NORDTEST Method
NT ACOU 056
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ROAD TRAFFIC:
MEASUREMENT OF NOISE IMMISSION – SURVEY METHOD

Key words: Acoustics, traffic noise, noise immision, test method

CONTENTS

1 SCOPE

This Nordtest method states procedures for measuring road traffic noise inside and outside buildings and in open terrain, under specified traffic and environmental conditions, at distances up to 100 m from the road. The accuracy is that of an ISO survey method (grade 3). The method aims at obtaining noise levels as they occur during slightly downward atmospheric refraction.

Measurements carried out according to this Nordtest method yield the total A-weighted energy-equivalent sound pressure level. Nordtest method NT ACOU 039 is an engineering method intended for more general application also enabling the measurement of maximum A-weighted sound pressure levels and sound pressure levels in octave bands. NT ACOU 039 allows measurements at distances in excess of 100 m from the road.

The method specifies how to measure the noise level at a given position in a well-defined way, and how, by measuring road traffic noise simultaneously in several microphone positions, the noise levels in these positions can be efficiently determined.

2 FIELD OF APPLICATION

Road traffic noise levels are often calculated according to “*Road Traffic Noise, Nordic Prediction Method”*. When calculation is considered insufficient, the traffic noise level can be measured according to this Nordtest method. This could for example be the case in particularly complicated topographical situations, with sound reflecting obstacles or several noise barriers or buildings screening the traffic noise.

The method is useful – within its constraints due to measurement uncertainty etc. – for testing compliance with noise limits, for example when residents complain about their exposure to traffic noise. The method is also applicable for assessing the effect of noise mitigation measures.

This Nordtest method and the Nordic prediction method for road traffic noise have been designed so that measured and calculated traffic noise levels should be the same. At positions far away from roads, however, there is a trend for measured noise levels to be higher than the calculated noise

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levels when measurements are carried out during the conditions of downward atmospheric refraction as specified in this Nordtest method.

The method does not give specifications for determining yearly average noise levels from road traffic.

At roads with low traffic intensity, the traffic noise will have to be measured over long time intervals in order to comply with the requirements of this Nordtest method.

3 REFERENCES

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Nordtest method. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Nordtest Method are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Nordtest, as well as members of ISO and IEC, maintain registers of currently valid International Standards.

Nordtest Method NT ACOU 039, Road Traffic: Measurement of noise immission. Engineering method.

IEC Publication 60942, *Sound calibrators*.

IEC Publication 61672, *Electroacoustics – Sound level meters.*[1])

TemaNord 1996:525, *Road Traffic Noise, Nordic Prediction Method*, Nordic Council of Ministers 1996.

4 DEFINITIONS

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

The A-weighted sound pressure level determined using frequency weighting A according to IEC 61672. The reference sound pressure is 20 µPa.

4.2 A-weighted energy-equivalent sound pressure level, in decibels, $L_{Aeq,T}$

The A-weighted sound pressure level of a continuous steady sound that within a specified time interval T has the same mean square sound pressure as a sound whose level varies with time[2]).

4.3 Uncertainty

An interval around the measurement result, with 90% probability that the “true” value of the noise level lies in this interval.

Note: In one-sided testing, 95% confidence is obtained.

5 MEASUREMENT PROCEDURE

The traffic noise shall be recorded during time intervals in accordance with Clauses 5.1–5.4. Measurements may be performed continuously for a certain period of time to characterise the traffic noise within that specific time interval, or, they may be considered as samples representing the traffic noise during other or longer periods of time.

The microphone shall be equipped with a windshield during noise recording. It is recommended to listen to the noise signal through high-quality headphones to ensure that the signal transmission through the instruments is stable, undistorted, and free of disturbing background noise, such as electrically generated noise.

During indoor noise measurements, doors and windows shall be closed, while air intakes shall be open.

5.1 Continuous measurement

By measuring the traffic noise continuously for a specific time interval the equivalent noise level for that time interval can be determined directly. For example, the 24-hour equivalent noise level $L_{Aeq,24h}$ can be determined based on a full 24-hour measurement.

If the noise levels during day, evening and night are determined separately, $L_{Aeq,24h}$ can be determined using Equation (1)

$$L_{Aeq,24h} = 10\ \log\ \frac{1}{T}\left(\Delta t_d 10^{\frac{L_d}{10}} + \Delta t_e 10^{\frac{L_e}{10}} + \Delta t_n 10^{\frac{L_n}{10}}\right) \qquad (1)$$

$T = \Delta t_d + \Delta t_e + \Delta t_n = 24$ hours

L_d, L_e and L_n are the equivalent noise levels measured for the day (time interval Δt_d hours), evening (Δt_e), and night (Δt_n), respectively.

Note 1: The definition of time intervals day, evening and night may differ from country to country and between categories of source.

Note 2: By adjusting the noise levels in Equation (1) to account for differences in people’s sensitivity to noise during different periods of the day, the noise indicator L_{den} chosen as a common European noise indicator can be determined by Equation (2).

$$L_{den} = 10\ \log\ \frac{1}{T}\left(\Delta t_d 10^{\frac{L_d}{10}} + \Delta t_e 10^{\frac{L_e+5}{10}} + \Delta t_n 10^{\frac{L_n+10}{10}}\right) \qquad (2)$$

[1]) To be published, replaces IEC 60651 and IEC 60804.

[2]) The expression ‘equivalent noise level’ has generally been used in the present Nordtest method in order to simplify the text.

5.2 Sampling

As an alternative to continuous measurement, the following procedure can be applied.

Measure $L_{Aeq,T}$ from the flow of traffic long enough for a sufficient number of vehicles to pass the microphone position in order to average individual vehicle variation. The necessary measurement time interval needed depends on the traffic and on the required accuracy, cf. Clause 9.

Note 1: At roads with low traffic intensity direct measurement of equivalent noise levels is sensitive to background noise and the equivalent noise level should be determined based on noise exposure levels of individual vehicle pass-bys, cf. Clause 5.1.2 of Nordtest method NT ACOU 039.

Count separately the numbers of each category of vehicle (for example light vehicles and heavy vehicles[3)]) passing during the measurement time interval and estimate the average vehicle speed, cf. 8.1.

Convert the measured equivalent noise level using the Nordic prediction method for road traffic noise to determine the noise level for the time period of interest, e.g. the yearly average traffic.

Note 2: The conversion can be made applying Equations (A.1)–(A.4) given in Annex A.

5.3 Relative noise level measurement

The traffic noise level at a number of microphone positions can be determined efficiently based on an extended measurement in one reference position and subsequent shorter measurements performed simultaneously in the reference position and in other microphone positions. Any such other microphone position shall be less than 30 m from the reference microphone position.

Based on the difference between these simultaneously measured noise levels the absolute noise level L_i at position No. *i* can be calculated

$$L_i = L_{ref} - \Delta L_i \tag{3}$$

L_{ref} = noise level at reference position determined by extended measurement

ΔL_i = difference between noise levels measured simultaneously in reference position and position No. *i.*

For each combination of microphone positions the noise from at least 10 vehicle pass-bys shall be recorded.

When indoor noise levels are measured, one microphone can be located outdoors in a reference position where the noise levels L_{ref} is already known. The second microphone shall be located successively at each of the indoor microphone positions specified in Clause 7.2. The average difference $\overline{\Delta L}$ between the noise levels measured outdoors and indoors shall be subtracted from the outdoor noise level L_{ref} to determine the indoor noise level L_{in}

$$L_{in} = L_{ref} - \overline{\Delta L}. \tag{4}$$

3) Heavy vehicles are defined the Nordic prediction method for road traffic noise as vehicles with gross weight exceeding 3.500 kg.

5.4 Background noise

The background noise level shall be at least 10 dB below the road traffic noise level to be measured. This includes noise in measurement instruments.

Normally accurate measurement cannot be made of the background noise level prevailing during a road traffic noise measurement, and therefore a correction of the measurement result is not allowed in this Nordtest method.

The noise level between vehicle pass-bys may serve as an estimate of the background noise level in situations with not too high traffic intensity, where measurements are most sensitive to background noise influence.

Data recording should be interrupted during periods of no vehicle pass-bys and during periods with noise from irrelevant sources such as aircraft, trains and warning signals on police cars or ambulances. The number of vehicle pass-bys during the measurement time interval shall be counted, while vehicle pass-bys during periods when recording is interrupted shall be disregarded.

Care shall be taken that noise due to wind does not influence the result of measurement. A microphone windshield shall always be used. Listening to the recorded noise signal by means of high-quality headphones is useful for ensuring that the wind-induced noise levels are not too high.

6 INSTRUMENTATION

6.1 General requirements

Measurement equipment shall be Class 1 or 2 as specified in IEC 61672. The complete measurement system shall comply with the IEC requirements. In general the equipment shall be calibrated at least every two years at a laboratory accredited for traceable calibration.

6.2 Calibration

Prior to and after each measurement the system shall be checked using an acoustical calibrator according to IEC 60942. It is recommended that the equipment should be calibrated regularly during extended periods of measurement.

The acoustic calibrator shall be calibrated at least once a year. Record the date of the last check and confirmation of compliance with the IEC standard.

7 MICROPHONE LOCATION

7.1 Outdoor noise measurement

Three categories of outdoor microphone locations are defined: a) “free-field”, b) “+6 dB”, and c) “+3 dB”. When the requirements in Clauses 7.1.2–7.1.4 cannot be fulfilled, see NT ACOU 039.

7.1.1 Microphone height

Outdoor noise levels to be used for calculating indoor noise levels (using sound reduction data for building components etc.) shall be measured at a height above the bottom window frame corresponding to two-thirds of the height of the windows.

Note 1: This often corresponds to 2 m above the ground in one-storey houses built since 1960.

Noise levels in gardens, parks, and recreational areas shall be measured at a height of 1.5–2 m.

Note 2: The difference in road traffic noise levels at a height of 1.5 m and 2 m, respectively, is normally in the order of 0.5 dB, and the noise level may be higher or lower at 2 m than at 1.5 m depending on terrain surface and geometry.

7.1.2 “Free-field”

The distance from the microphone to any sound-reflecting surface apart from the terrain shall be at least twice the distance from the microphone to the road.

7.1.3 “+6 dB”

The microphone shall be located directly on a plane and hard facade (of concrete, tile, glass, wood or similar material). The measurement yields a noise level equal to the level of the incoming sound plus 6 dB.

The facade must be plane within ±0.05 m within a distance of 1 m from the microphone, and the distance from the microphone to the surface edges shall be larger than 1 m.

7.1.4 “+3 dB”

The microphone shall be 0.5 m in front of the facing wall. The equivalent noise level measured deviates less than 1 dB from the level of the incoming sound plus 3 dB.

The facade shall be plane within ±0.3 m, and the microphone shall not be placed at positions where the sound field is influenced by multiple reflection of sound between protruding building surfaces. The distance from the microphone to the vertical edges of the facing wall shall be at least 2 m and the distance from the microphone to the horizontal edge of the facing wall shall be at least 1 m.

Windows shall be considered as any other part of the facade. They shall be closed during measurement, but a small opening for the microphone cable is allowed.

7.2 Indoor noise measurement

At least three microphone positions shall be selected. The microphones shall be positioned at least 0.5 m from walls, ceiling or floor, and at least 1 m from significant sound transmission elements such as windows or air intake openings. The microphones shall be distributed uniformly within the permitted space throughout the room. The distance between neighbouring microphone positions shall be at least 0.7 m.

The average equivalent noise level for the room shall be calculated according to Equation (5).

$$L_{Aeq} = 10 \ \log \frac{1}{n}\left(10^{\frac{L_{Aeq1}}{10}} + 10^{\frac{L_{Aeq2}}{10}} + \ldots + 10^{\frac{L_{Aeqn}}{10}}\right) \quad (5)$$

n = the number of microphone positions [-]

L_{Aeq1}, L_{Aeq2}, …, L_{Aeqn} = equivalent noise level in positions 1, 2, …, n [dB].

Note 1: If measurements are carried out during measurement time intervals with different traffic conditions, each of the noise levels L_{Aeq1}, L_{Aeq2}, …, L_{Aeqn} shall be converted to reference traffic conditions, cf. Clause 5.2.

8 MEASUREMENT CONDITIONS

8.1 Traffic

The number of passing vehicles shall be counted, see Clause 5.2. The noise from a sufficient number of vehicles shall be measured, see Clause 9.

The speed limit shall be registered and the average vehicle speed shall be estimated.

Note: The speed of vehicles selected at random could be measured using a radar, or the time needed to pass a known section of the road could be measured by means of a stop watch.

When studded tyres are in use during the measurement, this shall be registered.

8.2 Road and ground cover

The road shall be dry, the adjacent terrain shall be free of snow and ice, and the soil shall not be frozen or soaked with water unless such conditions are the topic for investigation.

The type and age of the road surface shall be registered. It is recommended that traffic noise measurements should be performed only when the road surface is not too cold and not too warm. It should not be frozen, and warm clear summer days should also be avoided.

8.3 Weather

Traffic noise measurements can be performed under any weather conditions as long as Equation (6) is fulfilled[4]).

$$h_S + h_R \geq 0.1 \ d \quad (6)$$

h_S is the height of the road surface and h_R is the height of the receiver above the surrounding terrain while d is the distance from the centre of the road to the receiver.

When Equation (6) is not fulfilled distinction is made between so-called “High” and “Low” situations.

8.3.1 "High" situations

The situation is "High" when the road surface is 1.5 m or more above the surrounding terrain and the receiver is not screened.

[4]) See Clause 5.4 concerning wind-induced background noise.

d ≤ 50m: Measurements can be performed with no restrictions on the atmospheric conditions[4]).

50 < *d* ≤ 100 m: The wind shall be blowing from the road to the measurement position with a component perpendicularly to the road measured 2 m above the ground of at least 1.5 m/s during clear sky and at least 1 m/s when it is clouded.

Note 1: A microphone at a height of 4 m or more is also considered a "High" situation even if the road surface is less than 1.5 m above the ground.

Note 2: The wind speed may be measured using simple equipment or the guidance given in Annex B may be used to judge the wind speed.

8.3.2 "Low" situations

The situation is "Low" when the road surface is less than 1.5 m above the surrounding terrain or when the receiver is screened.

d ≤ 25m: Measurements can be performed with no restrictions on the atmospheric conditions[4]).

25 < *d* ≤ 100 m: There shall be a wind speed component measured 2 m above the ground from the road to the measurement position of at least 2 m/s when the sky is clear and at least 1.5 m/s when the sky is clouded.

Note 3: See Note 2.

8.3.3 More than 100 m distance

At distances of more than 100 m from the road the measurements shall be performed according to NT ACOU 039.

9 UNCERTAINTY

The measurement uncertainty δ depends on the measurement time interval, the traffic intensity etc. and can be determined by Equation (7) where σ is the standard deviation given by Equation (8). The measurement uncertainty is in the order of 2 dB when measuring near a road with many cars, in the order of 4 dB outdoors at 50–100 m from the road and up to 5 dB indoors.

$$\delta = 1.65\ \sigma \qquad (7)$$

The standard deviation σ consists of a contribution σ_i from instruments, a contribution σ_k from variation in vehicle noise emission, a contribution σ_r from the effect of reflections, and a contribution σ_m from weather-induced variation in sound transmission path attenuation. The total standard deviation σ is calculated by Equation (8)

$$\sigma = \sqrt{\sigma_i^2 + \sigma_k^2 + \sigma_m^2 + \sigma_r^2} \qquad (8)$$

The measurement instrument contribution σ_i is less than 1 dB, provided the instruments have been maintained, controlled, and calibrated.

The contribution σ_k from variation in individual vehicle noise emission depends on the number of vehicle pass-bys during the measurement time interval. When 100 vehicles have passed during the measurement, $\sigma_k \cong 1$ dB, and when 500 vehicles or more have passed, σ_k is 0.5 dB or less.

The microphone location specified in Clause 7 ensures that a contribution σ_r from variation in reflections is less than 1 dB. For indoor measurements, the uncertainty caused by the limited number of microphone positions is typically in the range σ_r = 1–2 dB.

The contribution σ_m from weather-induced variation can be neglected when the whole terrain surface between the road and the microphone position is hard and the conditions in Clause 8.3 are fulfilled. When part of the terrain between road and microphone position is porous, then σ_m = 1.5–2 dB.

10 INFORMATION TO BE REPORTED

The purpose of the report is to document the measurement result, its uncertainty, and the measurement conditions in sufficient detail for another laboratory to be able to repeat the measurement.

State that the measurement has been performed in accordance with the specifications in this Nordtest method and state the measurement result and its associated uncertainty. The form in Annex C can be used as a checklist and should be filled in during the measurements.

The report shall contain the following information, when relevant:

- Sketch plan of the measurement site showing road and microphone positions with surrounding buildings, terrain, and vegetation, including distances and the direction of North.
- Vertical section with microphone position relatively to road, buildings, terrain, and other reflecting surfaces, etc.
- Description or drawing showing indoor microphone positions, room dimensions, materials and furniture, windows, air intakes, facing walls, and other facts of importance for the indoor noise level.

Note: Some of the above information may be given in clear photographs.

- Recording and analysis equipment, type, make and model, and time of latest control
- Procedure used when calibrating the equipment
- Measurement time and observation time interval, weekday and date
- Weather conditions: wind speed and direction, wind speed component; cloud cover
- Traffic: intensity; percentage heavy vehicles during measurement time interval; speed limit and estimated average vehicle speed; use of studded tyres
- Yearly average traffic intensity
- Conversion of equivalent noise levels

[4]) See Clause 5.4 concerning wind-induced background noise.

- Road: road surface type, age and condition; road gradient; road width and number of lanes; position of traffic light or other traffic regulation
- Background noise: sources; equivalent noise level
- Measured noise levels and their uncertainties
- Name, address, telephone, fax, and E-mail of the person or laboratory having carried out the measurement
- Name, address, telephone, fax, and E-mail of the person/ organisation having ordered the measurement.

ANNEX A (NORMATIVE): CONVERSION OF EQUIVALENT NOISE LEVELS

As an alternative to measuring throughout the whole day, evening or night period, measurements can be carried out during shorter time intervals, while counting the number of vehicles in each category separately. Then the measured noise levels from the traffic passing during the measurement time interval can be converted to correspond to average traffic conditions.

The conversion can be made applying Equations (A.1)–(A.4):

Heavy vehicles:

$$L_{AE}\ (10\ \text{m}) = \begin{cases} 80.5 + 30\ \log\left(\dfrac{v}{50}\right);\ 50 \le v \le 90\ \text{km/h} \\ 80.5\ ;\ 30 \le v < 50\ \text{km/h} \end{cases} \quad \text{(A.1)}$$

Light vehicles:

$$L_{AE}\ (10\ \text{m}) = \begin{cases} 73.5 + 25\ \log\left(\dfrac{v}{50}\right);\ v \ge 40\ \text{km/h} \\ 71.1\ ;\ 30 \le v < 40\ \text{km/h} \end{cases} \quad \text{(A.2)}$$

Note 1: Equations (A.1)–(A.2) have been taken from the 1996-version of the Nordic prediction method for road traffic noise. The most recent version should be used at any time. The newest proposal, Nord 2000, uses 3 categories of vehicles.

Traffic flow

$$L_{Aeq,1h}(10\ \text{m}) = 10\ \log\ \frac{1}{3600}\left[n_{heavy}\cdot 10^{\frac{L_{AE,heavy}}{10}} + n_{light}\cdot 10^{\frac{L_{AE,light}}{10}}\right] \quad \text{(A.3)}$$

n_{heavy} and n_{light} are the average numbers per hour of heavy and light vehicles, respectively, in the traffic flow.

L_{Aeq} shall be calculated for the yearly average traffic flow (*YDT*) and for the actual traffic flow (*MTT*) as it was counted during the measurement time interval. The measurement result shall be converted using Equation (A.4).

$$L_{Aeq,meas,YDT} = L_{Aeq,meas,MTT} + (L_{1,YDT} - L_{1,MTT}) \quad \text{(A.4)}$$

$L_{Aeq,meas,YDT}$ = Measured equivalent noise level converted to yearly average traffic conditions

$L_{Aeq,meas,MTT}$ = Equivalent noise level measured during the measurement time interval

$L_{1,YDT}$ = value L_1 of equivalent noise level, calculated by Equation (A.3) for yearly average traffic conditions

$L_{1,MTT}$ = value L_1 of equivalent noise level, calculated by Equation (A.3) for measurement time interval traffic conditions.

Example:

MTT	*Measured during 30 minutes $L_{Aeq,30\ min.}$ = 67.3 dB with 600 vehicles, including 22% heavy vehicles, average speed 54 km/h* *Calculation: $L_{1,MTT}$ = 72.5 dB*
YDT	*16,000 vehicles, including 16% heavy vehicles, average speed 52 km/h* *Calculation: $L_{1,YDT}$ = 68.8 dB*

$\boldsymbol{L_{Aeq,meas,YDT}}$ = *67.3 + (68.8 – 72.5) = 67.3 – 3.7 dB = 63.6 dB*

Note 2: Equations (A.1)–(A.4) presume that during the measurement time interval the traffic and its driving conditions are representative of the daily average vehicle noise emission. Normally measurements should not be performed during rush hours in case rush hour traffic is significantly slower than the traffic outside rush hours.

ANNEX B (INFORMATIVE): GUIDELINES FOR JUDGING THE WIND SPEED

Table B.1 gives guidelines for judging the wind speed.

Note: The wind speeds in the right column have been calculated from wind speeds at 10 m height assuming a logarithmic wind profile and a terrain roughness height z_0 = 0.02 m.

Table B.1. Characteristics of various wind speeds.

Designation	On dry land	On the open sea	Wind speed [m/s] at 2 m height
Calm	Vertical plume of smoke	Ocean smooth as a mirror	0.0–0.2
Almost calm	Plume of smoke just indicates the wind direction; weather vanes not affected	Small fish scale like ripples without foam	0.2–1.1
Light breeze	The wind is felt in one’s face; small leaves are moving on trees and bushes; streamers get lifted; weather vanes (in good condition) show wind direction	Very short ripples that do not break	1.2–2.4
Gentle breeze	Leaves and small twigs move continuously; light flags and streamers get stretched	Strong wavelet with tops beginning to be foamy; glassy foam	2.5–4.0
Moderate breeze	Dust, powdery snow, and pieces of paper get lifted off the ground; twigs and small branches move	Minor waves, rather frequent foam-crests	4.1–5.9

ANNEX C (INFORMATIVE): PROPOSAL FOR MEASUREMENT DOCUMENTATION FORM

Measurement documentation	Survey measurement of road traffic noise according to NT ACOU 056
Measurement site	Map ref. Date Sign.
Plan of site	Distances from microphones to road and reflecting surfaces. Description of ground surface, vegetation, and buildings. Wind direction.
Sectional view	Height of microphone, road, etc. above the ground

Speed limit km/h	**Road gradient** ‰	**Road surface**	Type, age, condition (worn, dry)

Atmospheric conditions Wind = m/s Wind dir = ° Temp. = °C Cloud =	**Measuring equipment** Type Calibrator

The results

Measurement time interval	Mic. pos.	Number of vehicles Light Heavy	Average speed [km/h]	Background noise L_{Aeq} [dB]	Measured A-weighted equivalent noise level [dB]	Uncertainty δ [dB]