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TECHNIQUES AND PROCEDURES FOR THE MEASUREMENT OF IMPULSE NOISE

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INTRODUCTION

Criteria for the measurement of continuous sound have been agreed upon on an international level in the "International Organization for Standardization". These criteria have been promulgated as ISO standards or recommendations.
The different nations, however, disagree on the criteria for the measurement and evaluation of impulse noise. Impulse noise measurement alone cannot be seen as an end in itself, but rather as a tool in the determination of the risk to personnel and materiel resulting from the impulse noise which may be produced by a weapon or an explosion.

HISTORICAL BACKGROUND

As early as in the forties Furrer[1] has presented first impulse noise records in his publication "Die Akustik des Knalles" (The acoustics of impulse noise).

The Ordnance Proof Manual, AIRBLAST PRESSURE MEASUREMENT – ELECTRONIC[2] from 1959 is to my knowledge the first compilation of the US side of some basic terms of modern impulse noise measurement. The importance of impulse noise measurement was considerably increased in 1968 when W. Dixon Ward published the CHABA criterion[3]. This criterion used the measurable characteristics of the blast pressure wave to avoid auditory impairment or to predict possible impairment. Since 1975 the impulse noise criteria important for the USA are defined in MIL-STD-1474. The latest edition from 1997 is MIL-STD-1474D[4].

In Germany impulse noise measurements have been carried out since the beginning of the sixties in close cooperation with medical science. This work resulted in the "Vorläufige Grenzpegeldiagramm zur Hörschädenvermeidung"[5] (Preliminary Limiting Level Diagram for the Avoidance of Auditory Impairment) in the mid-sixties which was repeatedly revised in the following years[6,7] and has been in force in Germany as "Grenzpegeldiagramm zur Hörschädenvermeidung" (Limiting Level Diagram for the Avoidance of Auditory Impairment) since 1974. The German limiting level diagram is also based on the measurable characteristics of the blast pressure wave to predict or even preclude possible auditory impairment.

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[1] FURRER, W.: Die Akustik des Knalles, Schweiz. Arch. angewandte Wissenschaft u. Technik, 12 , 1946
[2] OPM 80-12, ORD-M608-pm, Vol. IV, INSTRUMENTATION 20 April 1959
[3] WARD, W. Dixon: PROPOSED DAMAGE-RISK CRITERION FOR IMPULSE NOISE (GUNFIRE), NAS-NRC Committee on Hearing, Bioacoustics and Biomechanics. WG 57, July 1968
[4] MIL-STD-1474D, Noise Limits, Department of Defense Design Criteria Standard, AMSC A7245, Feb. 1997
[5] PFANDER, F.: Über die Toleranzgrenze bei akustischen Einwirkungen. HNO (Berlin), 13 , 27 (1965)
[6] PFANDER, F. (Hrsg.): Das Knalltrauma, Springer-Verlag Berlin Heidelberg New York 1975
[7] PFANDER, F. (Hrsg.): Das Schalltrauma, Schriftenreihe Präventivmedizin – PM 1 BMVg, Bonn Juni 1994

Paper presented at the RTO HFM Lecture Series on "Damage Risk from Impulse Noise", held in Maryland, USA, 5-6 June 2000 and Meppen, Germany, 15-16 June 2000, and published in RTO EN-11.

In the mid-seventies a Franco-German expert group under the proponency of the Franco-German Research Institute, Saint-Louis, France (ISL) developed a guideline[8] to make possible the comparison of impulse noise measurements performed by different institutions.
The NATO Research Study Group (RSG.6) on the Effects of Impulse Noise has published "Guidelines for the measurement of Impulse Noise from Weapons" in Annex 1 to its final report[9] drawn up in 1987.
Under the proponency of the ISL an expert group has again revised the Franco-German measurement regulation for the measurement of impulse noise in the nineties and promulgated the new edition[10] in 1995.
Since 1993 endeavors are being made to revise the US "Test Operation Procedure TOP 4-2-822" from 1981 and to use this revised version as a basis to elaborate a document valid for the nations of France, Germany, the United Kingdom and the United States. No standardization could be obtained until now also in the case of the current 7th draft of ITOP 4-2-822 "Electronic Measurement of Airblast Overpressure" from 1 September 1999. The special reasons for this will be discussed later.

PROCEDURE

As a mere physical phenomenon impulse noise does not fall under the category of acoustics, but rather under the category of fluid dynamics, gas dynamics and shock waves. In the fronts of the shock waves the pressure, velocity, density and temperature rapidly increase from small values ahead of the shock wave front up to high values in or closely behind the front.
Whenever a round is ejected from the muzzle of a weapon or an explosive charge detonates a large volume of heated gas is released into the surrounding atmosphere. The rapid expansion of the gases into the surrounding medium (undisturbed air) initiates a pressure wave which takes on the form of a shock wave. This shock front initially moves outward from the source point at supersonic speed; however, with increasing distance the velocity decreases to the velocity of sound. Behind the shock front an approximately exponential overpressure drop occurs followed by a lower-amplitude negative phase.
Impulse noise in its ideal form is therefore a double-sided sound pulse of a high acoustic level and extremely short time interval. Its energy is frequently so high as to produce auditory impairment in an unprotected ear. In special cases it may even result in damage to other organs of the human body, such as the lungs, the windpipe, the stomach etc. or in the destruction of non-human structures.

As to the evaluation of possible damage to personnel and materiel the following physically measurable impulse noise parameters may be important:

- peak overpressure,
- rise time,
- time-duration,
- impulse noise spectrum,
- impulse-noise energy.

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[8] VORSCHRIFTEN und RICHTLINIEN zur Registrierung und Auswertung von Waffenknallen, Deutsch-Französische Meßvorschrift für Waffenknallmessungen, BWB-/-DTAT/ETBS-/-ISL, März 1978
[9] FINAL REPORT on the Effects of Impulse Noise, Document AC/243(Panel 8/RSG.6) D/9 Feb. 1987
[10] VORSCHRIFTEN und RICHTLINIEN zur Registrierung und Auswertung von Waffen- und Detonationsknallen, Neufassung der Deutsch-Französiche Meßvorschrift für Waffenknallmessungen, ISL-/-DGA/ETBS-/-WTD91, 10.4.1995

All known international physical evaluation criteria are based on acoustic pressure (here: peak overpressure) and a rise time defined according to the respective guideline.
As to the traumatic effect of the impulse noises (noise in the working environment) the measurement and evaluation of the acoustic alternative pressure must be based on special criteria which will be discussed in the following.

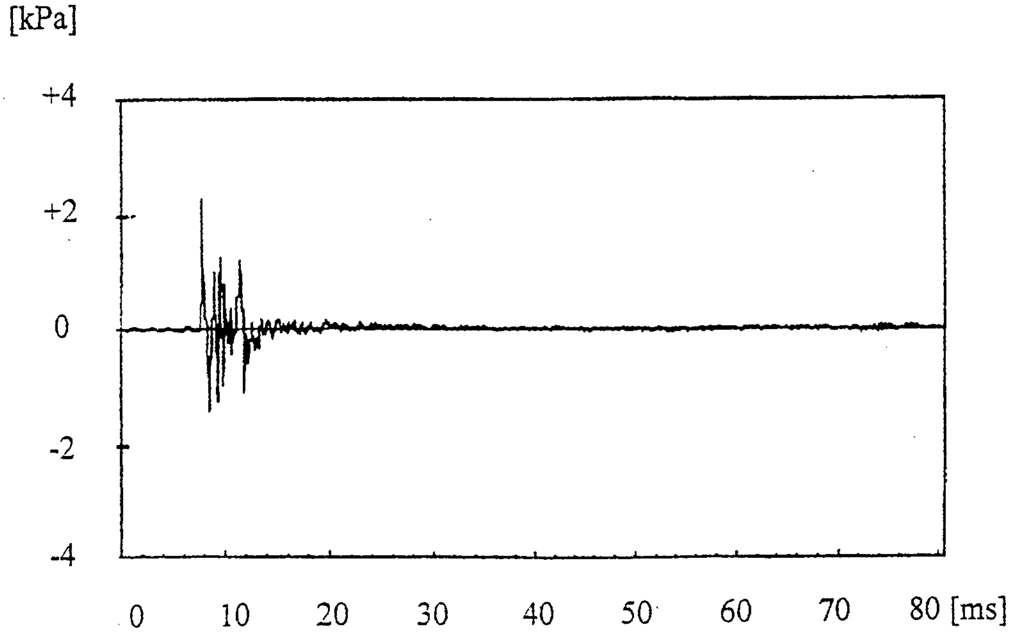

Figure 1: Pressure-time history of the typical impulse noise of a rifle. Acoustic pressure as a function of time.

PEAK OVERPRESSURE

The pressure-time history as shown as an example in Figure 1 is therefore required for the physical evaluation of an impulse noise. As long as the acoustic pressure p is small in relation to the atmospheric pressure p_A there is hardly any distortion (effects in the positive and negative directions are equal = sound in the usual sense). Impulse noises, however, which are studied with regard to possible damaging effects, are often characterized by a positive acoustic pressure portion (p_A + p) which is much greater than the negative portion (p_A - p). The negative portion may reach the maximum value of zero = zero pressure, i.e. vacuum, whereas in the positive phase of the impulse noise high peak pressure levels occur. In the near field of weapons – as determined e.g. during materiel stress tests – peak pressure levels of up to 10^6 Pa = 1 MPa (equivalent to 10 bar) may occur. At the operator or training personnel positions these positive peak pressure values of approx. 200 Pa (= 140 dB) for light weapons and up to 60 kPa (approx. 190 dB) for heavy weapons may vary by more than two decimal powers. The last-mentioned value of 60 kPa or 190 dB is considered as absolute limiting value in the new development of weapons.

RISE TIME

The slope of the pressure rise is of particular importance in the evaluation of an auditory impairment risk especially in the case of impulse sound, because all sound events with shock-like energy supply pass the transmission system of the middle ear fully and without attenuation and are transferred into the liquid-filled cochlea where they exert stress on the sensitive hair cells[11]. The protective reflex of the middle ear muscles cannot respond to this stress due to the relatively long latency of this reflex. It becomes clear that not only the level, but also the level rise time is essential. The determination of the level rise time of impulse noise, however, is difficult and only possible in exceptional cases.

Typically, the pressure rise of the impulse noise is produced by a shock wave which possesses a natural slope so that the front width in the density distribution of the wave, and thus the rise time becomes a function of the peak pressure p. Very weak shock waves with a peak pressure p = 100 Pa (= 134 dB) under standardized air conditions result in a front width of approx. 1.3 mm and a corresponding rise time of approx. 4 µsec[12,13]. According to the present state of the art, such a rise time can just be captured with the most modern pressure transducers.

In the near field of the gunmuzzle, however, a much higher peak value is produced in the course of the pressure history. The front width of the existing moderate up to strong shock waves is reduced to the mean free path of the gas particles (order of magnitude of 10^{-4} mm = 0,1 µm). Thus the slope is much steeper and the rise time very much shorter than 4 µsec. Time-preserving reproduction of the slopes is not possible even with the state-of-the-art reception microphones available at present. It is only possible to state that "the rise time must be very much shorter than 4 µsec".

Although time-preserving reproduction of the slope is not possible, the complete history of the impulse noise including peak pressure and succeeding oscillations is correctly recorded. The time of the positive phase, typically between 0.1 and 5 ms for usual impulse noises is always shorter than the time of the negative phase.

During sound propagation the medium particles move in the direction of propagation in the areas of positive acoustic pressure, in the areas of negative acoustic pressure, however, they move in the opposite direction. Furthermore, the propagation velocity of the pressure maxima is slightly faster, that of the pressure minima slightly slower than the speed of sound. Both effects, the propagation in a flowing medium and the temperature dependency of the speed of sound due to the pressure differences effect a change in the waveform during propagation: the maxima advance, whereas the minima stay behind[14]. As a result, increase-of-slope effects are produced again and again in the shock wave in the near field of weapons, provided that the energy density is high enough. This near field of the weapons, however, is the usual position of the operating personnel.

After a certain path during sound propagation (order of magnitude of 100 m for large-caliber weapons) a stable shock front is formed where increase of slope and the absorption of the higher frequencies rapidly increasing with increasing frequency balance each other.

Only when the sound path becomes longer the absorption of the high frequencies outweighs the increase of slope so that the steep pressure rise levels off more and more. The aforementioned effects, in particular the additional absorption of the high frequencies above

[11] SPRENG, M., LEUPOLD, S. und EMMERT, B.: Mögliche Hörschäden durch Tieffluglärm. Forschungsbericht 10501213-04 im Auftrag des Umweltbundesamtes, April 1988

[12] WECKEN, F., FROBÖSE, M.: Über die Frontsteilheit von Luftstoßwellen bei Ausbreitung über große Entfernungen. Technische Mitteilung T 27/62, Deutsch-Französisches Forschungsinstitut Saint-Louis, 1962

[13] BECKER, R.: Stoßwelle und Detonation. Z. Physik 8, 321-362, 1922

[14] MEYER, NEUMANN: Physikalische und technische Akustik, 4.8 Stoßwellen. Hochschul-Lehrbuch, 1967

grassy soil (in contrast to concrete floor or propagation above water) have been studied recently[15]. The unpleasantly sharp impulse noise near firing weapons therefore sounds increasingly dull with increasing distance from the source of the noise. Moreover, the intensity of the impulse noise, i.e. the peak value rapidly decreases with increasing distance which also contributes to the reduction of the damage risk.

TIME-DURATION

In the Anglo-American states two different time-duration definitions which are required for the application of the CHABA limiting criteria are used[16], the A-duration and the B-duration.

(1) The A-duration: This is the time from the beginning of the impulse noise until the first zero crossing after the drop from peak pressure. This time determines the energy maximum in the impulse noise spectrum, however, it certainly does not capture the time-duration which occurs in complex acoustic pressure histories with reflections after zero crossing. Intensive, short-time post-pulse oscillations (secondary peak values) with lower intensities than the primary peak value may –independent of the spectral composition – cause major impairment of the inner ear[17]. It is therefore important to take these phases into account just like this done in the other time durations.

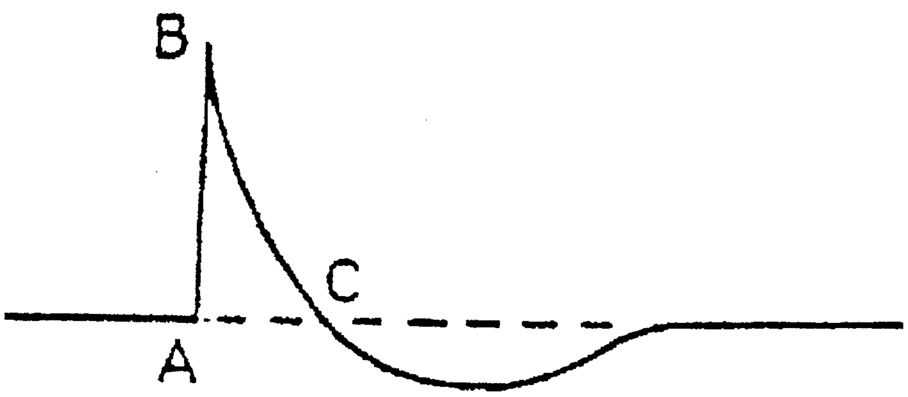

Figure 2: Idealized oscilloscopic waveform of an impulse noise. Peak height: pressure difference $\overline{AB}$; rise time: time difference $\overline{AB}$; A-time according to CHABA: time difference $\overline{AC}$.

[15] FORD, R. D., SAUNDERS, D.J. and KERRY, G.: The acoustic pressure waveform from small unconfined charges of plastic explosive. J. Acoust. Soc. Am., 94 (1), 1993, 408ff
[16] WARD, W. D.: Proposed Damage-Risk Criterion for Impulse Noise (Gunfire), Report of Working Group 57. NAS-NRC, Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), 1968
[17] SPRENG, M.: Auswirkungen des Lärms auf das Hören. Audiol. Akustik, 21, 1982, 66-74 und 94-113

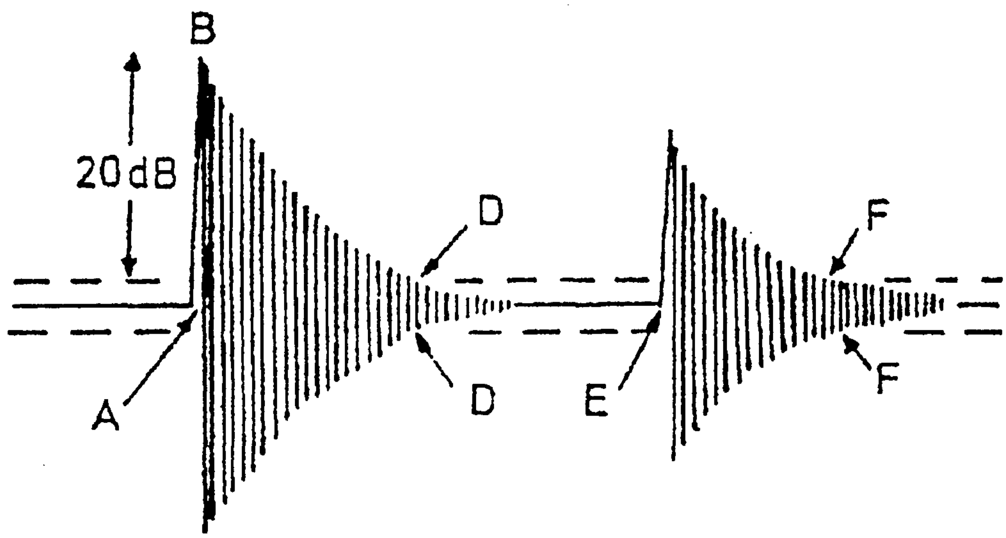

Figure 3: Idealized oscilloscopic waveform of impulse noise. Peak height: pressure difference $\overline{AB}$; rise time: time difference $\overline{AB}$; B-duration according to CHABA: time difference $\overline{AD}$ (and $\overline{EF}$, if reflection is present)

(2) B-duration (pressure envelope duration): The duration of the primary portion of an impulse noise plus the duration of significant subsequent fluctuations. These durations are considered to be the time interval during which the envelope of pressure fluctuations [positive and negative] is within 20 dB of the peak pressure level. The time-duration is then defined as the time from -20 dB before the maximum value of the peak pressure up to -20 dB after the maximum. The use of the definitions of A- and B-duration is practical for the idealized pressure-time histories described. Problems arise, however, with regard to most of the blast pressure records of firing weapons, in particular of impulse noise produced by antitank weapons and mortars and impulse noise within armored vehicles.

The German limiting-level diagram[6,7,19] is based on another time-duration definition.
The time-duration of impulse noise has been defined analogous to a time-duration regulation valid in Germany for aircraft noise as the time duration from -10 dB before the maximum up to -10 dB after the maximum: the **C-duration**[18,19]. The highest pressure peak has thus been selected as reference quantity. This type of time-duration definition is shown in Figure 4.

The value of "-10 dB" is equivalent on a linear scale to a reduction in pressure of approx. $^2/_3$ of the peak pressure value. All subperiods of the impulse-noise history are added on the "-10 dB line" in the positive and negative areas. The time-duration t_w thus is the sum of the periods ($\overline{AB}$ + $\overline{CD}$ + $\overline{EF}$).

[18] BÜRCK, W.: Unveröffentlichtes Gutachten über die Gesamtbeurteilung der Geräuschbelastung für den Menschen auch bei Kurzzeit-Schallvorgängen. Januar 1965

[19] PFANDER, F. (Hrsg.): Das Knalltrauma, Springer-Verlag Berlin Heidelberg New York 1975

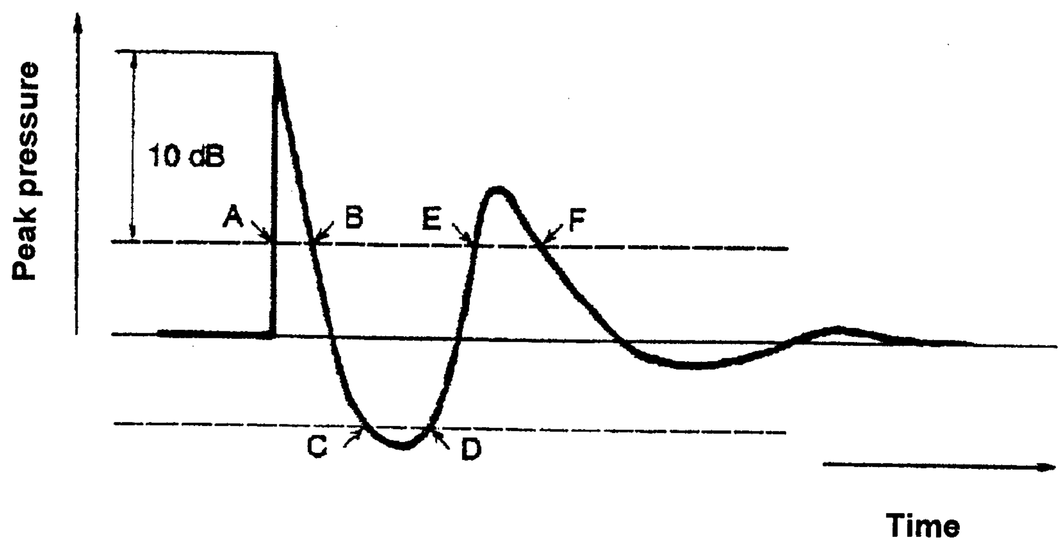

Figure 4: Peak-pressure dependent determination of the time-duration according to the German method; C-duration according to PFANDER

The use of the time-duration definition according to Figure 4 has proven successful in Germany, particularly since the range of interfering influences is often reached when the peak value is reduced by 20 dB[20]. The calculation of the maximum allowable number of rounds depends among other things on the frequency pattern of the individual round: large-caliber guns producing a higher quantity of low frequencies have a longer time-duration because of the more marked post-pulse oscillations. The different effects of low and higher frequencies are indirectly taken into account in the limiting-level diagram according to PFANDER. Low-frequency portions are captured in the calculation of the C-duration by means of the extension of time-duration.

If in order to achieve a common international definition of time-duration another definition is agreed upon, the limiting criteria would also have to be adjusted accordingly.

Another definition of time-duration is used in the Netherlands: the **D-duration** according to SMOORENBURG (see Figure 5). This duration is defined as the time from the beginning of impulse noise until the drop of one envelope around the pressure-time diagram to a value of -10 dB below maximum[21].

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[20] PFANDER, F., BONGARTZ, H., BRINKMANN, H. and KIETZ, H.: Danger of auditory impairment from impulse noise: A comparative study of the CHABA damage-risk criteria and those of the Federal Republic of Germany. J. Acoust. Soc. Am., 67(2), 1980, 628-633

[21] SMOORENBURG, G.F.: Damage risk criteria for impulse noise. in: HAMERNIK, R.; HENDERSON, D. and SALVI, R. (eds.): New perspectives on Noise-Induced Hearing Loss. Raven Press, New York, 1982, 471-490

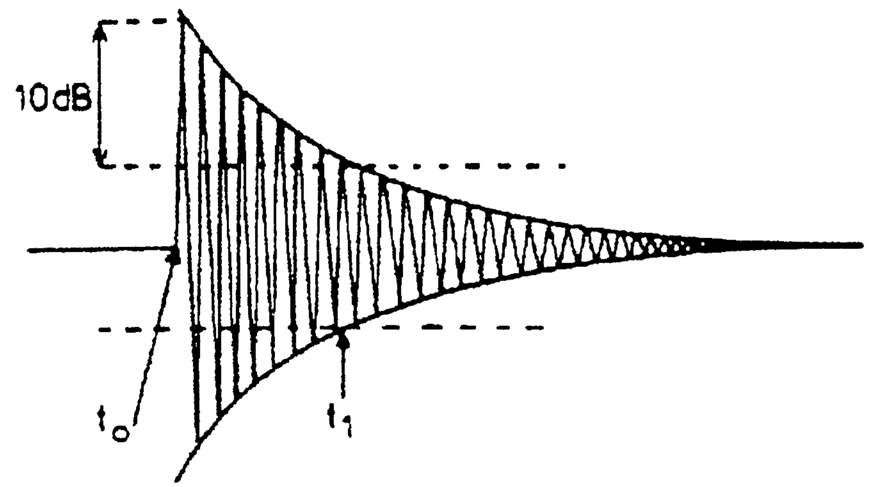

Figure 5: Representation of the D-duration according to SMOORENBURG: time t_0 to t_1

A schematic diagram of the four different time-durations mentioned is shown in Figure 6.

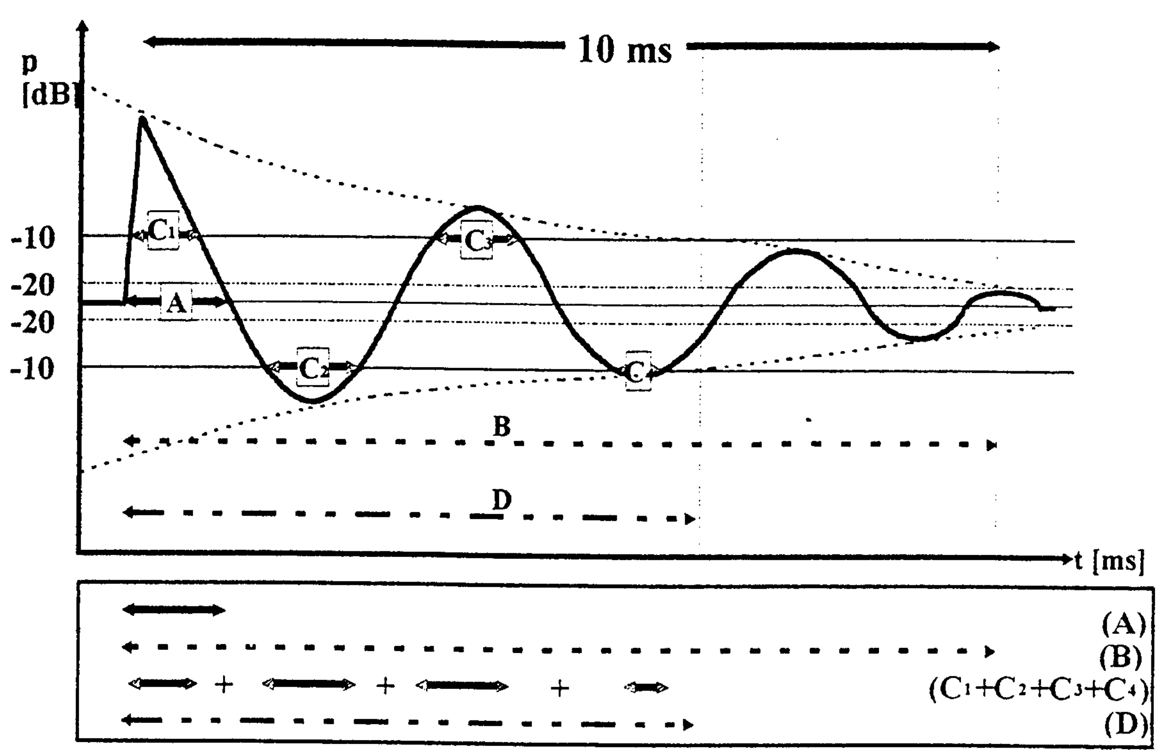

Figure 6: Schematic of different time-durations: A- and B-duration (according to CHABA), C-duration (according to PFANDER), and D-duration (according to SMOORENBURG)

IMPULSE NOISE SPECTRUM

Although not required by the limiting criteria, it seems sensible to examine the impulse noise in its spectral decomposition in addition to its representation in the pressure-time diagram. Already in 1946, FURRER[1] determined the impulse noise spectrum from pressure-time diagrams of impulse noises by time-consuming calculations (Fourier integral equations). In 1958, FURRER[22] presented the spectra of various impulse noises summed up over octaves. This analysis which is shown in Figure 7 proves that due to the bandwidth increasing towards higher frequencies, the smaller spectral portions of the amplitude density spectrum also contained in this range are not to be underestimated.

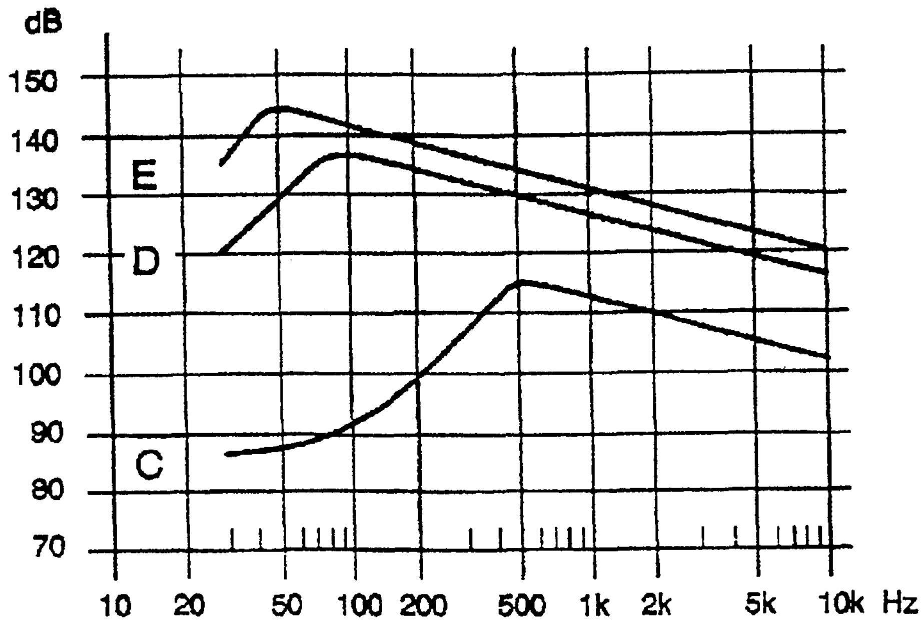

Figure 7: Impulse noise spectra summed up over octaves. C: pistol, 0.85 m distance; D: 7.5 mm gun, 5 m distance; E: explosion of 4 kg TNT, 4 m distance (according to[23]).

Regarding possible damages caused by impulse noise, however, it still cannot be clearly decided whether the spectral decomposition has to be performed with a constant bandwidth or with constant frequency intervals (octave or third-octave spectra).
For this reason it is considered best to perform the analyses with a constant bandwidth = amplitude density spectrum in order to be able to sum up over octaves or third-octaves.
One method to analyze the frequency of impulse noises with digital computers is the Fast Fourier Transformation (FFT) according to COOLEY and TUKEY which provides the desired spectrum from a time signal. With the help of an analog-to-digital converter, the analog pressure-time signal is quantified and stored in the analyzer either directly from the pressure transducer or from the magnetic tape that has recorded the noise. A computer with a suitable program computes the FFT spectrum from the time signal. The FFT spectrum can be represented on a monitor or a plotter within a few seconds after the impulse noise.

In Germany, the impulse noise is recorded by frequency analysis in the form of an amplitude density spectrum and a third-octave spectrum. For this purpose, a work station is used for

[22] FURRER, W.: Lärm und Lärmabwehr. Documenta Geigy, Mensch und Umwelt 3, 1958
[23] FURRER, W.: Lärm und Lärmabwehr. Documenta Geigy, Mensch und Umwelt 3, 1958

which the Franco-German Research Institute, Saint-Louis, France (ISL) has developed the software[24].

An example of this is shown in Figure 8.

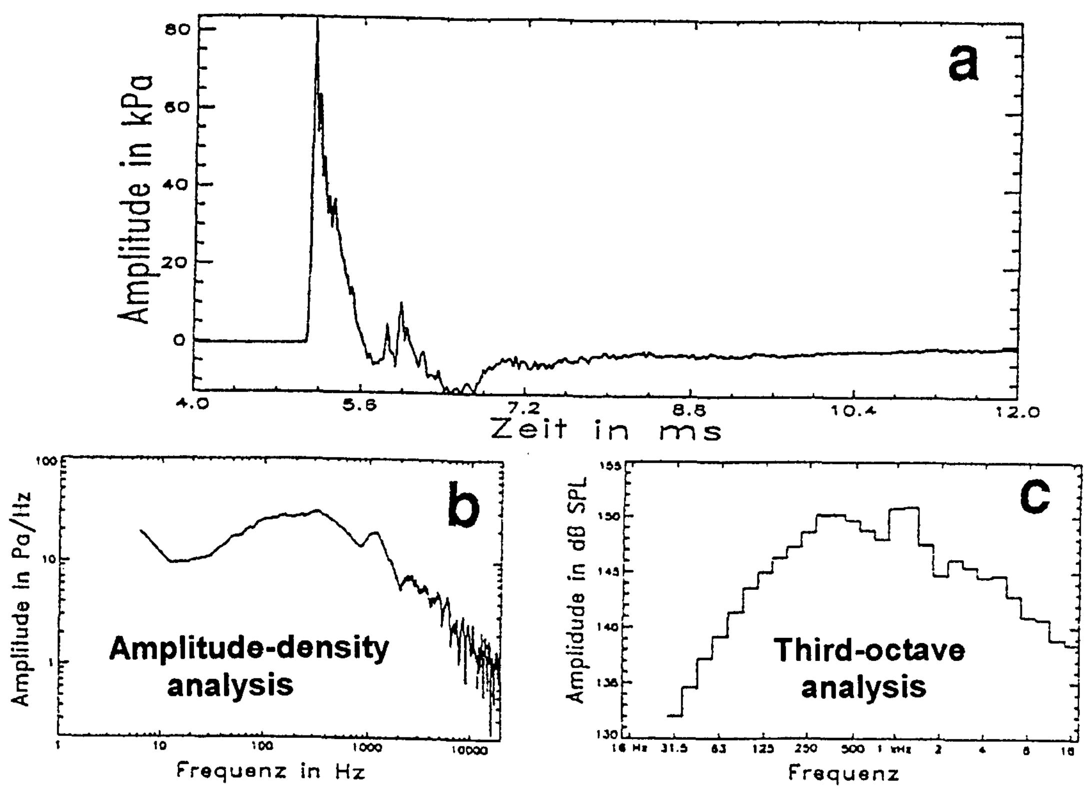

Figure 8: Pressure-time signal (a); with the related amplitude density- (b) and third-octave spectrum (c).

IMPULSE NOISE ENERGY

Lacking a direct measuring method for the impulse noise energy, the readily obtainable parameters of the peak pressure level p_{max} and the time duration t_w were in former times used to determine the previous limiting criteria. The determination of the time duration according to the method common in Germany is physically not necessary and is based only on an

[24] BUCK, K. und BREMGARD, V.: Die digitale Erfassung und Auswertung von Impulslärm, ISL-Bericht 1994

agreement. The use of the limiting level diagram, however, requires the determination of the actual time duration.
The computer-aided evaluation of impulse noise measurements also facilitates an easy determination of the impulse noise energy. The "acoustic impulse noise energy" is the acoustic energy per unit area which is defined as follows:

$$E^* = \frac{1}{Z_0} \int_0^T p(t)^2 \cdot dt \ [J/m^2]$$

where Z_0 is the characteristic acoustic impedance of the air in $N \bullet s/m^3$, p(t) is the instantaneous value of the acoustic pressure in Pa or N/m^2 and dt is the time increment for the scanning of the instantaneous acoustic pressure in seconds. According to BRESS[25] the characteristic acoustic impedance is defined as $Z_0 = 400\ N \bullet s/m^3$. According to the GUIDELINES FOR THE MEASUREMENTS OF IMPULSE NOISE FROM WEAPONS[26], Z_0 is to be 417 $N \bullet s/m^3$.
Up to now, the Bundeswehr Technical Center WTD 91 performed its evaluations following the first definition with $Z_0 = 400\ N \bullet s/m^3$. In fact, $Z_0 = \rho \bullet c$ and is thus dependent on the atmospheric density and the velocity of sound c. Both factors are pressure-dependent in the shock front and thus variable. At a peak pressure level of 160 dB corresponding to 2 kPa, $Z_0 = 409\ N \bullet s/m^3$, while at 180 dB corresponding to 20 kPa Z_0 will already be 492 $N \bullet s/m^3$ [27]. A higher Z_0, however, will have the result that the energy per unit area E* becomes smaller. The energy calculated with the above-mentioned formula is thus slightly higher than the actual energy. Studies performed at the WTD 91 data processing center have shown that at the usual impulse noises of up to approximately 180 dB the deviation is < 5 % if Z_0 is used as a constant instead of a variable.
The acoustic impulse noise energy includes the complete acoustic pressure history, while the previously used method with the evaluation of the peak pressure and the time duration leaves out considerable impulse noise portions. For this reason it results in a better correlation with the risk of an acoustic trauma than the method used so far. However, the admissible limiting criteria would have to be adapted for this purpose.

WEAPON IMPULSE NOISE MEASURING PROBLEMS CAUSED BY THE MEASURING METHOD

When measuring the impulse noise in the near field of firing weapons, the pressure transducers can be positioned or mounted in such a way that their membranes are positioned either vertically (direct incidence), parallel (grazing incidence) or backwards (180° offset from the direct incidence) towards the incoming acoustic beams.

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[25] BRESS, H.-J.: Einheitliche Beurteilung von Knallen und Dauergeräuschen anhand des energetisch gemittelten Impulsschallpegels. Rückführung verschiedener Beurteilungskriterien auf die Schallenergie. in: Kurzzeit-impulslärm. Schriftenreihe der Bundesanstalt für Arbeitsschutz und Unfallforschung (BAU) Nr. 12, Wirtschaftsverlag NW, Bremerhaven, 1976

[26] Guidelines FOR THE MEASUREMENT OF IMPULSE NOISE FROM WEAPONS. in: Final Report on the Effects of Impulse Noise / Research Study Group 6, Document AC/243(PANEL 8/RSG.6) D/9, Feb. 1987

[27] BRINKMANN, H.: Messung und Bewertung von Waffenknallen im Hinblick auf Hörschädenvermeidung. in NIXDORF, K. (Hrsg.): Tagungsband „Anwendungen der Akustik in der Wehrtechnik" 1978

In the case of a direct incidence, the following differentiation is made when measuring an impulse noise or shock wave with pressure transducers:

(1) Static pressure: This is the pressure in the undisturbed shock front.
(2) Dynamic pressure: This pressure results from the kinetic energy of the medium particles hitting a pressure transducer and is mainly depending on the shock wave velocity.
(3) Reflected pressure at the membrane of a pressure transducer: A reflected pressure always results when half the wavelength or the smaller wavelength of a pressure portion within the impulse noise spectrum equals the diameter of the pressure transducer membrane or the diameter of the mounting surrounding the membrane. In this case, a pressure increased by 6 dB (= a pressure duplication) is measured for this frequency range. This means that microphones with different diameters will measure different reflected pressure portions. For example, the reflected pressure (6 dB) is of influence for:
    (a) a microphone - ø 16 mm — from approx. 10 kHz,
    (b) a pressure transducer - ø 5,5mm — from approx. 30 kHz,
    (c) a miniature pressure transducer - ø 0,25 mm — from approx. 670 kHz.

For this reason, the aim is to use pressure transducers with the smallest-possible outer diameter and the smallest-possible membrane surface, however, still in consideration of a suitable sensitivity.
In the case of a grazing incidence, only the static pressure is measured. Since the shock front, with its width being relatively small as compared to the membrane diameter, runs across the membrane surface it excites only a part of the pressure-sensitive element. Therefore, the represented rise time of the shock front on the one hand is too high while on the other hand the actual pressure peak is not reached. This is the case especially if the pressure following very short impulses has dropped very rapidly.
In order to be able to achieve comparable results when measuring impulse noises with respect to the stresses imposed on the auditory system on a national and international level, it is mainly important to standardize the measuring technology and methods. In cooperation with the Franco-German Research Institute, Saint Louis, France (ISL), a harmonization both on the French and the German side was achieved in 1978 which resulted in the publication of a joint regulation for weapon impulse noise measurements[28].
It was commonly agreed that the problem of a correct measurement of shock waves (impulse noises) has not yet been solved completely. And it will remain a problem as long as electromagnetic transducers with a finite extension (pressure transducers/microphones) have to be used for measurement. So, if a correct measurement is impossible it should at least be possible to perform a standardized measurement "at any time and at any location". ***Because weapon impulse noise measurements are in general not reproducible, a successful initial measurement is especially important***[29]. In addition, the measuring values should correlate with the common limiting criteria for impulse noise stresses.
Some aspects of the joint agreement are:

(1) Diameter of the pressure transducer including the probe: ≤ 5,5 mm;
(2) unsupported length of the probe (at a ø of 5,5 mm): 80mm;
(3) electric filtering with a low pass with a cut-off frequency of 22.4 kHz (passing of low frequencies, cut-off of frequencies above 22.4 kHz/Bessel characteristic).

[28] Vorschriften und Richtlinien zur Registrierung und Auswertung von Waffenknallen, Deutsch-Französische Meßvorschrift für Waffenknallmessungen, BWB-/-DTAT/ETBS-/-ISL, März 1978
[29] BUCK, K. und BRENGARD. V.: Rechnergestützte Auswertemethoden für Waffenknalle. ISL, PU 312/96

Originally it was assumed that this measuring system could be used for a non-directional measurement (suppression of the reflected pressure portion of the shock wave with the filter). Tests performed at the ISL, however, have shown that a non-directional measurement is impossible with different peak pressure values. For this reason, both the German and the French side agreed upon an identical orientation of the transducers, i.e. a sound incidence of 90°.
The German-French measuring regulation for weapon impulse noise measurements was revised in 1994 and is now available in the bilingual new version of April 10, 1995. No changes were made with respect to the pressure transducer and filtering characteristics. A major modification was performed regarding the inclusion of the digital measuring processing which allows the calculation of the impulse noise energy and the equivalent noise levels as well as frequency analyses in the form of an FFT or a third-octave, in addition to the evaluation of impulse noises according to German, Anglo-American and Dutch criteria.[30,31].
The measuring regulation prepared within the frame of the Research Study Group ON THE EFFECTS OF IMPULSE NOISE[32], specifies a transducer configuration with a grazing sound incidence and the smallest-possible diameter. A 22.4 kHz filtering, however, is not required.
If, however, a grazing incidence cannot be ensured (as, for example, when measuring the impulse noises inside reflecting rooms or inside a tank), indefinable reflection portions at the pressure transducer membrane can distort the overall appearance of the pressure-time history through the rise of a slow, low-frequency pressure wave superimposing the actual impulse[33], while, with the measuring method according to the German-French regulation, these portions would be filtered out.

A "FR/GE/UK/US Four-Nation Standardization Group is working at the standardization of the test procedures mainly for large-caliber guns and ammunition. In the meantime, this group has presented the 7th draft of an ITOP 4-2-822, "Electronic Measurement of Airblast Overpressure"[34]. At present, there are considerable differences with respect to the pressure transducers to be used, including their mounting and the low-pass filtering. An agreement between the German-French point of view and the Anglo-American point of view has not yet been achieved.

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[30] Vorschriften und Richtlinien zur Registrierung und Auswertung von Waffen- und Detonationsknallen, 1995
[31] BUCK, K. und BREMGARD, V.: Die digitale Erfassung und Auswertung von Impulslärm, ISL-Bericht 1994
[32] Guidelines FOR THE MEASUREMENT OF IMPULSE NOISE FROM WEAPONS in: Final Report on the Effects of Impulse Noise / Research Study Group 6, Document AC/243(PANEL 8/RSG.6) D/9, Feb. 1987
[33] HAMERNIK, R.P. and HSUEH, K.D.: Impulse noise: Some definitions, physical acoustics and other considerations. J. Acoust. Soc. Am., 90(1), 1991, 189-196
[34] FR/GE/UK/US International Test Operations Procedure (ITOP) 4-2-822: Electronic Measurement of Airblast Overpressure and Impulse Noise. Draft 7. U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T,