




LRSSB - LRG - 5.0

Tramway Audible Warnings Acoustic Test Guidance

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SOURCE / RELATED DOCUMENTS:					
LRG 1.1 Tramway Safety Principles and Guidance (TPG) (LRSSB) LRG 4.0: Signing and Marking of Tramways (LRSSB) EN 15153-2:2019: Railway applications - External visible and audible warning devices - Part 2: Warning horns for heavy rail EN 15153-4:2019: Railway applications - External visible and audible warning devices - Part 4: Audible warning devices for urban rail EN 61672-1:2013: Electroacoustics. Sound level meters. Specifications BS EN 61672-2:2013+A1:2017: Electroacoustics. Sound level meters. Pattern evaluation tests BS EN IEC 60942:2018: Electroacoustics. Sound calibrators RAIB Report 19/2013: Fatal accident at Bayles and Wylies footpath crossing, Bestwood, Nottingham					
RELATED TRAINING COURSES:			RELATED LEGISLATION:		
N/A			Health & Safety at Work Act 1974 ROGS 2006 Control of Noise at Work Regulations 2005 Road Vehicles (Construction and Use) Regulations 1986		
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Revisions from first issue:

Reference made to LRG 4.0: Signing and Marking of Tramways (LRSSB).

Contents page made more succinct.

Terms table added to the document.

References section removed and footnotes added.

Introductory text / section added at the front of the document to make consistent with other LRSSB 'LRG' guidance documents.

Paragraph numbering and section renumbering / document formatting in line with above additional text added and to be consistent with other LRSSB 'LRG' guidance documents.

Text added / reordered to aid clarification where required / appropriate.

Numerous presentation, minor factual and typographical changes.


TERMS AND ABBREVIATIONS

Table 1 – Terms

Term	Definition
A-weighted sound pressure level	A sound pressure level that is weighted by a set of curves.
Class 1 Sound Calibrator	The highest of the reference standards in the calibration of sound i.e. is appropriate for calibrating high-precision analytical sound.
Instrumentation System	System for taking measurements
Line of Sight	Operating mode where a tram should be able to stop before a reasonably visible stationary obstruction ahead, from the intended speed of operation using the service brake.
Measuring System	A set of measuring devices where the operator receives the necessary information simultaneously.
Type 1 Instrument	Type of instrument used for precision measurements in the field.
Urban Guided Transport	(For this document) Tramway / Light Rail system

Table 2 – Abbreviations

Abbreviation	Definition
AWD	Audible Warning Device
BS	British Standard
BS EN	British (BS) adoption of a European (EN) standard
Db	Decibel
Hz	Hertz (Cycles per Second)
KhZ	Kilo-Hertz (thousand cycles per second)
LRSSB	Light Rail Safety Standards Board
LpAFmax	The maximum Sound Level with 'A' Frequency weighting and Fast Time weighting during the measurement period
M	Metres
Mr	Medium Range
ms	Milli-Seconds
PPE	Personal Protection Equipment
RAIB	Rail Accident Investigation Branch
SR	Short Range
UGT	Urban Guided Transport

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1 Introduction

- 1.1 This guidance supports the high level principles set out in LRG 1.1 Tramway Principles and Guidance (TPG) published by the Light Rail Safety Standards Board (LRSSB).
- 1.2 This document provides high level guidance for Tramway Audible Warning Acoustic Tests in relation to UK Light Rail / tramway systems based on 'line-of-sight' operations only. As with all guidance, this document is not prescriptive and is intended to give advice not to set a mandatory industry standard, and it is based upon goal setting principles as best practice. Much of this guidance is based on the experience gained from existing UK Light Rail systems and from published documents.
- 1.3 This guidance offers good practice that seeks to provide an acceptable level of assurance in Tramway Audible Warning Acoustic Tests by those delegated this responsibility. This document provides guidance and does not provide a process for type approving audible warning devices (AWDs).
- 1.4 This guidance is not intended to be applied retrospectively to existing tramway / Light Rail system. However, owners and operators should consider and assess any implementation of this guidance and / or any subsequent revision, to ensure continual improvement, so far as is reasonably practicable.

2. Scope

- 2.1 Tramways / Light Rail systems are Urban Guided Transport (UGT) systems that are not segregated from general road and pedestrian traffic. They share their right of way with general road and / or pedestrian traffic and are therefore embedded in their relevant national road traffic legislation (for example highway codes and specific adaptations etc).
- 2.2 The test procedure in this document is based on EN 15153-4:2019¹ and designed to be used by UGT suppliers and maintainers in order to validate that UGT systems meet the essential requirements as defined in the LRSSB guideline document LRG 1.1.
- 2.3 As stated in LRG 1.1, AWDs should be installed at both ends of a UGT to ensure that they provide sufficient sound pressure outputs in keeping with the environment in which the UGT runs.
- 2.4 In general, a UGT operating on-street must conform to the current Road Vehicles (Construction and Use) Regulations 1986² for road vehicles as far as appropriate. Although not subject to the mandatory requirements for road vehicles, a UGT should nevertheless include features in their construction and performance that make them safe for use on the highway and in other places where they share the infrastructure with other users.

¹ EN 15153-4:2019 – Railway applications - External visible and audible warning devices - Part 4: Audible warning devices for urban rail.

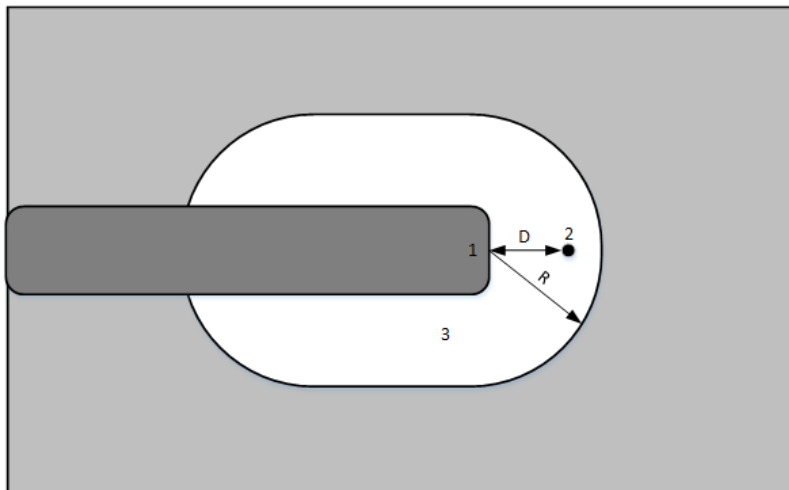
² The Road Vehicles (Construction and Use) Regulations 1986 SI 1986/1078
<https://www.legislation.gov.uk/uksi/1986/1078/made/data.pdf>

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3. Test Conditions

- 3.1 The test requirements of EN 15153-2³ Clause 6 should apply, with the following modifications as specified in EN 15153-4:
- 3.2 The test environment should be representative of the operating environment, i.e. it is not required to be ballast.
- 3.3 The measurement distance ('D') is 7m (as illustrated below in Figure 3.1) with a relative tolerance of $\pm 2\%$. This measurement is from the front of the vehicle along the centre-line of the track at a height of $1.6\text{ m} \pm 3\%$ above the top of rail.
- 3.4 For sound pressure level tests, three measurement samples should be taken. In each case, the arithmetic mean value of the three measurement results should be used. If the frequency results vary by more than 5% or the sound pressure level results vary by more than 3 dB, then the three measurement results should be discarded, and the measurements repeated.

Figure 3.1: Open Test Site



Key:

D= 7m


$R \geq 2D$

1 = Front of UGT

2 = Measurement of position

3 = Open Area

³ EN 15153-2:2019 – Railway applications - External visible and audible warning devices - Part 2: Warning horns for heavy rail.

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4. Test Equipment

- 4.1 The test equipment should conform to the following:
- 4.2 Each component of the instrumentation system should meet the requirements for a type 1 instrument, as specified in EN 61672-1⁴.
- 4.3 A suitable microphone windscreen should always be used during the tests.
- 4.4 The calibration of the measuring system should be verified before and after each series of measurements. The adjustment of the measurement equipment should use a class 1 sound calibrator that meets the requirements set out in EN 60942⁵, and should include the calibration at least at one frequency in the range of frequencies of interest. The measurement results should be rejected and retested if the difference between the adjusted results before and after calibration is greater than 0.5 dB.
- 4.5 As a minimum, the calibrator should be verified against the requirements of EN 60942 every 12 months.
- 4.6 As a minimum, all components of the measurement system should be verified against the requirements of EN 61672-1 and EN 61672-2⁶ every two years. The date of the last verification of the compliance of the calibrator with the relevant European Standards should be recorded.

5. AWD Limits

- 5.1 The sound pressure level of the background noise and wind noise must be at least 10 dB (A) below the sound to be measured (refer to BS EN 15153-4).

Short Range (SR) AWDs

- 5.2 Tramway / Light Rail systems should to be fitted with short range (SR) AWDs at each driving end of the vehicle (refer to LRG 1.1 TPG).
- 5.3 The types of permitted devices for providing audible alerts or drawing attention at short range are listed below and then explained in more detail in the following sections.
- SR soft bell - single sound;
 - SR soft bell - recurring sound;
 - SR whistle, and
 - SR warning horn.

SR Soft Bell - Single Sound

- 5.4 When actuated, the single sound SR soft bell AWD should emit an impulse sound with a decay having the following characteristics:
- Total audible duration not less than 500 ms;

⁴ EN 61672-1:2013 - Electroacoustics. Sound level meters. Specifications

⁵ BS EN IEC 60942:2018 - Electroacoustics. Sound calibrators

⁶ BS EN 61672-2:2013+A1:2017 - Electroacoustics. Sound level meters. Pattern evaluation tests

- Rise time not greater than 100 ms;
- Fundamental frequency of the sound should be within the range from 1 kHz to 4 kHz, and
- Sound pressure level of the emitted sound should be $76 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.

5.5 It should be noted that in the case of SR soft bells with a non-harmonic character, the decision for relevant frequency content should be based on the difference in level between peaks outside the specified spectrum and the level for the highest frequency peak.

5.6 When assessing suitability, frequency peaks at least 4 dB below the highest frequency peak should be considered to be not relevant.

SR Soft Bell - Recurring Sound

5.7 A SR soft bell AWD with a recurring sound should meet the criteria as for a SR Soft Bell AWD with a single sound, with the following additions:

- Recurring time-base with the following characteristics:
 - 1.5 to 4 Hz in the case of single-stroke bells, or
 - 20 to 40 Hz in the case of motor driven bells.

SR Whistle

5.8 A SR whistle AWD should meet the following criteria:

- Maximum peak frequency of $1.3 \text{ kHz} \pm 300 \text{ Hz}$, and
- Sound pressure level of the emitted sound should be $76 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.

SR Warning Horn

5.9 A SR warning horn AWD should meet the following criteria:


- Maximum peak frequency of $1.3 \text{ kHz} \pm 300 \text{ Hz}$, and
- Sound pressure level of the emitted sound should be $76 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.

Medium Range (MR) AWD

5.10 As with SR AWDs above, tram / Light Rail systems are also required to be fitted with a medium range (MR) AWD at each driving end of the vehicle. When actuated, AWDs should emit a continuous, uniform sound or a series of short, urgent, danger warnings.

5.11 The criteria for devices permitted in providing audible alerts or drawing attention at medium range are listed below and then explained in more detail in the following sections:

- MR bell - single sound;
- MR bell - recurring sound;
- MR whistle, and
- MR warning horn.

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MR Bell - Single Sound

- 5.12 When actuated, a MR bell AWD with a single sound should have the following characteristics:
- Total audible duration in the range 500 ms to 1 second,
 - Rise time not greater than 100 ms,
 - Fundamental frequency of the sound should be within the range from 1 kHz to 4 kHz, and
 - Sound pressure level of the emitted sound should be $96 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.
- 5.13 It should be noted that pursuant to the RAIB report into the Bayles and Wylies incident⁷, the recommended working of the AWD is to provide a series of short, urgent danger warnings.
- 5.14 It should also be noted that in the case of MR bells with a non-harmonic character (as with SR soft bells), the decision for relevant frequency content should be based on the difference in level between peaks outside the specified spectrum and the level for the highest frequency peak.
- 5.15 When assessing suitability, frequency peaks at least 4 dB below the highest frequency peak should be considered to be not relevant.

MR Bell - Recurring Sound

- 5.16 A MR bell AWD with a recurring sound should meet the criteria as for a MR bell AWD with a single sound, with the following additions:
- Recurring time-base with the following characteristics:
 - 1.5 to 4 Hz in the case of single-stroke bells, or
 - 20 to 40 Hz in the case of motor driven bells.


MR Whistle

- 5.17 A MR whistle AWD should meet the following criteria:
- Maximum peak frequency of $1.3 \text{ kHz} \pm 300 \text{ Hz}$, and
 - Sound pressure level of the emitted sound should be $96 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.

MR Warning Horn

- 5.18 A MR warning horn AWD should meet the following criteria:
- Fundamental frequency:
 - $370 \text{ Hz} \pm 20 \text{ Hz}$, or
 - $660 \text{ Hz} \pm 30 \text{ Hz}$.
 - Sound pressure level of the emitted sound should be $96 \text{ dB} \pm 5 \text{ dB}_{\text{pAFmax}}$.
- 5.19 It should be noted that is desirable for a warning horn AWD to provide a spectrum which is rich in harmonics to optimise audibility for persons with partial hearing loss.

⁷ RAIB Report 19/2013 - Fatal accident at Bayles and Wylies footpath crossing, Bestwood, Nottingham

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6. Test Procedure

- 6.1 When testing AWDs, consideration should be given to the location of the AWD, noting the above limits and also taking into account the possible exposure of staff to excessive noise.
- 6.2 It should be noted that this test should not be carried out in snow conditions.

Safe System of Work

- 6.3 The risk of accidental hearing damage to any person working close to the UGT when an AWD is sounded must be considered. All AWD testing must be carried out safely in accordance with the Control of Noise at Work Regulations 2005⁸.
- 6.4 In order to minimise any environmental impact, the AWD should be orientated along the longitudinal axis of the vehicle. It is permissible for additional AWDs to be fitted, for example bells.
- 6.5 The associated testing schedule for these tests should make appropriate allowance for the exposure to noise limits and provision of any necessary Personal Protection Equipment (PPE).
- Workers exposed to daily or weekly average noise exposure levels between 80 & 85 dB must use hearing PPE, and
 - Workers must not be exposed to noise exposure levels in excess of 87 dB (taking into consideration any hearing PPE).

AWD Installation

- 6.6 On installation, a visual inspection of the AWD and its control systems should be carried out to confirm that they are adequately protected from impact and any potential subsequent blockage by airborne objects such as debris, dust, snow, hail and birds etc as far as is reasonably practicable.
- 6.7 Where any such protection features are used, the acoustic requirements should apply, taking into account any protection features that have been installed.

Operation

- 6.8 As a minimum, functionality of the AWD should be checked each time the vehicle is handed back from maintenance to operation.
- 6.9 Although it is not required for a vehicle installed AWD to be included in regular maintenance activities, it is good practice for this to be part of the maintenance regime.

Frequency Measurement

- 6.10 Although a frequency measurement test is not required for a vehicle installed AWD, it is good practice for this to be undertaken and the AWD data sheet appended to the test report.

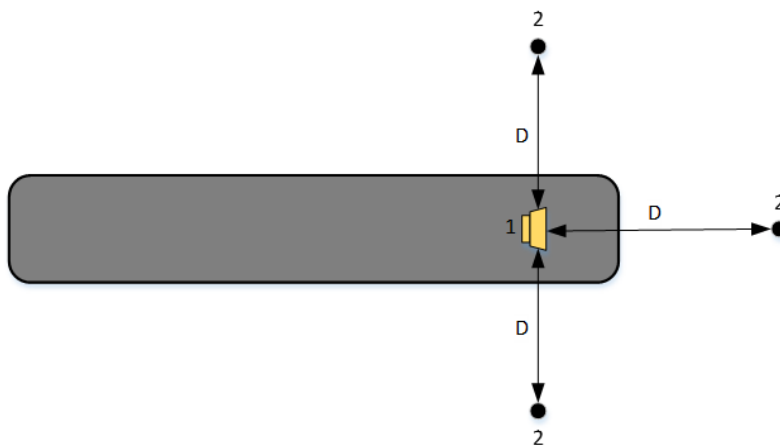
⁸ Control of Noise at Work Regulations 2005 <https://www.legislation.gov.uk/ukxi/2005/1643/made/data.pdf>

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Sound Pressure Levels

- 6.11 The A-weighted sound pressure level L_{pAFmax} produced by each AWD sounded separately (or in a group if designed to sound simultaneously) should be between 91 dB and 101 dB when measured and verified at location 2 as illustrated in Figure 3.1.
- 6.12 In order to minimise the environmental impact of the AWD, the A-weighted sound pressure level L_{pAFmax} from the mounted AWD when measured should be at least 5 dB lower than the level measured at location 2 in front of the vehicle as illustrated in Figure 6.1 below.

Figure 6.1: Lateral Measurements



Key:


- D = 7m
- 1 = AWD
- 2 = Measurement position

Energy

- 6.13 The vehicle electrical supply voltage to the AWDs should be recorded both before and after the suite of tests. The AWD should be operated using the normal energy supply on the vehicle.
- 6.14 The AWD should meet the technical requirements of the Standards referred to in this guidance for the full range of energy levels encountered on the vehicle in its normal operational condition.
- 6.15 Where agreed between vehicle supplier, owner and operator, the AWD should be operational over an extended range of energy levels.

7. Report

- 7.1 The test results should be documented in a test report and should as a minimum include the following details (not exclusively):
 - Reference to EN 15153-2, including any deviations;
 - Description of the environmental conditions of the test site location;
 - acoustical environment (presence of obstacles, ground cover);
 - meteorological conditions;

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- ambient temperature;
 - humidity;
 - wind speed and direction, and
 - precipitation;
- background sound pressure level.
- Description of the AWD (type and serial number(s), and mounting arrangements of the AWD),
- Description of the AWD test conditions:
 - conditions of energy source;
 - actuation device used, and
 - the duration of the evaluation time.
- Description of the measurement instrumentation:
 - type of acquisition system, and
 - type of microphone.
- Measurement positions,
- Number of sample measurements,
- Test results:
 - the frequency values and sound pressure levels of all measurement samples, and
 - the mean values of the test results.
- Any other useful information applicable to the tests.

7.2 The above list is not exhaustive as the test report should include any relevant additional detail that is specific to the test and UGT.

7.3 In the case of additional tests, all relevant information should be included in the report.