Railway noise
Technical Measures Catalogue

International Union of Railways (UIC)

Final document
Summary

There is a growing awareness of the impact of railway noise on public health, which has resulted in pressure from line-side inhabitants, governments and health organizations for increased noise mitigation. As a consequence, noise can be a limiting factor for many railway operations, introducing additional costs for mitigation, demands for limits on availability/capacity and resistance to expansion of the network.

Recent years have seen the development of new, and refinement of existing, strategies and technologies for noise management. Railway companies often face calls to implement these, and demonstrate that progress has been made with the use of new and innovative technology.

By collating best practice and case studies from "real life" tests and adding the theoretical knowledge in this Catalogue, UIC stimulates the implementation of publically available knowledge, demonstrate the progress that has been made and also manage stakeholder expectations.

This Noise Technical Measures Catalogue surveys recent developments for three topics in separate chapters:
1. Curve Squeal
2. Noise from freight marshalling yards
3. Noise from switches
In addition, one final chapter is dedicated to measures against rolling noise: rail and wheel dampers, K and LL blocks, noise barriers and acoustic grinding.

Curve squeal
Curve squeal is a highly annoying sound that is radiated by trains running through sharp curves. Much progress has been made during the past decades in understanding this phenomenon. Mitigation measures aim at avoiding squeal events or at least reducing their duration or strength. Flange lubrication and top-of-rail application of friction modifiers have demonstrated to be very effective (reduction$^1$: 5-20 dB(A)), provided that the dosing devices receive constant and dedicated maintenance. Friction products can be applied from track-based as well as vehicle-mounted devices and there are many manufacturers and suppliers of such devices.
Special bogie designs, aiming at improved steering performance in curved as well as straight track, also reduce squeal noise and are potential solutions for the future, provided that safety issues can be solved adequately.

$^1$ The ranges of noise reduction given in this summary always depend on the chosen reference situation.
Noise from freight marshalling yards
Marshalling yards are areas where freight trains are decoupled and coupled. Because of the large scale of the yard, mitigation by noise barriers is no option. Among the most important noise sources are screeching rail brakes (retarders), peak noise from coupling vehicles and starting diesel engines, and steady noise from locomotive engines and auxiliary systems. Recently, new solutions for noisy rail brakes have been developed, showing promising noise performances (5-15 dB(A)). For stationary noise of several locomotives, technical modifications have been developed. Stationary noise of diesel engines, for example to operate cooling vents, may be avoided by using a way-side electric power supply.

Noise from switches
Switches and crossings are among the most sensitive parts of the railway system, claiming a large part of the maintenance budget. Switches and crossings also produce noise: impact noises from joints (if present) and screeching noise similar to curve squeal. In a traditional switch, a wheel encounters several gaps, causing a train to produce a rattling sound. Jointless switches are state-of-the-art nowadays (2-4 dB(A)) on lines where trains run at operational speeds. Squeal noise and flange rubbing noise in switches may receive the same treatment as squeal noise in curves (5-20 dB(A)).

Rolling noise
Rolling noise is the most common type of railway noise and there are many technical measures that reduce it. High levels of rolling noise arise from irregularities on the wheel tread and rail head, called roughness. Roughness of the rails can be controlled by maintenance grinding and can be further reduced by acoustic grinding. Acoustic grinding requires that the rails are ground or polished as soon as a certain reference noise level is exceeded (1-3 dB(A)). The potential of acoustic grinding will increase if all train wheels are smooth as well. A large improvement in this field is expected from the homologation of LL braking blocks, which make retrofitting of freight vehicles a cost-effective option (8-10 dB(A)).

By application of rail dampers (0-3 dB(A)) and wheel dampers (0-2 dB(A)) a further noise reduction can be achieved. Rail dampers are applied in several countries. The noise reduction depends largely on the characteristics of the track system without rail dampers.

Promising developments for urban areas are low-close barriers, typically placed at only 1.70 m from the track with a height of 0.70-0.85 m. In certain cases low-close barriers are acoustically equivalent to much higher conventional barriers, their advantage being that they do not block the view. However, in view of safety issues with barriers placed close to the traffic, to date only few countries have decided about homologation.
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Introduction

1.1 Collecting information

This catalogue is the result of an inventory and study of literature from various congress and journals. The inventory took place in close cooperation with the UIC core group noise. Besides this, many interviews were performed to acquire additional information, reports, references to further publications, new projects, and information about practical experience.

The following railway noise experts were interviewed by telephone calls and e-mails, between January and May 2013: Bernd Asmussen (DB), Bohumir Trávniček (SZDC), Brigita Altenbaier (Elpa d.o.o.), Chris Jones (UK), Dave Anderson (RailCorp), David Thompson (ISVR), Eduard Verhelst (Infrabel), Erkki Poikolainen (FTA), Ferat Göçmen (DB), Franck Poisson (SNCF), Frans Slats (NS), Friedrich Krüger (STUVA), Günter Dinhobi (ÖBB), Jakob Oertli (SBB), Jasper Peen (LRRE), Jens Nielsen (CHARMEC), Leo Baures (Bombardier), Lisette Mortensen (Banedanmark), Margreet Beuving (Plurel), Markus Hecht (TU Berlin), Marta Ruiz Sierra (Adif), Martin Müller (SBB), Michael Dittrich (TNO), Michael Pal (Perth), Nick Craven (Network Rail), Nils Yntema (ProRail), Paul de Vos (DHV), Peter Hübner (UIC). Information was also received by e-mail from certain suppliers and manufacturers.

Disclaimer: despite of all effort done to collect and interpret many measurement reports and information from interviews of railway experts, neither the authors nor the UIC core group noise can guarantee the performance of any product. The various lists of manufacturers and suppliers are not exhaustive and they should not be seen as an endorsement.

1.2 Cost of measures

Noise measures are not for free. It is known that noise measures can have a significant impact on cost for railways. A well-balanced noise mitigation strategy including life-cycle costs is therefore important to keep the rail transport system competitive. Strategic decisions about application of (new) noise measures should always be preceded by a cost-benefit assessment. It can be difficult to determine relevant life-cycle costs (LCC), especially for innovative products, of which some are included in this catalogue. But even with state-of-the-art products, a good cost assessment is not simple.

Investment costs are sometimes presented with safety and track possession costs included, sometimes these additional factors are excluded. Also, prices for labour, interest rate and inflation differ between various countries and various years. This makes it hard to give exact
figures for general installation and annual maintenance costs in a certain year. What seems expensive in one country or situation can be affordable elsewhere. Also, comparison of costs between vehicle-based and track-based measures with equal acoustic efficiency will be very challenging, as these may depend both on the network length and on the rolling stock fleet size.

Useful recent studies on cost of railway noise measures (in the public domain, internet) are:

• *The real cost of railway noise mitigation - A risk assessment*, De Vos and Van der Stap (DHV), commissioned by UIC, 30 January 2013

• *Innovative Maßnahmen zum Lärm- und Erschütterungsschutz am Fahrweg, Schlussbericht*, DB Netze, 15 June 2012

Apart from these studies, cost information in this catalogue is derived from certain test reports cited in the respective chapters. In view of the complexity described above, in this technical catalogue no attempt is made to convert cost information to a common basis, such as Net Present Value or Equivalent Annual Costs, or to complete missing partial costs. It should also be noted that the cost and lifetime figures in the *Innovative Maßnahmen* report may refer to special cases and non-standard situations - for general purposes different figures may be applicable.

The cost information cited in this catalogue can therefore be used as indicative cost.
Curve Squeal

Executive summary

Curve squeal is a high-pitch sound that is radiated by trains running through sharp curves. The wheels of a bogie or a two-axled vehicle are excited due to frictional instability when the wheels are forced to follow the curve. The squealing sound corresponds to modes of wheel vibration and is highly annoying because it is both loud and tonal. Much progress has been made during the past decades in understanding the phenomenon, but it remains difficult to predict whether a train will or will not produce this noise. This is because its occurrence depends on a combination of many parameters.

In most countries curve squeal is not accounted for in their legal noise computation methods. As a result, most noise maps do not include squeal noise. Treatment of curve squeal is usually complaint-driven.

Most mitigation measures aim at avoiding squeal events or at least reducing their duration or strength. Flange lubrication and top-of-rail application of friction modifiers have demonstrated to be very effective (reduction: 5-20 dB(A)), provided that the dosing device receives constant and dedicated maintenance. Friction products can be applied from track-based as well as vehicle-mounted devices and there are many manufacturers and suppliers of such devices. Special bogie designs, aiming at improved steering performance in curved and tangent track, also reduce squeal noise and are potential solutions for the future. Wheel dampers are known to reduce squeal noise as well.

Sharpe curves near Deventer (Netherlands)

Squeal events in tight curves may be greatly reduced by these technical measures, but some railway vehicles will still squeal on some occasions. Poor curving performance of vehicles sometimes arises from axle-misalignment, requiring bogie maintenance.
2.1 Introduction

It is generally difficult to predict whether a train will or will not produce squeal noise. It depends on many parameters, like dry/rainy weather, tyre cross-section, curve radius, yaw stiffness and bogie wheelbase. Because of this, the understanding of curve squeal has been rather obscure for a long time. The squealing sound, which is radiated from the wheels, corresponds to axial normal modes of vibration. The main tones appear at frequencies between 250 Hz and 5 kHz [Thompson 2009]. Similar kinds of noise can occur in switches and crossings, but these are usually associated with flange rubbing, see Chapter 4. Most mitigation methods aim at avoiding the squeal noise or at least reducing its duration or strength.

In most countries curve squeal is not accounted for in their legal noise computation method. A few countries apply a fixed curve squeal penalty expressed in dB(A) for sharp curves. Other countries only account for squeal noise in industrial noise regulations, applicable for stabling and marshalling yards.

The application of lubricants and friction modifiers on the rail, either by track-mounted or vehicle-mounted systems, have demonstrated to be very effective. However, for a sustainable solution against squeal noise these systems require constant and dedicated maintenance. Special bogie designs may be able to avoid squeal as well. Anti-squeal railhead profiles and gauge narrowing have also been tested, but have not proven successful in practical implementations. Wheel dampers reduce squeal noise as well, though reducing curve squeal is generally not the main incentive for application of wheel dampers.

2.2 Technical description

Squeal noise may occur while a rigid bogie or a two-axle railway vehicle is negotiating a curve. Such vehicles have two parallel non-steerable axles, see Figure 1. While the wheels will roll in the forward direction, the required lateral motion in curves can be realized (partly) by the conicity of the wheel profile. In sharp curves additional lateral motion goes along with lateral slip (frictional instability), causing the wheels to be excited and to squeal.
The understanding of the occurrence of squeal noise has involved extensive measurement and modelling effort over the decades [Stappenbeck 1954, Rudd 1976, Périard 1998, Cataldi-Spinola 2007, Othman 2009, Pieringer 2011, Krüger 2013]. Though it is now understood why the leading inner wheel of a bogie is most likely to squeal, no model can fully predict squeal events. Special vehicle, bogie and track design, based on continued applied research, can possibly tackle the problem in the long run.

Due to the many parameters that have a large influence on the occurrence of squeal noise, an international measurement standard to specify this type of noise and to determine the effectiveness of measures against squeal, is still lacking. Defining a both useful and practical test set-up, including a reference test curve, is a challenging problem. The Combating Curve Squeal project financed by UIC [ERRI 2003, Oertli 2005] lead to useful practical knowledge on testing procedures and possible measures. Under the recently started Acoutrain project (EC, FP7) an attempt to define a measurement standard for curve squeal is being made.

It is customary to demonstrate the effect of measures against curve squeal graphically by distributions of event noise levels (SEL, $L_{Aeq}$ or $L_{AFmax}$) before and after application of a certain measure. This may be more meaningful than specifying an A-weighted noise reduction.

The effect of curve squeal is usually not accounted for in national noise computation models. The current version of German Schall03 includes a 3 dB(A) penalty for curves between 300 and 500 m radius that are known to produce squeal noise. The European method CNOSSOS suggests adding 8 dB for $R<300$ m and 5 dB for $300$ m-$R<500$ m to the rolling noise sound power spectra for all frequencies.
2.3 Infrastructure measures

2.3.1 Track-mounted friction modifiers and lubrication devices

Screeching problems in curves can be solved effectively by lubrication and application of friction modifiers. The friction coefficient in the wheel/rail contact should not become too low to avoid adhesion problems for traction and braking. Therefore, care is required with certain lubricants or greases, as these may only be applied on the gauge corner of the rail and on the wheel flange. Friction modifiers aim at controlling friction, rather than avoiding it, and are developed to be also applied on top of the rail.

The usual goal to apply these products is reduction of wear and corrugation in curves and switches, but as an important side-effect they avoid squeal and flanging noise.

Track-mounted systems can be considered state-of-the-art nowadays: wiping bars, drains and water spraying. The friction modifier is to be applied on top of the head of the inner rail and may also be applied between the wheel flange and gauge corner of the curve’s outer rail [DBNetze 2012]. The wheels will spread the lubricant further along the curve. After many axles have passed, the effective length of track were squeal is suppressed could be up to 200 meter [Nieuwenhuizen 2010]. Besides track-based systems, also vehicle-mounted systems exist. Especially on locomotives they are state-of-the-art in many railways.

General observations

Experiences in several countries with different devices are listed below. A few general conclusions can be drawn from them:

- Good field test results are important, but only proper maintenance of an application system can make an investment a success in the long run. This means that maintenance staff should be dedicated to avoid or clean clogged nozzles, to refill the tanks regularly, to check if the fluid is well spread along the curve.
- Optimal dosing under various weather conditions requires attention and care.
- Poor curving performance, meaning that a vehicle does not gently move through a curve, can also be a property of the vehicle. This would explain why certain vehicles will still produce squeal noise, even if friction conditions in the curve are perfect.
- ‘Noise reduction’ is not the same as ‘annoyance reduction’, as residents living nearby may still be annoyed by squeal noise in spite of good noise measurement results. This is because lubricants or friction modifiers cause squeal events to occur less often, to have a shorter duration, to be less intense, but hardly ever to vanish completely. The nature of squeal noise (high pitch, loud, unpredictable) makes it hard to ignore.

Test examples and experience with track-mounted devices

A large number of field tests have been performed in various countries. Due to differences in test conditions, friction products and application systems, measurement methods, and
vehicles and curved tracks involved, test results will not be mutually comparable. The results of the tests are summarized in Figure 3.

**Figure 3** Summary of measured noise A-weighted reductions

- Tests at three railway stations in Bern and Zürich over 2005-2009 with Rail Partner lubrication systems showed reasonable to considerable reductions of squeal events and average noise levels [Krüger 2013]. In Bern (curve radius 180 m), the noise around 5 kHz was attenuated by 11 dB and the average duration of squealing was reduced from 9 to 1 seconds. In Zürich-Airport (radius 480 m) the number of squealing events was cut by 30-50%. In Zürich-Stadelhofen (350 m) the main noticeable effect was that the duration of squeal events was halved. This did however not affect the overall noise level.

- The effects of three track-mounted lubrication systems have been evaluated during in the German Konjunkturprogramm II [DB Netze 2012]. These systems were applied in several curves with a radius between 300 and 500 m. The systems under test were anonymized. Results of system type 2 are shown in Figure 1 to the left. The red bars refer to noise events measured before installation, the blue bars after installation. The occurred maximum of peak levels is reduced by about 20 dB. An average noise reduction is not reported, but the results satisfy the 3 dB(A) requirement of the current German noise regulation2. Braking tests showed that the braking distance was not extended unacceptably due to lubrication. Also, electrical circuit measurements revealed no conflict with signalling requirements.

- Austrian Railways (ÖBB) have 600 track-side flange-lubricating devices in use for the purpose of reduction of rail wear and to contribute to better LCC of the track. Noise reduction is not a goal. Suppliers are Hy Power and Martin Schienenotechnik. Top-of-rail

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2 A new version of the Schall 03 regulation, with different prescriptions for curve squeal, is in preparation.
devices from Hy Power (lubricant Sintono Terra HLK) are now being tested in Vienna and Breitenstein.

- In Portugal noise measurements were carried out using the track-mounted system Elpa CL-E1 with friction modifier KL-trinAI [Alarcão 2010]. The reduction effect of lubrication varied between 3 to 10 dB(A), depending on the type of rolling stock. At frequencies above 3 kHz, reductions up to 20 dB were found on average.

- The CL-E1 system has also been tested by ZVD, the Slovenian Institute of Occupational Safety, in 2012. Noise measurements were performed in a long tight railway curve. Figure 4 shows the test results\(^3\). While noise levels up to 110 dB(A) occurred before application of KL-trinAI, the highest level after application was around 90 dB(A).

![Noise distribution - with and without CL-E1 system](image)

**Figure 4** Distribution of noise levels before and after installing the CL-E1 system (Elpa).

- In the UK several recent test with track-mounted systems have been conducted. On a tight curve (<200 m radius) on the Cannon Street line [Richardson 2010] a noise reduction of 1-2 dB(A) was found (Keltrack system). Though this reduction on the overall level is rather small, the report shows that tonal components are attenuated by more than 5 dB. The same device applied at the curve near Barnt Green (190 m radius) led to much higher overall reductions. The maximum $L_{Aeq}$ occurring in the Up direction was about 18 dB lower with the friction modifier active. Above 1 kHz, the reduction of the average noise is more than 15 dB. Possibly a mixture of flanging noise and top-of-rail squeal is addressed here.

\(^3\) Information provided in translation by the manufacturer, from the test report ‘The investigation of noise generated between rail and wheel, with trains running in the curves and the investigation of its reduction because of using an anti-noise device (CL-E1top) and lubricating device (CL-E1ws)’ written by the Institute of Occupational Safety ZVD, Ljubljana, 2012.
Complaints by residents indicate that the lubrication system installed at Barnt Green is only effective against squeal during short periods and certainly not during rainfall [Bailey 2013]. Barnt Green also has a long history with track-mounted water sprays. However, this was considered a rather ineffective means to control squeal and also caused problems with the track bed and the rails [Richardson 2009].

- At Fremantle Port in Perth (Australia), water spray is used in a tight railway curve. A 600 m long system sprays tap water 10 seconds before a train arrives. The results are satisfactory and there is no need to use add substances to the water to improve friction. In winter-time temperatures do not drop below 10 °C, so frost is no problem.

- Australian experience with curve squeal solutions shows that there are vehicles whose poor curving performance is the main controlling factor, on which friction modifiers or lubrication have hardly any effect [Anderson 2007]. Very slight axle misalignments may be associated with poor curving performance. Evidence for this has been derived from wayside angle-of-attack measurements and inspection in workshops. In that case proper maintenance of the bogies is the only cost effective option. In certain curves squealing only became a problem after the former track (timber sleepers, jointed rails) were upgraded (concrete sleepers, continuously welded rail).

- In New Zealand [Apps 2012, Block 2012a, 2012b] test were conducted with Keltrack ‘Trackside Transit’ friction modifier on the Johnsonville Line. The test site was located in curve with 200 m radius. The target friction coefficient of the substance is 0.35. For the test, the product was manually applied on top of the rail using paint rollers, while normally an automatic track-based device is to be used. The test results were promising. Maximum peak levels were reduced by 12 dB(A). Squealing events were reduced significantly. After a variable number of trains had passed, the squealing started again. It was recommended to optimize the frequency of application of the friction modifier.

Cost
The indicative cost of track-mounted friction modifier devices is given in Table 1. Cost refers to one system, which on average controls approximately 480 m of (curved) track.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track-based system friction modifier</td>
<td>DB, KP-II</td>
<td>Germany</td>
<td>per system</td>
<td>13</td>
<td>25,7</td>
<td>5,0</td>
</tr>
</tbody>
</table>
Impressions of track-mounted devices for application of friction modifiers

Friction modifier system (Kelsan)  Water spray system

Friction modifier system (Lincoln)  Friction modifier system (RPD)

Manufacturers and suppliers:
- Dipostel: www.dipostel.fr
- Elpa: www.elpa.si
- Hy Power: www.hy-power.eu
- IGRALUB: www.igralub.ch
- Lincoln: www.lincolnindustrial.com

As there are many different railway lubricants, friction modifier products and application systems, this list will certainly not be exhaustive.
2.3.2 Asymmetrical rail transverse profile and gauge narrowing

Asymmetrical rail profiles and/or slightly narrower track gauges have been proposed against wear in curves. The basic idea is that the contact position on the inside wheel is shifted nearer the flange, thus improving the rolling radius difference of the wheelset. This way, the bogie is caused to traverse the curve more gently [Thompson 2009].

Their effect on curve squeal has been tested in different countries. A pilot study in Switzerland over 2005-2006 disappointingly showed only positive effects for one type of passenger train [Krüger 2013]. A special anti-squeal design [Dirks 2007, Hiensch 2007] has been tested in a curve (200 m radius) near The Hague [Hiensch 2010]. Though the profile did not reduce the number of squeal events, the average $L_{Aeq}$ per squeal event was 3 dB lower than before the test. A second test section with the same profile, of which the inner rail had been impregnated with tungsten carbide (WC), was capable of reducing the number of squeal events from 74% to 26%. The average $L_{Aeq}$ of the squeal events was reduced by 4 dB. However, the wear rate of this sample rail did not meet requirements of sustainability. Also, due to the need to grind away corrugation in the long run, the metal particle impregnation would need to be renewed every five years.

A slightly narrower gauge than standard will shift the contact patch position of wheel and rail. Positive results were reported from tram systems.

![Figure 5 Asymmetrical rail head profile (Hiensch 2007). WC impregnation (Hiensch 2010).](image)
2.4 Rolling stock measures

2.4.1 Vehicle-mounted friction modifiers and lubrication devices

Vehicle-based flange lubrication and/or sanding systems are available on many different locomotives and passenger trains. These systems are more or less standard devices for new rail vehicles, but they are only installed if the customer prefers. Though the main objective of these systems is to improve rolling performance (less rolling resistance means less power consumption) and to reduce flange wear, they can in principle also be used as a measure against squeal noise.

Also truck-based lubrication systems are available on the market, featuring road trucks that can drive on the railway track (manufactured by Portec and by RBL, among others). This solution however requires track closure.

For vehicle-based applications of friction modifiers against curve squeal noise attention must be paid to several practical and organizational issues:

- Cooperation between infrastructure owner and railway operators
- Vehicle must have onboard power equipment (not possible on freight wagons)
- How to decide when and where to apply friction modifier
- Safety aspects (detection, adhesion)
- Environmental effects (emissions)

Impressions of vehicle-mounted devices for application of friction modifiers

Flange lubrication (Kelsan HPF)  
Flange lubrication (Willy Vogel)

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5 Information from Leo Baures (Bombardier Transportation), February 2013.
Test examples and experience with vehicle-mounted devices
The Dutch infrastructure manager ProRail recently finalized a large pilot study called the Wheel Rail Conditioning project (WRC). This study focused on technical aspects as well as organizational aspects required for successful implementation of vehicle-based application of friction modifiers against curve squeal [Van der Vliet 2012]. Noise measurements were conducted on behalf of ProRail in several campaigns in 2011-2012. The main aspects and results of the project are:

- The dosing devices (supplier REBS) were installed on a few EMUs of national type ‘SGM’ operated by NS on the national network
- Several units of train types GTW and Protos, operated by Veolia and Connexxion on regional lines, already had onboard flange lubrication devices, which had to be modified for top-of-rail application in the WRC pilot project
- The friction modifier selected for vehicle-based applications is the same as the one admitted for track-mounted devices in the Netherlands (Headlub 1200 Mb)
- Top-of-rail and flange application on different axles of the same bogie
- Dosing can be controlled remotely or automatically using onboard wheel slip detection [Kofmehl 2012]
- The number of squeal events in the test curve (700 m radius) was reduced from about 50% to about 10%. The average noise level was 4 dB(A) lower. This vehicle-mounted approach was equally effective as a track-mounted RPH system on the same curve [Beuving 2012a and 2012b].
- Possible reduction of wear of rails could not be confirmed during campaigns
- The participating regional operators reported positive effects on wheel wear, braking performance and/or wheel flats
- Tests show that it is difficult to verify the applied dose per meter of track by taking samples. It appears however fairly easy to prove the presence of the friction product,
by spraying some water on the top of the rail, which clearly forms pearls [Beuving 2012a].

**Impressions of vehicle-mounted devices in WRC project**

**Flange application of friction modifier**

**TOR application of friction modifier**

**Cost**

Indicative cost of vehicle-mounted friction modifier devices is given in Table 2.

**Table 2: Indicative cost of vehicle-mounted friction modifier devices.**

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle-based system friction modifier</td>
<td>ProRail, WRC</td>
<td>Netherlands</td>
<td>per train</td>
<td>15</td>
<td>20,0</td>
<td>3.6</td>
</tr>
</tbody>
</table>

**Manufacturers and suppliers:**

- Elpa: [www.elpa.si](http://www.elpa.si)
- Portec Rail: [www.PortecRail.com](http://www.PortecRail.com) (truck-based)
- Rail Partner Deutschland: [www.railpartnerdeutschland.de](http://www.railpartnerdeutschland.de)
- REBS Zentralschmiertechnik: [www.rebs.de](http://www.rebs.de)
- Robolube: [www.rblinc.com](http://www.rblinc.com) (truck-based)
- Vesconite Hilube: [www.vescofile.com](http://www.vescofile.com)
- Willy Vogel AG: [www.vogelag.com](http://www.vogelag.com)
2.4.2 Bogie design

Active steering control is applied in modern trains to improve steering performance of vehicle in curves [Shen 2003, Schneider 2008, Park 2010]. Track-friendly bogie design may also be advantageous for mitigating curve squeal [Andersson 2009]. The design goal is to develop a bogie with soft wheelset guidance in curves, in combination with appropriate yaw damping to ensure stability on straight tracks at higher speeds.

Active steering of wheelsets require advanced control systems that utilise actuators connected to the vehicle axle-boxes. Yawing of the wheelsets into radial alignment is to be enabled in a railway curve. The main challenge is to avoid safety problems at high speeds under any circumstances, for example also when control electronics are malfunctioning.

An alternative to active steering is the application of variable stiffness primary yaw bushes\(^6\) (eg. the HALL bush\(^7\)). These have low stiffness at low frequencies (i.e. low speeds) to achieve good curving behaviour, and high stiffness at higher frequencies to prevent unstable running at greater speeds. In the UK, Network Rail offers reduced track access charges as an incentive for railway operators to install variable stiffness bushes. However, any reduction in curve squeal has yet not been assessed as the main motivation is to reduce track damage.

Wheel dampers

Wheel dampers are only effective on the vehicles that are equipped with such dampers. This makes it a less appropriate measure on main lines that are used by different rolling stock. Nevertheless, wheel dampers have been applied on DMUs in the UK in the 1980s to prevent curve squeal\(^8\). The dampers were constraint layer devices, put on at the factory. The noise reduction effect of wheel dampers in curves is rarely documented, perhaps because a possible effect of wheel dampers is even more difficult to determine than with track-based solutions against squeal. For constrained layer dampers a reduction of 10-15 dB(A) is reported [Nelson 1997], but measurement circumstances are unknown.

Swiss experience with wheel dampers in tight curves show variable results [Bühler 2007]. Sometimes less squealing and sometimes no effect on squeal noise was observed between trains with and without wheel dampers.

Section 5.3.1 of this catalogue deals with rolling noise reduction by wheel dampers.

2.5 References


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\(^6\) Information from Nicholas Craven (Network Rail), May 2013.

\(^7\) HALL= Hydraulisches Achslenkerlager by manufacturer Freudenberg Schwab

\(^8\) Information from Chris Jones (private consultancy), January 2013.
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3

Noise from freight marshalling yards

Executive summary

Marshalling yards are areas where freight trains are formed and the freight wagons are decoupled and coupled. Various noisy activities take place on different periods of the day and on different areas of the yard. Because of the large scale of the yard, mitigation by noise barriers is no option. Measures can only be taken at the source. The most important noise sources are high-pitch curve and switch squeal and screeching brakes. Also impact sounds from coupling vehicles are of concern and starting (diesel) locomotive engines can be heard. Perhaps the most annoying sources on the yards are the rail brakes (retarders), for which new technical solutions have been developed with promising noise performances (5-15 dB(A)). For idling noise, caused by (diesel) locomotives running stationary, different measures are proposed for different types of locomotives. Operational mitigation measures may also be an option, but practical experience with the proposals are not available.

3.1 Introduction

Marshalling yards (French gares de triage, German Rangierbahnhöfe) are areas were freight trains are split up and sorted out. Many marshalling yards were originally built far away from
dwellings, but due to urbanization they often find themselves surrounded by residential areas now. Various sources of noise can be identified at marshalling yards: rolling noise, traction noise, stationary noise from idling diesel locomotives, flanging noise, noise of switches and impact noise from (de)coupling.
In most countries regulations for industrial noise apply to yard operations. Besides the requirements to fulfill noise limits, also the need to handle complaints from residents are incentives to reduce noise from marshalling yards.

3.2 Technical description
In principle, the marshalling process can be done by shunting locomotives that run to and fro. The wagons are collected on one side of the yard and are coupled to compose a new train on the other side.
However, more often gravity is used to do the sorting. For this purpose either a man-made hill, the hump, is used or the whole yard is built on a slope. A locomotive pushes a string of freight wagons to the top of the hump where the wagons are uncoupled, (mostly) one by one. Each wagon is given sufficient momentum to roll towards the so-called classification track to form a new train. On its way, it will pass switches and often also a retarder (rail brake) to slow down the wagon’s speed. If the speed is too low to reach the tail of the new train, a conveyor (German Förderanlage) is used to carry the wagon further.

Hot spot identification
Before a noise mitigation programme can be started on a marshalling yard, one has to determine which sources are contributing most, and also when and where. On a large yard, this is not a simple task. There are different approaches to hot spot identification.

One approach is to do interviews with yard staff in order to determine all relevant processes. The source strength of noisy activities can be assessed by measurements or by making use of existing noise source databases, for example as delivered by the IMAGINE project [IMAGINE 2006].
Another approach is using unmanned noise monitoring stations in combination with advanced signal processing. For example, the TNO Andante system is capable of making a both spatial and temporal identification of hot spots on a large area with multiple noise sources [TNO 2008]. Noise events outside the yard area are excluded automatically. Noise events inside the yard are recorded for playback, if desired.

The next step is to develop a mitigation plan adapted to the findings. In the SILENCE project, a innovative approach towards ‘depots and shunting yards’ has been developed [Beuving 2007]. Instead of a focus on noise levels, it may be more effective to reduce annoyance. To this end, a ranking can be made of the annoyance of various noise events. Though the SILENCE approach concentrates on stabling yards (passenger trains) rather than freight marshalling yards, the methodology is basically the same.
3.3 Infrastructure measures

3.3.1 Silent rail brakes (retarders)

A vehicle passing a rail brakes will in general produce a screeching type of noise, similar to curve squeal. As there are various types of rail brakes, a single solution is not available. In the Czech Republic, special rail brake systems by the Slovenian company Elpa were tested at the yards Havlíčkův Brod [Hlaváček 2012] and Brno-Maloměřice [Hlaváček 2010]. On both sites the system Bremex-Ansys has been installed. This system is designed to reduce wear as well as screeching noise through the use of a lubricant. The noise reports give average results per retarder, before and after lubrication. These noise reductions vary between 5 and 20 dB, presumably dependent on how well the lubricant is applied and on the way of braking.

In the German Konjunkturprogramm II (2009-2011) a lubrication system has been tested on the retarders at the Nuremberg marshalling yard [DBNetze 2012]. In total 14 lubrication devices were installed at various rail brakes. The principal of operation is that a friction modifier is applied to the inner and outer rim of every fifth wheelset passing the retarder. The occurrence of screeching events was reduced from 15% to 5% at the hill retarders and 50% to 10% at the down-hill retarders. The reduction of the average noise was 3.1 dB(A) and 8.0 dB(A), respectively, for the hill and down-hill retarders.

On the Swiss yards in Muttenz and Limmattal tests are being conducted with noise-optimized beam retarders over 2008 (Muttenz) and 2010-2013 (Limmattal). The principle idea is that the metal segments in the retarder are replaced by (sintered) ceramic ones. This would avoid the typical screeching noise of metal on metal. The so-called ‘Silent Segments’ in the retarder have been developed by the Sona company. The new braking system measures the speed of the approaching vehicle and automatically adjusts the braking strength. The replacement of the retarders is part of a large-scale renovation of the marshalling yard in Muttenz. In the final state, the yard will contain 38 switches and 32 classification tracks with a processing capacity of 2400 cars per day. The complete yard consists of continuously welded rails.

SBB commissioned acoustic measurements to verify the noise effect in 2008 [Strobel 2009]. During 18 days in Summer and 8 days in Autumn, measurements were conducted near a conventional and a ceramic rail brake. On dry days, the noise difference between both brakes was 13 dB(A) in Summer and 6 dB(A) in Autumn. This reduced performance could be attributed to strongly worn out sinter elements in Autumn, which were to be replaced after the measurement campaign. The frequencies between 2 and 4 kHz were reduced by about 20 dB. During rainy periods, both types of brakes produced less noise. Even then, the sinter brakes performed better than the conventional ones, 13 dB(A) in Summer, 11 dB(A) in Autumn.

Further experience with these ceramic elements will be built up by SBB on the Limmattal yard. The twelve retarders in Limmattal have all been replaced by the end of 2012. Noise measurements are conducted in Spring 2013.
Impressions of silent rail brakes systems

Lubrication on retarders (Nuremberg)  Bremex-Annsys system for retarders (Elpa)

Beam retarder (Sona)  Silent Segments applied in Muttenz (Switz.)

Cost
The indicative cost of rail brake friction modifier systems is given in Table 3.
### Table 3 Indicative cost of rail brake friction modifier devices.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction modifier system for rail brakes</td>
<td>DB, KP-II</td>
<td>Germany</td>
<td>per system</td>
<td>10</td>
<td>149,4</td>
<td>7,1</td>
</tr>
</tbody>
</table>

#### Manufacturers and suppliers:
- Elpa: [www.elpa.si](http://www.elpa.si) (‘Bremex-Ansyss’)
- Sona: [www.sona-blw.com](http://www.sona-blw.com) (‘Silent Segments’)

#### 3.4 Rolling stock measures

##### 3.4.1 Idling noise

Idling noise is an issue related to diesel locomotives. The first step to reduce idling noise is to investigate if there is a possibility to reduce the duration that locomotives are idling. This would not only be beneficial to minimize noise, but also for fuel consumption and exhaust emissions. Sometimes it is also feasible to find a different spot on the railway yard for locomotives to idle, further away from areas with complaints.

A case study in Chicago [Bubbosh 2004] showed that even though technical devices to reduce idling do exist, they are not applied because of economical reasons and hesitations due to lack of knowledge and ‘ingrained habits or customs’. Idle control technologies switch off the main engine on a locomotive when not in use, without damaging the engine. When the engine is shut down an auxiliary power unit will take over and keep the fuel, oil, water and cabin temperatures at a level necessary for safe, efficient and comfortable operation of the locomotive.

It is possible and feasible to make the cooling fans of Australian 4000 class locomotives more silent by reducing the amount of air passing across the fastest moving part of the blade [Brushe 2008]. It is considered possible to implement this during routine maintenance work.

Frequency analysis of all noise sources was the first step in tackling the stationary noise of a German diesel freight locomotive of type ‘Blue Tiger’ [Czolbe 2007]. Mainly the cooling fans and auxiliary aggregates appeared to be responsible for the excess of the Technical Specification for Interoperability (TSI) limits for stationary noise. Though on flat terrain the noise limit was easily met, on sloped terrain the loco’s piston compressor is permanently running in order to maintain braking pressure. It was demonstrated that mufflers for the compressors and slimshields in front of the cooler vents were appropriate measures to meet the limits.
Appendix C of the TSI Noise 2011 gives measurement details for stationary noise. Point C4.2 gives the definition of the normal operating conditions and does not include intermittent or impulsive sources. It is technically possible to keep idling noise (e.g. from cooling fans) at a fairly low level. However, the current TSI Noise does not set limits for intermittent or impulsive sources, some of which can be major contributors to idling noise. Unless additional noise criteria are included in the procurement specification there is currently no incentive for manufacturers to reduce these annoying types of noise. Noise levels may be up to 15 dB above what is acceptable for the environment. At the time of writing, proposals to include requirements for intermittent and impulsive noise were under discussion within the TSI revision working group and may be adopted in 2014.

3.4.2 Impact noise from bumping and coupling vehicles

Freight vehicles being shunted cause impact noise from bumping buffers and from coupling the draw gears. For mitigation of these impact noises, no feasible technical solutions on the vehicles are available to date. So far, optimization of the vehicle speed, allowing the vehicle to couple as smooth as possible, is probably the only option.

3.5 Operational measures

Various operational measures have been suggested to reduce noise or annoyance from marshalling and stabling yards [Roovers 2004a and 2004b, Beuving 2007]. The SILENCE project produced a list of operational measures, and besides this also suggestions to change the behaviour of the yard’s operating staff [SILENCE-IP 2008]. However, the feasibility of these proposals on real yards is less documented.

On stabling yards, where passenger trains are parked, washed, heated and so on, some flexibility is possible in handling and timing of noisy processes. But most marshalling yards have to cope with tight constraints regarding location and period of actions, which make it virtually impossible to re-arrange or relocate processes in a way that less annoyance is caused near the dwellings.

Banedanmark applies operational measures for stationary noise on marshalling yards\(^9\). Reduction of noise is forced by operation regulations. The main noise issue relates to idling noise of locos. The operators have the opportunity to connect the train to an electrical power system to keep the cooling system running without having the engine of the train running. After 5 minutes the train must be shut down and then the electricity power comes instead from the power stations.

3.6 References


\(^{9}\) Information from Lisette Mortenssen (Banedanmark), May 2013.
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4

Noise from switches

Executive summary

Switches and crossings produce impact noises and various types of screeching noise. If the wagon’s wheelset passes through the switch, it will encounter several interruptions that produce impact noise. The noise of a whole train typically sounds like rattling. Jointless switches are state-of-the-art in most railway networks (2-4 dB(A)). For existing switches most of those interruptions can in principle be replaced by thermite weldings. Insulated joints cannot be welded. Remedies available are low wear (low noise) alternatives that minimize vibrational effects. Also a crossing nose (see Figure 6) or frog cannot be welded. Remedies like swingnose crossings have no significant excess noise compared to normal tracks. In short switches it is not possible to completely avoid impact noise.

![Diagram of a switch with a crossing nose and crossing angle](image)

Figure 6  Top view of a switch, the position of a crossing nose and the definition of a crossing angle

The squealing noise that occurs in switches have the same origin as noise caused by small radius curves. Wheel squeal noise is tonal noise and is associated with lateral stick-slip. Top-of-rail application of friction modifiers is the usual treatment. Flanging noise is non-tonal and is related to rubbing of the wheel flange against the gauge corner of the rail. Application lubricants or friction modifiers in the gauge corner are remedies (5-20 dB(A)).

4.1 Introduction

A wide-range of switches and crossings is applied by the railways, even within one country. The curve radius of the turn-out branch depends on the operational driving speed and may vary between some 90 and 2000 m. Switches and crossings produce impact noises and various types of screeching noise. The cause of impact noises is the fact that a wheel running through the switch encounters one or more joints, sometimes dependent on the branch taken. The
noise of a whole train typically sounds like rattling. Apart from a rattling sounds, also squeal noise and flanging noise can be a nuisance. These noises are similar to those described in Chapter 2 on curve squeal. A switch also often contains check rails to avoid derailment, which may lead to additional flange-related noises.

A switch also produces noise when it is thrown. This noise level is generally much lower than that of a train running through it, and is therefore not normally considered to be a problem that needs to be solved.

Switches and crossings are sensitive parts of the railway system. Proper performance of these units requires much attention and budget. Therefore switches often represents a significant part of the overall track maintenance budget. Practical noise control measures will have to be sensitive to this issue and avoid any significant increase to these already high costs. For example:

- Sweden: 13% of the annual maintenance budget was spent by Banverket on their 12,000 switches and crossings in 2005.
- The Netherlands: The 7,500 switches and crossings consume 35% of ProRail’s maintenance budget. The investment costs per unit are 250,000 euro and the same budget is spent on maintenance during its average life time of 18 years [ProRail 2010b].

4.2 Technical description

**Rattling noise due to joints**

If the wheelset passes through the switch, it will encounter several interruptions that produce impact noise. There are basically two kinds of interruptions:

- Rail joints. Jointed switches are usually found on parts of the network where the speed is low (stations, yards and junctions).
- The gap near the crossing nose or frog. This gap is not present in so-called swingnose crossings.

A wheel passing an interruption invokes high contact forces. A gap is described physically by its width, the step height (vertical level difference on either side of the gap), and the dip angle (caused by the rail edge being pushed down by the wheel) [Thompson 2009]. Advanced model calculations show that the impact noise is mainly caused by the depth and the dip angle, so the gap width is rather unimportant. The speed dependency of the impact sound power of a single joint is about 20 log \( V \). This means that the noise at 80 km/h is about 6 dB(A) higher than at 40 km/h.

The relative displacement that is caused in the wheel/rail system by a wheel passing a joint can be described by an equivalent roughness spectrum. The theoretical basis for this conversion is given by Wu and Thompson, see for example [Wu 2001].
Most railways nowadays apply jointless switches and crossings on the network, especially were speeds well above 40 km/h are to be achieved. The turnout length of those switches is fairly large and the frog angle is shallow. If jointless switches and crossings are maintained well, there is no reason that they should cause excess noise, compared to the rolling noise on the track before and after them.

**Figure 7** Lay-out and terminology of switches and crossings.

**Squealing noise due to curvature**

The high pitch noises that occur in switches have the same origin as noise caused by small radius curves. It is important to be able to distinguish between flanging noise and curve squeal noise in a switch, as different solutions are proposed to either of them.

- Wheel squeal noise is tonal noise corresponding to distinct modal frequencies of the wheel, as described in detail in Chapter 2. Squeal noise is associated with lateral stick-slip. Top-of-rail application of friction modifiers is the usual treatment, see Chapter 2.
- More typical for switches than for curves are different noises related to rubbing of the wheel flange against the gauge corner of the rail. Also the noise of the flange against the check rail is noticeable. Flanging noise is non-tonal and sounds more or less like consonants ‘f’ and ‘s’ (at high levels). Application lubricants or friction modifiers in the gauge corner are remedies.
Other noises related to flange rubbing have been described as low frequency ‘grauenching’ [Thompson 2009].

![Figure 8 Cross-section of wheel and rail.](image)

4.3 Solutions

4.3.1 Jointless switches

Most of those interruptions in a switch and crossing can in principle be replaced by thermite weldings, as is explained in a text frame in this section. The insulated joints that are needed for signalling cannot be welded, but there are low wear (low noise) alternatives that minimize the vibrational effects of those gaps.

Another interruption that cannot be welded is located at the crossing nose or frog [Nieuwenhuizen 2011]. This means that a switch that is made jointless by welding (retrofitting) will still keep one impact point. In switches with shallow crossing angles it is possible to apply swingnose crossings (moveable frogs). Check rails are absent in such crossings. Switch systems with swingnose crossings have no significant excess noise compared to normal tracks [Oostermeijer 2002].

In short switches (high crossing angles), meant for low speeds (typically less than 40 km/h), it is not possible to completely avoid impact noise.

A double slip switch\(^{10}\) contains two types of crossings: V-shaped and X-shaped. The impact noise at the X-shaped crossing is usually much higher than at the V-shape, because both wheels of a wheelset are forced to pass a gap there [Nieuwenhuizen 2011].

\(^{10}\) In many countries this is called an ‘English switch’
Impressions of switches with swingnose crossings

Conventional track  High speed track

Jointless switches are state-of-the-art in most railway networks. Most existing switches can be made jointless by thermite welding. For insulated rail joints, i.e. joints that are necessary for signalling, various state-of-the-art solutions exist that reduce impact noise, wear and maintenance costs. These solutions comprise angular cuts, pre-stressed ceramics, V-shaped cuts, glued joints.

At marshalling yards with many switches it will be a rather costly solution to make all switches jointless. Besides this, if the trains speeds remain low, a well-maintained jointed switch will not cause excessive noise. If impact noise from switches contributes largely to the total noise of the yard, it could be worthwhile to remove the gaps by welding. Also, it should be considered that replacement of parts of switches due to wear will be much more difficult if switches are fully jointless [ProRail 2004].

Figure 9  Position of the gaps (numbered) in a low-speed jointed switch [ProRail 2004].

11 Information from Franck Poisson (SNCF), May 2013.
The UK computation model CRN [DeptTransport 1995] accounts for 2.5 dB increase of noise due to points and crossings.

Measurements in a classical turnout (switch) in the Netherlands revealed a rolling stock dependency on the excess noise due to joints [Wagemakers 1998]. It was shown that the impact noise from a gap in straight jointed track was similar to that from a similar gap in a switch. The point (=crossing) of the switch appeared not to contribute to the total noise of the jointed switch under test. The Dutch computation method accounts for 3 to 4 joints per classical switch. Locally this leads to 4-5 dB(A) excess noise compared to standard track.

RailCorp has many jointless switches, but does not apply swingnose crossings in their jointless switches.

4.3.2 Friction modifiers and lubrication

Squealing and flanging noise in switches can be an important source of complaints near stations and marshalling yards.

In the framework of the Dutch UPGE programme (2005-2010), friction conditioning devices of supplier Rail Partner Holland (RPH) have been installed in switches at 70 freight and passenger yards [MinI&M 2013]. The devices are basically the same as those designed for curve squeal. The target of this investment is that a 10 dB(A) lower source power can be used for the noise computations that are required for the environmental permits of the yards. The RPH track-based device is equipped with an axle counter. A new dose of is released after a certain amount of axles has been counted [ProRail 2007a]. ProRail has selected Headlub 1200 Mb as friction modifier to be used in these devices. There is a long-lasting experience with this the product in the Netherlands, it has been used at the Amsterdam stabling yard ‘Watergraafsmeer’ since 1998. The intermediate evaluations show that 10 dB(A) reduction can be achieved on switches, but sometimes it takes a few weeks [Nieuwenhuizen 2012b] or even a few months [Nieuwenhuizen 2012a] before satisfactory effects are observed. Once again it appears difficult to exactly quantify the effect by measurements, because the performance varies between rolling stock and it depends on relative air humidity. It also appeared necessary to correct the results for impact noise due to joints and increasing rolling noise due to corrugation growth.

In the stabling yard near the city of Alkmaar the percentage of squeal events in two switches was reduced from 90% (before treatment) to 10-30% (after treatment). In two switches at a railway yard near Apeldoorn the rate of squeal events was reduced from 33-45% (before) to 11-15% (after).

The effects of water spray as a measure against squeal noise from switches was tested in a switch (high angle 1:10) in the Netherlands [Kootwijk 1995]. Different passenger trains were used in the trials. Though it was observed that squeal events vanished completely in the wet

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12 Information from Dave Anderson (Railcorp), April 2013.
switch, there was a slight increase in noise emission between 250 and 500 Hz. The researchers found this rather ‘rumbling’ noise much less annoying than the squeal noise.

Cost
The indicative cost of friction modifier systems for switches is the same as for systems applied in curves, see Table 1 on page 14.

4.4 References

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Other noise measures

Executive summary

In this final chapter new techniques and developments of mitigation methods against rolling noise are treated. Rolling noise is the most common source of railway noise, caused by wheel and rail vibrations that are induced by the combined rail and wheel roughness in the contact patch.

There is a long history of technical measures against rolling noise. Some solutions aim at reducing rail roughness, for example by *acoustic grinding* (1-3 dB(A)), and wheel roughness, by applying *LL and K blocks* instead of cast-iron braking blocks (8-10 dB(A)). Other methods attempt to reduce the sound power at the source by vibration absorbers, such as *rail dampers* (0-3 dB(A)) and *wheel dampers* (0-2 dB(A)). Finally, the transfer path from the track to the environment can be shielded by *noise barriers*.

![Rolling noise generation](image)

Figure 10 Rolling noise generation.

5.1 Introduction

This chapter deals with technical solutions against other sources of railway noise. A division is made between infrastructure-related and vehicle-related solutions.

The infrastructure measures are:
- Rail dampers
- Acoustic grinding
- Low height barriers close to the track
- Special barrier tops
The rolling stock measures are:
- Wheel dampers
- K and LL blocks

5.2 Infrastructure measures

5.2.1 Rail dampers

Introduction
Rail dampers (or rail absorbers) are devices that reduce rolling noise by absorbing vibrations of the rail. Rail dampers consist of elements that are mounted to the rail web and foot, and sometimes also under the rail foot. Most types are placed at mid-span, halfway between the sleepers or fasteners. The first practical applications of rail dampers were on railway bridges. A large step forward was made with the Silent Track rail damper (2000). This type was effective on normal tracks as well. Many more dampers have been designed and tested during the past decade.

Technical description
The working principle of the rail damper is that the vibration bending waves in the rail, that radiated the noise, are attenuated [Thompson 2009]. The performance of rail dampers is characterised by the extend to which the track decay rate (TDR) is increased: the higher the decay rate, the lower the noise emission of rail and sleeper. As the rail is already highly damped, a good rail damper design will require a substantial amount of mass. The spring-mass system of an effective damper is tuned in a wide range between 500 and 2000 Hz, where the rail vibrations are important sources of rolling noise.

On theoretical grounds it can be expected that rail dampers also (slightly) reduce corrugation growth [Thompson 2009]. Short-term field tests seem to confirm this [Ho 2012], but long-term experiments would be necessary to prove this.

The effect of a rail damper cannot be expressed in a single noise reduction value that is valid for every country or situation. This is because the noise reduction depends largely on the characteristics of the track system without dampers. Figure 11 visualizes how rail dampers reduce the track contribution and thereby the total rolling noise. On most track systems, the sound power emitted by the vehicle is (much) less than that of the track. The rail damper does not affect the vehicle contribution. If the track is the dominating source, the total noise can be reduced considerably. At low speeds (<40 km/h), where traction noise may dominate the total noise, rail dampers will be ineffective. At high speeds, where aerodynamic noise is important, an effect of rail dampers of 1 dB(A) could still be determined. This is shown by measurements in France at speeds around 300 km/h still show [Létourneaux 2007].
In order to assess the efficiency of dampers, the STARDAMP project (2010-2012) has developed an ‘easy-to-handle methodology which allows manufacturers and end users to predict the noise mitigation potential of a damper on the basis of readily available laboratory tests without the necessity to perform field tests’ [Venghaus 2012]. This is possible because the additional damping caused by rail dampers can be superposed to the existing damping of a real track without dampers. The damping efficiency of the products can be estimated using a free rail in a laboratory, supported by very soft rubber pads. The project has delivered a software tool that enables users to calculate the noise reduction of different dampers on different track systems.

In Switzerland a large feasibility study including a field test programme with rail dampers is being conducted by SBB during 2010-2013 [Oertli 2013]. This study pays attention to the
effect of possible variations on the network (sleeper type, pad type, age, rolling stock, speed, temperature) on the noise reduction by rail dampers. This is important because of varying degrees of success with dampers in other countries. Variations of the achieved noise reduction measured on similar sites were sometimes of the same order of magnitude as the noise reduction itself. For this purpose the TDR has been measured on many representative locations of the network. Meanwhile, the so-called Car Park Test set-up, developed in STARDAMP, was followed (see Figure 12). The four rail dampers on trial were made by Tata, Vossloh, S&V and STRAIL.

The results in terms of the predicted noise reduction on different Swiss track types are still being studied and have not yet been published. So far, it can be concluded that the differences in TDR between track types are much larger than the differences in damping efficiency between different rail dampers.

In the framework of the German Konjunkturprogramm II, five different types of rail dampers were mounted on 92 km of track between 2009 and 2011 [DBNetze 2012]. The achieved noise reduction depends on the type of product but also on the rolling stock. The best performing dampers types appear to reduce the noise by 2 dB(A) on average (for speed < 200 km/h). In the same test program also ‘rail screens’ were investigated. These mini-screens are attached to the rail in a similar way as rail dampers, but they only absorb the noise radiated from the rails and do not affect rail vibrations. Again, the noise reduction varies with rolling stock and with the type of screening product. The average reduction of the total noise was 3 dB(A), which is slightly higher than for the rail dampers.

According to the UIC questionnaire of 2012 about 140 km of track in Germany has been equipped with rail dampers [DHV 2013b].

In France dampers were tested on tracks and on bridges [Scossa-Romano 2012]. The acoustic performance of dampers was tested in 2004. Design requirements for the dampers included that the operation and maintenance of the track will not be affected. The dampers were installed on a conventional railway line with ballasted track, bibloc concrete sleepers, UIC60 rail, 9 mm stiff rubber rail pads. The rail dampers were the Corus Silent Track (now by Tata Steel) and Schrey und Veit dampers. The noise reduction at operational train speeds was between 1.7 and 2.9 dB(A). This performance was not sensitive to the type of rolling stock, however, appeared to depend on the reference track definition. After repeated measurements in 2005, the conclusive reported reduction on normal track was between 2 and 4 dB(A). On the Gavignot bridge a reduction of 4 to 5 dB(A) was measured.

According to the UIC questionnaire of 2012 about 50 km of track in France has been equipped with rail dampers [DHV 2013b].

In Sweden and the Netherlands noise reductions between 1 and 3 dB(A) were measured with various dampers [Verheijen 2003, Nielsen 2009a and 2009b]. In the Netherlands, finally only the Schrey und Veit and Tata steel rail dampers were admitted to the network [ProRail 2007b]. For both a fixed 3 dB(A) reduction is accounted in the national computation method.
ProRail calculated that rail dampers are more cost-effective on a double track than noise barriers of 1 meter height at one side of the railway line. Because of this, between 2007 and 2012 about 106 km of rail dampers have been installed on the Dutch network at locations where otherwise (higher) barriers would have been necessary.

In 2011 Banedanmark tested the effect of rail dampers. From these tests Banedanmark decided not use rail dampers as a noise measure. The main reason was the relatively small noise reduction in view of the increased complexity of the railway track system.

In the Czech Republic, the Vossloh and Tata Steel dampers have been used since 2008 and so far been installed on three track sections. Especially with freight trains, the dampers seem to perform less than with disc braked passenger trains. Besides this, noise measurements after implementation demonstrated that the efficiency of the Vossloh damper decreased. Dampers of various makes have been tested: Schrey und Veit, Tata Steel, Vossloh, STRIALastic, CDM and others.

In the state-of-the-art UIC report *Rail Dampers, Acoustic Rail Grinding, Low Height Noise Barriers* [Scossa-Romano 2012] it is concluded that there is a large variability in the results ranging from small increases in noise to a maximum noise reduction of usually not more than 3 dB.

**Impressions of rail dampers mounted in track**

*Vossloh ‘short without coupler’*  
*Tata Steel ‘Silent Track’*
The indicative cost of rail dampers is given in Table 4.
Table 4 Indicative cost of rail dampers.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail dampers</td>
<td>DB, KP-II</td>
<td>Germany</td>
<td>per km track</td>
<td>13</td>
<td>226,2</td>
<td>10,7</td>
</tr>
<tr>
<td>ProRail</td>
<td>Netherlands</td>
<td></td>
<td>per km track</td>
<td>25</td>
<td>240</td>
<td>11,9</td>
</tr>
<tr>
<td>Rail screens</td>
<td>DB, KP-II</td>
<td>Germany</td>
<td>per km track</td>
<td>13</td>
<td>163,7</td>
<td>11,7</td>
</tr>
</tbody>
</table>

Manufacturers:
- CDM: [www.cdm.eu](http://www.cdm.eu)
- Schrey & Veit: [www.sundv.de](http://www.sundv.de)
- STRAIL: [www.strail.de](http://www.strail.de)
- Tata Steel: [www.tatasteelrail.com](http://www.tatasteelrail.com)
- Vossloh: [www.vossloh-innotrans.com](http://www.vossloh-innotrans.com)
- Wilson Acoustics: [www.wal.hk](http://www.wal.hk)

5.2.2 Maintenance grinding and acoustic grinding

Introduction
Rolling noise depends to a large extent on the sum of rail and wheel roughness. Therefore a smooth rail is an important element in reducing railway noise [Scossa-Romano 2012]. Most railways consider regular grinding to be an essential part of good track maintenance. Just like ballast tamping, regular grinding can be cost-saving as track defects and safety issues decrease.

Removal of the corrugation layer of the rail head can be achieved by different surface treatment techniques, such as milling and grinding. Most railway infrastructure managers apply a regular grinding regime for track maintenance. This will result in a railway network without severe corrugation, with obvious acoustic benefits. For example, Network Rail introduced a new grinding strategy from 2002, of which a large improvement of the overall acoustic track quality by 8 dB(A) was suggested by a survey [Craven 2012].

Technical description
‘Acoustic grinding’ implies that an additional and dedicated grinding process aims at rolling noise reduction. It means that the rails are kept in such (smooth) condition that in some countries it is legally allowed to apply a lower than normal noise emission value in noise computations (noise mapping or noise reception calculations of dwellings). However, as rail roughness tends to grow back again after grinding, it will be necessary to monitor the noise emission regularly, see Figure 13.
The first country that introduced acoustic grinding was Germany in the late 1990s [Umweltbundesamt 1997] in the framework of a noise remedial program. The railway lines that were treated by this new noise measure are called specially monitored tracks (German: BüG). A fixed noise reduction of 3 dB(A) is associated with BüG in the German computation model Schall 03. The roughness development is monitored regularly (twice a year) by a special noise measuring train (Schallmesszug). If the emission limit is exceeded, the track is ground again.

**High Speed Grinding**

High speed grinding has been developed in Germany as a special technical implementation of maintenance grinding. While normal grinding trains run at low speed, the machines used for high speed grinding (Vossloh Rail Services) can run up to 100 km/h (in Germany 80 km/h is allowed). Because of this relatively high speed, less rail material can be removed per run, but this may be compensated by running more often. The main advantage is that these high speed grinding trains can operate without track closure. Because track occupancy time for maintenance is reduced, the line capacity for normal service is increased.

It has furthermore been demonstrated in Konjunkturprogramm II that the resulting average roughness of a track under the regime of high speed grinding is of the same quality as BüG [DBNetze 2012]. A reduction of 6 dB(A) can be achieved. This means that high speed grinding in principal could fulfill the requirements of acoustic grinding, though this has not yet been acknowledged legally in Germany.

The indicative cost of high speed grinding is given in Table 4.

---

**Figure 13** Effect of maintenance grinding and acoustic grinding as a function of time.
Table 5: Indicative cost of high speed grinding.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed (acoustic) grinding</td>
<td>DB Netz</td>
<td>Germany</td>
<td>per km track</td>
<td>-</td>
<td>-</td>
<td>3.0 - 4.0</td>
</tr>
</tbody>
</table>

Roughness monitoring

The rail roughness and especially the effect of acoustic grinding should be monitored regularly. For this purpose different methods have been developed or proposed. Most of these apply a measuring coach, with microphones or axle-box accelerometers [Jones 2000, Windelberg 2006, Bongini 2008, Delavaud 2009, Kuijpers 2009]. As the sensitivity of this system is affected by the wheel roughness of the test vehicle, measuring bogie should possibly have unbraked (i.e. smooth) wheels. Special algorithms are needed to process the measured data into speed-independent values that can be compared with the legal limits. A limitation of these monitoring devices is that besides rail roughness also differences in track superstructure will determine the output [Bongini 2008].

Practical experience

In Finland acoustic grinding is tested as a measure on a track in 2011[14]. The first tests showed an increase of noise levels, while the second one shows a decrease. Grinding is not a regular noise measure in Finland because there is no grinding train (different track gauge) and because a lack of resources.

Banedanmark use high speed acoustic grinding at 80 km/h for sections with complaints about noise[15]. In 2013 Banedanmark will finish a research project with acoustic grinding on 4 to 5 sites. At present, no results are available.

The Belgian infrastructure manager InfraBel has conducted a test programme during 2011-2012 [Verhelst 2012]. During this programme a ‘semi-acoustic’ grinding treatment was developed, featuring a final pass of the grinding train at 12 km/h instead of 5 km/h. The target was to reduce the 2,5 cm corrugation waves better than with standard maintenance grinding. This corrugation wavelength dominates the noise emission at 1 kHz at regular train service speeds. By semi-acoustic grinding a 3-4 dB(A) noise reduction is achieved six months after grinding.

---

In the Netherlands acoustic grinding is in principle allowed. The main difference with other legal noise measures is that acoustic grinding is not included in the legal cost-benefit scheme of noise measures. This means that infrastructure manager ProRail can freely decide whether or not to apply acoustic grinding as an alternative to rail dampers or noise barriers. In other words, there is no legal possibility for municipalities to force ProRail to apply acoustic grinding instead of installing noise barriers or rail dampers. In practice, however, acoustic grinding is only applied on the high-speed line from Amsterdam to Antwerp. For a railway line where acoustic grinding is applied, deviating average roughness spectra should be used in legal noise calculations in the Netherlands, see the graph.

![Graph of Legal roughness spectra in the Netherlands (RMG 2012). TSI limit shown for reference.](image)

Grinding companies known to have experience with acoustic grinding:
- Schweerbau: [www.schweerbau.de](http://www.schweerbau.de)
- Speno International: [www.speno.ch](http://www.speno.ch)
- Vossloh Rail Services: [www.vossloh-rail-services.com](http://www.vossloh-rail-services.com)

5.2.3 Low-close noise barriers

**Introduction**

Low height barriers close to the track (‘low-close barriers’) can sometimes be an alternative for (higher) traditional barriers. Normal barriers are built at a distance of about 4-4.5 m from the track axis and have a height which usually varies between 1 and 4 m above the railhead. Low-close barriers are typically installed at about 1.70 m distance from the axis of the
nearest track and have a height of about 0.5 to 1 m. The advantage of low-close barriers is that the view across the track is not blocked, making them more acceptable in urban design and planning. The measured noise reduction of these barriers varies between 2 and 10 dB, depending on the strength of rolling noise compared to the total noise [Scossa-Romano 2012].

As Figure 15 points out, a low-close barrier is less effective in double track situations. The noise from the farther track is hardly shielded. In such cases, it could be necessary to place an additional low-close barrier between both tracks (not drawn in Figure 15).

![Figure 15 Conventional and low-close barriers on single and double track.](image)

**Technical description**

From an acoustic point of view, barriers close to the track may be more effective than at standard distances, provided that the dominant noise sources are below the top of the barrier. From a maintenance and construction point of view, there are reasons to be cautious [Scossa-Romano 2012]:

- Even with a small foundation there may be a conflict with drainage, cabling, and construction elements close to the track
- Track maintenance may be more difficult and therefore more expensive
- Problems may occur in case of accidents e.g. because of increase in evacuation time
- Increased risk for staff. Low barriers are for staff working on the rail a difficult obstacle to pass up in the case of train pass by.
- Risk of snow building up along the inside of the barriers and uncertain consequences for snow removal [Swets 2009].
- Costs can be similar to normal height barriers if low height barriers are required between tracks.
Nevertheless, certain countries have attempted to make progress in admission of low-close barriers to their railway network during the past decade. Their experiences are described below.

**Practical experience**

The Zbloc barrier, tested in Sweden, is placed at 1.70 m from the centre of track, at 0.73 above the rail head [Nielsen 2009b]. The efficiency of the barrier varies from about 4-6 dB(A) for freight trains, X40 train and IC train, until about 8-9 dB(A) for passenger trains X12 and X60. The difference is caused by the lay-out of the X12 and X60 trains, causing the effective source height of the train to be lower.

The National Rail Administration of Norway has approved the use of close-track barriers, following an extensive assessment study for upgrading the Stavanger-Sandnes railway line [Swets 2009]. The residents along the line had strong objections against the 2-2.5 m height barriers that were initially planned, because their sea views were blocked. Several maintenance and safety issues had to be solved before the barriers were admitted. Pilot projects in Sweden demonstrated that snow building up would not be a problem. A top platform ensures that passengers could pass safely in case of emergency. Steps were fitted every 30 m to allow safe descent.

The barrier design is 0.73 m above railhead, 1.70 m from track centre and the inner side is with absorptive material. The acoustic efficiency of the barrier design is such that both tracks need a barrier, were otherwise only one traditional barrier of 2-2.5 m height at normal distance (4-4.5 m) would be sufficient. However, there appeared to be little difference in life cycle costs compared to the traditional barrier.

Initially, ÖBB reported promising test results with low noise barriers near the track in Austria in 2011 [Sossa-Romano 2012]. Due to safety issues, the product could not be admitted and ÖBB decided not to proceed with low-close barriers.\(^\text{16}\)

Low level noise barriers have been installed in the UK on the HSE1 (Channel Tunnel Rail Link) on structures (bridges and viaducts). The original design consisted of traditional barriers of 2 m height at about 4-4.5 m from the centre of the track. The innovative design featured 1.4 m high barriers placed at approximately 2.5 m from the centre of the track [NECR 2011].

ProRail is testing low-close barriers along 600 m of track in the town of Hilversum [Hilversum 2013]. The trial aims at gaining experience with maintenance and safety aspects. Interestingly, an initial safety assessment led to the decision to place the 0.84 m high barriers at 1.70 m (similar to platforms at stations) from the centre of track, while 2.35 m was intended originally. The barrier design consists of stone-filled gabions tied together with wire. The barrier has a step-shaped outer side for emergency situations.

\(^{16}\) Information from Günter Dinhobl (ÖBB), e-mail 11 April 2013.
In Finland tests are planned with a barrier of height 0.85 m and length 2 x 140 m in Tampere\(^\text{17}\).

In the German Konjunkturprogramm II (KP II) a test with 7 different low-close barriers at 9 locations was set up [DBNetze 2012]. Besides the earlier mentioned Zbloc barrier, also various other types such as steel constructions and stone-filled gabions were investigated. The barriers were placed at a distance of 1.75 m to the centre of the track, and had heights of either 55 cm or 74 cm above the top of the rail. Acoustic measurements were conducted at 25 m distance at receiver heights 3.5 m, 6.3 m and 9.1 m. For the 74 cm barriers, the pass-by noise of the track next to the barrier was reduced by about 6 dB(A), 5 dB(A) and 4 dB(A) for the respective receiver heights. For the farther track, the reductions were lower: 4 dB(A), 1 dB(A) and 0 dB(A), respectively. The results for the 55 cm barriers varied between 0 at 3.5 m receiver height and about 2 dB(A) at 3.5 m receiver height. The reduction effect for freight trains was similar than for passenger trains, though sometimes 1 dB(A) less.

It was concluded for double-track situations with low-close barriers on both sides also a middle barrier would be desirable, theoretically improving the total reduction by 2 dB(A). However, this would probably require more space than usually available between existing tracks. Currently for reasons of employment protection and evacuation, only the one-sided barrier has been homologated.

**Acoustic calculations**

Besides technical and safety aspects, the introduction of barriers close to the track may require that legal noise computation models have to be modified. Such models have been designed to cope with regular distances of barriers and use simplifications that do not necessarily hold for low barriers near the track. For example in the Netherlands the national model has been tested for low-close barriers applications and was found to be suitable, but in Germany these barriers would require model adaptations.

\(^{17}\) Information from Erkki Poikolainen (Finnish Railways), February 2013.
Impressions of low-close barriers

KP II barrier Ludwigshafen
KP II barrier Mannheim
KP II barrier Oberwesel
KP II barrier Cologne
Zbloc (Sweden)
Soundlm Rail (Finland)

Installing 73 cm high barriers near Stavanger (Norway) with 30 cm wide top platform
Manufacturers:
- Ferrondo barrier: www.ferrondo.de
- ProKOP Rail: www.brens.cz
- SoundIm barrier: www.soundim.fi
- Zbloc barrier: zblocinternational.com

Cost
The indicative cost of low-close barriers is given in Table 6.

Table 6 Indicative cost of low-close barriers (74 cm height, rigid model, one-sided).

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-close barriers</td>
<td>DB, KP-II</td>
<td>Germany</td>
<td>per km track</td>
<td>25</td>
<td>1152</td>
<td>0,0</td>
</tr>
</tbody>
</table>

5.2.4 Noise barrier tops

Introduction
Special barrier tops have been proposed to improve the performance of noise barriers. The idea is that a noise barrier with such a top would be equally effective than a higher traditional barrier. The designs range from a T-top concept to a cylindrical top, a mushroom-shaped top edge, and an active noise control along the barrier’s top edge [Watson 2006].

Literature on these types of noise barriers concentrates mostly on road traffic applications. Some countries conducted also tests along railway lines. Special top designs typically give a reduction of a few decibels compared to a barrier without such a top. The observed effect
depends strongly on the relative positions of the source, the barrier and the receiver. The advantages of special barrier tops are:

- For new barriers: the total height can be lower, therefore the view from residents across the railway line is blocked less.
- For existing barriers: a light-weight top construction does not require modification of the foundation of the original barrier, and would therefore save costs in a situation where the original barrier would have to be replaced by a slightly higher barrier.

![Figure 16 Diffraction edge of a T-top (right) compared to a normal barrier (left).](image)

**Technical description**

The acoustic principle of operation of T-top and similar tops is that the diffraction edge of the barrier is moved closer to the source, thus slightly lifting the equivalent height of the barrier (Figure 16). Certain other barrier top designs would improve the barrier’s diffraction characteristics as a result of enlargement of the effective (absorptive) top surface but sometimes also by Helmholtz resonators or other devices.

Tests in Austria with top elements for noise barriers demonstrated that effects were noticeable but less effective than predicted\(^\text{18}\).

In The Netherlands a T-top noise barrier is developed for use along motorways. This development was part of the Innovation Programme Noise [Ooststroom 2006]. Since 2006 this barrier can be used as a regular noise measure. In The Netherlands no applications of barrier tops along motorways or railway lines are known to date.

In Germany a comb-shaped diffraction top has been tested for railway applications [DBNetze 2012]. The top device was a construction with discs made of absorptive material. Comparison with an equally high (2.5 m) conventional barrier showed no significant additional effect.

In France a modular top system has been developed and tested on a high speed line by SNCF [Belingard 2010]. Several different configurations with absorptive top panels are possible. These are placed in a metal frame on top of a concrete barrier. The Y-shaped configuration

\(^{18}\text{Information from Günter Dinhobl (ÖBB), e-mail 11 April 2013.}\)
appeared to be most effective. This configuration consists of two absorptive upper branches (V-shaped, height 1 meter) on top of a reflective basis of 1.1 m height (I-shaped) above the railhead. Compared to a standard reflective barrier of 2.1 m height above the railhead, this device yields an additional noise reduction of 4 dB(A) (TGV at 375 km/h, microphone at 25 m from the track axis, 3.5 m above the railhead).

Impressions of special barriers tops

No real life implementations with barrier tops along railways are known to date. Information about manufacturers and suppliers of special barrier tops is not available.
5.3 Rolling stock measures

5.3.1 Wheel dampers

Introduction
For a long time, application of wheel dampers has been more common in light-rail or tramways than in heavy rail. But new rolling stock is increasingly equipped with wheel dampers from the factory. An example is the Pendolino passenger trains in Finland\(^{19}\).

Technical description
There are various designs of wheel dampers:
- Plate dampers, a plate that absorbs noise and vibrations is mounted to the web
- Sandwich dampers, sets of sandwich dampers that are mounted to the tyre
- Ring dampers, a metal ring that is sprung into a groove in the tyre
- Constrained layer dampers, thin layers of damping material glued to the web
- Friction dampers, consisting of metal plates that produce friction energy while damping vibrations

In practice the choice to implement a wheel damper on a certain wheel is limited. For example, not all wheel dampers can be combined with cheek mounted disk brakes.

Practical experience
The noise reduction of DAAVAC multi-layered ring dampers on a TGV-duplex running at high speed (250-300 km/h) was about 3 dB(A) [Létourneaux 2007]. An AGC train with DAAVAC dampers at 80 km/h yielded about 1 dB(A) reduction [Asmussen 2008].

A freight wagon on which Lucchini wheel dampers were installed showed a noise reduction of 1 dB(A) at 80 km/h and 2 dB(A) at 120 km/h [Asmussen 2008].

In the LZarG project (2008-2012) the following wheel dampers were developed [Bänsch 2012]:
- Wheel damper (Schrey & Veit) for wheel set BA308 (Gutehoffnungshütte Radsatz)
- Wheel damper (Bochumer Verein Verkehrstechnik) for wheel set BA308 (Bochumer Verein Verkehrstechnik)

In principle, a good wheel damper will not only reduce the wheel noise but also rail noise, but this additional effect is usually negligible [Thompson 2009]. Measurements of the noise reduction caused by a plate damper on the Airport Express train near Oslo gave 3 dB(A) effect at 200 km/h [Färm 2001]. By model calculations it was estimated that this total effect was composed of 5 dB(A) wheel noise reduction and 1 dB(A) rail noise reduction. At lower speeds, the total noise reduction was lower, 1 dB(A).

\(^{19}\) Information from Erkki Poikolainen (Finnish Transport Agency - Liikennevirasto), February 2013.
Impressions of dampers mounted to the wheel

Wheelset BA308 (GHH) + dampers (S&V)  
Wheelset BA309 (BVV) + dampers (BVV)

Freight wheel + Lucchini damper (SILENCE-IP)  
DAAVAC ring damper (by Valdunes+ENAC)

Cost

The indicative cost of wheel dampers is given in Table 7.
Table 7 Indicative retrofitting cost of wheel dampers.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel absorbers</td>
<td>DHV/UIC 2013</td>
<td>Netherlands</td>
<td>per vehicle</td>
<td>20</td>
<td>27,0</td>
<td>0,4</td>
</tr>
</tbody>
</table>

Manufacturers:
BVV: [www.bochumer-verein.de](http://www.bochumer-verein.de)
Lucchini: [www.lucchinirs.it](http://www.lucchinirs.it)
S&V: [www.sundv.biz](http://www.sundv.biz)
Valdunes: [www.ghh-valdunes.com](http://www.ghh-valdunes.com)

5.3.2 Braking blocks (K and LL)

Introduction

K and LL blocks are alternatives for cast-iron brake blocks. While cast-iron blocks cause the wheel tread to become very rough, K and LL blocks do not roughen up the wheels, thereby reducing rolling noise considerably.

The differences in application of K and LL blocks are treated in the next sections. This section will focus on the achievable noise reductions.

K and LL blocks have been tested in various projects and campaigns in different countries, during the past decade. A synthesis report, recently issued by UIC, gives an overview of the measurement results [DHV 2013a]. This study collected more than 120 reports of which 39 contained information on noise levels. The noise reduction, with reference to cast-iron blocks, depends on the rail roughness level of the test track. On a track with a rail roughness in the range of the CEN ISO 3095 curve, which could be considered to have slightly smoother than average rails, the noise reduction is listed in Table 8.

Table 8 Reference values of noise reduction of K and LL blocks [DHV 2013a].

<table>
<thead>
<tr>
<th>type</th>
<th>make</th>
<th>on track with ISO 3095 rail roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>various types</td>
<td>8 to 10 dB(A)</td>
</tr>
<tr>
<td>LL</td>
<td>Jurid 777</td>
<td>7 to 8 dB(A)</td>
</tr>
<tr>
<td>LL</td>
<td>C952 and C952-1</td>
<td>8 to 9 dB(A)</td>
</tr>
<tr>
<td>LL</td>
<td>IB116*</td>
<td>10 to 12 dB(A)</td>
</tr>
</tbody>
</table>

From the LL blocks in this table, only the types C952-1 and IB 116* have been admitted in the Usage Guidelines for Composite (LL) Brake Blocks [UIC 2013].
On tracks with a lower rail roughness than CEN ISO 3095, higher reductions can be found. For example, the NICOB project by DB and SNCF in 2007-2008 [Meunier 2009] a test train was composed of 9 freight wagons (Haggiins 14, four axle sliding-wall wagons). The measurement track in Germany was TSI compliant. The three different brake blocks (K, LL, and CI) were installed on three groups of adjacent wagons, see Table 9. The noise reduction that can be calculated from these levels lies between 12.6 and 13.3 dB(A).

### Table 9  Pass-by noise level $L_{\text{pAeq, tp}}$ and noise reduction relative to cast-iron measured under TSI conditions at 7.5 m distance [Meunier 2009].

<table>
<thead>
<tr>
<th>Speed</th>
<th>Cast-iron</th>
<th>K (Becorit 929-1)</th>
<th>LL (IB116*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 km/h</td>
<td>93.7 dB(A)</td>
<td>80.4 dB(A)</td>
<td>-13.3 dB(A)</td>
</tr>
<tr>
<td>120 km/h</td>
<td>99.8 dB(A)</td>
<td>87.0 dB(A)</td>
<td>-12.8 dB(A)</td>
</tr>
</tbody>
</table>

**Cost**

The indicative cost of retrofitting with LL and K blocks is given in Table 10. The lifetime of the braking system is equal to the freight vehicle, about 40 years, during which the blocks have to be replaced regularly.

### Table 10 Indicative cost of LL and K blocks.

<table>
<thead>
<tr>
<th>Noise measure</th>
<th>Source</th>
<th>Country</th>
<th>Cost per unit</th>
<th>Life time [years]</th>
<th>Investment [x1000 euro]</th>
<th>Additional annual [x1000 euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>retrofitting LL blocks</td>
<td>[DHV 2013b]</td>
<td>Netherlands</td>
<td>per vehicle</td>
<td>40</td>
<td>2,1</td>
<td>0,4</td>
</tr>
<tr>
<td>retrofitting K blocks</td>
<td>[DHV 2013b]</td>
<td>Netherlands</td>
<td>per vehicle</td>
<td>40</td>
<td>8,0</td>
<td>0,3</td>
</tr>
</tbody>
</table>

**Manufacturers**

- Becorit: www.becorit.de
K-blocks

K-blocks are used mainly on new railway vehicles. This type of composite blocks have different friction characteristics than cast-iron blocks, see Figure 17. Vehicles with K blocks have an adapted braking pressure to compensate for these characteristics.

Retrofitting an existing vehicle with K blocks is possible. It requires adaptation of the vehicle braking system (pressure) and therefore the cost is much higher than retrofitting with LL blocks.

Figure 17  Friction characteristics, braking pressure and speed [Dörsch 2009].

LL-blocks

LL-blocks have 1:1 compatibility with most types of cast-iron brake blocks. They can be retrofitted to existing freight wagon fleets at moderate additional cost. Unlike with K-blocks, no modification to freight wagons is required.

The currently homologated blocks are C952-1 (manufacturer CoFren), which consists of sintered material, and IB116* (manufacturers Icer and Becorit) which are made of organic material.

Real life operational experience was gained with LL blocks in a large field campaign in the EuropeTrain project by UIC over the period 2010 - 2012. During this period the train ran tens
of thousands of kilometres. The above mentioned LL block types were fitted to Habbiillns and RS. The vehicles with cast-iron were of the types Eas, Eanos, Shimmns, RS, Remms and Sggmrs.

LL blocks require extra regular inspections to monitor wheel wear. The Usage Guidelines for Composite (LL) Brake Blocks gives practical recommendations on the usage of the blocks [UIC 2013].

The wheel roughness as measured on wagons with LL blocks remains low, even after many thousands of kilometers. Figure 18 shows measured wheel roughness spectra from the EuropeTrain project. The differences in wheel roughness between wheels equipped with different LL and K blocks is not significant. Variances of this order of magnitude are also found between wagons with the same blocks.

Impressions of the wheel tread roughness resulting from different brake blocks

![Cast-iron blocks](image)

![LL-block IB116*](image)

![LL-block C952-1](image)
Figure 18 Wheel roughness EuropeTrain [Heckelmüller 2012]. K-block from Nicobb project shown for reference [Meunier 2009].

5.4 References

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Title short
UIC Noise Technical Measures Catalogue

Client
International Union of Railways (UIC)
Contract number: P350/12.319

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Date
29 May 2013

Report reference
UIC003-01-04fe

Status
Final 1.0

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Autorisation
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Approval