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Guidance on Wheel / Rail Low Adhesion Simulation

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Guidance on Wheel / Rail Low Adhesion Simulation

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Guidance on Wheel / Rail Low Adhesion Simulation

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Part 1 Introduction

1.1 Purpose of this document

This document has been published by Rail Safety and Standards Board to give guidance on wheel / rail adhesion simulation and is supported by GM/GN2642 Guidance on Wheel / Rail Low Adhesion Measurement. It does not constitute a recommended method of meeting any set of mandatory requirements.

In association with the fundamental study of leaf contamination, this guidance note can be used in conjunction with Guidance Note GM/GN2642, Wheel / Rail Low Adhesion Measurement. This Guidance Note and GM/GN2642 have been produced to aid in the selection of adhesion measuring and monitoring methods and simulation of low adhesion.

Stakeholders from the industry-supported Adhesion Working Group (AWG) approved the content of this work. Further documents may be produced related to low adhesion as outputs from other studies in this topic are completed.

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1.3 Approval and authorisation of this document

The content of this document was approved by:

Rolling Stock Standards Committee on 06 July 2007

This document was authorised by RSSB on 05 December 2007

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Part 2 Wheel / Rail Low Adhesion Simulation

2.1 Background

- 2.1.1 Over the last 30 years significant effort has been applied to develop mitigation methods for low adhesion conditions. In the late 1970's and 1980's British Rail Research conducted a wide range of projects to measure adhesion levels on the network and to test methods of combating leaf fall contamination.
- 2.1.2 At this time sandite was developed and became the standard method of treating contaminated rails. However, the application of sandite requires a special low speed train which impacts on the timetable. Additionally, sand is an insulator and therefore puts track circuit operation at risk. Hence there has been continued interest in alternative treatment methods such as water jetting, lasers, mechanical scrubbing and chemicals, each of which has its own advantages and limitations.
- 2.1.3 The approach to treating leaf film contamination on the railhead has in general been targeted at removing the contamination once it has formed, by applying treatments to the surface of the film.
- 2.1.4 RSSB conducted a research project 'The Characteristics of Railhead Leaf Contamination'. The objective was to provide a comprehensive overview of current and previous research on low adhesion with respect to key areas chosen by stakeholders during the consultation process. The research included a review of past research into low adhesion management and identified and recommended further work in five other areas. These were:
- a) Influence of traction systems on low adhesion performance
 - b) Whole train control systems
 - c) Creating and measuring low adhesion for research and test purposes
 - d) Aerodynamic performance of rolling stock
 - e) Characteristics of leaf contamination properties.
- 2.1.5 RSSB's research into 'The Characteristics of Railhead Leaf Contamination' in relation to the requirements for simulating wheel / rail low adhesion were:
- a) Understanding the bonding mechanism of leaf film to the railhead with an aim of improving existing, or providing new, means of artificial leaf film.
 - b) Measuring leaf film and simulated film hardness and moisture properties in relation to low adhesion and track circuit operation.
- 2.1.6 Low adhesion simulation therefore, enables infrastructure managers and railway undertakings to be better prepared for the conditions, to develop and test mitigation procedures and to test equipment either after low adhesion incidents or prior to introduction into service. It is also a useful means of training drivers in low adhesion conditions (skid pan testing) or for testing equipment or low adhesion treatment methods.
- 2.1.7 The background to the requirement for low adhesion simulation is related to modern operation of the railway. This is often a high frequency service with short trains. The high frequency has been achieved in part by improved braking performance that demands high utilisation of available adhesion. These factors have increased the risk of demand exceeding available adhesion, particularly during the autumn period, which has been compounded by increased line side vegetation over the years.

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- 2.1.8 A range of equipment for the simulation of low adhesion conditions has been included as examples in this document. The application of this document is not limited to the equipment from manufacturers cited in these examples.

2.2 Purpose

- 2.2.1 There are two approaches to simulating low adhesion:
- a) Practical testing by generating a low adhesion layer
 - b) Reproducing the effects of low adhesion within a computer simulation.
- 2.2.2 The purpose of this document is to provide information and guidance to enable the selection of the most appropriate contaminant to replicate a low adhesion layer or artificial leaf film and the method that can be employed to implement the use of the selected contaminant. This includes the production of low adhesion contaminants on laboratory test rigs.

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Part 3 How to use this Guidance Note

3.1 Types of contaminant

3.1.1 The types of contaminants that have been used to simulate low adhesion are:

- a) Detergent
- b) Paper tape
- c) Lignin / ashless floc
- d) Real leaves.

3.1.2 The contaminants that can be used to produce low adhesion have very different properties, and some may not be suitable for all the applications in which the industry needs to create a contaminant. This document gives guidance on the methods for applying the contaminants, and individual characteristics of each.

3.1.3 The chemical constituents of low adhesion contaminants vary considerably, and can give a view as to the similarity of the contaminants to leaf film. Analyses on the chemical and physical constituents of the contaminants are detailed in report AEATR-ES-2005-079-01 under project T354: The Characteristics of Railhead Leaf Contamination (available at www.rssb.co.uk).

3.2 Selection of simulated low adhesion contaminants

3.2.1 The industry has identified a number of applications for simulated low adhesion. For each Part, guidance is given on the selection of a suitable contaminant and is out as follows:

- a) Part 5: Testing of leaf film removal techniques
- b) Part 6: Testing of friction modifiers
- c) Part 7: Low adhesion training for drivers
- d) Part 8: Testing vehicle braking and traction performance
- e) Part 9: Post incident investigation
- f) Part 10: Laboratory testing of contaminants and leaf film
- g) Part 11: Testing for track circuit actuation problems.

3.2.2 There are some general considerations that need to be taken into account irrespective of the contaminant type or method of application. These are dealt with in Part 4 and include guidance on the levels of adhesion under low adhesion conditions, the set-up of a low adhesion test site, calculation of braking distances and safety issues.

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3.3 How to apply the contaminant

3.3.1 The low adhesion contaminant selection process for the relevant application should identify the preferred contaminant. Guidance for using the selected contaminant is then set out as follows:

- a) Parts 12 to 16: Low adhesion detergent contaminants
- b) Parts 17 and 18: Paper tape low adhesion simulation
- c) Parts 19 and 20: Lignin / ashless floc low adhesion simulation
- d) Parts 21 and 22: Real leaf film on railhead
- e) Parts 23 to 25: Low adhesion simulation in the laboratory.

3.3.2 A relative cost for the application of each contaminant is set out in the materials and equipment section of each method and is as follows:

- | | | | |
|----|-------------|--------------------|--------------------------|
| a) | Low cost | £1,000 - £5,000 | per testing application |
| b) | Medium cost | £5,000 - £15,000 | per testing application |
| c) | High cost | £15,000 - £100,000 | per testing application. |

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Part 4 General Considerations

4.1 Simulation of low adhesion

- 4.1.1 Different methods of simulating low adhesion can be used in the laboratory and on the track. Laboratory and track testing both have advantages and disadvantages and the choice of which to use will depend on the purpose for which the tests are being conducted, the available testing time, number of variables, and type of contaminant to be used and weather conditions.
- 4.1.2 Most low adhesion testing will require a number of brake stops to be carried out. For these tests, the dry rail braking performance of the vehicle should be recorded. This will give a dry rail reference stopping distance to which the low adhesion stopping distance can be compared.
- 4.1.3 A three-step brake on a multiple unit can be used as a basis for assessing a relative low adhesion value. The approximate adhesion can be categorised as:

Brake demand	Adhesion level	Estimated adhesion range
wheel slide in step 1	very low adhesion	0 to 0.03 / 0.05 (3% / 5%)
wheel slide in step 2	low adhesion	0 to 0.05 / 0.09 (5% / 9%)
wheel slide in step 3	moderate adhesion	0 to 0.09 / 0.11 (9% / 11%)
no wheel slide in step 3	high adhesion	greater than 0.11 (11%)

Table 1 Brake demand adhesion ranges

4.2 Safety issues

- 4.2.1 Prior to commencing testing on the track, any safety issues must be addressed, including:
- Risk assessment
 - Track access
 - Possession arrangements
 - Length of safe run-out available
 - Line of responsibility
 - Engineering change assessment (if applicable see 4.6)
 - Staff competency.

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- 4.2.2 Prior to commencing testing in the laboratory, any safety issues must be addressed, including:
- a) Risk assessment
 - b) Protection of staff against failure of rig
 - c) Staff competency for operating the rig
 - d) Access arrangements for close inspection of the sample.

4.3 Environmental conditions

- 4.3.1 When testing or training is to be undertaken outside, any changes in weather must be considered. High moisture levels and heavy rain affect the properties of leaf film (for example hardness), this also applies to low adhesion contaminants and is particularly important where the contaminant is intended to reproduce the properties of leaf film.
- 4.3.2 Similarly testing that is undertaken inside on a laboratory test rig can be subject to changes in environmental conditions such as temperature and humidity. This may be controlled using an air-conditioned chamber.

4.4 Length of simulated low adhesion test site

- 4.4.1 The length of the simulated low adhesion test site will depend on the nature of the tests that are to be carried out. This can be a relatively long length such as 1 km for testing brake systems, or a very short length such as 60 mm for research purposes. The low adhesion test site should preferably be straight or with a radius not less than 1500 m, with no S & C.
- 4.4.2 The length of the simulated low adhesion test site to be used for braking purposes can be calculated using the vehicle entry speed and level of low adhesion that is to be generated.
- 4.4.3 The distance to stop from the point of braking for level track can be calculated by using the equation:

$$s = (v^2 - u^2) / 2a$$

Where:

s = distance to stop

v = initial speed before brake stop

u = final speed after brake stop (zero)

a = deceleration

- 4.4.4 The maximum braking deceleration can be calculated by using the equation:

$$a = (\mu / 100) \times g$$

Where:

μ = adhesion level (coefficient of friction), expressed as a percentage

g = gravity

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- 4.4.5 As an example, assuming a 50 m long train is travelling at 25 mile/h (11.1 m/s) and the contaminant has a worst case low adhesion of 3% (0.03). Then the maximum braking deceleration is:

$$a = 3 / 100 \times 9.81 = 0.294 \text{ m/s}^2$$

Therefore the stopping distance is:

$$s = ((11.1)^2 - 0) / (2 \times 0.294) = 209 \text{ m}$$

Therefore, a train travelling at 25 mile/h and encountering adhesion at 3% (0.03) would require a minimum length of 209 m to stop.

- 4.4.6 The contaminant limits will be the distance to stop plus the length of the train, which for this example, will be 259 m.
- 4.4.7 When creating a low adhesion test site, the site should also include an additional length of track based upon the contaminant limit distance, which will allow for a safe run out. It should take into account that the vehicle may spread the contaminant, the brake build up time, errors on the entry speed (allow 25% for these factors) plus an overall safety factor of 10%.
- 4.4.8 At higher speeds, this 35% run out distance may not be available, but if other mitigations are in place to prevent an incident, this distance can be reduced.
- 4.4.9 If testing in both directions, the run out distance should be applied to both ends of the contaminant limits.

4.5 Consideration for gradient

- 4.5.1 Any track gradient at the test / driver training site will have an effect on the stopping distance. If testing in the down gradient direction then the required run out stopping distance will be increased (and up gradient will be reduced). This should be taken into account when calculating the deceleration.
- 4.5.2 The change in stopping distance due to a down gradient can be worked out as follows:

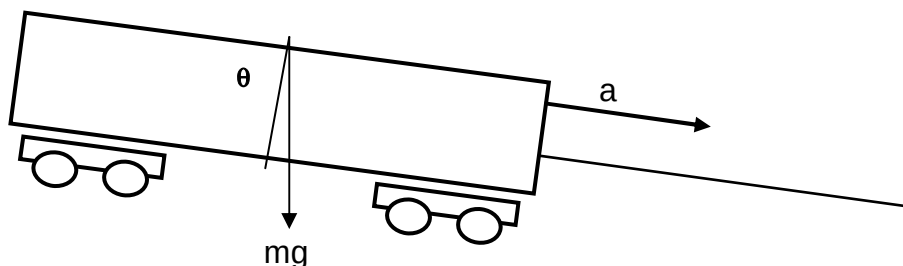


Figure 1 Calculation of stopping distance

- 4.5.3 With no braking force, the force (F) acting on the train can be calculated as:

$$F = mg \sin \theta = ma$$

Where:

m = mass of train

$\sin \theta$ = gradient of the slope

Therefore, the acceleration of the train, due to the gradient, can be calculated as:

$$a = g \sin \theta$$

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- 4.5.4 As an example, assuming a train is travelling at 25 mile/h (11.1 m/s) down a gradient of 1 : 120 and the contaminant has a worst case low adhesion of 3% (0.03). The vehicle acceleration due to the gradient is:

$$a = 9.81 \times (1 / 120) = 0.0818 \text{ m/s}^2$$

The overall vehicle deceleration is the deceleration due to braking, less the acceleration due to the gradient:

$$a = (3 / 100 \times 9.81) - (9.81 \times (1 / 120)) = 0.213 \text{ m/s}^2$$

The distance to stop the train is obtained from:

$$s = (v^2 - u^2) / 2a$$

$$s = ((11.1)^2 - 0) / (2 \times 0.213) = 289 \text{ metres}$$

- 4.5.5 Therefore, the stopping distance for a vehicle braking from 25 mile/h, on a down gradient of 1 : 120 and 3% (0.03) available adhesion is 289 m. This is an additional 80.84 metres compared to that on level track (see 4.4.5). In addition to the 289 m, an extra 35% run out distance should be added.

4.6 Engineering change assessment

- 4.6.1 Where equipment is fitted to a vehicle that is required to comply with Railway Group Standards, an engineering change assessment needs to be completed to ensure the modification does conform to applicable Railway Group Standards.

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Part 5 Testing of Leaf Film Removal Techniques

5.1 Introduction

- 5.1.1 There are a number of established methods currently employed in the UK to remove leaf film and 're-condition' the railhead, such as water jetting and grinding. Conditions representing leaf film can be simulated to test the effectiveness of these established methods but also to test any new methods so that they can be benchmarked against each other.
- 5.1.2 In this application it is not necessary to produce low adhesion but the contamination needs to simulate dry leaf film bonding strength to the rail.

5.2 Specific considerations

- 5.2.1 The length of the low adhesion test site must be sufficient to allow an assessment to be made of the removal of the contaminant. If a brake stop is necessary to assess the effectiveness, then a length of contaminant should be applied to enable a full brake stop to be carried out on the test section.
- 5.2.2 The simulated low adhesion test site should also include a length of track either side of the low adhesion contaminant limits, which will allow for a safe run out. This should take into account the level of low adhesion that is being simulated and should take into account that the train may spread the low adhesion contaminant outside of the low adhesion test site (see 4.4 and 4.5).
- 5.2.3 For example, a layer of contaminant is laid down in two sections (A and B) as shown in Figure 2 and two mitigation methods (M1 and M2) are to be tested. Mitigation M1 is applied to Section A and is successful whilst M2 is applied to Section B and fails.

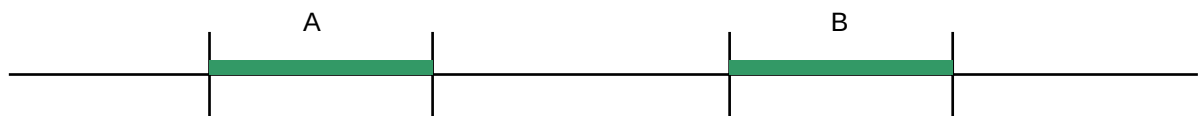


Figure 2 Possible setup of contamination test sections

- 5.2.4 This result could be interpreted as method M1 being viable and M2 not, but if the condition of the contaminant in Section A is such that it is more easily removed than in Section B then the result would be misleading. There are a number of options to overcome this problem:
- Repeat testing to produce a sufficiently significant set of results. This should involve switching the mitigation methods between Sections A and B to take into account any differences in properties at each test section.
 - Test over a sufficiently long section of track so that the condition of the film is averaged out.
 - Measure the properties of the test contaminants so that when assessing the effectiveness of the mitigation methods, they can be normalised (see GM/GN2642).
- 5.2.5 Contaminant layers of lignin / ashless floc, paper tape or real leaves can be generated on laboratory rigs, which would be suitable for a preliminary assessment of removal techniques before full-scale field tests.
- 5.2.6 In general, if the contamination is too easily removed compared to real leaf film then mitigation methods that appear viable may not perform well in practice.

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- 5.2.7 The effectiveness of removal techniques may be measured by percentage of film removed. It should be considered, however, that the only way to document the ultimate effectiveness of the removal technique would be to record a 'before and after' levels of adhesion.

5.3 Method for selection of contaminant

- 5.3.1 Tables 2 and 3 provide a reference to the contaminants and their suitability for testing leaf film removal techniques.
- 5.3.2 Once a preferred contaminant has been selected from Tables 2 and 3, refer to the Parts relevant to that low adhesion contaminant. For example, for paper tape, go to Parts 17 and 18 for guidance on how to use this method to produce an artificial leaf film layer.
- 5.3.3 The methods of leaf film removal need to be tested on a contaminant that is representative of dry leaf film. The physical properties of the film must be considered, and the hardness, thickness and adhesion values must also be representative, or at least factored into the assessment of the effectiveness of the removal method. If the hardness of the contaminant is considered softer than dry leaf film, the removal method may be better at removing the contaminant, than it would with a real leaf film.
- 5.3.4 It should be considered whether the treatment method will have a specific effect on the properties of the contaminant. For example, a contaminant may be more water absorbent than a real leaf film, but show similar properties in all other respects; therefore, it may not be suitable for removal methods that involve water. Similarly, a contaminant may be more flammable than a real leaf film; therefore it may not be suitable for removal methods that involve high temperature processes.
- 5.3.5 To obtain an estimate of the cost of carrying out the testing of leaf film removal techniques, the following factors should be taken into account:
- a) Arrangements:
 - i) Management time for the testing
 - ii) Methodology for testing
 - iii) Safety arrangements and staff
 - iv) Engineering change assessment (if applicable).
 - b) Materials / fitting / equipment:
 - i) Preparation of equipment for generating low adhesion
 - ii) Cost of the materials used to generate low adhesion
 - iii) Cost of applying the contaminant to the railhead
 - iv) Fitting of spray equipment to vehicle (if applicable).
 - c) Operating requirements:
 - i) Possession costs / track hire charge
 - ii) Rail vehicle hire costs
 - iii) Costs to operate the equipment / reapply the contaminant.
- 5.3.6 The list above does not include the associated costs of the different leaf film removal techniques and their application to the railhead.

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Low adhesion contaminant	Application time (500 m of track)	Time to condition	Removal time	Advantages	Limitations	Suitable Y / N?
Detergent (see Parts 12 to 16)	10 minutes (by vehicle) approximately 30 minutes (manually)	10 to 20 minutes	30 to 60 minutes	Can be applied / reapplied quickly. Easy removal. Minimal environmental impact. Good range of moisture in which it can work.	Contaminant layer very different to leaf film in all aspects except adhesion values. Engineering change assessment may be required if spray equipment fitted.	N
Paper tape 1 layer on track (see Parts 17 and 18)	approximately 40 minutes	10 to 20 minutes	approximately 90 minutes	Well bonded to railhead. Durable, similar hardness, moisture, thickness and conditioning characteristics to leaf film. Minimal impact on environment. Consistent low adhesion when activated with water spray. Very repeatable.	Application / removal time. Need vehicle to roll in. Operatives need access to track to lay tape. Needs risk assessment to use with electric stock. Affected by rain. Possession / engineering change assessment may be required.	Y
Paper tape 2 layers on track (see Parts 17 and 18)	approximately 60 minutes	10 to 20 minutes	approximately 90 minutes	Well bonded to railhead. Durable, similar hardness, moisture, thickness and conditioning characteristics to leaf film. Minimal impact on environment. Consistent low adhesion when activated with water spray. Very repeatable.	Represents a thickness greater than the measured average thickness of leaf film. Application / removal time. Need vehicle to roll in. Operatives need track access to lay tape. Needs risk assessment to use with electric stock. Affected by rain. Possession / engineering change assessment may be required.	N
Lignin / ashless floc on track (see Parts 19 and 20)	approximately 60 minutes	20 minutes dependant on atmospheric conditions	30 to 60 minutes or effective removal method	Well bonded to railhead. Similar hardness and thickness characteristics to leaf film. Consistent layer. Minimal impact on environment. Engineering change assessment not required as no spray equipment fitted.	Different in conditioning and moisture uptake to leaf film. Limited moisture range as to when it is effective. Possession may be required. Unsuitable for water based contaminant removal methods.	Y
Real leaves on track (see Parts 21 and 22)	Impractical to apply to 500 m, 20 minutes for 2 m section	10 minutes to 5 passes of train or similar	10 minutes for 2 m section	Usually well bonded to the railhead. Similar in hardness, moisture, thickness and conditioning characteristics to operational leaf film. No issues with similarity. Removal not so critical on short section. Minimal impact on environment.	Leaf availability at the time of testing. Cannot replicate performance tests (acceleration / deceleration). Not as repeatable as other films. Affected by moisture. Access at track to lay films. Possession / engineering change assessment may be required.	Y

Table 2 Leaf film removal simulation methods

Guidance on Wheel / Rail Low Adhesion Simulation

Low adhesion contaminant	Application time (500 m of track)	Time to condition	Removal time	Advantages	Limitations	Suitable Y / N?
Real leaves Wheel-on-rail test rig (see Parts 21, 22 and 24)	N / A	approximately 3 hours to generate a leaf film	N / A	Well bonded to railhead. Similar moisture, thickness and conditioning characteristics to leaf film. Controlled environment wheel / rail contact areas. Variable vertical loading and creep application. No possession access required. Safety simple to arrange.	Availability of leaves at time of testing. Inserts expensive to manufacture. Treatment methods may be difficult to administer in situ. Cannot replicate performance tests (acceleration / deceleration tests). Limited availability of such rigs.	Y
Paper tape Wheel-on-rail test rig (see Parts 17, 18 and 24)	N / A	approximately 2 hours to generate a film	N / A	Well bonded to railhead. Similar hardness, thickness, moisture and conditioning characteristics to leaf film. Controlled environment wheel / rail contact areas. Variable vertical loading, and creep application. No possession access required. Safety simple to arrange.	Inserts expensive to manufacture. Treatment methods may be difficult to administer in situ. Cannot replicate performance tests (acceleration / deceleration tests). Limited availability of such rigs.	Y
Lignin / ashless floc Wheel-on-rail test rig (see Parts 19, 20 and 24)	N / A	approximately 3 hours to generate a film	N / A	Well bonded to railhead. Similar in hardness and thickness characteristics to leaf film. Controlled environment wheel / rail contact areas. Variable vertical loading and creep application. No possession access required. Safety simple to arrange.	Inserts expensive to manufacture. Treatment methods may be difficult to administer. Different in conditioning and moisture uptake to leaf film. Cannot replicate performance tests (acceleration / deceleration). Not suitable for water based contaminant removal methods. Limited availability of such rigs.	Y
Real leaves Twin disc machine (see Parts 21, 22 and 25)	N / A	approximately 2 hours to generate a leaf film	N / A	Well bonded to discs. Similar in moisture, thickness and conditioning characteristics to leaf film. Controlled environment. Variable vertical load and creep application. No possession access required. Manufacture of discs relatively simple. Safety simple to arrange.	Availability of leaves at time of testing. Scaling factors reduce similarity to wheel / rail contact. Fixed speeds. Cannot replicate performance tests (acceleration / deceleration tests).	Y

Table 3 Leaf film removal simulation methods (laboratory)

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Low adhesion contaminant	Application time (500 m of track)	Time to condition	Removal time	Advantages	Limitations	Suitable Y / N?
Paper tape Twin disc machine (see Parts 17, 18 and 25)	N / A	approximately 1 hour to generate a film	N / A	Well bonded to discs. Similar in moisture, thickness and conditioning characteristics to leaf film. Controlled environment wheel / rail contact areas. Variable vertical loading and creep application. No possession access required. Safety simple to arrange.	Treatment methods may be difficult to administer in situ. Scaling factors reduce similarity to wheel / rail contact. Fixed speeds. Cannot replicate performance tests (acceleration / deceleration tests).	Y
Lignin / ashless floc Twin disc machine (see Parts 19, 20 and 25)	N / A	approximately 2 hours to generate a film	N / A	Well bonded to railhead. Similar in hardness and thickness characteristics to leaf film. Controlled environment wheel / rail contact areas. Variable vertical loading and creep application. No possession access required. Safety simple to arrange.	Treatment methods may be difficult to administer in situ. Different in conditioning and moisture uptake to leaf film. Scaling factors reduce similarity to wheel / rail contact. Fixed speeds. Cannot replicate performance tests (acceleration / deceleration tests).	Y

Table 3 Leaf film removal simulation methods (laboratory) continued

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Part 6 Testing of Friction Modifiers

6.1 Introduction

- 6.1.1 As an alternative to removing leaf film to improve adhesion, the level of friction can be increased by adding a friction modifier to the railhead. The modifier is applied onto the railhead or directed into the wheel / rail contact of a service train. Examples of friction modifiers include sand and Sandite but others have been tested such as ceramic particles.

6.2 Specific considerations

- 6.2.1 The simulated low adhesion test site must be of a sufficient length to allow an assessment to be made of the influence of the friction modifier. A length of low adhesion contaminant should be applied to the track to enable a full brake stop to be carried out on the test section.
- 6.2.2 The simulated low adhesion test site should also include a length of track either side of the low adhesion contaminant limits, which will allow for a safe run out. This should take into account the level of low adhesion that is being simulated and should take into account that the train may spread the low adhesion contaminant outside of the low adhesion test site (see 4.4 and 4.5).
- 6.2.3 The effectiveness of a friction modifier can be assessed by measuring the 'before and after' levels of adhesion. It is recommended that changes in adhesion levels should be checked when testing a friction modifier. In addition it is important that the friction modifier works well in worst case conditions and a low adhesion contaminant that can reproduce these levels should be used for the tests.
- 6.2.4 Figure 3 shows a set of results from testing the effectiveness of friction modifiers. A base level of low adhesion should be simulated and a number of test runs should be undertaken to make sure that this level is repeatable (runs 1 to 3), a friction modifier should be applied and on test run 4 a brake stop should be undertaken. This will represent the first result for the friction modifier; however, repeat runs will be needed to assess the longevity of the product in keeping the level of adhesion high. For example, friction modifier 3 (FM3) indicates that this product only lasts for the duration of one brake stop before the adhesion level decreases again.

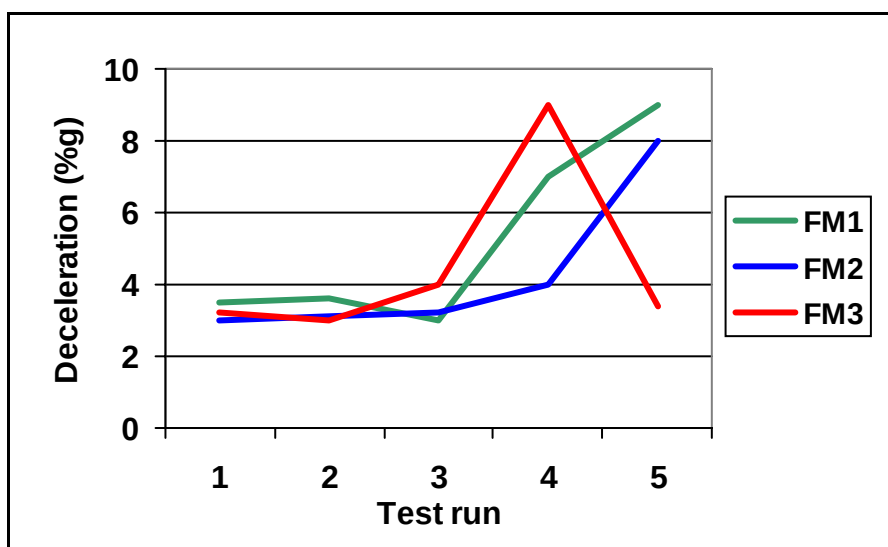


Figure 3 Example of the effectiveness of friction modifiers

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- 6.2.5 The performance of the friction modifier should also be checked for repeatability by undertaking multiple tests, and a similar method should be adopted as explained in 5.2.3 and 5.2.4.
- 6.2.6 The application of the friction modifier will change the adhesion level, it may be necessary to remove all of the low adhesion contaminant (which now has the friction modifier on its surface) from the railhead before a new test commences. It may be possible to move to a new section of track, but cleaning of the railhead will usually be the only solution.
- 6.2.7 Applying any material to the railhead may affect track circuit operation. The introduction of any new product must be assessed for its insulating properties in tandem with its effectiveness in increasing the level of adhesion.
- 6.2.8 Consideration should also be given to the potential damage to the wheels / railhead by the friction modifier either from a chemical reaction or mechanical scoring, pitting, or crack initiation.
- 6.2.9 Low adhesion test sites with S & C or lubricators should be avoided since the test materials could detrimentally affect their performance by contaminating the lubricants used in this type of equipment. Scoring damage could also occur to S & C slide plates.
- 6.2.10 Lubricator spreader bars could become contaminated. The application of a friction modifier may detrimentally affect their performance.
- 6.2.11 The performance of the friction modifier could be affected by the system of application. For example, the automatic delivery of the friction modifier by a train will usually be dependant on the wheel slide protection (WSP). However, a brake stop using an early WSP will give a very different result to using a modern vehicle-optimised system. This should be considered when selecting a vehicle for the tests and assessing the results.
- 6.2.12 The chemical constituents of the low adhesion contaminant may also be important, and it should be considered how the low adhesion contaminant might react to the friction modifier, which could be significantly different to the reaction between leaf film and the friction modifier. Therefore a low adhesion contaminant that best represents the chemical constituents of leaves are more suitable (see 3.1.3).
- 6.2.13 The contaminant will need to be retreated after each test, as the surface of the material will be impregnated with the friction modifier, and the adhesion level, if the friction modifier is successful, will remain high.
- 6.2.14 The physical properties of the low adhesion contaminant, such as hardness and thickness values, must be considered as the friction modifier could affect the contaminant more or less than leaf contaminant. For example, the particles could become embedded in the low adhesion contaminant if it is softer or thicker than leaf contaminant, thus giving unrepresentative results.

6.3 Method for selection of contaminant

- 6.3.1 Tables 4 and 5 provide a reference to the contaminants that may be suitable for testing friction modifiers.
- 6.3.2 Once a preferred contaminant has been selected from Tables 4 and 5, refer to the Parts relevant to that low adhesion contaminant. For example, for lignin / ashless floc, go to Parts 19 and 20 for guidance on how to use this method to produce a simulated low adhesion contaminant layer.

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- 6.3.3 To obtain an estimate of the cost of carrying out the testing of friction modifiers, the following factors should be taken into account:
- a) Arrangements:
 - i) Management time for the testing
 - ii) Methodology for testing
 - iii) Safety arrangements and staff
 - iv) Engineering change assessment (if applicable).
 - b) Materials / fitting / equipment:
 - i) Preparation of equipment for generating low adhesion
 - ii) Cost of the materials used to generate low adhesion
 - iii) Cost of applying the contaminant to the railhead
 - iv) Fitting of low adhesion equipment to vehicle (if applicable).
 - c) Operating requirements:
 - i) Possession costs / track hire charge
 - ii) Rail vehicle hire costs
 - iii) Costs to operate the equipment / reapply the contaminant.
- 6.3.4 The list above does not include the associated costs of the different friction modifiers and their application to the railhead.

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Low adhesion contaminant	Application time (500 m of track)	Time to condition	Removal time	Advantages	Limitations	Suitable Y / N?
Detergent (see Parts 12 to 16)	10 minutes (by vehicle) approximately 30 minutes (manually)	10 to 20 minutes	30 to 60 minutes	Can be applied / reapplied quickly. Easy removal. Minimal environmental impact. Good range of moisture in which it can work.	Contaminant layer very different to leaf film in all aspects except adhesion levels. Engineering change assessment may be required if spray equipment is fitted.	Y
Paper tape 1 layer (see Parts 17 and 18)	approximately 40 minutes	10 to 20 minutes	approximately 90 minutes	Well bonded to railhead. Durable, similar hardness, moisture, thickness and conditioning characteristics to leaf film. Minimal impact on environment. Consistent low adhesion layer when activated by water spray. Very repeatable.	Application / removal time. Need vehicle to roll in. Operatives need access to track to lay tape. Needs risk assessment to use with electric stock. Affected by rain. Possession required. Engineering change assessment required.	Y
Paper tape 2 layers (see Parts 17 and 18)	approximately 60 minutes	10 to 20 minutes	approximately 90 minutes	Well bonded to railhead. Durable, similar hardness, moisture, thickness and conditioning characteristics to leaf film. Minimal impact on environment. Consistent low adhesion layer when activated by water spray. Very repeatable.	Represents a thickness greater than the measured average thickness of leaf film. Application / removal time. Need vehicle to roll in. Operatives need access to track to lay tape. Needs risk assessment to use with electric stock. Affected by rain. Possession / engineering change assessment may be required.	N
Lignin / ashless floc (see Parts 19 and 20)	approximately 60 minutes	20 minutes to dry but dependant on atmospheric conditions	30 to 60 minutes	Well bonded to railhead. Similar hardness and thickness characteristics to leaf film. Consistent layer. No rolling in necessary. Minimal impact on environment. No engineering change assessment required.	Application and re-application time significant. Different in conditioning and moisture uptake to leaf film. Limited moisture range as to when it is effective. Possession may be required.	Y
Real leaves on track (see Parts 21 and 22)	Impractical to apply to 500 m, 20 minutes for 2 m section	10 minutes to 5 passes of train or similar	10 minutes for 2 m section	Usually well bonded to the railhead. Similar in hardness, moisture, thickness and conditioning characteristics to leaf film. No issues with similarity. Removal not so critical on short section. Minimal impact on environment.	Leaf availability at the time of testing. Cannot replicate performance tests (acceleration / deceleration). Not as repeatable as other films. Affected by moisture. Track access required to lay films. Possession / engineering change assessment may be required. Long lengths impractical	Y

Table 4 Friction modifier simulation methods