Railway Group Standard
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Issue Two
Date October 2000

Resistance of Railway Vehicles to Roll-Over in Gales

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Synopsis
This document prescribes safety criteria for railway vehicles to ensure safe performance when operating under gale conditions on Railtrack Controlled Infrastructure. The objective is to minimise the risks of vehicle roll-over.

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Part A

Issue Record

This document will be updated when necessary by distribution of a complete replacement.

Revisions in this issue have not been marked by a vertical black line in the adjacent margin because the text has been revised throughout.

Issue	Date	Comments
One	June 1994	Original Document
Two	October 2000	Replaces Issue One

Responsibilities

Railway Group Standards are mandatory on all members of the Railway Group * and apply to all relevant activities that fall into the scope of each individual's Railway Safety Case. If any of those activities are performed by a contractor, the contractor's obligation in respect of Railway Group Standards is determined by the terms of the contract between the respective parties. Where a contractor is a duty holder of a Railway Safety Case then Railway Group Standards apply directly to the activities described in the Safety Case.

* The Railway Group comprises Railtrack and the duty holders of the Railway Safety Cases accepted by Railtrack.

Compliance

The effective date of this document is 02/12/2000 and the requirements mandated in this document shall be complied with no later than the dates detailed below.

The design requirements are to be complied with by all vehicles of previously uncertificated designs with a Design Scrutiny certificate signed on or after 02/12/2000. The design requirements shall be complied with from 03/12/2005 by any future vehicles, built to the same design as a vehicle already having Engineering Acceptance.

The design requirements do not apply retrospectively to existing vehicles with Engineering Acceptance. The exception is that where vehicles are undergoing engineering change, the requirements shall be applied so far as is reasonably practicable.

For tilting trains the provision of this document are to be complied with from the commencement of their operation.

Health and Safety Responsibilities

In issuing this document, Railtrack PLC makes no warranties, express or implied, that compliance with all or any documents published by the Safety & Standards Directorate is sufficient on its own to ensure safe systems of work or operation. Each user is reminded of its own responsibilities to ensure health and safety at work and its individual duties under health and safety legislation.

Supply

Controlled and uncontrolled copies of this document may be obtained from the Industry Safety Liaison Dept, Safety and Standards Directorate, Railtrack PLC, Railtrack House, DP01, Euston Square, London, NW1 2EE.

Part B

1 Purpose

The purpose of this document is to prescribe safety criteria for railway vehicles to ensure safe performance when operating under gale conditions on Railtrack Controlled Infrastructure. The objective is to minimise the risks of vehicle roll-over.

2 Scope

The overall scope of Railway Group Standards is as specified in Appendix A of GA/RT6001.

This document contains requirements which are applicable to the duty holders of the following category of Railway Safety Case:

- Train Operator

Specifically the contents of this document apply to traction and rolling stock (T&RS) vehicles and to on-track machines.

Requirements for rail-mounted maintenance machines are contained in GM/RT2402 and for road-rail vehicles are contained in GM/RT1300.

3 Definitions

Cant Deficiency
The difference between (i) the angle to which track would have to be canted on a curve to just counterbalance the centrifugal forces acting on a vehicle, and (ii) the actual cant angle of the track.

Engineering Change
Any alteration or modification to the design of a vehicle that affects its technical performance, particularly where it influences vehicle weight, aerodynamic behaviour or suspension characteristics.

Exposed Route
A route (or section of route) which is orientated generally in a north-south direction and which features hillsides, embankments or viaducts which are open and exposed to south-westerly winds. Examples of such routes are: West Coast Main Line north of Weaver Junction, and the Cumbrian Coast Line.

Gales
Extreme wind conditions, specifically gust wind speeds above 30 m/s (70 mile/h) as reported by the Meteorological Office in broadcast gale warnings.

Intermediate Streamlined Vehicle
A vehicle which incorporates some of the characteristics of both streamlined and unstreamlined vehicles. Examples of such vehicles are: Class 87 locomotive, Mark I Coach and Class 155 multiple unit.

Intrinsic Roll-over Wind Speed
The wind speed that is just sufficient to cause a vehicle to roll-over when (i) the vehicle is running within a train formation at its maximum design operating speed on straight and level track, and (ii) the wind is blowing perpendicular to the direction of travel of the vehicle.

On Track Machines
An on-track machine is a vehicle that meets the requirements of GM/RT2400.

Permissible or Enhanced Permissible Speed
The maximum speed published in the Sectional Appendix at which traffic is allowed to run on a line.

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Reference Wind Gust Speed
The wind gust speed over a specified short time interval that is equalled or exceeded once on average over a specified wind return period at a specified location.

Roll-Over
The situation reached when all the wheels on one side of a vehicle reach 100% unloading with their running rail and the whole weight of the vehicle is supported by the wheels on the other running rail.

Roll-Over Probability
The probability that a vehicle will roll-over when exposed to gales in conjunction with the normal range of operating speeds and cant deficiencies.

Streamlined Vehicle
A vehicle characterised by all or most of the following: a smooth continuous body profile which blends with its neighbours; roof corners are rounded; noses on end vehicles are smooth and slender or rounded; bodyside features such as windows, doors, steps and handles are flush-mounted; underbodies are side-faired and bogies or wheelsets are contained within the body profile and may be faired. Examples of such vehicles are: HST power car and Mark 3 coach.

Technically Competent Authority
A recognised person or organisation with professional expertise and experience in the aerodynamics of railway or other ground-borne vehicles. (See Appendix A, Section A.9)

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.

Unstreamlined Vehicle
A vehicle characterised by all or most of the following: extensive discontinuities in body profile with large irregular inter-vehicle gaps; corners are sharp, and extensive bluff surfaces are presented to the wind; doors, steps and handles are mounted external to the body surface; running gear and bogies are exposed. (Examples of such vehicles are: Class 58 locomotive, MGR coal-hopper wagon, and open car-carrier vehicle.) Passenger vehicles are excluded from this category.

Wind Return Period
The average period of time in years between occurrences of wind gust speeds equal to or higher than a specified level at a specified location.

4 Roll-Over Safety Criteria - General Requirements

4.1 General requirements

Vehicles that operate on Railtrack Controlled Infrastructure shall be designed and maintained so that they do not roll-over when exposed to gales under normal track and operating conditions on those routes where they are permitted to operate.

4.2 Trains travelling at conventional cant deficiencies

A passenger carrying vehicle that operates at up to 6° of cant deficiency, or a freight vehicle that operates at up to 4.25° of cant deficiency, shall satisfy at least one of the following requirements to ensure its safe operation in gales:

(a) The intrinsic roll-over wind speed when the vehicle runs on straight and level track shall be greater than a prescribed critical value.

(b) The roll-over probabilities for the vehicle when running at its operational speeds and cant deficiencies over its proposed routes of operation shall be determined. A risk assessment shall be carried out to ensure that the probability of roll-over is broadly acceptable. A technically competent authority shall validate and endorse these assessments. An indicative list of factors to be considered is listed in section 4.4.

4.3 Trains travelling at higher cant deficiencies

A passenger carrying vehicle that operates at cant deficiencies greater than 6° or a freight vehicle that operates at cant deficiencies greater than 4.25° shall satisfy the requirements of 4.2(b).

It is permissible to satisfy the requirements of 4.2(b) by determination of the enhanced permissible speed as detailed in GC/RT5021.

4.4 Factors to be considered for roll-over probability calculations

Roll-over probability calculations shall take into account at least the following factors:

(a) Aerodynamic characteristics of the vehicle;

(b) Weight, mass and suspension characteristics of the vehicle including changes due to tilting of the vehicle;

(c) Speed of operation and cant deficiencies and their variation along the route;

(d) Position of vehicle in train;

(e) Aerodynamic characteristics of adjacent vehicles;

(f) Track parameters along the route, particularly track irregularities, line direction, curvature and cant;

(g) Reference wind gust speeds along the route having a specified wind return period;

(h) Wind direction probability;

(i) Topography of the route;

(j) Ground roughness of the land surrounding the route;

(k) Height above sea level of the route;

(l) Local height of the track above the general level of terrain, and whether the track runs on level ground, on a viaduct, in a cutting or on an embankment;

(m) Size of the wind gusts acting on the vehicle, and hence the averaging time over which the wind is measured;

(n) Frequency of operation on the route.

The calculation of roll-over probability shall take account of variations in vehicle loading. Usually a vehicle is most susceptible to roll-over when unloaded but, for a tilting train, consideration shall also be given to the effect of uneven passenger loading combined with a shift in the centre of mass due to tilt or tilt failure.

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4.5 Variations in vehicle condition

Vehicles shall meet the requirements of this document over the full range of variations in vehicle condition that are likely to be experienced. Account shall be taken of tolerances in vehicle dimensions, mass distributions and wheel loadings, suspension characteristics, normal variations in vehicle maintenance condition and wear, and any other relevant variables.

4.6 Vehicle maintenance

Vehicles shall be maintained so that the prescribed tolerances for components, assemblies and systems that influence roll-over resistance are sustained over the lives of the vehicles.

4.7 Deviations from specific requirements of this document

Deviations from the specific requirements of this document are permissible providing that an equivalent level of safety is achieved. In such cases, any deviations shall be supported by an appropriate technical justification which shall be validated and endorsed by a technically competent authority.

5 Intrinsic Roll-Over Wind Speed

5.1 Minimum acceptable intrinsic roll-over wind speed

Except as in section 5.2, the intrinsic roll-over wind speed for a vehicle in tare condition shall not be less than:

- 40.8 m/s for passenger carrying vehicle;
- 31.0 m/s for freight vehicle.

5.2 Vehicles not required to operate over exposed routes

Where a vehicle is not required, and not authorised, to operate over exposed routes, the minimum acceptable roll-over wind speeds may be reduced. In this case, a reduction factor of 0.92 may be applied to the wind speeds listed in section 5.1.

5.3 Calculation of intrinsic roll-over wind speed

The intrinsic roll-over wind speed for a vehicle shall be calculated using the following formula:

$$V_W = \left[\frac{2G}{dAhf_1} - \frac{V_T^2}{12.96} \right]^{0.5}$$

where:

V_W = intrinsic roll-over wind speed (m/s)

V_T = train maximum operating speed (km/h)

G = restoring moment due to vehicle weight (N m)

d = density of air (1.225 kg/m^3)

A = total projected side area of vehicle (m^2)

h = mean height of roof above axle centreline (m)

f_1 = aerodynamic factor specified in sections 5.6 and 5.7

5.4 Determination of restoring moment G

The value of the restoring moment G shall be determined from:

$$G = Mgb - G_o$$

where:

M = total tare mass of vehicle (kg)

g = acceleration due to gravity (9.81 m/s^2)

b = semi-span of wheelset-to-rail contact points (0.75 m)

G_o = roll-over moment due to lateral and roll suspension displacements under wind loading together with any in-built vehicle weight asymmetry (Nm)

5.5 Vehicles with articulated bogies

For vehicles with articulated bogies, or with other forms of weight support arrangements between adjacent vehicles, masses shall be appropriately shared between vehicles for the purpose of calculating the restoring moment G.

5.6 Values for the aerodynamic factor f_1

Values for the aerodynamic factor f_1 for trailing vehicles in a train shall be chosen from the following table.

Vehicle Type (Trailing) Train Speed (km/h)	Streamlined Vehicle Factor f_1	Intermediate Streamlined Vehicle Factor f_1	Unstreamlined Vehicle Factor f_1
100	0.532	0.733	0.998
120	0.482	0.661	0.872
140	0.441	0.600	0.756
160	0.400	0.540	0.640
180	0.362	0.485	0.551
200	0.324	0.431	0.462
225	0.285	0.367	0.388
240	0.262	0.330	0.345
250	0.250	0.313	0.326
275	0.232	0.271	0.280
300	0.190	0.230	0.235

5.7 Supplementary factor for leading vehicles

For the leading vehicle in a train, the aerodynamic factors f_1 set out in section 5.6 shall be further multiplied by the following supplementary factors:

Vehicle Type	Leading Vehicle Supplementary Factor
Streamlined	1.44
Intermediate	1.13
Unstreamlined	0.90

5.8 Vehicles which cannot be categorised as streamlined, intermediate or unstreamlined

Where a vehicle cannot be clearly categorised as streamlined, intermediate or unstreamlined, but lies somewhere between two categories, it is permissible to interpolate values for the aerodynamic factor f_1 between those set out in section 5.6. A technically competent authority shall validate and endorse such interpolation.

6 Vehicles Operating at Cant Deficiencies in Excess of 6°

6.1 Determination of vehicle characteristics

Train operators shall determine the following vehicle characteristics for vehicles that are required to operate at cant deficiencies in excess of a nominal 6°:

- maximum train speed (as determined by its design);
- total projected side area of vehicle or side area used to determine its aerodynamic rolling moment coefficient about the lee rail from tests;
- vehicle mean roof height above axle centreline or height used to determine its aerodynamic rolling moment coefficient about the lee rail from tests;
- vehicle aerodynamic rolling moment coefficient about the lee rail at 50° yaw, taking account of the position of the vehicle in the train (two values required: leading vehicle; and second vehicle in the train);
- vehicle mass;
- height of vehicle centre of mass above rail level.

6.2 Conditions for the determination of vehicle characteristics

The above vehicle characteristics shall be those under the most unfavourable conditions of loading and tilt, including the effects of uneven passenger loading, combined with credible failure modes of tilt, that is the case where the rolling resistance is lowest.

6.3 Supply of information to the Infrastructure Controller

Train operators shall make available to the Infrastructure Controller the vehicle characteristics set out in section 6.1

This information is required by the Infrastructure Controller 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/RT2141.

7 Records

Auditable records of roll-over calculations and risk assessments shall be retained and maintained for the life of each vehicle type to demonstrate that the requirements of this document have been met, and to facilitate any future investigative requirements.

Appendix A
Technical Background and Guidance

A.1 Purpose of Appendix A

Appendix A quotes, verbatim and boxed, sections 4.2, 4.3 and 5 of this document and gives a commentary explaining the technical background to these sections. It also provides guidance on how the sections should be interpreted and applied. The contents of Appendix A are for information only.

A.2 Basic Roll-Over Risk

Two quantities are used to express basic roll-over risk. These are coupled with the concept of benchmark vehicles.

The first quantity is the intrinsic roll-over wind speed, which defines under specified operating conditions, what wind force and hence what wind speed is required to roll-over a vehicle.

The second quantity is the statistical chance of that particular roll-over wind speed actually occurring on a given stretch of line whilst a train is present.

Benchmark vehicles have been chosen which, whilst being relatively light in weight per unit side area, have safe histories of operation over exposed routes in Britain (see section A.7.1). They therefore define benchmarks in terms of actual acceptable levels of risk at typical frequencies of operation. Having accepted those levels of risk, their intrinsic roll-over wind speeds are adopted as benchmarks themselves.

A.3 Roll-Over Safety Criteria

A.3.1 Introduction to roll-over safety criteria

The acceptance criterion in section 4.2(a) of this document requires that the intrinsic roll-over wind speed V_W for a vehicle is greater than a prescribed value. If it is so, no other criteria need be considered if the vehicle does not tilt.

If a vehicle fails to meet this simple criterion or operates at higher cant deficiencies, then the probability of the vehicle roll-over on its proposed route or routes of operation is to be determined. Section 4.2(b) requires a risk assessment to demonstrate that the probability of a vehicle roll-over is broadly acceptable.

A.3.2 Trains travelling at conventional cant deficiencies

4.2 Trains travelling at conventional cant deficiencies

A passenger carrying vehicle that operates at up to 6^o of cant deficiency, or a freight vehicle that operates at up to 4.25^o of cant deficiency, shall satisfy at least one of the following requirements to ensure its safe operation in gales:

(a) The intrinsic roll-over wind speed when the vehicle runs on straight and level track shall be greater than a prescribed critical value.

(b) The roll-over probabilities for the vehicle when running at its operational speeds and cant deficiencies over its proposed routes of operation shall be determined. A risk assessment shall be carried out to ensure that the probability of roll-over is broadly acceptable. A technically competent authority shall validate and endorse these assessments. An indicative list of factors to be considered is listed in section 4.4.

Criterion (a) will confirm that a vehicle with a significant safety margin is safe, without incurring excessive costs and the need for validation tests.

It is anticipated that most vehicles will meet the requirements on the basis of satisfying criterion (a), although inevitably, because the technical issues involved in vehicle roll-over are very complex, some vehicles may fail this simple test. In such cases, a vehicle may still be able to meet the requirements of this document by taking advice from a technically competent authority concerning the vehicle's particular characteristics, especially its aerodynamic features. If the vehicle still does not meet the requirements of (a), it will be necessary to undertake a more detailed analysis as indicated in criterion (b).

A.3.3 Trains travelling at higher cant deficiencies

4.3 Trains travelling at higher cant deficiencies
A passenger carrying vehicle that operates at cant deficiencies greater than 6^{o} or a freight vehicle that operates at cant deficiencies greater than 4.25^{o} shall satisfy the requirements of 4.2 (b).

It is permissible to satisfy the requirements of 4.2(b) by determination of the enhanced permissible speed as detailed in GC/RT5021.

A vehicle operating above cant deficiencies set out in 4.2 (for example a tilting train) is required to satisfy the requirements of 4.2(b) because of operating at higher cant deficiencies and the likely increased susceptibility to roll-over in cross-winds.

For a vehicle designed to curve at higher speeds and at higher cant deficiencies, roll-over behaviour during curving also needs to be considered. It is likely that the roll-over wind speeds on curves will be less than those of existing stock of comparable aerodynamic characteristics travelling on the same curves. It is thus necessary to determine the probability of roll-over for a tilting train over its proposed routes of operation as specified in section 4.2(b). GC/RT5021 details the requirements for calculation of enhanced permissible speed for tilting trains including the determination of the roll-over probability, taking into account train, infrastructure and environmental conditions. These calculations are to ensure that the probability of roll-over is tolerable.

A.4 Minimum Acceptable Intrinsic Roll-Over Wind Speed

A.4.1 Minimum acceptable intrinsic roll-over wind speed

5.1 Minimum acceptable intrinsic roll-over wind speed
Except as in section 5.2, the intrinsic roll-over wind speed for a vehicle in tare condition shall not be less than:

- 40.8 m/s for passenger carrying vehicle;
- 31.0 m/s for freight vehicle.

The document requires that the minimum intrinsic roll-over wind speed for a vehicle shall not be less than a prescribed value. The minimum intrinsic roll-over wind speeds listed in section 5.1 are those associated with the benchmark vehicles defined in section A.7.1.

A.4.2 Vehicles not required to operate over exposed routes

5.2 Vehicles not required to operate over exposed routes
Where a vehicle is not required, and not authorised, to operate over exposed routes, the minimum acceptable roll-over wind speeds may be reduced. In this case, a reduction factor of 0.92 may be applied to the wind speeds listed in section 5.1.

For vehicles that are required to operate only over less exposed routes, the application of the benchmark vehicles' intrinsic roll-over wind speeds would result in a much lower level of risk. This could be unnecessarily restrictive. Therefore, with the aim of equalising risk a reduced value of minimum roll-over wind speed is permitted. This is specified by the reduction factor of 0.92 in section 5.2.

Application of this factor to the minimum acceptable intrinsic roll-over wind speeds in section 5.1 is only acceptable if a vehicle is not required to run over exposed routes with comparable risks of encountering extreme wind conditions.

A.5 Intrinsic roll-over wind speed

A.5.1 Intrinsic roll-over wind speed V_W related to the train speed V_T

The intrinsic roll-over wind speed V_W for a vehicle is that wind speed which is just sufficient to cause 100% unloading of the wheels on the windward side of the vehicle, when the vehicle is running in its tare condition at its maximum operational speed on straight track. This wind is considered to blow perpendicular to the direction of travel of the vehicle.

The intrinsic roll-over wind speed is related to the train speed V_T and the resultant wind speed relative to the train V_R by:

$$V_W^{\ 2} + \frac{V_T^{\ 2}}{12.96} = V_R^{\ 2}$$

A.5.2 Aerodynamically induced rolling moment R and roll restoring moment G

At the moment of 100% wheel unloading, the aerodynamically induced rolling moment R about the wheel contact points on the lee rail is exactly balanced by the roll restoring moment G due to the weight of the vehicle, that is:

$$R = G$$

A.5.3 Equation for aerodynamically induced rolling moment R

The aerodynamic rolling moment is given by the following expression:

$$R = \frac{d\ A\ h\ f_1 V_R^2}{2}$$

where

R = aerodynamic rolling moment (Nm)

d = density of air (kg/m^3)

A = vehicle total projected side area (m^2)

h = vehicle mean roof height above axle centreline (m)

V_R = wind speed relative to train (m/s)

f_1 = aerodynamic factor (see section A.7.1)

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A.5.4 Intrinsic roll-over wind speed V_W

Combining the equations developed above in sections A.5.1, A.5.2 and A.5.3, the intrinsic roll-over wind speed can be expressed as:

$$V_w = \left[\frac{2G}{dAhf_1} - \frac{V_T^2}{12.96} \right]^{0.5}$$

This is the formula quoted in section 5.3:

5.3 Calculation of intrinsic roll-over wind speed

The intrinsic roll-over wind speed for a vehicle shall be calculated using the following formula:

$$V_W = \left[\frac{2G}{dAhf_1} - \frac{V_T^2}{12.96} \right]^{0.5}$$

where:

V_W = intrinsic roll-over wind speed (m/s)

V_T = train maximum operating speed (km/h)

G = restoring moment due to vehicle weight (N m)

d = density of air (1.225 kg/m^3)

A = total projected side area of vehicle (m^2)

h = mean height of roof above axle centreline (m)

f_1 = aerodynamic factor specified in sections 5.6 and 5.7

A.6 Roll restoring moment

A.6.1 Determination of restoring moment G

5.4 Determination of restoring moment G

The value of the restoring moment G shall be determined from:

$$G = Mgb - G_O$$

where:

M = total tare mass of vehicle (kg)

g = acceleration due to gravity (9.81 m/s^2)

b = semi-span of wheelset-to-rail contact points (0.75 m)

G_o = roll-over moment due to lateral and roll suspension displacements under wind loading together with any in-built vehicle weight asymmetry (Nm)

The restoring moment G due to vehicle mass is to be calculated taking into account the various vehicle body, bogie and wheelset masses and their lateral and roll suspension displacements. Freight vehicle payloads, even if detachable, are considered to be securely connected for the purpose of this document, which does not cover loss of load.

G_o, the roll-over moment due to lateral and roll suspension displacements under wind loading together with any in-built vehicle weight asymmetry (Nm), can be determined from:

$$G_O = m_b g y_b + m_c g (y_c + y)$$

where:

m_b = mass of bogies (kg)

y_b = lateral displacement of bogies (m)

m_c = mass of body (kg)

y_c = lateral displacement of body (m)

y = body centre of gravity offset due to roll and/or weight asymmetry (m)

A.6.2 Vehicles with articulated bogies

5.5 Vehicles with articulated bogies
For vehicles with articulated bogies, or with other forms of weight support arrangements between adjacent vehicles, masses shall be appropriately shared between vehicles for the purpose of calculating the restoring moment G.

Where articulated vehicles are used, equivalent values of M and G_o need to be determined. These should be based on the specific articulation arrangements adopted and on the degree of mass and stiffness coupling across bogies and between adjacent vehicles.

A.7 Values for the aerodynamic factor f_1

A.7.1 Values for the aerodynamic factor f_1

5.6 Values for the aerodynamic factor f_1
Values for the aerodynamic factor f_1 for trailing vehicles in a train shall be chosen from the following table.

Vehicle Type (Trailing) Train Speed (km/h)	Streamlined Vehicle Factor f_1	Intermediate Streamlined Vehicle Factor f_1	Unstreamlined Vehicle Factor f_1
100	0.532	0.733	0.998
120	0.482	0.661	0.872
140	0.441	0.600	0.756
160	0.400	0.540	0.640
180	0.362	0.485	0.551
200	0.324	0.431	0.462
225	0.285	0.367	0.388
240	0.262	0.330	0.345
250	0.250	0.313	0.326
275	0.232	0.271	0.280
300	0.190	0.230	0.235

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The aerodynamic factor f_1 is the rolling moment coefficient at a wind angle relative to the train of $\tan^{-1}(V_W/V_T)$ where V_W is the intrinsic roll-over wind speed and V_T is the train maximum operating speed.

Values of f_1 that are to be used for determining intrinsic roll-over wind speeds are defined in the table in section 5.6 of this document. These are based on values which apply to some existing railway vehicles which have had long periods of widespread service in Great Britain. The vehicles are representative of three types of stock with different aerodynamic characteristics. They are the Mark 3 Coach (Streamlined Vehicle); the Class 108 'Derby Lightweight' Diesel Multiple Unit vehicle (Intermediate Streamlined Vehicle); and the Freightliner vehicle with empty containers (Unstreamlined Vehicle).

The values of f_1 listed for these vehicles are generally conservative. The choice of these vehicles as benchmarks has been constrained by available aerodynamic information on roll-over risks and the need to specify vehicles with safe, long-term and country-wide service histories.

A.7.2 Supplementary factor for leading vehicles

5.7 Supplementary factor for leading vehicles

For the leading vehicle in a train, the aerodynamic factors f_1 set out in section 5.6 shall be further multiplied by the following supplementary factors:

Vehicle Type	Leading Vehicle Supplementary Factor
Streamlined	1.44
Intermediate	1.13
Unstreamlined	0.90

The values of f_1 specified in section 5.6 are for trailing vehicles. The aerodynamic roll-over moment characteristics vary along a train with, in general, the leading vehicle developing the largest values of rolling moment R. For a leading vehicle, a supplementary correction factor has to be applied to the value of the factor for trailing vehicles. The corrections are specified in section 5.7.

A.7.3 Vehicles which cannot be categorised as streamlined, intermediate or unstreamlined

5.8 Vehicles which cannot be categorised as streamlined, intermediate or unstreamlined

Where a vehicle cannot be clearly categorised as streamlined, intermediate or unstreamlined, but lies somewhere between two categories, it is permissible to interpolate values for the aerodynamic factor f_1 between those set out in section 5.6. A technically competent authority shall validate and endorse such interpolation.

It may not be easy to place some vehicles into the named aerodynamic types, as they may lie between two type descriptions. In these cases, the value of f_1 may be interpolated, provided it is validated and endorsed by a technically competent authority.

A.7.4 Accurate values of f_1 relevant to actual vehicles

More accurate values of f_1 relevant to the actual vehicle under consideration can be obtained from suitable wind tunnel tests on a scale model of the vehicle (see section A.8). In this case, values of A and h may differ from those defined in section A.5.3. It is important that the appropriate values are used to determine the correct aerodynamic rolling moment.

For vehicles that are very similar aerodynamically to other vehicles for which values of f_1 already exist, it may be possible to infer new values of f_1 from existing data. Such evaluations are to be validated and endorsed by a technically competent authority.

A.8 Aerodynamic force and moment determination

The aerodynamic forces and moments which act on a vehicle in a train are usually determined from suitable wind tunnel tests. This is because it is extremely difficult to evaluate these at full-scale due to practical problems of controlling the wind flow upstream of the vehicle and resolving the relevant forces and moments.

Wind tunnel tests on scale model vehicles, therefore, offer a controllable and repeatable test environment in which to evaluate the aerodynamic forces and moments.

In order to model the full-scale situation, it is necessary to achieve aerodynamic similarity between the wind tunnel and full scale. This is achieved in part by ensuring that the model is a sufficiently large-scale and accurate representation of the full-scale vehicle, although some small-scale details may not need to be modelled. In addition, to provide correct similitude, the vehicle motion relative to the ground should be accounted for and a sufficient representation of the upstream wind flow impinging on the vehicle should be provided.

Under certain circumstances it is possible to relax some of these requirements. These tests and the decisions governing how they are undertaken for a particular vehicle are complex and require the validation and endorsement of a technically competent authority.

A.9 Technically competent authority

A technically competent authority should have expertise in the aerodynamics of railway or other ground-borne vehicles and be recognised in the United Kingdom or internationally, and may be one of the following:

- *a member or group of staff or a department of a university or similar institution;*
- *a research or combined research and consultancy group in private industry;*
- *an individual or group within any railway organisation.*

Resistance of Railway Vehicles to Roll-Over in Gales

References

GA/RT6001 Railway Group Standards Change Procedures

GC/RT5021 Track System Requirements

GM/RT1300 Engineering Acceptance of Road-Rail Vehicles

GM/RT2141 Resistance of Railway Vehicles to Derailment and Roll-Over

GM/RT2400 Design of On-Track Machines

GM/RT2402 Engineering Acceptance of Rail-Mounted Maintenance Machines

Related Documents

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EDSU International plc
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London
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The Catalogue of Railway Group Standards and the Railway Group Standards CD-ROM give the current issue number and status of documents published by the Safety & Standards Directorate.