: RGS GM/RT2452 is specifically aimed at controlling risk where vehicles, whose primary use is on another network, are used on NR controlled infrastructure.

- 2.4 Where this standard conflicts with any referenced documents or standards, this standard shall take precedence. Such conflicts shall be brought to the attention of LU.

- 2.5 In this standard it shall be construed that:

- a) the following, being words which are used in the text according to the derivation of the particular requirement stated, are interchangeable:
 - I. “rolling stock” and “train(s)”;
 - II. “passenger” and “customer”.
- b) “degraded” is descriptive of all states or conditions, except “normal”.

3 Requirements

3.1 General requirements for trains

3.1.1 General

3.1.1.1 Trains shall:

- a) be designed as an integral part of the whole LU system;
- b) incorporate and interact with all of the supporting systems of the lines over which they operate;
- c) be safe to use under all operating conditions including when the train is powered down.

3.1.1.2 In order to obtain approval to operate new or modified trains on LU infrastructure, compliance with S1538 shall be achieved.

3.1.1.3 The design and functionality of the train shall be such that the risk of malfunction or the effects of abuse by passengers ensures that the potential for injury is ALARP.

3.1.1.4 The risk of unplanned de-trainment of passengers or staff shall be as low as reasonably practicable.

Note : In the small space of a tube tunnel, temperatures can rise quickly and de-trainment can take longer than 1 hour. Thus stalled trains and de-trainment both increase safety risk.

3.1.1.5 New trains shall be designed to make maximum use of the space that the infrastructure permits.

3.1.1.6 Consideration shall be given to future upgradeability of the train.

Note: Past practice has been, at build, to:

- a) install approximately 10% additional train wiring;
- b) provide approximately 20% spare capacity in:

- I) train control and monitoring systems;
- II) train data recorders;
- III) passenger information systems;
- IV) auxiliary services and supplies.

3.1.1.7 Trains shall comply with the relevant LU, Railway Group, National, European and International Standards. In addition, the standards listed in Section 6.1 shall be complied with fully except where this standard conflicts, in which case this standard shall take precedence. The full list of standards shall be agreed with LU before contract award.

3.1.2 Degraded operations

3.1.2.1 Trains shall be able to operate for the purposes of recovery (but not to remain in service) under degraded conditions.

3.1.2.2 Information defining the level and type of degradation the train is undergoing shall:

- a) be presented to the operator to enable him to take the appropriate action;
- b) recognise the likely stress which the operator is experiencing.

3.1.2.3 A hierarchy of degraded conditions shall be defined, which shall also be recorded in the Defective In Service Instructions (DISIs)

Note: The following are possible degraded states or conditions, when the train is [DISI terms in square brackets]:

- a) Able to remain in passenger use [Remain]. Some loss of function which does not have a safety implication, i.e. loss of level of redundancy, does not affect current service e.g. loss of wipers on a sunny day, loss of heaters on summer days;
- b) Able to continue in passenger use for only a limited period, [In service to depot] Risk of passenger carriage increased but does not exceed the risk of de-trainment at given locations; use of procedures to manage risk short-term; fault may worsen with time; item of safety equipment that is only needed when called upon (safety incident) is not working; fault only affects one driving position – can be driven from another driving position in one direction only; where loss of redundant system leaves only one which could be a safety hazard as there is an increased risk of failure on demand or breakdown through the loss of redundancy;
- c) Able to be taken out of service without passengers being conveyed [Withdraw]. Level of risk inappropriate to the conveyance of passengers. In other words, the level of risk of customer carriage is greater than the risk of de-training, hence no passengers allowed on the train;
- d) Not able to operate – requiring rescue ('Sit down' – colloquial term). Train cannot move under its own control systems; continuing to operate the train would exacerbate damage to the train and or the infrastructure.

3.1.2.4 In the event of loss of traction or auxiliary supply, the train shall automatically use backup supply to maintain essential functions (essential functions do not include motoring).

3.1.2.5 The essential functions referred to in 3.1.2.4 shall:

- a) be defined;
- b) include load shedding, in order to maximise battery life, whilst the essential functions are maintained.

- 3.1.2.6 A safe system for the recovery of a stalled train shall be provided by the Supplier.
- 3.1.2.7 Instructions and guidance for the movement and recovery of failed, damaged and disabled trains shall:
- a) be provided by the Supplier;
 - b) include information regarding lifting, cutting and jacking points.
- 3.1.2.8 Trains shall be able to be re-railed after derailment using only jacking equipment held by the Emergency Response Unit.
- 3.1.2.9 A safe method of coupling and uncoupling trains of the same type for push-outs and pull-outs, which requires only one person who remains on board the train or trains, shall be provided by the Supplier. This shall be effective when the trains are positioned at any horizontal or vertical curve found on the routes on which the train operates.
- 3.1.2.10 Any device that trips, requiring resetting to avoid immobilising the train, shall be able to be reset from the driving position.

3.1.3 Emergency equipment

- 3.1.3.1 Agreement shall be reached with the LU:
- a) as to the degraded conditions which constitute an emergency situation;
 - b) as to the items of equipment specific to the particular rolling stock type and its area of operation which shall be provided, in addition to those normally required by and listed in Tc001.
- 3.1.3.2 Each item of emergency equipment shall be:
- a) accessible by the operator from the driving position within 1 minute, under tare loading conditions;
 - b) identified unambiguously on a label, and shown on a plan of the train at the operator's normal operating position, which depicts the stowage location of each item.
- 3.1.3.3 Fire extinguishers shall be stowed such that one extinguisher can be accessed from the driving position by the operator within 30 seconds.
- 3.1.3.4 Fire extinguishers shall not be carried in the saloon and shall not be accessible to passengers.

3.1.4 Exterior lights and indicators – general

- 3.1.4.1 Lights and indicators as defined in 3.1.5 and 3.1.6, shall be provided to enhance train visibility and shall indicate the train states for normal and degraded operation and de-trainment, in accordance with Table 1 below:

Train state	Lights showing at front of train	Lights showing at rear of train
Operational – any forward driving mode selected	2 head lights	2 tail lights
Operational – Reverse mode selected	2 tail lights	2 head lights
Operational (train stationary & secure)	2 head lights	2 tail lights and a 'calling-on' light to indicate train is secure and will not move
Shut down	2 tail lights	2 tail lights

Powered down or Stabled	At least one tail light at each end of the formation	At least one tail light at each end of the formation
De-trainment	Lighting sufficient to illuminate the surface on to which the passengers will step, the handrails provided and the track to a distance of 5m beyond the end of the de-trainment system The illumination provided by these lights shall minimize both the shadows impairing the view of de-training passengers and the glare directed at those assisting de-trainment from the train.	

Table 1 – Exterior lights

3.1.4.2 On de-icing trains a blue light shall be provided to indicate to trackside and platform staff that de-icing fluid is currently being dispensed.

3.1.4.3 Means of retaining the LU specified Bardic lamp shall:

- a) be provided;
- b) be adjacent to the operating position;
- c) be positioned to cause the lamp:
 - I. to face forward;
 - II. to shine through the front windscreen;
 - III. not to obscure sightlines.

3.1.5 Headlights

3.1.5.1 Each end of the train shall be fitted with two headlights which:

- a) can be illuminated only at the front of the train when the train is operational;
- b) have a white light source;
- c) have a clear lens.

3.1.5.2 Both head lights shall be:

- a) located between the solebar and the car waist line, with their horizontal centre-lines between 1500mm and 1750mm above rail level;
- b) mounted symmetrically at the same height;
- c) mounted with a minimum lateral separation of 1300mm between their vertical centre-lines.

3.1.5.3 The beam pattern of the headlights shall be elliptical with a flattened top.

3.1.5.4 As given in Figure 1, the illuminance at key points on a surface perpendicular to the beam centre-line at a distance of 5m in front of a single headlight shall be thus:

- a) the illuminance at points across the beam pattern horizontal centre-line shall be maintained as high possible so as to provide illumination of the side of the track;
- b) the illuminance at points more than 240mm above the beam pattern horizontal centre-line, and beyond 450mm to either side of the beam pattern vertical centre-line, shall be as low as possible so as to minimise the level of glare at the eyes of on-coming train operators and passengers standing on platforms.

Note: The illuminance 200mm directly above the beam pattern horizontal centre-line is a compromise between maximising the amount of light thrown forward to aid visibility on the track and minimising glare in the eyes of operators of on-coming trains.

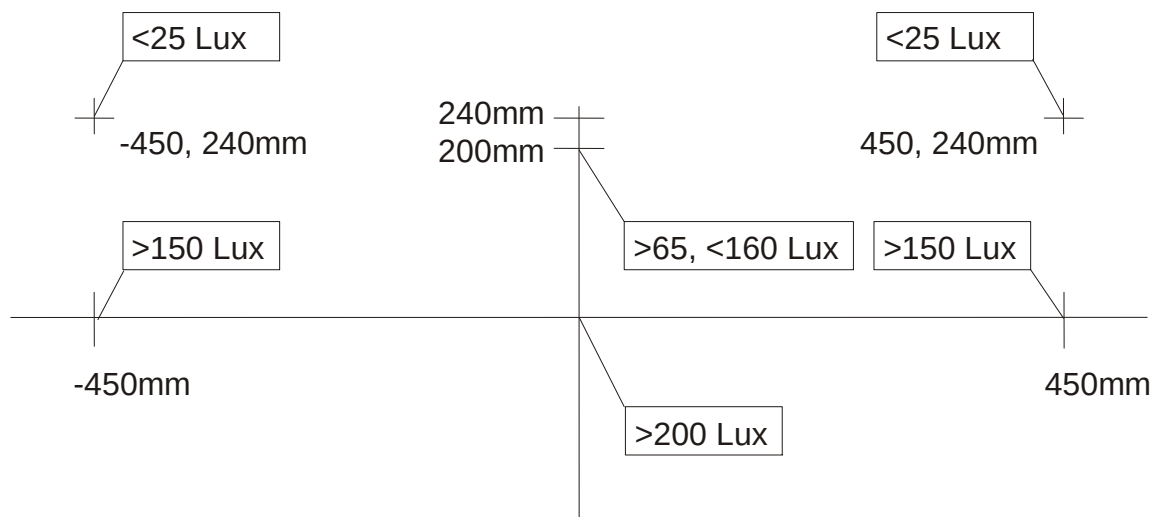


Figure 1 – Headlight illumination levels at 5m

3.1.5.5 Each headlight beam shall:

- be inclined downwards so that the beam pattern horizontal centre-line strikes the running rails $40m \pm 4m$ in front of the train whilst on straight level track;
- not deviate laterally from straight track;
- be fed from the control supply independently of the availability of the traction supply;
- be separately controlled and electrically protected so that in the event of a failure in the control or mechanism of one, the other headlight remains operational.

3.1.5.6 When activated for hazard warning, headlights shall:

- flash at 40 ± 4 cycles per minute. The mark: space ratio shall be such that the lamps are fully on and fully off once in each cycle;
- be independent of train state and the availability of the traction supply;
- be manually controlled via a switch located near the Operator's position. The switch position shall be logged by the Train Data Recorder;
- flash at both ends of the train.

3.1.6 Tail Lights and Calling-on lights

3.1.6.1 Tail lights shall:

- be mounted at the same height with their horizontal centre-lines at least 1500mm above rail level;
- have a minimum lateral separation of 1300mm between their vertical centre-lines;
- be clearly visible from a distance of 300m in daylight conditions;
- have an output of Signal red, Colour Class B in BS 1376;
- have a beam pattern which shall be circular with a viewing angle of at least 15° ;
- have an illuminance of greater than 6.5 Lux on a surface perpendicular to, and on, the beam centre-line, at a distance of 2m from the tail light;
- be fed from the control supply independently of the availability of the traction supply;
- be separately controlled and electrically protected so that in the event of a failure in the control or mechanism of one, the other light remains operational;
- remain illuminated for at least 2 hours following a parted inter-car coupling. This requirement shall be met by ensuring that any car with tail lights complies with one of the following:
 - it contains a normal standby battery;



- II. it contains an auxiliary battery, to supply the tail lights only. Such a battery, if used, shall be of sufficient capacity to maintain both tail lights for at least 2 hours.

3.1.6.2 A calling-on light shall be:

- a) fitted, at the outer ends of the train, so that a member of staff, external to the train, can be aware that the train is secure and it is safe to approach the train;
- b) separate from but identical in performance to the tail light, except that the colour shall be yellow;
- c) manually controlled by a switch located at each service driving position which, when operated, causes it to illuminate continuously;
- d) automatically controlled so that when an OPO(T) deadman alarm is sent, the light is illuminated continuously and when the alarm is cancelled, the light is extinguished;
- e) arranged to flash at both ends of the train when the train protection system is bypassed or isolated, unless an equivalent means of warning staff is provided.

Note: This function is implemented on existing trains to warn trackside staff that the train is in Restricted Manual and that it will not respond to trackside or platform emergency stop plungers.

3.1.6.3 The calling-on light shall only be permitted to illuminate continuously once it is proven that:

- a) the train is prevented from movement under traction power;
- b) the train brakes are applied.

3.1.6.4 Activation of the calling-on light from:

- a) the other train when two trains are coupled together shall not be possible;
- b) an end car at one end of the train shall cause the calling-on light at both end cars to illuminate.

3.1.7 Train Identification

3.1.7.1 A Train Number Indicator shall:

- a) be fitted at each end of the train;
- b) display the train's set number (also known as the running number or train number) which shall be identifiable from the outside except when either the train is powered down or load shedding has occurred or both;
- c) show the same number, in the range 000 to 999, at both ends of the train within 2 seconds of the operator selecting a number;
- d) comply with legibility requirement for the front of the train destination display in 3.12.4.15 and 3.12.4.16.

3.1.7.2 Unique car numbers, as advised by LU, shall be allocated to and displayed on individual cars in accordance with 1-382, as follows:

- a) inside the saloon at both ends;
- b) outside the car near all four corners;
- c) inside the car at the driving position;
- d) on the outer ends of cars at the front and rear of the train.

3.2 External interfaces and environment

3.2.1 General

- 3.2.1.1 All interfaces, inputs and outputs between any system or component on rolling stock and any asset, system or component on stations or the infrastructure on routes over which that rolling stock runs under all credible operating and fault conditions, shall be controlled such that risks and hazards from them are ALARP.
- 3.2.1.2 The types of interface input and output which shall be considered are shown in Figure 2.

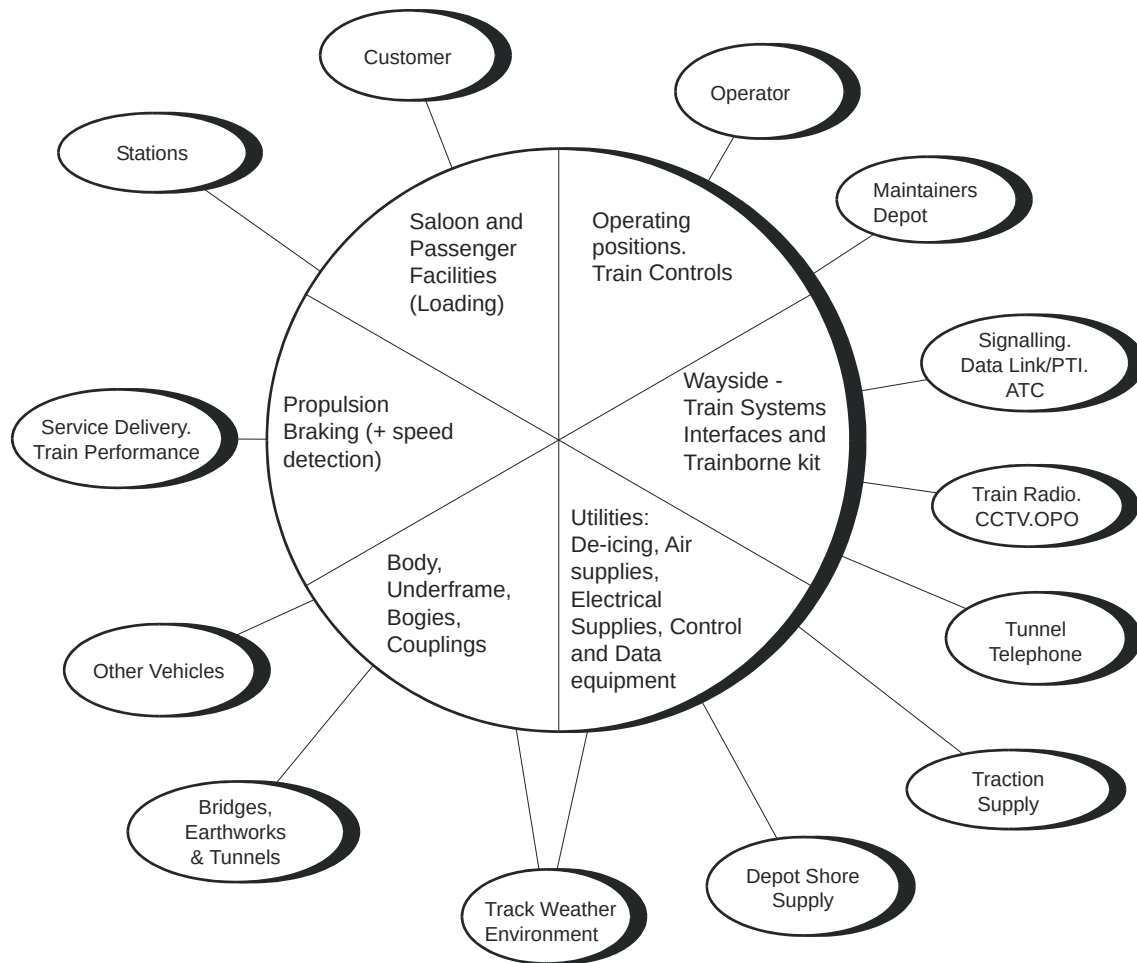


Figure 2 – Systems context diagram

Note: This is not an exhaustive illustration and suppliers may identify and develop other interfaces.

- 3.2.1.3 The impact of rolling stock operations on adjacent railway operations and all other neighbours shall be minimised as far as reasonably practicable.

3.2.2 Kinematic limits

Rolling stock shall comply with the kinematic limits for the line or lines over which it is required to pass.

Note: Reference should be made to 1-156.



3.2.3 Current collector system

- 3.2.3.1 The current collector system shall not damage or be damaged by the conductor rail system.
- 3.2.3.2 On lines which have passenger train operation above ground, at least 30% of the train fleet shall be fitted with de-icing fluid tanks and dispensing equipment which shall:
- have a de-icing fluid capacity of at least 900litres per train;
 - have three dispensing units, one for the negative rail and one for each of the positive rails;
 - dispense 1.2ml nominal of de-icing fluid onto every metre of each conductor rail;
 - have a dispensing rate adjustable between 0.5ml and 3.0ml per metre;
 - permit re-filling of the tank from either side of the train at a rate of not less than 450litres per minute;
 - have a facility to drain the tank of fluid as part of the summer preparation maintenance task;
 - be able to accommodate the de-icing fluid which is Ethylene Glycol and Water in equal parts and which will contain a dye and which may contain mineral and metallic contaminants in suspension;
 - be able to accommodate the de-icing fluid known as Magic Ice Stop;
 - minimise fluid loss and leakage during re-filling, conveyance on the train and dispensing;
 - incorporate a dial gauge indicator on either side of the train to indicate to a maintainer filling the tank the amount of fluid in the tank;
 - report the fluid level to the Train Monitoring System;
 - dispense fluid when commanded by the Train Monitoring System;
 - not dispense fluid when the train is in a tunnel.
- 3.2.3.3 On lines which have passenger train operation above ground, sleet brushes shall be fitted to the front end of the leading bogie of every outer end car. The sleet brush shall be fully effective in removing snow and frost from the conductor rails over the full train speed range. The application and retraction of the sleet brushes shall be controlled by the Train Monitoring System, which shall ensure that only the sleet brushes at the leading end of the train are deployed.

3.2.4 Power supply

- 3.2.4.1 Rolling stock shall:
- be compatible with the traction supply system for the routes over which it operates;
 - operate over the range from 450V (maximum) to 800V (minimum);
 - initiate motoring above 450V, continue motoring between 400V and 450V, although at reduced performance;
 - not be damaged by voltages lower than 400V traction supply;
 - continue to operate normally with either the positive or negative poles of the supply being earthed;
 - select from several preset values the maximum regeneration voltage limit depending on the geographic location of the train.
- 3.2.4.2 Means shall be provided to permit maintenance staff to inhibit regeneration, including:
- the ability for one person to make the change to a train within fifteen minutes;
 - locating the facility in either the cab or the saloon or both (i.e. access to external side of train or underframe not required);
 - limiting the voltage to a level no higher than 5% over nominal supply voltage.

3.2.5 Wheel rail interface

- 3.2.5.1 The train shall, under all envisaged environmental and load conditions, be compatible with the track systems of the route over which it operates.
- 3.2.5.2 Unless analysis indicates an alternative would be better, the LT5 wheel profile shall be used.
- 3.2.5.3 Effects of adverse interaction at the wheel and rail interface shall be as low as reasonably practicable under both normal and reasonably foreseeable and credible abnormal operating conditions including:
- a) wheel and rail (including sliding past signals);
 - b) wheel flats;
 - c) rail burns;
 - d) stalled trains due to wheel spin;
 - e) de-railments;
 - f) mal-operation of track circuits;
 - g) rolling contact fatigue and corrugation;
 - h) thermally initiated squat-like defects resulting from limited creep wheel spin control.
- 3.2.5.4 If the wheel load/wheel diameter ratio P_2/D is greater than 15, where:
- P_2 = wheel load in tonne in Full Load condition,
- D = fully worn wheel diameter in m,
- then the effect on the track shall be assessed.
- 3.2.5.5 Sanders shall be fitted to ensure that safe and optimum use is made of the adhesion levels between wheel and rail. The number of sanders, their location and the sand dispensing rate shall be as determined in the adhesion management strategy appropriate for the line(s) over which the train shall run.
- 3.2.5.6 Equipment to lubricate the interface between wheel and rail shall be fitted. Every bogie shall have provision to fit this equipment, such provision being space, mounting holes and a suitable mating surface. This equipment shall consist of either:
- a) Solid stick lubricant dispensers evenly dispersed along the train which shall be fitted to:
 - I. 30% of wheelsets to dispense at the gauge corner,
 - II. 25% of wheelsets to dispense on the wheel tread;
 - b) Liquid lubricant dispensers fitted to the outer end of each train.
- 3.2.5.7 Space, power, mountings and cable routes shall be provided on the underframe of at least 20% of the train fleet to accommodate the Company's Automated Track Monitoring System (ATMS) on the train.

Note: This space could be shared with the space allocated to other equipment fitted to a proportion of the fleet such as the de-icing tanks.

3.2.6 Train Protection and Detection

- 3.2.6.1 Rolling stock shall be fitted with a train protection system, compatible with the associated track-side signalling equipment in place on the routes over which the train runs.
- 3.2.6.2 Every individual vehicle shall be capable of operating track circuits, axle counters and position detectors in both static and dynamic modes.

3.2.6.3 A train shall have:

- a) a minimum of four axles,
- b) a minimum load per axle of 5 tonnes if not equipped with tread braking,
- c) a minimum load per axle of 4 tonnes if equipped with tread braking,
- d) a maximum separation of 13.5m between any two adjacent axles in the train,
- e) a minimum separation of 13.1m between the outermost axles of the train,
- f) a maximum electrical resistance of 0.01Ω between the wheels of an axle when tested statically.

3.2.6.4 The distance between the coupler and leading axle and between the coupler and tripcock (if fitted) shall be compatible with the signalling and fouling points on the line over which the train runs.

3.2.6.5 At such locations where a trainstop and tripcock system is being used for train protection, the tripcock shall:

- a) be compatible with the train stops defined in:
 - I. 1-195;
 - II. RGSs GM/RT2149, GE/RT8018, where the Rolling stock is required to run on NR infrastructure.
- b) apply the emergency brake when tripped;
- c) invoke speed control that ensures that train speed cannot exceed 16 km/h for three minutes after the tripcock is manually reset. It shall not be possible to:
 - I. defeat the three minute delay using any sequence of operation of any train controls;
 - II. cause the delay to start using any sequence of operation of any train controls other than the resetting of the tripcock.
- d) have a "tripcock delay" indicator at the operators position which illuminates when the tripcock is reset and extinguishes at the end of the three minute delay.
- e) be capable of withstanding interaction with the train stop up to maximum train speed;
- f) not require the operator to leave the driving position to reset the tripcock;
- g) interrupt the round train circuit if the tripcock at the rear of the train is tripped.

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

3.2.6.7 Train borne signalling equipment shall be appropriately integrated into the train systems for the function concerned.

3.2.6.8 The interface between the train borne signalling protection device and the train safety circuits shall have an integrity level not less than SIL4 (Safety Integrity Level) given in BS EN 50126.

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

3.2.7 Information and Control Interfaces

3.2.7.1 Sufficient interfaces to systems external to the train shall be provided by the Supplier such that the Train Monitoring System, the Customer Information System (CIS) and other systems requiring a data link to and from the train can function in accordance with all requirements.

3.2.7.2 Information shall be shared between train borne systems and allocated between off-train systems so as to minimise or eliminate duplication as far as reasonably practicable.

Note: Further requirements can be found in 1-312.

3.2.8 Environmental conditions, dust, heat, smoke and fluids

3.2.8.1 Rolling stock shall be designed and manufactured to:

- a) operate (including start-up and shut down) at full performance under reasonably expected climatic conditions encountered in the operating environment;
- b) cope with the fluctuations in climatic conditions between surface and tunnel running that occur throughout the routes over which that rolling stock operates.

3.2.8.2 Emissions from consumable materials or components used on the rolling stock which are deposited in tunnels or elsewhere on the infrastructure or which become air borne particles, shall be controlled so that they do not constitute an unacceptable risk to health.

3.2.8.3 The generation of dust shall be minimised:

- a) without prejudicing compliant friction brake performance, when friction braking is required;
- b) by maximising the use of dynamic braking;

3.2.8.4 Heat emitted shall be reduced as low as reasonably practicable and shall be ducted and directed to minimise the uptake of heat by other train systems is minimised. The heat emitted by the train and its principal components under a range of different operating conditions shall be declared at the final design stage.

Note: Principal components might be cab and saloon Heating Ventilating and Air Conditioning (HVAC) traction motors, friction brakes, brake resistors. Operating conditions might be extremes of ambient temperature, maximum traction, coasting, maximum friction braking, maximum dynamic braking through rheostatic and regenerative braking. This information will be used to assess the effects of the train on the Tunnel and Public Areas Ventilation to indicate any changes that may be necessary to those facilities in consequence.

3.2.8.5 The train shall operate without its performance being degraded outside design limits by dust, including pollen and similar airborne particles, found in the LU operating environment.

Note: Tunnel dust

- a) The passage of new trains can disturb long-standing deposits of dust and so initial dust levels can be higher than expected, unless control measures are taken.
- b) The major components are iron/iron oxides (typically 60%), siliceous matter (typically 25%), the remainder being largely organic matter and other wear metal oxides from various sources.
- c) It is recommended that analyses be conducted on samples of dust representative of the tunnels in which the train will operate.

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

3.2.8.7 Adhesion improvement aids, windscreen washer, ice prevention and other such fluids shall be dispensed accurately and only as necessary.

3.2.8.8 Refrigerant units shall be located in a safe place, away from arcing risk areas and be labelled to indicate the presence of primary refrigerant.

3.2.9 Noise inside and outside trains and whistle noise

- 3.2.9.1 Unless otherwise specified, all measurements shall be made in accordance with BS EN ISO 3095 and BS EN ISO 3381.
- 3.2.9.2 The noise limits specified shall be reduced by 3 dB(A) if significant pure tones in the range 200 Hz to 4000 Hz are present. Pure tone noise shall be considered significant in this context if any 1/3 octave band sound pressure level is 5 dB, or more, higher than the average of the two adjacent 1/3 octave band levels that contain no pure tone or 'tonal' noise.
- 3.2.9.3 The requirements for noise levels inside the train when it is stationary are:
- the noise level in the car and cab (where separate) shall not exceed 65 dB(A) measured using the Fast time constant with all auxiliary equipment operating at its greatest noise output capacity. The noise level in the car interior at any point along the car centre-line shall be measured at both 1200mm and 1600mm above the floor and not less than 600mm from the end of the saloon;
 - the noise levels in the cab (where separate) shall be measured 1000mm above the floor and not less than 200mm from any wall;
 - the simultaneous operation of all saloon doors on one side of the car (with the audible warning beepers disabled) without operation of any other auxiliary equipment, shall not produce a noise level exceeding 75 dB(A) measured using the Fast and Impulsive time constant. The noise level shall be measured at any point along the car centre-line at both 1200mm and 1600mm above the floor.
- 3.2.9.4 The requirements for noise levels inside the train when it is moving on a surface section are:
- The average inter-station noise levels (L_{eq}) in the train running at the scheduled speed profile of the upgraded railway shall not exceed 72 dB(A). The noise level shall be measured at any point along the centre-line of the car at both 1200mm and 1600mm above the floor and not less than 600mm from the end walls, with all auxiliary systems operating normally and simultaneously;
 - The average inter-station noise levels (L_{eq}) in the cab (where separate) shall not exceed 70dB(A), measured at any point 1000mm above the floor and 200mm from any wall.
- 3.2.9.5 The requirements for noise levels inside the train when it is moving in underground sections are:
- The average inter station noise levels (L_{eq}) in the train interior, when running at the scheduled speed profile of the upgraded railway in any underground tunnel with all auxiliary systems operating normally, shall not exceed 75dB(A). The noise levels shall be measured at any point along the centre-line of the car at both 1200mm and 1600mm above the floor and not less than 600mm from the end walls;
 - The average inter-station noise levels (L_{eq}) in any driving cab (where separate) shall not exceed 72dB(A) measured at any point 1000mm above the floor and 200mm from any wall.
- 3.2.9.6 The requirements for noise levels outside the train when it is stationary on a surface section are that the noise level with all auxiliary systems operating shall not exceed 65dB(A) at any point along the length of the train on either side. The noise level shall be measured at a position 7.5m horizontally from the centre-line of the track and at any point between 1200mm and 1500mm above the top of the running rail. A second microphone position at a height of 3500mm above the top of the running rail shall be used if significant sound sources are present in the upper part of the car under test.

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

3.2.9.8 A whistle system shall be fitted to all driving positions of rolling stock, which meets the test requirements stated in Table 2 below:

Train type	Position of Measurements	Distance	Sound pressure level dB(A) at maximum output	Height of test equipment microphone
Passenger train-front of train – “high” position on whistle control	along the extension of the centre-line of train at the specified distances from the whistle and front of train	1m	125 minimum. 130 maximum.	Level with whistle
		1m	120 maximum	At any height up to and including 1.6m above rail
		300m	73 minimum	1.6m above rail

Train type	Position of Measurements	Distance	Sound pressure level dB(A) at maximum output	Height of test equipment microphone
Passenger train-front of train – “low” position whistle control. Also at shunting panel positions if shunting panels fitted.	Along the extension of the centre-line of train at the specified distances from the whistle and front of train	1m	120 maximum.	At any height up to and including 1.6m above rail
		150m	69 minimum	1.6m above rail

Train type	Position of Measurements	Distance	Sound pressure level dB(A) at maximum output	Height of test equipment microphone
Non-passenger trains – speed limit 30mph – at ends of train	along the extended longitudinal centre-line of the vehicle at the specified distances from the buffer beam of the vehicle.	1m	115 minimum	Up to and including 1.6m above rail
		1m	125 maximum	1.6m above rail
		130m	73 minimum	1.6m above rail

Table 2 – Whistle performance measurements

3.2.10 Shock and vibration

- 3.2.10.1 Ground-borne vibration resulting from train movement shall be minimised to levels that are as low as reasonably practicable.
- 3.2.10.2 Specific acceptance and operating criteria to be met by each type of rolling stock shall be established. As regards vibration the following apply:
- a) Rolling stock and its associated equipment shall be manufactured to minimise inherent vibration;
 - b) Rolling stock shall be designed and maintenance instructions shall be produced in order to prevent acts or omissions during maintenance from causing vibration to be induced.

3.2.11 Electromagnetic compatibility (EMC)

- 3.2.11.1 Within the overall obligation for rolling stock to be electromagnetically compatible with its environment, particular attention shall be paid to compatibility with safety critical systems such as signalling and train protection.

Note: LU's requirements for EMC are given in S1222, S1193 and S1196.

3.2.12 Forward facing CCTV camera

- 3.2.12.1 The outer ends of each train shall be fitted with a forward facing CCTV camera and recording equipment compliant with GM/GN2606.

3.3 Condition and maintenance

3.3.1 General

- 3.3.1.1 Trains shall be designed such that they may be easily maintained and kept clean.
- 3.3.1.2 Where possible, degradation shall be identifiable by the maintainer before failure occurs.
- 3.3.1.3 Where possible, the Train Monitoring System shall be used to identify and report degraded and failed conditions so that maintenance action can be taken before a service affecting failure occurs.
- 3.3.1.4 A full task analysis shall be carried out at the design stage for each of the maintenance tasks to be undertaken. This shall show how each task can be carried out within the time claimed for the task and to the correct quality by the maintenance staff within the constraints of the depot, their capabilities and the tools available to them.
- 3.3.1.5 Computer simulations and physical mock-ups shall be used to demonstrate that the proposed design can be maintained by the full population of maintenance staff using only the tools specified in the maintenance manual. These shall be followed by practical demonstrations as part of first article inspection and type testing.
- 3.3.1.6 It shall be possible to access components for repair and overhaul with a minimum of dismantling and disturbance to other parts of the train.
- 3.3.1.7 There shall be a minimum number of fixings for panels, covers and other means of access. Where possible they shall be quick release and it shall be possible to identify easily that they are not correctly fastened.
- 3.3.1.8 The design shall minimise the opportunity for errors during routine maintenance and component replacement activities. Error proofing devices shall be designed into the train and where applicable, gauges, jigs or alignment devices shall be provided to confirm correct set up.

- 3.3.1.9 A Whole Life Cost model shall be used to evaluate the maintenance and maintainability of the train. It shall be used to determine the optimum compromise between initial and ongoing cost.
- 3.3.1.10 As far as possible, Special tools and test equipment shall not be needed to carry out maintenance. Standard tools and test equipment is preferred.
- 3.3.1.11 Information about failures, poor performance and relevant corrective actions that may be relevant to common stock and components in the LU network shall be formally notified to and acknowledged by LU, to enable others who may be affected to be informed.
- 3.3.1.12 In order to achieve consistency across the LU network in the referencing of rolling stock physical components and systems, they shall be indexed in accordance with 1-187 (LU Category 1 Standard).

3.3.2 Cleaning

- 3.3.2.1 The design of the train shall facilitate the maintenance and cleaning of the interior and exterior of the train in order to:
- a) control the risk of infestation;
 - b) control the risk of health problems for staff and passengers;
 - c) control the potential fire hazard posed by accumulated waste;
- 3.3.2.2 The use of all maintenance and cleaning materials shall be controlled by documented processes that ensure that their use does not result in damage to equipment or to the appearance of surfaces.

Note: Further requirements can be found in 1-383 (LU Category 1 Standard).

3.3.3 Competence of staff

- 3.3.3.1 All staff undertaking the maintenance of the rolling stock shall be:
- a) trained against defined work or process instructions;
 - b) tested and certified to demonstrate that they possess the practical competence to undertake the tasks allocated to them;
 - c) certified for all tasks that are safety critical (as defined by the railways safety critical work legislation);
 - d) subject to adequate supervision to demonstrate that only staff who are certified to carry out the work are allocated maintenance tasks;
 - e) subject to a monitoring process.
- 3.3.3.2 The person responsible for the acceptance and sign-off of any work carried out on a car shall be identified.

3.3.4 Train Maintenance Regime

- 3.3.4.1 The Maintenance Regime shall be managed to deliver the following:
- a) achievement of design life of equipment;
 - b) optimisation of reliability;
 - c) achievement of availability targets;
 - d) maintenance of a good passenger environment throughout the train life;
 - e) maintenance of external condition of train;
 - f) maintenance of asset condition;
 - g) support of safe operation.

3.3.4.2 The Maintenance Regime shall be established by a structured analysis (which may include use of data on similar equipment used elsewhere under a similar operating context as a template) of:

- a) service requirements;
- b) operating environment;
- c) rolling stock design;
- d) maintenance facilities;
- e) historical data.

3.3.4.3 The Maintenance Regime shall be submitted for review and acceptance by LU.

3.3.4.4 In determining the Maintenance Regime, the following shall be established and declared:

- a) the operational context;
- b) the philosophy for maintenance over the life of the particular rolling stock;
- c) the maintenance procedures and tests to be performed;
- d) the standards to be achieved;
- e) how the train Maintenance Regime and Maintenance Plan will support and be a fundamental part of the Safety Case for the particular lines on which the train operates.

3.3.4.5 A fleet maintenance management system shall be operated to enable the identification and thereby the prevention from entering service of rolling stock below Minimum Acceptable Condition Standard (MACS) or outside declared limits.

3.3.4.6 The Maintenance Regime shall ensure that a process exists to manage operations when train condition or performance falls below the MACS or when declared maintenance limits are temporarily exceeded.

3.3.4.7 A review of the Maintenance Regime shall be carried out if there is a change to either:

- a) the duty cycle; or
- b) the operating environment of the train.

Note: Examples of the changes are (a) an increase in mileage or (b) the transfer of a train from one line to another which may have different inter-station distances. Hence for a given train mileage, the duty cycle of the equipment will be different.

3.3.4.8 Alterations to any part of the Train Maintenance Regime shall:

- a) be subject to a change control system and be documented;
- b) not be implemented until their implications have been considered and formally accepted by LU.

3.3.4.9 The Maintenance Regime shall be reviewed not less than once every three years and updated as required, to take account of rolling stock utilisation.

3.3.4.10 The Maintenance Regime shall ensure that the Maintenance Plan and MACSs are reviewed:

- a) periodically, as defined in the Maintenance Regime;
- b) whenever a change occurs (e.g. duty cycle, operating context including an issue of a new Defective In Service Instructions (DISI) or revision of a current DISI, engineering modification);
- c) after the occurrence of a defect rated at MACS Grade E or F.

3.3.4.11 The Maintenance Regime shall define the interval of reviews.



3.3.4.12 Prior to new or modified trains being considered as complete, the Maintenance Regime shall be:

- a) fully documented, containing the maintenance information to sustain the new and modified trains in a safe condition;
- b) available to staff to enable them to be suitably instructed.

3.3.5 Maintenance Regime documentation

3.3.5.1 Maintenance documentation that supports the Maintenance Regime shall be kept up-to-date and shall include the following:

- a) definitions;
- b) philosophy for maintenance;
- c) the Train Maintenance Plan;
- d) illustrated parts list;
- e) "as built" drawings and electrical, pneumatic and software schematics;
- f) instructions for maintenance and repair, including tools, test equipment and facilities required and standard to be achieved;
- g) star chart;
- h) post maintenance and repair test instructions and pass and fail criteria;
- i) MACS, consistent with DISIs;
- j) fault finding guide;
- k) operating manual;
- l) emergency recovery plan;
- m) equipment overhaul manual;
- n) software and hardware configurations;
- o) supplementary information, as required to complete the documentation for the Maintenance Regime.

3.3.5.2 Maintenance manuals shall be made available to LU, the custodian and the maintainer in a controlled manner.

3.3.6 Train Maintenance Plan

3.3.6.1 A Train Maintenance Plan shall:

- a) be delivered as part of the Train Maintenance Regime;
- b) be produced so that the following requirements are included:
 - I. a series of tests and inspections, usually known as Train Preparation including but not limited to those shown in Table 3. They and any changes to them shall be agreed by LU and recorded in the appropriate Train Maintenance Regime;
 - II. a second level of tests and inspections;
 - III. a third level of tests, inspections and calibration;
 - IV. additional levels of maintenance as required by the stock design and duty to maintain the condition and safety levels of the stock;
 - V. arrangements for testing units which are made into trains.

Type	System or equipment	Requirement
Train Systems	Braking System	Prove: a) Emergency brake applies and releases quickly on all cars, in response to demand b) All emergency brake system safety devices function at operational cab c) Friction brake generates a retarding force d) Service brake operates with no identified defect



Type	System or equipment	Requirement
	Door System	Prove: a) Saloon sliding doors open only in response to a valid combination of inputs b) The circuit on each car for detecting open doors is functioning c) Traction is inhibited when any saloon sliding door is open d) Correct side door enable system override will automatically re-set after use
	Batteries	Check functioning at outer ends of trains
	Air System	Check Main line air pressure is automatically maintained with normal limits
	Passenger alarm	Prove: a) the audible cab alarm sounds in response to operation of Passenger Alarm Button (or handle) b) The “mute” facility operates
	Automatic Train Operation (ATO) / Automatic Train Protection (ATP)	Prove: a) Loss of safety code will initiate emergency brake application b) Traction is initiated only in response to a valid combination of “Start” commands
	Train radio alarm	Prove operation
	Public address	Prove operation
Operator's position tests	Windscreen	Check for clear vision
	Headlights	Prove operation
	Tail lights	Prove operation
	Stabling light	Prove operation
	Calling on light	Prove operation
	Whistle	Prove operation
	Headstock isolating cocks and switches	Check in correct running position
	Fire extinguisher	Check present and serviceable
	Emergency equipment	Check present
	Isolating switch seals	Check present and intact
	Tunnel telephone	Check present
Middle cab and uncoupling non driving motor (UNDM) checks	Shunting control cabinets and “middle cabs”	Check secure and free from interference
	Headstock isolating cocks	Check in correct running position
	Passenger saloon	Check free from hazards
Saloon Checks	Seats	Check security
	Lighting	Prove operation
	Accessible inter-car isolating cocks	Check in correct running position
Service fault records	Fault recording card, or logbook	(Depots) – check for reported defects, and take appropriate action

Table 3 – Train preparation tasks

- 3.3.6.2 A Maintenance Plan shall comprise a series of maintenance activities structured to follow the maintenance levels outlined in the Train Maintenance Regime.
- 3.3.6.3 The intervals, content and activities of the Maintenance Plan shall be defined, including:
- a) measurement technique for the intervals between maintenance (e.g. service hours, distance run (km) or time);
 - b) a limit for each activity after which the train shall be withdrawn from service until the maintenance has been completed.
- 3.3.6.4 The Train Maintenance Plan shall:
- a) form part of the Train Maintenance Regime, which shall set out how the continuing adequacy of the Train Maintenance Plan will be confirmed;
 - b) be submitted to LU for review and acceptance:
 - I. prior to the initial entry of trains into service;
 - II. in the event of any changes to the Train Maintenance Plan.
- 3.3.6.5 The following changes require the acceptance of LU:
- a) increasing the interval between a routine maintenance or inspection activity;
 - b) changing the structure of a routine maintenance activity (e.g. moving from service days to hours in service);
 - c) significant changes to the work content or order for a particular package of tasks.

3.3.7 Records

- 3.3.7.1 The following shall be recorded:
- a) work due on rolling stock;
 - b) work done on rolling stock;
 - c) the operational status of rolling stock;
 - d) changes to Maintenance Regimes;
 - e) changes to Maintenance Plans;
 - f) traceability of safety critical components. This is to include traceability of all cars on which safety critical traced components have been used and all safety critical traced component changes;
 - g) traceability of safety critical work;
 - h) all faults found on any train including those which:
 - I. cause delay to service;
 - II. result in unscheduled maintenance to correct them;
 - III. result in a train safety irregularity;
 - i) all staff training and assessment;
 - j) all occasions where rolling stock outside maintenance limits is operated or offered for service;
 - k) modifications to trains or components;
 - l) Cases for Continued Safe Operation.
- 3.3.7.2 The retention periods for records including those that are to be retained for the whole life of the rolling stock shall be defined in the Maintenance Regime.

3.3.8 MACS

- 3.3.8.1 MACSs shall be:
- a) produced to define acceptable and unacceptable levels of degradation of asset components and systems and shall be agreed with LU;
 - b) used to determine whether an asset is safe for service by setting acceptable and unacceptable conditions;
 - c) used to inform and support the DISI.

3.3.8.2 The scope of the MACS shall cover every system and major component for the asset concerned and shall define the following:

- a) minimum acceptable condition;
- b) most likely unacceptable conditions, related to wear or functionality;
- c) hazardous consequences of any unacceptable condition;
- d) category;
- e) action to be taken;
- f) timescales for the actions.

3.3.8.3 The MACS shall define the types of sub-standard conditions and categorise them in accordance with Table 4, in which:

- a) Grades A, B and C are acceptable conditions for an asset;
- b) Grades D, E and F are unacceptable conditions, although assets may run with a small number of Grade D defects, if absolutely necessary.

Grade	Hazard definition	State of asset that Grade represents	Action required, if hazard found
A	General observation	As new or condition just following overhaul	Record during routine condition inspections
B	Minor point, not likely to cause a problem	Acceptable condition after intrusive preventative maintenance	Fix on next scheduled restoration maintenance activity
C	Minor defect	Minimum acceptable condition for the equipment to remain in service.	Fix on next planned maintenance activity
D	Serious defect, but not a major hazard.	Below minimum condition required for asset to enter service.	Train can remain in service until the end of the service day. It cannot be re-offered for service unless it is impractical to rectify the defect immediately. Continued use of asset may be acceptable for a limited period, providing LU grants approval and the substandard condition is monitored.
E	Major defect, asset unfit to use	Below minimum condition required for asset to remain in service.	Remove asset from service until defect has been rectified.
F	Major Safety Hazard, asset unfit to use. Circumstances which allowed this fault to develop to be investigated in depth. The investigation shall include checking a sample of other assets of similar design or with similar Maintenance Regime to determine whether the fault is a one-off incident or exists elsewhere.	A major breakdown in asset integrity, either through design deficiencies or ineffective maintenance.	Remove asset from service. Record in detail the defect. Formally record on the Notifiable Incident Report. Asset not to return to service until defect has been rectified. Report as for E Grade defect and in addition to LU.

Table 4 – Categorisation of sub-standard conditions

3.3.9 Maintenance

- 3.3.9.1 The intervals between maintenance work shall be determined in accordance with 3.3.6.
- 3.3.9.2 An auditable system shall be operated for the management of trains that are not fit for service, which shall include methods of:
- a) identifying a train as unfit for service;
 - b) ensuring that the sub-standard condition has been identified and rectified, prior to the train being offered for service;
 - c) ensuring the appropriate post-maintenance tests and inspections are undertaken before the train returns to service.
- 3.3.9.3 A train offered for service shall be fit for use. The condition and all maintenance shall be within the stated limits. Any outstanding work shall be assessed by a competent person in accordance with clause 3.3.8.3 and shall be recorded in the rolling stock records.
- 3.3.9.4 A train shall only remain in service providing all its maintenance continues to be within the declared maintenance limits.
- 3.3.9.5 In exceptional circumstances following service disruption, for any train that stables in a location where a Train Preparation activity cannot be carried out and the train is therefore not fit to be offered for service, the limit shall be extended to a maximum of a further 12 hours to allow the train to be moved in passenger service to a suitable place. Every occasion of this shall be recorded in the rolling stock records.
- 3.3.9.6 A clearly defined handover shall take place when the train is ready for service.
- 3.3.9.7 The register of hazardous materials shall be consulted in the planning of maintenance activities; particularly in relation to unscheduled maintenance, such as cutting, welding or burning.

3.3.10 Faults in service

- 3.3.10.1 A system shall be put in place to enable the maintainers of rolling stock to receive reports of failure, including those which:
- a) cause a delay to service;
 - b) result in unscheduled maintenance to correct;
 - c) result in an alleged train safety irregularity;
 - d) render the train condition below the minimum that is acceptable for entry to service.
- 3.3.10.2 Faults shall be recorded in a way that reports generated for or to LU permit comparisons to be made between different types of train used on the LU network.
- 3.3.10.3 Instructions on fault rectification shall be:
- a) in or linked to the Operation Manual;
 - b) compatible with the DISI.

3.3.11 Post maintenance testing

- 3.3.11.1 A system shall exist to ensure that the train is tested and inspected to demonstrate that it has been correctly reassembled following:
- a) maintenance;

- b) fault finding;
- c) dismantling.

3.3.11.2 When individual units of cars are coupled into trains for service, test and inspections shall be performed to prove key circuits operate across couplings (known as a 're-form test')

3.3.12 Monitoring and review of train performance

3.3.12.1 Train performance shall be reviewed on a periodic basis to ensure that the Maintenance Regime is continuing to achieve the goal of safe and reliable trains.

3.3.12.2 The review described in 3.3.12.1 shall include reference to actual and predicted performance in the following areas:

- a) safety;
- b) customer satisfaction indices;
- c) mystery shopper indices;
- d) train availability;
- e) train reliability;
- f) faults found during routine maintenance;
- g) proportion of routine and casualty maintenance;
- h) rate of wear of consumable components including wheels and wheel treads;
- i) results of independent review of train physical condition and functional performance inspections (for existing stocks this is known as the routine train condition inspection).

3.3.12.3 The performance of the train and its systems shall be monitored to:

- a) enable reviews to be carried out and trend analysis to be undertaken on specific failure modes;
- b) enable the reviews and trend analyses to be undertaken on component failures;
- c) demonstrate that the performance of critical components is maintained during the life of the train;
- d) allow information to be shared between all parties operating across the LU network to assist in risk assessment and prevention of incidents.

3.3.12.4 The arrangements and intervals between the reviews of failure described in 3.3.12.3 shall be documented in the Train Maintenance Regime.

3.3.12.5 Routine train condition inspections shall be conducted by an entity independent of the maintainers, as part of the review described in 3.3.12.2 i); and the report made available to LU, as part of the train assurance monitoring process. The MACS shall be used as the criteria for the inspection.

3.3.12.6 Intervals between reviews:

- a) of failures shall not exceed three months;
- b) of the Maintenance Plans shall not exceed one year.

3.3.13 Specific maintenance requirements for critical systems and components

3.3.13.1 The criticality of rolling stock systems and components shall be assessed and identified, as described in 3.4.5 and 3.4.6.

3.3.13.2 Systems and components identified as critical shall:

- a) have appropriate Maintenance Regimes and MACSs developed for them;
- b) be implemented with records that ensure traceability of:
 - I. work; and
 - II. components throughout the supply chain.

- 3.3.13.3 During a Warranty or period when a Supplier holds Design Authority for a train or part of a train and a substandard condition in a critical component is discovered and continued use of that component is desired, the Supplier shall be responsible for producing a justified case for continued safe operation pending rectification of the defect and the underlying cause. See LU Standard S2453, Control of Rolling Stock Sub-Standard Conditions.

3.4 Safety and reliability

3.4.1 General

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

Note 1: LU and its Suppliers associated with the provision and operation of rolling stock on the LU network, in addition to:

- a) supporting the particular aim of providing safe transit across London;
- b) meeting safety legislation;
- c) supporting the Safety Case for the Railway to operate;
- d) supporting the principle of managing safety risks,
are expected to give consideration to:
 - i) the safety risks associated with failure of rolling stock, operating principally in a tunnel environment;
 - ii) the reliability of the service,
 - iii) tolerance to other external faults and operational conditions.

Note 2: Due to the potential for equipment failures to create safety risks, the philosophy behind this standard is to treat safety and reliability as inseparably linked in LU network operations and thus to encourage suppliers to give consideration to the following:

- a) safety and reliability are built into rolling stock as an inherent part of the design;
- b) design records include documentation that demonstrates that risks have been managed to be ALARP;
- c) design outputs include adequate documentation to ensure safe and reliable operation throughout the life of the rolling stock;

In addition, there are particular aspects of rolling stock design, which are contained in other standards, that have specific prescriptive design requirements in order to manage the total system risk.

Note 3: LU's approach to risk management is defined in 1-526 (LU Category 1 Standard).

- 3.4.1.2 Throughout this standard, the requirements applying to design and review shall apply equally to new rolling stock and to modifications to existing rolling stock.

3.4.2 Design process

- 3.4.2.1 The design of rolling stock shall be:



- a) planned and managed in accordance with a formal, structured, documented and auditable process;
- b) undertaken by competent personnel.

3.4.2.2 Documentation of the design process shall include:

- a) identification of the checking and approval entities;
- b) a description of the methods to be followed;
- c) a description of the formal analyses to be undertaken.

3.4.2.3 It shall be demonstrated that:

- a) the requirements of LU have been adequately captured and verified;
- b) the requirements have been embodied in the concept design.

3.4.2.4 The systems and sub-systems shall:

- a) be concisely listed to provide clarity as to how each system interacts with other LU interfaces, e.g;
 - I. wheel and rail;
 - II. shoe and power system;
 - III. Platform Train Interface (PTI);
- b) be supported by assurance for:
 - I. all parts of the train that do not interact with any other LU system;
 - II. those parts that interact within the train itself;
 - III. the train combined with any with which it interacts, in with the wider LU system context.

3.4.2.5 The design process shall consider, in respect of each system or component:

- a) its physical arrangement;
- b) its defined interaction with other components and systems;
- c) its intended usage;
- d) the processes and documentation associated with maintaining it within its designed operating limits.

3.4.2.6 The design process shall take account of the full life cycle of the rolling stock including:

- a) testing and commissioning;
- b) hand-over and acceptance;
- c) deployment, including mixed fleet operation ('interrunning'), if appropriate;
- d) maintenance;
- e) storage;
- f) refurbishment and re-commissioning;
- g) disposal;
- h) making provision to collect what useful vehicle service performance, fault and defect information can reasonably practicably be captured in service and made available in appropriate format to support the efficient maintenance and operation of the train;
- i) obsolescence, particularly regarding safety-related items, microcomputers, microprocessors, integrated circuits and software.

3.4.2.7 All proposed changes in the operation of rolling stock shall include:

- a) a review of the original design conditions and specifications;
- b) a validation that the rolling stock will continue to work within approved design parameters.

3.4.3 Design Reviews

3.4.3.1 Regular planned design reviews shall be:

- a) conducted at all stages of the design;
- b) carried out by persons who were not directly responsible for producing the design.
- c) notified sufficiently in advance to allow LU or its representatives to participate.

3.4.3.2 The design reviews in 3.4.3.1 shall include:

- a) ensuring that the requirements for the design have been comprehensively captured;
- b) assessment of compliance with the requirements including performance, safety, reliability, operability and maintainability;
- c) assessment of the proposed validation and verification activities;
- d) any additional functionality inherent in the product that is not directly linked to a requirement;
- e) design calculations for their accuracy, applicability and comprehensiveness;
- f) feedback as a result of any testing;
- g) identification of any areas where the design could be improved.

3.4.3.3 The proceedings, conclusions and agreed proposals arising from design reviews and any other form of design scrutiny shall be formally documented and implemented.

3.4.3.4 An auditable change control system shall be used to control and document the review, approval and implementation of all design changes.

3.4.3.5 A formal review of each change shall be carried out to identify:

- a) potential impacts in other areas of the design and to ensure compatibility;
- b) the means by which the configuration of affected rolling stock is to be actively managed during all stages of the product life cycle.

3.4.3.6 Proposed changes to the design, configuration or usage of rolling stock shall occur only with documented formal approval, assessed against the current design.

3.4.4 Safety reviews

3.4.4.1 Safety reviews shall be conducted utilising a structured systems approach to assess all areas of the design and maintenance of rolling stock to identify, quantify and reduce the risks to be ALARP.

Note: LU's approach to risk management is defined in 1-526 (LU Category 1 Standard).

3.4.4.2 The safety reviews shall include the following studies, as a minimum:

- a) Hazard Identification;
- b) Hazard Analysis;
- c) Risk Assessments and Risk Reduction Assessments;
- d) Failures Modes and Effects Criticality Analysis (FMECA) and Fault Tree Analysis (FTA) to enable the updating of LU's Quantitative Risk Assessment (QRA).

3.4.4.3 Risks associated with all aspects of the rolling stock shall be reviewed.

Note: The following aspects are amongst those that may be considered:

- a) movement;
- b) access;

- c) containment;
- d) operating in 'degraded mode' including in-service failure;
- e) structural failure of rolling stock or components;
- f) interfaces;
- g) precursors to specific potential risks;
- h) precursors to LU Top Event Risks (listed in 3.4.5.2).

3.4.4.4 The proceedings, conclusions and proposals arising from safety reviews shall be formally documented including a statement on the assumptions made and the sources of the information included in the analyses. The findings shall be fed back into the design process.

3.4.4.5 The results of the safety reviews shall be subject to independent review by a competent authority.

3.4.4.6 Minimum life requirements for all rolling stock components that affect safety shall:

- a) be documented;
- b) be justified;
- c) take into account:
 - I. the criticality of the component;
 - II. the associated maintenance regime.

3.4.4.7 Safety risks related to maintenance activities shall be identified and managed to be ALARP.

3.4.5 Hazards and assessments

3.4.5.1 New trains and modifications to existing trains shall be subject to risk assessments to demonstrate that the changes meet the LU Corporate Risk Model requirements and also address any relevant recommendations.

Note: The risk assessments might also consider any recommendations from incident or accident inquiries (e.g. Great Heck, Southall, Ladbroke Grove, Potter's Bar, Chancery Lane, Camden Town) which may be relevant and where such recommendations have not been incorporated in standards

3.4.5.2 The hazards associated with the following Top Event Risks shall be explicitly addressed:

- a) arcing;
- b) collision between trains;
- c) collisions, other than b);
- d) derailment;
- e) explosion;
- f) PTI;
- g) power failure;
- h) train fire;
- i) ventilation.

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

- a) passenger door incident;
- b) passenger accident;
- c) structural failure of rolling stock component or of car structural member;
- d) stalled train;
- e) loss of emergency lighting/ventilation, external lights or train whistle;
- f) communications failure;
- g) brake failure.

3.4.5.4 The following systems and components shall also be considered:

- a) those involved in mitigating the risk of platform train interface incidents (flooring, doors, and door opening and closing systems, Correct Side Door Enable (CSDE), One Person Operation Platform to Train CCTV (OPO CCTV), Passenger Emergency Alarm Brake (PEAB);
- b) those involved in mitigating the risk of derailment (wheels, bogies, bearings, axles, suspension, mountings, brakes, braking systems and controls);
- c) those involved in mitigating the risk of collision (speed systems, propulsion and their control systems, direction control, Electromagnetic Compatibility (EMC), brakes, braking systems and controls, interface with signalling);
- d) those involved in mitigating the risk of fire (virtually everything);
- e) those involved in mitigating the risk of arcing (virtually everything but specifically protection);
- f) those involved in mitigating the risk of ventilation failure (heating, ventilation and air cooling, ventilators);
- g) software in safety systems;
- h) communication systems;
- i) auxiliary systems;
- j) lighting systems;
- k) relays;
- l) any potential disabling failure;
- m) any other relevant system or component, identified as traceable, and treated accordingly in the Maintenance Regime.

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

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

3.4.5.6 Failures for systems, functions or components in Table 5 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 3.2.6.3.
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.



System, function or component	Classification	Requirement
Traction / Doors Interlocking	Vital	Not to motor with doors not proved closed.
Evacuation system	Vital	Not to suffer any blockage, subject to regular deployment testing of permanently installed evacuation aids.
Underframe 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.
Saloon door opening	Vital	Not to open without valid command.
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.
Overspeed protection (non-ATP)	High Integrity	Includes post-trip speed limiting.
Vehicle coupling	High Integrity	Includes Autocoupler uncouple control.
Suspension height (active suspensions)	High Integrity	Including overheight protection system.
Control Supply	High Integrity	Loss of supply to other High Integrity users.
Compressed air supply	High Integrity	Total supply loss (whole train).
Emergency lighting	High Integrity	Includes inability to sustain for specified period for any reason.
Emergency ventilation	High Integrity	Includes inability to sustain for specified period for any reason.
Saloon door operation	High Integrity	Includes emergency opening.
Saloon door control	High Integrity	Includes end door cut-out and correct side door enable and Zero Velocity Interlocking. Excludes Vital door functions listed above.
Radio	High Integrity	Deadman Alarm interface to radio.
Passenger Emergency Alarm	High Integrity	Excludes talk-back facility.
Public Address	High Integrity	Clarity and audibility.
Head, tail, stabling 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 5 – Classification of Vital and High Integrity functions

- 3.4.5.7 Any safety isolation, bypass or over-ride features proposed shall be specifically considered under the safety review process with the participation of the users.
- 3.4.5.8 The risks associated with the use and misuse of safety isolation, bypass or over-ride features shall be identified and action taken to ensure they are ALARP.

3.4.5.9 As far as is reasonably practicable all faults shall be detected and reported by the train including those on standby or backup systems. Backup and standby systems shall be exercised routinely during normal operation to ensure that hidden and dormant failures are revealed. Deployment of standby or backup systems shall be recorded and reported.

3.4.6 Safety critical components

3.4.6.1 The criticality of components shall be assessed and identified using a formal documented and auditable process.

3.4.6.2 Rolling stock components shall be categorised into three groups of safety criticality:

- a) Low risk – where failure of the component to perform as designed has no effect on safety;
- b) Medium risk – where the consequences of failure are moderate – i.e. where the likelihood of failure is low and impact on the railway of failure is not significant;
- c) Critical risk – where failure would or could have a significant impact on the railway.

3.4.6.3 Components shall be assessed and a safety criticality rating assigned. For existing rolling stock LU has assessed the criticality of rolling stock items using the technique outlined below.

3.4.6.4 Failures Modes and Effects Criticality Analysis (FMECA) shall be used to give quantified assessment in areas where the result is not obvious from an initial overview of a component.

3.4.6.5 The ratings for risk and consequence in Tables 6 and 7 respectively shall then be combined using Table 8 to reach a combined rating for each item and its consequential position in the low, medium and critical category.

Risk	Rating	Frequency of failure	FMECA scores
High	A	One failure in 12 months or worse	7 to 10
Medium	B	One failure per 10 years or worse, but better than one failure per 12 months	5 to 6
Low	C	Less than one failure per 10 years	0 to 4

Table 6 – Risks, ratings and FMECA scores

Consequence	Rating	Examples, in rolling stock context	FMECA scores
Major loss	1	Any loss of life or major injuries. Delays to train services in excess of 20 minutes. Damage or faults resulting in a train being withdrawn from service for more than 7 consecutive days.	6 to 10
Serious loss	2	No loss of life but minor injuries. Delays to train service of between 2 and 20 minutes. Damage or fault resulting in cars comprising a unit being out of service for more than two consecutive peak periods, but not more than 7 consecutive days.	3 to 5

Consequence	Rating	Examples, in rolling stock context	FMECA scores
Not significant	3	No loss of life, injury or illness. Delays to train services of less than 2 minutes. Damage or faults resulting in cars comprising a unit being withdrawn from traffic for not more than two consecutive peak periods.	0 to 2

Table 7 – Consequences, ratings and FMECA scores

3.4.6.6 The two ratings shall then be combined, as shown in Table 8 below to reach the safety criticality category:

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

Table 8 – Likelihood of Failure and Consequence

3.4.6.7 The assessment shall be carried out:

- initially by a competent person;
- using a method such as FMECA to give quantified assessment in areas where the result is not obvious from an initial overview of a component.

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

3.4.7 Change control

3.4.7.1 All proposed changes to components shall:

- be regarded as a change to the rolling stock where the change is a change in supplier for all critical risk components;
- include in (a) Critical risk rolling stock components, as defined in 3.4.6.2, in cases where there is a change of component supplier;
- be subject to approval through this process prior to implementation.

3.4.7.2 A change in 3.4.7.1 a) also includes a change in the supplier of replacement components, where the original design information is not available. The criteria of acceptability of such components, not manufactured from the original engineering drawings and specifications, shall be those for new components and be demonstrated to be fit for service, prior to being fitted to a train.

Note: This is often known as the “Reverse Engineering” of components.

3.4.7.3 All proposed modifications to rolling stock shall be:

- assessed using the same process for design of the new rolling stock and the assessment shall be proportionate to the change.

- b) not implemented until approval has been gained using the process shown in S1538.

3.4.8 Maintainability

3.4.8.1 The design of rolling stock shall allow for ease of all maintenance and servicing activities. As far as is reasonably practicable, all items that need to be routinely removed for maintenance or replacement shall be capable of being removed without disturbing other systems.

3.4.8.2 Types of visually similar but functionally different components shall be:

- a) such that it is not possible for one type to be fitted in place of another type;
- b) shown in documentation, made available during the design process, if requested, how the incorrect fitting of such similar types of equipment will be avoided during maintenance.

3.4.9 Reliability

3.4.9.1 Design and maintenance shall deliver rolling stock that reliably performs its time-tabled operational duty.

Note: Due to the intensity of the LU service and the tunnel environment in which it mainly operates, poor reliability of rolling stock can quickly lead to delays and cancellations, with additional stresses to the system, resulting in safety hazards. The latter include platform and station overcrowding, trains stalled in tunnels and an increased level of errors by people working in degraded or abnormal conditions.

3.4.9.2 The train shall achieve a mean distance between service affecting failures of at least 250,000km per car where a service affecting failure is defined as a delay to service of two minutes or greater or a withdrawal from service or a failure to enter service when required. This reliability shall be achieved within 24 months from the first train entering timetabled passenger service.

3.4.9.3 There shall be an efficient means of recovery from all foreseeable failure modes.

Note: Categories of failure are:

- a) causing no delay;
- b) causing a delay of 2 minutes or more to the service;
- c) causing a delay of 15 minutes or more to the service;
- d) causing train withdrawal;
- e) of train to enter service at the time-tabled time and place. This category applies to trains which fail in depot or on departure from depot such that they do not disrupt the running lines.

3.4.9.4 All rolling stock components shall be assigned a failure category taking full account of the risks and hazards to which staff and passengers would be exposed, in the event of failure in adverse circumstances, such as in a tunnel between stations.

3.4.9.5 The design of rolling stock shall be reviewed to determine any areas that require life cycle testing to limit the reliability risks with new or unproven designs or to demonstrate the suitability of the design in its intended application.

3.4.9.6 Reliability assessments shall be conducted during the design stage for items assessed as likely to affect the reliability of the rolling stock. Reliability calculations shall be based on internationally recognised methods.

3.4.9.7 The proceedings, conclusions and proposals arising from planned reliability assessments shall be managed and documented to a level that demonstrates that the rolling stock will meet the reliability requirements.

3.4.10 Operability

- 3.4.10.1 A formal analysis shall be carried out to demonstrate that the design meets the operability requirements of LU.
- 3.4.10.2 A human factors assessment shall be conducted as part of the design process, which shall consider the full life cycle of the rolling stock with reference to:
- a) all relevant personnel, including passengers, train staff and maintainers along with other personnel, including security, breakdown and emergency services;
 - b) all normal and degraded modes of operation;
 - c) all times of the day and night;
 - d) all climatic conditions.
- 3.4.10.3 Recommendations from the assessment described in 3.4.10.2 shall be implemented or otherwise formally closed.
- 3.4.10.4 Recovery procedures shall:
- a) be established for all credible failure modes in the design process;
 - b) provide, in the design, the configuration of equipment to facilitate recovery in the safest manner practicable;
 - c) include:
 - I. separate safety and operability assessments;
 - II. instructions for training and assessment of staff in their use.

3.5 Whole life documentation

3.5.1 General

- 3.5.1.1 All documentation shall be in the English language, available in electronic format and capable of being printed on ISO standard A-size paper.
- 3.5.1.2 All documentation described in this standard for rolling stock, driving position simulators and other learning aids shall be:
- a) maintained in a formal and timely manner;
 - b) made available to LU.
- 3.5.1.3 LU and the person or entity responsible for the Maintenance Regime shall have unrestricted access to the following data, some of which may be archived:
- a) confirmation that the train, as supplied, meets the requirements of the relevant Standards;
 - b) a formal listing of all concessions granted against the requirements in a).
 - c) a suite of data:
 - I. describing the design;
 - II. describing the manufacture and assembly of the rolling stock;
 - III. describing the driving position simulators or other learning aids;
 - IV. including all test specifications, results and reports.
 - d) data detailing safe levels of deterioration;
 - e) data on the duty the train is intended to perform.

3.5.2 Design documentation

- 3.5.2.1 A suite of design information shall be provided for all trains to:
- a) enable a full understanding of:
 - I. the original requirements for the design;
 - II. the requirements for all subsequent modifications.