Real noise reduction of freight wagon retrofitting

Supporting communication on noise reduction

Synthesis report

Union Internationale des Chemins de Fer

January 2013
final (update)

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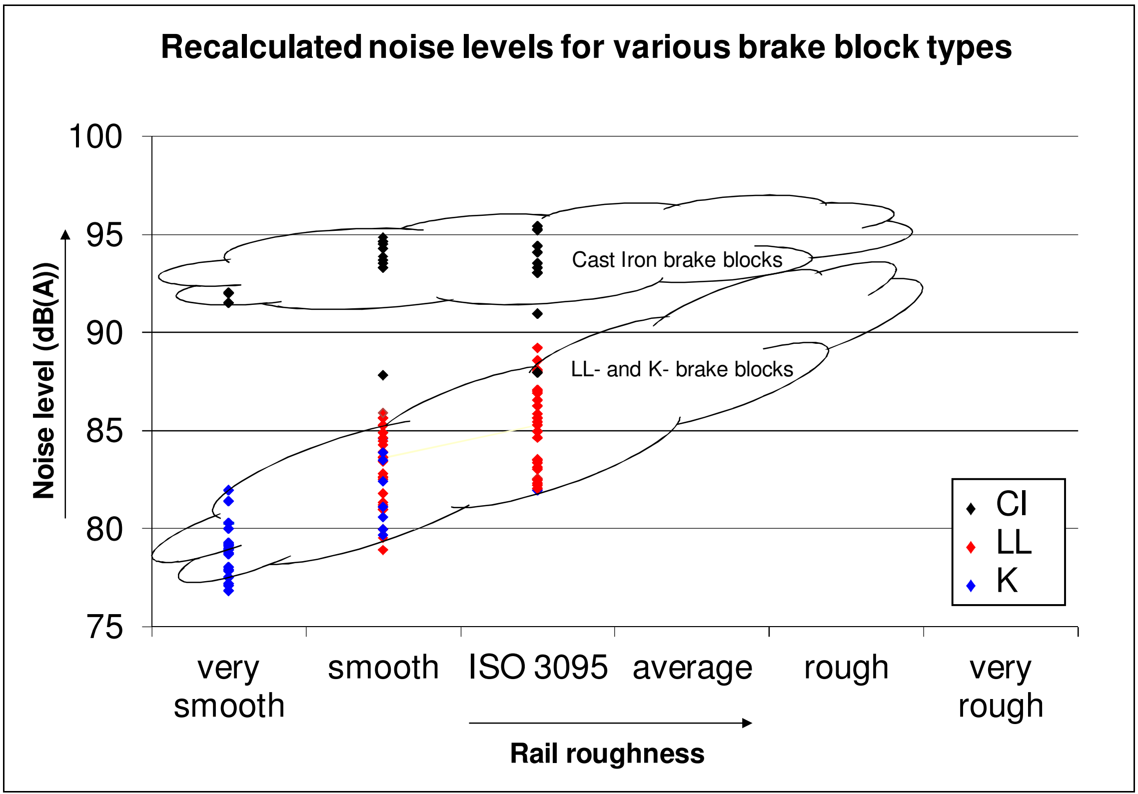
EXECUTIVE SUMMARY

Freight trains are the main contributors to noise from mixed railway lines. The railway sector, represented by UIC, proposes the retrofitting of the existing European freight fleet, by replacing cast iron brake blocks with composite (organic or sinter metal) brake blocks. Over the past years, various scenarios have been proposed to support the sector financially to achieve this goal. Whether or not this program should be supported by public means depends on the benefit of the operation. The benefit can be expressed as the reduction of noise levels to be achieved by retrofitting.
In the past decade, many field tests have been carried out, focusing on the feasibility of retrofitting and the economical and safety implications of it. Occasionally, such tests have been combined with noise measurements intended to assess the achieved reduction of noise levels.

The study reported here has collected more than 120 reports on such experiments. In only 39 of these, noise data were reported. These data have been analyzed, interpreted and converted. It turns out, that absolute pass by noise levels show large spread, mainly because of different track conditions. This is illustrated in the following graph, copied from section 4.1



Noise levels recalculated to a comparable APL of 0,2 and a train speed of 80 kph for variable rail roughness (typical examples of rail roughness spectra for smooth and very smooth tracks can be found in chapter 3, for instance figure 3 for smooth tracks and figure 1 for very smooth tracks)

On the basis of these absolute levels, no simple single figure could be derived with respect to the achievable reduction. Therefore, the noise data have been converted to a situation where the track conditions have been normalized to the roughness graph according to the CEN ISO 3095. This normalization to the roughness curve is used only as a point of comparison. The normalized roughness spectrum does not represent an actual real situation; it is merely a compromise between various good quality tracks in Europe. It turns out that, after this conversion, the results are very consistent and similar, with very few exceptions.

From this analysis we conclude, that, for a track roughness normalized to the CEN ISO 3095 limit, the following reductions are achieved compared to a similar wagon equipped with cast iron brake blocks:

- K-blocks:[1] - 8 to 10 dB(A)
- LL Jurid 777 block: - 7 to 8 dB(A)
- LL Cosid 952/LL Cosid 952-1 block: - 8 to 9 dB(A)
- LL Becorit IB116[*] block: - 10 to 12 dB(A)

It is emphasized here that a reduction of 7 to 10 dB(A) implies that 5 to 10 times as many trains can be operated with the same long term average noise level, i.e. within the same legal limit.

In practical situations, if the real track roughness exceeds the CEN ISO 3095 values, the reduction would be less than the values shown above. For other tracks however, with lower roughness levels than the CEN ISO 3095 curve, the reduction would be similar to or even larger than the value indicated above. This would apply for instance to the “especially monitored track” (besonders überwachtes Gleis) in Germany. For a relatively good quality track, the reduction values could be typically 3 dB(A) less than indicated above. In exceptional cases with bad track quality the reduction could be negligible.

[1] because of the limited information for each type off K-block the different K-blocks are presented as one

1 INTRODUCTION

1.1 Rail freight noise abatement

In 1998, the International Union of Railways UIC, in conjunction with CER and UIP, launched the “Freight Traffic Noise Reduction Action Program”. This program aims to equip new freight wagons with composite brake blocks and to achieve the retrofitting of the existing fleet. In doing so, the program intends to achieve a substantial noise reduction of rail freight transport in Europe.
In October 2005, the Action Program organized a first workshop set up to build consensus and promote retrofitting of the European freight fleet. Additional workshops have taken place on a yearly basis.

Over the years, the Action Program and adjacent initiatives have reached some major achievements and milestones:

- UNIFE and UIRR joining the group of organizations backing the Action Program,
- SBB and the Swiss Federal State finalizing the Swiss rail noise abatement program, including the retrofitting of the complete Swiss passenger and freight rolling stock fleet.
- The Decision 2006/66/EC of the European Commission on the technical specification for interoperability relating to the subsystem ‘rolling stock — noise’ of the trans-European conventional rail system (TSI-noise). The TSI-noise requires that newly homologated freight rolling stock be equipped with K-blocks.
- Several K-type brake blocks were homologated, two LL-type brake blocks received preliminary and conditional homologation.
- German Federal Government deciding on financing the Leiser Rhein project, including a pilot retrofitting of appr. 5000 wagons.
- Communication 2008-432 of the EU Commission on “Rail noise abatement measures addressing the existing fleet”, introducing a possible harmonization of noise dependent track access charges. The focus of the rail sector is to stimulate retrofitting by introducing a bonus for low noise vehicles.
- Dutch government deciding on the introduction of a noise bonus on the infrastructure access agreement with rail operators.
- UIC starts the Europe train project, with the objective to assess the long term wear behavior of various brake block configurations under a wide range of operating conditions.

All of these activities have been undertaken under the firm assumption that replacing conventional cast iron brake blocks by composite brake blocks of K- or LL-type would drastically reduce the rolling noise of freight wagons. This assumption has been largely confirmed by measurements in several field tests and other experiments.

Large scale Implementation of the UIC Action Program however has not really started yet. In the current phase, which could be a preparatory phase before actual implementation, the main concern of UIC is the communication about the subject of retrofitting in general, and about the expected noise reduction in particular.

1.2 Expected noise reduction

One of the main concerns is about the consistency of the communication on the expected efficiency. This concerns the noise reduction achieved in practice with wagons equipped with K- or LL-shoes, relative to the noise of wagons equipped with cast iron (CI) shoes.

There are many reasons why the results of various experiments may differ, or may seem to be inadequate. Most of these reasons refer to the conditions of the vehicle and the track at the moment of the measurements.

The general public, and often also policy makers, are interested mainly in the result of the replacement of brake blocks for the noise levels experienced at their dwellings. In other words, the general public is interested in the reduction of the perceived pass-by noise level in a given situation, which depends on the quality of the track, the distance to the track, the speed of the train, the quality of the ground between track and receiver, and possibly other factors.

> For the purpose of communication with the public, the appropriate indicator for noise reduction by retrofitting is the reduction of the **perceived pass-by level** of a commercial freight train on a track in normal maintenance condition.

Policy makers are interested in the reduction of the legal noise level, which is generally a long term average line side level, at the façade of a dwelling, including not only the freight trains to be retrofitted, but also other trains, the frequency of these trains, their speed, wind and weather conditions averaged over the year, etc. Closely related to this is the long term average noise level produced by the retrofitted freight trains relative to the noise capacity of the line, expressed in terms of a noise ceiling or noise contingency, as it is implemented in The Netherlands and Switzerland and may be implemented in other countries. This quantity shows how noise freight trains consume the capacity of a line, while quieter freight trains or disk braked passenger train allow more traffic from other trains within the same capacity.

> For the purpose of communication with policy makers and track capacity managers, the appropriate indicator for noise reduction by retrofitting is the reduction of the **long term average (legal) level at a façade**, caused by commercial freight trains on a track in normal maintenance condition.

Both noise reductions are more or less irrelevant to the noise engineer who is carrying out the measurement to assess the noise reduction. The assessment measurement would be carried out preferably according to CEN ISO 3095, including a low rail roughness, rather high track decay rates, and a train speed which is within limits of certain harmonized speeds.

The vehicle itself may differ from one measurement to another, particularly with respect to:

- The initial wheel roughness, which is influenced by the mileage that the vehicle has run between the moment of retrofitting and the moment of measurement (however, cast iron brake blocks will result in rough wheels already after a small mileage of approximately 1000 km after retrofitting, while composite brake blocks will result in smooth wheels even after much higher mileage),
- The presence of wheel flats,
- The presence of additional noise mitigation measures, such as wheel dampers, (and tuned rail absorbers on the track),
- Possibly the wheel type, diameter and shape (although it is known that this has very little influence when the brake blocks are not replaced),
- And last but not least: the brake block type. Too often it is simply assumed that any K-type brake block introduces the same noise reduction, and so does any LL-type brake block. This is not at all trivial, as some of the blocks within one category of braking behavior may include totally different materials and may therefore have quite different noise behavior.

As we have seen, there are many plausible reasons why measured noise reduction of composite brake blocks may spread widely. This fact represents a risk for the credibility of the communication on noise reduction.

Therefore, in the current study, we have collected measurement data from a large database of different sources, with the objective to convert this data into a consistent set of noise reductions for different situations.

1.3 Approach for the selection of suitable data

For the data to be suitable for further analysis in this survey, we have introduced the following criteria:

- The data has to be mutually comparable and consistent,
- The data has to be reproducible

On the basis of these criteria, the best indicator for noise reduction is the reduction achieved with a measurement according to CEN 3095, i.e. on a low roughness and high track decay rate track. Therefore, our approach in this study has been to select and analyze only those results that comply with this condition. This is then the preferred quantity for communication with noise engineers.

Starting from these results, we consider it feasible to predict, on a reproducible basis, the results that would have been collected on a normal commercial track, both for the pass-by level and the long term average level. These were the two preferred quantities for communication with the public, with policy makers and with track capacity managers.

It would be difficult, if not impossible, to work the other way around, i.e. to derive CEN 3095 results from the results obtained on a commercial track. This would only be feasible if a large amount of additional information (e.g. wheel roughnesses, track roughnesses, track decay rates) would have been available. This is usually not the case.

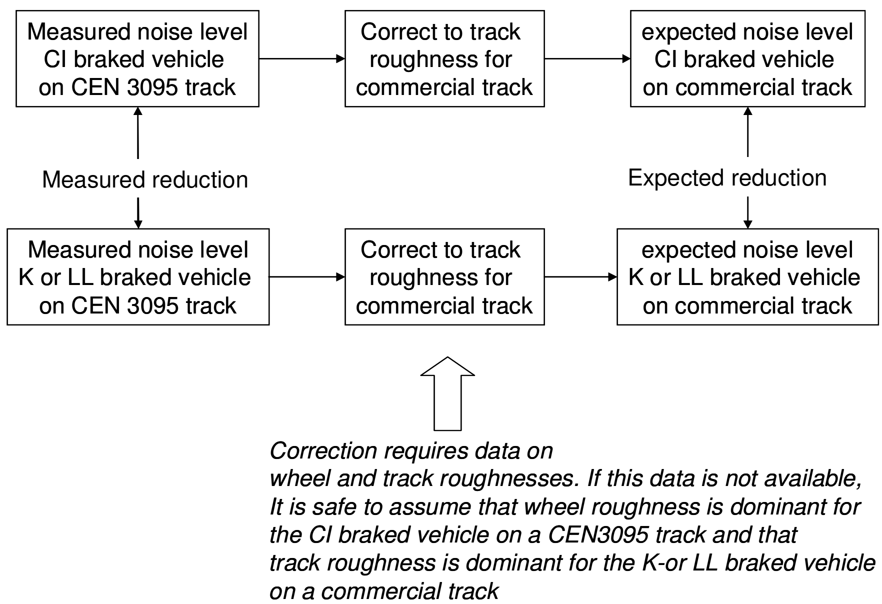


Figure 1. Approach deriving the expected reduction on a commercial track from the measured reduction on a CEN3095 track. The other way around would be difficult

1.4 Objective of the study and report content

The overall aim of the study is to help enhance the credibility and consistency of the communication on expected noise reduction by retrofitting. UIC has assigned DHV:

- to investigate the information/data on noise reduction (measured noise characteristics of wagons with either cast iron brake blocks or composite brake blocks) currently available;
- to analyze this information and assess its background;
- in as far as possible to explain differences.

The final result of the project should be a document that will help enhance the credibility and consistency of the communication on expected noise reduction. This report gives an overview of the activities performed, information analyzed and first conclusions of the project. It will form the basis for the document mentioned.

Chapter 2 of this report deals with the survey method used for the project. In chapter 3 the information obtained is described and analyzed. In chapter 4 the results of various recalculations of noise levels (APL, train speed and track and wheel roughness) and the resulting potential noise reduction are presented and described. Finally the main findings and conclusions are summarized in chapter 5.

2 SURVEY METHOD

The approach of the survey distinguishes the following four steps:

- Data collection
- Data analysis and clarification
- Ranking of the data
- Recalculation of noise levels and potential noise reductions
- Formulation of main findings and conclusions

2.1 Data collection

The project activities have started with a selection of potential sources (suppliers, co-ordinators of research programs and research institutes) for data available on measured noise characteristics of freight wagons with either cast iron brake blocks or composite brake blocks. Based on this selection the following organizations/persons have been contacted during the data collection:

- Deutsche Bahn Technology Center and Environment Center (Mr. Dörsch, Mr. Meunier, Mrs. Fleckenstein)
- Schweizerische Bundesbahnen SBB Environmental Center (Mr. Oertli)
- Swiss Ministry of Traffic (Mr. Attinger)
- Dutch Infrastructure Manager ProRail (Mr. Roovers, Mr Yntema)
- Dutch Ministry of Environment and Infrastructure (Mr. Vierling)
- Brake block supplier Cosrail (Mr. Schroeder, Mr. Freudenberg)
- Brake block supplier Jurid (Mr. Moehring, Mr. Berthold)
- Brake block supplier IB Italian Brakes SpA (Mr. Bellicoso, Mr. de Martino)
- Consultant Prose (Mr. Bühler for the Swiss Ministry of Environment)
- Consultant dBvision (Mr. Verheijen)

In total, more than 200 reference documents have been collected during this data collection phase. To some extent, these documents were already in de possession of DHV or have been obtained from SBB, ProRail (IPG, innovation program noise road and rail) and the Dutch Ministry of Environment. The suppliers of the composite brake blocks have indicated that they themselves don't have any noise data available, but are very interested in such results.

Germany and the Deutsche Bahn technology center have played an important role in the approval or rejection of various types of brake blocks. The German input into the UIC brake block committees has been very significant and still is. We understand that for commercial reasons not all measurement data can be provided for use in this report. Nevertheless, we feel that the data collected is sufficiently representative for the whole of Europe, including Germany.

Out of the 200 collected documents 39 have been considered relevant for this study. They can be found in the list of references in chapter 5. The remaining documents were considered not relevant, either because they did not contain any noise data at all or did not supply sufficient back ground information to interpret the noise data included. Insufficient background information may include: no information regarding noise measurement conditions (distance from track, measurement not in compliance with CEN 3095 etc.), train velocity, track conditions (smooth or rough), train type, type of brake block or any combination of these.

During the finalizing stages of this study the final report of the L Zar G (Leiser Zug auf realem Gleiss) project became available. This report does not present new data with regard to noise levels when using composite brake blocks. It makes reference to existing data and confirms the results of this study as presented in the chapters 4 and 5.

2.2 Data analysis and clarification

The 39 documents have been analyzed. During this analysis the following criteria have been taken into account:

- Availability of noise data (in dB(A) and/or frequency bands)
- Compliance with CEN 3095
- Availability of information regarding track roughness
- Availability of information regarding train speed
- Type of brake block (CI, K- or LL-blocks) used

In analyzing the data and selecting suitable data sets, we have considered the fact that some parameters would affect the resulting reduction, some others would not, and for some parameters the influence is questionable. The following table presents our assumptions:

Table 1: Parameters that may affect the resulting noise reduction

Parameter	Affects resulting noise reduction	Does not affect resulting noise reduction	Influence unclear
Track roughness	X		
Track decay rate	X		
Mileage after reprofiling		X[1)]	
Vehicle type		X	
Vehicle APL		X	
Vehicle speed		X[2)]	
Brake block type	X		
Brake block make (same type)			X
p.m.			

[1)] Provided that the minimum mileage is 1000 km

[2)] Theoretically there is a reason to suspect influence, because the influence of the speed will not be equal for the total noise spectrum. The influence of the speed in combination with differences in rail roughness will vary for different wavelengths. However, when the simplified recalculation formula 30 * log (v_{train}) is applied in practice for limited speed corrections, the influence on the noise reduction is negligible by definition.

In several cases additional contact has been made with the authors of the documents to be able to clarify certain elements in the reports. The data analysis has lead to the selection of the following 25 documents for the phase of ranking of the data:

- Geräuschmessung von in Betrieb stehenden Eisenbahngüterwagen (Abschlussbericht), Andreas Herbst, Prose 03-2-068, 12 November 2003 [1]
- AAE Sggmrs 90' Hupac-AAE mit BAFU-MVW Lärmmessung Schlussbericht, Tobias Märki, Prose Bericht 2-455, 15 June 2009 [8]

- Presentation Pilot project test train with LL-blocks (for the Meeting of the “Expert Network Noise and Vibration”), Jan Hlavácek, VUZ, 10 November 2008 [11]
- UIC Project Nicobb – WP2 field tests: Noise measurements of freight wagons equipped with K-, LL- and CI-blocks (week 38/2007), Test report – Version 3, Nicolas Meunier, DB Systemtechnik, 13 June 2008 (Results presented during the Meeting “Project Nicobb WP2” on 14 November 2007) [12]
- Memo Geluidniveaus (SEL in dB(A)) van de ertstreinen bij Tilburg (Annex to PRO030-01), Edwin Verheijen, dBVision, 6 March 2009 [13]
- Noise and vibration measurements on container wagons with LL brake blocks, H.W. Janssen M.Sc. and M.G. Dittrich M.Sc., TNO MON-RPT-033-DTS-2007-00882, 26 March 2007 [16]
- Noise and vibration measurements on freight wagons with LL and K brake blocks for TSI compliance testing, H.W. Jansen M.Sc., TNO MON-RPT-033-DTS-2007-03512, 18 December 2007 [17]
- Dolomiet shuttle Rapport geluidmetingen - fase 1 - referentiemetingen (version 1), Paul van der Stap, AEA Technology AEAT/03/2400060/008, 1 April 2003 [19]
- Dolomiet shuttle Rapport geluidmetingen - fase 2 - prototypemetingen (version 1), Paul van der Stap, AEA Technology AEAT/03/2400102/008, 1 April 2003 [20]
- Dolomiet shuttle Rapport geluidmetingen - fase 3 – duurtest, Paul van der Stap, AEA Technology AEAT/04/4400046/002, 1 March 2005 [21]
- Dolomiet shuttle Rapport geluidmetingen - fase 4 - secundaire maatregelen, Gerrit van Keulen, Paul van der Stap and Bernard Lefranc, AEA Technology AEAT/2005/540009/007, 1 October 2005 [22]
- Dolomiet shuttle Summary measurements on dolomiet-shuttle Phase 1 to phase 4, Michiel Berkheij, Delta Rail DeltaRail/06/60126/004, 1 November 2006 [23]
- Dolomiet shuttle Rapport geluidmetingen - fase 5 - meting wielruwheid, Gerrit van Keulen and Bernard Lefranc, Delta Rail DeltaRail/06/60094/004, 1 November 2006 [24]
- Dolomiet shuttle Rapport Akoestische eindanalyse geluidsreducerende Dolomite-Shuttle (version 13), Elly Waterman & Jasper Peen, Lloyd's Register Rail Europe B.V. TL/JP/C031K/03-323788, 21 April 2008 [25]
- Geluidspilot Dolomiet shuttle Eindrapportage voor het IPG, Elly Waterman & Jasper Peen, Lloyd's Register Rail Europe B.V. TL/JP/C031K/03-324585, 26 May 2008 [26]
- Notitie Dolomiet-shuttle in categorie 8, Elly Waterman, dBVision LRR003-01-03 versie 3, 15 January 2007 [27]
- Cobelfret Noise and vibration measurements on three-axled freight cars with LL brake blocks (first measurement), M.G. Dittrich, M. Janssens, P.J. G. van Beek, R. Vermeulen, TNO IS-RPT-060078-033-DTS-2006-00341, 12 July 2006 [28]
- Cobelfret Noise and vibration measurements on three-axled freight cars with LL brake blocks (second measurement), H.W. Jansen M.sc., M.G. Dittrich M.Sc., TNO IS-RPT-033-DTS-2006-01147, 31 October 2006 [29]
- Cobelfret Noise and vibration measurements on three-axled freight cars with LL brake blocks (third measurement), H.W. Jansen M.Sc., M.G. Dittrich M.Sc., TNO MON-RPT-033-DTS-2007-00339, 1 February 2007 [30]
- Cobelfret Noise and vibration measurements on three-axled freight cars with LL brake blocks (fourth measurement) H.W. Jansen M.Sc., M.G. Dittrich, M.Sc.,TNO MON-RPT-033-DTS-2007-01215, 4 May 2007 [31]
- Cobelfret Noise and vibration measurements on three-axled freight cars with LL brake blocks (fifth measurement), H.W. Jansen M.Sc., M.G. Dittrich M.Sc., TNO MON-RPT-033-DTS-2008-00070, 1 January 2008 [32]
- Cobelfret Noise and vibration measurements on three-axled freight wagons with LL brake blocks – Final report, H.W. Jansen, M.G. Dittrich, TNO MON-RPT-033-DTS-2008-00694, 22 February 2008 [33]

- The Whispering Train Programme Final report LL-block pilots for the Noise Innovation Programme, Jasper Peen, Lloyd's Register Rail Europe B.V. OI/JP/0864/03-390378, 21 April 2010 [36]
- Memorandum “Corrected noise reductions retrofitted freight wagons”, H.W. Jansen M.Sc., TNO, 12 March 2008 [38]
- Prüfbericht “Akustische Vorbeifahrmessung des EuropeTrain bei Großburgwedel”, H. Heckelmüller, DB Systemtechnik 12-12702-T.TVI32(3)-PR, 19 December 2012 [39]

The measurements reported in these documents are all in compliance with CEN 3095 and all have the required data described and include noise data for both cast iron brake blocks and for composite brake blocks on the same freight wagon type. This makes it possible to compare noise data for the CI blocks with data for LL- or K-blocks which are measured under the same circumstances (same track conditions and wagon type). In this manner we ware able to base the resulting calculated noise reduction on the measured data. The reduction has not been influenced by recalculation errors introduced by APL corrections or corrections for different track conditions. An exception has been made for the Prose report “Bericht 2-455“ of 15 June 2009 [8]. In this report no noise data for cast iron blocks are available, but the noise data for two types of composite brake blocks are compared. These data are analyzed to determine the mutual differences between these types.

No APL corrections have been made in the present report as part of the calculation of the potential noise reductions. APL corrections are the same for CI-, LL- or K-blocks. If noise emission data for CI-blocks and composite blocks both on the same wagon type are compared, different APL will only lead to differences in the absolute height of the emission levels itself but not on the noise reduction potential. APL corrections have only been done to show the spread of noise levels found in various reports (see paragraph 2.4).

The remaining 14 reports of the total list of 39 lack the availability of reference data for standard CI brake blocks and have not been used for the calculations regarding the potential noise reduction. They have only been used in the cloud plot described in paragraph 4.1.

2.3 Ranking the data

The analyzed noise emissions and calculated potential noise reductions, when using composite brake blocks, are discussed in chapter 3. Also the circumstances under which the measurements have been done will be described, taking into account:

- Type of freight wagon used
- Train speed
- Type of brake block used (CI, LL or K)
- The track roughness

On the basis of these differences a first qualitative categorization in different data sets has been made. Within each data set the results should be comparable.

2.4 Recalculation of noise levels and potential noise reductions

On basis of data in the reports two types of recalculations have been performed:

- Recalculation of noise emissions to a comparable APL of 0,2 and train speed of 80 kph
- Recalculation of noise emissions to a track roughness normalized to the ISO 3095 limit

On the basis of the results of these recalculations again a categorization in different data sets has been made. Within each data set the results should be comparable. Differences between the data sets are discussed and clarified.

2.5 Formulation of main findings and conclusions

The results from the analysis, recalculations and categorization has lead to the formulation of main findings and conclusions (chapter 5). This includes a description of the noise reductions to be expected under different practical conditions. An explanation has been given of the reasons why reported noise reductions may show some spread. Finally the influence of the rail roughness on the potential noise reductions has been described and values for the potential noise reduction for the different types of brake blocks on a track normalized to the CEN ISO 3095 limit are given.

3 SURVEY RESULTS

In this chapter the results of the data analysis and categorization are described in the paragraphs 3.1 to 3.11 for each of the documents (or group of documents belonging together) analyzed. A summary of the results is presented in paragraph 3.12.

3.1 Buwal Noise measurements by Prose in November 2003

In November 2003 Prose has performed noise measurements [1] on various types of freight wagons with CI- and with K-brake blocks (type Jurid 816). Only for the Sgnss wagons both CI- and K-blocks (K Jurid 816) have been assessed. Therefore only the results for this wagon type have been taken into consideration for the present study. The measurements have been performed for Sgnss (APL = 0,2) which have had different travelling distances after retrofitting with the K-brake blocks. The number of kilometers appears to have little or no influence on the results. The measurements have been performed on a rail track specially adapted for the measurements. The rail roughness of this track was lower than the CEN ISO 3095 limits (see Figure 2). The measurements were performed for train speeds of 50, 80 and 100 kph.

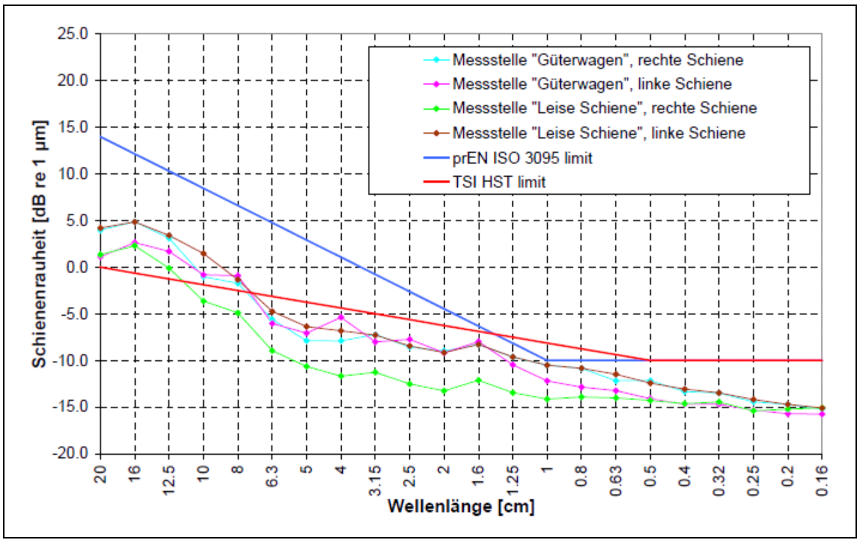


Figure 2 Rail roughness during measurements (Messstelle "Güterwagen") in comparison with the ISO 3095 limit (Picture taken from the Prose report [1])

Results

The results of the noise measurements are presented in Table 2 for the actual rail roughness. Application of a K-block (Jurid 816) instead of a CI-block resulted in a noise reduction between **12,0** and **15,2** dB(A). The train speed has no clear influence on the potential noise reduction, only on the noise levels themselves. No spectral data were available in the Prose report. However in the report the noise levels are recalculated by Prose to a rail roughness normalized to the CEN ISO 3095 limit. This results in a noise reduction as a result of application of a K-block (Jurid 816) instead of a CI-block between **8,3** and **9,6** dB(A).

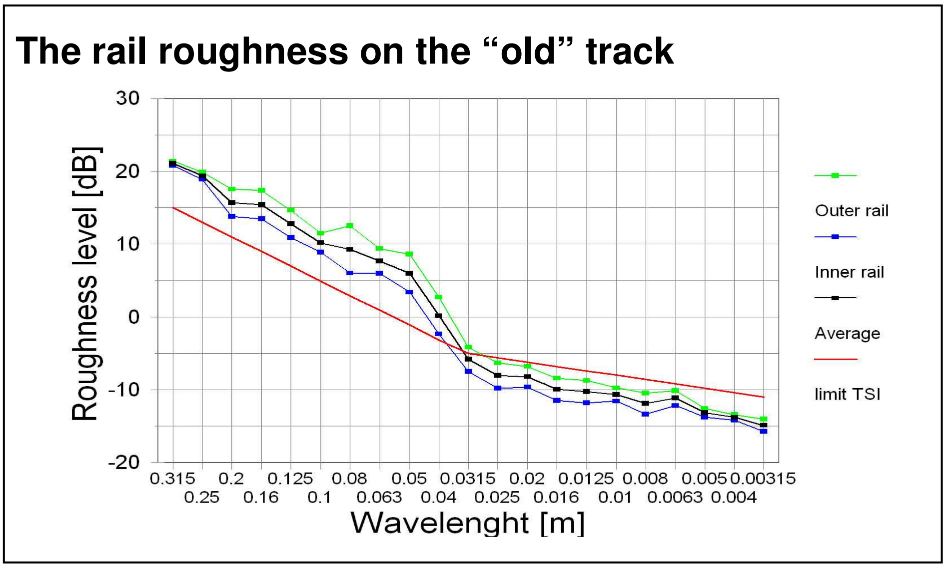
Table 2: Overview of the average measured pass-by levels in dB(A) for Sgnss wagons and the influence of the K brake block type (for a track with very low rail roughness)

	Train speed (kph)					
Brake block type	**50**		**80**		**100**	
CI	86,0	-	91,6 (± 0,6)	-	95,0	-
K Jurid 816:						
Sgnss 30/1000	71,8	- 14,2	79,2 (± 1,0)	- 12,4	82,2	- 12,8
Sgnss UIC	71,5	- 14,5	77,2 (± 1,0)	- 14,4	80,2	- 14,8
Sgnss 6/0	72,0	- 14,0	79,0 (± 1,1)	- 12,6	81,7	- 13,3
Sgnss 30/0	70,8	- 15,2	78,0 (± 1,5)	- 13,6	82,0	- 13,0
Sgnss 6/1000	71,5	- 14,5	79,0 (± 1,2)	- 12,6	83,0	- 12,0

3.2 Measurements Pilot project test train (VUZ) November 2008

In November 2008 Mr. Jan Hlavácek (VUZ) presented the results of noise measurements of a Pilot project referring to a test train with LL-blocks on a meeting of the “Expert Network Noise and Vibration”) [11]. The noise measurements were performed on Eas (APL= 0,284) freight wagons with CI- and with LL-brake blocks (type Becorit IB116*).

The measurements have been performed on an “old” and a “new” rail track. The rail roughness of the “old” track (see Figure 3) was slightly lower than the CEN ISO 3095 limits (not in the figure). The rail roughness of the “new” track was even lower than that of the “old” track. The measurements were performed for a train speed of 75 kph.



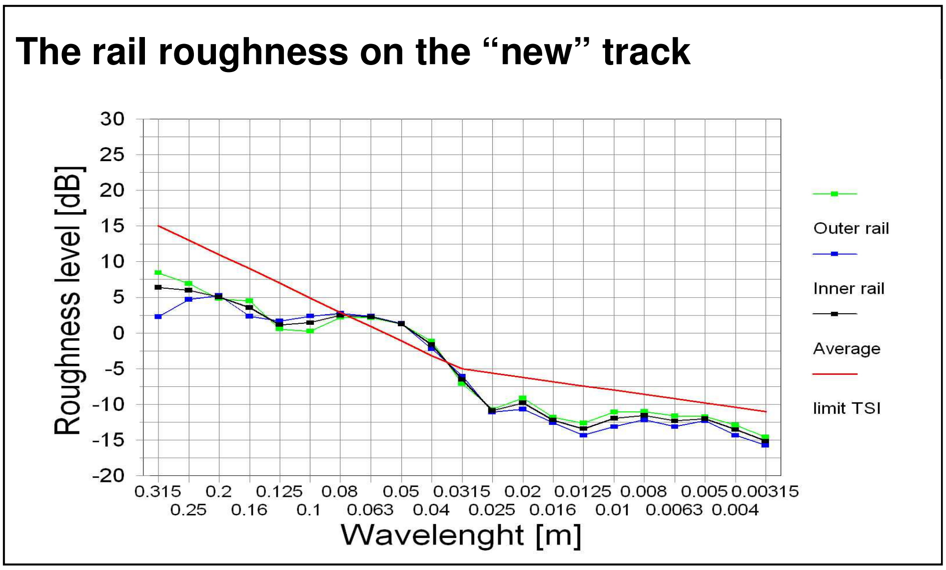


Figure 3 Rail roughness during measurements ("old" and "new" track) in comparison with TSI limits (Pictures taken from the presentation of Jan Hlavácek [11])

Results

The results of the noise measurements are presented for the actual rail roughness. These results are presented below in Table 3. No spectral data were presented in the presentation. Application of a LL-block (LL Becorit IB116*) instead of a CI-block resulted in a noise reduction of **6,2** dB(A) on the "old" track and **6,7** dB(A) on the "new" track. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on the basis of a first qualitative analysis that the noise reduction for both situations will be comparable for both situations and **lower than 5** dB(A).

Table 3: Overview of the average measured pass-by levels in dB(A) for a Eas wagon and the influence of the different brake block types (Rail roughness of the "old" and a "new" track)

	Train speed (kph)	
Brake block type	**75**	
"Old" track:		
CI	96,1	-
LL Becorit IB116*	89,9	- 6,2
"New" track:		
CI	88,5	-
LL Becorit IB116*	81,8	-6,7

3.3 Measurements Project Nicobb WP2 November 2007

In September 2007 DB Systemtechnik (Nicholas Meunier) performed noise measurements as part of the "Project Nicobb[2] WP2" [12] on Hbbins14 (APL= 0,17) freight wagons with CI-, K- (type Becorit 929-1) and with LL-brake blocks (type Becorit IB116*). The measurements have been performed on a very smooth track with a rail roughness which is much lower than the TSI or CEN ISO 3095 limits (see Figure 4). The measurements were performed for train speeds of 80 and 120 kph.

[2] Noise Impact assessment of Cast-iron, K- and LL-blocks On test Benches, WP2, field tests

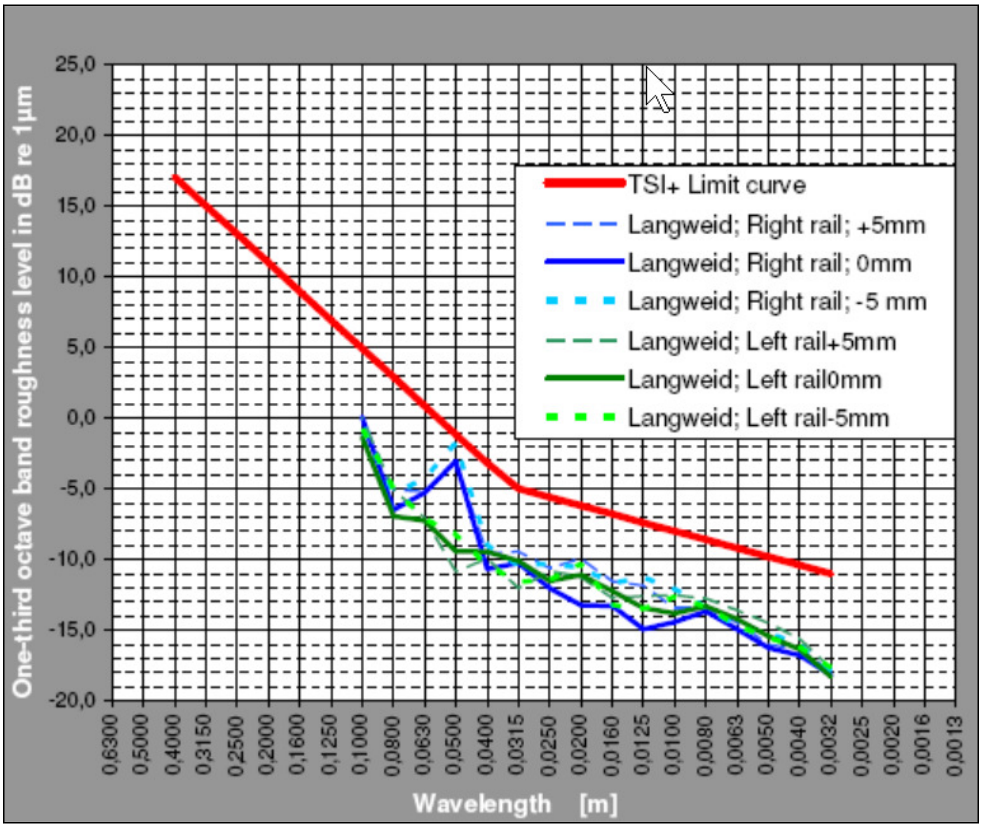


Figure 4 **Rail roughness during measurements in comparison with TSI limits (Picture taken from the DB Systemtechnik report [12])**

Results

The results of the noise measurements are presented for the actual rail roughness. These results are presented below in Table 4. The presentation also presents spectral data which could be used to recalculate the data to a rail roughness normalized to the CEN ISO 3095 limits. Application of a LL-block (Becorit IB116*) instead of a CI-block resulted in a noise reduction of approximately **13** dB(A). Application of a K-block (Becorit 929-1) shows approximately the same noise reductions. The small differences between the composite brake blocks are well within the spread of the data found. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on the basis of a first qualitative analysis that the noise reduction in comparison with CI-blocks will drop to a difference **less than 10** dB(A). The train speed didn't have an influence on the potential noise reduction, only on the noise levels themselves.

Table 4: Overview of the average measured pass-by levels in dB(A) for Hbbins14 wagons and the influence of the different brake block types (for a track with very low rail roughness)

	Train speed (kph)			
Brake block type	**80**		**120**	
CI	93,7 (± 0,4)	-	99,8 (± 0,6)	-
K Becorit 929-1	80,4 (± 1,0)	- 13,3	87,0 (± 0,7)	- 12,8
LL Becorit IB116*	81,1 (± 0,7)	- 12,6	87,1 (± 1,2)	- 12,7

3.4 Measurements ore trains Tilburg (Netherlands) March 2009

As annex to a memorandum written by dBVision in March 2009 [10] comparing various noise measurement results on freight wagons the results of noise measurements on ore trains performed in February 2009 in Tilburg (the Netherlands) have been reported by dBVision [13]. The noise measurements were performed on Falrrs freight wagons with CI- and with K-brake blocks (no brake block make is mentioned).

The measurements have been performed on an actual track with a rail roughness, which was lower than the standard (average) Dutch rail roughness. The standard (average) Dutch rail roughness is slightly higher than the CEN ISO 3095 limits (see Figure 6 in paragraph 3.6 where standard Dutch rail roughness, TSI limit and CEN ISO 3095 limit are compared). No data on the rail roughness was given in the report but the authors of the document state that they have recalculated the measurement results to a standard Dutch rail roughness by adding 2 dB(A) to the values for the composite brake blocks. The 2 dB(A) addition was based on the results of other measurements performed on the same track on passenger coaches. The measurements were performed for variable train speeds between 66 and 91 kph.

Results
The results of the noise measurements are recalculated to an average Dutch rail roughness. These results are presented below in Table 5. No spectral data were available in the dBVision document. Application of a K-block instead of a CI-block resulted in an average noise reduction of **6,6** dB(A). The values vary between 5,9 en 8,6 dB(A), but there doesn't seem to be an influence of the train speed on the potential noise reduction. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on basis of a first qualitative analysis that the noise reduction in comparison with CI-blocks will increase slightly.

Table 5: Overview of the average measured pass-by levels in dB(A) for ore trains (Falrrs wagons) and the influence of K-brake blocks (recalculated to an average Dutch rail roughness)

	Brake block type		
Train speed (kph)	**CI**	**K**	
66	87,0	81	- 6,0
73	88,3	82,4	- 5,9
78	90,3	81,7	- 8,6
81	89,3	83,2	- 6,1
81	90,4	84,0	- 6,4
82	89,6	83,6	- 6,0
82	89,7	82,8	- 6,9
84	89,5	83,6	- 5,9
86	90,6	83,8	- 6,8
91	91,3	83,6	- 7,7

3.5 Measurements TNO March 2007

TNO has reported the results of noise measurements on container wagons with LL brake blocks, performed in December 2006, in a report in March 2007 [16]. The noise measurements were performed on Sgns freight wagons (APL = 0,2) with CI- and with two types of LL-brake blocks (types Jurid 777 and Cosid 952). The wagons with the Jurid 777 brake blocks had covered an average distance of 26,000 km since retrofitting. For the wagons with the Cosid 952 brake blocks this was 29,000 km.

The measurements have been performed on an actual track with a rail roughness comparable to the CEN ISO 3095 limit (see Figure 5). The measurements were performed for speeds of 50, 78,8 and 100,1 kph.

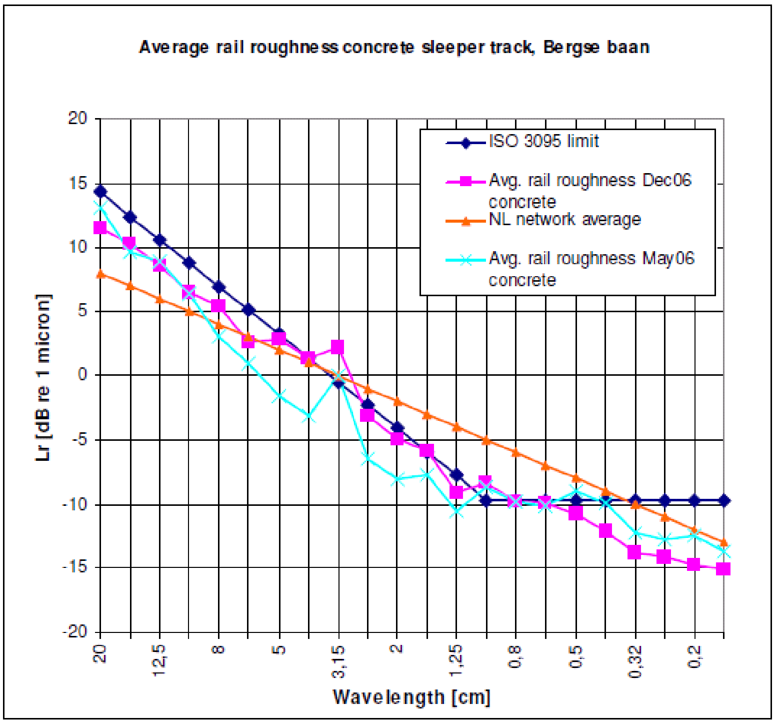


Figure 5 **Rail roughness during measurements in comparison with ISO 3095 limits and the average Dutch rail roughness (Picture taken from the TNO report [16])**

Results

The results of the noise measurements are presented for the actual rail roughness. These results are presented below in Table 6. The TNO report also presents spectral data of the noise measurements. Application of the LL-blocks instead of a CI-block resulted in an average noise reduction of **9,0** dB(A) for the Cosid brake blocks and **7,7** dB(A) for the Jurid brake blocks. The lowest noise reduction is measured at 78,8 kph. The noise reduction achieved with the Cosid brake blocks is 2 dB(A) higher than with the Jurid brake block when the measurement results at 50 and 100,1 kph are considered. At 78,8 kph the difference is small. The measurements with the Cosid brake blocks show a remarkable peak at 1600 Hz, which is probably not the result of the rolling noise but is caused by a different source in these wagons at this speed. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on basis of a first qualitative analysis that this will have no influence on the potential noise reduction.

Table 6: Overview of the average measured pass-by levels in dB(A) for a SGNS wagons and the influence of the different brake block types (for a track with a rail roughness comparable to the ISO 3095 limit)

	Train speed (kph)					
Brake block type	**50**		**78,8**		**100,1**	
CI	87,5	-	93,2	-	97,1	-
LL Jurid 777	79,4	- 8,1	86,9	- 6,3	88,3	- 8,8
LL Cosid 952	77,5	- 10,0	86,8	- 6,4	86,5	- 10,6

3.6 Measurements TNO December 2007

TNO has reported the results of noise measurements on container wagons with LL- and K-brake blocks tor TSI compliance testing, performed in August and October 2007, in a report in December 2007 [17]. The noise measurements were performed on Laeks (APL = 0,11), Shimms (APL = 0,33) and Sgns (APL = 0,2) freight wagons with CI-, one type of K-brake blocks (type Cosid 810) and with three types of LL-brake blocks (types Jurid 777, Cosid 952 and Becorit IB116*). The Laeks and Sgns wagons had covered a distance of 50,000 to 65,000 km since retrofitting. For the Shimss wagons the covered distance was unknown.

The measurements have been performed on an actual track with a very low rail roughness (see Figure 6). The measurements were performed for speeds of 80, 100 and 120 kph.

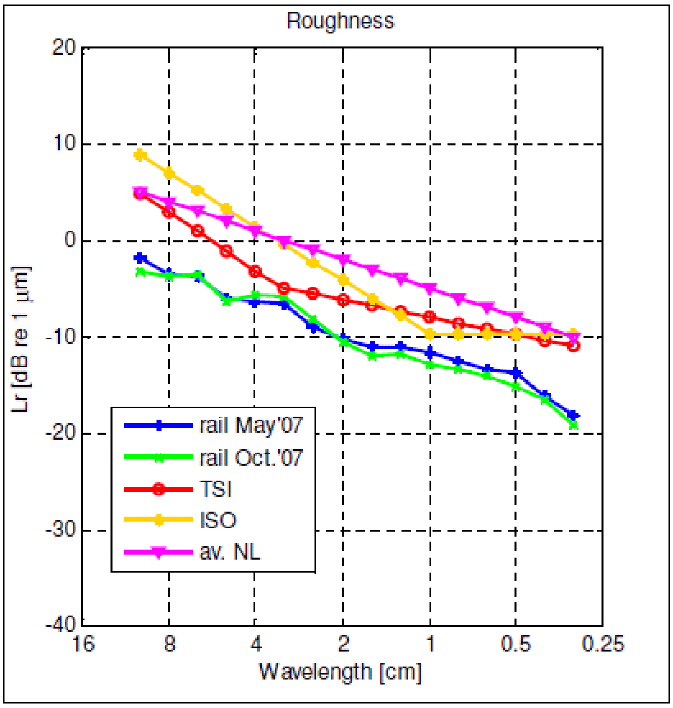


Figure 6 Rail roughness during measurements in comparison with ISO 3095 and TSI limits and the average Dutch rail roughness (Picture taken from the TNO report [17])

Results

The results of the noise measurements are presented for the actual rail roughness. These results are presented below in Table 7. The TNO report also presents spectral data of the noise measurements. Application of the LL-blocks instead of a CI-block resulted in an average noise reduction of:

- just above **9** dB(A) for the Jurid 777 LL-brake blocks
- between **10** and **10,5** dB(A) for the Cosid 952 LL-brake blocks
- approximately **10** dB(A) for the Cosid 810 K-brake blocks
- approximately **12** dB(A) for the Becorit IB116* LL-brake blocks

In March 2008 TNO has written a memorandum [38], in which the noise levels described in the December 2007 report are recalculated to an average Dutch rail roughness (slightly higher than the ISO 3095 limit, see figure Figure 6). This resulted in the following average noise reduction:

- between **7** and **8** dB(A) for the Jurid 777 LL-brake blocks
- approximately **8** dB(A) for the Cosid 952 LL-brake blocks
- approximately **6** dB(A) for the Cosid 810 K-brake blocks
- between **9** and **10** dB(A) for the Becorit IB116* LL-brake blocks

When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected that the noise reductions will end up somewhere in the middle between both situations The exact decrease of the noise reduction will depend on the exact noise spectra. The train speed didn't seem to have an influence on the potential noise reduction, only on the noise levels themselves.

Table 7: Overview of the average measured pass-by levels in dB(A) for a various wagon types and the influence of the different brake block types (for a track with very low rail roughness)

	Train speed (kph)					
Brake block type	**80**		**100**		**120**	
Laeks:						
CI	92,3	-	95	-	97	-
LL Jurid 777	83,1	- 9,2	86	- 9	88	- 9
LL Cosid 952	81,9	- 10,4	84	- 11	87	- 10
Sgns:						
CI	93,4	-	-	-	100	-
LL Jurid 777	83,7	- 9,7	-	-	91	- 9
LL Cosid 952	82,7	- 10,7	-	-	90	- 10
LL Becorit IB116*	81,3	- 12,1	-	-	88	- 12
Shimms:						
CI	95,9	-	99	-	102	-
K Cosid 810	86,8	- 9,1	89	- 10	91	- 11

3.7 Measurements Dolomiet shuttle 2003 - 2006

As part of the Dutch Noise Innovation program a pilot project has been performed aimed at the reduction of the noise levels produced by the Dolomiet-shuttle (Tapps wagons, APL = 0,26). The measurements for this pilot project have been done in the period 2003 and 2006. The main goal of the pilot project was to obtain more practical experience with retrofitting existing freight wagons with noise reducing measures. The Dolomiet-shuttle of Raillion was retrofitted with various measures, including K- brake blocks (Cosid 810). First reference measurements have been performed with CI-brake blocks. After retrofitting, measurements have been performed with the composite brake blocks. Finally durability tests have been executed periodically. All these measurements have been performed under varying conditions and on various tracks. The results of these measurements have been recalculated to comparable conditions and have been reported in many documents [19, 20, 21, 22, 23, 24, 25, 26, 27]. In these documents all the rail roughness data and spectral data of the noise measurements have been reported. In this study only the summarized results will be reported.

Results

The summarized results show a potential noise reduction of approximately **7,5** dB(A) for an average Dutch rail roughness when applying the Cosid 810 K-block instead of a CI-block. The durability tests show that this noise reduction remains constant, even after very long use of the K-blocks without reprofiling. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on basis of a first qualitative analysis that the noise reduction in comparison with CI-blocks will increase slightly.

For measurements on a very smooth track with very low rail roughness, noise reductions as high as **14** dB(A) have been calculated. However after correction to a rail roughness normalized to the CEN ISO 3095 limits it is expected that the noise reduction in comparison with CI-blocks will decrease to a level below **10** dB(A).

3.8 Measurements Cobelfret train 2006 - 2007

Over a period of 15 months (May 2006 tot August 2007) the effects of the retrofitting of the Cobelfret train on the noise reduction have been followed (the Cobelfret train has smaller wheels). During this period the noise measurements have been repeated five times on the same freight wagons (Laeks, APL = 0,11) partly fitted with CI-brake blocks and partly retrofitted with two types of LL-brake blocks (types Jurid 777 and Cosid 952). During these measurements the distances covered since reprofiling of the wheels have been registered. The freight wagons of the test train were divided into six categories:

- With CI-brake blocks, which were not reprofiled
- With CI-brake blocks, which were reprofiled just before the project started
- With LL Jurid 777 brake blocks, which were reprofiled just before the project started
- With LL Cosid 952 brake blocks, which were reprofiled just before the project started
- With LL Jurid 777 brake blocks, which were not reprofiled
- With LL Cosid 952 brake blocks, which were not reprofiled

All these measurements have been performed under slightly varying conditions but on the same track. The results of these measurements have been recalculated to comparable conditions and have been reported in various documents [28, 29, 30, 31, 32, 33]. In these documents all the rail roughness data and spectral data of the noise measurements have been reported.

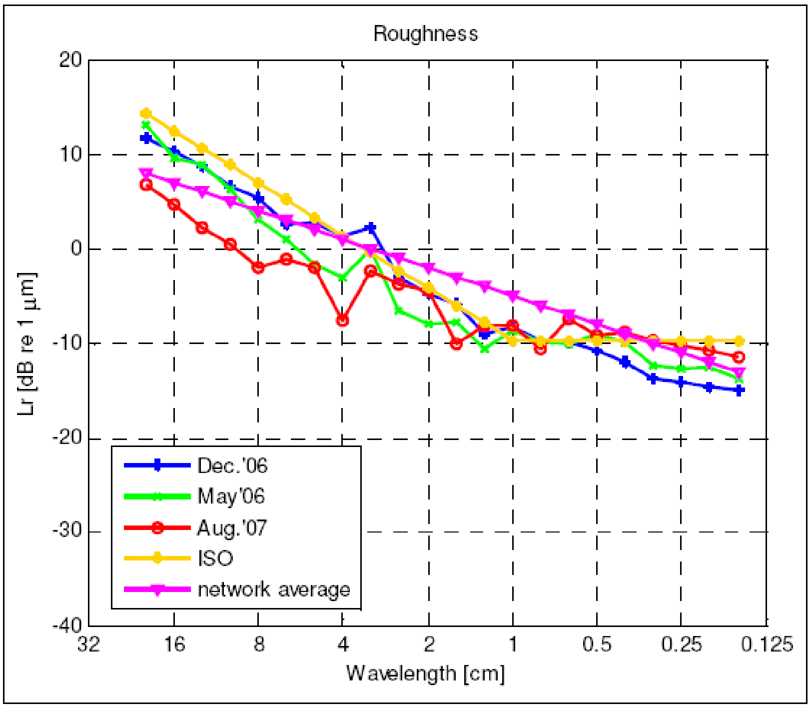


Figure 7 Rail roughness during measurements in comparison with ISO 3095 limits and the average Dutch rail roughness (Picture taken from the TNO report [33])

The measurements have been performed on an actual track with a rail roughness comparable to the CEN ISO 3095 limit (see Figure 7). The measurements were performed for speeds of 50, 80 and 100 kph.

Results
The average pass-by levels are presented for the actual rail roughness below in Table 8. These results show a potential noise reduction of **7** dB(A) for an average Dutch rail roughness when applying the Jurid 777 LL-block instead of a CI-block. For the Cosid 952 LL-block the potential noise reduction is calculated to be **8** dB(A). When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected on basis of a first qualitative analysis that this will have no influence on the potential noise reduction.

Reprofiling of the wheels fitted with the LL-blocks had little influence on the measured noise levels or the associated noise reduction. Even after many kilometers have been covered, there was little change in the noise emission.

This was not the case for the wheels fitted with the CI-blocks. A reduction in noise of a few dB(A) was observed immediately following reprofiling of these wheels. With increasing millage the noise level also increases and then stabilizes at the higher level, as demonstrated by a small increase in noise measured after 300 km and the higher stable level measured after 10.000 km. This indicates that the state of the wheels fitted with CI-blocks (and millage since re-profiling) can have a significant influence on the associated noise emission.

Table 8: Overview of the average measured pass-by levels in dB(A) for a Laeks wagon and the influence of the different brake block types (for a track with a rail roughness comparable to the ISO 3095 limit)

	Train speed (kph)					
Brake block type	**50**		**80**		**100**	
CI	86,6	-	90,5	-	93,4	-
LL Jurid 777 (reprofiled)	79,9	- 6,7	84,0	- 6,5	86,6	- 6,8
LL Cosid 952 (reprofiled)	78,4	- 8,2	82,4	- 8,1	85,0	- 8,4
LL Jurid 777 (not reprofiled)	79,4	- 7,2	83,3	- 7,2	86,0	- 7,4
LL Cosid 952 (not reprofiled)	79,3	- 7,3	83,3	- 7,2	86,0	- 7,4

3.9 Noise measurements by Prose in May 2009

In May 2009 Prose has performed noise measurements [8] on freight wagons with two types of LL-brake blocks (type Becorit IB116* and Cosid 952-1). No CI-blocks have been assessed as reference. Therefore the results can only be used for a comparison between these two composite brake blocks. The measurements have been performed for Sggmrs 90' (APL = 0,2) with travelling distances between 9.000 and 30.000 kms The measurements have been performed on the same rail track as described in paragraph 3.1, specially adapted for the measurements. The rail roughness of this track was lower than the CEN ISO 3095 limits. The measurements were performed for train speeds of 80 and 120 kph.

Results

The results of the noise measurements are presented in Table 9 for the actual rail roughness. Application of the LL Becorit IB116* instead of the LL Cosid 952-1 brake block resulted in a noise reduction of slightly **less than 4** dB(A). The train speed has no influence on this potential noise reduction, only on the noise levels themselves. No spectral data were available in the Prose report.

Table 9: Overview of the average measured pass-by levels in dB(A) for Sgggmrs 90' wagons for two LL brake block types (for a track with very low rail roughness)

	Train speed (kph)			
Brake block type	**80**		**120**	
Cosid 952-1	82,9	-	88,8	-
Becorit IB116*	79,0	-3,9	84,9	-3,9

3.10 Measurements EuropeTrain August 2012

DB Systemtechnik has reported the results of noise measurements on the EuropeTrain, performed in August 2012, in a report in December 2012 [39]. The EuropeTrain is a test train with different types of freight wagons, which has been making test runs in Europe since 2010 under varying conditions. During this period the wagons have covered a distance of various ten thousands of kms. The noise measurements were performed on various freight wagons with CI- and with two types of LL-brake blocks (types Cosid 952-1 and Becorit IB116*). In the measurement report it is stated that the noise measurement results for some of the freight wagons were not representative because the profile of the wheels of these wagons had flaws, which had a big influence on the measured noise levels. The noise measurement results for these wagons have not been taken into account during the analysis for this study. The freight wagons fitted with CI-brake blocks were of the types Eas, Eanos, Shimmns, RS, Remms and Sggmrs (APL between 0,2 and 0,33). The wagons with the Cosid 952-1 brake blocks were of the type Habbillns (APL = 0,129). The wagons with the Becorit IB116* brake blocks were of the type RS (APL = 0,2).

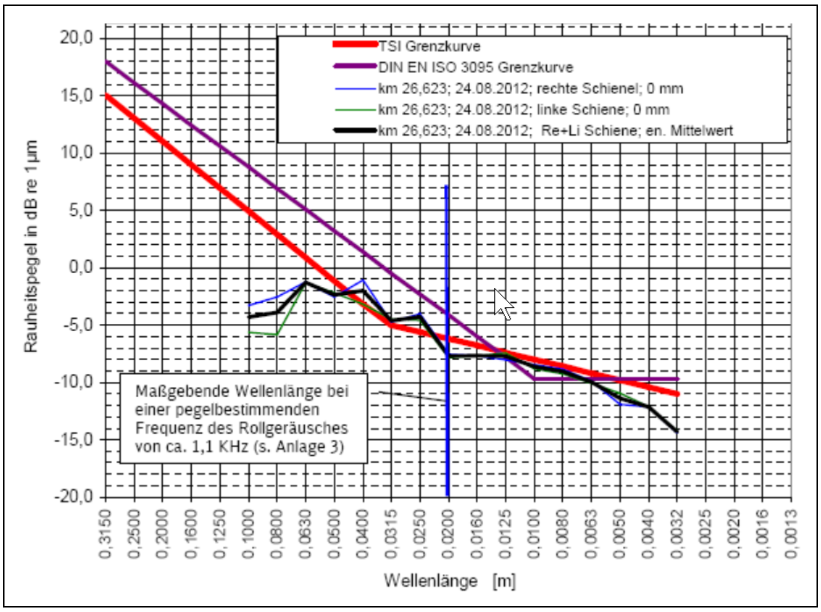


Figure 8 Rail roughness during measurements in comparison with ISO 3095 and TSI limits (Picture taken from the EuropeTrain report [39])

The measurements have been performed on an actual track with a rail roughness slightly lower than the CEN ISO 3095 limit (see Figure 5). The measurements were performed for speeds of 80 (4 measurements) and 98 kph (1 measurement).

Results
The results of the noise measurements are presented for the actual rail roughness. These results have already been recalculated to an APL of 0,2 in the EuropeTrain report. The results are presented below in Table 10. The EuropeTrain report also presents spectral data of the noise measurements. Application of the LL-blocks instead of a CI-block resulted in an average noise reduction of **9 to 10** dB(A) for the Cosid brake blocks and **13 to 14** dB(A) for the Becorit brake blocks. The train speed has limited influence on the noise reduction. When corrections would be made to a rail roughness normalized to the CEN ISO 3095 limits it is expected that the potential noise reduction will show a small decrease.

Table 10: Overview of the average measured pass-by levels in dB(A) for the various wagons (recalculated to an APL = 0,2) and the influence of the different brake block types (for a track with a rail roughness slightly lower than the ISO 3095 limit)

	Train speed (kph)			
Brake block type	**80**		**98**	
CI	94,0		98,0	
Becorit IB116*	80,7	-13,3	84,0	-14,0
Cosid 952-1	84,9	-9,1	87,9	-10,1

3.11 Summary of measurement results of the Noise Innovation Programme

In the final report of the Whispering Train Program [36] the combined results of the Dutch Noise Innovation Program for LL-brake block pilots have been reported. The report combines the results of the paragraphs 3.5, 3.6 and 3.8 in a summarized form and doesn't give new information.

3.12 Summary of the results

In Table 11 an overview is given of all the potential noise reduction values mentioned in the previous paragraphs. The table doesn't contain the results of recalculations by DHV as part of this study. These are presented in chapter 4. The recalculations mentioned in the table below have been performed as part of the studies described in the analyzed reports. The data is sorted by brake block type and in order of descending rail roughness. In green the potential noise reduction found for a rail roughness comparable to ISO 3095 is presented.

In general the data show clearly that with decreasing rail roughness the potential noise reductions increase. The rail roughness of the tracks, where the measurements have been performed, has a big influence on the noise levels measured. When using CI-brake blocks the influence is limited, because the wheel roughness will also be high resulting in high noise levels even on a smooth track. When LL- or K-brake blocks are used the wheel roughness will be lower and noise levels are mainly dominated by the track roughness. The influence of the use of composite brake blocks will therefore be higher on a smooth track, resulting in higher noise reductions (see also figure 9 in chapter 4).

All types of composite brake blocks have a significant effect on the noise levels. On basis of the information in Table 11 it is difficult to conclude which composite brake blocks have the best performance.

Table 11: Overview of the potential noise reduction sorted on brake block type and in order of descending rail roughness (with the paragraph in which the data are described)

Rail roughness	Brake block type	Potential noise reduction in dB(A)	Paragraph
Recalculated to average Dutch	K	6,6	3.4
Recalculated to average Dutch	K Cosid 810	6	3.6
Recalculated to average Dutch	K Cosid 810	7,5	3.7
Actual lower than ISO 3095	K Cosid 810	10	3.6
Actual very low	K Jurid 816	12,0 – 15,2	3.1
Actual very low	K Becorit 929-1	13	3.3
Actual very low	K Cosid 810	14	3.7
Recalculated to average Dutch	LL Jurid 777	7-8	3.6
Actual comparable to ISO 3095	LL Jurid 777	7	3.8
Actual comparable to ISO 3095	LL Jurid 777	7,7	3.5
Actual lower than ISO 3095	LL Jurid 777	9	3.6
Recalculated to average Dutch	LL Cosid 952	8	3.6
Actual comparable to ISO 3095	LL Cosid 952	8	3.8
Actual comparable to ISO 3095	LL Cosid 952	9	3.5
Actual lower than ISO 3095	LL Cosid 952-1	9 - 10	3.10
Actual lower than ISO 3095	LL Cosid 952	10 – 10,5	3.6
Recalculated to average Dutch	LL Becorit IB116*	9 - 10	3.6
Actual slightly lower than ISO 3095	LL Becorit IB116*	6,2	3.2
Actual lower than ISO 3095	LL Becorit IB116*	6,7	3.2
Actual lower than ISO 3095	LL Becorit IB116*	12	3.6
Actual lower than ISO 3095	LL Becorit IB116*	13 - 14	3.10
Actual very low	LL Becorit IB116*	13	3.3
N.B. The LL Cosid 952, mentioned in this table, has been withdrawn from homologation and is replaced by the C952-1. Only three of the reports [8, 37, 39], analyzed for this study, present data for the LL Cosid 952-1 brake block instead of the C952 break block. Two of these reports [8, 39] are discussed in paragraph 3.9 and 3.10. The noise levels and noise reductions presented for the LL Cosid 952-1 in the three reports are comparable to the data presented in the other paragraphs for the LL Cosid 952. It is therefore assumed that the acoustical properties of both types of brake blocks will not differ much.			

At first look the K-blocks and the LL Cosid 952 brake block show a slightly better performance than the LL Jurid 777 brake block. For the LL Becorit IB116* brake block four studies (see paragraphs 3.3, 3.6, 3.9 and 3.10) show noise reductions which are a few dB(A) higher than the K-blocks and the LL Cosid 952/LL Cosid 952-1 brake block. However the data of Mr. Jan Hlavácek (VUZ), described in paragraph 3.2, show lower noise reduction. This study however also shows relative low noise levels, when CI brake blocks are used. This could be the result of a recent re-profiling of the wheels. It is however uncertain if this has been the case.

In paragraph 4.2 the noise reductions after recalculation of the noise levels to a rail roughness normalized to the CEN ISO 3095 limit are discussed. This will give a clearer picture of the differences in performance of the different composite brake block types.

4 RECALCULATION RESULTS (APL, SPEED AND TRACK/WHEEL ROUGHNESS)

In this chapter the results of two types of recalculations are presented and described:

- In paragraph 4.1 the results of the recalculation of the noise emission levels to a comparable APL of 0,2 and a train speed of 80 kph for variable rail roughness are presented.
- In paragraph 4.2 the results of the recalculation of the noise emission levels to a track roughness normalized to the ISO 3095 limit and the resulting potential noise reductions are presented and discussed.

4.1 APL and train speed correction

All of the noise levels described in the 39 reports, mentioned in the reference list in chapter 5, have been recalculated to a comparable APL and train speed. This recalculation has been done by adding the following correction factors:

- APL correction to an APL of 0,2: 10 * log (0,2 / APL).
- Train speed correction to a train speed (= v) of 80 kph: 30 * log (80 / v).

The results of this recalculation are presented below in Figure 9 as a kind of noise level "clouds" for variable rail roughness. Typical examples of rail roughness spectra for smooth and very smooth tracks can be found in chapter 3. Figure 3, for instance, shows an example for smooth tracks and figure 1 for very smooth tracks.

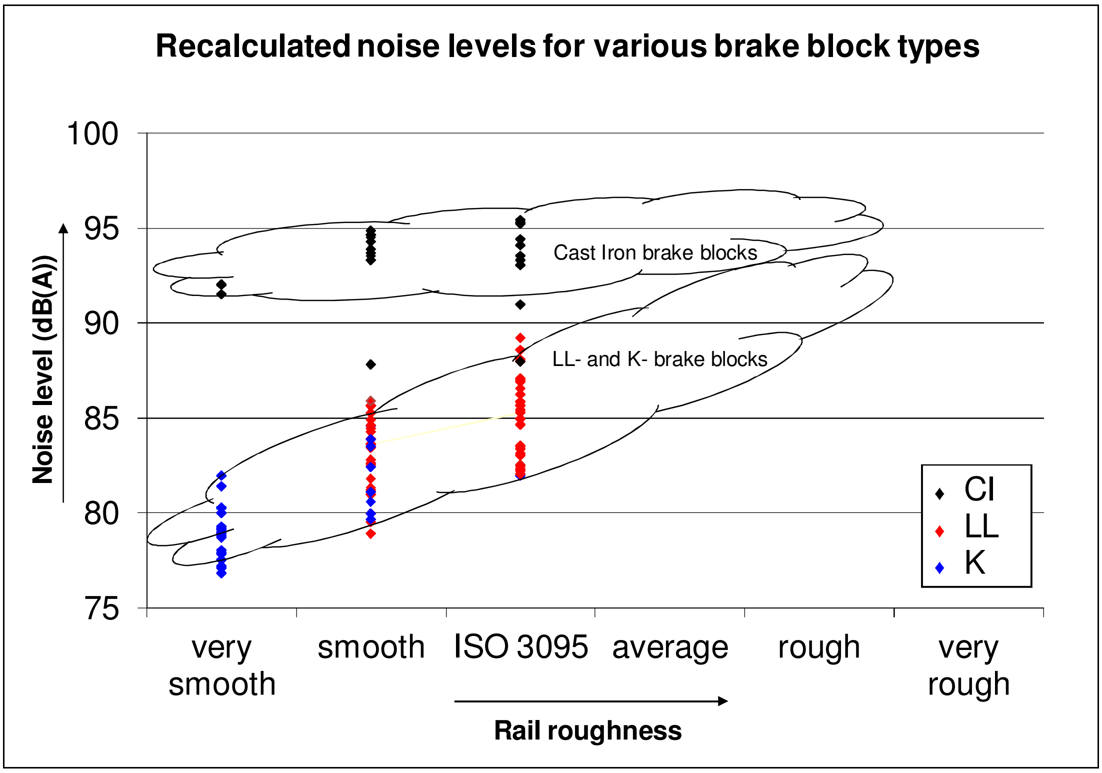


Figure 9 Noise levels recalculated to a comparable APL of 0,2 and a train speed of 80 kph for variable rail roughness

A distinction is made between the noise levels caused by freight wagons equipped with cast iron, LL- and K-brake blocks. Clearly it can be seen that application of composite brake blocks results in lower noise levels. Figure 9 also shows that the difference between the noise levels for the CI brake blocks in comparison to the noise levels for composite brake blocks (the potential noise reduction) decreases with increasing rail roughness. Both noise level “clouds” approach each other with increasing rail roughness. This figure confirms the theory presented in the impression of the influence of rail roughness on the potential noise reduction when using composite brake blocks as shown in figure 10 below. When using CI-brake blocks the influence of rail roughness is limited and wheel roughness is dominating. Only when the rail roughness is very high some influence on the noise levels may be seen, when using CI-brake blocks. When LL- or K-brake blocks are used this is the other way round. As a result potential noise reduction, when using composite brake blocks, will be much higher than mentioned above on very smooth tracks and much lower on very rough tracks.

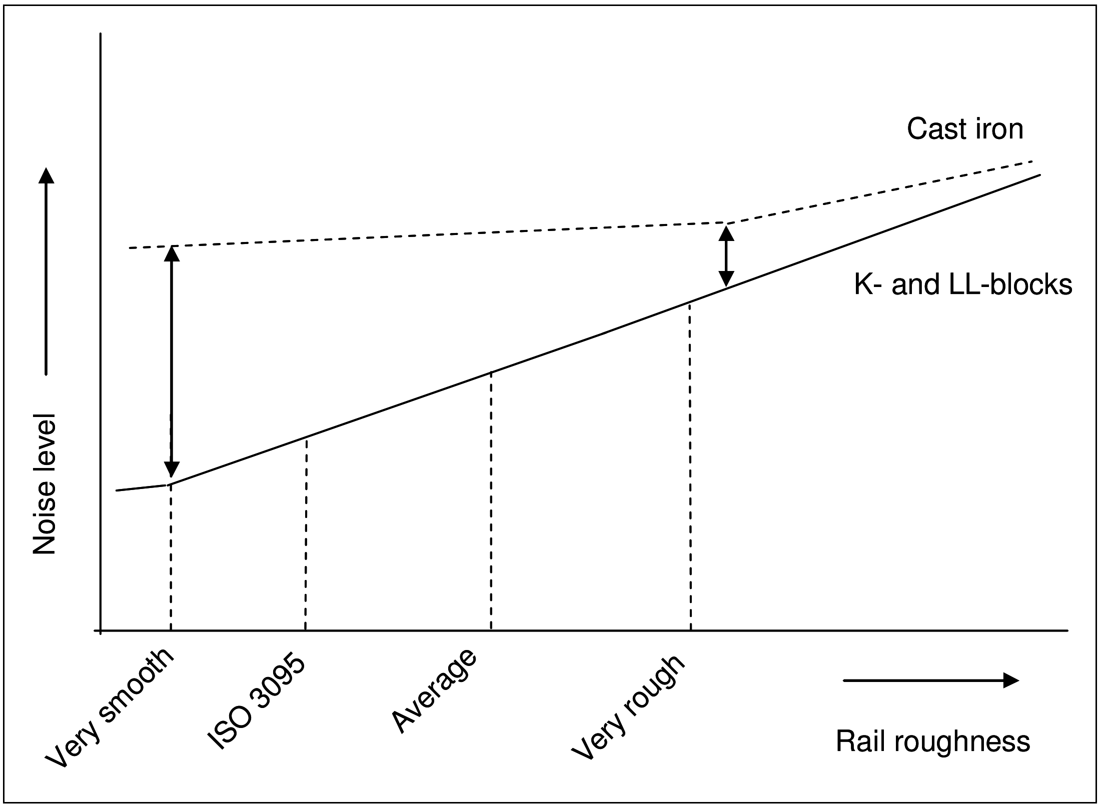


Figure 10 Impression of the influence of rail roughness on the potential noise reduction when using composite brake blocks

Figure 9 also shows that, even after recalculation to a comparable APL and train speed, noise levels for each of the brake block types used may differ 5 to 10 dB(A) depending on the circumstances. This spread is caused by other factors than train speed, APL or rail roughness. Other factors influencing the noise levels could be: train load, type of track, track decay rate and train conditions.

Figure 9 shows clearly why very different noise levels can be measured, depending on the location. In some locations (with high rail roughness) trains equipped with composite brake blocks might even produce almost comparable noise levels as trains with CI brake blocks in locations with a low rail roughness.

4.2 Rail roughness correction (reference ISO 3095 limit)

All of the noise levels, presented in chapter 3, have been recalculated to a rail roughness normalized to the CEN ISO 3095 limit. For these recalculations rail roughness and wheel roughness data are required. For all documents analyzed the rail roughness data belonging to the presented noise levels was available. The wheel roughness was only available for a few documents. However, the wheel roughness data, which were available, were very comparable. Therefore these have been assumed applicable for all recalculations.

In Figure 11 the wheel roughness data and CEN ISO 3095 rail roughness limit, used for the recalculation, are presented. The actual rail roughness data for each of the reports analyzed are presented in the various paragraphs in chapter 3. The influence of track decay rates has not been taken into account. No corrections have been made for differences in track decay rates. Track decay rates have a (limited) influence on the spread of the noise levels measured. However, studies in general don't present data, which make a correction for the track decay rate possible.

It is important to notice, that the rail roughness according to CEN ISO 3095 does not represent an actually existing track. It is merely a compromise between various good quality tracks. In many networks, the actual average track roughness could be well below the CEN ISO 3095 values, if the track is regularly maintained. Such tracks would be "quieter" than the theoretical CEN ISO 3095 track.

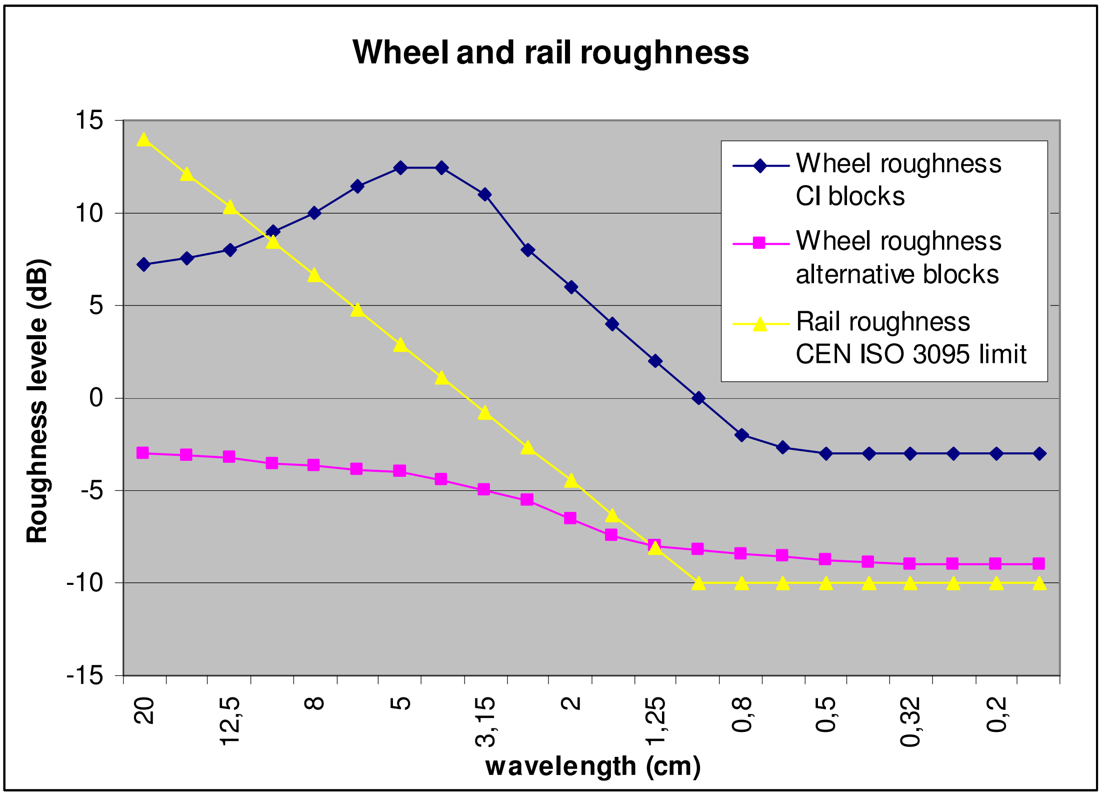


Figure 11 Wheel roughness data and rail roughness CEN ISO 3095 limit used for recalculation

Figure 11 supports the assumption made previously, namely that for cast iron brake blocks, the wheel roughness is dominant and the rail roughness has little influence on the resulting noise level, unless it is extremely high. For K- and LL-blocks on the other hand, the rail roughness is dominant and the resulting noise level is determined by the rail roughness. Noise reductions assessed will be coincidental, unless the measured data is corrected.

If spectral data (1/3 octave band spectra) of the pass by noise levels were available, the 1/3 octave band levels for each of frequencies have been corrected for the total (wheel and rail) roughness, depending on train speed, and summed up to a total recalculated noise level. Examples of these pass by noise spectra for various wagon types and different types of brake blocks at a train speed of 80 kph are shown in appendix 1. If no spectral data were available (only total noise level), an average rail roughness correction has been calculated for the most relevant frequencies (800, 1000 and 1250 Hz). This average correction has been implemented on the measured noise levels, also resulting in a recalculated noise level.

In Table 12 an overview of all recalculated noise reduction values is given. The data are sorted by brake block type. Table 12 gives a much clearer picture of the differences in performance of the different composite brake block types, than Table 11 in paragraph 3.12.

Table 12: Overview of the noise reduction, recalculated to a rail roughness normalized to the CEN ISO 3095 limit and sorted on brake block type (with the paragraph in which the original data are described)

Brake block type	Potential noise reduction in dB(A)	Paragraph
K	8	3.4
K Cosid 810	8	3.6
K Jurid 816	9	3.1
K Cosid 810	10	3.7
K Becorit 929-1	10	3.3
LL Jurid 777	7	3.6
LL Jurid 777	7	3.8
LL Jurid 777	8	3.5
LL Cosid 952	8	3.6
LL Cosid 952	8	3.8
LL Cosid 952-1	8	3.10
LL Cosid 952	9	3.5
LL Becorit IB116*	5	3.2
LL Becorit IB116*	5	3.2
LL Becorit IB116*	10	3.3
LL Becorit IB116*	10	3.6
LL Becorit IB116*	12	3.10

N.B. The figures in yellow are considered out of range, see discussion in the text below this table.

N.B. The LL Cosid 952, mentioned in this table, has been withdrawn from homologation and is replaced by the C952-1. Only three of the reports [8, 37, 39], analyzed for this study, present data for the LL Cosid 952-1 brake block instead of the C952 break block. Two of these reports [8, 39] are discussed in paragraph 3.9 and 3.10. The noise levels and noise reductions presented for the LL Cosid 952-1 in the three reports are comparable to the data presented in the other paragraphs for the LL Cosid 952. It is therefore assumed that the acoustical properties of both types of brake blocks will not differ much.

Only for the LL Becorit IB116* brake block the data remain inconsistent. Four studies (see paragraphs 3.3, 3.6, 3.9 and 3.10) show noise reductions which are a few dB(A) higher than the K-blocks and the LL Cosid 952/LL Cosid 952-1 brake block. One study (paragraph 3.2) shows much lower reductions (see the figures colored yellow). It is assumed that this is caused by a very low wheel roughness (maybe as result of a recent wheel re-profiling) for the wheels equipped with the CI brake blocks. These data are therefore considered out of range and are suppressed in the further summary.

5 MAIN FINDINGS AND CONCLUSIONS

General remarks and findings
As described in paragraph 1.2 there are various aspects which can influence measured noise levels and resulting potential noise reductions, when using composite brake blocks. Types of brake blocks used, type of freight wagon (different APL's), rail roughness and wheel roughness are the most important ones. Most of the documents, selected for analysis in the present study, take these aspects into account.

Figures presented for the potential noise reduction when using composite brake blocks will be influenced strongly by the type of data that are compared with each other:

- If pass by levels of different types of freight wagons are compared with each other the difference in APL of these wagons would influence the height of the noise levels of each of the wagon types and thus would result in a non realistic noise reduction. Therefore, in the present study noise data have been used only if both the noise information of the CI blocks and on the composite LL- or K- blocks were available for the same type of freight wagons. In this manner no recalculation on the basis of APL adjustments was required for the calculation of the potential noise reduction.
- Different types of composite brake blocks may have a different efficiency and thus result in different noise reductions. During this study the effect of the different types of brake blocks has been analyzed separately.
- The rail roughness of the tracks, where the measurements have been performed, has a big influence on the noise levels measured. When using CI-brake blocks the influence is limited, because the wheel roughness will also be high, resulting in high noise levels even on a smooth track. When LL- or K-brake blocks are used the wheel roughness will be lower and noise levels are mainly dominated by the track roughness. The influence of the use of composite brake blocks will therefore be higher on a smooth track. All results have therefore been presented together with the rail roughness information (TSI, ISO 3095, very smooth track, standard Dutch track). To enable a reliable comparison of the performance of the various composite brake blocks a recalculation has been made of the noise level data to a rail roughness normalized to the CEN ISO 3095 rail roughness limit. On tracks smoother than this CEN ISO 3095 curve, and quite likely on the German BüG, the reduction could be higher. This however has not been investigated due to a lack of experimental data.
- Wheel roughness will have a big influence on the measurement results. If wheels with CI blocks have been reprofiled shortly before the measurement this may result in confusing information. The noise levels will drop a few dB(A) in comparison to wheels that have not been re-profiled. Then it will seem as if the effects of LL- and K-brake blocks are lower than they are in practice. The wheel roughness with CI blocks will increase rapidly when in use. Measurements have shown that this is not the case with wheels fitted with LL- or K-brake blocks. After re-profiling the noise levels produced by these wheels will remain the same for a long time.

Observation of noise levels
All data analyzed clearly show that application of composite brake blocks results in lower noise levels. It is however also clear that, even after recalculation to a comparable APL and train speed, noise levels for each of the brake block types used presented for variable rail roughness may differ between 5 to 10 dB(A) depending on the circumstances (see Figure 9 in paragraph 4.1). Therefore citizens might experience very different noise levels depending on the location. In some locations (with high rail roughness) trains equipped with composite brake blocks might therefore even produce a higher noise level than trains with CI brake blocks in locations with a low rail roughness.

Potential noise reduction
The data analyzed during this study show the following potential noise reductions (for a rail roughness normalized to the ISO 3095 limit) for the various composite brake block types:

- K-blocks: - 8 to 10 dB(A)
- LL Jurid 777 block: - 7 to 8 dB(A)
- LL Cosid 952/LL Cosid 952-1 block: - 8 to 9 dB(A)
- LL Becorit IB116* block: - 10 to 12 dB(A)

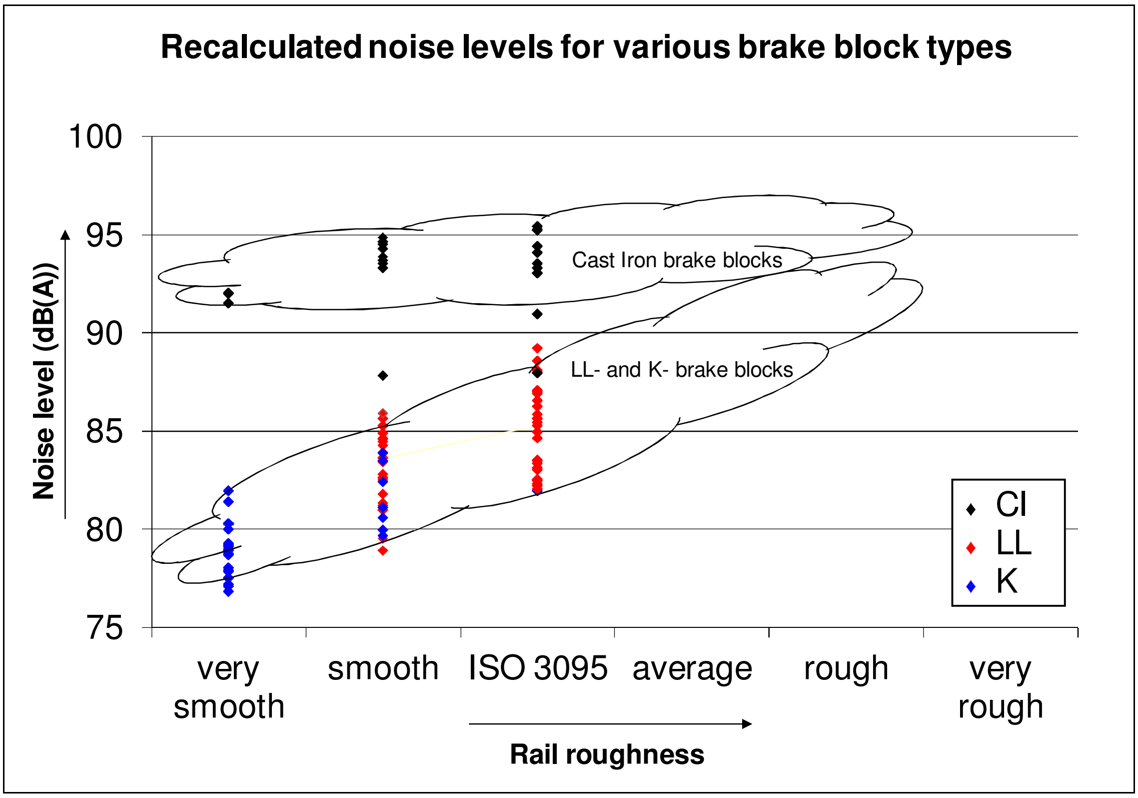
Because of the limited information for each type off K-block the different K-blocks are presented as one. The conclusions for the K-blocks are confirmed by the final report of the L Zar G (Leiser Zug auf realem Gleiss) project, which recently became available.

The influence of track decay rates has not been taken into account in this study. No corrections have been made for differences in track decay rates. Track decay rates have a (limited) influence on the spread of the noise levels measured. However, studies in general don't present data, which make a correction for the track decay rate possible.

The rail roughness has a big influence on the potential noise reduction. This is due to the fact that both the infrastructure and the wheel contribute to the generation of noise. This fact is similar to the situation with road traffic. Here, the car tyre type and the road surface both contribute to the rolling noise level. Changing tyres for a "quiet" tyre would be noticeable on a smooth and porous asphalt road surface, whereas it would hardly be noticeable on a cobble stone pavement. Vice versa: the use of studded car tyres in the Nordic countries makes the efficiency of quiet road surfaces hardly noticeable.

When using CI-brake blocks the influence of rail roughness is limited and wheel roughness is dominating. Only when the rail roughness is very high some influence on the noise levels may be seen, when using CI-brake blocks. When LL- or K-brake blocks are used this is the other way round. As a result potential noise reduction, when using composite brake blocks, will be much higher than mentioned above on very smooth tracks and much lower on very rough tracks. This theory is schematically presented in Figure 10 in paragraph 4.1 and is confirmed by the results of the recalculated noise levels (to a comparable APL of 0,2 and a train speed of 80 kph for variable rail roughness) as presented in the following figure, copied from figure 9 in paragraph 4.1.

In this figure a distinction is made between the noise levels caused by freight wagons equipped with cast iron, LL- and K-brake blocks. Clearly it can be seen that application of composite brake blocks results in lower noise levels. The figure also shows that the difference between the noise levels for the CI brake blocks in comparison to the noise levels for composite brake blocks (the potential noise reduction) decreases with increasing rail roughness. Both noise level "clouds" approach each other with increasing rail roughness.



Noise levels recalculated to a comparable APL of 0,2 and a train speed of 80 kph for variable rail roughness

On the basis of the findings of this report, it is recommended to express the noise reduction to be achieved by retrofitting in two different numbers. One would be the reduction achieved on a CEN ISO 3095 track. The other would be the reduction on a typical track. If used to national purposes only, a rail infra manager could define a standard roughness for good quality track in his network. If used for promotional purposes, the UIC could define a "standard good quality European track" and express reductions against this average.

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7 COLOPHON

Client	:	Union Internationale des Chemins de Fer
Project	:	Real noise reduction of freight wagon retrofitting
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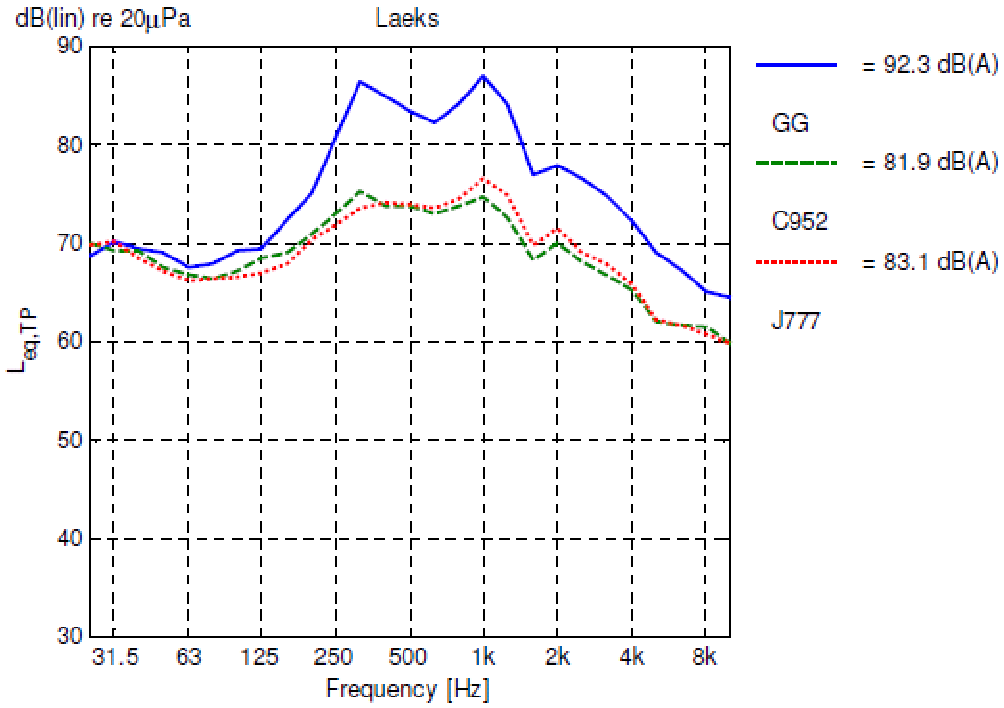
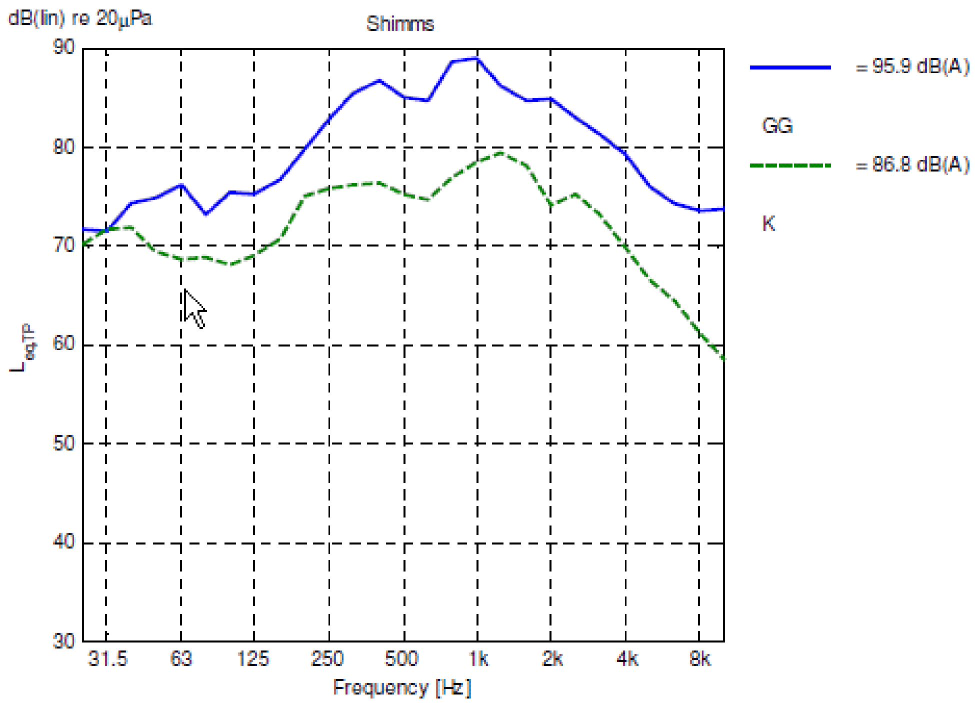
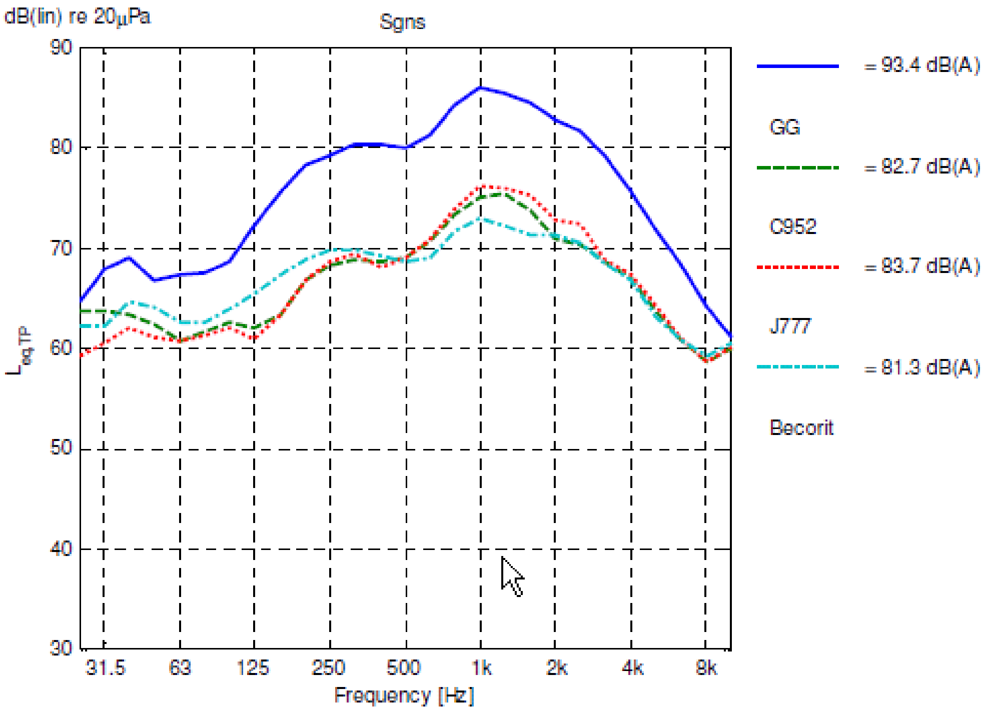
APPENDIX 1 Examples of pass by noise spectra for various wagon types and different types of brake blocks at a train speed of 80 kph (pictures taken from the TNO report [17])






dB(lin) re 20µPa
Sgns
90
80
70
60
50
40
30
$L_{eq,TP}$
31.5
63
125
250
500
1k
2k
4k
8k
Frequency [Hz]
= 93.4 dB(A)
GG
= 82.7 dB(A)
C952
= 83.7 dB(A)
J777
= 81.3 dB(A)
Becorit