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AN UPDATE ON THE PREDICTION ON SMALL ARMS SHOOTING NOISE

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1. INTRODUCTION

Since 1984 a common Nordic prediction method for calculating noise from shooting ranges has existed [1]. The method is based on prediction schemes given in terms of the A-weighted "Impulse" level (L_{pAI}) for single shots. The general basis for [1] is the Nordic general prediction method for industrial noise [2].

Since [1] was released some shortcomings have been identified, primarily concerning bullet noise (not included), screening (multiple screens not included), shooting halls (simplified calculation), uneven reflecting terrain (not included) and reflections (very simplified calculation).

This proposal for a revised method is the result of a NORDTEST project (contract no. 1151-94). Most of the work is carried out within the frame of the project. Supplementary data analysis, measurements and calculations were made in cooperation by Jørgen Jakobsen, DELTA Acoustics & Vibration, Denmark, and Edvard Falch, KILDE Akustikk A/S, Norway.

2. THE PREDICTION METHOD

The prediction method is based on "summer" and downwind conditions, and it is limited to small arms with caliber less than 20 mm. Noise from single shots are calculated, both muzzle noise and bullet noise (from supersonic projectiles).

A frequency region with octave bands 31.5-8000 Hz aims at covering noise immission from all small arms, both for muzzle noise and bullet noise. The noise level in the immission point should always be calculated in octave bands 63-8000 Hz. The 31.5 Hz octave band should be included for larger weapons. (Example: machine guns 12.7 mm and larger weapons).

The prediction method calculates muzzle noise and bullet noise separately. The direct sound and reflected sound are also calculated separately. These contributions are not added (in the immission point), even if they (theoretically) would arrive simultaneously. Usually only the highest contribution is considered.

The type of weapon and angle between shooting direction and immission direction (Φ) determine the reference noise levels for the muzzle noise and bullet noise. Corrections for enclosures (shooting halls or firing sheds), distance, atmospheric absorption, ground surface, screens, vegetation and reflections are added. The calculations are done separately in each octave band. The octave band levels are then A-weighted (according to the standard IEC-curve) and added on an energy basis to give the A-weighted "Impulse" level for single shots L_{AI} (dB).

Calculation formulas for each 1/1 octave band in the immission point are given by eq(1) and (2). These are of type $L = L_{ref} + \Delta L_i$, and are different for the muzzle noise and the bullet noise.

L : Noise level in a immission point. (Immission level)

L_{ref} : Reference level near the source at 10m distance. (Emission level. Free field conditions)

ΔL_i : Corrections. (The index (i) refers to different corrections. (See above). The index is the same for both muzzle noise and bullet noise corrections, though the quantities are not generally equal for the two sources of noise).

Muzzle noise:

$$L_{pI} = L_{pI}(\Phi,10m)+\Delta L_h+\Delta L_d+\Delta L_a+\Delta L_g+\Delta L_s+\Delta L_v(+\Delta L_r) \quad (1)$$

Bullet noise: (supersonic projectiles only. S_B is the bullet source point)

Immission point within the bullet noise region:

$$L_{pI} = L_{pI}(S_B,10m)+\Delta L_d+\Delta L_a+\Delta L_g+\Delta L_s+\Delta L_v(+\Delta L_r) \quad (2)$$

3. MAIN REVISIONS

Reference level. Muzzle noise

A measurement method for obtaining reference levels is adapted to the revised version of the prediction method. The complete method is described in [3]. A simple correction for unlinear sound propagation is included, based on Fig.1 and [4]

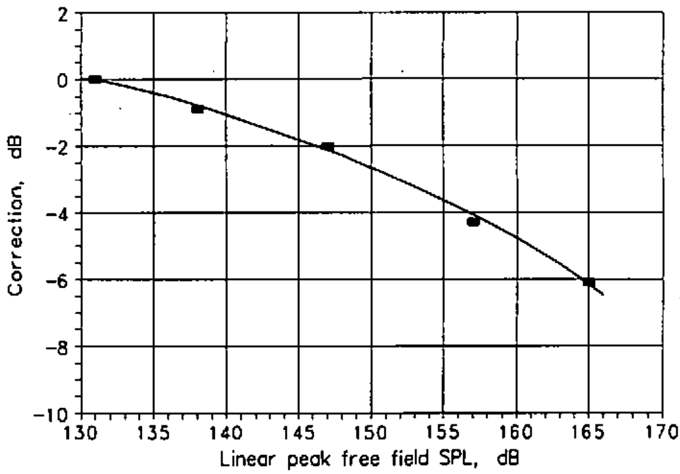

Fig.1. Correction for unlinear sound propagation as a function of the linear peak free field sound pressure level.

The octave band with the highest sound pressure level (center frequency = f_0) is identified. The correction (which is negative) is added to the levels in all octave bands with center frequency higher than f_0. The level in octave band f_0 is not corrected and the levels in octave bands below f_0 are corrected by <u>subtraction</u> of half the correction in Fig.1.

Reference level. Bullet noise

Measurements, clearly identifying the bullet noise ("sonic boom") are made to distances approx. 800 meters. The measurements comply well with Whithams "far-field" theory, as described f.ex in [5]. The classical "N-curve", with peak pressure L_{pk} and total duration T is frequency analyzed in octave band(s) with center frequency F, according to eq.(3), [6]):

$$L_{pl}(S_B,10m) = L_{pk}(10m)+10lg([2/(\pi F)^2][(\sin\pi FT(10m))/(\pi FT(10m)) + \cos\pi FT(10m)]^2[0.707F]) + 14.6 \qquad (3)$$

Firing sheds

The insertion loss of several firing sheds (Fig.2) are measured, with a standard 7.62mm military rifle as sound source. The sheds are both "standard" shooting halls, and sheds with prolonged roof, prolonged side walls and interlane screens.

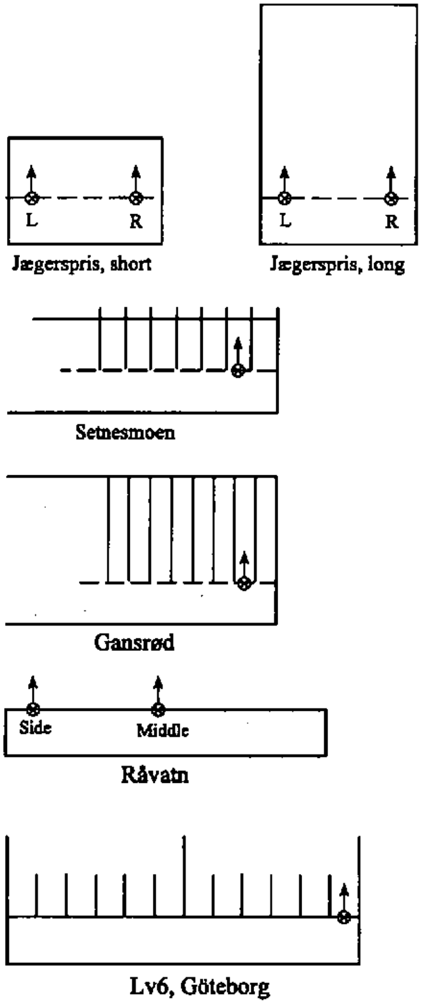

Fig.2. Firing sheds (seen from above). Dimensions in [3].

Rel. shooting direction:	15°	30°	45°	90°	135°	180°
Jægerespris, short,L	4	10	14	14		25
Jægerespris, short,R	1	1	+2	8		20
Jægerespris, long,L	(6)	(10)	(17)	27		22
Jægerespris, long,R	(+10)	(+7)	(11)	24		23
Setnesmoen	4	10	8	15		
Gansrød		11		19	26	
Råvatn, mid. pos.	(0)	(0)	(0)	18	16	19
Råvatn, side pos.	(0)	(0)	(0)	4	11	16
Lv6, Gøteborg	2		(1)	16	15	15

Table 1. Insertion loss of firing sheds and shooting halls at 100 meter distance for $L_{pA,I}$. Values in brackets are estimated.

Multiple screens
According to [1] all screens are simplified to thin screens and the most effective one is chosen. Measurements have been made to investigate whether a multiple screen calculation should be included or not. Sound source is a 7.62mm military rifle.

Two screens far apart. Side barriers with height 1.2-4.8m, at 1.5-19.4m distance, were supplemented with a screening hill, height 7m, at 100m distance. Measuring distances were 510-1440m. Calculated insertion loss from [7], allowing for one and two screens are compared with measured insertion loss from 13 series of measurement, ranging from 7-21 dB.

	Average difference, dB	Max – min difference, dB
Single screen (hill)	4.1	+11 – +2
Two screens	+4.1	+1 – +8

Table 2. Differences between calculated and measured insertion loss. (Positive number means calulated overestimation).

Revision proposal: Two screens are in particular the situation with one screen (or barrier) less than about 50 m away from the source and one screen further away, formed by the terrain. Two (ore more) terrain screens normally should not be considered as multiple screens, but the most effective one should be chosen as single screen. Calculations are done according to [7]. If a very large attenuation is obtained by this procedure, it should be ensured that the noise level in the immission point is not dominated by reflected sound paths. In practice, diffuse reflections will tend to limit the obtainable screen correction.

Reflections

In lack of actual acoustical data the reflection correction ΔL_r may be considered frequency independent and equal for the muzzle noise and the bullet noise. The correction is based on [2] and limited data from [3], and is proposed as an appendix to the prediction method. The correction for reflections from a mountainous slope is considered as a rather coarse method. The correction for reflection eq(4) is based on the reflection coefficient (ρ) for different surfaces, as given in Table 3.

$$\Delta L_r = 10 \lg(\rho) \qquad (4)$$

Reflecting surface	ρ
Plane and acoustically hard wall	1.0
Buildings etc. with openings ca. 50% of the wall area	0.4
Building with windows and small irregularities	0.8
Security baffles, hard surface	0.2
Security baffles, absorption coefficient = α	0.2 $(1-\alpha)$
Dense forest edge	0.025
Partly wood covered mountain slope	0.015

Table 3. Reflection coefficient ρ

4. REFERENCES

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[3] JAKOBSEN J, FALCH E: Noise from Shooting Ranges. Revision of Common Nordic Prediction Method. Technical report AV 412/95. DELTA Acoustics & Vibration, Lyngby 1995.

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[5] Pierce A.D: Acoustics. An Introduction to Its Physical Principles and Applications. Acoustical Society of America, 1989.

[6] Young R: Sonic Boom Spectra of Space Shuttle Colombia Landing 10 december 1990. Inter-Noise 91, pp 345-348.

[7] Beregning af ekstern støj fra virksomheder. Miljøstyrelsen, vejledning nr.5, 1993. (Danish version of [2], including a revised method for selecting the two most effective single screens in calculating multiple screen correction)