Compatibility Requirements for Braking Systems of Rail Vehicles

Synopsis
This document defines the compatibility and performance requirements for the braking systems of rail vehicles for operation in trains on the mainline railway.

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Compatibility Requirements for Braking Systems of Rail Vehicles

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Superseded documents

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GMRT2040 issue one, GMRT2041 issue two, GMRT2042 issue two, GMRT2043 issue two, GMRT2044 issue four, GMRT2045 issue three and GMRT2046 issue one, cease to be in force and are withdrawn as of 04 June 2016.

The relevant sections of GMGN2615 issue one and GMGN2688 issue two are to be withdrawn as of 04 June 2016.

Supply

The authoritative version of this document is available at www.rssb.co.uk/railway-group-standards. Enquiries on this document can be forwarded to enquirydesk@rssb.co.uk.
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Part 1  Purpose and Introduction

1.1  Purpose

1.1.1  This document mandates requirements for brake systems of rail vehicles for operation in trains on the Great Britain (GB) mainline railway.

1.2  Introduction

1.2.1  Background

1.2.1.1  This document defines the principles of operation and the performance of the braking systems fitted to rail vehicles. It includes requirements and guidance for the brake systems and is intended to be read in conjunction with the Rolling Stock Technical Specifications for Interoperability (TSI) ‘Locomotives and Passenger’ (LOC & PAS) TSI and ‘Freight Wagons’ (WAG) TSI.

1.2.1.2  The requirements set out in the LOC & PAS TSI and WAG TSI are developed to complement the requirements in other TSIs. For braking requirements, these are essentially those associated with the European Train Control System (ETCS) set out in the Control, Command and Signalling (CCS) TSI.

1.2.1.3  The existing rail system is predominantly signalled by lineside signals with established signal spacing, and the braking performance of vehicles when operating in train formations needs to be sufficient to ensure they can stop within such signal spacing. The braking performance requirements mandated by this standard are intended to achieve the compatibility between the signal spacing and the braking performance of rail vehicles when operating in train formations.

1.2.2  Principles

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

1.2.2.2  This document sets out National Technical Rules (NTRs) for the mainline railway in GB. Compliance with NTRs is required under the Railways Interoperability Regulations 2011 (RIR 2011) (as amended).

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

a)  To support UK specific cases in TSIs.

b)  To set out requirements to maintain compatibility between existing subsystems and / or vehicles that do not conform to the requirements in TSIs and new, upgraded or renewed subsystems and / or vehicles conforming to TSIs.

1.2.2.4  This document sets out the NTRs supporting the specific cases permitted by the LOC & PAS TSI, associated with emergency braking rates and drivers’ brake controller ergonomics.

1.2.2.5  This document also sets out the NTRs associated with braking performance of rail vehicles when operating in train formations which are needed to maintain technical compatibility with existing signal spacing.

1.2.3  Structure of this document

1.2.3.1  This document sets out a series of requirements that are sequentially numbered.

1.2.3.2  This document also sets out the rationale for the requirement. The rationale explains why the requirement is needed and its purpose. Where relevant, guidance supporting the requirement is also set out in this document. The rationale and the guidance are indicated by prefixing the clause number with the letter ‘G’.
1.2.3.3 The national rules relating to relevant TSI parameters have been identified, together with the relevant clause from the TSI.

1.2.3.4 The clause order of the document follows the section headings in Chapter 4 of the LOC & PAS TSI relating to the operation, performance and interface requirements of rail vehicle brake systems.

1.2.4 Related requirements in other documents

1.2.4.1 The following Railway Group Standards (RGSs) contain requirements that are relevant to the scope of this document:

a) GERT8075 - AWS and TPWS Interface Requirements.
b) GKRT0075 - Lineside Signal Spacing and Speed Signage.
c) GMRT2111 - Rolling Stock Subsystem and Interfaces to AC Energy Subsystem.
d) GMRT2113 - Rolling Stock Subsystem and Interfaces to DC Conductor Rail Energy Subsystem.
e) GMRT2400 - Engineering Design of On-Track Machines in Running Mode.
f) GMRT2461 - Sanding Equipment Fitted to Multiple Units and On-Track Machines.
g) GORT3056 – Working Manual for Rail Staff Freight Train Operations

1.2.5 Supporting documents

1.2.5.1 The following Rail Industry Guidance Notes support this Railway Group Standard:

a) GEGN8628 - Guidance on Preparation for and Operation during Winter.
b) GMGN2607 - Guidance on the Braking Requirements for Hauling Unbraked Multiple Units in Freight Trains.
c) GMGN2615 - Guidance on the Conventional Rail Locomotives and Passenger Rolling Stock TSI.
d) GMGN2688 - Guidance on Designing Rail Freight Wagons for use on the GB Mainline Railway.
e) GMGN2695 - Guidance on Testing of Wheel Slide Protection Systems Fitted on Rail Vehicles.

1.3 Approval and authorisation of this document

1.3.1 The content of this document was approved by Rolling Stock Standards Committee on 04 December 2015.

1.3.2 This document was authorised by RSSB on 12 February 2016.
Part 2  Requirements for Brake Systems

2.1  General

2.1.1  Except where otherwise required by this document, the braking requirements applicable to rail vehicles of either the LOC & PAS TSI or the WAG TSI shall apply as if they were requirements mandated by this document.

G 2.1.1.1  **Rationale for 2.1.1:** The technical requirements of the LOC & PAS TSI and WAG TSI are also applicable to modifications to the brake system where the vehicle is deemed not to be new, renewed or upgraded as defined in RIR 2011 (as amended). These requirements will help achieve compatibility with the TSI and the non-TSI compliant parts of the existing railway system.

G 2.1.1.2  This document includes additional requirements and guidance for the braking systems for rail vehicles and is intended to be read in conjunction with the LOC & PAS TSI and WAG TSI. The exceptions to the LOC & PAS TSI and WAG TSI are set out in this document.

G 2.1.1.3  This document also contains the NTRs applicable to rail vehicle brake systems when operating on the GB mainline network. This document provides a set of requirements to follow such that compatibility with the existing rail system is maintained.

G 2.1.1.4  The majority of the braking requirements in both the LOC & PAS TSI and WAG TSI are set out in section 4.2.4 of the respective documents. Guidance on the braking requirements of the LOC & PAS TSI and WAG TSI are set out in Appendix F of this document.

G 2.1.1.5  Where Euronorms (ENs) are considered complete and a suitable substitute for RGSs, reference to the EN is made.

G 2.1.1.6  The brake system(s) fitted to the rail vehicles performs four functions:

   a) Emergency brake achieved using the automatic and continuous power brake fitted to all rail vehicles.

   b) Service brake used to control the speed of the train, including to a stop.

   c) Holding brake to secure the train at standstill during a stop in a station and to secure the train on a gradient during a hill start.

   d) Parking brake used to immobilise the rail vehicle / train.

2.2  Brake command

2.2.1  General

2.2.1.1  From the active driving cab, it is permitted to push the brake control lever(s) forwards to increase the service brake demand and for the emergency brake position to be furthest from the driver.

G 2.2.1.1.1  **Rationale for 2.2.1.1:** This requirement supports the specific case for ‘Driver’s Desk – Ergonomics (4.2.9.1.6(4) of the LOC & PAS TSI)’ applicable to the GB mainline network, permitted by in clause 7.3.2.19 of the LOC & PAS TSI.
The GB specific case permits the continuation of the GB convention for controlling the brake in the majority of driving cabs on the GB mainline railway. In this situation the brake controller (or combined traction brake controller) is arranged to apply the brake when the handle is moved forwards / away from the driver and release the brakes when the handle is moved backwards / towards the driver.

This direction of movement also applies to any separate brake controllers provided for the dynamic brake and direct brake. The direct brake is also known as the independent brake or straight air brake.

The direction of movement of the brake controller was originally selected by British Rail (BR) on the basis that an incapacitated driver was considered more capable of pushing the brake controller and thereby chose this direction to apply the brake.

The installation of train protection and driver vigilance systems provide alternative and independent means to apply the brake in the event a driver becomes incapacitated.

The LOC & PAS TSI adopted the general continental practice (also used by some GB operators), which is to apply the brake when the handle is moved backwards / towards the driver and release the brakes when moved forwards / away from the driver.

The GB specific case in clause 7.3.2.19 of the LOC & PAS TSI is not a condition of access to the GB mainline railway. Where it is preferred that the brake controllers comply with the LOC & PAS TSI directions of movement, consideration needs to be given for safe operation on the GB mainline railway. Factors to be considered in the assessment include:

a) Whether drivers will be required to work totally on rail vehicles of one particular type or are required to interwork with other GB fleets.

b) The ability to retrain existing drivers from the GB standard direction of control.

c) The proposed duty of the train.

Emergency brake command

On existing (ex-BR) disc braked multiple units that were retrospectively modified to provide the enhanced emergency braking capability, the control systems shall incorporate a deterrent feature to discourage the use of this brake by a driver in non-emergency situations.

Rationale for 2.2.2.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.4.4.1. The enhanced emergency brake on the retrospectively modified rail vehicles generates higher forces in bogie and brake equipment that are above those used for the original brake design.

To reduce the risk of mechanical failure the general use of the enhanced emergency brake needs to be restricted. The generally adopted deterrent following a driver initiated enhanced emergency brake application is for the brake control system to prevent the driver releasing the brake until the train is at a standstill.
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G 2.2.2.1.3 Alternative deterrent measures are permitted provided they address the risk of mechanical failure to bogie and brake equipment.

2.2.3 Service brake command

2.2.3.1 On existing GB multiple units fitted with a 3 step service brake control it is permitted to retain this feature.

G 2.2.3.1.1 Rationale for 2.2.3.1: This requirement is an exemption to the requirements of the LOC & PAS TSI clause 4.2.4.4.2, to maintain operational compatibility between existing GB multiple units fitted with 3 step service brake control.

G 2.2.3.1.2 This is not an exemption for new vehicles from the LOC & PAS TSI clause 4.2.4.4.2 which sets out a requirement for graduated application and release with a minimum 6 steps of service brake application.

G 2.2.3.1.3 In those situations where it is intended to couple and operate a TSI compliant unit with an existing unit with a 3 step service brake control, the provision of a “brake translator” is one means to generate the relevant electrical command signals at the ends of the unit.

2.2.4 Holding brake command

2.2.4.1 The application of the holding brake shall be possible by the direct brake or combined with a service brake initiated automatically or by the driver.

G 2.2.4.1.1 Rationale for 2.2.4.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.4.4 to prevent unauthorised movement (roll back of the train).

G 2.2.4.1.2 The LOC & PAS TSI is silent on the provision of the holding brake function. In order to permit hill starts it is necessary to apply traction while using a partial brake application. This feature is considered necessary when a combined traction / brake controller is fitted.

G 2.2.4.1.3 The holding brake can be configured to release after:

a) A certain tractive effort has been developed.

b) A period of time following the traction command.

c) A manual command.


## 2.3 Braking performance

### 2.3.1 General

#### 2.3.1.1 The braking performance for rail vehicles when operating in train formations shall be achieved with rail vehicles in:

a) The design mass in working order.

b) Any loading conditions up to, and including, the maximum permitted for the vehicles.

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#### G 2.3.1.1.1 Rationale for 2.3.1.1: This requirement is additional to the requirements of the LOC & PAS TSI and WAG TSI for compatibility with existing GB signalling systems on routes not operating with ETCS supervision.

#### G 2.3.1.1.2 GKRT0075 sets out the requirements for the minimum signalling distances. GKRT0075 also includes the rules to extend and reduce the individual signalling distances, depending on the local gradient of the line.

#### G 2.3.1.1.3 This standard sets out the level track full service braking performance requirements for rail vehicles when operating in train formations for compatibility with the GB signalling distances.

#### G 2.3.1.1.4 The brake performance of individual rail vehicles needs to consider the intended train formations in which the rail vehicles are to be operated. Factors to be considered include:

a) Any propagation delay of the brake command signals arising from increasing length of train formation.

b) The sharing of the braking duty between different brake systems and rail vehicles in the train formation.

#### G 2.3.1.1.5 The train formation braking performance requirements set out in this document incorporate a safety margin to cover for speedometer error and the random reduction in nominal adhesion.

#### G 2.3.1.1.6 The definition of design mass in working order is set out in BS EN 15663:2009.

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#### 2.3.1.2 The braking performance of on-track machines (OTMs) capable of being driven independently on the mainline railway shall comply with locomotive braking performance requirements.

#### 2.3.1.3 The braking performance of OTMs that operate as hauled rail vehicles on the mainline railway shall comply with freight wagon braking performance requirements.

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#### G 2.3.1.3.1 Rationale for 2.3.1.2 and 2.3.1.3: These requirements are additional to the requirements of the LOC & PAS TSI and WAG TSI. The braking performance requirements of OTMs in their ‘running mode’ depends on whether they are capable of operating independently or require to be hauled on the network in a freight train.
### 2.3.2 Emergency braking

2.3.2.1 Except for degraded modes, the emergency braking performance of the automatic and continuous brake shall not exceed the maximum permitted full service stopping distance requirements in 2.3.3 of this document.

G 2.3.2.1.1 **Rationale for 2.3.2.1:** This requirement is additional to the requirements of the LOC & PAS TSI, in order to maintain compatibility with existing GB requirements for the traffic operation and management subsystem. For compatibility with the GB operational requirements the emergency braking performance for locomotives and passenger vehicles is to be equal to or better than the full service brake.

2.3.2.2 Disc braked multiple units shall be fitted with an enhanced emergency braking capability. The brake forces used to achieve the enhanced emergency brake application shall be increased above that used for a full service brake application by:

a) A nominal 30%, provided that the adhesion limits permitted for emergency braking are not exceeded.

b) If the above is not achievable then a minimum of 15%, even if the adhesion limits for emergency braking are exceeded.

2.3.2.3 On multiple units fitted with enhanced emergency braking, this shall be applied when there is an emergency brake request by the on-board CCs systems.

G 2.3.2.3.1 **Rationale for 2.3.2.2 and 2.3.2.3:** These requirements are additional to the requirements of the LOC & PAS TSI. The provision of enhanced emergency braking capability is required for compatibility with the GB Class B Train Protection and Warning System (TPWS), as set out in GERT8075.

G 2.3.2.3.2 Passenger train TPWS settings were developed to exploit the higher enhanced emergency brake retardation rates available on disc braked multiple units.

2.3.2.4 The requirement to fit enhanced emergency braking does not apply to existing (ex-BR) disc braked multiple units where they are not already fitted.

G 2.3.2.4.1 **Rationale for 2.3.2.4:** These requirements are additional to the requirements of the LOC & PAS TSI. For existing Classes 158, 159, 313, 314, 442, 507 and 508 their full service / emergency braking performance and operational duty for these units did not justify their modification to provide enhanced emergency braking.

2.3.2.5 Individual freight vehicles with a maximum operating speed of either 60 mile/h (96 km/h) with brakes in goods timing, or 75 mile/h (120 km/h) with brakes in passenger timing, shall have an emergency stopping distance not exceeding 951 m.

2.3.2.6 Individual freight vehicles that are to be operated at 75 mile/h (120 km/h) in freight trains from 690 m up to 750 m in length, with brakes in passenger timing, shall have an emergency stopping distance not exceeding 890 m.
### Rationale for 2.3.2.5 and 2.3.2.6:
These requirements are additional to the requirements of the WAG TSI for compatibility with existing GB signalling systems on routes not operating with ETCS supervision.

### The specified stopping distances are such that a train of compliant freight vehicles is capable of satisfying the full service brake performance requirements set out in 2.3.3.1 of this document.

### Individual freight vehicles have traditionally been assessed in terms of their emergency braking performance (slip brake testing).

#### Service braking

2.3.3.1 Freight trains containing freight vehicles that are required to operate over routes signalled in accordance with GKRT0075 Appendix A shall not exceed the stopping distances defined by Curve V in Figure 1 of this document.

2.3.3.2 Freight trains that consist entirely of rail vehicles that meet the stopping distance defined in 2.3.2.5 of this document are permitted to be operated up to the following lengths and speeds:

- 750 m and operating up to 60 mile/h (96 km/h) with brakes in goods timing.
- 690 m and operating up to 75 mile/h (120 km/h) with brakes in passenger timing.

2.3.3.3 Freight trains longer than 690 m with brakes in passenger timing can be operated if all the individual freight vehicles meet the stopping distances defined in 2.3.2.6 of this document.

2.3.3.4 Locomotives required to operate over routes signalled in accordance with GKRT0075 Appendix A, shall have the following braking performance:

- Existing (ex-BR) locomotives shall not exceed the stopping distances defined by Curve ‘A1’ in Figure 1 of this document.
- New locomotives capable of operating at speeds not exceeding 110 mile/h (176 km/h) shall not exceed the stopping distances defined by Curve ‘A2’ in Figure 1 of this document.

#### Rationale for 2.3.3.1 to 2.3.3.4:
These requirements are additional to the requirements of the LOC & PAS TSI, in order to maintain compatibility with existing infrastructure. Lines signalled to GKRT0075 Appendix A permit the operation of all types of trains.

2.3.3.5 Locomotives, locomotive hauled passenger trains and fixed formation passenger trains required to operate over routes signalled in accordance with GKRT0075 Appendix A or Appendix B shall have the following braking performance:

- For trains containing any existing (ex-BR) rail vehicles the stopping distances shall not exceed those defined by Curve ‘B1’ in Figure 2 of this document.
- For trains composed entirely of new rail vehicles capable of operating at speeds not exceeding 110 mile/h (176 km/h) the stopping distances shall not exceed those defined by Curve ‘B2’ in Figure 2 of this document.
Compatibility Requirements for Braking Systems of Rail Vehicles

2.3.3.6 Tread braked multiple units with a maximum speed of 100 mile/h (160 km/h) required to operate over routes signalled in accordance with GKRT0075 Appendix A or Appendix B, shall have the following braking performance:

a) The stopping distances of trains containing any existing (ex-BR) rail vehicles shall not exceed those defined by Curve ‘B1’ in Figure 2 of this document.

b) The stopping distances of trains composed entirely of new rail vehicles shall not exceed those defined by Curve ‘B3’ in Figure 2 of this document.

Rationale for 2.3.3.5 and 2.3.3.6: These requirements are additional to the requirements of the LOC & PAS TSI. Lines signalled to GKRT0075 Appendix B permit the operation of all types of passenger trains. The signalling distances up to 100 mile/h (160 km/h) were derived from locomotive hauled trains fitted with cast iron tread brakes.

2.3.3.7 Disc braked multiple units with a maximum speed of 100 mile/h (160 km/h) required to operate over routes signalled in accordance with GKRT0075 Appendix A or Appendix B, shall not exceed the stopping distances defined by Curve ‘B3’ in Figure 2 of this document.

Rationale for 2.3.3.7: This requirement is additional to the requirements of the LOC & PAS TSI. It sets out the nominal 7%g full service braking performance to permit operation at the line speed signed in accordance with GKRT0075 Appendix B.

To enable disc braked multiple units to exploit higher differential line speeds (signed in accordance with GKRT0075 Appendix C) the brake performance will need to comply with 2.3.3.9.

2.3.3.8 Disc braked locomotive hauled passenger trains and fixed formation trains required to operate over routes signalled (or with differential speeds signed) in accordance with GKRT0075 Appendix C shall not exceed the stopping distances defined by Curve ‘C1’ in Figure 3 of this document.

Rationale for 2.3.3.8 to 2.3.3.9: These requirements are additional to the requirements of the LOC & PAS TSI. Lines signalled to GKRT0075 Appendix C permit the operation of passenger trains which have a nominal 9%g full service braking capability.

2.3.3.9 Disc braked multiple units required to operate over routes signalled (or with differential speeds signed) in accordance with GKRT0075 Appendix C shall not exceed the stopping distances defined by Curve ‘C2’ in Figure 3 of this document.

On GB mainline railway routes permitting operation above 125 mile/h (200 km/h) but not exceeding 155 mile/h (250 km/h), the trains braking performance above 125 mile/h (200 km/h) shall not exceed the stopping distances defined by Curve ‘D1’ in Figure 4 of this document.
### Compatibility Requirements for Braking Systems of Rail Vehicles

<table>
<thead>
<tr>
<th>Section</th>
<th>Rationale for 2.3.3.10:</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 2.3.3.10.1</td>
<td>This requirement supports the specific case in clause 7.3.2.7 of the LOC &amp; PAS TSI not to comply with the requirements of point (9) of clause 4.2.4.5.2 for GB domestic trains with a design maximum speed higher than or equal to 155 mile/h (250 km/h).</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Rationale for 2.3.4.1:</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 2.3.4.1.1</td>
<td>This requirement is additional to the requirements of the WAG TSI clause 4.2.4.3.3 in order to maintain compatibility with existing infrastructure.</td>
</tr>
<tr>
<td>G 2.3.4.1.2</td>
<td>The brake thermal capacity is a means of declaring the capability of the brake systems on rail vehicles to maintain a constant operating speed on a falling gradient. It is declared in terms of the maximum line gradient, associated length and operating speed for the load condition maximum braking load.</td>
</tr>
<tr>
<td>G 2.3.4.1.3</td>
<td>The reference cases in the LOC &amp; PAS TSI clause 4.2.4.5.4 and WAG TSI clause 4.2.4.3.3 are to permit operation over the Alpine gradients. For GB domestic rail vehicles it is not necessary to have this high thermal capacity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Rationale for 2.3.5.3:</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 2.3.5.3.1</td>
<td>This requirement is additional to the requirements of the LOC &amp; PAS TSI clause 4.2.4.5.5 to permit passenger trailer vehicles (coaches) not to be fitted with parking brakes when operating on the GB mainline railway.</td>
</tr>
<tr>
<td>G 2.3.5.3.2</td>
<td>The use of scotches is permitted if the passenger train formation is to be immobilised on steeper gradients than the design capability of the parking brake and the appropriate number of scotches are carried on the train.</td>
</tr>
</tbody>
</table>
2.3.5.4 On freight vehicles the parking brake, where fitted, shall be capable of holding the vehicle, in the design mass under normal payload (fully laden), stationary on a minimum gradient of 1 in 40 (25\degree). In the case of the semi-permanently coupled vehicles, those with a parking brake shall be capable of holding stationary all the vehicles that are semi-permanently coupled together.

G 2.3.5.4.1 Rationale for 2.3.5.4: This requirement is additional to the requirements of the WAG TSI clause 4.2.4.3.2.2, in order to provide the operational flexibility to detach defective vehicles from freight trains and to immobilise them with the parking brake.

G 2.3.5.4.2 The changes in load state of the rail vehicle and suspension movements need to be considered when designing parking brake systems, principally the impact on parking brake performance and the ability to release the parking brake.

G 2.3.5.4.3 For the purpose of designing the parking brake the maximum force that can be applied by a manual operator is 500 N at the mechanical interface (hand brake wheel or lever).

G 2.3.5.4.4 The use of scotches is permitted if the freight train formation is to be immobilised on steeper gradients than the capability of the available parking brake and the appropriate number of scotches are carried on the train.

2.4 Wheel slide protection system

2.4.1 Disc braked locomotives and passenger vehicles shall be fitted with wheel slide protection (WSP) systems.

G 2.4.1.1 Rationale for 2.4.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.4.6.1 for compatibility with GB infrastructure. To minimise the risk of wheelset damage, and to optimise the braking performance during low adhesion conditions, all GB locomotive and passenger vehicles fitted with disc brakes have WSP equipment fitted regardless of their nominal adhesion requirement.

G 2.4.1.2 The LOC & PAS TSI sets out requirements for WSP fitment to tread braked vehicles designed to utilise high adhesion values. The WAG TSI also sets out requirements for WSP fitment to freight vehicles designed to utilise high adhesion values.

G 2.4.1.3 WSP systems compliant with BS EN 15595:2009+A1:2011 are considered sufficient to comply with the LOC & PAS TSI. The EN includes testing of rail vehicles on simulated low adhesion conditions generated using detergents applied to the railhead.

G 2.4.1.4 GB experience has shown that this level of compliance is insufficient for satisfactory operation on the variable low adhesion conditions that are experienced on the GB mainline railway. This is reflected in the GB national foreword to BS EN 15595:2009+A1:2011. Further guidance for assessing WSP systems for operation in GB adhesion conditions is given in GMGN2695.

G 2.4.1.5 It is good industry practice to arrange the WSP system so that there is control of the brake force on a per wheelset basis on a vehicle of a multiple unit, except on wheelsets that are coupled by a mechanical drive system.
Comprising Requirements
for Braking Systems of Rail
Vehicles

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GMRT2045
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G 2.4.1.6 The brake energy supply needs to be sufficient for the intended train formations and all combinations of brake applications, including the effect of WSP operation. Where the brake systems are designed to utilise high levels of adhesion the effect of WSP activity, when operating on low adhesions, will influence the amount of energy required on the train formation. For additional guidance see Appendix K of this document.

G 2.4.1.7 The interaction of the cross blending of the friction brake and the dynamic brake with powered and unpowered wheelsets needs to be considered during low adhesion events. Suspension of the dynamic brake, in response to the onset of significant wheelslip / slide, can assist in the reducing the wheelset adhesion demand and the extension in stopping distances.

2.5 Brake requirements for rescue purposes

2.5.1 Where rail vehicles are to be capable of being rescued by GB domestic locomotives the vehicle end air connections shall be compatible with:

a) Brake pipe coupling (red) to BS EN 15807:2011 Figure 2.

b) Main reservoir pipe coupling with valve (yellow) to BS EN 15807:2011 Figure 8.

G 2.5.1.1 Rationale for 2.5.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.4.10. The ability to move a disabled train by a rescuing locomotive requires the provision of a means to release and subsequently control the brakes on the disabled train.

G 2.5.1.2 On multiple units this has typically required a hose connection to the unit’s main reservoir pipe to release the spring applied air release parking brakes. This alleviates the need to manually release the individual parking brake units and allows the unit to be stabled with the parking brake applied after the rescue move.

G 2.5.1.3 Spring applied air release parking brakes are generally fully released when supplied with a pressure of 5 bar. Connecting the locomotive brake pipe to the multiple unit’s main reservoir pipe could also provide a limited means to control a brake on the unit being rescued. This method is more applicable for multiple units up to 200 tonnes when most of the braking can be provided by the rescuing locomotive and the train formation is moved at reduced speeds.

G 2.5.1.4 When it is intended to use the brake pipe pressure to release the spring applied parking brakes, reducing the volume of the multiple unit’s main reservoir system avoids compromising the brake pipe control from the locomotive. This can be achieved by isolating air systems from the multiple unit’s main reservoir pipe (including air reservoirs and air suspension systems).

G 2.5.1.5 Where normal operating speeds are required during rescue operations, there needs to be provision for the multiple unit’s brakes to be controlled by a locomotive. Suitable options are:

a) The provision of a parallel or integrated pneumatically controlled brake system that is compatible with the locomotive brake system permits locomotive haulage of train formations fitted with electrically controlled brake systems.
b) Use of a ‘translator’ at the unit ends to convert the brake pipe command pressures into the relevant electrical signals. This would, however, require the provision of electrical power on the unit during the rescue move. The ‘translator’ control being configured so that loss of electrical power on the unit being rescued initiates a brake application on the rescuing locomotive.

G 2.5.1.6 For additional guidance on hauling un-braked multiple units in freight trains see GMGN2607.

G 2.5.1.7 The compatibility of the main reservoir systems on the assisting vehicle and the train formation being rescued needs to be checked prior to coupling the main reservoir systems.

G 2.5.1.8 British Rail historically adopted a main reservoir pipe pressure of 7 bar for hauled coaching stock and multiple units. More recent multiple units have followed the continental UIC practice with the main reservoir pipe pressure between 9 and 10 bar. The brake system components on GB rail vehicles are generally designed to tolerate 10 bar pressures.

G 2.5.1.9 On some multiple unit classes, the air system safety valves are set to open at 8.5 bar. To avoid the safety valves continuously trying to vent the excess pressure in their air system, it is recommended that the reservoir pipe on these multiple units are not connected to air systems charged to greater than 7 bar when being rescued.

G 2.5.1.10 The LOC & PAS TSI is silent on the identification of the inter-vehicle air connections. British Rail adopted the colours, red for the brake pipe and yellow for the main reservoir pipe, when air braked vehicles were introduced to the GB mainline railway.

2.6 Environmental conditions

2.6.1 For operation on the GB mainline railway, rail vehicle brake systems shall be designed to operate within the ambient temperature range T1 (-25°C to +40°C).

G 2.6.1.1 **Rationale for 2.6.1:** This requirement specifies the option in the LOC & PAS TSI clause 4.2.6.1.1 and WAG TSI clause 4.2.5 for the ambient temperature range that is considered to be sufficient for brake equipment used on the GB mainline railway.

G 2.6.1.2 Solar gain and heating from other equipment may lead to localised higher temperatures and these will need to be considered in design of the brake equipment.

G 2.6.1.3 Where the emergency and full service brake applications rely on the exhausting of compressed air, consideration needs to be given to the provision of protection from blockage of the exhaust outlets, particularly by ice or frozen snow. The exhaust outlets from individual brake command devices are to be kept separate.

G 2.6.1.4 The use of automatic slack adjuster mechanism permits a close clearance to be maintained between the braking surface on the disc or wheel and the friction material, which minimises the build-up of ice on these surfaces.
2.7 Interface with energy subsystem

2.7.1 Regenerative braking

2.7.1.1 For compatibility with the GB mainline railway, the requirements for regenerative braking into the AC energy subsystem are set out in GMRT2111.

2.7.1.2 For compatibility with the GB mainline railway, the requirements for regenerative braking into the DC energy subsystem are set out in GMRT2113.

2.8 Interface with infrastructure subsystem

2.8.1 Maximum average deceleration

2.8.1.1 The maximum average deceleration requirements of the infrastructure subsystem developed with all brakes in use, including brakes independent of wheel / rail adhesion are satisfied by compliance with this standard.

2.9 Interface with operation subsystem

2.9.1 Braking performance

2.9.1.1 For compatibility with the GB mainline railway, the braking performance requirements of the operation subsystem are satisfied by compliance with this standard.

2.10 Interface with control, command and signalling subsystem

2.10.1 Train detection

2.10.1.1 For compatibility with the train detection systems of the GB mainline railway, the sanding criteria during braking for multiple units and OTMs are set out in GMRT2461.

G 2.10.1.1.1 Rationale for 2.10.1.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.3.3.1 for compatibility with GB train detection systems based on track circuits.

G 2.10.1.1.2 The LOC & PAS TSI only mandates the recording of the rolling stock characteristics in the European Register of Authorised Types of Vehicles (ERATV) where they comply with CCS TSI Index 77.

G 2.10.1.1.3 The CCS TSI Index 77 document incorporates a series of target rolling stock characteristics for use when designing train detection system(s) (track circuits, axle counters, and loop equipment).

G 2.10.1.1.4 The LOC & PAS TSI does not mandate compliance with the rolling stock characteristics set out in Index 77. Alternative interface criteria are permitted and for compatibility with GB train detection systems based on track circuits the isolating emission compatibility of sanding systems are covered by compliance with GMRT2461.
2.10.2 European Rail Traffic Management System (ERTMS) equipped routes

2.10.2.1 On rail vehicles fitted with the on-board ETCS, the brake control system shall incorporate interfaces to initiate an emergency brake application.

G 2.10.2.1 Rationale for 2.10.2.1: The on-board ETCS equipment calculates a series of intervention curves based on the braking characteristics of the train. Should the train speed exceed any of these intervention curves the on-board ETCS equipment will request a brake application.

G 2.10.2.1.2 Depending on the configuration of the on-board ETCS additional brake control system interfaces may be provided to initiate service brake applications.

2.10.3 GB Class B signalling systems (non-ERTMS) equipped routes

2.10.3.1 On rail vehicles fitted with on-board GB CCS systems (for example TPWS as set out in GERT8075, and trip-cocks as set out in GERT8018), the brake control system shall incorporate interfaces to initiate, as a minimum, a full service brake application.

G 2.10.3.1 Rationale for 2.10.3.1: On GB vehicles fitted with an automatic air brake system the GB CCS initiated brake application is achieved by a controlled venting of the brake pipe that replicates a full service brake application made by the driver.

G 2.10.3.1.2 On multiple units fitted with enhanced emergency braking, this is applied when there is a brake request by the GB CCS systems.

2.11 Interface with other on-board systems

2.11.1 Passenger alarm system

2.11.1.1 The brake system interface with the passenger alarm system shall initiate at least a full service brake application. For passenger alarm activations during platform departures the resulting brake application shall be at the enhanced emergency rate (where fitted).

G 2.11.1.1 Rationale for 2.11.1.1: This requirement is additional to the requirements of the LOC & PAS TSI clause 4.2.5.3 and sets out the braking criteria when the passenger alarm system requests a brake application.

G 2.11.1.1.2 LOC & PAS TSI compliant passenger alarm systems are primarily a communication system between the passenger and the driver. The principal exception being during station departures when the risk to passenger safety means the brakes are immediately applied. Outside station areas acknowledgement of the passenger alarm activation by the driver suspends / overrides a brake request from the passenger alarm system. Compliance with BS EN 16334:2014 is deemed to satisfy these requirements.

G 2.11.1.1.3 Historically, on GB hauled passenger vehicles, activation of the passenger alarm was configured to initiate a brake application by locally venting the brake pipe to below 2 bar. An override feature to cancel the passenger alarm brake request is fitted to Mk4 coaches when operated with compatible driving cabs (Class 91 locos and Mk4 Driver Van Trailers (DVTs)).
2.11.2 Train safety systems
2.11.2.1 The brake control system shall provide interfaces for train safety systems to initiate an emergency brake application. It is permitted to initiate an enhanced emergency brake application (where fitted).

G 2.11.2.1.1 Examples of on-board safety systems with interfaces with the brake system include:

a) Driver's activity control function.
b) Direction control (prevents selection of neutral or change of direction when moving).
c) Detection of hot axle boxes and bogie instability.
d) Emergency door release interlock.

2.12 Conformity assessment
2.12.1 Verification of the emergency and service braking performance of locomotive and passenger vehicles shall be assessed by stopping distance tests in train formations that represent the intended use of the rail vehicles. The train formations used for these tests shall be recorded as part of the technical information.

G 2.12.1.1 Rationale for 2.12.1: Stopping distance testing is the accepted means of verifying the brake performance calculations.

G 2.12.1.2 The results of the stopping distance tests are assessed on the basis of a mean stopping distance curve derived from the individual stopping distances. Factors to take into consideration include:

a) Testing from different brake entry speeds to generate a stopping distance curve.
b) At least two stopping distance tests at each nominal test speed.
c) The mean stopping distance curve derived using a suitable mathematical process.
d) The mean stopping distance curve being less than or equal to the target stopping distance.
e) Brake force build-up time.
f) Any fade associated with the increase in temperature of a friction material that may arise during any brake application, including drag braking.
g) Tolerances on equipment settings.
h) Any degradation in braking performance between maintenance or during the bedding in of new components.
i) The environmental conditions prevailing during the testing.
It is permissible for a certain amount of the scatter in the stopping distances to exceed the maximum braking distance by a maximum of 5% of the target braking distance. It is good industry practice that the total amount of scatter in the stopping distances at any speed does not exceed ±15% of the mean stopping distance curve (see Appendix G of this document). Further guidance on testing methodology is set out in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47).

Train formations that do not meet the stopping distances requirements specified in this document may still run on routes signalled in accordance with the appropriate signal spacing in GKRT0075 Appendices, if:

a) The permissible train speed is reduced so the resultant stopping distances comply with the requirements.

Or

b) It can be demonstrated that the signal spacing distances are greater than the permitted minimum. Noting that the warning boards for speed restrictions are placed at the minimum signal spacing distance appropriate for the line speed.

Or

c) In the case of locomotives there are other trailing vehicles in the train formation that are able to compensate for the under-braked locomotive, so that the train formation meets the stopping distance requirement.

If a locomotive needs trailing vehicles to provide the overall train braking performance, further trailing vehicles may be required for each additional locomotive included in the train formation, to ensure that the required train braking performance is achieved.

From a braking perspective, where train formations exceed the braking performance required for the line speed and signal spacing distances on a route, it may be possible for these train formations to run at a higher speed on that route.

The verification of the braking performance of an individual freight vehicle in tare (design mass in working order) and loaded condition (design mass under normal payloads) shall be by one of the following methods:

a) A slip coupling test.

b) Calculated stopping distances based on brake performance tests carried out in freight train formations with the hauling locomotive un-braked. The requirements associated with this method are set out in Appendix B of this document.

c) Calculated stopping distances based on brake performance tests carried out in freight train formations with the brakes operational on the hauling locomotive. The requirements associated with this method are set out in Appendix C of this document.

Rationale for 2.12.2: The traditional method of checking the braking performance of freight vehicles is by slip coupling tests that determine the stopping distances with an emergency brake application.
G 2.12.2.2 It is not considered appropriate to use slip coupling tests when assessing the braking performance of complex freight vehicles (such as hauled on-track machines). Alternative assessment methods using train formations are set out in the Appendices of this document.

2.12.3 Freight vehicles fitted with a change-over device for the tare (design mass in working order) and loaded condition (design mass under normal payloads) respectively shall additionally have their stopping distances checked at the maximum load condition that still retains the brake force for the tare condition.

G 2.12.3.1 Rationale for 2.12.3: The assessment is to confirm compliance with the brake performance requirements with an intermediate load condition. This is not necessary on freight vehicles that only operate in the tare and fully laden conditions.

2.12.4 Static and stopping distance tests, designed to demonstrate that the individual vehicle or train formation meets the stopping distance requirements specified in this document for that particular group of rail vehicles, shall be undertaken when existing rail vehicle designs are modified such that the braking performance could be affected.

G 2.12.4.1 Rationale for 2.12.4: Stopping distance testing is the accepted means of verifying the brake performance following rail vehicle modifications.

G 2.12.4.2 Stopping distance tests are not required in the following circumstances:

a) Each individual vehicle of a particular design does not have to be tested but there are sufficient tests to establish that the modified vehicle design meets the specified requirements.

b) If the brake system and brake forces of a new rail vehicle are very similar to an existing design and the rail vehicle design masses are similar and records exist of satisfactory stopping distance tests.

c) If for modified rail vehicles with friction braking there is sufficient data available from stopping distance tests with other rail vehicles that meet the conditions listed below, to enable a calculation to be made to verify that the modified rail vehicle will meet the required stopping distances:

i) Same brake forces and friction couple (materials) were used.

ii) The specific pressure at the friction couple is similar to that used on the previous rail vehicles.

iii) The rail vehicle design masses are similar.

iv) The maximum rail vehicle speeds are the same.

G 2.12.4.3 If the maximum speed or design mass of the modified vehicle is greater than the value of the existing test data, it is recommended that tests are undertaken at speeds and / or design mass for which there is no data available.
2.12.5 The verification of new brake control systems, components, sub-assemblies and friction materials shall be undertaken when there is no previously demonstrated service experience of that combination of the brake system.

G 2.12.5.1 **Rationale for 2.12.5:** The brake system is a key safety system and as such the operational performance of the brake system and its components need to be verified.

G 2.12.5.2 The assessment can be undertaken on a test rig, provided that all the forces and conditions, including climatic, that could reasonably be expected to be met in service are covered. For further guidance on the assessment of friction materials, see Appendix H of this document.

G 2.12.5.3 A service trial with all new major components or sub-assemblies that employ new principles of operation, new friction couples or complete brake systems confirms the suitability before they are put into fleet-wide service. The principles of the current GB friction braking systems are set out in Appendix J of this document.

G 2.12.5.4 The service trial is normally undertaken for a 12 months duration and covers representative climatic conditions and duty cycles on a sufficient number of rail vehicles. If a service trial of 12 months is not considered necessary, a risk analysis can be undertaken to determine the minimum length of the trial.

G 2.12.5.5 On rail vehicles fitted with WSP equipment and that use a compressed air energy supply, it is necessary to demonstrate that the air pressure in the brake supply reservoir is maintained at a level to provide an emergency brake application. A test to simulate WSP activity, to replicate large air flows, is typically undertaken, and Appendix K of this document gives guidance on how this can be achieved.

2.12.6 The conformity assessment methods set out in LOC & PAS TSI clause 6.2.3.5 is not required for modifications where the vehicles are deemed not to be new, renewed and upgraded.

G 2.12.6.1 **Rationale for 2.12.6:** The LOC & PAS TSI clause 6.2.3.5 which sets out requirements which are applicable for the design of new, renewed and upgraded rolling stock.

G 2.12.6.2 The Common Safety Method on Risk Evaluation and Assessment (CSM RA) regulations are applicable where the modifications to the vehicle braking system or the braking performance of the vehicle are considered a significant change by these regulations.

G 2.12.6.3 Additional guidance on the application of the CSM RA is given in GEGN8640 to GEGN8645 inclusive.

G 2.12.6.4 RIS-2700-RST sets out processes that can be adopted when undertaking projects that require verification of an engineering change to rail vehicles.
Part 3  Braking Data for Train Operation

3.1 GB ‘brake force’ data

3.1.1 A GB ‘brake force’ value that enables the braking performance of all rail vehicles to be compared on the same basis shall be calculated for inclusion in the Rolling Stock Library part of R2 in accordance with Appendix D of this document.

G 3.1.1.1 Rationale for 3.1.1: The GB ‘brake force’ data is used by Total Operation Processing System (TOPS) and GORT3056 Table E1 to determine the operating parameters when moving rail vehicles in freight trains on routes signalled in accordance with GKRT0075 Appendix A.

3.2 GB ERTMS brake data

3.2.1 There are two methodologies to manage brake data for the ETCS to calculate the emergency brake intervention curves:

a) Gamma train – multiple unit and fixed formation trains where the braking performance (nominal emergency brake deceleration profile and brake build-up time) are preset in the on-board ETCS equipment. The driver selects the appropriate train configuration from the range of datasets.

b) Lambda train – general operation trains (locomotive hauled) where the braking performance is input as a Lambda value (also known as braked weight percentage). The on-board ETCS converts this Lambda value into an equivalent deceleration profile and brake build-up time for the train. The use of Lambda values is permitted up to a maximum speed of 125 mile/h (200 km/h).

3.3 GB ERTMS Gamma train brake data

3.3.1 The Gamma train emergency brake data requirements are set out in ERTMS / ETCS System Requirements Specification Subset-26, clause 3.13.2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_brake_emergency(V)</td>
<td>m/s²</td>
<td>Nominal emergency brake deceleration (up to 7 speed bands)</td>
</tr>
<tr>
<td>T_brake_build_up</td>
<td>s</td>
<td>Time for emergency brake to build-up after commanded by ERTMS</td>
</tr>
<tr>
<td>Kdry_rst</td>
<td></td>
<td>Correction factor – statistical distribution of emergency braking performance on dry rails. Value for each of the speed bands</td>
</tr>
<tr>
<td>Kwet_rst</td>
<td></td>
<td>Correction factor for wet rails. Values for each of the speed bands</td>
</tr>
</tbody>
</table>

Table 1  Gamma train emergency brake data

3.3.2 The means to determine the Kdry_rst and Kwet_rst correction factor for the nominal emergency brake deceleration values are set out in ERTMS / ETCS System Requirements Specification Subset-40, clauses 4.4.1.4 and 4.4.1.5.
3.4 GB ERTMS Lambda train brake data

3.4.1 The Lambda value for the train is defined by:

\[
\text{Lambda} = \frac{\sum \text{available vehicle braked weights}}{\text{Mass of the train}} \times 100
\]

3.4.2 The ‘braked weight’ values of the individual vehicles shall be determined using the methodology set out in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47).

3.4.3 For freight vehicles the ‘braked weight’ values shall be determined for the tare (design mass in working order) and loaded condition (design mass under normal payloads). For other vehicles the ‘braked weight’ values shall be determined for the design mass in working order.

3.4.4 To permit passenger rolling stock to be rescued by locomotives or moved in freight trains, ‘braked weight’ values shall be determined for those vehicle brakes which are capable of being controlled by the locomotive.

3.4.5 For existing GB rail vehicles it is permitted for an equivalent GB ‘braked weight’ value to be calculated from their GB ‘brake force’ value using the methodology set out in Appendix E of this document.
Part 4 Application of this document

4.1 Scope

4.1.1 The requirements set out in Part 2 and Part 3 of this document apply to all new and modified brake systems (this excludes like-for-like replacement of components) of rail vehicles for operation on the GB mainline railway (unless as set out in 4.1.2).

4.1.2 The requirements set out in 2.2.2.1, 2.2.3.1, 2.3.2.4 and 2.12.6 only apply to modifications where the vehicles are deemed not to be new, renewed and upgraded.

4.1.3 The braking performance of on-track machines (OTMs) for use in running mode is within the scope of this document.

4.1.4 Action to bring existing braking systems into compliance with the requirements of this document is not required.

4.2 Exclusions from scope

4.2.1 The requirements in the document are not applicable to the following types of vehicles:

a) On-track machine (except as set out in 4.1.3).

b) General Contract of Use (GCU) wagons.

4.3 General compliance date

4.3.1 This Railway Group Standard comes into force and is to be complied with from 04 June 2016.

4.3.2 After the compliance dates, or the date by which compliance is achieved if earlier, compliance with the requirements set out in this Railway Group Standard is to be maintained.

4.4 Deviations

4.4.1 Where it is considered not reasonably practicable to comply with the requirements of this document (including any requirement to comply with a TSI requirement referred to in 4.1.2), permission to comply with a specified alternative should be sought in accordance with the deviation process set out in the Railway Group Standards Code.

4.4.2 In the case where TSI compliance is required for a new, renewed or upgraded vehicle or structural subsystem, the derogation process to be followed is set out in the Railways (Interoperability) Regulations 2011 (as amended).

4.5 Exceptions to general compliance date

4.5.1 There are no exceptions to the general compliance date specified in 4.3 of this document.

4.5.2 If, at the time this document becomes mandatory, a project is at an advanced stage of development, having regard to the impact that a change in technical specification would have on the project, it is permissible to continue to meet the equivalent requirements in the Railway Group Standards applying before this document becomes mandatory.

4.5.3 If the project requires an authorisation for placing into service, a decision to continue to meet the equivalent requirements in the Railway Group Standards applying before this document becomes mandatory should be discussed with the Office of Rail and Road.
4.6 Health and safety responsibilities

4.6.1 Users of documents published by RSSB are reminded of the need to consider their own responsibilities to ensure health and safety at work and their own duties under health and safety legislation. RSSB does not warrant 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.
Compatibility Requirements for Braking Systems of Rail Vehicles

Appendix A  Braking Performance Requirements to Operate Over Routes Signalled in Accordance with GKRT0075

The content of this appendix is required by 2.3.3

**Figure 1** Performance for trains required to operate over routes signalled in accordance with Appendix A of GKRT0075

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve V)</td>
<td>195</td>
<td>281</td>
<td>401</td>
<td>532</td>
<td>669</td>
<td>829</td>
<td>916</td>
<td>990</td>
<td>1058</td>
<td>1116</td>
<td>1218</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve A1)</td>
<td>177</td>
<td>256</td>
<td>365</td>
<td>483</td>
<td>608</td>
<td>754</td>
<td>833</td>
<td>900</td>
<td>961</td>
<td>1015</td>
<td>1107</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve A2)</td>
<td>170</td>
<td>244</td>
<td>349</td>
<td>463</td>
<td>582</td>
<td>721</td>
<td>797</td>
<td>861</td>
<td>920</td>
<td>970</td>
<td>1059</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
<th>120</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve V)</td>
<td>1258</td>
<td>1258</td>
<td>1354</td>
<td>1537</td>
<td>1750</td>
<td>2041</td>
<td>2041</td>
<td>2041</td>
<td>2041</td>
<td>2054</td>
<td>2054</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve A1)</td>
<td>1144</td>
<td>1144</td>
<td>1231</td>
<td>1397</td>
<td>1591</td>
<td>1856</td>
<td>1814</td>
<td>1814</td>
<td>1814</td>
<td>1826</td>
<td>1826</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve A2)</td>
<td>1094</td>
<td>1094</td>
<td>1177</td>
<td>1337</td>
<td>1521</td>
<td>1775</td>
<td>1775</td>
<td>1775</td>
<td>1775</td>
<td>1775</td>
<td>1786</td>
</tr>
</tbody>
</table>

The curve ‘V’ is the level track signal spacing distances for speeds up to 60 mile/h defined by Appendix A of GKRT0034 (now superseded by GKRT0075) and for speeds above 60 mile/h by Appendix A of GKRT0075.

The stopping distances on level track of curve ‘A1’ is derived from the signal spacing distance of curve ‘V’ as follows:

\[
\text{Curve ‘A1’ up to 100 mile/h: } = \frac{\text{‘V’}}{1.1} \quad \text{above 100 mile/h: } = \frac{\text{‘V’}}{1.125}
\]

The stopping distances on level track of Curve ‘A2’ is derived from the signal spacing distances follows:

\[
\text{Curve ‘A2’} = \frac{\text{‘V’}}{1.15}
\]
### Compatibility Requirements for Braking Systems of Rail Vehicles

**Figure 2** Performance for trains required to operate over routes signalled in accordance with Appendix B of GKRT0075

The curve ‘W’ is defined by the signal spacing distances given for level track in Appendix B of GKRT0075. The stopping distances on level track of curves ‘B1’, ‘B2’ and ‘B3’ are derived from the signal spacing distance of curve ‘W’ as follows:

- Curve ‘B1’ up to 100 mile/h: \( \frac{\text{'W'}}{1.1} \) above 100 mile/h: \( \frac{\text{'W'}}{1.125} \)
- Curve ‘B2’ = \( \frac{\text{'W'}}{1.15} \)
- Curve ‘B3’ = \( \frac{\text{'W'}}{1.2} \)

**Notes**

- Values in grey boxes are for guidance compliance required with Curve ‘W’ distances.
- Up to 100 mile/h the curve for level track in Appendix B of GKRT0075 is based on the friction characteristic of cast-iron brake-blocks.

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve W)</td>
<td>80</td>
<td>112</td>
<td>154</td>
<td>203</td>
<td>258</td>
<td>332</td>
<td>418</td>
<td>515</td>
<td>632</td>
<td>742</td>
<td>870</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B1)</td>
<td>73</td>
<td>102</td>
<td>140</td>
<td>185</td>
<td>235</td>
<td>302</td>
<td>380</td>
<td>468</td>
<td>575</td>
<td>675</td>
<td>791</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B2)</td>
<td>70</td>
<td>97</td>
<td>134</td>
<td>177</td>
<td>224</td>
<td>289</td>
<td>364</td>
<td>448</td>
<td>550</td>
<td>645</td>
<td>757</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B3)</td>
<td>67</td>
<td>93</td>
<td>128</td>
<td>169</td>
<td>215</td>
<td>277</td>
<td>348</td>
<td>429</td>
<td>527</td>
<td>618</td>
<td>725</td>
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</table>

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
<th>120</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve W)</td>
<td>1030</td>
<td>1190</td>
<td>1354</td>
<td>1537</td>
<td>1750</td>
<td>2041</td>
<td>2041</td>
<td>2041</td>
<td>2041</td>
<td>2041</td>
<td>2054</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B1)</td>
<td>936</td>
<td>1082</td>
<td>1231</td>
<td>1397</td>
<td>1591</td>
<td>1856</td>
<td>1814</td>
<td>1814</td>
<td>1814</td>
<td>1814</td>
<td>1826</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B2)</td>
<td>896</td>
<td>1035</td>
<td>1177</td>
<td>1337</td>
<td>1522</td>
<td>1775</td>
<td>1775</td>
<td>1775</td>
<td>1775</td>
<td>1786</td>
<td></td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve B3)</td>
<td>858</td>
<td>992</td>
<td>1128</td>
<td>1281</td>
<td>1458</td>
<td>1701</td>
<td>1701</td>
<td>1701</td>
<td>1701</td>
<td>1712</td>
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</table>
Compatibility Requirements for Braking Systems of Rail Vehicles

Railway Group Standard
GMRT2045
Issue Four
Date March 2016

Figure 3 Performance for trains required to operate over routes signalled in accordance with Appendix C of GKRT0075

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve Y)</td>
<td>72</td>
<td>103</td>
<td>143</td>
<td>191</td>
<td>246</td>
<td>304</td>
<td>368</td>
<td>438</td>
<td>514</td>
<td>597</td>
<td>684</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve C1)</td>
<td>63</td>
<td>90</td>
<td>124</td>
<td>166</td>
<td>214</td>
<td>264</td>
<td>320</td>
<td>381</td>
<td>447</td>
<td>519</td>
<td>594</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve C2)</td>
<td>60</td>
<td>86</td>
<td>119</td>
<td>159</td>
<td>205</td>
<td>253</td>
<td>307</td>
<td>365</td>
<td>428</td>
<td>497</td>
<td>570</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
<th>95</th>
<th>100</th>
<th>105</th>
<th>110</th>
<th>115</th>
<th>120</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve Y)</td>
<td>779</td>
<td>879</td>
<td>986</td>
<td>1101</td>
<td>1223</td>
<td>1341</td>
<td>1472</td>
<td>1608</td>
<td>1751</td>
<td>1900</td>
<td>2054</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve C1)</td>
<td>677</td>
<td>764</td>
<td>857</td>
<td>957</td>
<td>1063</td>
<td>1166</td>
<td>1280</td>
<td>1398</td>
<td>1523</td>
<td>1652</td>
<td>1786</td>
</tr>
<tr>
<td>DISTANCE (metres) (Curve C2)</td>
<td>649</td>
<td>733</td>
<td>822</td>
<td>918</td>
<td>1019</td>
<td>1118</td>
<td>1226</td>
<td>1340</td>
<td>1459</td>
<td>1583</td>
<td>1712</td>
</tr>
</tbody>
</table>

The curve ‘Y’ is defined by the signal spacing distances given for level track in Appendix C of GKRT0075. The stopping distances on level track of curves ‘C1’ and ‘C2’ are derived from the signal spacing distance of curve ‘Y’ as follows:

Curve ‘C1’ = "Y" /"1.15"  
Curve ‘C2’ = "Y" /"1.2"

Note:
- Values in grey boxes are for guidance compliance required with Curve Y distances.
Figure 4  Performance for trains which operate above 125 mile/h (200 km/h)

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>130</th>
<th>135</th>
<th>140</th>
<th>145</th>
<th>150</th>
<th>155</th>
<th>160</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve D1)</td>
<td>2089</td>
<td>2319</td>
<td>2558</td>
<td>2805</td>
<td>3061</td>
<td>3325</td>
<td>3597</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INITIAL SPEED (mile/h)</th>
<th>165</th>
<th>170</th>
<th>175</th>
<th>180</th>
<th>185</th>
<th>187</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE (metres) (Curve D1)</td>
<td>3879</td>
<td>4168</td>
<td>4466</td>
<td>4773</td>
<td>5088</td>
<td>5214</td>
</tr>
</tbody>
</table>

Train formations capable of operating above 125 mile/h (200 km/h), when operating at speeds up to and including 125 mile/h (200 km/h), shall not exceed the distances defined by Curve ‘C1’ of Figure 3 for fixed formation trains and Curve ‘C2’ of Figure 3 for multiple units respectively.

Explanation of the factors used to derive the stopping distances from the minimum signalling distances:

- The factor of 1.1 is to cover a maximum 5% error in speed.
- The factor of 1.125 used above 100 mile/h is considered appropriate for existing vehicles.
- The factor of 1.15 is the currently accepted contingency for new vehicles in locomotive hauled trains or fixed formation trains (except multiple units).
- The factor of 1.2 is the currently accepted contingency for new multiple units. This larger contingency has been adopted to mitigate for the operation of shorter formations associated with multiple units.
Appendix B  Methodology to Determine the Braking Performance of New Vehicles using an Unbraked Locomotive

The content of this appendix is required by 2.12.2 b)

B.1  General

B.1.1 Slip coupling tests have traditionally been used to determine the braking performance of individual freight vehicles. While this approach is appropriate for simple vehicles, it is considered to be less suitable for the testing of more complex freight vehicles, for example, OTMs that are locomotive hauled between worksites.

B.1.2 The alternative permissible strategy set out in this Appendix involves undertaking brake performance testing of the vehicle(s) (the ‘consist’) to be assessed within a freight train formation with the hauling locomotive attached. This method is derived from that described in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47) to assess simple freight wagons when they are coupled to form a rake of identical wagons. The consist under assessment shall be at least twice the mass of the locomotive to ensure that the testing method is valid.

B.2  Methodology

B.2.1 The locomotive used for the testing shall be equipped with both an automatic air brake and an independent brake. During the brake tests the automatic air brake on the locomotive shall be isolated. In the event of an emergency, the driver shall still be able to use the independent brake to apply the brakes on the locomotive.

B.2.2 Stopping distance brake tests shall be carried out with the consist being assessed on its own or in the train formations that are intended to be used on the GB mainline railway. Level track stopping distance brake tests shall be undertaken from a range of operating speeds from 20 mile/h (32 km/h) up to the maximum service speed of the formation using full service brake applications with the air brake distributor(s) on the locomotive isolated.

B.2.3 Rail vehicles that operate in different loading conditions shall have the brake tests carried out in both tare and laden conditions. On those rail vehicles not fitted with load compensating brake equipment, the tare tests shall be at the maximum load before changing from tare to laden.

B.2.4 The braking performance shall be assessed on the basis of a mean level track stopping distance curve derived from the individual brake stopping distances. The mean level track stopping distance curve shall be determined.

B.2.5 If the consist under assessment only operates in the formations used for the brake tests, then compliance with the brake performance requirements is demonstrated by the level track stopping distances for the test train formation. The level track stopping distances for the consist under assessment and the unbraked locomotive shall not exceed those set out by Curve V in Figure 1 of this document.

B.2.6 Where the requirements of B.2.5 are not demonstrated, or if the consist under assessment operates in different freight train formations, then the consist’s contribution to the overall brake performance shall be determined. This shall be demonstrated by calculating the equivalent stopping distance for the consist if it were operating on its own.
B.2.7 For the purpose of determining the brake performance of the consist under assessment, the level track stopping distance measured during the brake tests shall be expressed as:

$$SD_T = D_{FR} + BD_T$$

Where:
- $D_{FR}$ = Free run distance
- $BD_T$ = Braking distance
- $SD_T$ = Level track stopping distance from brake entry speed $V$ (m/s)
- $D_{FR} = \frac{1}{2} V \times$ average brake cylinder fill time of the consist

$$BD_T = \frac{V^2}{2A_T}$$

Where:
- $V$ = Brake entry speed (m/s)
- $A_T$ = Test train deceleration

$$BD_T = SD_T - D_{FR}$$

The test train's deceleration shall be expressed as:

$$A_T = \frac{F_T}{M_T}$$

If the consist is operating without the unbraked locomotive, the deceleration of the consist ($A_C$) shall be increased by the ratio:

$$A_C = A_T \times \frac{M_T}{M_C}$$

Where:
- $F_T$ = Test train brake retarding force
- $M_T$ = Mass of test train
- $M_C$ = Mass of test consist

Note: The mass of test train ($M_T$) is the mass of test consist ($M_C$) plus the mass of the unbraked locomotive.

The braking distance of the consist under test without the unbraked locomotive is shorter and shall be calculated as:

$$BD_C = \frac{M_C}{M_T} \times BD_T$$

Thus the equivalent level track stopping distance for the consist under test ($SD_C$) on its own shall be calculated as:

$$SD_C = D_{FR} + BD_C$$

Where:
- $D_{FR}$ = Free run distance
- $BD_C$ = Braking distance

$$SD_C = D_{FR} + \left( \frac{M_C}{M_T} \times BD_T \right)$$

Substituting for $BD_T$ gives:

$$SD_C = D_{FR} + \left( \frac{M_C}{M_T} \times (SD_T - D_{FR}) \right)$$
Compatibility Requirements for Braking Systems of Rail Vehicles

B.2.8 The calculated level track stopping distance for the consist on its own shall include determining the stopping distance from 60 mile/h (96 km/h) in goods timings and from 75 mile/h (120 km/h) in passenger timings for those consists capable of operating at the higher speed. The calculated level track stopping distance shall be used to demonstrate compliance against the performance requirements set out in 2.3.2.5 and 2.3.2.6 of this document.

B.2.9 The test method set out in this Appendix shall be used to demonstrate the overall braking performance of the consist for the freight train formation with the hauling locomotive attached. Where consists have different rail vehicles, for example, OTMs, the brake force and braked weight values required for the R2 (RSL) for the individual vehicles shall be determined by calculation. The requirements for the calculation of the brake force values and braked weight values are set out in Appendix D and Appendix E of this document.
Appendix C  Methodology to Determine the Braking Performance of New Vehicles using a Braked Locomotive

The content of this appendix is required by 2.12.2 c)

C.1  General
C.1.1  Slip coupling tests have traditionally been used to determine the braking performance of individual freight vehicles. While this approach is appropriate for simple vehicles it is considered to be less suitable for the testing of more complex freight vehicles, for example, OTMs that are locomotive hauled between worksites.

C.1.2  The alternative permissible strategy set out in this Appendix involves undertaking brake performance testing of the rail vehicle(s) to be assessed as a freight train with the hauling locomotive attached. This method is different from that described in Appendix B, of this document, in that during the testing the locomotive brakes remain operational. The rail vehicles (the ‘consist’) under assessment shall be at least 25% of the train mass (including the locomotive and any support vehicles) to ensure that the testing method is valid.

C.2  Methodology
C.2.1  Two sets of testing shall be carried out to produce level track stopping distance data to determine the brake performance of the consist under assessment. The test train formations shall be:

a)  The test locomotive, any support vehicles and the consist under assessment.

b)  The same test locomotive and support vehicles without the consist under assessment.

C.2.2  Level track stopping distance brake tests shall be undertaken for the two test train formations from a range of operating speeds from 20 mile/h (32 km/h) up to the maximum service speed of the consist under assessment. The tests shall be carried out using full service brake applications with the brakes operational on all the rail vehicles and the distributors set to passenger timings.

C.2.3  Where the rail vehicles in the consist under assessment operate in different loading conditions the brake tests shall be carried out in both tare and laden conditions. On those rail vehicles not fitted with load compensating brake equipment the tare tests shall be at the maximum load before changing from tare to laden.

C.2.4  The braking performance shall be assessed on the basis of a mean level track stopping distance curve derived from the individual brake stopping distances. The mean level track stopping distance curve shall be determined.

C.2.5  Using a suitable mathematical process (such as the ‘Trendline’ polynomial function in Microsoft Excel), a best fit equation shall be determined for each test train formation which then enables the level track stopping distance to be calculated for any given speed. For a series of nominal braking entry speeds (as a minimum 20 mile/h (32 km/h), 40 mile/h (64 km/h), 60 mile/h (96 km/h) and 75 mile/h (120 km/h)), up to the maximum service speed of the consist under assessment, the corresponding level track stopping distances shall be determined for each of the two test train formations.
For the purpose of determining the brake performance of the consist under assessment, the level track stopping distance measured during the brake tests with the test train formation of locomotive, support vehicles and consist stopping distance and braking distance shall be expressed as:

\[
SD_T = D_{FRT} + BD_T
\]
\[
BD_T = SD_T - D_{FRT}
\]

Where: 
- SD$_T$ = Level track stopping distance from brake entry speed V (m/s) 
- D$_{FRT}$ = Free run distance 
- BD$_T$ = Braking distance 
- D$_{FRT}$ = $\frac{1}{2} \times V \times$ average test train brake cylinder fill time

Rearranging gives:

\[
A_T = \frac{V^2}{2BD_T}
\]

Also

\[
A_T = \frac{F_T}{M_T}
\]

Similarly, the level track stopping distance measured during the brake tests with the locomotive and any support vehicles shall be expressed as:

\[
SD_L = D_{FRL} + BD_L
\]
\[
BD_L = SD_L - D_{FRL}
\]

Where: 
- SD$_L$ = Level track stopping distance from brake entry speed V (m/s) 
- D$_{FRL}$ = Free run distance 
- BD$_L$ = Braking distance 
- D$_{FRL}$ = $\frac{1}{2} \times V \times$ loco brake cylinder fill time

Rearranging gives:

\[
A_L = \frac{V^2}{2BD_L}
\]

Also

\[
A_L = \frac{F_L}{M_L}
\]

Where: 
- F$_L$ = Locomotive brake retarding force 
- M$_L$ = Mass of locomotive

Note: Loco and L includes any support vehicles

Assuming the brake forces generated by the rail vehicles are independent of train formation, then for any brake entry speed the brake retarding force for the consist (F$_C$) shall be expressed as:

\[
F_C = F_T - F_L
\]
\[
F_C = M_C \times A_C = (M_T \times A_T) - (M_L \times A_L)
\]

Where: 
- M$_C$ = Mass of test consist 
- A$_C$ = Consist deceleration

Substituting for A$_L$ and A$_T$:

\[
F_C = M_C \times A_C = \left( \frac{M_T \times V^2}{2BD_T} - \frac{M_L \times V^2}{2BD_L} \right)
\]
Rearranging gives:

$$A_C = \frac{V^2}{2M_C} \times \left( \frac{M_T}{BD_T} - \frac{ML}{BD_L} \right)$$

The braking distance of the consist if operating alone shall be expressed as:

$$BD_C = \frac{V^2}{2A_C}$$

Substituting for $A_C$ gives:

$$BD_C = \frac{M_C}{\left( \frac{M_T}{BD_T} - \frac{ML}{BD_L} \right)}$$

$$BD_C = \left( \frac{M_C}{\left( \frac{M_T}{SD_T - D_{FRT}} \right) - \left( \frac{ML}{SD_L - D_{FRL}} \right)} \right)$$

C.2.7 The equivalent level track stopping distance for the consist under assessment (SDC) if operating alone shall be expressed as:

$$SD_C = D_{FRC} + BD_C$$

Where: $D_{FRC}$ = Free run distance

$BD_C$ = Braking distance

$D_{FRC} = \frac{1}{2} V \times \text{average consist brake cylinder fill time}$

Substituting the measured data for $BD_C$ the equivalent level track stopping distance for the consist under assessment (SDC) if operating alone from brake entry speed $V$ (m/s) shall be expressed as:

$$SD_C = D_{FRC} + \left( \frac{M_C}{\left( \frac{M_T}{SD_T - D_{FRT}} \right) - \left( \frac{ML}{SD_L - D_{FRL}} \right)} \right)$$

C.2.8 The calculated level track stopping distance for the consist on its own shall include determining the stopping distance from 60 mile/h (96 km/h) in goods timings and from 75 mile/h (120 km/h) in passenger timings for those consists capable of operating at the higher speed. The calculated level track stopping distance shall be used to demonstrate compliance against the performance requirements set out in 2.3.2.5 and 2.3.2.6.

C.2.9 The test method set out in this Appendix shall be used to demonstrate the overall braking performance of the consist. Where consists have different rail vehicles, for example, OTMs, the brake force and braked weight values required for the R2 (RLS) for the individual vehicles shall be determined by calculation. The requirements for the calculation of the brake force and braked weight values are set out in Appendix D and Appendix E of this document.
Appendix D  Calculation of GB ‘Brake Force’ Data for the Rolling Stock Library

The content of this appendix is required by 3.1.1

D.1  General
D.1.1  The GB ‘brake force’ value is an indication of the braking ability of a rail vehicle. To be consistent with existing values, the ‘brake force’ is the force that needs to be exerted on an equivalent tread brake arrangement to give the same brake retarding force at the rail. The equivalent tread brake arrangement assumes a nominal coefficient of friction 0.13 for the GB ‘brake force’ calculations.

D.2  Vehicles with either a single value of GB ‘brake force’, or values fixed for the tare and laden conditions
D.2.1  The ‘brake force’ value, as required by GMRT2453, shall be calculated from the brake retarding force as follows:

\[
B_T = \frac{F_T}{0.13 \times 9.81} \quad \text{and} \quad B_L = \frac{F_L}{0.13 \times 9.81}
\]

Where: \(B_T\) = the ‘brake force’ value to be declared to R2 (RSL) for the rail vehicle in tare condition (tonnes).

\(B_L\) = the ‘brake force’ value to be declared to R2 (RSL) for the rail vehicle in laden condition (tonnes).

\(F_T\) & \(F_L\) = the vehicle brake retarding force (kN), appropriate for the tare or laden condition respectively, that acts at the rail and over the period during which the brake cylinder pressure has reached at least 95% of its maximum value.

D.3  Vehicles with a value of ‘brake force’ that varies in proportion to the load
D.3.1  For freight vehicles fitted with load proportional braking it is necessary to calculate brake force factors that are in the form of a constant and a variable component; these shall be calculated as follows:

a)  Brake Force Factor 1 is \(C_L\) or \(C_T\) (tonnes)

Where \(C_L = B_L - (m \times W_L)\) and \(C_T = B_T - (m \times W_T)\)

b)  Brake Force Factor 2 is \(m\)

Where \(m = \frac{B_L - B_T}{W_L - W_T}\)

\(B_L\) = Equivalent ‘brake force’ in max laden condition (tonnes)

\(B_T\) = Equivalent ‘brake force’ in tare condition (tonnes)

\(W_L\) = Max laden mass (tonnes)

\(W_T\) = Tare mass (tonnes)

D.3.2  The values of Brake Force Factors 1 and 2 calculated above are those to be supplied to R2 (RSL) for freight vehicles fitted with load proportional braking.
D.4 Factors to be considered in the derivation of GB ‘brake force’

D.4.1 The brake retarding force for a rail vehicle can be calculated from design data or derived from the results of braking distance tests, in either case this shall be from the maximum rail vehicle speed, up to a maximum of 125 mile/h (200 km/h). Where actual tests are undertaken, the value of the calculated ‘brake force’ shall be validated.

D.4.2 For tread braked rail vehicles, the brake retarding force is calculated from the product of the total value of the brake application force and the coefficient of friction between the brake blocks and wheel tread. In the case of a disc brake, it is the product of the brake application force, coefficient of friction and the ratio of effective radius at which the disc pad acts and the new wheel radius of the vehicle.

D.4.3 When calculating the brake retarding force, account shall be taken of any losses due to rigging efficiency, or slack adjusters within the brake application system, between the brake cylinder and brake blocks or pads. If a reliable value for brake application force cannot be derived, it should be measured directly at the block or pad. In this case, account shall be taken of the effects of vibration on the value of static friction in the rigging.

D.4.4 The coefficient of friction used shall take account of all influencing aspects, such as the brake application force, the area of the friction material and vehicle speed, as all these factors affect the value of the coefficient of friction. For example, for a given brake block area, increasing block loads and speeds will reduce the effective value of the coefficient of friction for cast iron brake blocks.

D.4.5 If there is no data available giving the coefficient of friction for particular combinations of load, speed and area of the friction interface, tests shall be undertaken to establish a value, if it is subsequently used to calculate the brake retarding force.

D.4.6 Where there is one vehicle number to cover several vehicles that are semi-permanently coupled by bar type couplers or are articulated, the brake retarding force shall be calculated for each distributor using the appropriate vehicle mass braked by each distributor.

D.4.7 To permit passenger vehicles to be moved in freight trains, the ‘brake force’ values shall be determined for those vehicle brakes which are capable of being controlled by the hauling locomotive.

D.4.8 Where it is intended to haul ‘dead’ locomotives at the rear of freight trains and this results in the locomotive operating with reduced brake cylinder pressures, additional ‘brake force’ values shall be determined for this mode of operation. This reduced ‘dead’ locomotive brake force value is then used when determining the available brake force for the train.
Appendix E  Calculation of GB Equivalent ‘Braked Weight’ from ‘Brake Force’ Data for the Rolling Stock Library

The content of this appendix is required by 3.4.5

E.1  General

E.1.1  The ERTMS brake data entry for general operation trains (locomotive hauled trains) utilises a Lambda value (also known as braked weight percentage). The Lambda value for the train is defined by:

\[
\text{Lambda} = \frac{\sum \text{available vehicle ‘braked weights’}}{\text{Mass of the train}} \times 100
\]

E.1.2  The ‘braked weight’ values of the individual vehicles is determined from its braking performance using the methodology set out in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47).

E.1.3  Historically, GB vehicles have had their braking performance defined in terms of the ‘brake force’ values, as set out in Appendix D of this document.

E.1.4  The ‘braked weight’ value and the GB ‘brake force’ value are both derived from the vehicle’s stopping distances. This Appendix sets out a methodology to convert the existing GB ‘brake force’ values to derive equivalent GB ‘braked weight’ values.

E.2  Vehicles with either a single value of GB ‘brake force’, or values fixed for the tare and laden conditions

E.2.1  The conversion methodology set out below has been developed and validated by the ERTMS Braking Aspects Working Group.

E.2.2  The UIC single vehicle ‘braked weight percentage’, as set out in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47) is defined by the formula:

\[
\lambda = \frac{C}{S} - D
\]

Where:

\( \lambda \) = Braked weight percentage (Lambda)
\( S \) = Emergency brake stopping distance with passenger timings (m)

<table>
<thead>
<tr>
<th>Brake entry speed ( v )</th>
<th>( C )</th>
<th>( D )</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 km/h ( (27.7 \text{ m/s)} )</td>
<td>52840</td>
<td>10</td>
</tr>
<tr>
<td>120 km/h ( (33.3 \text{ m/s)} )</td>
<td>83634</td>
<td>19</td>
</tr>
<tr>
<td>140 km/h ( (37.9 \text{ m/s)} )</td>
<td>119179</td>
<td>19</td>
</tr>
<tr>
<td>160 km/h ( (44.4 \text{ m/s)} )</td>
<td>161280</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 2  Lambda formula constants vs speed
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E.2.3 The emergency stopping distance of a single vehicle is defined by the formula:

\[ S = \frac{vt}{2} + \frac{v^2}{2a} \]

Where:
- \( S \) = Emergency brake stopping distance with passenger timings (m)
- \( v \) = Brake entry speed (m/s)
- \( t \) = Emergency brake fill time – 3 to 5 seconds for passenger timings
- \( a \) = Vehicle deceleration

E.2.4 Vehicle emergency deceleration is defined by the formula:

\[ a = \frac{F}{M} \]

Where:
- \( M \) = Mass of vehicle (tonnes)
- \( F \) = Retarding force at rail (kN)

E.2.5 GB ‘brake force’ value as set out in Appendix D of this document is defined as:

\[ B = \frac{F}{0.13 \times 9.81} \]

E.2.6 Substituting ‘brake force’ for retarding force gives:

\[ a = \frac{0.13 \times 9.81 \times B}{M} \]

E.2.7 Substituting for ‘a’ gives distance:

\[ S = \frac{vt}{2} + \frac{v^2}{2 \times 1.275 \frac{B}{M}} \]

E.2.8 Substituting for ‘s’ gives Lambda:

\[ \lambda = \frac{C}{\frac{vt}{2} + \frac{Mv^2}{2 \times 1.275 B}} - D \]

E.2.9 Assuming the distributor set to passenger timings and in single pipe operation has the minimum emergency brake fill time (\( t \)) of 3 seconds (this gives the minimum brake performance for the vehicle). Substituting for the different speed ranges gives:

\[ \lambda(@100 \text{ km/h}) = \frac{52840}{41.5 + \frac{300M}{B}} - 10 \]
\[ \lambda(@120 \text{ km/h}) = \frac{83634}{50.0 + \frac{435M}{B}} - 19 \]
\[ \lambda(@140 \text{ km/h}) = \frac{119179}{58.4 + \frac{593M}{B}} - 19 \]
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\[ \lambda(\text{at } 160 \text{ km/h}) = \frac{161280}{66.6 + \frac{773 M}{B}} - 19 \]

E.2.10 UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47) defines the vehicle’s braking performance as being the minimum Lambda value calculated for the different speeds up to the vehicle’s maximum speed above.

E.2.11 The GB vehicle’s equivalent UIC ‘braked weight’ value is thus given by:

\[ \text{UIC 'braked weight' = } M \cdot \frac{\lambda(\text{min})}{100} \]

Where:

- $M$ = Mass of vehicle (tonnes)
- $\lambda(\text{min})$ = Minimum Lambda value calculated for the different speeds

E.3 Vehicles with a ‘brake force’ that varies in proportion to the load
E.3.1 Conversion methodology is an open point in this document

E.3.1.1 Guidance for clause E.3.1: A methodology is being developed by the ERTMS Braking Aspects Working Group.
Appendix F  Additional Guidance on Braking Requirements in LOC & PAS TSI and WAG TSI

The content of this appendix is provided for guidance only

F.1  General

F.1.1 The structure of this appendix follows the section headings in Chapter 4 of the LOC & PAS TSI relating to the operation, performance and interface requirements of rail vehicle brake systems. It contains additional guidance on aspects of the LOC & PAS TSI and WAG TSI that have not already been covered in Part 2 of this document.

F.1.2 This document replaces the guidance on the braking requirements of the LOC & PAS TSI set out in GMGN2615.

F.1.3 This document replaces the guidance on the braking requirements of the WAG TSI set out in GMGN2688.

F.2  Functional requirements

F.2.1 The brake system functional requirements are set out in section 4.2.4 of the LOC & PAS TSI or the WAG TSI depending on the type of rail vehicle.

F.2.1.1 Guidance for clause F.2.1: The brake system(s) fitted to the rail vehicles performs four functions:

   a) Emergency brake achieved using the automatic and continuous power brake fitted to all rail vehicles.

   b) Service brake used to control the speed of the train formation, including to a stop.

   c) Holding brake to secure the train formation at standstill during a stop in a station and to secure the train on a gradient during a hill start.

   d) Parking brake used to immobilise the individual vehicle / train formation.

F.2.2 To mitigate the failure of the brake energy supply, the brake system requirements of the LOC & PAS TSI clause 4.2.4.2.1 point (12) apply.

F.2.2.1 Guidance for clause F.2.2: The brake system needs to be able to hold the train formation stationary until it can be assisted. A two-hour duration is considered to be a realistic upper limit before the train can be assisted.

F.2.2.2 It is permitted to use an automatic substitution of the power brake by the parking brake when they use a common friction brake.
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F.2.3 An automatic brake application command shall take control of the brake system, even in case of active brake release command. The requirements of LOC & PAS TSI clause 4.2.4.2.1 point (14) apply.

F.2.3.1 Guidance for clause F.2.3: The LOC & PAS TSI does not permit intentional suppression (overriding) of the brake application by the normal action of the driver when the brake application command comes from, for example, the CCS systems (ERTMS, AWS, TPWS, etc).

F.2.4 Where the control medium is used to transmit the brake application command and also distribute the energy supply for the brake force, the requirements of the LOC & PAS TSI clause 4.2.4.2.1 point (14) apply.

F.2.4.1 Guidance for clause F.2.4: On train formations with an automatic air brake, the brake controller needs to restrict the normal supply rate into the brake pipe so that it is not capable of suppressing an emergency brake request (such as caused by a train division). This is generally achieved by feeding the brake pipe via a choke so that an open brake pipe coupling will ensure the drop in brake pipe pressure triggers an emergency brake application.

F.2.4.2 It is permissible to provide the driver with a means of increasing the supply rate into the brake pipe when releasing the brake. In this case the brake controller has to be held in the 'release' position by an intentional action of the driver.

F.2.5 The maximum jerk rate requirements are set out in LOC & PAS TSI clause 4.2.4.2.1 point (15).

F.2.5.1 Guidance for clause F.2.5: The LOC & PAS TSI jerk rate limit of 4 m/s$^3$ is generally associated with rapid changes to the brake demand on metro and light rail applications with rail vehicles provided with grab handles for standing passengers.

F.2.5.2 A maximum jerk rate of 1 m/s$^3$ is more appropriate from a passenger comfort point of view, for mainline railway applications, for changes to brake demand and during blending of the brake systems.

F.2.5.3 When assessing the braking jerk limit, the changes in acceleration associated with the dynamic movement of the rail vehicle are excluded.

F.3 Safety requirements

F.3.1 For brake systems providing the emergency braking and parking brake functions on vehicles (excluding freight wagons and OTMs) the safety requirements of the LOC & PAS TSI clause 4.2.4.2.2 apply. For braking systems on freight wagons the safety requirements of the WAG TSI clause 4.2.4.2 apply.

F.3.1.1 Guidance for clause F.3.1: The principle of a fail-safe, energise to release, control is applied to the emergency brake function (for example, the loss of the release command triggering an automatic brake application).
F.3.1.2 The methodology used in order to demonstrate compliance with the safety requirements is as follows:

a) Perform a safety analysis at the highest level of the system, with the use of adequate tools, such as fault tree analysis, failure mode, effects, and criticality analysis (FMECA), in order to identify critical parts or components of the system.

b) Identify the parts or components of the system for which the notion of ‘reference system’ or ‘code of practice’ is adequate to justify their reliability and safety performance.

c) Demonstrate for other parts or components of the brake system (if any) that their reliability and safety performance allows the fulfilment of the requirement, for example those parts or components that do not constitute ‘weak points’ in the system.

F.3.1.3 Where a ‘reference system’ is proposed to be adopted, consideration is to be given to the characteristics of that system, and the rationale for its suitability for the intended purpose will form part of the rail vehicle design file.

F.3.1.4 Appendix K sets out examples of brake systems that have been proven to be safe and reliable in operation on either the GB mainline railway or another major railway network having equivalent operating conditions and speeds to the GB mainline railway.

F.3.1.5 The LOC & PAS TSI requires that the effect caused by the failure of one part of the brake system has on the braking of the train formation is assessed and minimised. This is particularly important where a stored energy system is used to produce the brake force.

F.3.1.6 Where auxiliary systems share their energy supply with that also used for braking, the provision of protection measures ensure that under normal or degraded conditions these auxiliary systems cannot impair the efficiency of the brake systems.

F.3.1.7 No single point failure is permitted if it results in a lower than demanded brake retarding force being achieved on more than one rail vehicle (or alternatively a local brake control system affecting no more than two bogies on adjacent rail vehicles) in the train formation simultaneously.

F.3.1.8 A particular example is where a change in brake retardation rate is required, such as when operating at speeds exceeding 125 mile/h (200 km/h); in this case the change is initiated individually on each rail vehicle and not solely through a train wire command.

F.3.1.9 On rail vehicles that can operate alone, the key elements of the control system and brake energy supply need to be duplicated. The duplication ensures that nominally 50% of the power brake is retained on the rail vehicle in the event that one element fails.

F.3.1.10 This requirement applies to elements of the control system between the device responding to the signal from the driver’s brake controller and the brake force application system. The operation of the control elements are independent of one another so the failure of one does not degrade the performance of the other.
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F.3.1.11 On locomotives, the provision of the independent direct brake is considered to satisfy the duplication requirements.

F.3.2 The safety requirements of the LOC & PAS TSI clause 4.2.4.2.2 also apply to the service brake function when these brake systems do not operate independently of the emergency braking function.

F.3.2.1 Guidance for clause F.3.2: It is permitted to utilise the energise to release principle for the service brake function. It is also permitted to utilise energise to apply service brake commands, provided that a separate dedicated emergency brake control is provided.

F.3.2.2 Where separate emergency and service brake control systems are fitted an emergency brake application has priority over a service brake release command.

F.4 Type of brake system

F.4.1 For the types of brake systems on vehicles (including freight wagons and OTMs) the requirements of the LOC & PAS TSI clause 4.2.4.3 apply.

F.4.1.1 Guidance for clause F.4.1: The LOC & PAS TSI references BS EN 14198:2004 as being applicable for general operation trains (locomotive hauled). This Euronorm (EN) is currently being updated by CEN and it is anticipated this revised document will continue to be referenced by the LOC & PAS TSI.

F.4.1.2 For general operation the GB automatic air brake is functionally compatible with the International Union of Railways (UIC) brake system set out in BS EN 14198:2004 but has detailed differences, as follows:

a) GB freight wagons generally have brake release times between 30 - 45 seconds which are shorter than the UIC values of 45 - 60 seconds.

b) For GB rail vehicles used in general operation the pneumatic half couplings are:

i) Brake pipe coupling (red) to BS EN 15807:2011 Figure 2.

ii) Main reservoir pipe coupling with valve (yellow) to BS EN 15807:2011 Figure 8.

F.4.1.3 On locomotives intended to haul freight trains, the provision for the driver to select between ‘passenger’ and ‘goods’ brake application and release timings permits locomotives to be operationally compatible with the freight wagons in the train formation, the operating mode ‘passenger’ / ‘goods’ being clearly indicated to the driver. Adopting a default condition of ‘passenger’ timings when the locomotive is ‘dead’ permits faster speeds when hauled in ‘light engine’ formations.

F.4.1.4 Where the control system permits tolerances in the brake command signal, the control system needs to incorporate the capability to fully release the brakes on the train formation. On train formations with an automatic air brake, the provision of the overcharge facility within the brake controller satisfies this requirement.
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F.4.2 For multiple units and fixed formation trains, any type of braking system may be combined with any other type of braking system.

F.4.2.1 Guidance for clause F.4.2: The LOC & PAS TSI clause 4.2.3.4 point (2) does not mandate the type of brake to be fitted to multiple units and fixed formation trains.

F.4.2.2 Where more than one system of braking is used it is recommended there is provision for them to be controlled by the same brake controller. This allows a smooth transition between the systems of braking, without any degradation of braking performance.

F.4.2.3 Automatic and continuous operation of the power brake and its control is required where rail vehicles are coupled to others in a train formation to provide a system of emergency braking that defaults to brakes applied.

F.4.2.4 The capability of automatic and manual coupling connectors provides the brake system with continuity and an energy supply between compatible rail vehicles. The brake system couplings are to be designed to prevent inadvertent disconnection while rail vehicles remain connected by the normal drawgear but disconnect easily if trains separate due to the failure of the drawgear. Inter-vehicle hose couplings compliant to BS EN 15807:2011 satisfy this requirement.

F.4.2.5 It is acceptable for rail vehicles to be mechanically coupled via auto-couplers. Where the brake control systems are incompatible, it is good practice to have measures in place to prevent the connection of the brake systems via the auto-coupler.

F.4.2.6 If the brake system couplings can be manually disconnected and contain stored energy, consideration is to be given to a method of dissipating any energy trapped in the coupling, before disconnecting. Vehicle end cocks compliant to BS EN 14601+A1:2010 satisfy this requirement.

F.5 Emergency brake command

F.5.1 Where a compartment is provided specifically for authorised train crew, it is permissible to provide a method to initiate an emergency brake application and monitor the status of the brake control system.

F.5.1.1 Guidance for clause F.5.1: This is additional to the requirements of the LOC & PAS TSI clause 4.2.4.4.1 to provide the functionality for authorised train crew to deal with an emergency situation.

F.5.1.2 The LOC & PAS TSI sets out requirements for the driver to apply the emergency brake from the active cab. It is silent on the provision of additional locations where authorised staff may apply the emergency brake and to monitor the status of the brake control system.

F.5.1.3 The operation of the emergency brake push button plunger in a non-active cab is one means to provide this functionality.
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F.6 Service brake command
F.6.1 From the active driving cab, the service brake command requirements of the LOC & PAS TSI clause 4.2.4.4.2 apply.

F.6.1.1 Guidance for clause F.6.1: There is no requirement to have mechanical notches on the brake lever corresponding to specific brake steps. The provision of mechanical notches, however, provides feedback to the driver when varying the brake application. A continuously variable brake control is permitted.

F.7 Parking braking command
F.7.1 From the active driving cab, the parking brake command requirements of the LOC & PAS TSI clause 4.2.4.4.5 apply.

F.7.1.1 Guidance for clause F.7.1: The note in this clause of the LOC & PAS TSI permits the use of anti-compounding designs of the parking and power brake. This has been a common feature on GB multiple units. It alleviates the need for brake callipers and actuators to be designed for the simultaneous application of both the service and parking brakes.

F.7.1.2 It is recommended that locomotives and rail vehicles with driving positions are capable of applying and releasing the parking brake on compatible rail vehicles marshalled in the train formation. This is to support efficient release of the parking brake when changing active cabs.

F.7.1.3 Where remote control of the parking brake is utilised, consideration is to be given to limiting the tractive effort so that it is not possible to achieve a speed of more than 5 mile/h (8 km/h) until the parking brake has been released.

F.8 Braking performance
F.8.1 For the calculation of emergency and service braking performances the requirements of the LOC & PAS TSI clause 4.2.4.5 apply.

F.8.1.1 Guidance for clause F.8.1: The LOC & PAS TSI specifies the method to evaluate the braking performance by calculation and to verify it by testing. BS EN 14531-1:2005 sets out a common approach to calculate the brake performance of a train formation from first principles. This allows brake performance supporting data from different suppliers to be compared.

F.8.1.2 The friction coefficients of composition blocks and pads are often reduced by humidity. In the context of railway operation this is generally associated with operation through powdery snow which is melted by the brake system and is absorbed by the friction materials. It is generally more of an issue in European alpine and Nordic countries.

F.8.1.3 Operation during winter conditions in GB is also covered by additional degraded mode operational rules and the use of speed restrictions, see GEGN8628.
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F.9 Wheel rail adhesion profile

F.9.1 For emergency brake applications, including dynamic brakes used during emergency braking, the limits of wheel rail adhesion set out in the LOC & PAS TSI clause 4.2.4.6.1 apply.

F.9.1.1 Guidance for clause F.9.1: The LOC & PAS TSI adhesion values are considered as realistic upper limit wheel / rail adhesion values for the purposes of designing the emergency brake.

F.9.1.2 The wheel rail adhesion limits specified in the LOC & PAS TSI are higher than has historically been necessary to achieve the GB mainline brake performance requirements when the braking duty is shared across all the wheelsets.

F.9.1.3 The use of un-braked wheelsets to provide accurate reference speeds for odometry and WSP purposes is permitted provided that the adhesion limits for the other braked wheelsets are not exceeded.

F.9.1.4 When braking on low adhesion conditions the rotational speed of the wheelset can deviate from the actual vehicle speed. This discrepancy can cause issues with on-board systems that rely on speed information and positional knowledge of the vehicle, such as the Tilt Authorisation and Speed Supervision system (TASS).

F.9.1.5 It is accepted that in conditions of low wheel / rail adhesion the friction force that can be maintained at the wheel / rail interface is reduced and other measures to achieve the required stopping distance are necessary. These include, but are not limited to, a reduction in speed, railhead surface conditioning or using a means of braking that does not rely on the wheel / rail adhesion.

F.9.2 Dynamic brakes when used alone or in conjunction with the service brake, are permitted to exploit higher levels of adhesion than those adhesion levels permitted to be used during emergency brake applications.

F.9.2.1 Guidance for clause F.9.2: The LOC & PAS TSI adhesion values are considered as realistic upper limit of wheel / rail adhesion for the purposes of designing the emergency brake. Traction systems are generally capable of exploiting higher adhesion levels. However, these higher levels of adhesion cannot be assumed to be generally available.

F.9.2.2 When the dynamic brakes are intended to exploit high levels of wheel / rail adhesion, it is recommended that they incorporate WSP systems that have been optimised for these conditions. Designing systems to utilise high levels of adhesion for the dynamic brake will result in increased incidents of dynamic brake WSP activity when those adhesion levels are not available.

F.10 Dynamic brake – braking system linked to traction system

F.10.1 It is permissible to fit locomotives, multiple units and fixed formation trains with dynamic brake systems. Operational uses of the dynamic brake include:

a) Applied independently of the service and emergency brakes, such as by a cruise control system.

b) Applied in conjunction with the service brake and not applied during emergency brake application.
c) Applied in conjunction with the service brake and retained during emergency brake applications (alone or in combination with the friction brake).

F.10.1 Guidance for clause F.10.1: The use of a dynamic brake permits energy recovery during braking and reduces the braking duty (and wear) on the friction brakes.

F.10.1.2 When the dynamic brake is utilised during an emergency brake application the safety analysis requirements of the LOC & PAS TSI clause 4.2.4.7 apply.

F.10.1.3 In the event of a failure of the dynamic brake during an emergency brake application, the brake control needs to automatically apply the friction brake system that provides the emergency brake function.

F.10.1.4 The ability to command an emergency brake application without the dynamic brake is considered necessary to mitigate the loss of performance from the dynamic brake. The operation of the emergency brake push button is one means of achieving this alternative command.

F.10.1.5 Isolation of the dynamic brake by the driver, when operating in adverse weather conditions, permits the friction brake to be used to prevent the build-up of snow and ice on the brake equipment.

F.10.1.6 Isolation of the dynamic brake by the driver may also be necessary when brake blending generates longitudinal shocks (for example, on electric locomotives the dynamic brake has generally been isolated when hauling sleeper train formations).

F.10.2 If an emergency brake command replaces an existing service brake command, any active dynamic brakes are to be controlled so that the required adhesion levels do not exceed those specified for an emergency brake application.

F.10.2.1 Guidance for clause F.10.2: The emergency brake fulfils the safety requirements and the availability of the wheel / rail adhesion is a key factor in its delivery.

F.11 Braking system independent of adhesion conditions

F.11.1 The operation of magnetic track brakes (MTBs) on the GB mainline railway will require demonstration of compatibility with the infrastructure along the intended route to be used.

F.11.1.1 Guidance for clause F.11.1: MTBs provide a means of slowing the train formation by frictional contact with the railhead that is independent of the adhesion between the wheel and the rail.

F.11.1.2 The functional and performance requirements for MTBs, used as a supplementary brake or as a part of an emergency brake system, are set out in BS EN 16207:2014.
F.11.2 The operation of eddy current track brakes (ECTBs) on the GB mainline railway will require demonstration of compatibility with the infrastructure along the intended route to be used.

F.11.2.1 Guidance for clause F.11.2: ECTBs provide a means of slowing the train formation that is independent of the adhesion between the wheel and the rail. The ECTB does not contact the railhead.

F.11.2.2 The control and performance of ECTBs enables them to be deployed as part of a blended service brake or as a part of an emergency brake system when operated on compatible infrastructure.

F.12 Brake state and fault indication
F.12.1 The requirements of the LOC & PAS TSI clause 4.2.4.9 apply when monitoring the brake system operational status.

F.12.1.1 Guidance for clause F.12.1: Information needs to be available to train staff to allow the identification of degraded conditions concerning the vehicles braking performance. The LOC & PAS TSI permits a centralised control system allowing the train staff to perform all brake status checks from one location. The fitment of train monitoring systems (TMSs) permits remote monitoring of the brake systems on individual vehicles in multiple units and fixed formation trains.

F.12.1.2 When brake continuity is not self-proving as part of the control system design, provision of a means on the rail vehicle for staff to check the continuity of the automatic brake, when in train formation, is required.

F.12.1.3 Brake status at standstill, on GB hauled rail vehicles, as a minimum, is achieved by means of test points on the rail vehicle. Multiple units generally have pressure gauges within their equipment cases displaying the service brake pressures and, where appropriate, the pressure in the parking brake release cylinder. Visual indicators, as set out in BS EN 15220-1:2008+A1:2011, also satisfy this requirement.

F.12.1.4 Brake status when running, as a minimum, is achieved by the use of cab gauges monitoring the main reservoir pipe pressure, brake pipe pressure and brake cylinder pressure (on that vehicle). On rail vehicles with dynamic brakes, provision of a means to monitor each braking system or the indication of the overall braking performance (retardation) is required.

F.12.1.5 It is good industry practice for devices incorporated into the brake system to be provided with a means of isolating or draining of particular parts and for these to be:

a) Accessible and visible to authorised users and, in the case of isolation devices, clearly and indelibly labelled to indicate their function.

b) Located and protected to prevent, as far as is reasonably practicable, inadvertent or malicious operation.

c) For isolating cocks, when open, have their handles aligned with the pipes in which they are connected. Alternatively, have a label to indicate the open / isolated status.
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d) For drain cocks, have the handle in line with the pipe when the cock is closed.

F.12.1.6 Where drain cocks are in an exposed position, providing protection or having the axis of the handle arranged to be in line with the direction of travel of the rail vehicle, so that when operated the handle is moved across the rail vehicle. This will reduce the risk of the handle being moved by track debris during operation.

F.12.1.7 It is good industry practice to provide a means by which any type of brake application can be released manually if there is a failure of the normal method of brake release, without having to go underneath the vehicle.

F.12.2 The requirements of the LOC & PAS TSI clause 4.2.4.9 (5) apply when monitoring the operational status of the brake system energy supply.

F.12.2.1 Guidance for clause F.12.2: The LOC & PAS TSI clause 4.2.4.2.1 point (9) requires sufficient brake energy to be available on-board the train formation. Monitoring the energy supply permits the detection when there would be insufficient energy remaining to make an emergency brake application.

F.12.2.2 Detection of insufficient energy supply remaining to make an emergency brake application is generally combined with the control system preventing the release of the brake. Overriding this feature using the normal operating controls has been limited to GB rail vehicles that are capable of operating through the Channel Tunnel.

F.12.2.3 On locomotive hauled train formations the detection is generally provided by monitoring the available pressure in the main reservoir pipe on the locomotive. If the supply pressure falls below that necessary for an emergency brake application, the common practice on GB locomotives is for the control system to trigger an automatic brake application.

F.12.2.4 Interlocks between the traction control system and the brake control system provide a means to prevent traction power being applied until sufficient energy has been proved to be available to provide at least an emergency brake application.

F.12.2.5 If the method of isolating the brake reservoir from its source of supply is independent from the method of isolating the brake on the vehicle, the driver needs to be advised if the brake reservoir energy supply is not being maintained at the level required to provide the emergency brake.
## Appendix G  Assessment of Stopping Distance Test Results

The content of this appendix is provided for guidance only

![Graph](image.png)

**Figure 5**  Assessment of stopping distance test results

*Note:* Acceptability of a, b, x and y comparisons are to be performed using distance and not speed measurements.
Appendix H  Dynamometer Testing of Friction Materials

The content of this appendix is provided for guidance only

**H.1 Dynamometer testing of brake blocks**

H.1.1 The process for assessing composition material brake blocks is set out in BS EN 16452 2015.

H.1.2 BS EN 16452 2015 sets out a series of brake block frictional characteristics for ‘K’, ‘L’, or ‘LL’ designations to permit interchangeability between brake block suppliers.

H.1.3 It is permissible to use brake blocks with frictional characteristics outside those set out in BS EN 16452 2015 provided the rail vehicle brake performance is achieved. This may require the use of operational restrictions during winter weather conditions (see GEGN8628 for further guidance).

H.1.4 Details of composition brake blocks, which have been assessed as suitable for the GB mainline railway and guidance on their use on freight vehicles is given in GMGN2688.

H.1.5 Reassessment may be necessary to confirm performance requirements are maintained following any change to the product design, method of manufacture and principal constituents. Assign a new brake block identity when there are changes to the performance characteristics.

**H.2 Dynamometer testing of brake pads**

H.2.1 Pending the publication of BS EN 15328 an assessment process for brake pads is set out in UIC leaflet 541-3:2010.

H.2.2 UIC leaflet 541-3:2010 sets out a series of frictional characteristics for composition and sintered brake pad materials to permit interchangeability between brake pad suppliers.

H.2.3 It is permissible to use brake pads with frictional characteristics outside those set out in UIC leaflet 541-3:2010 provided the rail vehicle brake performance is achieved. This may require the use of operational restrictions during winter weather conditions (see GEGN8628 for further guidance).

H.2.4 Reassessment may be necessary to confirm that performance requirements are maintained following any change to the product design, method of manufacture and principal constituents. Assign a new brake pad identity when there are changes to the performance characteristics.
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Appendix I  Not Used
Appendix J  Principles of Operation of Friction Brake Systems

The content of this appendix is provided for guidance only

J.1  Automatic air-brake (single or two pipe)

J.1.1  Each rail vehicle has a distributor, air operated brake cylinders and an auxiliary reservoir (AR) and is connected by an automatic air-brake pipe (ABP) charged to 5 bar, which is continuous throughout the train formation. The distributor is connected to the ABP and responds to variations in brake pipe pressure to pass compressed air from the AR to the brake cylinders or vent the air from the brake cylinders.

J.1.2  A second pipe, the main reservoir pipe (MRP), normally charged to 7 bar, can be used to charge the AR directly to form the two-pipe system. Failure of the MRP does not affect the automatic air-brake pipe and the system reverts to single pipe operation.

J.1.3  An initial 0.4 bar reduction of the pressure in the ABP is sensed by the distributor to generate the minimum application of the brake on each rail vehicle. The amount of application is proportional to the reduction in the ABP pressure and the brake is released by recharging the ABP pressure.

J.1.4  A reduction of 1.5 bar in the ABP pressure is required to produce a full service brake application and the ABP pressure reduction occurs in 5 - 8 seconds. In an emergency brake application the ABP pressure falls to zero.

J.1.5  The reduction or increase in the ABP pressure can be achieved by means of an air-brake valve at the driving position or by a control at the driving position which is connected electrically or pneumatically to devices remote from the driving position which regulate ABP pressure in response to the electrical signals.

J.1.6  The automatic and continuous element is given by the inter-vehicle connections of the automatic air-brake pipe. If these are broken, the loss of air pressure results in an automatic brake application on both parts of the train. The coupling heads comply with the following:

   a)  Brake pipe coupling (red) to BS EN 15807:2011 Figure 2.

   b)  Main reservoir pipe coupling with valve (yellow) to BS EN 15807:2011 Figure 8.

J.1.7  The colour of the vehicle end cocks matches those of the coupling heads, except on rail vehicles fitted with a through brake pipe where the end cock is painted white.

J.1.8  To take account of the different coupling characteristics and operating speeds of freight and passenger trains, different brake force application and release times are used. For the automatic air-brake system, the following times have been adopted for an individual rail vehicle. These times are related to an emergency brake application.
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**Compatibility Requirements for Braking Systems of Rail Vehicles**

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<tr>
<th>Brake Timing Type</th>
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<td>30 - 60 ***</td>
<td>30 - 60 **</td>
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**Table 3** Brake force build-up and release times

Note: For locomotives: * these times are 20 - 28 seconds, ** these times are 9 - 12 seconds.

For GB wagons: *** these times are typically 30 - 45 seconds.

For international wagons: *** these times are typically 45 - 60 seconds.

**J.2 Automatic air-brake with electro-pneumatic (EP) assist**

J.2.1 The arrangement is as for section J.1 but, in addition to the continuous ABP, there are train wires connecting EP valves on each rail vehicle. When the driver operates the air-brake controller, the train wires are arranged to carry an electrical signal to the EP valves which locally vary the brake pipe pressure simultaneously on each rail vehicle, on the basis of either an energise to apply or release principle.

J.2.2 The automatic and continuous element is given by the inter-vehicle connections of the automatic air-brake pipe.

J.2.3 The brake force build-up time is 4 - 5 seconds and release time is 5 - 6 seconds.

**J.3 Automatic air-brake and electro-pneumatic (EP) control**

J.3.1 The arrangement is as for section J.1 but, in addition to the continuous ABP, there is an additional EP system with train wires that carry an electrical signal to EP valves on each rail vehicle, which control the application of the brakes by admitting air from the main reservoir pipe to the brake cylinders, on the basis of energise to apply. The release of the brakes is obtained by venting the brake cylinders.

J.3.2 As the EP system in J.3.1 is not fail-safe, the automatic and continuous element is given by the inter-vehicle connections of the air-brake pipe charged to 5 bar. Under normal operation, the brake pipe is not used to control the brake but can be used if the EP control fails.

J.3.3 The brake force build-up time is 4 - 6 seconds.

**J.4 Air-brake with electro-pneumatic (EP) control**

J.4.1 Each rail vehicle has air operated brake cylinders, together with a reservoir for the storage of compressed air and is connected by a MRP that supplies compressed air to each rail vehicle. A train wire is arranged to carry the electrical supply to the driver’s brake controller from the rear of the train formation, thereby ensuring electrical continuity throughout the train formation is proven.

J.4.2 Electrical signals from the driver’s brake controller are carried down train wires to the EP valves on each rail vehicle that control the release and application of the brakes, on the basis of the energise to release principle.

J.4.3 The automatic and continuous element is given by the inter-vehicle connections of the train wires. If the continuity in the train wires is interrupted, and therefore the electrical supply to the brake controller and thus to the EP valves is lost, the brakes automatically apply.

J.4.4 The brake force build-up time is 2 - 3 seconds and release time is 3 - 6 seconds.
J.5 Direct air-brake

J.5.1 The direct air-brake provides an additional brake, independent of the automatic train brake on traction units, using compressed air controlled separately from the automatic brake system, which is fed directly to the air-brake cylinders on the rail vehicle.

J.5.2 This brake is not fail-safe because, when running as a single rail vehicle, there is no requirement for an automatic or continuous element.

<table>
<thead>
<tr>
<th>Application Time for Brake Cylinder Pressure to Reach 95% of Maximum (Seconds)</th>
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Table 4 Direct air-brake, brake force build-up and release times
Appendix K  Guidance on the Energy Requirements to take account of WSP Activity

The content of this appendix is provided for guidance only

K.1  Guidance on WSP activity

K.1.1 WSP activity will increase the energy used by the brake system, although the amount of additional energy will depend on the value and extent of the low adhesion and the effectiveness of the WSP system.

K.1.2 In the case of a compressed air system, the ability of the system to provide sufficient air will depend on:

a) The compressor delivery capacity and reservoir volume.

b) The ability of the system pipework and valves to deliver the required flow rates to all the rail vehicles.

c) The effectiveness of the WSP system.

K.1.3 Experience indicates that a flow rate of approximately 600 litres / min / vehicle is required. This air consumption needs to be sustained for the length of time that would be required to stop the rail vehicle in low adhesion conditions. This will depend on the vehicle maximum speed and adhesion available.

K.1.4 Based on adhesion surveys, a reasonable value likely to be present over the entire duration of a stop would be one that gave a mean retardation of 4.5%g. Using the vehicle maximum speed and this retardation, it is possible to calculate the time taken for the stop and therefore the time over which the air needs to be delivered. For rail vehicles with a maximum speed of 100 mile/h (160 km/h) this equates to 100 seconds.

K.1.5 Air delivery less than 600 litres / min can be accepted if it can be demonstrated that the WSP system on the rail vehicle is such that the air consumption requirements of the WSP under low adhesion conditions is less than this value.

K.1.6 A method to assess the ability of the brake system to provide sufficient energy is to create a series of controlled ‘leaks’ at the brake actuators on each rail vehicle to simulate the WSP venting activity. A full service brake application will then result in high air consumption. By monitoring the compressor run times and its rated delivery capacity the air consumption can be established. The nominal air pressure on which the delivery rate of the compressor is established is the mid point between the governor settings.

K.1.7 At the end of the period of time calculated by the method set out in K.1.4, the pressure in the reservoir on each rail vehicle needs to be sufficient to provide a full service brake application.
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Definitions

**Automatic brake**
A braking system where any interruption of the continuity of the brake control system causes an emergency application of the power brake to be made automatically (see also definition of continuous brake).

**Brake application**
Where an application of the brake results in a brake force being applied to the rail vehicle.

**Brake controller**
The device operated by the driver at the driving position by which means the demand for a brake application or release is relayed to the brake system.

**Brake force**
The force applied to the brake block / pad / braking surface interface.

**Brake force build-up time**
The elapsed time from when the brake controller handle is moved to signal the requirement for a brake application until the brake force has reached a specified value (normally 95% of maximum).

**Brake force release time**
The elapsed time from when the brake controller handle is moved to signal the release of a brake application until the brake force has fallen to the level at which it is effectively released (normally 5% of maximum).

**Brake force factors**
Factors that enable the Total Operation Processing System (TOPS) computer system to calculate the brake force on a rail vehicle fitted with a device that varies the brake force in proportion to the vehicle mass.

**‘Brake force’ value**
This is the value of brake force that needs to be exerted on an equivalent tread brake arrangement with a standard coefficient of friction (0.13), to produce the same value of brake retarding force as that generated by the rail vehicle.

**Brake retarding force**
The resultant force, generated by the brake system, which produces a retardation of the rail vehicle.

**Brake system**
All the components and sub-assemblies that provide the means by which brake applications on rail vehicles are made and controlled, including the means by which the energy is provided and / or stored to generate the brake retarding force and the equipment which provides the retarding force.

**Brake system couplings**
The inter-vehicle couplings that connect the brake systems on adjacent rail vehicles and transmit the brake control signals that provide the system continuity and, where appropriate, also transmit the energy.
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‘Braked weight’ value
This is the continental Europe (UIC) means of describing a rail vehicle’s braking performance. It is derived from the stopping distances using the methodology set out in UIC leaflet 544-1:2013 (a harmonised Euronorm prEN 16834 is being prepared by CEN TC256 WG47).

Compatible brake systems
Those systems which have the same brake control signals and produce a similar retardation rate on rail vehicles for a given position of the brake controller handle.

Continuous
An unbroken series of connections through all individual rail vehicles in any train formation and where the power brake control system relies on the integrity of these connections for its operation.

Continuous brake
A power brake that operates on all parts of the train formation, such that any interruption of the continuous element of the inter-vehicle connections of the brake control system, results in an emergency application of the power brake being automatically made on all parts of the train formation, that will bring all parts of the train to a standstill.

Drag braking
A partial brake application that is sustained for a period of time to hold the speed of a train constant, for example down a falling gradient.

Driving position
The designated position from which a driver controls the braking of a rail vehicle or train formation.

Dynamic braking
A method of braking where retardation of a rail vehicle is produced by a method that does not involve friction as the principal means by which the kinetic energy is dissipated.

Emergency brake application
A brake application that uses a more direct and separate part of the control system, that as a result may be quicker, to signal for a brake application, than that used for the full service application. On certain rail vehicles, the retardation rate may be specified to be higher than that of the full service application and is described as enhanced emergency braking.

ex-BR
Rolling stock that was placed into service before April 1994.

Friction brakes
A system in which friction is used to convert the kinetic energy of the rail vehicle into heat.

Full service brake application
The brake application that gives the minimum retardation rate that meets the performance requirements of this standard.

Graduated service brake application
An application of the brake that results in the value of brake force being controlled incrementally to a particular value that may be less than the maximum value that the system can generate.
Graduated service brake release
A brake release in which the value of the brake force can be reduced incrementally to a particular value without completely releasing the brake.

Mass
The definition of rail vehicle masses used in this document are set out in BS EN 15663:2009.

Maximum braking load condition
A defined condition in excess of the mass under normal payload condition that may arise during exceptional operating circumstances. Also commonly known as crush laden.

Multiple unit
For the purposes of this document a multiple unit is a fixed formation of five vehicles or less having a driving position at both outer ends of the formation and traction equipment.

Note: Fixed formations of more than five vehicles that incorporate traction equipment distributed within the train do not fall within the scope of either a trailer vehicle (because some vehicles have traction equipment) or a multiple unit (more than five vehicles). For the purposes of braking performance these fixed formations may meet the requirements of multiple units or locomotive-hauled passenger trains.

On-board driving data recording system
The on-board system for recording and retaining data with respect to the operation of the train.

On-track machine
Any rail mounted machine meeting the requirements of GMRT2400 and permitted to be moved, either self-propelled or in train formation, outside a possession.

Parking brake
A brake system designed to hold a rail vehicle stationary for an indefinite period without the addition of further energy to maintain the brake force, provided no additional external force is applied to the rail vehicle.

Power brake
A means by which the retardation of a rail vehicle or a train formation can be achieved by the application of a brake force that is generated by energy stored on the rail vehicle.

Wheel slide protection (WSP) equipment
A system designed to make the best use of available adhesion by a controlled reduction of the brake force to prevent wheelsets from locking and sliding.
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References

The Catalogue of Railway Group Standards gives the current issue number and status of documents published by RSSB. This information is also available from

www.rssb.co.uk/railway-group-standards.

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## Compatibility Requirements for Braking Systems of Rail Vehicles

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### Uncontrolled When Printed
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Amendments to this document can be found on the RSSB Standards Catalogue - [http://www.rssb.co.uk/railway-group-standards](http://www.rssb.co.uk/railway-group-standards).