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Guidance on Wheel / Rail Low Adhesion Measurement
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Guidance on Wheel / Rail Low Adhesion Measurement

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Guidance on Wheel / Rail Low Adhesion Measurement

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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 low adhesion measurement. It does not constitute a recommended method of meeting any set of mandatory requirements. RSSB make no endorsement for the use or identification of the equipment and its uses within the document.

In association with the fundamental study of leaf contamination, this guidance note can be used in conjunction with Guidance Note GM/GN2643, Wheel / Rail Low Adhesion Simulation. This Guidance Note and GM/GN2643 have been produced to aid in the selection of adhesion measuring and monitoring methods and simulate low adhesion.

Stakeholders from the industry-supported Adhesion Working Group (AWG) approved the content of this work. Further Guidance Notes 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

Guidance on Wheel / Rail Low Adhesion Measurement

Part 2 Guidance on Wheel / Rail Low Adhesion Measurement

2.1 Background to wheel / rail low adhesion

- 2.1.1 Over the last 30 years a significant effort has been applied to developing 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 the effectiveness of methods to combat 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 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 levels for research and test purposes
 - d) Aerodynamic performance of rolling stock
 - e) Characteristics of leaf contamination properties.
- 2.1.4 RSSB's research into 'The Characteristics of Railhead Leaf Contamination' in relation to the requirements for measuring wheel / rail low adhesion were:
 - a) To identify industry requirements and purposes for measuring low adhesion levels.
 - b) To review the available devices for measuring low adhesion levels and match the capability of the devices to industry requirements.
- 2.1.5 The work identified that moisture content, thickness, shear torque and hardness of leaf film contamination have been measured on a few ad hoc occasions to try and understand the properties of railhead contaminants, but the data has not been acquired consistently and no procedure exists for the application of measuring devices.
- 2.1.6 This guidance note lists the reasons for measuring low adhesion levels between wheel / rail and considers which methods are most suited to different requirements and looks at the measuring methods currently available. A range of methods and devices for the measurement of low adhesion conditions have been included as examples.
- 2.1.7 An input has also been obtained from other railway administrations including German (DB), French (SNCF), Dutch (NS) and Italian (FS) so that overseas experience could be incorporated into a review of adhesion measurement methods.

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- 2.1.8 The relationship between adhesion levels and speed is explained in Part 9. Guidance on the tools that are available for measuring contaminant properties is given in Part 10.

2.2 Application of this document

- 2.2.1 Low adhesion measurements are required for a number of reasons relating to the safe operation of the railway and for improving performance. These reasons are:
- a) The safe operation of trains in low adhesion conditions requires the industry to assess the risks and provide mitigation methods (see GE/RT8040, GI/RT7006 and GI/GN7606). Development of successful methods is dependent upon the ability to reliably measure and in some instances reproduce low adhesion conditions.
 - b) Post incident analysis enables the industry to determine the causes of problems that have arisen and therefore improve equipment and procedures (see GO/RT3252 and GO/GN3652).
 - c) Simulated low adhesion levels allows driver experience to be obtained under controlled conditions. An assessment of simulated low adhesion levels enables consistent conditions to be produced for training purposes.
 - d) Simulated low adhesion levels can also be used to test the effect of changes to existing equipment on performance and safety.
- 2.2.2 Note that for braking, adhesion levels of 0.14 or greater should sustain all braking rates and an adhesion level between 0.1 and 0.3 is required for reliable operation in traction.

2.3 Low adhesion measurement methods

- 2.3.1 Measurement of adhesion levels can be obtained directly by use of a tribometer, which may be full sized or scaled for manual operation on-site. Scaled tribometers should only be used for comparative measurements because the scaling can influence the magnitude of the results.
- 2.3.2 This document provides guidance on the selection of a method for measuring low adhesion levels. It also provides details of the various measuring options; Part 3 (Train Mounted Methods), Part 4 (Vehicle Borne Tribometer) and Part 5 (Portable Tribometer Methods). Part 6 provides guidance on the use of laboratory test rigs for measuring adhesion levels. Report AEATR-VTI-2005-015 under project T354: The Characteristics of Railhead Leaf Contamination is a useful additional reference document on the measurements of low adhesion levels and can be found on the RSSB web site (www.rgsonline.co.uk).
- 2.3.3 Where portable tribometers have been identified, practical measurements were carried out in the laboratory to assess the results obtained from the devices for measurements on a number of contaminants. These results have then been compared to historical data from the full-scale tribometer train.
- 2.3.4 Assessment of low adhesion levels can also be obtained indirectly by a number of methods as shown in Part 7 and Part 8. These are:
- a) Measurement of the train deceleration (for example as acquired from the on train monitor recorder (OTMR) - see 7.4).
 - b) Monitoring wheel slide protection (WSP) activity using train management system (TMS) for example Mitrac™ - see 7.5 and / or WSP Data for example LAWS™ see 7.6).
 - c) Timing or measuring the distance for a train to stop from a known braking point (Part 8).

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- 2.3.5 An adhesion management system (AMS) for monitoring adhesion conditions is under development by the industry but is not yet available and details are therefore not included within this Guidance Note.

2.4 Selection of measuring method

- 2.4.1 The requirement for assessing low adhesion conditions (for example incident investigation, skidpan driver training, test purposes, product testing) will determine the method(s) that are suitable for the application. In this document 'test purposes' refers to checking brake systems, WSP etc and 'product testing' refers to checking products that are used on the railway that could affect the railhead adhesion levels, for example weed killers.
- 2.4.2 Table 1 lists industry requirements for the measurement / assessment of adhesion levels and ranks the options (1 being the preferred option) of devices / methods suitable for obtaining data for the specified purposes.
- 2.4.3 Choice of tribometer or assessment method will be governed by availability of the device or method and the practicality of using it at the location where the data is to be acquired. Where possible it is recommended that full scale or vehicle borne tribometer should be used in preference to portable tribometer because of scaling effects on the results from the latter.
- 2.4.4 The selection process in Table 1 should be used in conjunction with Table 2, which gives guidance regarding the advantages and limitations of using a particular tribometer or assessment method for a specific application.
- 2.4.5 As an example of using the Tables 1 and 2, take the scenario of assessing a new rail cleaning technique. Assuming that a service train and section of track are available on which to conduct the tests, Table 1 suggests that there are three options: OTMR, brake test and modified service or test train (as shown in the box where the 'assess low adhesion treatment methods / rail cleaning' intersects with the 'service test train' column). Assuming all three methods are available then the advantages and limitations of each can be obtained from Table 2. Each method is considered in turn and for example one possible outcome would be:
- a) Option 1 the OTMR, is rejected on the grounds that the staff and equipment for downloading the data are not available.
 - b) Option 2 the brake test is considered the best option on this occasion since the method is simple and only a preliminary assessment is needed.
 - c) Option 3 the modified test train, is rejected because of the time and expense of fitting load measuring wheels.
- 2.4.6 For ease of reference the sections of Table 2 are set out in the same sequence as the order of tribometers in the header row of Table 1:
- a) Train mounted methods
 - b) Vehicle borne tribometers
 - c) Portable tribometers
 - d) Laboratory test rigs
 - e) Service test train
 - f) Adhesion management methods.

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	Train mounted methods	Vehicle borne tribometers	Portable tribometers	Laboratory test rigs	Service / test trains	Adhesion management methods
Incident investigation	No	No	1. Braked wheel tribometer 2. Static breakout friction 3. Skid resistance slider	No	1. OTMR 2. Brake test	No
Assess low adhesion treatment methods / rail cleaning	Yes	Yes	1. Braked wheel tribometer 2. Static breakout friction 3. Skid resistance slider	1. Twin disc test rig 2. Pin on disc machine 3. Full-scale wheel-on-rail rig	1. OTMR 2. Brake test 3. Modified service or test train (load measuring wheels or strain gauged axles)	No
Network adhesion status	Yes	No	No	No	1. TMS / WSP data 2. Modified service train (strain gauged axles)	Yes
Identify low adhesion sites	Yes	Yes	No	No	1. TMS / WSP data 2. Modified service train (strain gauged axles)	Yes
Check adhesion levels for test purposes (see 2.3.2)	Yes	Yes	1. Braked wheel tribometer 2. Static breakout friction 3. Skid resistance slider	No	1. Brake test 2. OTMR 3. Test train (load measuring wheels)	No
Check adhesion levels for driver training	No	No	1. Static breakout friction	No	1. Brake test distance to stop / deceleration	No
Laboratory investigations	No	No	1. Skid resistance slider 2. Static breakout friction	1. Twin disc test rig 2. Pin on disc machine 3. Full-scale wheel-on-rail rig	No	No
Product testing	Yes	Yes	1. Braked wheel tribometer 2. Skid resistance slider 3. Static breakout friction	1. Twin disc test rig 2. Pin on disc machine 3. Full-scale wheel-on-rail rig	1. Brake test 2. OTMR	No

Table 1 Options for assessing adhesion levels

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Tribometer type	Outputs	Advantages	Limitations
Train mounted methods			
Tribometer train see 3.4	Exact measurement	Provides a direct measurement of the adhesion level. No scaling effects. Adhesion profiles can be measured. Peak adhesion levels can be measured. Could be incorporated into treatment train(s).	System not readily available. Tribometer train expensive to construct and operate. Difficult to get to sites and a path is required. Data processing and analysis needed to determine the wheel / rail forces. Flange contact will affect the results
Load measuring wheels see 3.5 / 3.6	Exact measurement	Full-scale wheel / rail forces are measured to provide the peak adhesion levels and adhesion profiles. Could be fitted to a service vehicle for test purposes (vehicle withdrawn from service whilst modified). Fitted to a train so can measure anywhere on the system.	System not readily available. Expensive and complex to build. Needs to be fitted to a train (service or departmental). Significant analysis and data processing required. Flange contact will affect the results.
Strain gauged axles see 3.7	Exact measurement	Uses full sized wheel / rail contact. Could be fitted to treatment train(s) or potentially to service trains. Peak adhesion levels and adhesion profiles can be obtained.	System still under development. Requires fitting to train in harsh environment. Data processing and analysis needed to determine the wheel / rail forces. Flange contact will affect the results.
Vehicle borne tribometers			
Vehicle borne tribometer see 4.4	Relative measurement	Readily available and easy to use. Rolling / sliding measurement. Both rails can be measured simultaneously with adjustable wheel position across rail. Measurement speed up to 30 mile/h. Significant lengths of track measurable. More accurate than portable tribometers.	Possession required for taking the measurements. More expensive than portable devices. Scaling effects (but more accurate than the portable device).

Table 2 Advantages / limitations of low adhesion measurement and assessment methods

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Tribometer type	Outputs	Advantages	Limitations
Portable tribometers			
Braked wheel tribometer see 5.5	Relative measurement	Readily available. Portable and easy to use. Rolling / sliding measurements gives the peak adhesion level. Adjustable wheel position across rail. Short recording time approximately 15 to 25 seconds per adhesion value measurement.	Scaling effects with no simple calibration, adhesion values obtained are generally high. Low speed measurements (walking pace).
Static breakout friction tribometer see 5.6	Relative measurement	Readily available Hand held, easy to use. Normally friction should be measured over a significant length of rail but this device could be used on very short sections (15 to 20 cm) of rail for example on damaged track at a derailment site. Very short recording time per measurement, approximately 5 - 10 seconds.	Sliding friction measurements only. Flat slider will not be in full contact with curved rail. Roughness and lubricants affect the results - scaling effects. Requires modification - rubber slider - to improve resolution of results.
Skid resistance slider tribometer see 5.7	Relative measurement	Readily available. Easy to use. Portable. Demonstrated to give significant resolution between contaminant types.	Design of pendulum frame not very suitable for use on track. Sliding friction measurements only. Slightly more complex set up than braked wheel or static breakout friction tribometers. Scaling effects.
Laboratory test rig			
Laboratory test rigs see Part 6	Direct measurement	Readily available. Controlled environment. Rig(s) can be instrumented to measure adhesion level. Contaminants easily introduced into the contact area. Multiple tests can be easily conducted to determine statistical variation.	Most rigs are small size wheel-on-wheel configurations (for example Amsler) and scaling affects results. Wear of discs can be high new or turned discs are required for each test.

Table 2 Advantages / limitations of low adhesion measurement and assessment methods (continued)

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Tribometer type	Outputs	Advantages	Limitations
Service / Test trains			
Service trains OTMR data see 7.4	Average adhesion levels over length of track	Readily available. All trains are required to have OTMR fitted. Measures effect of adhesion levels in a real wheel / rail contact. The railway industry are familiar with the output from OTMR since it is in regular use for incident analysis.	Most OTMR systems require downloading after the incident. OTMR requires search and analysis of data. Output is an average value. Only provides data when the train is braking. Experience with analysing the data is necessary.
Service trains TMS for example Mitrac™ see 7.5	Provides estimate of adhesion levels	Readily available. Measures effect of adhesion levels in a real wheel / rail contact. Mitrac™ can be accessed in real time. Provides mapping.	Only provides data when the train is braking. Output is an estimate of adhesion level. Experience with using the software is necessary.
Service trains WSP data for example LAWS™ see 7.6	Provides estimate of adhesion levels	Readily available. Measures effect of adhesion level in a real wheel / rail contact. Operates in real time. LAWS™ provides mapping and statistics.	Only provides data when the train is braking. Output is an estimate of adhesion level. Experience with using the software is necessary.
Service / test train braking test see Part 8	Provides estimate of adhesion levels	Demonstrates train performance. Very useful for incident investigations (for example SPADs or overruns) No instrumentation necessary to record data (but an accelerometer or OTMR output could be used to record / obtain train deceleration).	Takes time to set up test during which adhesion conditions may change, (for example results may be significantly affected by moisture level). Train needs to be braked, and this impacts on service performance. Path required if using a non-service train.
Adhesion management methods			
Adhesion management system	Indirect measure	Provides a network (route) relative adhesion status and enables identification of low adhesion sites.	System under development. Not a direct measurement of adhesion level.

Table 2 Advantages / limitations of low adhesion measurement and assessment methods
(continued)

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2.5 Recording conditions

- 2.5.1 Table 3 is a matrix of the conditions that should be recorded for a range of purposes, the main reason being that these parameters can influence adhesion levels. Recording of the conditions at a site should generally be subjective. The information should be used to support the interpretation of results / findings from an investigation and monitor changes in conditions during tests or driver training.

Parameter	Purpose				Reason
	Incident investigation	Assess rail cleaning	Check adhesion levels for test purposes	Driver training	
Weather	✓	✓	✓	✓	Affects wheel / rail adhesion levels
Site features	✓	✓	✓		Affects wheel / rail adhesion levels
Railhead contamination	✓	✓	✓		Affects wheel / rail adhesion levels
Contaminant properties	(Note: contaminant properties at incident sites are normally recorded by taking swabs).	✓	✓		Affects test results or assessment
Speed	✓	✓	✓	✓	Adhesion / speed variation
Adhesion measurement	✓	✓	✓	✓	Selected method affects interpretation of adhesion conditions

Table 3 Condition matrix

- 2.5.2 An example table for recording low adhesion site conditions is given in Table 4. In general subjective assessments (see 2.5.4 to 2.5.11) should be made and the table should not take more than a few minutes to complete. The table should be completed at the start of the activity and if conditions change significantly (for example the onset of rain or a deliberate change of test parameters) a note should be made of the change.
- 2.5.3 Example record sheets are given in Appendix A for each purpose (that is incident investigation, driver training etc).
- 2.5.4 The ambient weather conditions under which the measurements are taken should be recorded including:
- Wind speed and direction (a subjective assessment - light easterly breeze, strong south westerly gusts etc)
 - Temperature (record only required for detailed studies)
 - Humidity (record only required for detailed studies)
 - Rainfall (a subjective assessment that is drizzle, light, moderate or heavy, showery etc)
 - Other weather conditions (a subjective assessment that is sunny, dull, dry, mist or fog).

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- 2.5.5 Track formation at the measurement location should be recorded for example:
- a) Flat open track
 - b) Shallow cutting
 - c) Deep cutting
 - d) Stepped formation - embankment one side cutting the other
 - e) Embankment
 - f) Gradient.
- 2.5.6 Other factors that may influence the adhesion levels should be recorded including:
- a) Vegetation for example large broad leafed trees with branches overhanging the track, open land with a few shrubs, hawthorn etc
 - b) Line side factories, which are a potential for pollution
 - c) Local lakes, which indicate that the area may be susceptible to mist and fog
 - d) Proximity of airports, roads etc.
- 2.5.7 A subjective assessment of the condition of the railhead should be recorded for example:
- a) Amount of rust present for example none, low, moderate or high
 - b) Presence of sand or sandite for example none, low, moderate or high
 - c) Contamination for example leaf film none, low, moderate or high
 - d) Moisture level for example dry, damp or wet
 - e) Surface roughness if considered to be a relevant factor for example where the contaminant film thickness appears to be similar to the roughness.
- 2.5.8 The condition of contamination under which adhesion levels is measured should be recorded (see Part 10 for guidance) including the following:
- a) Hardness or shear torque of visible films with an area of 15 mm x 15 mm or greater
 - b) Thickness (3 random sample measurements)
 - c) Moisture content (3 random sample measurements).
- 2.5.9 In the event that there is insufficient time available to take the measurements (as might arise during an incident investigation for example) then subjective notes can be made:
- a) Hardness - film removed / penetrated with finger nail, film difficult to scratch
 - b) Thickness - film appears to be compressed to a very thin black layer, film appears to be relatively thick, multiple layers of leaves in green condition
 - c) Moisture - record if the film is dry, damp or wet.

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- 2.5.10 The measurement speed needs to be recorded so that, if required, the adhesion / speed relationship can be taken into account. If a portable tribometer is used at walking speed a best estimate of the speed may be used. The vehicle speedometer or timings between two fixed points may also be used to provide an estimate of speed.
- 2.5.11 A sufficient number of adhesion measurements should be taken in order to obtain a statistically significant sample.
- 2.5.12 In the following Parts 3 to 8 guidance is given on the application of each of the adhesion assessment and measurement options listed in Tables 1, 2 and 3.
- 2.5.13 Part 9 gives guidance on the adhesion / speed relationship which applies to all of the tribometer measurement options.
- 2.5.14 Part 10 gives guidance on the measurement of contamination properties to provide supporting evidence to the adhesion measurement.

Guidance on Wheel / Rail Low Adhesion Measurement

Location		Purpose:				Comments
Parameter	Time:					
Weather	Sub parameter					
	Wind speed					
	Wind direction					
	Temperature					
	Humidity					
	Sun					
	Dry					
	Dull					
	Mist					
	Fog					
	Drizzle					
	Rain					
	Sleet					
	Snow					
Site features						
	Flat open					
	Shallow cutting					
	Deep cutting					
	Embankment					
	Stepped					
	Gradient					
	Vegetation					
	Factories					
	Lakes					
	River / stream					
	Airport					
	Busy road					
Railhead contamination						
	Rust					
	Sand					
	Sandite					
	Leaf					
	Grease					
	Oil					
	Other					
	Dry					
	Wet					
	Damp					
	Roughness					
Contaminant properties						
	Hardness					
	Thickness					
	Moisture					
Speed						
Adhesion measurements						

Table 4 Example table for recording low adhesion site conditions (see Appendix A for examples)

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Part 3 Train Mounted Methods

3.1 Scope

- 3.1.1 The methods described in this Part are intended to directly evaluate the available wheel / rail adhesion level that would be experienced by a train in service.
- 3.1.2 This includes measurement for each of the following parameters:
- a) Measurement vehicle speed and location
 - b) Vertical force per axle or per wheel
 - c) Lateral and / or longitudinal force per axle or per wheel.
- 3.1.3 This Part gives guidance on achieving accurate and repeatable adhesion measurements from a tribometer train or service train (including test trains formed from service vehicles). Measurements with a tribometer train could use load cells, load measuring wheels or axle mounted strain gauges. Measurements on service or test trains could be achieved by fitting axle mounted strain gauges or load measuring wheels.

3.2 Purpose

- 3.2.1 These methods should only be used to obtain an accurate measurement of the adhesion level.

3.3 Uses

- 3.3.1 Data obtained from train mounted tribometers can be used for:
- a) Assessing low adhesion treatment methods / rail cleaning using a tribometer train, load measuring wheels or modified service train for example fitted with axle mounted strain gauges.
 - b) Measuring network adhesion status and using a tribometer train is possible. It would be an expensive method and it is difficult to obtain train paths.
 - c) Identifying low adhesion sites using a tribometer train is possible. It would be an expensive method and it is difficult to obtain train paths.
 - d) Checking adhesion levels for test purposes for example assessing brake systems using a tribometer train or load measuring wheels.
 - e) Product testing for example checking weed killer solutions do not cause low adhesion conditions and braking problems.

3.4 Tribometer train

3.4.1 Introduction to the tribometer train

- 3.4.1.1 The measurements of longitudinal and vertical forces should be carried out with the suspension in its normal operating condition.
- 3.4.1.2 There are two options for including the vertical wheel / rail force in the calculation of the low adhesion levels:
- a) Use the static wheel load
 - b) Measure the vertical wheel / rail force.

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- 3.4.1.3 If the approximation of the static wheel loads is not used, the test arrangement should be capable of determining the vertical wheel / rail forces. In most applications the use of the static wheel loads will be sufficient (particularly if the measurement speed is low that is less than 48 km/h (30 mile/h)).
- 3.4.1.4 The vertical force is a combination of static and dynamic components. A measurement may be made of the resultant force or of only the dynamic component depending on the arrangement available for the measuring system. The resultant force should be determined to an accuracy of ± 5 kN irrespective of the measurement method.
- 3.4.1.5 Measurement might be achieved by use of strain gauges or a linear suspension displacement technique. Where a linear displacement technique is used, the vertical force is derived from the product of the known vertical stiffness and the displacement.
- 3.4.1.6 The test arrangement should be capable of determining the longitudinal wheel / rail force(s). If a load cell is used for this measurement and a low adhesion level is to be measured (μ down to 0.01) then it should be capable of reading to ± 0.1 kN.

3.4.2 Test conditions

- 3.4.2.1 The data should be captured on tangent track in order to avoid flange contact which would affect the results.
- 3.4.2.2 When the measurement is taken the vehicle should be free from external forces other than the traction force. The traction force applied to the measuring vehicle should be maintained as near to constant as possible during the measurement.
- 3.4.2.3 The test vehicle brake application should be independent of the train brakes.
- 3.4.2.4 The brake force should be increased steadily until wheel slide is detected. Then the brake should be released to avoid wheel damage.
- 3.4.2.5 A WSP system that has optimised for low adhesion conditions should be used to detect wheel slide.
- 3.4.2.6 Any low adhesion mitigation system (for example sanders) should be disabled during the measurements provided that due consideration has been given to safety implications.
- 3.4.2.7 The test conditions set out in 2.5.4 to 2.5.11 should be recorded as appropriate for the parameters given in Table 3.

3.4.3 Measured values and evaluations

- 3.4.3.1 The speed of the train should be recorded during the measurement.
- 3.4.3.2 Unless the static wheel load is being used for the calculation of the coefficient of friction, the vertical wheel forces (N) of both wheels of the axle should be measured. Evaluation should be done using the average of the arithmetic mean of the values for each wheel recorded during the measurements. If only the dynamic component of the vertical force is measured then the average from the two wheels should be added to the static load.
- 3.4.3.3 If the longitudinal wheel forces (F_{Long}) of both wheels of the axle are measured, the evaluation should be done using the average of the arithmetic mean of the values for each wheel recorded during the measurements.
- 3.4.3.4 The coefficient of friction (F_{Long} / N) should be calculated from the directly measured mean longitudinal force or from the value calculated from the arithmetic mean of the values from each wheel.

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3.4.4 Statistical sample

3.4.4.1 A statistically significant set of measurements should be taken in to account for the variability along the track under nominally constant conditions.

3.4.4.2 The mean and standard deviation for the measurements obtained should be calculated for stated conditions, for example:

An average adhesion level of 0.1 with standard deviation ± 0.05 on dry, leaf affected track, measured with a full-scale wheel at a measurement speed of 15 km/h.

3.4.5 Constraints and limitations

3.4.5.1 At the time of issuing this document the original BR tribometer research train is obsolete. A new train would need to be built and equipped to undertake new measurements.

3.4.5.2 A train path is required when using tribometer trains.

3.4.5.3 Flange contact will affect the results.

3.4.5.4 Significant data processing and analysis is needed to determine the wheel / rail forces.

3.4.6 Advantages

3.4.6.1 A tribometer train provides full-scale wheel / rail adhesion measurements and is therefore not subject to scaling effects.

3.4.6.2 Adhesion profiles can be acquired with this type of train measuring system. Each adhesion profile point is obtained from a full traction or braking curve showing the peak adhesion level.

3.4.6.3 The system could be built into rail head treatment trains.

3.5 Load measuring wheels

3.5.1 Introduction to load measuring wheels

3.5.1.1 Load measuring wheels can be fitted to a specially built tribometer vehicle or fitted under a service vehicle for test purposes.

3.5.1.2 An example of a load measuring wheel is shown in Figure 1.

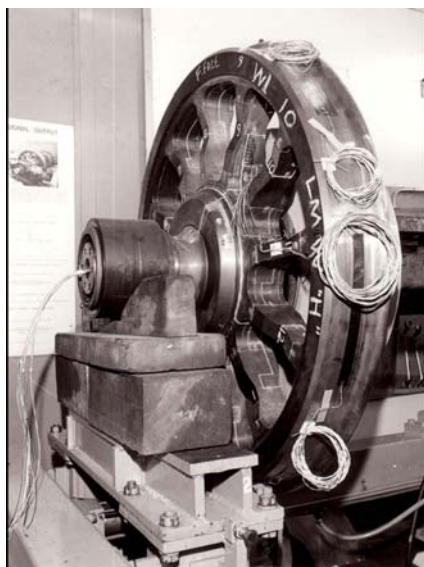


Figure 1 Load measuring wheel