

09 Hearing protection

ELEC-E5640 - Noise Control P

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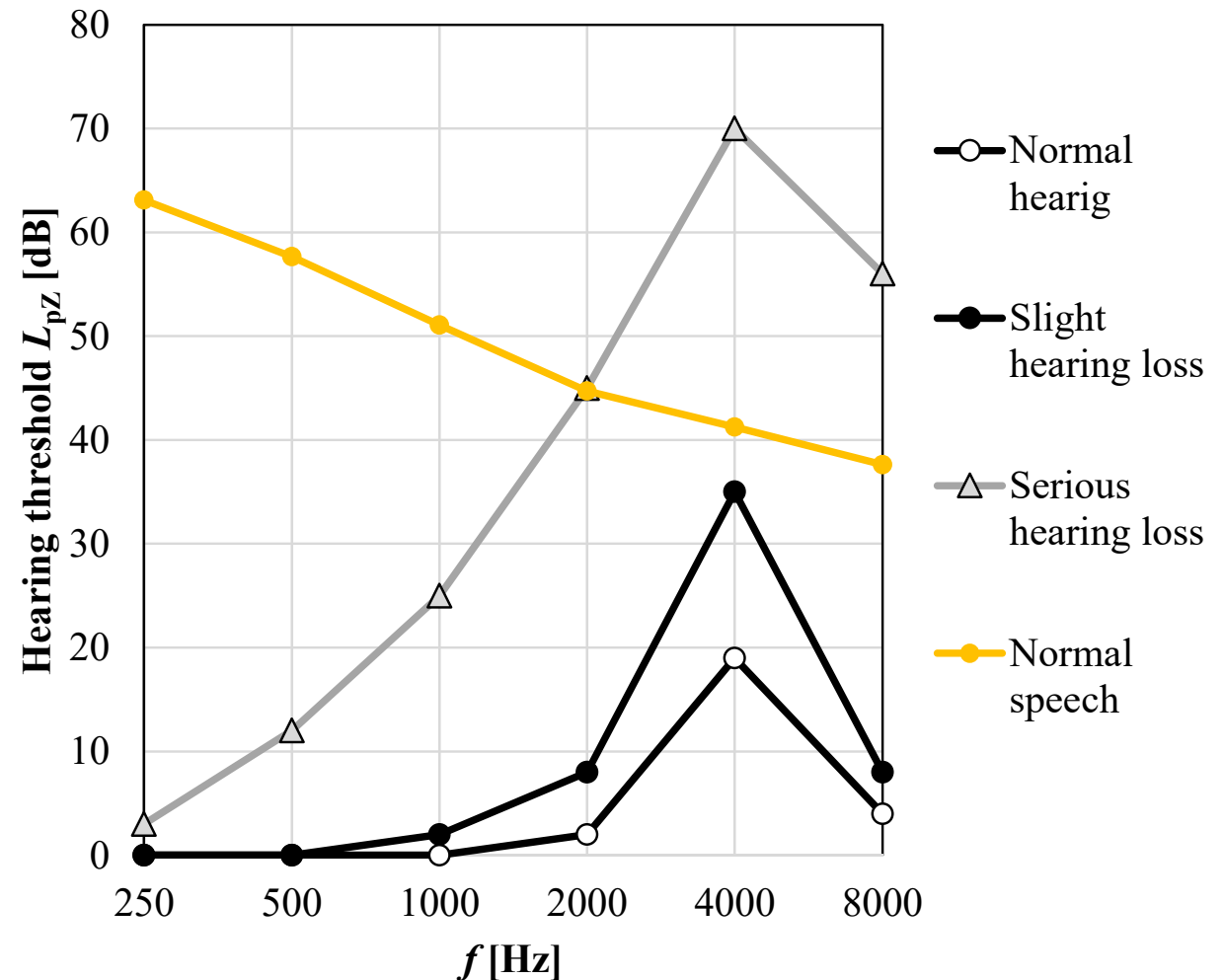
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Espoo, **20 Nov 2023**

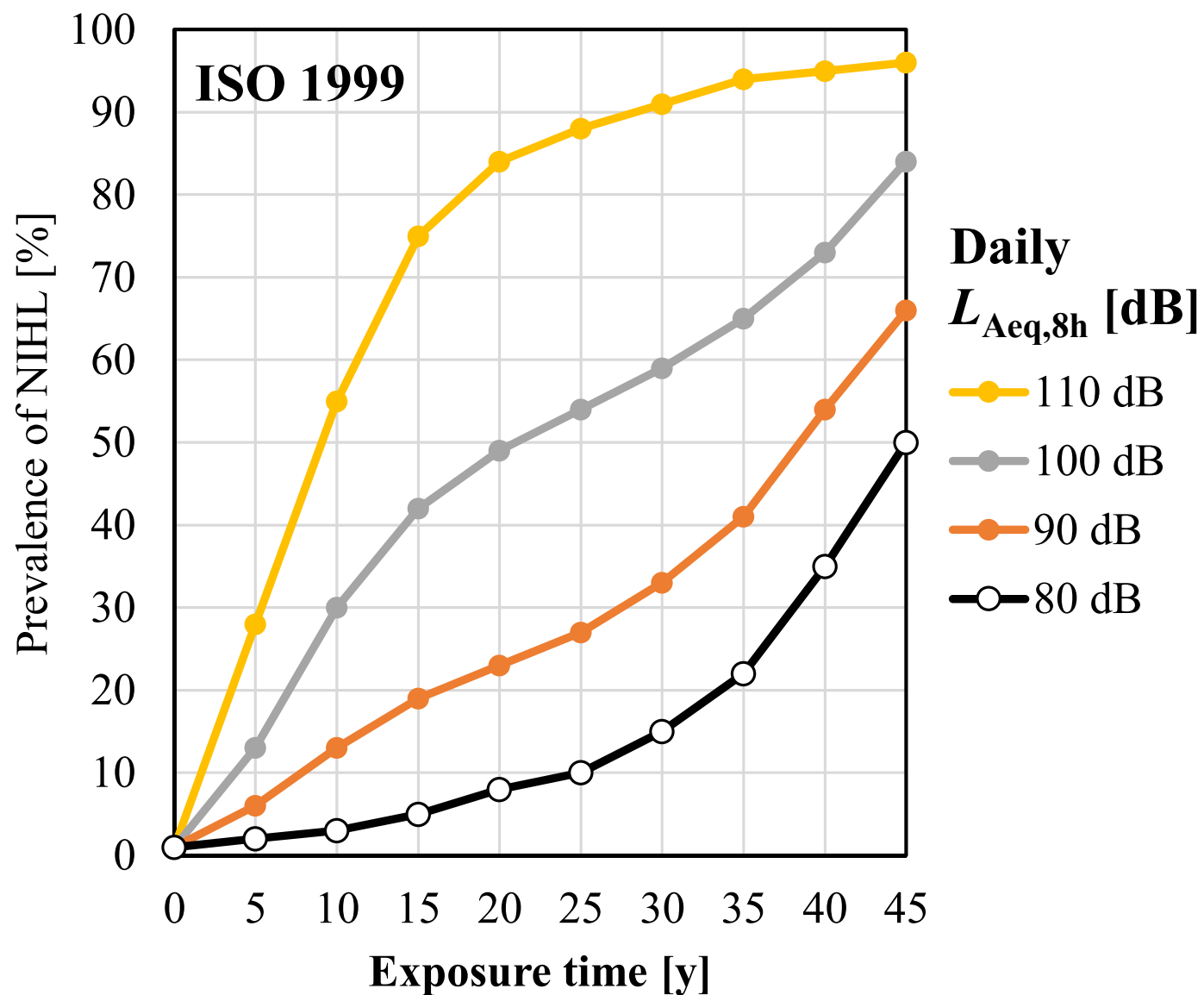
Noise-induced hearing loss - NIHL

- Hearing is normal if the hearing threshold is less than 20 dB within 250-8000 Hz.
- NIHL can be observed as a notch in hearing threshold at 4 kHz
- Serious hearing loss makes normal communication difficult due to reduced speech intelligibility.
- NIHL is usually preceded by temporary hearing loss
- NIHL is also associated with tinnitus



Risk of NIHL

- Present threshold level for launching noise control measures in workplaces, 80 dB $L_{Aeq,8h}$, is based on the lowest curve: less than half of the population should get NIHL after 45-year work exposure.



Regulated values of workplace noise exposure in Europe

| | $L_{A,eq,8h}$ [dB] | $L_{A,eq,40h}$ [dB] | $p_{C,peak}$ [Pa] | $L_{C,peak}$ [dB] |
|------------------------------|-----------------------|------------------------|----------------------|----------------------|
| Lower exposure action values | 80 | 80 | 112 | 135 |
| Upper exposure action values | 85 | 85 | 140 | 137 |
| Exposure limit values* | 87 | 87 | 200 | 140 |

* Exposure is determined in ear channel.

The effect of hearing protector and utilization rate must be considered.

Valtioneuvoston asetus 85/2006 is based on 2003/10/EC.

English: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0010&from=EN>.

Finnish: <http://eur-lex.europa.eu/legal-content/FI/TXT/PDF/?uri=CELEX:32003L0010&from=EN>

Regulated values of workplace noise exposure in Europe

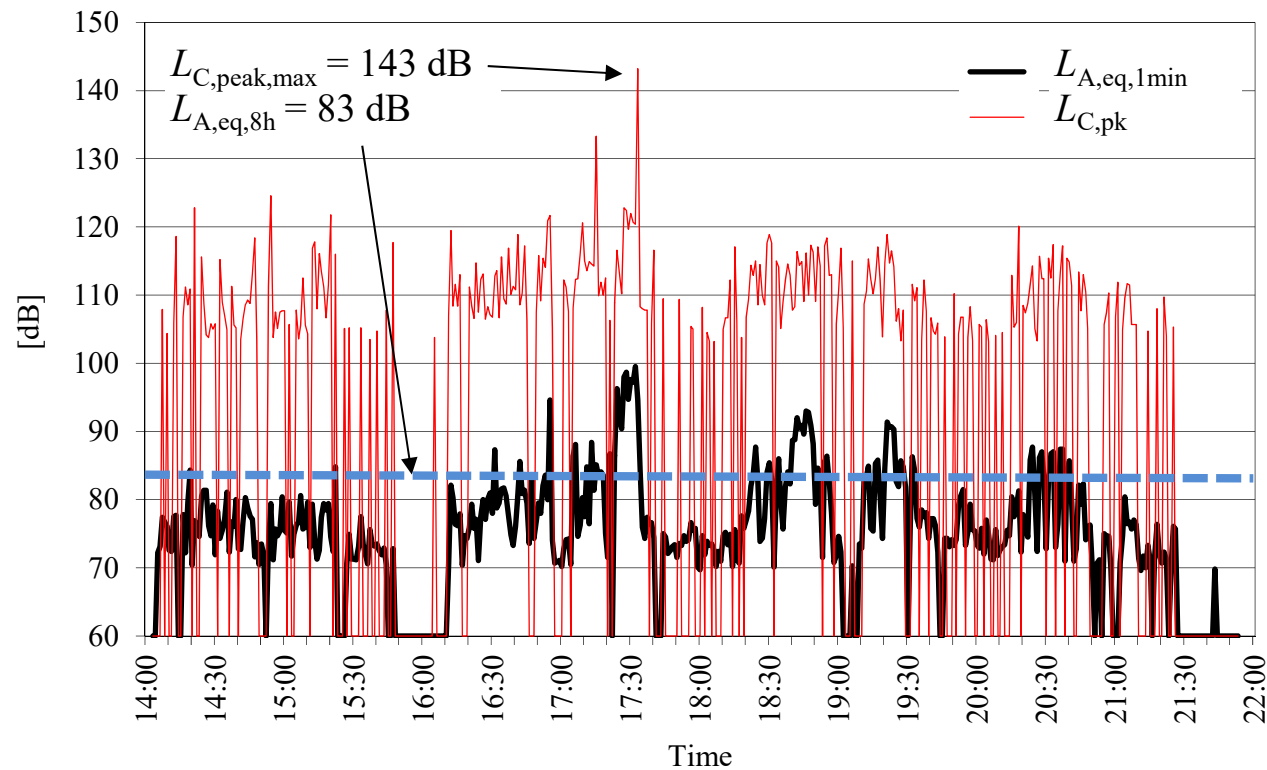
| Noise exposure exceeds | Sanctions to the employer |
|-----------------------------|---|
| Lower exposure action value | Ⓜ Personal hearing protectors shall be available for employees. Ⓜ Information and education must be given to employees about noise protection. |
| Upper exposure action value | Ⓜ Employees must wear hearing protectors. Ⓜ Noise areas shall be marked. Ⓜ Noise control program shall be developed to reduce noise exposure. |
| Exposure limit value | Ⓜ Exceedance shall be prevented immediately. Ⓜ Preventive actions.* |

* If NIHL is observed, the preventive actions must be reconsidered.

- **Noise control program:** use of low-noise methods and machinery, adequate hearing protectors, noise reducing materials, screens and enclosures, reduction of noise exposure time and training about noise control.

Measurement of noise exposure

- $L_{EX,8h} = L_{Aeq,8h}$ is the main quantity to be measured
- Continuous monitoring near to ear channel outside protectors
- Monitoring time depends on the variation within a day
- If the daily exposure varies, weekly exposure is estimated



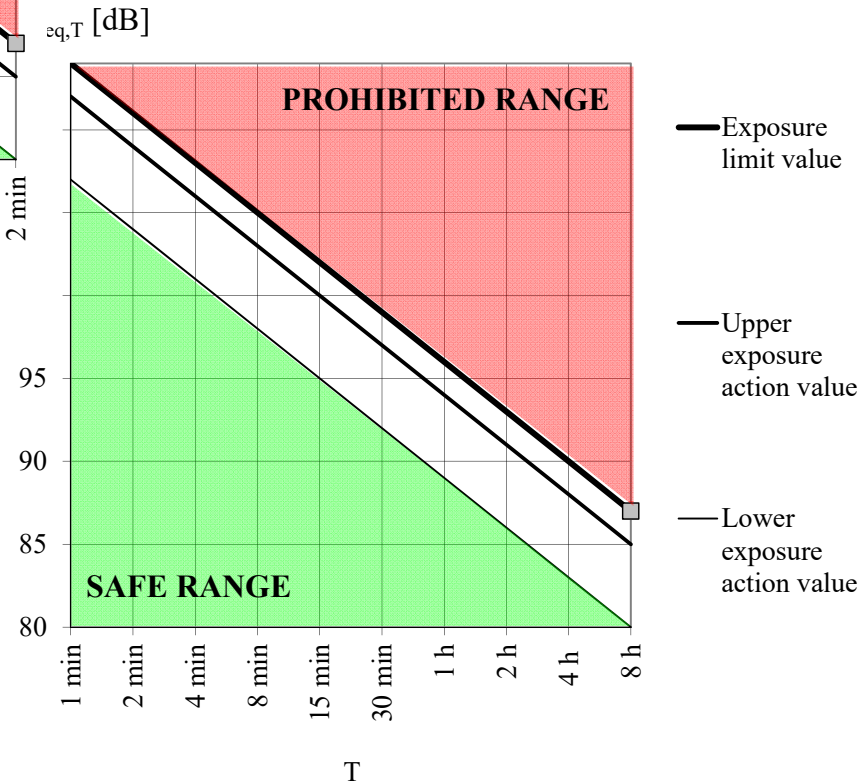
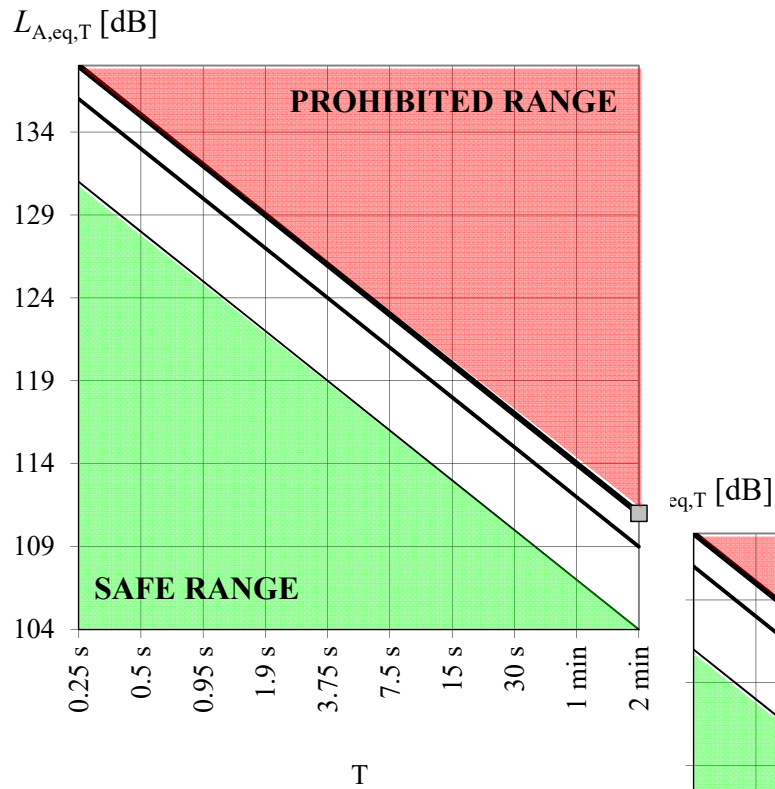
Safety limits

- Noise exposure for 8 hours is

$$L_{Aeq,T_0} = L_{Aeq,T_e} + 10 \lg \left(\frac{T_e}{T_0} \right) \text{dB}$$

- where $T_0=28800$ s.

- L_{pAeq,T_e} [dB] is the noise level during time T_e [s]



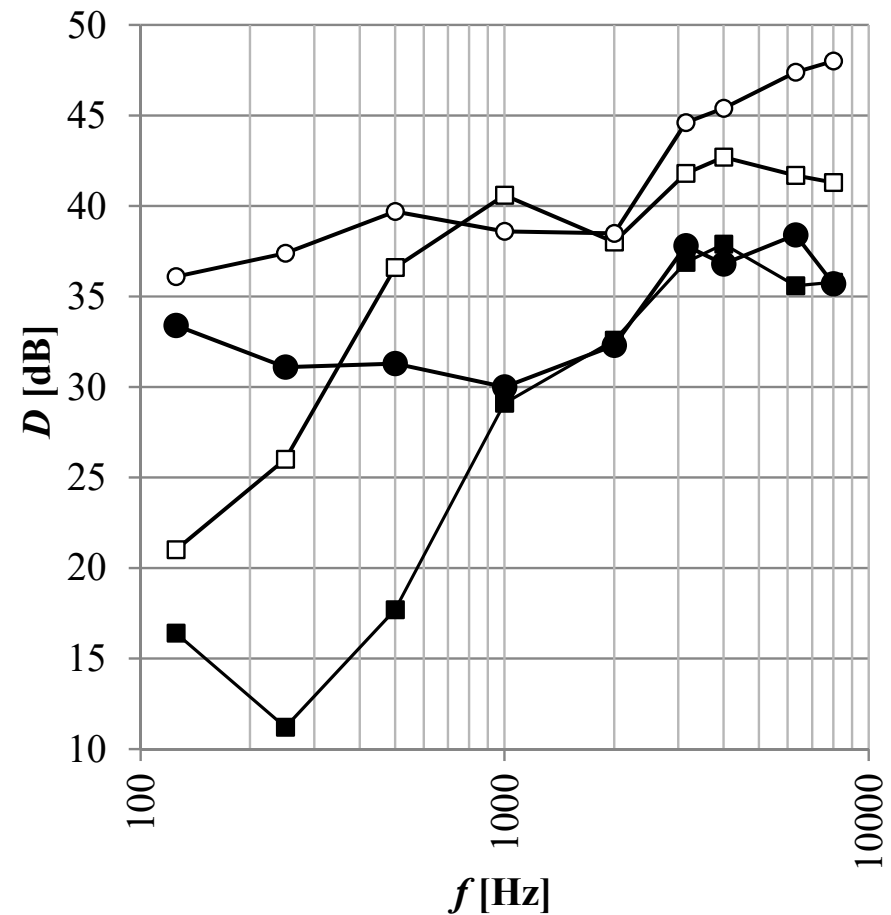
Basics of hearing protection

- Protectors are available between 10 and 40 dB noise reduction
- Too large noise reduction may reduce utilization rate due to discomfort
- Dimensioning: 70—80 dB L_{Aeq} inside the ear channel
- Nominal noise reduction of a protector is achieved with correct wearing and 100% utilization rate
- Inappropriate wearing of protectors can reduce noise reduction significantly:
 - ear muffs 3—6 dB
 - ear plugs 5—13 dB
- Training can improve the actual noise reduction of ear plugs by several decibels
 - proper mounting, 100% utilization rate

Some protector types

- Ear muffs
- Ear plugs
- Ear muffs with
 - radio, auxiliary input, Bluetooth
 - communication unit and peak sensor (hunters)
- Active noise control in
 - ear muffs
 - ear plugs
- Helmet
- Individually shaped ear plugs
 - Enable flat frequency responses
- Double protection
 - plug + helmet
 - plug & muff

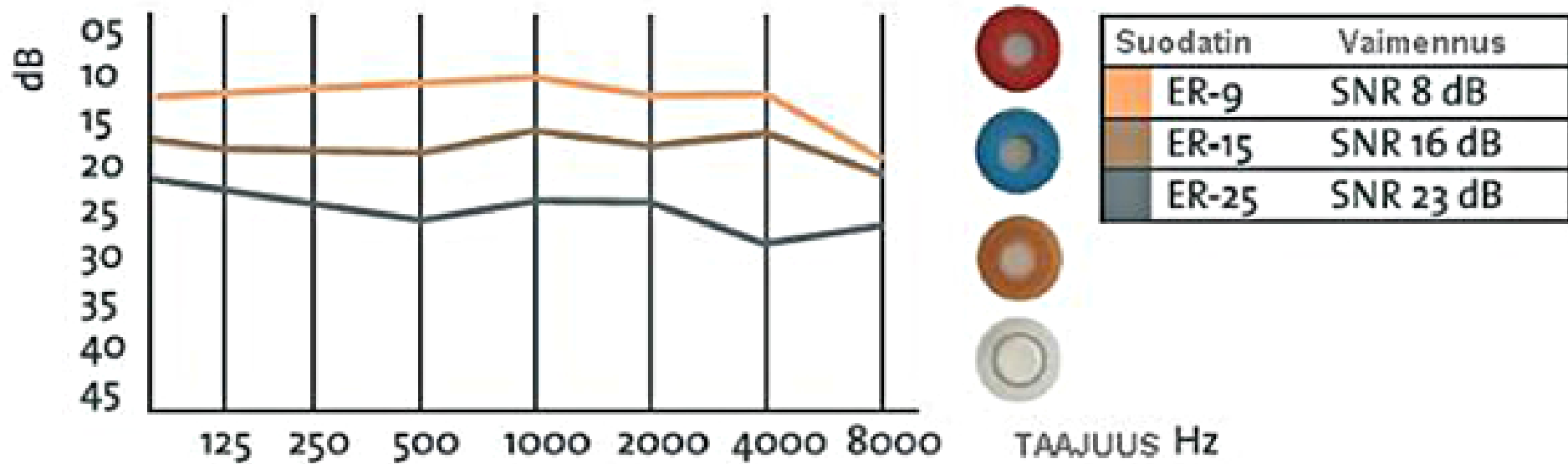
Values declared by a single manufacturer



- Ear muff, the smallest SNR (16 dB)
- Ear muff, the largest SNR (30 dB)
- Ear plug, the smallest SNR (21 dB)
- Ear plug, the largest SNR (32 dB)

Individually shaped ear plugs

- DEMO <http://www.elacin.fi/tuotteet/tarvikkeet/item/er-suodattimet>



Dimensioning of protectors

- Desired level inside the protector (in ear channel) is $L'_A = 75 \pm 5$ dB.
- Manufacturers usually report three values
 - Octave band APV values (most accurate)
 - HML-values (not reported here)
 - SNR Single Number Rating (most uncertain but simple)

$$L'_A = L_C - SNR$$

STAR Kuulonsuojain
Hörselskydd

Suojain täyttää standardin EN 352-1 (SFS-EN-352-1) vaatimukset
Skyddet uppfyller fordringarna i standarden EN 352-1 (SFS-EN-352-1)

| Taajuus Frekvens Hz | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
|-------------------------------|-----|------|------|------|------|------|------|
| Keskiarvo Medelvärde dB | 8,5 | 13,9 | 20,7 | 22,8 | 31,1 | 30,8 | 32,4 |
| Sf/dB | 2,9 | 2,1 | 1,9 | 2,0 | 4,0 | 1,7 | 2,3 |
| APVf/dB | 5,6 | 11,8 | 18,8 | 20,8 | 27,1 | 24,1 | 30,1 |



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SNR: 23
H: 27 M: 20 L: 13

Paino/Vikt: 160 g

Sangan puristusvoima/Bygelns fjäderkraft: 11,5 N
Paine päätä vastaan/Tryck mot huvudet: 3,2 kPa

OCTAVE BAND METHOD

$$L'_A = 10 \lg \sum_{i=1}^7 10^{(L_{Z,i} + A_i - APV_i) / 10}$$

- $L_{Z,i}$ [dB] is the linear SPL of noise
- A_i [dB] is A-weighting
- i is the octave band index (125—8000 Hz)
- APV_i [dB] is the assumed protection value
- L_C [dB] is the C-weighted total SPL in the room

Utilization rate

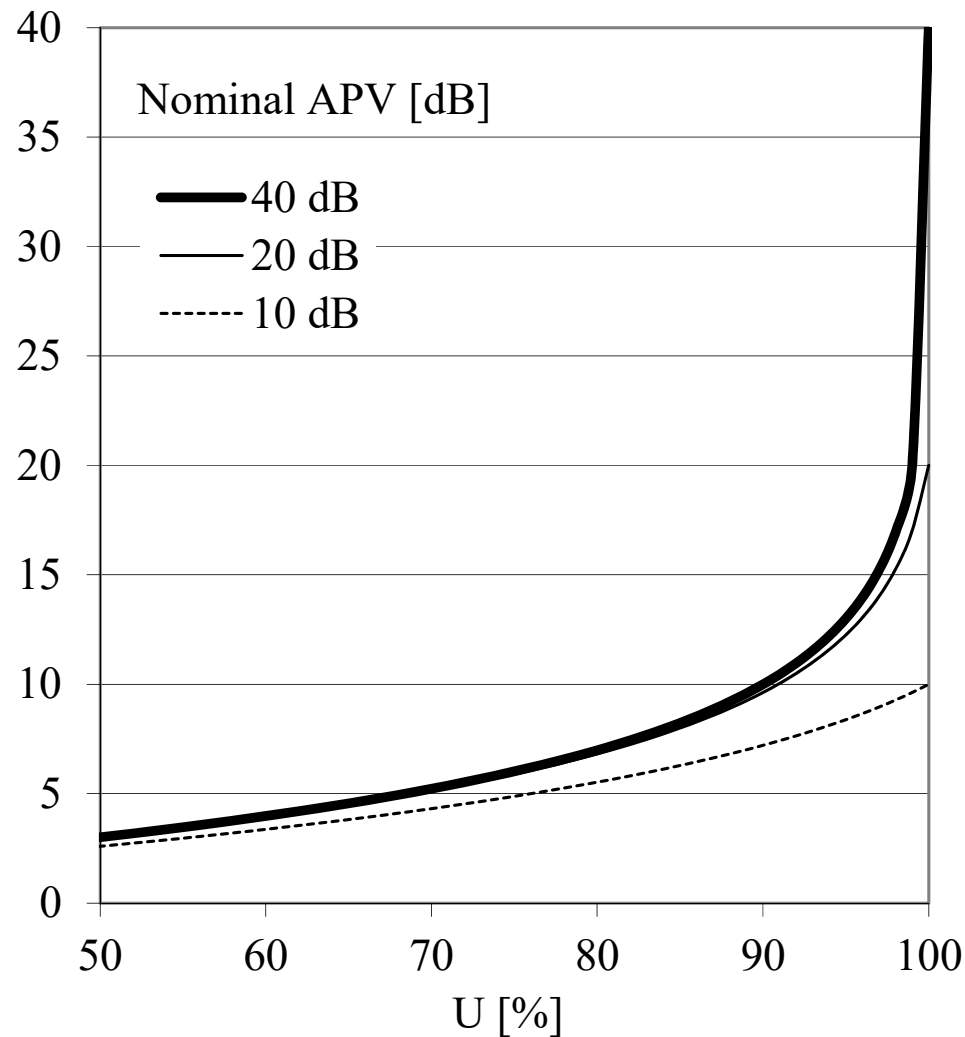
- D' [dB] is the actual noise reduction for a $T=8$ h working day when the protector's utilization time is T_D

$$D' = 10 \lg \left[\frac{1}{T} \left(T_D 10^{-D/10} + T - T_D \right) \right]$$

- D [dB] is the nominal protection (APV)
- Increased user comfort and knowledge about NIHL increase utilization rate.
- Utilization rate U [%] is

$$U = 100 \frac{T_D}{T}$$

Actual noise reduction D' [dB]

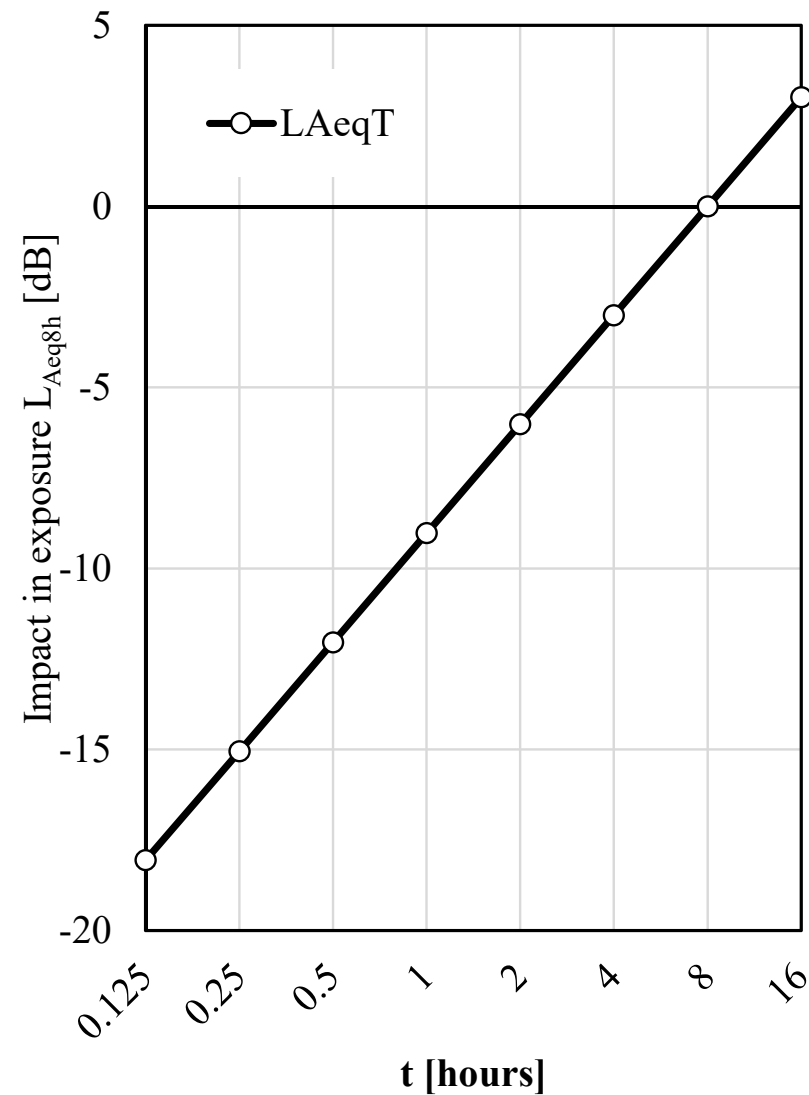


Limitation of noise exposure

- In some places, noise level is very high so that $L_{A,eq,8h}=87$ dB is exceeded even after wearing the best possible hearing protectors 100% of time.
- Limitation of noise exposure to time t is applied in such situations

$$L_{A,eq,T} = L_{A,eq,t} + 10 \log_{10} \frac{t}{T}$$

- $T=8$ h



Study on headphones with ANC

- Headphones with ANC are known to reduce noise up to 500 Hz. Speech intelligibility depends mostly on 500-4000 Hz.
- Are these devices efficient in environments where speech is main noise source?
- Purpose was to determine how well such devices reduce ambient speech. More specifically, is it possible to reach STI 0.20 inside headphones which is the limit of confidential privacy and provides full concentration.
- Speaker produced standard real speech in the room to reach 50 dB L_{Aeq} in listener position outside headphones.
- Background noise level of the room was 40 dB L_{Aeq}
- Masking was brown noise from the headphones



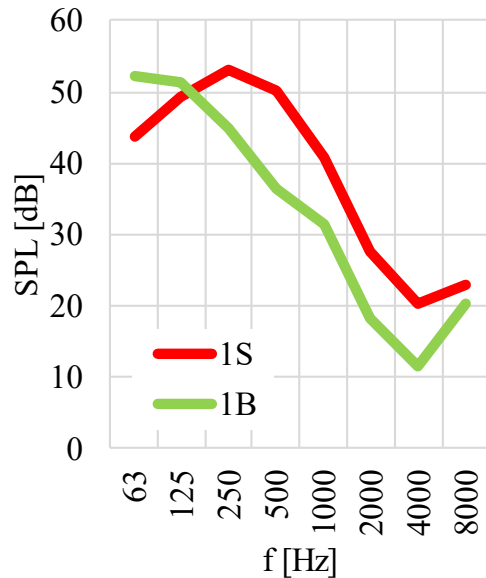
Conditions, while speaker is on with 50 dB:

- 1 – Without headphones**
- 2 – With Headphones, ANC off**
- 3 – With headphones, ANC on**
- 4 – With headphones, ANC on, masking on**

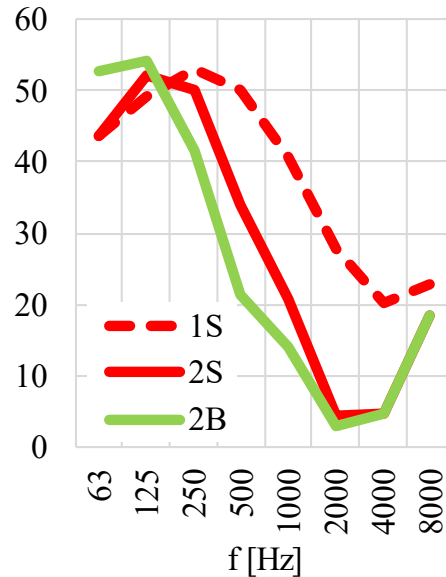
Acoustic results

Conditions:

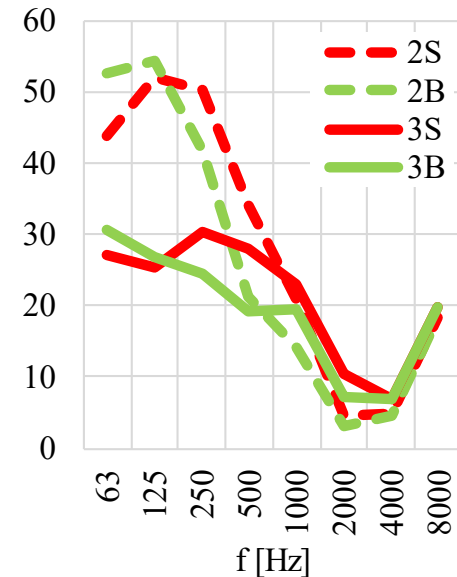
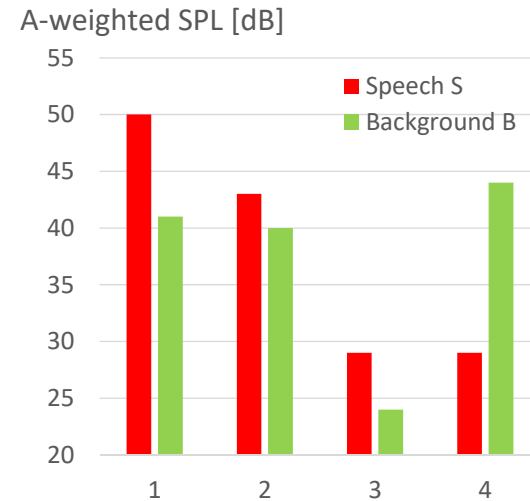
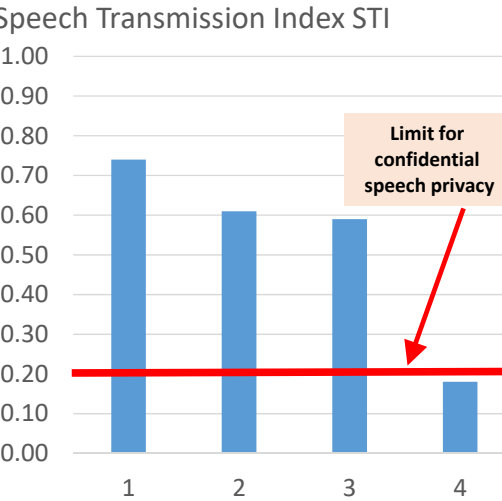
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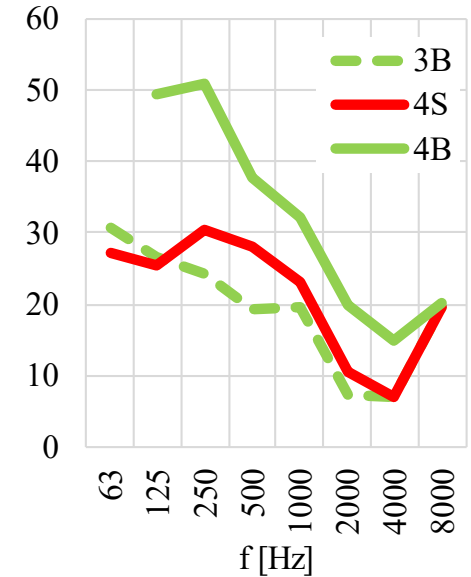
SNR is high.
Speech privacy poor.



SNR is still positive.
Speech privacy poor.



Levels below 1 kHz get down.
SNR is still positive.
Speech privacy poor.



SNR is negative.
Speech privacy is good.