

Railway Group Standard**GM/RT2141****Issue Three****Date June 2009**

Resistance of Railway Vehicles to Derailment and Roll-Over

Synopsis

This document mandates requirements for rolling stock to ensure acceptable resistance against flange climbing derailment and against roll-over induced by overspeeding.

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Issue	Date	Comments
One	February 1998	Original document Supersedes GM/TT0087
Two	October 2000	Replaces issue one Includes new requirements for tilting trains
Three	June 2009	Replaces issue two Includes a new vertical acceleration curve for bogie freight vehicles tested on jointed track

Amended or additional parts of revised pages have been marked by a vertical black line in the adjacent margin.

Superseded documents

The following Railway Group documents are superseded, either in whole or in part as indicated:

Superseded documents	Sections superseded	Date when sections are superseded
GM/RT2141, issue two Resistance of Railway Vehicles to Derailment and Roll-Over	All	01 August 2009

Supply

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Railway Group Standard**GM/RT2141****Issue Three****Date June 2009****Resistance of Railway Vehicles to Derailment and Roll-Over****Part 1 Purpose and Introduction****1.1 Purpose**

- 1.1.1 This document mandates requirements for rolling stock to ensure acceptable resistance against flange climbing derailment and against roll-over induced by overspeeding.

1.2 Introduction**1.2.1 Resistance to derailment**

- 1.2.1.1 This document defines the criteria by which acceptable derailment resistance of vehicles is to be demonstrated. The most direct method of assessing derailment propensity is by on-track measurement of the ratio of lateral to vertical force at the wheel-rail interface, but long experience has shown that rather more indirect methods can provide adequate assurance of safety against derailment. Such methods are usually easier to implement than on-track wheel / rail force measurements, but will generally lead to more conservative engineering solutions.

1.2.2 Derailment resistance compliance methods

- 1.2.2.1 This document sets out three methods for gaining acceptance. It allows the user to opt, where appropriate, for the most easily implemented method, but with the possibility, where it is not possible to demonstrate acceptability in this way, to move to a more direct method or ultimately to an on-track force measurement.

1.2.3 Derailment resistance compliance method 1

- 1.2.3.1 This combines laboratory based wheel unloading and (where appropriate) bogie rotation tests with on-track ride tests so as to check compliance with defined criteria which have been shown by practical experience to confer satisfactory derailment resistance. If all the criteria are met, this is a sufficient condition for the vehicle to be acceptable in respect of derailment resistance. However, this method does not give any indication of the ability of certain vehicles to cope with the geometric chord offset effect which arises in negotiating curves. Hence it is not applicable to vehicles with a multi-bogie / axle configuration. Moreover, the indirect criteria used in the wheel unloading, bogie rotation and ride tests which have been developed by largely empirical methods may not be applicable to vehicles with novel suspension or running gear. The method is therefore not applicable to vehicles with a novel suspension or running gear.

1.2.4 Derailment resistance compliance method 2

- 1.2.4.1 Replaces the acceptance criteria contained in the wheel unloading and bogie rotation tests by a criterion based on predicted wheel/rail forces (Y/Q) using a computer simulation. A computer model of the vehicle, which has been validated against the laboratory $\Delta Q/Q$ and X-factor tests, is used to predict the Y/Q ratio as a time history when negotiating prescribed track inputs. If all the criteria are satisfied, completion of a ride test is then a sufficient condition for the vehicle to be acceptable in terms of derailment resistance. As the method gives an indication of the ability of vehicles to cope with the geometric chord offset effect it is applicable to vehicles with a multi-bogie / axle configuration, but should not be applied to vehicles with a novel suspension or running gear.

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1.2.5 Derailment resistance compliance method 3

- 1.2.5.1 Replaces the wheel unloading, bogie rotation and ride tests and the computer simulation by a direct on-track measurement of derailment propensity derived from the ratio of lateral to vertical dynamic force (Y/Q) at the wheel / rail interface. This method is applicable to any vehicle. If the Y/Q criterion is met, this is a sufficient condition for the vehicle to be acceptable in terms of derailment resistance.

1.2.6 Route to compliance

- 1.2.6.1 From the above, it can be seen that for certain types of vehicle there is more than one possible route to compliance. Tables 1a and 1b summarise those routes, as follows:

- a) Allowable methods of acceptance for different vehicle types
- b) Appendices applicable to the methods indicated above.

	Method 1	Method 2	Method 3
Vehicles having neither novel suspension or running gear nor a multi-bogie / axle configuration	X	X	X
Vehicles having a multi-bogie / axle configuration but not having a novel suspension or running gear		X	X
Vehicles having a novel suspension or running gear			X

Table 1a Allowable methods of acceptance for different vehicle types

	Appendix A Static or quasi-static measurement of wheel unloading on twisted track	Appendix B Measurement of bogie rotational resistance	Appendix C Computer simulations designed to examine whether the vehicle has an acceptable resistance to flange climbing derailment at low speed	Appendix D On-track ride tests	Appendix E On-track dynamic measurement of Y/Q ratio and analysis of the results
Method 1	X	X		X	
Method 2			X	X	
Method 3					X

Table 1b Appendices applicable to the methods in Table 1a

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- 1.2.6.2 Guidance on the procedure to be followed in choosing the compliance route is given in Appendix F.

1.2.7 Resistance to roll-over induced by overspeeding

- 1.2.7.1 This document also sets out criteria by which acceptable resistance of vehicles to roll-over induced by overspeeding is to be demonstrated.

1.2.8 Supporting documents

- 1.2.8.1 The following Railway Group document supports this Railway Group Standard:
GM/RC2641 Recommendations for Vehicle Static Testing.

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Part 2 Requirements for Resistance of Railway Vehicles to Derailment and Roll-Over

2.1 Resistance to derailment

2.1.1 Requirements for tilting trains

- 2.1.1.1 These requirements apply to both tilting and non-tilting trains. For tilting trains the assessment of derailment risk shall consider the possibility of counter-acting tilt failure leading to vehicle body twist on a single vehicle or group of vehicles. Measures shall be implemented to minimise the possibility of tilt failure and the consequences should it occur.

2.1.2 Vehicles not having a novel suspension or running gear and not having a multi-bogie / axle configuration

- 2.1.2.1 Such vehicles shall satisfy all the requirements of method 1, or all the requirements of method 2 or all the requirements of method 3 (see 2.1.5).

2.1.3 Vehicles not having a novel suspension or running gear but having a multi-bogie / axle configuration

- 2.1.3.1 Such vehicles shall satisfy all the requirements of method 2, or all the requirements of method 3 (see 2.1.5).

2.1.4 Vehicles having a novel suspension or running gear

- 2.1.4.1 Such vehicles shall satisfy all of the requirements of method 3 (see 2.1.5.3).

2.1.5 Derailment resistance compliance method details

- 2.1.5.1 Method 1 - This requires that the vehicle shall satisfy the requirements of Appendix A and the requirements of Appendix B and the requirements of Appendix D.
- 2.1.5.2 Method 2 - This requires that the vehicle shall satisfy the requirements of Appendix C and the requirements of Appendix D.
- 2.1.5.3 Method 3 - This requires that the vehicle shall satisfy the requirements of Appendix E.

2.2 The effect of vehicle conditions on resistance to derailment

- 2.2.1 Vehicle conditions and loads can affect the resistance to derailment and therefore consideration shall be given to the range of test conditions necessary.
- 2.2.2 The range of vehicle test conditions shall take account of the effect of:
- a) Inter-vehicle connections on wheel unloading performance (for example in certain articulated trains where the design may 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)

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- d) Vehicle weight distribution (for example tare, laden, partially laden)
- e) Range and effect of possible in-service loading configurations (for example distribution of containers, stiffness effect of the load)
- f) Any other design feature or in-service condition that might significantly affect the wheel unloading performance.

2.2.3 In cases where the magnitude of the effect is outside the range of previous service experience, such that it casts doubt on the validity of the simplified test or simulation methods (set out in 2.1.5), on-track Y/Q measurements (as required by method 3 of 2.1.5) shall be made in order to demonstrate acceptability.

2.3 The effect of traction and propelling forces on resistance to derailment

2.3.1 Where the magnitude of traction or propelling force is outside the range of previous service experience, such that it casts doubt on the validity of the simplified test or simulation methods (set out in 2.1.5), on-track Y/Q measurements (as required by method 3 of 2.1.5) shall be made in order to demonstrate acceptability.

2.4 Resistance to roll-over induced by overspeeding**2.4.1 Design requirements for resistance to roll-over**

2.4.1.1 Vehicles shall be designed with mass distribution and suspension characteristics which ensure the capability to run round smooth curves at constant speed, without rolling over, at:

- a) Not less than 16.5° cant deficiency for freight vehicles designed to operate at speeds no greater than 75 mph
- b) Not less than 21° cant deficiency for all other vehicles.

2.4.1.2 For all vehicles that operate at a cant deficiency greater than 6° particular attention shall be given to maximising, so far as is reasonably practicable, the margin between the operating cant deficiency and the roll over resistance.

2.4.2 Determination of required resistance to roll-over

2.4.2.1 Vehicles' resistance to roll-over shall be demonstrated by theoretical methods, practical tests, comparison with other vehicles, or a combination of these.

2.4.2.2 In all cases the curve shall be taken as smooth, such that quasi-static centrifugal effects are taken into account, but not the effects of transitions or track irregularities. Wind effects shall not be taken into account.

2.4.2.3 Vehicles not meeting the requirements of 2.4.1 shall not be permitted to operate.

2.4.2.4 Where vehicles are intended to operate at cant deficiencies greater than 6° additional measures to control the risk of roll-over are required. These are set out in GC/RT5021, GE/RT8012 and GM/RT2142.

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2.4.3 Supply of information to the infrastructure manager

- 2.4.3.1 Railway undertakings shall make available to the infrastructure manager the resistance to roll-over of all vehicles required to operate at cant deficiencies in excess of 6°. They shall also make available the maximum service cant deficiency at which the vehicles are designed to operate.
- 2.4.3.2 The above information is required by the infrastructure manager to determine the enhanced permissible speed of vehicles through curves in accordance with the requirements detailed in GC/RT5021. Additional information requirements for this purpose are set out in GM/RT2142.

2.5 Application to vehicles undergoing modification

- 2.5.1 In respect of vehicles undergoing modification, where the modification is such that it may have an effect on the resistance to derailment or roll-over, there shall be an analysis of the potential consequences of that modification. This analysis shall assess the significance of the modification on the derailment or roll-over behaviour and, where appropriate, shall be used to decide which aspects of the behaviour of the modified vehicle require to be re-examined so as to demonstrate compliance with the requirements of this document.

2.6 Application to vehicles having characteristics similar to those of other vehicles

- 2.6.1 Where vehicles being newly introduced or being modified have characteristics similar to those of other vehicles having an authorisation for placing into service, or other vehicles having a Certificate of Engineering Acceptance, or to those of vehicles which, whilst pre-dating that process, have been shown to be satisfactory by the methods mandated in this document or by sufficient service experience, it is permissible to reduce the amount of analysis and testing required by Part 2 of this document. This shall apply for vehicles built or modified to previously accepted designs, and to variants of a base design (such as might appear in a multiple unit having driving trailers, non-driving trailers, motor trailers etc) where the full process is applied to the 'base' vehicle and a reduced process to the others. In all such cases, there shall be an analysis of the potential consequences of:
 - a) The changes from the previous or 'base' design which may have an influence on the propensity to derail or roll-over
 - b) Changes in the proposed duty which may have an influence on the propensity to derail or roll-over.
- 2.6.2 Where the potential consequences are significant, the analysis shall be used to decide which aspect of the behaviour of the vehicle require to be re-examined so as to demonstrate compliance with the requirements of this document.