

RAILWAY TRAFFIC: NOISE

UDC 534.61

Key words: Railway traffic noise, single train passage, noise immission, test method

1 SCOPE

This Nordtest method specifies a method for measurement of A-weighted sound pressure levels (noise immission) from railway traffic inside and outside buildings and in open terrain. The method includes manually operated measurements only (and not long term automatic measurements). In Annex A a few guidelines are given for the performance of measurements under weather conditions other than those described in the main body of this Nordtest method.

2 FIELD OF APPLICATION

This Nordtest method specifies a method for the performance of measurements of noise immission for instance in residential areas. The method is based on measurements of equivalent and maximum sound pressure levels of single train passages. Noise from rail terminal operations is not included in the method. The method may be used as a complement to standardised calculation procedures, such as "The Nordic prediction method for railway noise". The method does not cover measurements of noise emission (close to the vehicles).

3 REFERENCES

IEC 651, Sound level meters.

IEC 804, Integrating-averaging sound level meters.

IEC 942, Sound level calibrators.

Railway Traffic Noise - Nordic prediction method. Tema Nord 1996:524, Nordic Council of ministers

4 DEFINITIONS

For the purpose of this Nordtest method the following definitions apply.

4.1 A-weighted sound pressure level, L_{pA} , in decibels

The value of the sound pressure level determined using frequency weighting A, as defined in IEC 651. The reference sound pressure is 20 μ Pa.

4.2 Equivalent sound pressure level, $L_{eq,T}$, in decibels

The value of the sound pressure level of a continuous, steady sound that, within a specified time interval T ($= t_2 - t_1$), has the same mean square sound pressure as the sound under consideration, the level of which varies with time. It is given by the formula:

$$L_{eq,T} = 10 \lg \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} dt \right] \text{ dB} \quad (1)$$

where

$p(t)$ = the instantaneous sound pressure of the noise signal
 $p_0 = 20 \text{ mPa}$

$T = t_2 - t_1$ = a specified time interval

The equivalent sound pressure level can be A-weighted and determined for different time periods, T , and will then be denoted $L_{Aeq,T}$, for instance 24-hour equivalent level $L_{Aeq,24h}$.

4.3 Sound exposure level, L_{AE} , in decibels

The sound exposure level (SEL), L_{AE} , is given by

$$L_{AE} = L_{Aeq,T} + 10 \lg \frac{T}{T_0} \text{ dB} \quad (2)$$

where

$L_{Aeq,T}$ = The A-weighted equivalent level during the measurement time T (seconds)

T = The time of measurement of a single train passage, in seconds.

$T_0 = 1 \text{ second}$

4.4 A-weighted maximum sound pressure level, L_{Amax} , in decibels

The A-weighted maximum sound pressure level measured with time weighting F, L_{AFmax} , or with time weighting S, L_{ASmax} . L_{AFmax} is used unless otherwise specified. See Annex B for further information.

5 MEASURING EQUIPMENT

5.1 General

The entire instrumentation and analysis system, including tape recorder, if any, shall meet the class 1 requirements of IEC 651 for sound level meters and IEC 804 for integrating-averaging sound level meters.

Calibrators shall comply with IEC 942, class 1 calibrators. All instruments shall be operated according to the manufacturers instructions and within their specified environmental conditions.

A free field microphone is preferred for these measurements. A microphone of pressure type can also be used. The difference between free field and pressure microphones is insignificant within the frequency range of interest for the A-weighted values.

5.2 Calibration and verification

At least immediately before and after each series of measurements place a sound calibrator on the microphones for checking the calibration of the entire measuring system at one or more frequencies (between 100-2000 Hz).

Calibrate and verify instrument performance, with traceable documentation, regularly in order to comply with the above IEC Publications. The commonly accepted verification interval is 2 years for sound level meters and 1 year for calibrators.

6 MEASUREMENTS

6.1 Selection of test samples

Before starting a measurement series determine which train types dominate the noise levels (equivalent and maximum level). This can, for instance, be carried out by a preliminary measurement or a prediction with the Nordic calculation method. Consider the train lengths and speeds in the calculation. Both the lengths of the individual trains (for maximum level) and the total length during a part of or a whole day (for equivalent level) must be considered. It is possible that different train types are of different relative importance for the maximum and the equivalent level.

Find a time during the day, for the measurement series, when the train types that dominate the noise levels are as well represented as possible. In each measurement series include at least 3 different train passages for each of the dominating train types. The total length, of the three (or more) train passages, shall exceed 500 metres.

6.2 Weather conditions

During the measurements the ground shall not be frozen or covered with snow. The mean value of the wind speed (during the train passage) shall not exceed 8 m/s at the microphone position. The mean wind direction shall deviate less than 60° from the direction of the shortest line between the microphone and the tracks. Avoid measuring in rainy weather.

Note. In rainy weather microphones and other equipment may be influenced by moisture. The sound of the trains (for instance the noise in curves) can also be different.

Alternatively the measurements can be carried out when there is temperature inversion (the temperature increases with the height above the ground) and no wind. Such is often the case during nights following clear days.

In some specific situations it is possible to measure in other weather conditions than those mentioned above, see Annex A.

6.2.1 Measurement distances up to 30 metres

No additional requirements. The requirement for the wind direction is not necessary in this position.

6.2.2 Measurement distances between 30 and 100 metres

The wind speed measured at the height of 1.5 metre above the ground shall be greater than 1 m/s during the train passage. There shall be a wind component from the railway track (the part of the track that gives the highest noise level) towards the measurement position ($\pm 60^\circ$).

6.2.3 Measurement distances beyond 100 metres

For distances beyond 100 metres the requirement is the same as for the distance 30-100 metres, except for an upper limit of the wind speed due to background noise at the microphone position. Check the background sound pressure level whenever the wind speed exceeds 5 m/s, see clause 6.4.

6.3 Procedure

6.3.1 General

For each individual train included in the measurements observe and report the following:

- noise level (L_{AE} , L_{Amax})
- train type
- speed of the train
- length of the train
- other details of special interest
- time of day when the train was passing

Measure L_{AE} during the time T, which, due to background noise, shall be as short as possible but long enough to include all important noise contributions of the whole train passage.

Determine the speed of the train either by measuring it directly or by calculating it from known data of the train length and a measurement of the time the train takes to pass between two fixed points along the track.

Determine the length of the train either by first counting the carriages and engines and then calculating the length using known data of engine and carriage lengths or by calculating it from time of passage and speed, if measured.

Other details according to clause 6.7 shall also be observed and reported.

6.3.2 Outdoor measurements

The choice of microphone position depends on the purpose of the measurement. If the purpose of the measurement is to *compare the noise level with limit values in a regulation* the microphone shall be positioned as stated in that document.

1) Free field position

This position shall be free from nearby reflecting surfaces other than the ground. Exceptions can be made for small reflecting surfaces and in other cases when it can be shown that the reflections have negligible effect (< 0.5 dB). If no other position is mentioned in guidelines etc, use the position 1.5 metre above the ground. This is the preferred position when the ground is level and/or the line of sight is unobstructed from the microphone position to the railway track. Place the microphones on, for instance, a tripod.

Note. If the position 1.5 metre above the ground is below the line through the source and the top edge of the screen, the measurement results may have poor reproducibility.

2) Comparison measurements

These can be carried out before and after a change in track or traffic conditions, building construction or before and after introduction of noise reduction. The position of the microphones shall be typical of the area considered. It is, in these cases, important that all parameters except the one investigated remain unchanged.

Avoid microphone positions around the line through source and the top of the screen, measure either below or above this line.

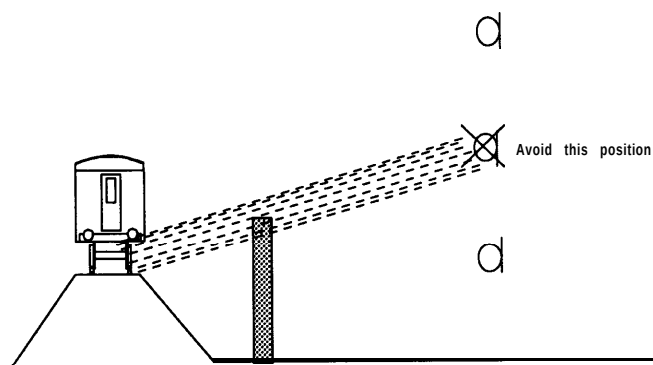


Figure 1 Avoid microphone positions at and around the line: "source - screen top": measure well above or below this line.

3) Outdoor measurements close to a building (+6 dB- and +3 dB-position)

When noise levels are measured outside a house, it is recommended to use a facade position (+6 dB-position) for the microphone. To be considered as a +6 dB-position the microphone shall be fastened directly to the facade (window). To be comparable with a free field position the measured value on the facade shall be reduced by 6 dB. This position can not be used if the facade has large recesses or balconies. Then the +3 dB-position shall be used. The microphone shall be placed in a position 0.5-2 metre in front of the facade to

be considered as a +3 dB-position. The noise level measured in this position shall be reduced by 3 dB to be comparable with a free field position.

6.3.3 Indoor measurements

Use a microphone of pressure or free field type.

The microphone positions shall be chosen in accordance with Nordtest method NT ACOU 042, Rooms: Noise Level. However, for the purpose of measuring train noise, fixed measurement positions shall be used (i.e. not a continuously moving microphone). The most important guideline in NT ACOU 042 is that at least 3 microphone positions, randomly distributed in the room, shall be used. No microphone position shall be located closer than 0.5 metre from the room surfaces and 1 metre from the dominating sound transmission element (usually windows and ventilators). For more information, see NT ACOU 042.

Note. Indoors it may be difficult to comply with the requirements regarding the highest permissible background noise level. If the limit value is exceeded the result may still be reported but with an indication that the measured value is higher than the real one, i.e. $L_{AE} < 42$ dB.

6.3.4 Procedure for measuring in several positions with a two channel instrument

Under some circumstances it is necessary to measure simultaneously in two or more microphone positions.

Select one position, the most important one, as a fixed reference position. In this position record all train passages of the measurement series. Move the other microphone between the other positions. The result in the other positions shall only be used to calculate the difference in sound pressure level in relation to the reference position.

The final result shall be based on the result in the fixed reference position calculated according to clause 6.5 and the difference between the measured noise levels in the reference position and the additional positions. In annex C an example of this is given.

6.4 Background noise

The equivalent A-weighted background noise level including the internal instrument noise shall be at least 15 dB below the maximum sound pressure level during the train passage. This criterion shall be applied to all microphone positions in question. Wind noise counts as background noise. Check the wind noise at the microphone position to ensure that this source of background noise does not influence the measurement result.

6.5 Expression of results

6.5.1 Calculation of L_{Aeq} for a whole day or a part of the day

All train passages measured shall be considered as typical for the site. Check and report the speed of the trains. However, if a train passage is atypical it can be excluded.

All L_{AE} values for each train type shall be added and the measured train length of the train type shall be normalised to the real length of that train type during the part of the day considered. This will give a $L_{AE,type}$ for each train type:

$$L_{AE,type} = 10 \lg \left[\frac{L_{type}}{l_{type}} \left(10^{\frac{L_{AE,1}}{10}} + 10^{\frac{L_{AE,2}}{10}} + \dots + 10^{\frac{L_{AE,n}}{10}} \right) \right] \text{ dB} \quad (3)$$

where

L_{type} = total length of the train type during the part of the day considered

l_{type} = length of the trains, for the train type, in the measurement series

$L_{AE,1}$, $L_{AE,2}$ etc = SEL for passage no 1, 2 etc for the train type in question

Finally, calculate the total equivalent level for all train types from:

$$L_{eq,T} = -10 \lg(3600T) + 10 \lg [10^{\frac{L_{AE,type1}}{10}} + 10^{\frac{L_{AE,type2}}{10}} + \dots] \text{ dB} \quad (4)$$

where

T in hours can be a whole day or any part of the day

$L_{AE,type1}$ = Total L_{AE} according to equation (3), for train type 1

6.5.2 Calculation of maximum noise level

The result of the measurement is the average maximum A-weighted sound pressure level given for each single train passage of the train type that gives the highest maximum A-weighted sound pressure level:

$$L_{Amax} = 10 \lg \left(\frac{10^{\frac{L_{1,max}}{10}} + 10^{\frac{L_{2,max}}{10}} + \dots + 10^{\frac{L_{n,max}}{10}}}{n} \right) \quad (5)$$

where

$L_{1,max}$ = The maximum level for train no 1 of the train type in question.

L_{Amax} is calculated for each train type and the final result is the one with the highest level.

6.6 Measurement uncertainty

The measurement uncertainty is not known.

Note. A joint Nordic Round Robin measurement series has been carried out according to this measurement method. 4 participants carried out measurements, one at a time, in the same position at the distance 100 metres from the track. The result of this limited test was that the uncertainty in most situations is ± 2 dB for L_{Aeq} and ± 5 dB for L_{Amax} .

6.7 Test report

The test report shall include the following information, if relevant:

- 1) Test results
- 2) Purpose of the test
- 3) Name and address of the testing organisation
- 4) Name and other identification marks of the trains included in the measurement series. The type, length and speed of each individual train.
- 5) Condition of the track(type, curves, maintenance, etc)
- 6) Environmental data during the test (wind speed and direction etc)
- 7) Date of the measurement
- 8) Test method including the microphone positions.
- 9) Any deviation from the test method
- 10) Identification of the test equipment and instrument
- 11) Method of sampling and other circumstances
- 12) Uncertainty of the test result
- 13) Name and address of the organisation or the person who ordered the test
- 14) Identification number of the test report
- 15) Date and signature
- 16) Sketch of the measurement site (with all distances and heights).

ANNEX A

(Informative)

Measurements in other weather conditions and with class 2 instruments

In some measuring situations it may become necessary to modify the normal procedure. In this annex a few guidelines about possible modifications are presented. It must, however, be observed that any such modification is the sole responsibility of the person (or company) carrying out the measurements. All modifications shall be clearly stated in the test report.

Measuring equipment - General

The entire measurement system shall, at least, meet the class 2 requirement of IEC 651.

Calibration and verification

See clause 5.2 in the main body of this Nordtest method.

Weather conditions - Measurement distances above 30 metres

If the wind component is in the wrong direction, there still remain some alternatives to carry out the measurement:

a) Move the microphone position closer to the rail, that is approximately 25 metres from the track centre. Use the values measured here to calculate the expected values at other positions. Use the Nordic prediction method for this calculation.

b) Move the microphone position to the opposite side of the track (where the wind component is in the "right" direction). The terrain must be equal on both sides of the track.

c) Move the microphone to a higher position above the ground. As an example a position 4-5 metres above the ground is preferable to one 1.5 metres above the ground, when the wind component is in the "wrong" direction. The measurement distance shall, however, never exceed $10 \times (\text{source height} + \text{receiver height})$.

Measurement uncertainty

When any of the modifications described in this annex is used the accuracy will be worse than stated in the method.

ANNEX B (Informative)

Information about the difference between time weighting F and S

The difference between A-weighted maximum sound pressure level with time weighting F and S has been discussed several times in the Nordic countries. The difference will depend on distance, train length, track and rolling stock condition and speed. In [B.1] the information in Table B.1 is given as a guidance.

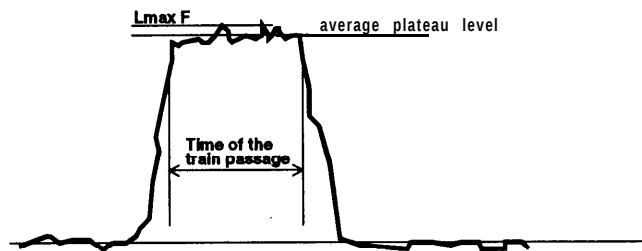
Table B. 1. The difference between L_{AFmax} and L_{ASmax}

Distance of measurement	Mean value of difference	Largest individual difference	Smallest individual difference	Number of trains in the measurement series
20-30 metres	1.7 dB	4.3 dB	0.5 dB	450
100 metres	0.9 dB	2.2 dB	0.3 dB	25
250 metres	0.7 dB	2.4 dB	0 dB	25

The conclusion of this is that the time weighting is less and less important the further away from the track the measurement is made. Already at the distance 100 metres the difference between the two time weightings is less than 1 dB (mean value).

The corrections of table B.1 can be applied to the measured A-weighted maximum level, if necessary.

Note. In the Nordic prediction method (dated 1983) the A-weighted maximum sound pressure level with time weighting S is used. In the revised method (dated 1995) the time weighting F or the "average plateau level", see figure below, is to be used.



REFERENCE

[B.1] SP report 94F36057, date 23rd August 1994. "Mätning av maximala bullernivåer från tag, med tidsvägning F och S (in Swedish).

[B.2] PM 93-08-09 Conny Larsson, Department of Meteorology Uppsala University "Vaderinverkan på val av integrations-tiden fast eller slow" (in Swedish).

ANNEX C (Informative)

Example of a measurement in 5 positions with 2 sound level meters

This annex gives an example of how measurements are to be carried out in five positions, at a time when only two sound level meters are available.

The principle is to place one of the sound level meters in one fixed position (for instance the most interesting position, if any) and it shall remain there during the whole measurement series. The other (one or more) sound level meter shall be moved between the additional positions of interest. If possible, try to measure approximately the same number of train passages (of all train types) in all the additional positions.

A measurement has been carried out with two sound level meters yielding the results given in Table C.1. The first sound level meter was placed in a reference position, in the garden, during the whole measurement series. The second sound level meter was moved between four other positions, one outside and three inside a room. The number of trains included in the measurement series is 15, with two types of trains on the track.

Table C. 1. Results of measurements in two positions

Type of train	reference position	additional position outside	inside pos 1	inside pos 2	inside pos 3	Difference ΔL inside-ref	Difference ΔL add,out-ref
type 1	82.3	79.2					-3.1
type 2	77.8	76.1					-1.7
type 2	77.5	77					-0.5
type 1	84.4	84					-0.4
type 1	79.8	75					-4.8
type 1	78.3		41.5			-36.8	
type 2	76.6		50			-26.6	
type 2	77.4		47.5			-29.9	
type 1	86.5			51.5		-35	
type 1	66.1			36.1		-30	
type 1	82.3			45.8		-36.5	
type 1	85				55.2	-29.8	
type 2	83.3				59.7	-23.6	
type 1	83.2				48.2	-35	
type 1	84.6				57	-27.6	

The result measured in the reference position shall be calculated according to clause 6.5 in the main body of this Nordtest method. For the additional positions the procedure below shall be applied:

a) Calculation of the terms ΔL_{inside} and $\Delta L_{\text{additional outside position}}$

$$\Delta L_{\text{inside}} = -10 \lg \frac{1}{n} \sum_{i=1}^{i=n} (10^{\Delta L_i/10})$$

n = the number of trains measured.

$$\Delta L_{\text{inside}} = -10 \lg$$

$$\left[\frac{1}{n} (10^{-3.68} + 10^{-2.66} + 10^{-2.99} + 10^{-3.5} + 10^{-3.0} + 10^{-3.65} + 10^{-2.98} + 10^{-2.36} + 10^{-3.5} + 10^{-2.76}) \right] = 29.1 \text{ dB}$$

$$\Delta L_{\text{inside}} = 29.1$$

$$\Delta L_{\text{additional outside position}} = -10 \lg \frac{1}{n} \sum_{i=1}^{i=n} (10^{\Delta L_i/10})$$

$$\Delta L_{\text{additional outside position}} =$$

$$-10 \lg \left[\frac{1}{n} (10^{-0.31} + 10^{-0.17} + 10^{-0.05} + 10^{-0.04} + 10^{-0.48}) \right] = 1.8 \text{ dB}$$

$$\Delta L_{\text{additional outside position}} = 1.8 \text{ dB}$$

The terms $\Delta L_{\text{additional outside position}}$ and ΔL_{inside} shall finally be subtracted from the result for the reference position calculated according to clause 6.5 in the main body of this Nordtest method.

Note. The outside-inside differences will often differ between different train types because of differences in spectra. In some cases it may be more convenient to study the differences for each individual train type than to study the average of all train types.