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Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles

This document sets out requirements for railway vehicles regarding permissible track forces, derailment resistance and resistance to roll-over due to overspeed.

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Synopsis

This document sets out requirements for railway vehicles regarding permissible track forces, derailment resistance and resistance to roll-over due to overspeed.

Published by RSSB

Issue record

Issue	Date	Comments
One	01/02/1998	Original document. Supersedes GM/TT0087.
Two	07/10/2000	Replaces issue one. Includes new requirements for tilting trains.
Three	06/06/2009	Replaces issue two. Includes a new vertical acceleration curve for bogie freight vehicles tested on jointed track.
Four	01/06/2019	Replaces issue three. Amended to align with EU Rolling Stock Technical Specifications for Interoperability. Merges GMRT2141 issue three Resistance of Railway Vehicles to Derailment and Roll-Over, with GMTT0088 issue one Permissible Track Forces for Railway Vehicle and GMRC2513 issue one Commentary on Permissible Track Forces for Railway Vehicles. Includes new requirements for testing to demonstrate that vehicles are not susceptible to cyclic top and for testing ISO container carrying vehicles in offset load conditions. The requirement to manage the risk of vehicle roll-over as a result of overspeed on curves changed from a 21˚ roll-over limit for non-tilting passenger trains to 18˚. The requirement for the wheel load to wheel diameter (Q/D) limit has increased from 0.13 to 0.17. Editorial changes throughout.

Issue	Date	Comments
4.1	07/12/2019	Correction release Updates at clauses 1.2.1, G3.4.4, Appendix F and in the References. These reflect the fact that amendments to the Locomotives and Passenger Rolling Stock Technical Specification for Interoperability 2014 (LOC&PAS TSI) and Wagon Technical Specification for Interoperability 2013 (WAG TSI) were published by the European Commission subsequent to the publication of issue four of this document. Cross reference errors within Appendix F have also been corrected.
Five	01/06/2024 [proposed]	Replaces issue 4.1. Updated to add additional information and guidance on the Delta Q/Q requirement for offset loading, applicable to vehicles carrying intermodal load units. Additional flow diagram added at industry request. References to TSIs updated to NTSNs as appropriate and EN references also checked and updated where needed.

Revisions have been marked by a vertical black line in this issue. Definitions and References may also have been updated but these are not marked by a vertical black line.

Superseded documents

The following Railway Group documents are superseded, either in whole or in part as indicated:

Superseded documents	Sections superseded	Date when sections are superseded
GMRT2141 issue 4.1 Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles	All	07/09/2024 [proposed]

Supply

The authoritative version of this document is available at www.rssb.co.uk/standards-catalogue. Enquiries on this document can be submitted through the RSSB Customer Self-Service Portal https://customer-portal.rssb.co.uk/

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Part 1 Purpose and introduction

1.1 Purpose

1.1.1 This document sets out requirements for railway vehicles regarding permissible track forces, derailment resistance and resistance to roll-over due to overspeed.

1.2 Introduction

1.2.1 This document should be read in conjunction with:

a) 'Locomotives and Passenger National Technical Specification Notice 1 January 2021' (LOC&PAS NTSN), published by the Secretary of State.
b) 'Freight Wagons National Technical Specification Notice 1 January 2021' (WAG NTSN), published by the Secretary of State.
c) BS EN 14363:2005 'Railway applications.Testing for the acceptance of running characteristics of railway vehicles. Testing of running behaviour and stationary tests'.
d) BS EN 14363:2016+A2:2022 'Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests'.
e) BS EN 15663:2017+A1:2018 'Railway applications. Vehicle reference masses'.

1.2.2 The LOC&PAS NTSN sets out requirements for vehicle testing and mandates compliance with specific clauses of BS EN 14363.

1.2.3 The WAG NTSN sets out requirements for freight vehicle testing and also mandates compliance with specific clauses of BS EN 14363.

1.2.4 BS EN 14363:2016+A2:2022 sets out the requirements and methodology for the testing of vehicles and references that are made in this document to BS EN 14363 without indicating an issue reference are to this version. For the purposes of this document this version is identical to BS EN 14363:2016. The technical requirements of BS EN 14363:2005, supplemented by ERA/TD/2012-17/INT, are for the purposes of this document equivalent to BS EN 14363:2016+A2:2022.

1.2.5 The requirements for on-track machines (OTMs) in running mode are set out in GMRT2400 'Engineering Design of On-Track Machines in Running Mode'.

1.2.6 The requirements for on-track plant (OTP) are set out in RIS-1530-PLT 'On-Track Plant, Trolleys and Associated Equipment'.

1.3 Principles

1.3.1 The requirements of this document are based on the following principles.

1.3.2 This document sets out requirements that meet the characteristics of national technical rules (NTRs) and are applicable to the Great Britain (GB) mainline railway. Compliance with NTRs is required under the Railways Interoperability Regulations 2011 (as amended).

1.3.3 The NTRs in this document are used for the following purposes:

a) To support GB or UK specific cases in NTSNs.
b) To enable technical compatibility between:
    i) Vehicles that conform to the requirements of the NTSNs, and the existing infrastructure.
    ii) Infrastructure that conforms to the requirements of the NTSNs, and the existing vehicles.

1.4 Structure of this document

1.4.1 Where relevant, the national technical rules relating to relevant NTSN parameters have been identified together with the relevant clause from the NTSN.

1.4.2 This document sets out a series of requirements that are sequentially numbered. This document also sets out the rationale for the requirement, explaining why the requirement is needed and its purpose and, where relevant, guidance to support the requirement. The rationale and the guidance are prefixed by the letter 'G'.

1.4.3 Some subjects do not have specific requirements but the subject is addressed through guidance only and, where this is the case, it is distinguished under a heading of 'Guidance' and is prefixed by the letter 'G'.

1.5 Related requirements in other documents

1.5.1 The following Railway Group Standards contain requirements that are related to the scope of this document:

a) GMRT2400 'Engineering Design of On-track Machines in Running Mode'
b) GMRT2466 'Railway Wheelsets'
c) GERT8006 'Route Availability Number for Assessment of Compatibility between Rail Vehicles and Underline Bridges'
d) GCRT5021 'Track System Requirements'
e) GMRT2142 'Resistance of Railway Vehicles to Roll-Over in Gales'.

1.6 Supporting documents

1.6.1 The following Railway Group documents support this Railway Group Standard:

a) GMGN2641 'Rail Industry Guidance Note on Vehicle Static Testing'
b) GMGN2615 'Guidance on the Locomotives and Passenger Rolling Stock NTSN'
c) GMGN2688 'Application of the WAG NTSN and NOI NTSN to the Design of Freight Wagons'
d) RIS-8012-CCS 'Controlling the Speed of Tilting Trains through Curves'.

1.7 Approval and authorisation of this document

1.7.1 The content of this document will be approved by Rolling Stock Standards Committee on 18 April 2024 [proposed].

1.7.2 This document will be authorised by RSSB on 03 May 2024 [proposed].

Part 2 Permissible track forces

2.1 Vertical static forces

2.1.1 The vertical static wheel force (Q) shall not exceed 124.5 kN (based on the maximum permitted axle load of 25.4 tonnes).

2.1.2 The minimum wheel tread diameter shall not be less than 250 mm.

2.1.3 The vertical static wheel force divided by the wheel diameter (Q/D) shall not exceed the following limits:

Minimum wheel diameter (mm)	250 ≤ D < 460	D ≥ 460
Q/D Limit	0.13	0.17

Table 1: Q/D requirement

Q = maximum vertical static wheel force (kN) (of the heaviest wheel in the 'design mass under normal payload' condition as defined in BS EN 15663)

D = minimum wheel tread diameter (mm) (scrapping diameter)

Rationale

G 2.1.4 This requirement is for compatibility with the existing GB mainline railway. Vehicles need to be designed so that the combined effect of the static wheel loading and wheel diameter does not cause excessive stresses and deformation in the contact zones between wheel tread and rail head under all normal track conditions.

Guidance

G 2.1.5 RSSB research project T889 'Controlling rail vertical contact stresses' concluded that there was no step change in wheel to rail damage within the Q/D range from 0.13 to 0.17, so the limit has been increased to align with the Q/D ratios of current and historical wagons. There was no current experience to benchmark vehicles with wheels below 460 mm diameter, so the previous limit of 0.13 remains for small wheels.

G 2.1.6 GMRT2466 lists the permitted wheel profiles and defines the datum points for measurement of the wheel tread diameter.

2.2 Vertical dynamic forces

2.2.1 The maximum vertical dynamic force per wheel (P2) shall not exceed 322 kN.

2.2.2 The P2 force shall be calculated using the following formula:

$$P2 = Q + (A_z.V_m.M.C.K)$$

Where:

$$M = \left[\frac{M_v}{M_v + M_z}\right]^{0.5}$$

$$C = 1 - \left[\frac{\pi . C_z}{4[K_z(M_v + M_z)]^{0.5}}\right]$$

$$K = (K_z . M_v)^{0.5}$$

Q = Maximum static wheel load (N)

V_m = Maximum design operating speed (m/s)

M_v = The effective vertical unsprung mass per wheel (kg)

A_z = Total angle of vertical ramp discontinuity

- = 0.020 rad (for speeds up to 44.7 m/s (100 mph))
- = 0.018 rad (for speeds over 44.7 m/s up to 49.2 m/s (over 100 mph up to 110 mph))
- = 0.016 rad (for speeds over 49.2 m/s up to 55.9 m/s (over 110 mph up to 125 mph))

M_z = 245 kg (effective vertical rail mass per wheel)

C_z = 55.4 x 10^3 Ns/m (effective vertical rail damping rate per wheel)

K_z = 62.0 x 10^6 N/m (effective vertical rail stiffness per wheel)

Rationale

G 2.2.3 This requirement is for compatibility with the existing GB mainline railway. Vehicles need to be able to run over the normal range of vertical track irregularities at maximum design operating speeds without generating excessive vertical loads and stresses in the rails and track. This includes negotiating a vertical ramp discontinuity in rail top profile, equivalent to a dipped rail joint on straight track.

Guidance

G 2.2.4 The requirement is a well-established P2 peak force criterion used as a benchmark. This prescribes the allowable total vertical force (static plus 'low frequency' dynamic forces) per wheel when a vehicle operates at its maximum permissible speed on straight track over a defined angular discontinuity (ramp) in the rail vertical profile, representing an idealised dipped rail joint. The reader should not assume that normal track in GB contains a large number of 0.020 rad vertical ramps. For track with line speeds greater than 44.7 m/s (100 mph) the improved track quality requirements might be expected to result in the population of track features present having smaller dip angles.

G 2.2.5 The maximum permissible P2 force of 322 kN per wheel corresponds to that which was theoretically generated by the Class 55 'Deltic' locomotive when running over the prescribed rail joint at 44.7 m/s (100 mph). The relevant parameters for the Class 55 locomotive are as follows:

Q = 86,000 N Maximum static wheel load

V_m = 44.7 m/s Maximum design operating speed

M_v = 1680 kg Effective vertical unsprung mass per wheel

2.3 Track shifting force

2.3.1 For the assessment of the track shifting force, the method set out in Appendix *H* shall be used if Appendix *A*, 'on-track ride test', is being used as an alternative method to that set out in BS EN 14363.

Rationale

G 2.3.2 This requirement is for compatibility with the existing GB mainline railway. Vehicles need to be designed so that under all normal track and operating conditions they do not generate excessive lateral forces which could damage the structural integrity of the rails and track.

Guidance

G 2.3.3 The requirements for assessing the track shifting force, or ΣY, are set out in the LOC&PAS NTSN and WAG NTSN which both reference BS EN 14363 where the Normal or Simplified testing method is used.

G 2.3.4 If the Normal or Simplified testing method in BS EN 14363 is being used, assesssment of the dynamic track shifting force, as set out in Appendix *H*, is not required.

G 2.3.5 For vehicles operating solely in GB, an alternative approach is permitted to amend the requirements of BS EN 14363 for running dynamic behaviour. The alternative method set out in Appendix *H* is used when Appendix *A* 'on-track ride test' is being used.

G 2.3.6 A diagram showing process options for the use of the alternative approach is given in Appendix *F*.

G 2.3.7 For freight wagons, the factor of 0.85 given in BS EN 14363 for the track shifting force (ΣY) need not be applied for vehicles operating solely in GB.

G 2.3.8 At axle loads above 183 kN, the lateral dynamic forces requirement in *2.4.1* is typically more stringent compared with the track shifting 'average limit'.

2.4 Lateral dynamic forces

2.4.1 Lateral Kink discontinuity - A vehicle shall be able to negotiate a lateral ramp discontinuity in track alignment when travelling on a curve at maximum design operating speed and at maximum cant deficiency without exceeding a total lateral force level per axle of 71 kN, calculated using the following formula:

$$Y = W \cdot A_d + A_y \cdot V_m \left[\frac{M_u}{M_u + M_y}\right]^{0.5} \left[K_y \cdot M_u\right]^{0.5}$$

Where:

Y = Lateral force per axle (N)

W = Static axleload (N)

A_d = Maximum normal operating cant deficiency angle (rad)

V_m = Maximum design operating speed (m/s)

M_u = The effective lateral unsprung mass per axle (kg)

A_y = (angle of lateral ramp discontinuity)

- = 0.0039 rad (for speeds up to 49.2 m/s (110 mph))
- = 0.0034 rad (for speeds over 49.2 m/s up to 55.9 m/s (over 110 mph up to 125 mph))

M_y = 170 kg (effective lateral rail mass per wheel)

K_y = 25.0 x 10^6 N/m (effective lateral rail stiffness per wheel)

Rationale

G 2.4.2 This requirement is for compatibility with the existing GB mainline railway. Vehicles need to be designed so that under all normal track and operating conditions they do not generate excessive lateral forces which could damage the structural integrity of the rails and track.

Guidance

G 2.4.3 There are two different requirements for demonstrating acceptable behaviour of vehicles in terms of maximum lateral track force levels: (a) compliance with the track shifting force limit, which relates to the avoidance of lateral shifting of plain track; and (b) compliance with an absolute maximum value of lateral force, which relates to damage to track structures and track components. Both requirements need to be satisfied but the latter case tends to dominate when axle loads are high.

G 2.4.4 Limiting the maximum permissible total lateral force of 71 kN at an axle when a wheelset negotiates short-wave misalignments in lateral track profile provides protection against damaging the structural integrity of the rails and track. The lateral force limit of 71 kN at short-wave lateral irregularities is justified in British Rail Research Report (TM-VTI-013) 'A design case track irregularity for theoretical prediction of dynamic lateral track forces' available from RSSB.

G 2.4.5 The expression for the maximum permissible lateral force per axle is similar in form to the P2 vertical force criterion, but excludes the damping term, which is negligible. In the lateral case, however, the situation relates to a vehicle running on curved track at its maximum permissible speed and at its maximum permissible cant deficiency over a defined lateral ramp. This ramp does not model any specific track feature but is a

generalised representation of any short-wave lateral track misalignments, which gives rise to high transient lateral forces.

G 2.4.6 The highest permissible lateral force of 71 kN per axle corresponds to that theoretically generated by a Class 86/2 electric locomotive when running through a curve and over the prescribed lateral ramp in the outer rail at a speed of 50 m/s and at a cant deficiency of 0.1013 rad (approx. 150 mm). The relevant parameters for the Class 86/2 locomotive are as follows:

W = 213,000 N static axleload

A_d = 0.1013 rad maximum normal operating cant deficiency angle

V_m = 50.0 m/s maximum normal operating speed

M_u = 2711 kg effective lateral unsprung mass per axle

2.5 Longitudinal forces

Guidance

G 2.5.1 The LOC&PAS NTSN sets out the requirements for the maximum deceleration rate.

G 2.5.2 The effects of longitudinal traction and braking forces on the track infrastructure have not historically been a strong concern of traction and rolling stock engineers. However, the development of powerful creep controlled six-axle locomotives and the application of double heading, to increase payload capacity, could lead to excessive longitudinal forces being applied to bridge structures and the risk of rail creep. Currently, limitations in coupler strengths may protect against excessive longitudinal loading.

2.6 Bridge and track dynamics

Guidance

G 2.6.1 The NTSNs set out requirements for axle load and wheel load to manage compatibility with underline structures. GB has a permission in the INF NTSN to use the route availability (RA) system. The requirements for determining the RA number for a vehicle / train and for assessing compatibility with infrastructure are set out in GERT8006.

G 2.6.2 The combination of axleloads and axle spacings for a vehicle, or for an operationally inseparable rake of vehicles, is assessed to determine compatibility between the static load characteristics of rail vehicles and the capacity of underline bridges to carry the vertical static and dynamic loads imposed by the rail vehicles. This assessment and classification ensure that the requirements of the RA system, as set out in GERT8006, are met for the desired routes of operation.

G 2.6.3 If the pattern of axle spacings within and between vehicles are made up of integers, then this can lead to the generation of harmonic loading cycles or induce resonances

within the track infrastructure and bridges. Further guidance on compatibility between vehicles and bridges is given in GERT8006.

Part 3 Resistance to derailment

3.1 Vehicle assessment conditions

Guidance

G 3.1.1 The conditions under which the vehicle assessments are carried out are defined and recorded in the test report and include taking into account the effects of:

a) Inter-vehicle connections on wheel unloading performance (for example, in certain articulated trains where the design can have a significant effect on this performance);
b) In-built vehicle design asymmetry (either longitudinal or lateral);
c) Differences in the suspension system behaviour at the two ends of the vehicle (including different levelling valve systems, where appropriate);
d) Vehicle weight distribution (for example tare, laden and particularly partially laden where multiple-stage springs are used);
e) Range and effect of possible in-service loading configurations (for example, exceptional loads for passenger vehicles, and the distribution of containers and the stiffness effect of the load for freight vehicles);
f) Any other design feature or in-service condition that might significantly affect the wheel unloading performance; and
g) Credible suspension failure conditions such as deflated secondary air-springs.

G 3.1.2 The defined offset load conditions are only applicable to section *3.3* ('low speed flange climb derailment assessments for vehicles carrying intermodal load units').

G 3.1.3 Guidance on the definition of vehicle loading conditions can be found in BS EN 15663.

3.2 Low speed flange climb derailment

Guidance

G 3.2.1 The LOC&PAS NTSN and the WAG NTSN set out an assessment for a vehicle's resistance to low speed flange climb derailment and refer to BS EN 14363, which includes three different methods.

G 3.2.2 GB practice has been to carry out combinations of the following assessments (Method 3 in BS EN 14363):

a) Delta Q/Q – wheel unloading (BS EN 14363, section 6.1)
b) X factor – bogie yaw resistance (BS EN 14363, section 6.1)
c) Y/Q Simulation – low speed flange climb derailment (BS EN 14363, Annex B).

The restrictions on vehicle type and flange angle, when using Method 3 in BS EN 14363, section 6.1.5.3.1, do not need to be applied for vehicles solely to be used in GB as permitted by the UK(GB) specific cases in the LOC&PAS NTSN, clause 7.3.2.4 and WAG NTSN, clause 7.3.2.3. The use of Method 1 or Method 2 is also acceptable for demonstrating compliance with the offset load requirements in section *3.3*.

However, the static Delta Q/Q assessment may not be representative of on-track behaviour for non-conventional vehicles, for example those with active primary suspensions or for vehicles with multi-bogie / axle configurations such as 3-axle bogies. For these vehicle types, the Y/Q simulation assessment is the most suitable.

G 3.2.3 Vehicle conditions and loads can affect the resistance to low speed flange climb derailment. The list in section *3.1* of this document sets out factors to consider.

G 3.2.4 A diagram illustrating the various process options is included in Appendix *F*

3.3 Low speed flange climb derailment for vehicles carrying intermodal load units

3.3.1 For vehicles carrying intermodal load units, an additional assessment of safety against derailment on twisted track (BS EN 14363, section 6.1) shall be carried out to demonstrate that the vehicle still meets the relevant limit value for the method selected with the load unit having an offset load.

3.3.2 The vehicle shall be assessed in the following three offset conditions:

a) Lateral offset – The sum of the wheel loads on one side of the wagon shall have a ratio of not less than 1 : 1.38 to those on the opposite side. This is given by $(C + D) \geq 1.38 \times (A + B)$.

Figure 1: Lateral offset condition

b) Combined offset i) – The sum of the wheel loads on one end of the wagon shall have a ratio of not less than 1 : 1.35 to those on the opposite end, combined with a lateral offset of 1 : 1.2. This is given by $(B + D) \geq 1.35 \times (A + C)$ and $(C + D) \geq 1.2 \times (A + B)$.

Figure 2: Combined offset condition i)

c) Combined offset ii) – The sum of the wheel loads on one end of the wagon shall have a ratio of not less than 1 : 3 to those on the opposite end, combined with a lateral offset of 1 : 1.1. This is given by $(B + D) \geq 3.0 \times (A + C)$ and $(C + D) \geq 1.1 \times (A + B)$.

Figure 3: Combined offset condition ii)

3.3.3 The vehicle shall be loaded with the minimum amount of additional load needed, suitably positioned, to achieve these offsets within the normal vehicle load arrangements. The additional load used shall be documented.

3.3.4 In cases where one or more of the conditions specified above are not achievable because of restrictions on the permitted vehicle loading, the maximum achievable offset loading condition shall be assessed and the reasons for the restriction documented.

Rationale

G 3.3.5 These requirements check that a vehicle is not susceptible to low speed flange climb derailment by limiting the:

a) Vertical suspension stiffness;
b) Bogie frame torsional stiffness (where applicable);
c) Vehicle body torsional stiffness; and
d) Vehicle body to bogie rotational stiffness (where applicable).

G 3.3.6 This enables the vehicle to negotiate twisted track without significant wheel unloading and negotiate tight curves by limiting the lateral force on the rail from the leading outer wheel.

G 3.3.7 The requirement to achieve the offset load conditions using the minimum amount of additional load is due to the lightest condition being the most onerous for wheel unloading.

G 3.3.8 The requirement for testing with offset load is for compatibility with the existing GB mainline railway. Only the low speed flange climb derailment is assessed against these offset load cases.

Guidance

G 3.3.9 RSSB Research project T1119 'Investigating the effects of offset loading in containers on the risk of derailment on twisted track' provides further background reading for this requirement. For the additional assessment of vehicles carrying intermodal load units (using Method 3 of BS EN 14363) the study concluded that:

a) The key assessment is the Delta Q/Q wheel unloading test;
b) It is generally not necessary to repeat the bogie yaw resistance test as it has been demonstrated that offset loading has a negligible effect on the results; and
c) The wheel unloading limit leads to equivalent control to the Y/Q limit for resistance to flange climb derailment. This was demonstrated by the empirical relationship (cross-correlation of derailment metrics from simulation outputs) and the analytical relationship between wheel unloading and Nadal's limit.

G 3.3.10 For the offset loading assessment to be demonstrated by a Y/Q simulation alone, the vehicle model is validated for the offset load conditions. For example, if the new vehicle is similar to an existing vehicle that has passed the offset wheel unloading test and had the vehicle model validated using the test results, then a technical justification could be made.

G 3.3.11 Use of Method 1 or Method 2 of BS EN14363 is also suitable for the offset loading assessment.

G 3.3.12 The orientation of the offset loading on the vehicle is also important to consider, so that the worst case scenario can be assessed. For example, longitudinal asymmetry of the wagon could determine which end requires the heaviest load, particularly if different spring stiffnesses are used.

G 3.3.13 GMGN2641 includes a worked example showing determination of the required loading.

G 3.3.14 GMGN2641 includes a worked example showing determination of the achievable worst case for restricted loading.

G 3.3.15 A diagram illustrating the various process options is included in Appendix *F*.

G 3.3.16 Research is being considered to derive the Delta Q/Q (wheel unloading) offset loading requirements for other vehicle types that may be liable to offset loading conditions.

G 3.3.17 Further guidance on performing static tests is given in GMGN2641.

3.4 Dynamic behaviour - derailment assessment

3.4.1 If the permission in the UK (GB) specific case is selected, the method set out in Appendix *A* of this document shall be used.

Rationale

G 3.4.2 These requirements quantify the vehicle's dynamic performance under known representative conditions of operation and infrastructure, including curve transitions and constant radius curves. The margin in the limits covers normal variations such as track geometry and vehicle suspension parameters. This includes vertical and lateral dynamic behaviour and wheelset hunting motion.

Guidance

G 3.4.3 The requirements for running dynamic behaviour are set out in the LOC&PAS NTSN and the WAG NTSN, which reference BS EN 14363. The assessments include:

a) Ride test - Dynamic Y/Q and dynamic ΣY (Normal method);
b) Ride test - Dynamic accelerations (Simplified method); and
c) Ride test - Stability assessment.

G 3.4.4 In the following cases an alternative approach is permitted:

a) Specific cases in the LOC&PAS NTSN (clause 7.3.2.5) and in the WAG NTSN (clause 7.3.2.4).
b) Demonstration of equivalent safety (as permitted in BS EN 14363).

G 3.4.5 Related information is provided in BS EN 14363 section 7.

G 3.4.6 The range of vehicle assessment conditions to be considered are set out in *3.1*.

G 3.4.7 Appendix *B* gives evidence to demonstrate that GMRT2141, issue four, Appendix *A* 'on-track ride tests', offers an equivalent safety method to BS EN 14363 clause 7 'dynamic performance assessment'. This includes reference to a report titled 'Comparison of the dynamic running behaviour assessment in GM/RT2141 and BS EN 14363' available from RSSB. These documents may be used as part of the demonstration of equivalent safety permitted in BS EN 14363, clause 4.

G 3.4.8 The various methods do this by assessing:

a) The vertical and lateral wheel to rail forces (BS EN 14363 Normal method);
b) The bogie and body accelerations (BS EN 14363 Simplified method);
c) The damping of wheelset hunting (BS EN 14363 Stability assessment); and
d) The vertical and lateral body accelerations (GMRT2141 issue four, Appendix *A* method).

G 3.4.9 Diagrams showing possible compliance methods are provided in Appendix *F*.

3.5 Overturning due to overspeed on curves

3.5.1 A vehicle's resistance to roll-over shall be demonstrated by simulation, calculations, practical tests, comparison with other vehicles, or a combination of these.

3.5.2 The following minimum cant deficiency limits shall be complied with, without 100 % unloading of all the wheels on one side of the vehicle:

a) For freight vehicles and OTMs designed to operate at speeds no greater than 75 mph, not less than 16.5° cant deficiency;
b) For vehicles that operate up to 6° cant deficiency, not less than 18° cant deficiency;
c) For vehicles that operate above 6° cant deficiency, not less than 21° cant deficiency.

Rationale

G 3.5.3 This requirement is for compatibility with the existing GB mainline railway and manages the risk of vehicle roll-over as a result of overspeed on curves. Vehicles have a margin against rolling over to allow for:

a) A train failing to slow down sufficiently before entering a curve; and
b) A long train accelerating out of a tight curve too early putting the rearmost vehicles at risk.

G 3.5.4 Passenger vehicles that operate at up to 6˚ cant deficiency have a 12˚ safety margin, as they are required to meet the 18˚ minimum roll-over limit. Conventional freight vehicles and OTMs have the lower limit of 16.5˚, as they only operate at up to 4.25˚ cant deficiency . Tilting trains or other vehicles that operate above 6˚ cant deficiency have the higher limit of 21˚ to maintain a reasonable safety margin.

Guidance

G 3.5.5 GB infrastructure can contain short transitions, reverse curves and so on.

G 3.5.6 For all demonstration methods, the curve is taken as being smooth, such that only quasi-static centrifugal effects are taken into account. The effects of curve transitions or track irregularities are not included. The effect of cross-wind is not taken into account.

G 3.5.7 For an articulated train, a vehicle constitutes one vehicle body and the bogies / wheelsets supporting it.

G 3.5.8 GCRT5021 and RIS-8012-CCS provide further information for vehicles operating above 6˚ cant deficiency.

G 3.5.9 Requirements for vehicle roll-over, due to cross-wind loading, are set out in GMRT2142.

3.6 Cyclic top derailment

3.6.1 To demonstrate that vehicles are not susceptible to derailment due to cyclic top track features, one of the following two processes shall be used:

a) A comparison with an existing vehicle of similar design, as set out in Appendix *C*;
b) A simulation assessment of a validated model over track with a sinusoidal waveform, as set out in Appendix *D*.

Rationale

G 3.6.2 This requirement is for compatibility with the existing GB mainline railway.

G 3.6.3 GB mainline track can contain cyclic top where cyclic irregularities in the vertical track alignment can excite under-damped behaviour in the vehicle at particular speeds. This behaviour can lead to complete loss of vertical wheel load and consequent derailment.

G 3.6.4 The infrastructure manager's (IM's) standards set the limit for the amplitude and length of cyclic top track features before maintenance or speed restrictions are

required. Vehicles can encounter cyclic top track features anywhere on the GB mainline railway, including on continuous welded track.

Guidance

G 3.6.5 Guidance on the two available routes to demonstrate that a vehicle is not susceptible to cyclic top is given in Appendices *C* and *D*.

Part 4 Application of this document

4.1 Scope

4.1.1 If a change to a railway vehicle is considered new, renewal or upgrade as defined in the Railways (Interoperability) Regulations 2011 (as amended), then all or part of the railway vehicle is required to comply with the LOC&PAS NTSN or WAG NTSN and other relevant NTSNs and NTRs, unless given exemptions allowed for in the Regulations.

4.1.2 The requirements of this document apply to all new and modified (excluding like-for-like replacement of components) railway vehicles.

4.1.3 Action to bring existing railway vehicles into compliance with the requirements of this document is not required.

4.2 Exclusions from scope

4.2.1 The requirements for on-track machines (OTMs) in running mode are set out in GMRT2400 'Engineering Design of On-Track Machines in Running Mode'.

4.2.2 The requirements for on-track plant (OTP) are set out in RIS-1530-PLT 'On-Track Plant, Trolleys and Associated Equipment'.

4.3 General enter into force date

4.3.1 The requirements in this document enter into force from 07 September 2024 [proposed].

4.4 Exceptions to general enter into force date

4.4.1 There are no exceptions to the general enter into force date.

4.5 Applicability of requirements for projects already underway

4.5.1 The Office of Rail and Road (ORR) can be contacted for clarification on the applicable requirements where a project seeking authorisation for placing into service is already underway when this document enters into force.

4.6 Deviations

4.6.1 Where it is considered not reasonably practicable to comply with the requirements of this document, permission to comply with a specified alternative should be sought in accordance with the deviation process set out in the Railway Standards Code.

4.6.2 In the case where NTSN compliance is required for a new, renewed or upgraded vehicle or structural subsystem, the process for any exemptions needed is set out in the Railways (Interoperability) Regulations 2011 (as amended).

4.7 User's responsibilities

4.7.1 Industry experts representing railway industry stakeholders are involved in the process for settling the content of documents which are prepared in accordance with the procedures set out in the Railway Standards Code and Manual.

4.7.2 Users of documents published by RSSB are expected to be competent or should take specialist advice before following or applying any practices or principles contained within them and are reminded of the need to consider their own responsibilities to ensure safe systems of work and operation, health and safety at work and compliance with their own duties under health and safety legislation. While documents published by RSSB can be used to help inform and devise safe practices and systems of work, their content has not been designed or prepared for:

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b) application or use in all possible operational or working environments.

4.7.3 No representation, warranty, guarantee, confirmation or other assurance is given or made (whether expressly or implicitly) that compliance with all or any documents published by RSSB is sufficient in itself to ensure safe systems of work or operation or to satisfy such responsibilities or duties.

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Appendices

Appendix A On-track ride tests for assessing dynamic performance

Note: The content of this appendix is required by clause *3.4.1*. Where this appendix is used, then the track shifting force assessment in Appendix *H* is also required.

A.1 Vehicle assessment conditions

Guidance

G A.1.1 The vehicle assessment conditions are set out in *3.1*.

A.2 Track geometry conditions

A.2.1 The tests shall be conducted over routes representative of those to be used in service, using a sufficient length of track to ensure that a wide range of track conditions has been encountered.

Rationale

G A.2.2 Representative results are unlikely to be obtained unless a suitable length of track and track features are analysed for each speed. A minimum length of 8 miles is considered to be appropriate.

Guidance

G A.2.3 Track geometry quality may be characterised by standard deviations (SDs) in stated wavelength ranges, or appropriate time histories, and so on.

G A.2.4 It is normal GB practice for the track geometric quality to be characterised by the SDs in the wavelength range up to 35 m in ⅛ mile sections along a route (⅛ mile SDs). This data is obtained separately for vertical and for lateral geometry.

G A.2.5 Evidence that the test route is 'representative' could include:

a) Comparison of the range of ⅛ mile SDs from the test routes(s) with those for appropriate parts of the network for the intended operation, both vertically and laterally.
b) Evidence that some poorer ⅛ mile sections have been included, appropriate to the local test speed.
c) Using a range of track sections with different track category classifications and therefore different maintenance requirements (different SD requirements as set out in the relevant IM's track standard).
d) A minimum distance of around 8 miles for each track category and speed.

G A.2.6 It is not generally necessary for the track geometry to be measured during the test run(s) as track geometry does not change rapidly unless maintenance activity takes place. Track geometry is measured using a specialised track recording vehicle on one of its routine measurement runs. The track data recorded at the closest time to the vehicle test can be requested from the relevant IM.

G A.2.7 Documented evidence of running over jointed track is not required as this risk is now covered by the cyclic top assessment, as set out in Appendix *D*.

A.3 Speeds

A.3.1 Parts of the route shall be covered at a range of speeds up to and including the intended maximum operating speed and with appropriate increments.

A.3.2 Higher-speed vehicles, unless restricted to dedicated high-speed lines, shall also be tested on lower-speed lines.

Rationale

G A.3.3 Testing over a range of speeds enables identification of any resonance effects, which might cause the behaviour to be worse at intermediate speeds than at the intended maximum operating speed.

G A.3.4 Testing higher-speed vehicles on lower-speed lines enables assessment of their behaviour on the relevant track geometric quality at the appropriate lower speeds.

Guidance

G A.3.5 Testing of the vehicle in over-speed conditions is not necessary as this is allowed for in the acceptance criteria.

G A.3.6 This test is validated for maximum vehicle operating speeds of up to 125 mph.

A.4 Curves and cant deficiency

A.4.1 Tests shall be conducted over curved sections of route at cant deficiencies representative of those to be used in service.

Rationale

G A.4.2 Testing over a range of curve radii and at a range of cant deficiencies, including the maximum, will identify whether the vehicle is stable and has acceptable ride safety performance in these conditions rather than just on straight track.

Guidance

G A.4.3 It is not necessary to include small radius curve sections in the test route. The risk of flange-climb derailment on small radius curves is assessed separately (see section *3.3*).

G A.4.4 The maximum intended service speed and maximum intended service cant deficiency can be assessed separately where they do not occur on the same curve.

A.5 Wheel-rail contact conditions

A.5.1 The tests shall be carried out on dry rails.

A.5.2 Wheel-rail contact conditions shall be representative of those expected in service, particularly for the higher-speed tests where equivalent conicity is an important influence. A narrow range of equivalent conicity values shall be avoided.

A.5.3 The wheel profiles on the test vehicle shall be measured and equivalent conicity calculated with suitable representative rail profiles and track gauges.

Rationale

G A.5.4 Dry rails ensure that the vehicle is tested in the most onerous condition, as the higher friction enables higher steering and creep forces to be generated between the wheel and rail, which could lead to vehicle instability.

G A.5.5 It is important to ensure that the vehicle is stable over a range of equivalent conicities. This allows for a range of wheel profile wear, different rail profiles and rail profile wear that may be encountered on a route.

Guidance

G A.5.6 Measurement of the wheel-rail coefficient of friction is generally not useful. The requirement for 'dry rails' can be assessed subjectively by experienced testing staff.

G A.5.7 It is considered good practice to regularly monitor the railhead conditions during test running at a frequency that captures any changes that would affect the railhead condition, particularly at the beginning and end of the data sampling period that will be used for compliance demonstration.

G A.5.8 Methods of assessing the railhead condition could include:

a) Observations from cab riding;
b) Observations from forward facing camera;
c) Observations from side windows; and
d) Wheel slide protection (WSP) activity.

G A.5.9 The time of day of the test run is also an important consideration as the early morning dew or evening mist can greatly affect the conditions.

G A.5.10 Appropriate values of equivalent conicity can be obtained by a suitable choice of wheel profile. If a design wheel profile with a 'worn' tread shape is used, for example the P8 profile, this may be sufficient.

G A.5.11 Testing with a conical wheel profile is unlikely to provide a suitable range of wheel-rail contact conditions, and testing with the S1002 (or other 1 to 40 based wheel profile) is unlikely to provide a suitable range of conditions on the GB mainline railway.

G A.5.12 It is not usually necessary to use artificially 'worn' wheel profiles for testing but consideration of the effect of wheel profile wear on the effective conicity is appropriate, particularly if this is likely to be different from existing vehicles. Where the likely worn profile cannot be predicted with sufficient confidence, then monitoring during the accumulation of service mileage may be appropriate in order to confirm the performance.

G A.5.13 Calculation of equivalent conicity for the wheel profiles of the test vehicle combined with sample measured rail profiles from the selected test route(s) may be useful but is not required. The use of a range of suitable rail profiles from an existing library can be used, together with a justification as to why they are representative, such as they are linked to the test route.

A.6 Test measurements

A.6.1 The tests shall measure the lateral and vertical body accelerations at under-frame level at a position directly above the centre of each bogie (or each axle in a two-axle vehicle), or as near to this point as it is practicable to place the necessary transducers.

A.6.2 The signals shall be filtered at 6 Hz, low pass, with a 36 dB/octave rejection rate.

Rationale

G A.6.3 These test requirements need to be controlled because the required performance criteria are based on this methodology.

Guidance

G A.6.4 BS EN 14363, section 7.6.2, provides guidance on sampling frequency and anti-alias filtering.

A.7 Analysis of results

A.7.1 The peak-counting analysis shall be undertaken using sections of the test route where the speed is similar.

A.7.2 The different speed ranges shall be analysed individually.

A.7.3 The analysis shall take account of the track conditions as well as the speed, such that short sections of poorer quality track are not combined with long sections of good quality track to distort the results.

A.7.4 The acceleration signals shall then be subjected to a peak count zero crossing analysis and compared with the permissible values as follows:

a) **Vertical accelerations**

   i) Except for bogie freight vehicles on jointed track, the comparison is against Figure *4* (created from the values set out in Table *2*);
   ii) For bogie freight vehicles on jointed track, the comparison is against Figure *5* (created from the values set out in Table *3*).

b) **Lateral accelerations**

   i) The lateral comparison shall be made against Figure *6* (created from the values given in Table *4*).

A.7.5 The analysis for **vertical accelerations** shall be carried out as follows:

a) Only the accelerations which off-load the suspension are taken into account:

   i) The peak value of acceleration between each zero crossing is logged;
   ii) A peak value below 0.025 g is ignored;
   iii) A peak value between 0.025 g and 0.075 g is regarded as having a level of 0.05 g;
   iv) A peak value between 0.075 g and 0.125 g is regarded as having a level of 0.1 g and so on;
   v) Peak values above 1.025 g are regarded as having a level of 1.0 g.

b) The number of peak values equal to or exceeding 0.05 g is then calculated and expressed as a percentage of the total number of peak values that have been taken into account;
c) This process is repeated for 0.1 g, 0.15 g and further increments of 0.05 g up to 1.0 g;
d) The results are plotted and compared with the curve shown in Figure 4, or Figure 5 where the vehicle is a bogie freight vehicle tested on jointed track.

A.7.6 The analysis for **lateral accelerations** shall be carried out as follows:

a) Accelerations in both lateral directions are included:
   i) The peak value of acceleration between each zero crossing is logged. It is regarded as positive irrespective of the direction of the acceleration;
   ii) A peak value below 0.0125 g is ignored;
   iii) A peak value between 0.0125 g and 0.0375 g is regarded as having a level of 0.025 g;
   iv) A peak value between 0.0375 g and 0.0625 g is regarded as having a level of 0.05 g and so on;
   v) Peak values above 0.5125 g are regarded as having a level of 0.5 g.
b) The number of peak values equal to, or exceeding 0.025 g, is then calculated and expressed as a percentage of the total number of peak values that have been taken into account.
c) This process is repeated for 0.05 g, 0.075 g and so on up to 0.5 g. The results are plotted and compared with the curve shown in Figure 6.

Rationale

G A.7.7 Representative results are unlikely to be obtained unless a suitable length of track and track features are analysed for each speed range. Different sections of track may be combined to achieve a suitable total length for each speed range.

G A.7.8 These test requirements need to be controlled because the required performance criteria is based on this methodology.

Guidance

G A.7.9 Different speed ranges are analysed individually. A speed range of +/- 5 mph has been used for data analysis; a significantly larger speed range, such as +/- 15 mph, analysed in one dataset is unlikely to give representative results.

G A.7.10 For vehicles with a soft lateral suspension, this method may not be sufficient (conventional vehicles only) where bogie or wheelset hunting motions may not generate unacceptable body accelerations despite producing wheel-rail forces that are significant in derailment terms. Examination of representative time history records can be used to look for instability. The measurement of bogie and / or axlebox lateral accelerations can also be helpful in identifying any instability and it is good practice to monitor the output in real-time during the test runs.

A.8 Required performance

A.8.1 Except as set out in *A.8.2*, the vertical acceleration performance of the vehicle shall be such that the measured exceedance values lie below the limit curve shown in Figure *4* for track within maintenance limits.

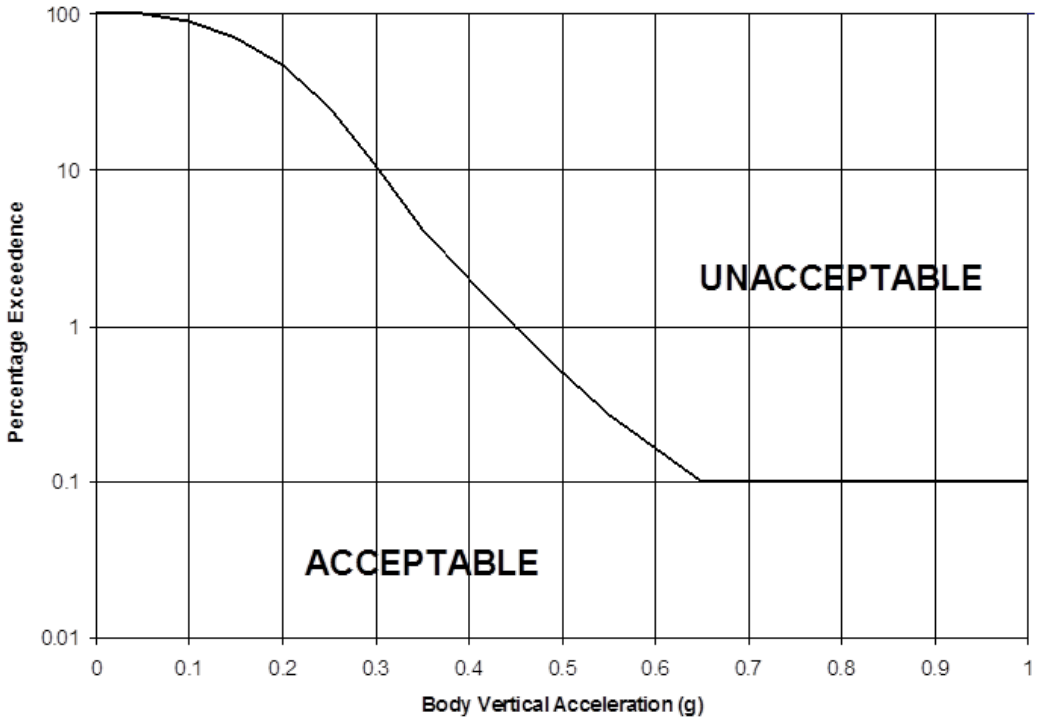

Figure 4: Cumulative vertical peak acceleration curve, for all vehicles except bogie freight vehicles on jointed track

Vertical acceleration (g)	Percentage
0.05	100
0.1	89
0.15	70
0.2	47
0.25	25
0.3	11
0.35	4.2
0.4	2

Vertical acceleration (g)	Percentage
0.45	0.97
0.5	0.5
0.55	0.27
0.6	0.16
0.65	0.1
> 0.65	0.1

Table 2: Values for the cumulative vertical peak acceleration curve, for all vehicles except bogie freight vehicles on jointed track

A.8.2 To assess the vertical performance of bogie freight vehicles on jointed track only, it is permissible to use Figure 5 (instead of Figure 4) and the vertical acceleration performance shall be such that the measured exceedance values lie below the limit curve shown in Figure 5.

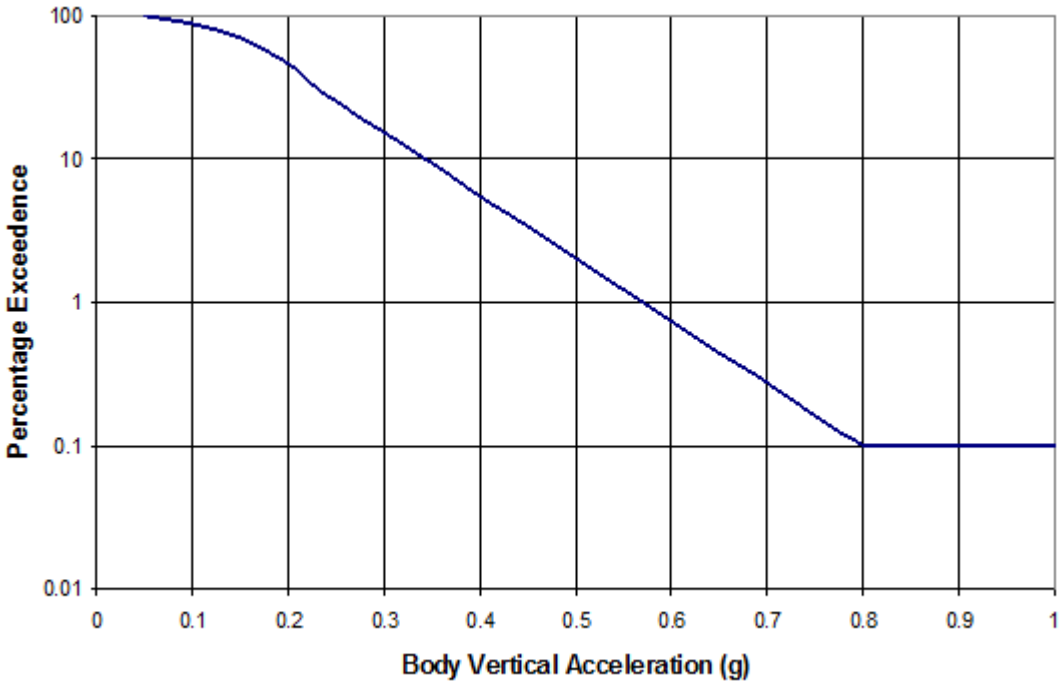

Figure 5: Cumulative vertical peak acceleration curve for bogie freight vehicles on jointed track

Vertical acceleration (g)	Percentage
0.05	100
0.1	89
0.15	70
0.2	47
0.25	25
0.8	0.1
> 0.8	0.1

Table 3: Values for the cumulative vertical peak acceleration curve values for bogie freight vehicles on jointed track

A.8.3 The lateral acceleration performance of the vehicle shall be such that the measured exceedance values lie below the limit curves shown in Figure *6* for track within maintenance limits.

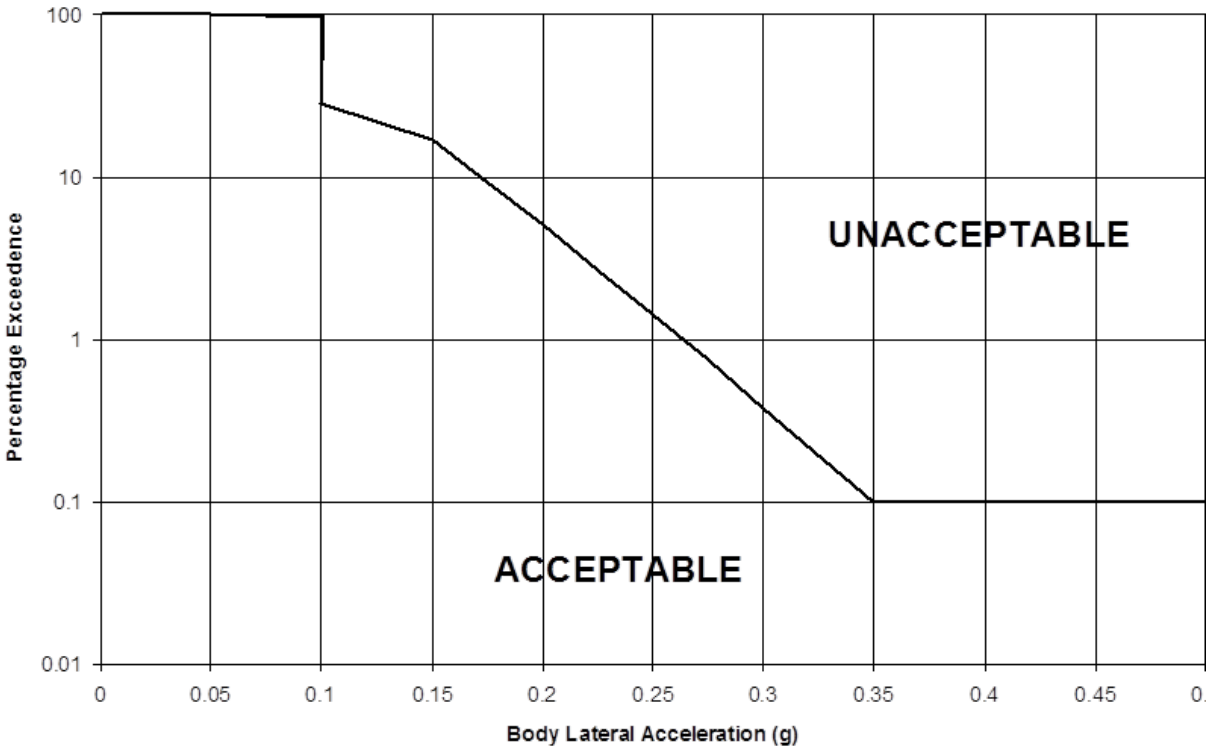

Figure 6: Cumulative lateral peak acceleration curve, for all vehicles

Lateral acceleration (g)	Percentage
0.025	100
0.05	100
0.075	100
0.1	50
0.125	29
0.15	17
0.175	9.2
0.2	5
0.225	2.7
0.25	1.4
0.275	0.75
0.3	0.38
0.325	0.2
0.35	0.1
> 0.35	0.1

Table 4: Values for the cumulative lateral peak acceleration curve, for all vehicles

Rationale

G A.8.4 The required performance has been benchmarked against vehicles with a history of safe operation.

Guidance

G A.8.5 The IM can provide details on track maintenance limits, which enables certain results caused by track features outside the maintenance limits to be identified and discarded if appropriate. Evidence of such features is recorded in the test report.

A.9 Record of assessment conditions

A.9.1 Records of the cumulative acceleration values, the routes and track sections used, wheel-rail contact information and the geometric quality of the track used for the assessment shall be retained.

A.9.2 A justification that the selection of routes is representative of planned service conditions shall be included in the assessment report.

Rationale

G A.9.3 Records of assessment conditions are important to retain for future reference and are particularly useful for model validation purposes if the vehicle is modified.

Guidance

G A.9.4 None.

Appendix B Evidence to demonstrate that GMRT2141, issue four, Appendix A 'on-track ride tests' offers equivalent safety to the method of BS EN 14363:2016 clause 7 'dynamic performance assessment'

Note: The content of this appendix is provided for guidance only.

B.1 Background

Guidance

G B.1.1 BS EN 14363:2016 clause 4, Deviations from requirements, states:

'If deviating from some points of the requirements of this standard for a particular assessment, these deviations shall be reported and explained. Then the influence on the assessment of the vehicle in terms of the acceptance criteria shall be evaluated and recorded. The outcome of this study shall be considered as an integral part of the requirements of this standard when applied to the assessment process of the vehicle, as long as evidence can be furnished that safety is at least the equivalent to that ensured by complying with these rules.'

G B.1.2 ERA/TD/2012-17/INT and BS EN 14363:2005, as called up within the LOC&PAS TSI 2014 and WAG TSI 2013, also permit *'to deviate from the rules laid down if evidence can be furnished that safety is at least the equivalent to that ensured by complying with these rules'*. This Appendix has used BS EN 14363:2016 as the basis for comparison, but the technical requirements of BS EN 14363:2005, supplemented by ERA/TD/2012-17/INT, are for this purpose equivalent and the same assessment is valid for these requirements.

G B.1.3 The on-track ride test described in Appendix D of GMRT2141 issue three, and updated in Appendix A of GMRT2141 issue four, is considered to be a suitable equivalent for the 'Second stage – dynamic performance assessment' described in BS EN 14363:2016, clause 7. The background to this equivalence is set out below.

G B.1.4 Method 3 for assessment of the 'Safety against derailment on twisted track' (BS EN 14363:2016, clause 6.1.5.3 and Annex B) is the same as the method described in GMRT2141 issue three (Appendix A, Appendix B and Appendix C). The three methods included in BS EN 14363:2016, for the assessment of derailment on twisted track, are already accepted as equivalent to each other and so no demonstration of equivalence is required.

B.2 Consideration of equivalence

Guidance

G B.2.1 The following aspects are considered in establishing the equivalence of two or more different test methods:

a) The test conditions (track geometry, speeds, cant deficiency, wheel-rail contact conditions);
b) Types of vehicle;

c) The measured parameters;
d) The evaluation methods and limit values;
e) Previous experience.

G B.2.2 These aspects are considered together as it is the combination that provides an equivalent assessment, not the individual aspects; however, it is also useful to consider the available evidence against the different aspects. The following table sets out an overview of the two different methods.

Aspect	**BS EN 14363:2016**	**GMRT2141 issue four**
Test conditions	Four test zones with different combinations of conditions (7.3.1)	See Appendix A
• Track geometry	Straight and curves to 250 m, track quality (Annex M)	Representative of those to be used in service
• Speed	V_{adm} +10 % or 10 km/h	V_{adm}
• Cant deficiency	0.7 I_{adm} to 1.15 I_{adm}	Representative of values up to I_{adm} to be used in service
Contact conditions	See Table 2 and Annex P	See Appendix A.5
Types of vehicle	Conventional technology vehicle (Defn 3.14)	For conventional vehicles only
	Special vehicle (Defn 3.15)	Not applicable
• Fault modes	From analysis of design	No specific requirements
• Loading conditions	Empty and Loaded (5.3.2) (BS EN 15663)	See section 3.1
Measured parameters	Depends on choice of Normal / Simplified method and any permitted extension (Annex U)	See Appendix A.6
	Forces, accelerations	Accelerations
Evaluation methods	Generally via testing, simulation accepted in defined conditions	Generally via testing, simulation accepted in defined conditions

Aspect	BS EN 14363:2016	GMRT2141 issue four
• Filtering	See Figure 10 and Table 5	See Appendix A.6
• Statistical analysis	Each test zone (Annex R)	See Appendix A.7
• Criteria and limit values	See Table 4	See Appendix A.8
Previous experience	BS EN 14363 and the predecessor UIC518 used for many years on mainland European railways for passenger vehicles and locomotives. Most freight wagons approved under exemptions and not tested	Many years' experience on GB railways for passenger vehicles, locomotives, freight and on-track machines

Table 5: Overview of BS EN 14363:2016 and GMRT2141 issue four test methods

G B.2.3 The European Foreword to BS EN 14363:2016 states:

'It is not necessary to require further assessment of vehicles which have been already assessed under the conditions of previous standards in this field. Test results achieved under the conditions of the previous standards remain valid and can be used for the extension of acceptance of a vehicle or vehicle design according to this standard.

'Prior to the first issue of this standard, national procedures were applied for vehicle acceptance, for example in Germany or UK. The underlying principles that were applied in these earlier standards are also incorporated in this standard. The fundamentals have not been changed but the formulation of the requirements has been made consistent. Therefore, it is considered that also vehicles that were previously approved utilizing these earlier requirements have an equal status compared to vehicles that are approved according to this standard. This applies to the infrastructure and operating conditions that were considered in the earlier approval. This includes also a use as reference vehicle for extension of acceptance.'

G B.2.4 For UK(GB) operation, the national procedure referred to here is GMRT2141 and the text above is an indication that vehicles approved under GMRT2141 can be considered as having an equal status, meeting the same level of requirements, for the appropriate infrastructure and operating conditions, as vehicles approved under BS EN 14363, as the underlying principles and fundamentals are not changed.

G B.2.5 Further investigations have been undertaken to support this conclusion and these are described below.

B.3 Theoretical investigation

Guidance

G B.3.1 A theoretical investigation was undertaken by RSSB in 2015 to compare the running behaviour requirements in BS EN 14363 and GMRT2141 issue three (report number PB025305 available from RSSB). This covered six freight wagons, three locomotives, two passenger multiple units and a passenger coach and used the Vampire® multi-body software package to simulate the different tests.

G B.3.2 The study found that results for the BS EN 14363 methods correlate well with the GMRT2141 acceleration-based assessment; the Normal Method tends to give slightly higher limiting pass speeds than GMRT2141, whilst the Simplified Method gives slightly lower limiting pass speeds. However, results for all methods can vary depending on the route chosen and the options used in each assessment. The analysis used the draft of the updated BS EN 14363 available in 2013, but there are no relevant technical differences between this and the published BS EN 14363:2016.

G B.3.3 On the basis of this work, it was proposed to accept vehicles tested to BS EN 14363 (either Normal or Simplified method) onto the GB mainline railway without any further running dynamics assessment for compatibility. The exception to this would be if an assessment of the vehicle behaviour on cyclic top was required.

G B.3.4 This work supports the use of GMRT2141 as providing equivalent safety to BS EN 14363, but additional work, documented here, has been undertaken to further substantiate this.

B.4 Test and operating conditions

Guidance on track layout

G B.4.1 A comparison was undertaken by Network Rail and RSSB to compare the technical requirements for plain line track in the Infrastructure Technical Specification for Interoperability (INF TSI), the relevant EuroNorms (which includes BS EN 13848) and relevant Railway Group Standards clauses. This comparison was reported to GB Standards Committees and is available from RSSB (Reference number PB025490 'Infrastructure TSI / RGS / Network Rail standards comparison').

G B.4.2 The comparison found that the majority of technical requirements were very similar for all three documents, indicating that ‘representative’ GB routes would also be ‘representative’ for the broader European network.

Guidance on track geometric quality

G B.4.3 BS EN 14363:2016 has specific requirements for the track geometric quality of the test routes. This is based on the track quality bands developed by CEN TC256 WG28 and described in BS EN 13848-6:2014 'Railway applications. Track. Track geometry quality: Characterisation of track geometry quality'. These track quality bands were developed from a survey of a number of European railways, which included Network Rail. The results of this survey are reported in (CEN/TR 16513 'Railway applications - Track - Survey of track geometry quality') and, whilst the survey was intentionally anonymous, Network Rail (network 13) waived its anonymity so its results can be

compared with the range of values for the other networks. It is important to note that the Standard Deviation (SD) values quoted in this report are for the wavelength range 3 m to 25 m (D1 according to BS EN 13848) and are not directly comparable with the usual Network Rail data which include wavelengths up to 35 m.

G B.4.4 The study reported the 50 % and 90 % values of the SD values for each network for a range of speeds and for both vertical (LL) and lateral (AL) data. This comparison shows that, speed for speed, the lateral geometric quality 50 % value on GB track infrastructure is within the range of the other networks, whilst the 90 % is generally towards the 'rougher' end of the range. The vertical geometric quality on GB track infrastructure (both 50 % and 90 % values) is generally 'rougher' than the other railways, with the difference being most marked at the lower end of the speed range considered in this study.

G B.4.5 This comparison gives confidence that vehicles tested on 'representative' GB routes will have encountered track geometry where the quality is towards the lower end of the European range.

G B.4.6 A particular feature of some GB track, that is not so well recognised in other networks, is cyclic top. The GB approvals process, through the requirement for 'representative track', has some consideration of this, although, before the publication of GMRT2141 issue four, there was no explicit requirement. Many vehicles are not susceptible to cyclic top; for those that are, the GB process set out in GMRT2141 issue four is believed to be more onerous than the BS EN 14363 requirements and hence includes an additional margin.

Guidance on wheel-rail contact

G B.4.7 For the purpose of testing vehicle dynamic behaviour and stability / instability, the key parameter which describes the wheel-rail contact is equivalent conicity (see BS EN 15302). BS EN 14363:2016 requires at least three test sections where $\tan\gamma_e$ exceeds a speed-dependent minimum value for the stability test and representative conditions, but with no specific values, for the other tests. GMRT2141 issue four, Appendix A.5 sets out the requirements for equivalent conicity and states that it is an important influence.

G B.4.8 The EU Framework Programme (FP7) DynoTRAIN project, Work Package 3, investigated, in depth, the in-service values of equivalent conicity across a range of European networks. This survey showed that the real in-service conditions created similar effects in terms of equivalent conicity for all the considered networks, whilst some high and some low values are also seen on all networks. Thus, vehicles tested in GB in accordance with GMRT2141 and vehicles tested on other networks in accordance with BS EN 14363 (or UIC518) are likely to have covered similar ranges of equivalent conicity.

Guidance on speed and cant deficiency

G B.4.9 GMRT2141 issue four (and predecessor documents) requires testing up to the intended operating speed, whilst BS EN 14363 requires testing to a margin above the intended operating speed. GMRT2141 issue four requires testing up to the maximum cant deficiency, but does not set a requirement for how many curves need to be tested at this condition, whilst BS EN 14363, test zone 2, has explicit requirements for

combinations of speed and cant deficiency. The earlier theoretical study by RSSB in 2015 to compare the running behaviour requirements in BS EN 14363:2005 and GMRT2141 issue three addressed these differences (report number PB025305, available from RSSB).

B.5 Types of vehicle, fault modes and loading conditions

Guidance

G B.5.1 Both BS EN 14363 and GMRT2141 apply to the full range of vehicle types: passenger, freight, locomotive and on-track machines (in running mode). In practice, very few freight vehicles have been tested to BS EN 14363 as most use 'established' bogies and are approved under dispensations. See further discussion on previous experience at section *B.7* below.

G B.5.2 BS EN 14363 has a clear definition of the loading conditions to be assessed. GMRT2141, issue four, clause 3.1 requires consideration to be given to the range of conditions necessary and this includes loading conditions. In both cases, the inclusion of fault conditions is for the applicant to select; no specific requirements are given.

B.6 Measured parameters, evaluation methods and limit values

Guidance

G B.6.1 The theoretical study described above considered the different measured parameters, together with their evaluation methods and limit values, and concluded that the methods were all equivalent. No further analysis is required, though it should be noted that it is important to use the method selected consistently and it is not appropriate to mix parts of different methods.

B.7 Previous experience

Guidance

G B.7.1 GMRT2141 issue one came into force in 1998, with very similar requirements to later issues. GB vehicles introduced since 1998 will therefore have been assessed in accordance with these principles.

G B.7.2 Information from R2 (the database containing details of all vehicles authorised to operate on the GB mainline railway) has been used to give an indication of the number of vehicles that have been introduced to service since 1998. This lists more than 10,000 multiple unit vehicles, 15,000 freight wagons and several hundred locomotives that have been introduced in this time. Not all of these vehicles, of a wide range of types, will have been tested but all will have gone through an approval process. This shows that the principles of GMRT2141 have been successfully applied to a very significant number of vehicles.

G B.7.3 Various sources of data were then reviewed to seek to establish a comparison between derailment incidents for vehicles approved in accordance with GMRT2141 and those approved in accordance with BS EN 14363 or UIC 518 (a predecessor document in use in various EU networks). Whilst data for incidents on the GB mainline

railway are relatively well documented, that for other European networks appear to have been less well reported, making like-for-like comparison of accident statistics inappropriate. However, all the evidence that has been found, which includes EU databases and various EU and European Union Agency for Railways (ERA) studies, indicates that the GB mainline railway is one of the safest in Europe. There is therefore strong circumstantial evidence that the GB approved vehicles are no more derailment prone than those approved in other EU member states. It is worth repeating that the vast majority of freight vehicles approved elsewhere in Europe are not tested, as they use 'approved' bogies and are therefore exempt.

B.8 Summary

Guidance

G B.8.1 In summary:

a) Track layout rules are equivalent for UK(GB) mainline and other European networks;
b) Track geometric quality is similar or rougher for the UK(GB) mainline railway compared to other European networks;
c) Wheel-rail contact conditions are similar on the different European networks;
d) The RSSB theoretical study has compared the different assessment methods and found that the results correlate well for a range of vehicles; and
e) Previous experience and available information on derailments indicate that GB operations are amongst the safest in Europe.

B.9 Conclusions

Guidance

G B.9.1 On the basis of the investigations described above, the on-track ride test described in Appendix A of GMRT2141 issue four is a suitable equivalent for the 'Second stage – dynamic performance assessment' described in BS EN 14363:2016, clause 7. No further evidence is required to show that safety, when applying Appendix A of GMRT2141 issue four, is at least the equivalent to that ensured by complying with BS EN 14363:2016, clause 7.

G B.9.2 The technical requirements of BS EN 14363:2005, supplemented by ERA/TD/2012-17/INT, as called up within the LOC&PAS TSI 2014 and WAG TSI 2013, are for this purpose equivalent, and the same conclusion is valid for these requirements.

Appendix C Comparison of a new vehicle to a similar existing comparator vehicle that is not susceptible to cyclic top (or has a history of safe operation)

Note: The content of this appendix is provided for guidance only.

C.1 Comparison of a new vehicle to a similar existing comparator vehicle that is not susceptible to cyclic top (or has a history of safe operation)

Guidance

G C.1.1 For a new vehicle to be exempt from a cyclic top assessment, it is considered good practice for it to be similar in design to an existing vehicle with a documented history of safe operation. For the comparator vehicle to be classed as similar, it is important to consider the following vehicle parameters:

a) Bogie pivot centres / axle spacing;
b) Bogie wheelbase;
c) Primary and secondary suspension types;
d) Vertical damper rates or percentage of friction damping; and
e) Natural frequencies.

G C.1.2 BS EN 14363 contains table U.1 'Parameter change table' that can be used as a guide for how the vehicle parameters can differ. However, the suggested parameter ranges in table U.1 for the parameters listed in *G C.1.1* above could, in some circumstances, lead to unacceptable vehicle response to cyclic top.

G C.1.3 It is also considered good practice for the comparator vehicle to have similar operating conditions and to take into account factors such as:

a) Loading pattern and conditions;
b) Maximum speed and typical operating speeds;
c) Track quality on intended routes; and
d) Maintenance limits on components subject to wear / deterioration.

Appendix D Simulation methodology for demonstrating that a vehicle is not susceptible to cyclic top

Note: The content of this appendix is required by clause *3.6.1 b)*. The aim of this methodology is to demonstrate that a computer model of the candidate vehicle is not predicted to exhibit significant wheel unloading while running over a track file that has a sinusoidal waveform of increasing wavelength at a range of speeds.

D.1 Methodology

D.1.1 A multi-body simulation (MBS) model that meets the validation requirements set out in Appendix *E* shall be used with a validated MBS software package.

D.1.2 The cyclic top wavelength shall increase from 5 to 31 m over a distance of 400 m after a suitable lead in. Figure *7* shows an example of a graphical representation of the track file.

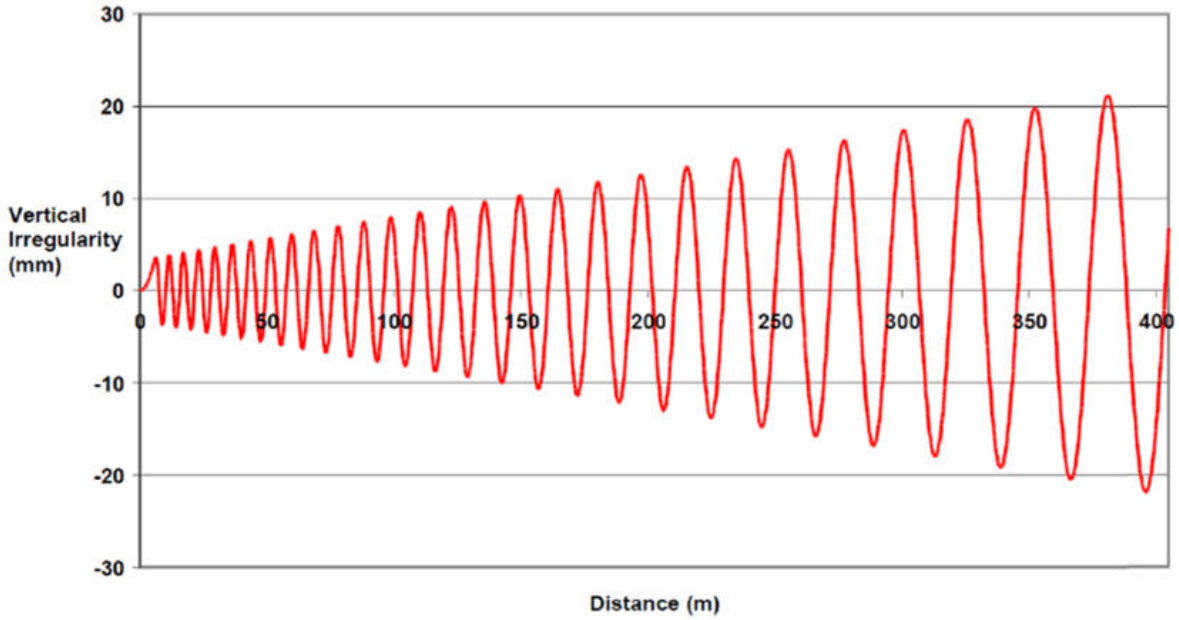

Figure 7: Example of a graphical representation of the cyclic top track file

D.1.3 A vertical amplification factor for each different speed shall be used and is provided in Table *6*.

Speed (mph)	Factor		Speed (mph)	Factor
40	1.336		90	0.777
45	1.293		95	0.737
50	1.251		100	0.700
55	1.209		105	0.667
60	1.167		110	0.636
65	1.077		115	0.609
70	1.000		120	0.583
75	0.933		125	0.560
80	0.875		130	0.538
85	0.824		135	0.519

Table 6: Cyclic top track file speed amplification factors

D.1.4 The vehicle model shall be run over the waveform in the cyclic top track file for each speed starting from 40 mph up to the vehicle's maximum operating speed + 10 % (capped at +10 mph above 100 mph), in increments of 5 mph.

D.1.5 The wheel profile for the simulation shall be the same as for the real vehicle. A standard rail profile, track gauge and coefficient of friction level between the wheels and rails shall be used to ensure that there are no significant lateral wheelset accelerations or dynamic instability that could affect the predicted vertical wheel loads.

Rationale

G D.1.6 This methodology has been demonstrated to identify vehicles susceptible to cyclic top track features and has been benchmarked against current known poor vehicles.

Guidance

G D.1.7 The cyclic top track file to be used is available from RSSB.

D.2 Vehicle conditions

Guidance

G D.2.1 The vehicle conditions are set out in section *3.1* of this document.

G D.2.2 It is particularly important for this assessment to consider the intermediate loading conditions such as part-laden that might lead to increased risk for vehicles with multi-stage suspension and transition points.

G D.2.3 It is industry practice to consider credible failure conditions such as deflated air-springs.

G D.2.4 The cyclic top assessment is valid up to vehicle speeds of 125 mph (+10 mph over-speed). For the assessment speeds that are not multiples of 5 mph, the following calculations can be used to determine the track file amplification factor:

a) $\geq 60mph = \frac{70}{speed(mph)}$

b) $< 60mph = 1.675 - \left(\frac{speed(mph)}{118}\right)$

G D.2.5 For vehicles carrying intermodal load units, it is not required to assess the vehicle against the cyclic top requirement with an offset load. The offset load assessment is a separate requirement as set out in section *3.3*.

D.3 Performance requirement

D.3.1 The value of the unfiltered wheel unloading quotient (Delta Q/Q) shall be recorded, for each wheel of the vehicle, over the full length of the cyclic top track file.

D.3.2 The vehicle shall be deemed to have satisfied the performance requirement if at no point, for all speeds and conditions, does the wheel unloading (Delta Q/Q) value exceed 0.8.

Rationale

G D.3.3 The required performance has been benchmarked against vehicles with a history of safe operation.

Guidance

G D.3.4 The background to the original development of the cyclic top simulation assessment is described in AEA Technology Rail (now Resonate) report AEATR-T&S-2002-154, 'Review of GM/RT2141 Stage 4 – Cyclic Top Investigation'. Details of the updated track file and choice of the sine wave amplification factor is described in Resonate report 5359-DEL-REL-001, 'Adjustments to proposed simulation method for assessment of cyclic top derailment risk'.

Appendix E Multi-body simulation (MBS) model validation for use in the cyclic top assessment

Note: The content of this appendix is required by *D.1.1*. The cyclic top assessment requires a vehicle dynamics multi-body simulation (MBS) of a mathematical model of the candidate vehicle running over a defined 'obstacle course'. In order for this process to be used, clarity is needed on what validation is required for such a mathematical model.

E.1 Validation options for cyclic top assessment

E.1.1 One of the following options shall be used to demonstrate that the mathematical vehicle model is sufficiently validated:

a) Validation in accordance with Method 1 of BS EN 14363 Annex T.3.3.3, including confirmation by an independent reviewer (Annex T.3.3.6);
b) Validation in accordance with Method 2 of BS EN 14363 Annex T.3.3.4, using the declared metrics and limit values;
c) A combination of a suitably validated model of a similar vehicle, in accordance with BS EN 14363 Annex T.3.3.3 or T.3.3.4, and confirmation of the correct implementation in the model of changes from that base vehicle to the current candidate vehicle (Annex T.3.3.6) with the reviewer's report;
d) An alternative, technically justified validation process may be used if it meets the declared objective of achieving the same level of confidence as on-track tests.

E.1.2 If the vehicle is to be assessed in different loading conditions, then the simulation model shall require a separate validation for each of these conditions.

Rationale

G E.1.3 The validation assessment is required to demonstrate that the mathematical model is a correct representation of the particular vehicle design, taking into account the intended use of the model.

Guidance

G E.1.4 For option *a)* above, using this process with a restriction to a limited range of application is permitted and, subject to agreement by the independent reviewer (Annex T.3.3.6), this could be used to limit the amount of validation required for plan-view behaviour and to restrict the validation to straight track. If wheel-rail force measurements are not included in the validation, then alternative evidence could be used to support the claim that the dynamic behaviour of the primary suspension is correctly modelled. As an example, this could include suspension displacements.

G E.1.5 For option *b)* above, this is the most comprehensive validation requirement but it may be considered to be too onerous for this application and a less restrictive option may be more suitable.

G E.1.6 For option *c)* above, BS EN 14363 Annex U can be used as an indication of the range of parameter variation between the base and candidate vehicles that is appropriate, but this is subject to confirmation by the independent reviewer.

G E.1.7 For option *d)* above, the introduction to BS EN 14363 Annex T states: '*… the use of simulation in place of on-track test is permitted under controlled conditions. The objective when using simulation is to achieve the same level of confidence in the results as would be achieved by on-track tests. The simulation process described in this annex sets out one means by which this can be achieved. Other simulation procedures that achieve the same level of confidence are also permitted.*'

G E.1.8 The use of multi-body simulations is now a routine part of railway vehicle design and is increasingly used as part of the approval process. There are various commercial software packages available for this purpose, and verification that the code of these packages operates correctly has been undertaken by the developers. However, it is necessary for each application to show that the mathematical model is a correct representation of the particular vehicle design, taking into account the intended use of the model.

G E.1.9 Various methods have been considered for model validation, with the most extensive investigation being undertaken as part of the DynoTRAIN European Union (EU) Framework Programme 7 (FP7) project ('Railway Vehicle Dynamics and Track Interactions Total Regulatory Acceptance for the Interoperable Network').

G E.1.10 The principles of model validation are generally based on a combination of comparison with physical test results, in laboratory and / or on-track, and experience from modelling similar vehicles. DynoTRAIN WP5 investigated three different approaches: (1) a process for comparing values from simulation with physical on-track tests; (2) subjective engineering judgement of comparative results by experts; and (3) use of validation metrics. The first method was recommended as the most effective and reliable. The results of this work were incorporated in BS EN14363 as Method 2 (see clause *G E.1.13*).

G E.1.11 BS EN 14363 Annex T incorporates two methods for vehicle model validation.

G E.1.12 Method 1 (described in Annex T.3.3.3) is based on a comparison of vehicle model outputs with the measured vehicle response to various inputs, with the results of the analysis judged by an independent reviewer to confirm the range of validity of the model. This process was first described in BS EN 15827:2011 before being incorporated into BS EN 14363 and is based on GB experience in using simulations in place of, or in support of, the ride test of GMRT2141.

G E.1.13 Method 2 (described in Annex T.3.3.4) is based on a mathematical comparison between the results of on-track tests performed according to the normal measuring method of BS EN 14363 and the corresponding simulation results and was developed and validated by the DynoTRAIN EU FP7 project. This generally requires the use of force measuring wheelsets, as comparison of wheel-rail forces is part of the process, unless alternative measurements are justified.

Cyclic top assessment by simulation

G E.1.14 The key requirement for a multi-body simulation of the response of a vehicle to cyclic top is a detailed representation of the dynamic behaviour in the vertical direction for a range of amplitudes of input. The plan view behaviour of the model also has to be satisfactory but the detail of this is less significant for this particular application.

Modelling of vertical behaviour is generally assumed to be easier than plan-view, as details of wheel and rail profiles, wheel-rail friction levels and so on are not required. However, for many of the vehicles likely to be assessed for cyclic top, particularly freight vehicles, this will require modelling of friction suspension elements, which are particularly complex and highly non-linear.

G E.1.15 A simulation model fully validated in accordance with the process of BS EN 14363 Annex T.3 is suitable for use in assessment of the cyclic top response. However, full validation to all of these requirements may be unduly onerous and alternative approaches may be considered.

G E.1.16 Assessment of susceptibility to cyclic top is a separate evaluation from that described in BS EN 14363 clause 6.1.5.3 and Annex B (or previously in GMRT2141, issue three, Appendix C) for assessment of flange climb derailment at low speed, and different model validation is therefore required. It is important to note that model validation by comparison with static laboratory tests, such as the Delta Q/Q wheel unloading test (set out in GMGN2641), can still be useful but is not sufficient for use of the model for the cyclic top assessment as this does not confirm the dynamic behaviour of the suspension, including any friction damping.

Appendix F Guidance on alternative routes to compliance with this document

Note: The content of this appendix is provided for guidance only.

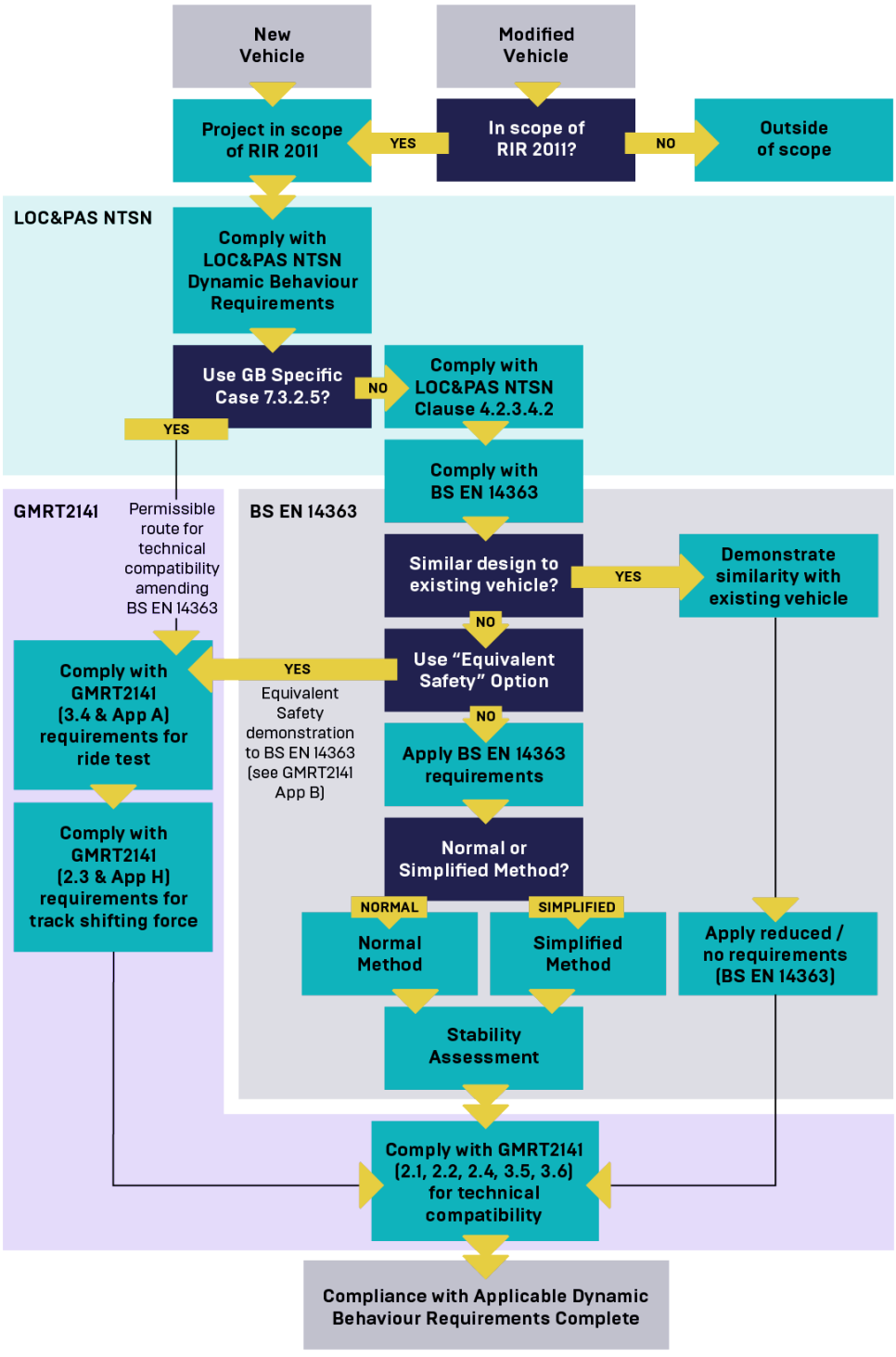

Figure 8: Running Dynamic Behaviour Requirement Process Diagram - LOC&PAS NTSN

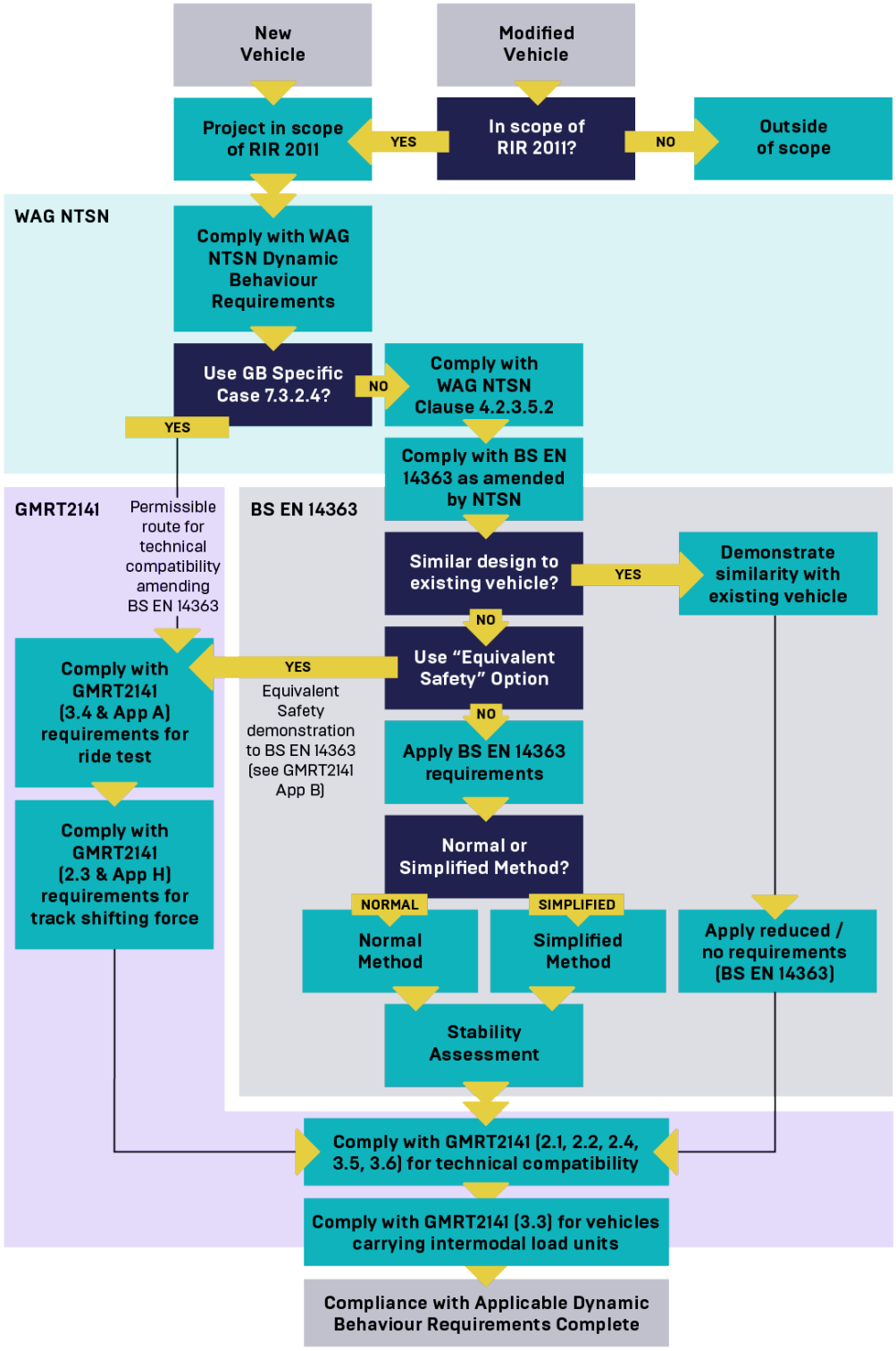

Figure 9: Running Dynamic Behaviour Requirement Process Diagram - WAG NTSN

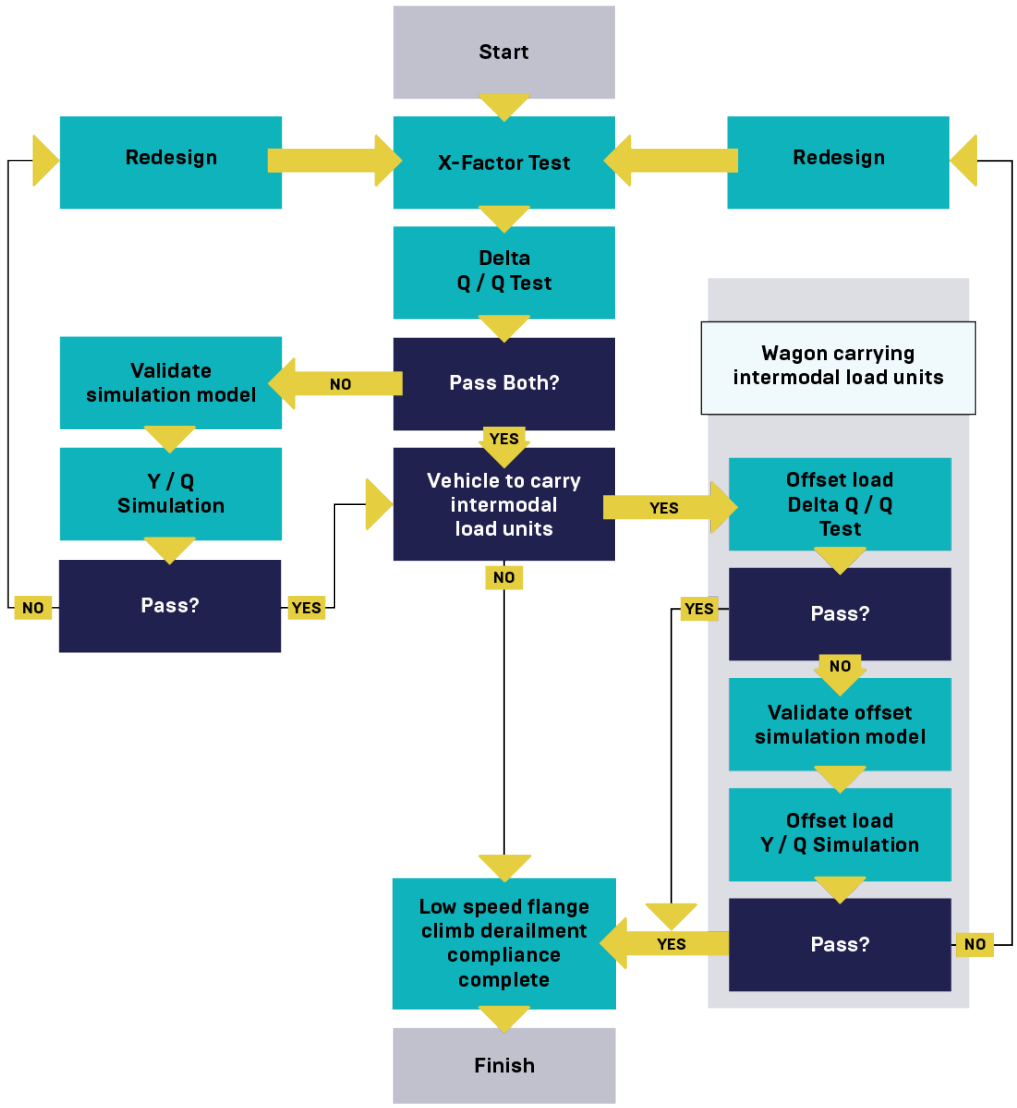

Figure 10: Diagram of Process Options for Low Speed Flange Climb Assessment

Appendix H Simulation methodology for demonstrating that a vehicle meets the track shifting force limits

Note: The contents of this appendix is required by clause *2.3.1*. The aim of this methodology is to demonstrate that a mathematical model of the candidate vehicle is not predicted to exceed the track shifting force (ΣY) limits applicable to the axleload of the vehicle. This alternative method is applicable for maximum operating speeds up to 125 mph and a maximum operating cant deficiency up to 6˚.

H.1 Methodology

H.1.1 The vehicle shall be assessed at its maximum design operating speed (up to 125 mph) and its maximum operating cant deficiency (up to 6˚).

H.1.2 The wheel-rail contact geometry shall be based on new wheels with the design wheel profile running on new CEN 60E2 rails laid at 1:20 inclination and 1435 mm track gauge.

H.1.3 The wheel-rail coefficient of friction μ shall be 0.24.

H.1.4 One of the following options shall be used to demonstrate that the mathematical vehicle model is sufficiently validated:

a) Validation in accordance with Method 1 of BS EN 14363 Annex T.3.3.3, including confirmation by an independent reviewer (Annex T.3.3.6).
b) Validation in accordance with Method 2 of BS EN 14363 Annex T.3.3.4, using the declared metrics and limit values.
c) A combination of a suitably validated model of a similar vehicle, in accordance with BS EN 14363 Annex T.3.3.3 or T.3.3.4, and confirmation of the correct implementation in the model of changes from that base vehicle to the current candidate vehicle (Annex T.3.3.6), subject to agreement and reporting by an independent reviewer.
d) An alternative, technically justified validation process if it meets the declared objective of achieving the same level of confidence as on-track tests.

H.1.5 If the vehicle is to be assessed in different loading conditions, then the simulation model shall require a separate validation for each of these conditions.

Rationale

G H.1.6 This requirement is for compatibility with the existing GB mainline railway. Vehicles need to be designed so that under all normal track and operating conditions they do not generate excessive lateral forces, which could damage the structural integrity of the rails and track.

G H.1.7 The validation assessment is to demonstrate that the mathematical model is a correct representation of the particular vehicle design, taking into account the intended use of the model.

Guidance

G H.1.8 Validation Method 1 as described in BS EN14363, annex T.3.3.3, is based on the process which has previously been followed in GB.

G H.1.9 Where certain test data are not available for comparison with the mathematical model, BS EN 14363 permits the impact of the missing data on the model accuracy to be assessed and a technical justification made for the independent reviewer to consider.

G H.1.10 When results from load measuring wheelsets are not available for comparison, current practice typically involves using the results of axlebox and/or bogie lateral accelerations and/or lateral displacements.

G H.1.11 Work described in TM-VTI-013 and in TM-VTI-023 developed a methodology and track input that are set out in this document.

G H.1.12 GCRT5021 sets out requirements for permissible combinations of curvature, installed cant, transition design and cant deficiency.

H.2 Track input

Guidance

G H.2.1 The two 'assault course' track inputs that have historically been used for the assessment of lateral track forces are taken from BR Research report TM-VTI-023 and are described below.

Details of High Speed Track Input (No.1)

The lateral track input, for use with vehicles with maximum design operating speed in the range 90 – 125 mph, consists of the following:

a) A short wavelength input consisting of a left hand 'kink' of 5.5 mrad starting at 10 m from the start;
b) A 100 m long spiral transition curve starting at 10 m, followed by a constant radius right hand curve. The radius and cant of the constant radius curve are chosen such that, at the maximum design operating speed of the vehicle being assessed, the cant deficiency is the maximum allowable for the vehicle. Any cant is applied on the transition in proportion to the increasing curvature;
c) Superimposed on the constant radius curve is a sinusoidal waveform with a variable amplitude and wavelength starting at 200 m from the start. The wavelength begins at 125 m in length and reduces to 40 m. The amplitude starts at 50 mm and reduces in proportion to the wavelength to the 1.5 power;
d) The overall length of the track input is 1,000 m;
e) The lateral track model consists of a 20 MN/m spring in parallel with a 0.1 MNs/m damper.

The magnitude of the response to the 'kink' input is a measure of the vehicle's effective lateral unsprung mass; the magnitude of the response on the sinusoidal input is a measure of the adequacy of the secondary suspension.

Details of Low Speed Track Input (No.2)

The concept of the low-speed track input is similar to that of the high-speed input. It is for use for vehicles with maximum design operating speeds below 90 mph. It consists of the following:

a) A left hand 'kink' of 9.4 mrad starting at 5 m from the start;
b) An uncanted right hand spiral transition curve starting at 10 m from the start;
c) Superimposed on the transition is a lateral irregularity repeating every 18.2 m, starting at 72.8 m from the start. The co-ordinates for the lateral irregularity are set out in Table 7 below. (Note: smoothing of the curve fit is typically applied depending on the software used);
d) The overall length of the track input is 500 m;
e) The lateral track model consists of a 20 MN/m spring in parallel with a 0.1 MNs/m damper.

Predictions on this track input are performed for the vehicle decelerating linearly in time from its maximum design operating speed at the beginning to 15 m/s (approx. 34 mph) at the end. The curvature through the spiral from 50 m to the end is calculated in order to maintain the maximum allowable cant deficiency for the vehicle as the speed reduces. Between 0 and 50 m, the curvature is calculated in order to cause a linear increase in cant deficiency with distance such that the maximum value is achieved at 50 m. Between 0 and 10 m, the curvature is set to zero, so there is a small step change at 10 m. The lateral irregularities are passed at steadily decreasing frequency, due to the decreasing speed and the excitation they provide is a test of the adequacy of the secondary suspension. The response to the 'kink' gives a measure of the vehicle's effective lateral unsprung mass.

Distance (m)	Lateral amplitude (mm)
0	0
0.5	1.06
1.0	3.71
2.0	9.00
4.0	13.76
6.0	16.94
8.0	18.00
10.2	18.00
12.2	16.94
14.2	13.76
16.2	9.00
17.2	3.71
17.7	1.06
18.2	0

Table 7: Lateral irregularity input for the Low Speed Track Input (No.2)

H.3 Performance requirements

H.3.1 A vehicle operating solely on the GB mainline railway shall not subject the track to lateral forces greater than:

$$Y = 10 + \frac{W}{3}$$

where:

Y = lateral force transmitted to track per axle (kN)

W = static axleload (kN)

H.3.2 To take account of the dynamic nature of peak lateral forces, a 2 m running average filter shall be applied to the predicted lateral track shifting forces.

Rationale

G H.3.3 This requirement is for compatibility with the existing GB mainline network. Vehicles need to be designed so that under all normal track and operating conditions they do

not generate excessive lateral forces, which could damage the structural integrity of the rails and track.

Guidance

G H.3.4 None.

Definitions

bogie freight vehicle	A freight vehicle fitted with bogies that is used exclusively for the transportation of freight commodities / loads, excluding on-track machines (as defined in GMRT2400).
cant deficiency	The difference between actual cant and the theoretical cant that would have to be applied to maintain the resultant of the weight of the vehicle and the effect of centrifugal force, at a nominated speed, such that it is perpendicular to the plane of the rails.
cyclic top	Cyclic top is the term used to describe a series of regular dips in the vertical alignment of one or both rails. They may not always be apparent visually because other top irregularities may obscure the cyclic pattern. Cyclic irregularities in track geometry have the potential, when combined with a vehicle's natural vertical response for a given speed and load, to cause a derailment.
infrastructure manager (IM)	Has the meaning given to it in the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended), but is limited to those infrastructure managers who hold a safety authorisation issued in respect of the mainline railway. Source: *ROGS*
Intermodal load unit	Goods container used in intermodal transport. Typically either shipping containers or swap bodies.
P2 force	The total vertical force generated at the interface between a wheel and a rail, comprising the static gravitational loading on the wheel and the inertia forces associated with the dynamic response of the unsprung masses to defined variations in the vertical alignment of the rail.
permissible speed	The authorised maximum speed over a section of line, either for all trains or (where differential or enhanced permissible speeds are applied) for specific types of trains, as set out in the Sectional Appendix.
roll-over	A burr of extruded material forming on the outer rim side of the wheel during service by plastic deformation.
tilting train	A train having a system which tilts the train body to reduce the lateral acceleration experienced by passengers when operating around curves, allowing the train to run at higher speeds through curves than non-tilting trains.
unsprung mass	The mass of a wheel, or wheelset, and other associated components which are not dynamically isolated from the track by vehicle suspension arrangements.
vehicle	An individual vehicle or car of any train formation.

References

The Standards catalogue gives the current issue number and status of documents published by RSSB: http://www.rssb.co.uk/railway-group-standards.

RGSC 01	Railway Standards Code
RGSC 02	Standards Manual

Documents referenced in the text

Railway Group Standards

GCRT5021	Track System Requirements
GERT8006	Route Availability Number for Assessment of Compatibility between Rail Vehicles and Underline Bridges
GMRT2142	Resistance of Railway Vehicles to Roll-Over in Gales
GMRT2400	Engineering Design of On-Track Machines in Running Mode
GMRT2466	Railway Wheelsets

RSSB documents

GMGN2615	Guidance on the Locomotives and Passenger Rolling Stock NTSN
GMGN2641	Recommendations for Vehicle Static Testing
GMGN2688	Application of the WAG NTSN and the NOI NTSN to the Design of Freight Wagons
RIS-8012-CCS	Controlling the Speed of Tilting Trains through Curves
RIS-1530-PLT	On-Track Plant, Trolleys and Associated Equipment

Other references

AEATR-T&S-2002-154	Review of GM/RT2141 Stage 4 – Cyclic Top Investigation, available from RSSB
BS EN 13848-6:2014	Railway applications. Track. Track geometry quality. Characterisation of track geometry quality
BS EN 14363:2005	Railway applications.Testing for the acceptance of running characteristics of railway vehicles.Testing of running behaviour and stationary tests
BS EN 14363:2016	Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests
BS EN 14363:2016+A2:2022	Railway applications.Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running behaviour and stationary tests

BS EN 15302:2021	Railway applications. Wheel rail contact geometry parameters. Definitions and methods for evaluation
BS EN 15663:2017+A1:2018	Railway applications. Vehicle reference masses
BS EN 15827:2011	Railway applications. Requirements for bogies and running gears
CEN TR 16513:2014	Railway applications. Track. Survey of track geometric quality
DynoTRAIN FP7	Railway Vehicle Dynamics and Track Interactions Total Regulatory Acceptance for the Interoperable Network
DynoTRAIN WP5	Validation of simulation models in context of railway vehicle acceptance
ERA/TD/2012-17/INT	Application of EN 14363:2005 – modifications and clarifications
INF NTSN	Infrastructure National Technical Specification Notice, published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This NTSN replaces and substantially reproduces the provisions of Commission Regulation (EU) No 1299/2014 (INF TSI) and includes relevant amendments made by Commission Implementing Regulation (EU) 2019/776 which cam into force in June 2019.
INF TSI	Commission Regulation (EU) No 1299/2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union. Amended by Commission Implementing Regulations (EU) 2019/776, 2023/1694 and dated 28.09.2023.
JRRT Special Issue 2015	A multi-national survey of the contact geometry between wheels and rails
LOC&PAS NTSN	Locomotive and PAssenger National Technical Specification Notice, published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This NTSN replaces and substantially reproduces the provisions of Commission Regulation (EU) 1302/2014 (the LOC&PAS TSI), and includes relevant amendments made by Commission Implementing Regulation (EU) 2019/776 which came into force in June 2019.
LOC&PAS TSI	Commission Regulation (EU) No 1302/2014 concerning a technical specification for interoperability relating to the 'rolling stock - locomotives and passenger rolling stock' subsystem of the rail system in the European Union. Amended by Commission Regulations (EU) 2016/919, 2018/868, 2019/776, 2020/387, 2023/1694 and dated 28.09.2023.
PB025305	'Comparison of the dynamic running behaviour assessment in GM/RT2141 and BS EN 14363' July 2015, available from RSSB
PB025490	Network Rail standards comparison, available from RSSB

RIR 2011	Railways Interoperability Regulations 2011 (as amended)
T889	Controlling rail vertical contact stresses
T1119	Investigating the effects of offset loading in containers on risk of derailment on twisted track
TM-VTI-013	British Rail Research Report: 'A design case track irregularity for theoretical prediction of dynamic lateral track forces'
TM-VTI-023	British Rail Research Report: 'A procedure for predicting dynamic lateral track forces for traction and rolling stock'
UIC Code 518	Testing and Approval of Railway Vehicles from the Point of View of Their Dynamic Behaviour : Safety, Track Fatigue, Ride Quality
WAG NTSN	Freight Wagons National Technical Specification Notice, published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This NTSN replaces and substantially reproduces the provisions of Commission Regulation (EU) 321/2013 (the WAG TSI), and includes relevant amendments made by Commission Implementing Regulation (EU) 2019/776 which came into force in June 2019.
WAG TSI	Commission Regulation (EU) No 321/2013 concerning the technical specification for interoperability relating to the subsystem 'rolling stock - freight wagons' of the rail system of the European Union and repealing decision 2006/861/EC. Amended by Commission Regulations (EU) 1236/2013, 2015/924, 2020/387, 2023/1694 and dated 28.09.2023.
5359-DEL-REL-001	'Adjustments to proposed simulation method for assessment of cyclic top derailment risk', by Resonate