Mõõdistamistunnistus

MEASUREMENT CERTIFICATE

Akrediteeritud L151

Mõõdistamistunnistuse nr:
Number of Measurement Certificate: **3-064-14**

Kuupäev:
Date: 13.02.2015

Tellija:
Customer: OÜ TerraMil

Objekt:
Measurement site **Estonian Defence Forces central proving ground September 13th. 2014**

Aadress:
Address: Kuusalu parish, Harjumaa county

Töö sisu:
Content of work: **Measurement of acoustic parameters in defence structures**

Mõõdistusparameetrid:
Measurement parameters:

Mürataseme määramine (M302:09.10.2014)
Determination of sound power level (M302:09.10.2014)

Vibratsiooni mõõtmine (M304:09.09.2013)
Vibration measurement (M304:09.09.2013)

Mark and model of measuring device		Measurement range	Traceability
Noise analyser Brüel & Kjaer (S313)	Type 2260	31,5:16k Hz, 44,4…95 dB	OÜ Tehnokontrollikeskus, nr. KL-15-1-029 → Kalibrator B&K 4226, national etalon of Denmark
Logging noise analysers Casella (S309)	CEL-350/K5	70…140 dB(A)	Inspecta Estonia OÜ, nr. KL-165-2-131 → Kalibrator B&K 4226, national etalon of Denmark

Allkirjad:
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Dokument koosneb mõõdistamistunnistusest ja -tulemuste kokkuvõttest kokku 13 lehel ning on välja antud ühes (1) allkirjastatud eksemplaris.

The document consists of a Certificate of Measurement with a Summary of Results on a total of 13 pages in one (1) signed copy

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1 Introduction. Objectives and Procedure of the Measurements

This document presents the results of measurement of acoustic parameters, conducted at the central military training field of the Defence Forces on September 13th. Its objective was to evaluate the conditions in a trenched defensive structure (a bunker) under conditions, where it is hit by mortar fire. For this reason, the bunker was buried under 2 metres of sandy earth, in accordance with the procedures of use. An entrance pipe was located on the surface, which opening was covered with a "cap“ to avoid the direct pressure wave from entering the room.

The bunker was fired upon from 81 mm mortars. The locations and order of the hits have been indicated on Figure 1.

The measurements were carried out by Andres Laur, a measuring technician of the Laboratory of Work Environment of the University of Tartu. The measurement results, together with references to the utilised regulatory documents and a short analysis of the measurement results[1], have been provided in the following chapters.

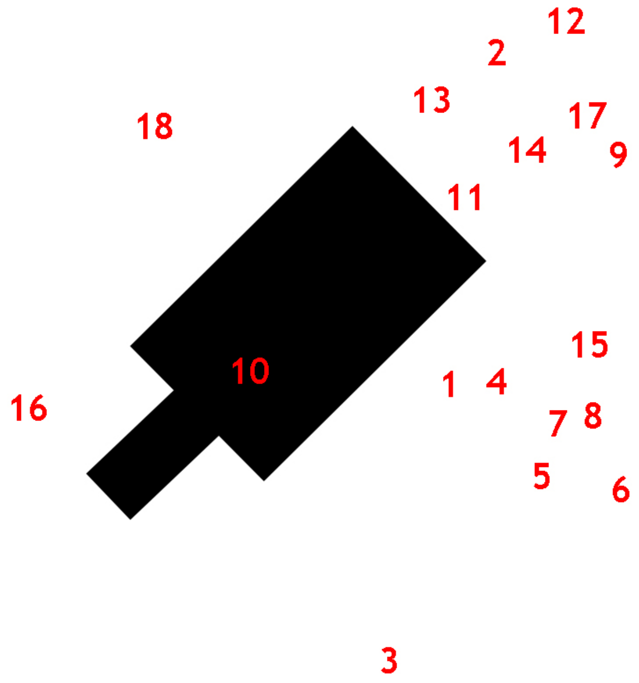

Figure 1: distribution of 81 mm mortar shell strikes around the bunker area

1.1 Presentation of measurement results

In this measurement certificate, all of the measurement results have been provided with an estimation of measurement uncertainty. None of the measurement results presented herein can and must not be regarded without taking into account the estimated measurement uncertainty.

Generally, the measurement results are depicted as a 95% probability range, or as expanded measurement uncertainty. Based on measurement theory, the actual value X_{real} of the

[1] The analysis of the measurement results has not been included in the laboratory’s scope of accreditation, the existing limit values and the accompanying explanations have been provided as information for the contracting entity that has ordered this document.

measured element X remains within the X-U...X+U range, whereas none of the values in this range can be considered “more true” than any other. E.g. when then the measurement result has been presented in the following way:

Table 1: an example of presentation of measurement results

X	U(X)
59.2	8.3

it means, that with a probability of 95%, the real value of X remains between 50.9 and 67.5, whereas no values within this range are preferred to another. Meaning that, if the tolerances prescribed for X remain within the described range of values, it cannot be conclusively claimed that the result exceeds or remains below the limit (as it cannot be verified that the limit *has not* been violated). In that case, the result is conventionally evaluated using the worst case method – the value with the most harmful effects to the health in the range of results shall be considered the most likely outcome and the criterion for deviation from the standard.

2 Noise Level

2.1 Definitions

The terms and abbreviations used in this chapter, this text, the tables and the figures have been explained below:

$L_{pA,eq,T}$, $L_{pC,eq,T}$ — The equivalent noise level that has been corrected with the A or C filter; the energetic equivalent of a sound (sound exposition) that is present for a certain time period, expressed in dB(A)

$L_{pA,max}$, $L_{pC,max}$ — The maximum noise level measured as the root-mean-square of the 125 µs measuring window registered, and corrected with A or C filter, during the whole measurement period

$L_{pC,peak}$ — The absolute maximum value of the sound pressure, corrected with the C filter, during the measurement period.

2.2 Normative documents

2.2.1 Work health and work safety requirements for an environment affected by noise, the noise limits in a work environment, and the noise measurement procedure. Regulation No. 108 of April 12, 2007, from the Government of the Republic of Estonian.

Excerpt from 2.2.1.

§ 3. Noise limits and the action values of measures in a work environment

(1) The daily noise exposure level affecting a worker (in case of an 8 hour work day) may not exceed 85 dB(A), and the peak sound pressure of noise (also in case of impulsive sound) may not exceed 137 dB(C).

(2) If the noise exposure level of a worker exceeds 80 dB(A) or the peak sound pressure 135 dB(C) (hereinafter the action value of measures), measures for reducing the effect of noise must be implemented.

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(6) In determining the daily noise exposure level affecting a worker, the attenuation provided by the individual hearing protectors worn by the worker shall be taken into account.

End of excerpt

2.3 Measurement method

The measurement method used for measuring noise levels is in accordance with the international standard ISO 1996-1:2006. Integrating noise analysers that satisfy the Class 2 requirements provided in standard EVS-EN IEC 60804:2001, Electroacoustics – Integrating-averaging sound level meters, were used to evaluate the noise levels inside the bunker caused by the 81 mm shell bombs hitting the surroundings of the bunker. The noise analysers registered the peak sound pressure and the equivalent sound pressure in 10 second intervals in the 70-145 dB range, some selected devices also in the 50-125 dB range. The layout of the noise analysers in the structure has been described in Table 2.

The measurement and calculation results have been provided in Table 3 (results summary) and 4 (results by single hits), and on Figures 2 to 4.

The measurement and calculation results have been compared, in accordance with the recommendations provided in international standards, to the limit values provided in the standard documents above, based on the worst case method (see section 1.1). The measurement results that exceed the limit values, when taking into account the measurement uncertainty, have been marked with a shaded (grey) cell base in the measurement results tables.

Table 2: layout of noise level measuring locations in the defensive structure (microphones near the headboards of the bunks)

No.	Measuring device	Location	Measurement range
1	CEL460-6	Front right stack	50-125 dB
2	CEL460-3	Front left stack	70-145 dB
3	CEL460-1	Middle left stack	70-145 dB
4	CEL460-2	Rear right stack	70-145 dB
5	CEL460-4	Rear left stack	50-125 dB

N.B.! In cases where the sound pressure exceeded the measuring capacity of the measuring device, the corresponding cell has been marked with a red background. The corresponding results have not been marked on the figures.

2.4 Measurement results

When comparing the measurement results provided in Table 4 with the peak sound pressure ($L_{pC,peak}$) limit in section 2.2.1, it was discovered that the peak sound pressure remained below the limit value for most of the strikes. In certain cases, though, the peak sound pressure did exceed the set limit. For this reason, it is advisable to protect one's in the bunker, when it is under fire.

Table 1: measurement results of peak sound pressure, summary of results

No.	Measurement site	Measurement device no.	Time		Measurement results				Legal limits (re. EE law)	
			Start [hh:mm:ss]	Finish [hh:mm:ss]	Equivalent noise level [dB(A)]		Peak sound pressure [dB(C)]		Equivalent noise level [dB(A)]	Peak sound pressure [dB(C)]
					$L_{pAeq,t}$	$U(L_{pAeq,t})$	$L_{pC,tipp,t}$	$U(L_{pC,tipp,t})$	$L_{pAeq,t}$	$L_{pC,peak,t}$
1	Front right stack	CEL460-6	7:09:00	9:41:50	67,7	1,6	>125[2]	-	85	137
2	Front left stack	CEL460-3	7:08:00	9:41:50	67,3	1,3	142,4	1,3		
3	Middle left stack	CEL460-1	7:10:00	9:41:50	67,5	1,3	139,9	1,3		
4	Back end right stack	CEL460-2	7:08:00	9:40:50	69,1	1,4	140,3	1,3		
5	Back end left stack	CEL460-4	7:07:00	9:40:50	66,0	1,6	>125	-		

[2] Reduced measurement range device

Table 2: measurement results for peak sound pressure, by each 81 mm mortar shell hit

No	Time [hh:mm:ss]	Measurement device / Peak sound pressure [dB(C)], U=1,3 dB(C)					Permitted peak pressure [dB(C)]
		CEL460-1	CEL460-2	CEL460-3	CEL460-4	CEL460-6	
1	8:56:00	132,2	132,0	135,6	>125[3]	>125	137
2	8:58:20	119,8	119,8	123,4	119,6	118,9	
3	9:01:00	125,3	128,2	129,4	126,4	>125	
4	9:03:40	131,3	131,1	132,8	>125	>125	
5	9:04:50	130,7	130,6	132,5	>125	>125	
6	9:07:10	115,8	116,3	133,2	>125	>125	
7	9:08:00	138,5	139,5	141,6	>125	>125	
8	9:12:10	133,0	133,9	135,4	>125	>125	
9	9:13:20	130,9	130,3	133,7	>125	>125	
10	9:15:20	131,8	131,6	133,7	>125	>125	
11	9:16:10	116,8	117,6	130,5	>125	>125	
12	9:18:20	137,1	139,8	139,8	>125	>125	
13	9:19:20	139,9	140,3	142,4	>125	>125	
14	9:21:50	123,4	123,2	127,5	122,7	122,1	
15	9:22:50	134,6	135,0	138,2	>125	>125	
16	9:26:00	128,0	126,9	130,1	>125	>125	
17	9:26:50	131,8	131,4	133,8	>125	>125	
18	9:28:00	124,6	124,2	126,9	123,6	123,0	
Average $L_{pC,peak,t}$:		**129,2**	**129,5**	**133,4**	**125,9**	**124,7**	

[3] Reduced measurement range device

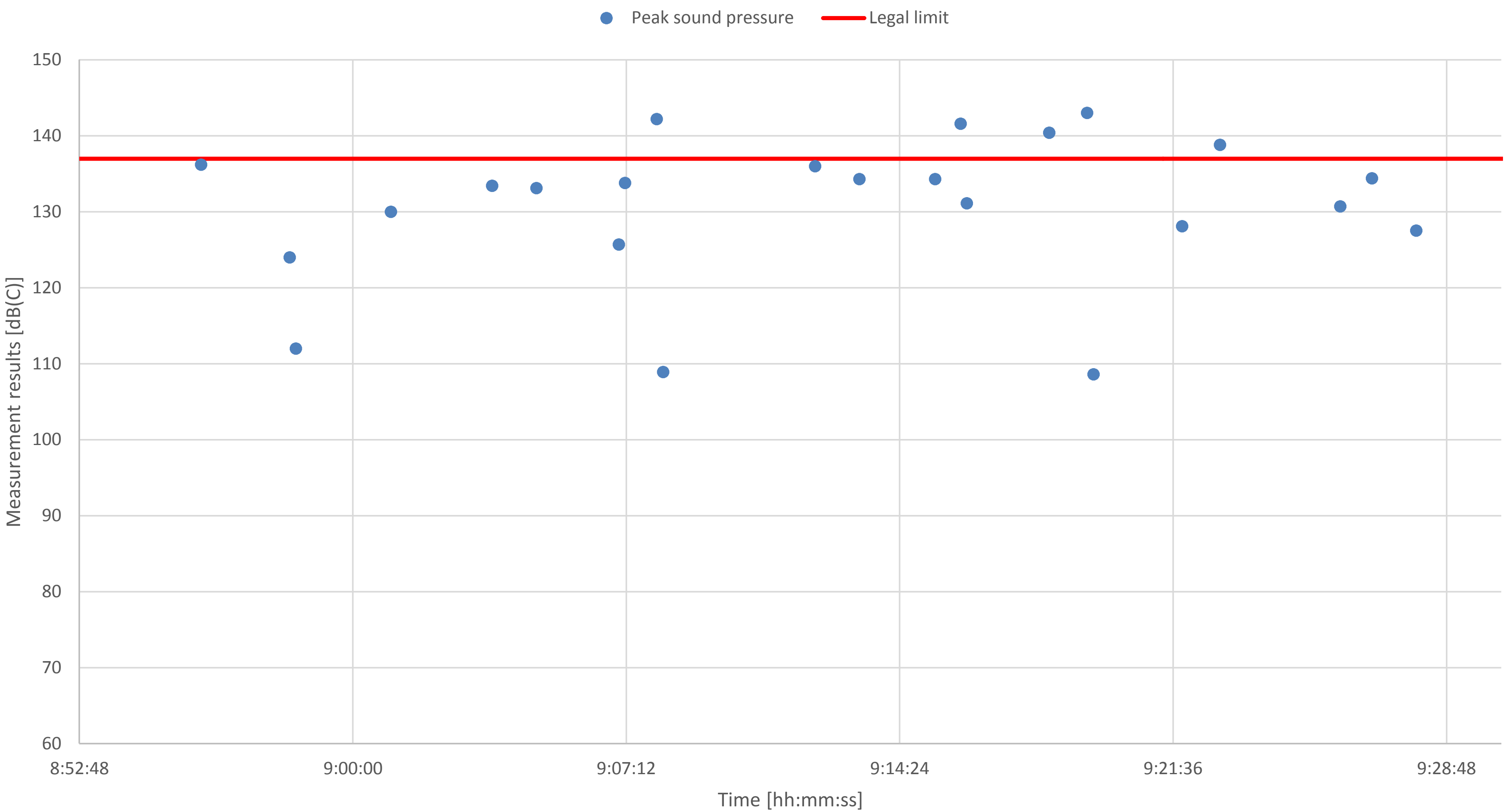

Figure 2: peak sound pressure, front left stack, CEL460-3

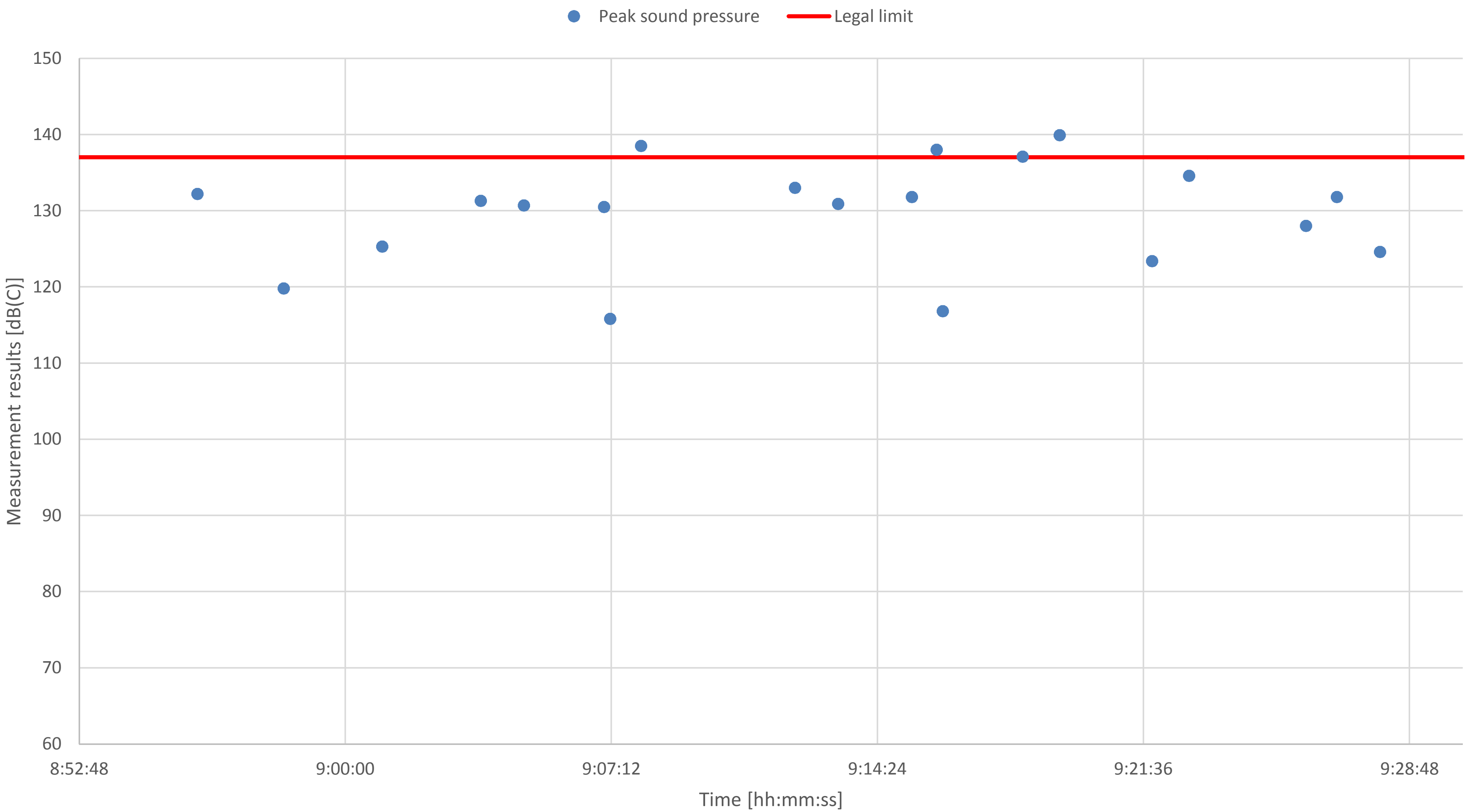

Figure 3: peak sound pressure, mid-left stack, CEL460-1

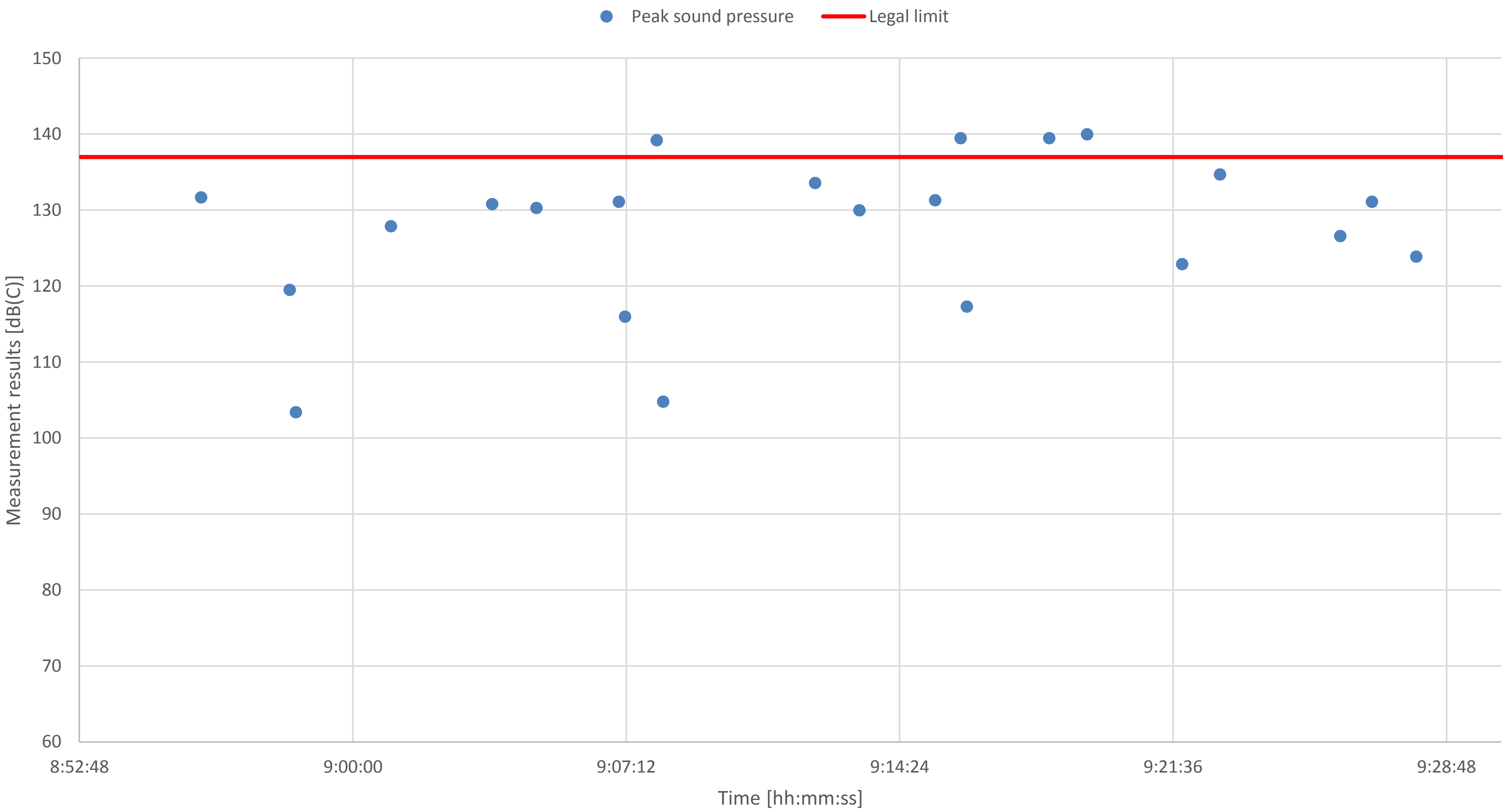

Figure 4: peak sound pressure, rear right stack, CEL460-2

1 Shocks and blows

An evaluation of the effects of shocks and blows caused by the explosions was performed to obtain qualitative information on the possible health effects for persons located inside the bunker.

Please note: The described method is not within the laboratory's scope of accreditation.

1.1 Method

A pressure wave resulting from the explosion of an explosive charge propagates through the environment as single pulses that may cause a mechanical shift when transferring from the ground into the bunker, which can be felt as single shocks or blows. If the shock or blow is strong enough, it may cause damage to the health. To carry out this evaluation, the "ShockWatch Label" shock-sensitive stickers from the ShockWatch Corporation were used. The sensitivity of these devices to acceleration and its duration is similar to that of the human body.

Figure 5: ShockWatch Label with a burst ampoule

The stickers contain calibrated ampoules that would break under a shock or blow with a predetermined strength and duration, painting the ampoule red (see Figure 5). To qualitatively evaluate the strength of shocks and blows felt by the users of the bunker, several stickers with a different sensitivity setting were used:

Table 5: The colour and calibrated sensitivity of the ShockWatch Label stickers

Colour of the sticker	Calibrated sensitivity	Proportional health effect[4]
Grey	15 G[5]	5% probability of damage
Yellow	25 G	Danger of serious health damage
Red	50 G	High probability of health damage
Orange	75 G	
Green	100 G	Car crash

Stickers were placed on the walls of the bunker and the bunks of the middle stack, presuming that the amplitude of any pressure wave is the highest at the middle of any cylindrical body. The layout

[4] Kazarian LE, et al, ìThe Dynamic Biomechanical Nature of Spinal Fractures and Articular Facet Derangementî, Aerospace Medical Research Division, AMRL-TR-71-17, August 1971
[5] G – shock or blow (vibration) acceleration. 1 G is equal to gravity acceleration. Please also see http://www.hse.gov.uk/research/hsl_pdf/2003/hsl03-09.pdf for more information

of the stickers has been provided on Figure 6. In case any of the stickers are activated during the course of the test, but a sticker with a higher nominal value remains intact, it can be concluded that the effective shock remains between these two values.

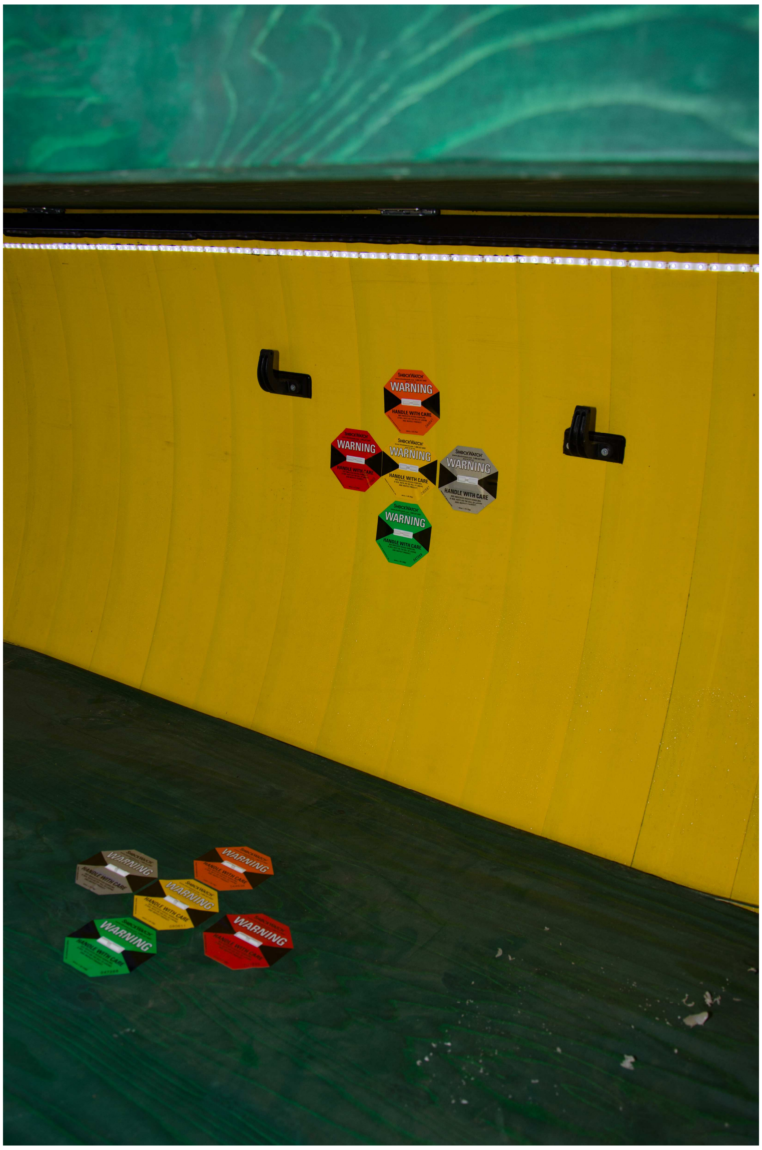

Figure 6: The layout of the ShockWatch stickers on the walls and bunks of the bunker.

1.2 Results

After the end of the exercise, the condition of the stickers was inspected, and it was determined that none of them were broken. Thus, it can be concluded that the shocks and blows inside the bunker in case of long-range fire from 81 mm mortars remained within limits that are safe for the health.