Investigation of design criteria for self-propelled mortar regarding sound pressure levels

SIMON HALLIN

KTH Industrial Engineering and Management

Master of Science Thesis
Stockholm, Sweden 2013

Investigation of design criteria for self-propelled mortar regarding sound pressure levels

Simon Hallin

Master of Science Thesis MMK 2013:25 MKN 088
KTH Industrial Engineering and Management
Machine Design
SE-100 44 STOCKHOLM

KTH Industriell teknik och management	**Examensarbete MMK 2013:25 MKN 088** **Utredning av designkriterier för fordonsmonterad granatkastare med avseende på ljudtrycksnivå** Simon Hallin	
Godkänt 2013-06-05	Examinator Ulf Sellgren	Handledare Ulf Sellgren
	Uppdragsgivare Försvarets Materielverk (FMV)	Kontaktperson Joakim Lewin

Sammanfattning

Behovet av en mer mobil granatkastare har resulterat i en utredning av möjliga koncept som sedan ska gallras bort och resultera i en investering i ett nytt fordonsmonterat granatkastarsystem.
Denna rapport beskriver utredningen av en potentiell risk med ett av de potentiella koncepten. Konceptet består av att placera en granatkastare i personalutrymmet i en stridsfordon90-vagn och avfyra den med öppna takluckor. Detta koncept har använts av andra länder och deras arméer, bland dem finns USA som använder sig av fordonsplattformen Stryker.
Säkerheten för soldaterna i Försvarsmakten är högt prioriterat och strängt reglerat av standarder och reglementen som ständigt revideras.
Den största potentiella risken med det aktuella konceptet har identifierats att vara ljudtrycksnivån som soldaterna utsätts för vid avfyrning. Om en undersökning av ljudtrycksnivåerna skulle visa att konceptet inte är säkert så finns därmed inget behov att vidare utreda konceptet och det skulle därmed bli uteslutet.
För att fastställa vilka nivåer som kan förväntas av denna lösning så planerades och genomfördes en testskjutning med hjälp av FMV Test och Evaluering i Karlsborg samt representanter från BAE Systems Hägglunds.
Provskjutningen genomfördes genom att placera den svenska 120mm granatkastaren M/41 i ett testchassi, som i stora drag motsvarar Strf90 chassiet, och sedan skjuta granater i flera olika testscenarion för att undersöka parametrarna elevation, laddning, riktning, användning av tratt, vinkel på takluckor öppen/stängd bakre lucka samt upphöjt chassi.
Provet visade att dubbla hörselskydd kommer att behövas inne i fordonet och att potentiellt kommer personal längst in i fordonet att klara sig med enkla hörselskydd. Högst troligt är att det slutgiltiga konceptet kommer att ha en begränsning på 30-50 avfyrningar per dag med högsta laddning, 40-50 med laddning 7 och 70-80 med laddning 5.
Användning av en tratt visade sig effektivt och minskade ljudtrycksnivån med 5-10 dB och därmed ökar antalet tillåtna avfyrningar till över 100 skott per dag för högsta laddningen.

Nyckelord: granatkastare, ljudtrycksmätning, hörselskydd,

KTH Industrial Engineering and Management	**Master of Science Thesis MMK 2013:25 MKN 088** **Investigation of design criteria for self-propelled mortar regarding sound pressure levels** Simon Hallin	
Approved 2013-06-05	Examiner Ulf Sellgren	Supervisor Ulf Sellgren
	Commissioner Swedish Defence Materiel Administration (FMV)	Contact person Joakim Lewin

Abstract

The need of a more mobile mortar has led to an investigation of possible concepts which will be narrowed down and end in a purchase of a self-propelled mortar system. This report describes the exploration of a possible risk with one of these concepts. The concept is to place a mortar in the back storage area of a CV90 where it will be fired with open hatches. This concept has been used by other countries armies, amongst them the US Army which uses the Stryker vehicle platform.

The safety of the personnel in the Swedish Army is prioritized and strictly regulated by set standards and regulations which are frequently revised. The largest potential risk with the concept in question has been identified to be the sound pressure acting on the personnel. If the concept would indicate levels over the permissible levels it would not have any potential and would not be further investigated.

To conclude which levels a concept like this would have, a test shooting was planned and conducted with the help from FMV Test and Evaluation centre in Karlsborg and representatives from BAE Systems Hägglunds

The shooting was conducted by placing the Swedish 120 mm mortar GRK M/41 inside a CV90 chassis mock-up and firing grenades in several scenarios which would test the different parameters; elevation, charge, direction, BAD, angle of roof hatches, open/closed rear door and elevated chassis.

The test showed that double ear protectors will be needed in the vehicle and with the potential that it will suffice with single ear protectors for personnel furthest in the vehicle. It is most likely that it will be restrictions on number of permissible rounds fired per day of 30-50 firings for charge 9, 40-50 with charge 7 and 70-80 with charge 5.

The use of BAD resulted in the sound level decreasing between 5-12 dB which would increase the restrictions to a maximum of 100 rounds per day for maximum charge.

Keywords: Mortar, sound pressure measurements, ear protectors

PREFACE

This master thesis is the culmination of the author’s studies at KTH in Stockholm. First of all I would like to thank my friends and family for their support during the five years at KTH.

I would like to thank Joakim Lewin (FMV Head of Indirect Fire Systems Office) for giving me this opportunity of performing this master thesis at FMV. I would also like to thank Lars Taraldsson (Project leader) for mentoring me and guiding me in the FMV organization and help making this project possible.

A great thank goes out to the personnel at FMV Test and Evaluation Centre Karlsborg, especially Dan Englund and Odd Sundqvist for their support, cooperation, understanding and quick response on every request and question I had. Their hard work made the test a success.

A special thanks to Försvarets Verkstäder (FSV) for their rigorous work making the test chassis as requested despite great problem with the mine protection. Despite being delayed they delivered a test rig that was beyond expectations.

Lastly I would like to thank my supervisor and examiner Ulf Sellgren at KTH for his support, input and guidance during this whole project

Simon Hallin
Stockholm 2013

Abbreviations

Abbreviation	Description
AMOS	Advanced MOrtar System
IED	Improvised Explosive Device
BAD	Blast Attenuation Device
ANOVA	ANalysis Of VAriances
CV90	Combat Vehicle 90
FMV	eng. Swedish Defence Materiel Administration, sv. Försvarets materielverk
FM	eng. Swedish Armed Forces, sv. Försvarsmakten
GRK	eng. Mortar sv. Granatkastare
T&E	FMV Test and Evaluation
TBI	Traumatic Brain Injury
ANR	Active Noise Reduction
MSS	eng. Land warfare centre, sv. Markstridsskolan
CAS	Close air support
CWVP	Chest Wall Velocity Predictor
PMD	Pressure Measurement Device
SNR	Single number rating

Denotations

Symbol	Description
$L_{EX,8h}$	A-weighted energy equivalent for a 8 hour exposure
$L_{pC,Peak}$	C-weighted peak level
H	High frequency range attenuation level
M	Middle frequency range attenuation level
L	Low frequency range attenuation level
SNR	Ear protectors attenuation rating defined in ISO 4869-2
L'_{Ax}	Attenuation level
$L_{pC,1sEq}$	C-weighted sound pressure equivalent for a 1 second sequence
L'_{pC}	Predicted sound pressure level under ear protectors
d_m	Ear protectors predicted attenuation for set impulse noise type

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background

The Swedish Defence Material Administration (FMV) has been assigned the task to develop the 120 mm mortar system. An investigation made by the Land Warfare Centre (Markstridsskolan, MSS) in the fall of 2011 [1] concluded that the mechanised infantry battalions needed an upgraded mortar system. The system needs to be faster to deploy, have better mobility, higher protection grade and be quicker to respond and regroup. A system called AMOS (Advanced Mortar System) was developed but it was decided not to invest in this system for several reasons.

Figure 1. CV9040 during training facing UNMIL mission (Mathias Hallin)

The mechanised infantry stands for the majority of the land units and they use the Combat Vehicle 90-system (CV90, see Figure 1). The CV90 has a very high level of mobility and protection grade and their battle technique is fast and aggressive advancements with the soldiers inside the vehicles. The mechanised infantry gets supported from a battalion-artillery which at the present exists of towed 120 mm mortars.

The old 120 mortar system (120 mm Grk m/41) is placed on a trailer (see Figure 2) and towed by a vehicle. The deployment of the mortar takes time and effort from at least 4 soldiers, and the mobility is limited. The mortar provides firepower on a range of up to 7 km and supports the advancements of the infantry by suppressing and destroying the enemies. It is therefore important that the mortars can keep up with the mechanised infantry.

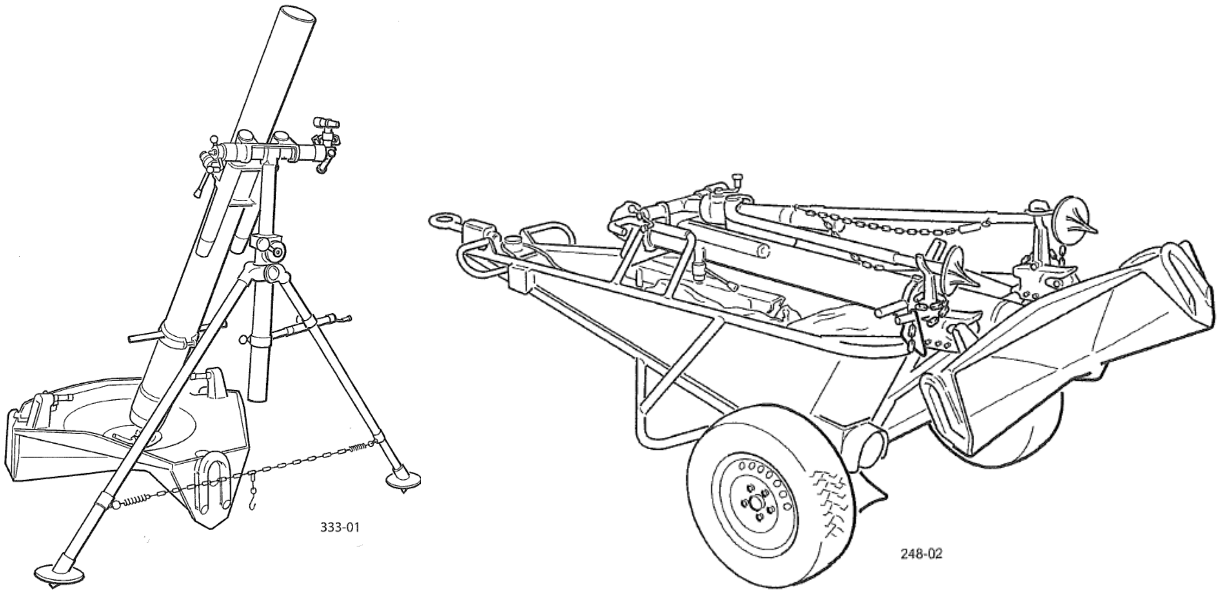

Figure 2. GRK m/41, deployed to the left, ready for transportation to the right [2]

The recommendations that followed from the investigation [1] were that a vehicle mounted mortar was required and the preferred carrier was the CV90 vehicles. A vehicle-mounted mortar would be faster to fire the first rounds and have better protection for the personnel. The use of the CV90 would provide mobility and protection that is equal to the mechanised infantry. It is also preferred to use CV90 since the system is well established in the Swedish Armed Forces and the mechanised battalion's unit vehicle and also the required logistics (spare parts, manuals, etc.) already exists.
A vehicle mounted mortar on the CV90 can be implemented in several ways and the relevant alternatives are presented in Figure 3. The investigation suggested that FMV should further investigate the hood mounted and the floor mounted/open hatch alternatives.

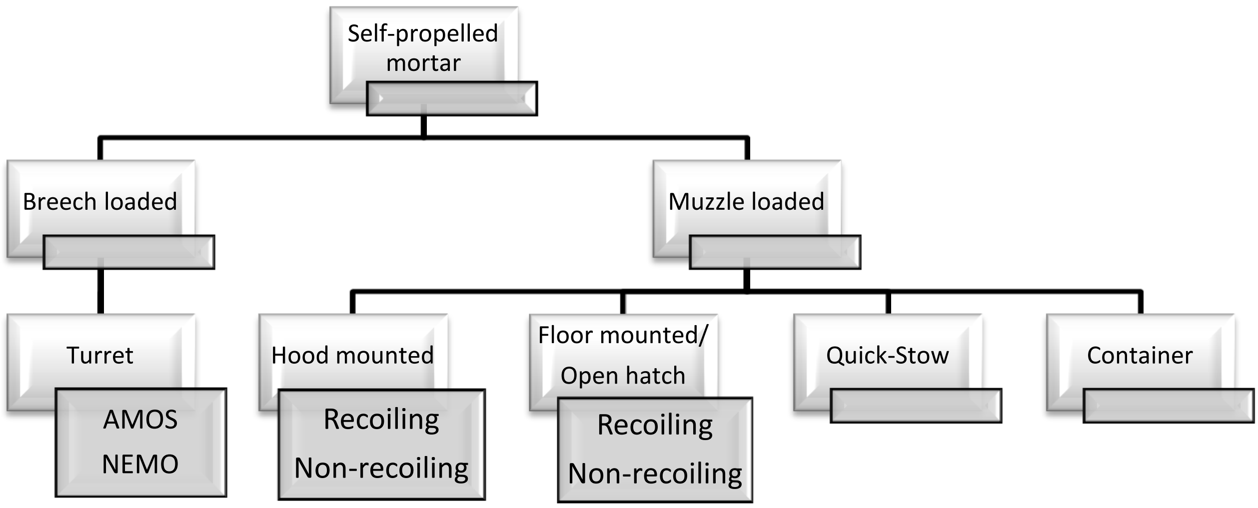

Figure 3. Alternatives for a self-propelled mortar system

Booth of the system concepts has advantages and disadvantages and a more thorough investigation in collaboration with the industry (BAE Systems) follows. The project will also further investigate other potential concepts.

1.1.1 Hood mounted muzzle-loaded (CV90 MTA)

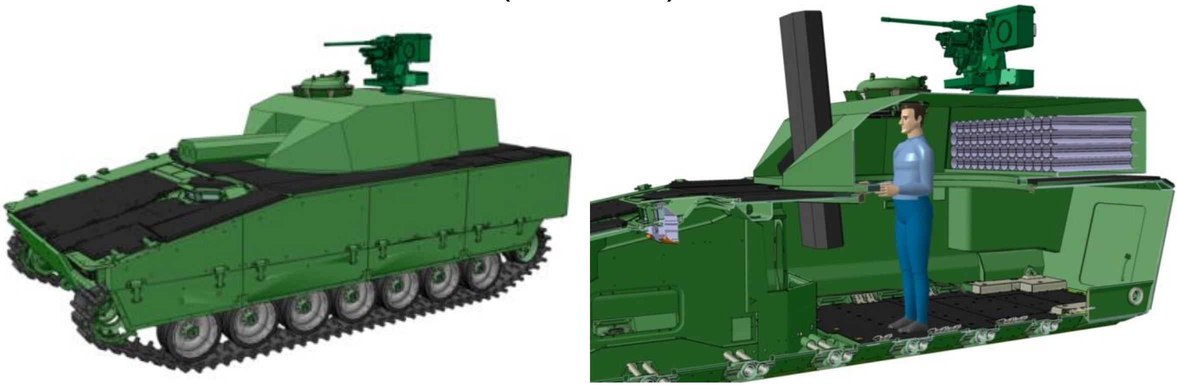

Figure 4. Muzzle loaded, hood mounted concept (BAE Systems Hägglunds)

The first concept discussed reminds a lot of a standard CV9040 but it does not have a tower, instead it has a hood. The difference is that a tower has a basket inside the vehicle where the personnel is in and it swivels with the tower, the hood does not have this basket and only the hood rotates, the personnel moves by their own. In the hood the rear part can store grenades in what is called a backpack. This gives the opportunity to bring more grenades or use the wagon space for storing other equipment or transport personnel. An advantage of the hood is also that it provides more protection for the personnel. The mortar is still front loaded and the grenades are loaded from within the hood manually via linkage. The idea is to have two barrels which increases the efficiency of the weapon system requiring fewer units to complete the task with the downfall of losing more effect if a unit gets taken out.
There is however a risk with this concept and it is that is not in use yet. The development of this concept can be problematic and costs more than expected and also take longer time to get fully operational.

1.1.2 Floor mounted/open hatch (CV90 MEP)

The floor mounted mortar solution appears to be the easiest solution at a first look but it involves several problematic issues that need to be resolved. The idea is to use the rear space, normally used for personnel, and mount a mortar on the floor and with open hatches, raise the mortar barrel to be ready for use (see Figure 5). When it is time to regroup the barrel will be lowered and the hatches will close, giving the crew the full protection of the CV90 under transportation.

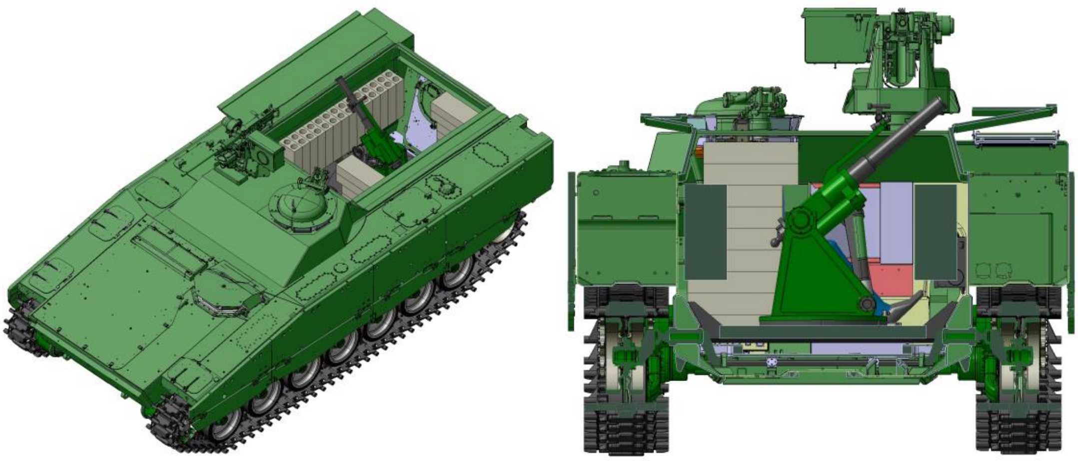

Figure 5. Muzzle loaded, floor mounted/open hatch (BAE Systems Hägglunds)

This solution requires investigations of the force from the recoil and the space required to manoeuvre the mortar. This sort of solution already exists in the US Army in the M1129 Mortar Carrier where a Elbit Cardom mortar is placed in a Stryker vehicle (see Figure 6), and also in the M1064 Mortar Carrier which is based on a M113 chassis.

Figure 6. M1129 Mortar Carrier (Military-Today.com)

1.1.3 Risks

Within the military there are always risks and FMV strives to minimize the risks and hazards. To do this FMV follows set regulations and standards to ensure a safe work environment. The regulations and standards itself are frequently revised to ensure that they take in account the most updated research in each given area. The equipment goes through thorough testing before they get clearance for usage.
As can be seen in Figure 7, a vehicle mounted mortar means several potential risks, the most important ones are sound pressure level, toxic gases, high temperatures and the limited space.

Figure 7. Visualization of potential risks (Military-Today.com)

The regulations regarding sound pressure exposure has been topical the last years since a lot of research has investigated damages soldiers got during missions in Afghanistan and where they had been exposed to IED (Improvised Explosive Device) and afterwards been diagnosed with traumatic brain injury(TBI). A lot of research has exposed pigs of blast waves and examined the damage [3].

1.2 Purpose and objective

A key issue when choosing a concept is personnel safety. The sound pressure level acting on the soldiers is one of the greatest risks when mounting a mortar inside a vehicle. The purpose of this study is to investigate the sound pressure levels inside the vehicle for the CV90 MEP concept for different firing scenarios. The objective is to conclude if this is a potential solution, if further investigations are needed or if the solution requires too much effort to make feasible.

1.3 Delimitations

The test methods, data-analyses and recommendations will be regulated by the standards set by the Swedish Armed forces and the Swedish Defence Materiel Administration. However discussions will be made regarding other aspects.

The tests will be conducted on a CV90 mock-up (Figure 8) and not on a real vehicle with its interior. This means that the result from the tests is not fully representative for a final vehicle solution but gives directions whether to continue developing the concept or not.

1.4 Methods

During the project test-shootings will be conducted. The tests will include measurements over the full aiming area as well as test several actions that may or may not minimize the sound pressure levels. The tests will be conducted in a test rig that represents the interior space of the CV90 (Figure 8). The measurements will be conducted in collaboration with FMV Testing and Evaluation (FMV T&E) Test Centre Karlsborg and in accordance to FM’s current regulations for sound pressure measurements with some deviations since it is just a pre-study. During the test-shooting representatives from FM and BAE Systems will attend, inspect and contribute with expertize.

Figure 8. CV90 Mock-up

2.1 Mortars

Mortars have been renowned since the 15th century [4] and were originally a siege weapon and were heavy and difficult to transport but effective during sieges of castles and keeps. It was also used as defence weapon for protection of harbours. The more modern and mobile mortar was first used during World War 1 and was effective during trench wars where the mortar allowed to be fired from the protection of the trench and land in the enemies trench which could not be done using i.e. artillery. The mortars advantage against artillery was also that it was lighter and more mobile. The mortar design that is most commonly used is based on the Stokes mortar designed by Sir Wilfred Stokes in January of 1915. Its simplicity made it easy to handle and very robust. It basically consisted of three parts; a smooth bore barrel attached to a baseplate and a bi-pod [5]. The grenade was dropped in the barrel and slides down to the bottom where the impact against a firing pin ignites the propelling charge thus ejecting the grenade.
Distinctive for mortars is that they usually fire with an elevation over 45° and a low projectile velocity (<340m/s) which gives them high-arcing projectile trajectories (see Figure 9).

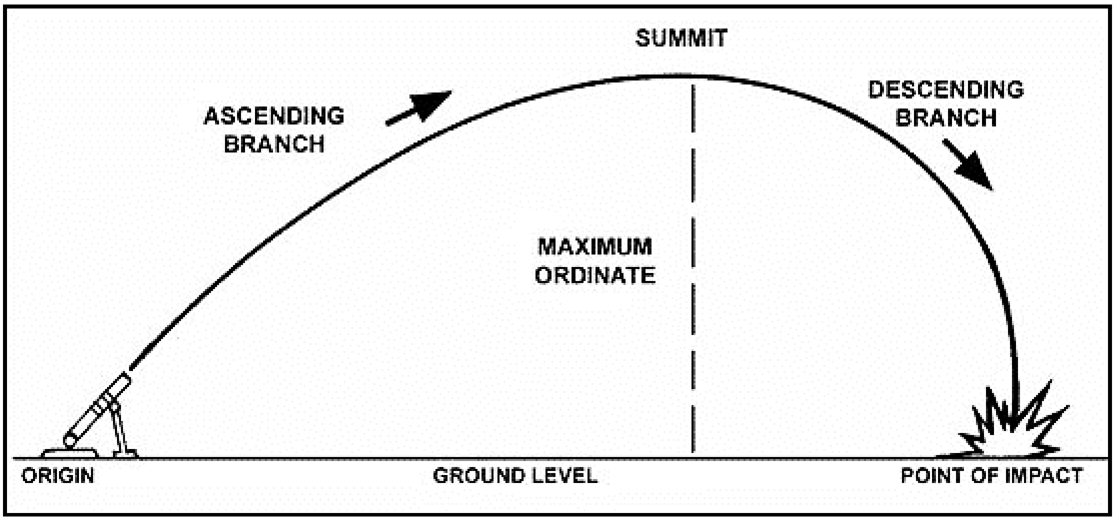

Figure 9. Trajectory of mortar rounds [6]

To change the trajectory and the range, the elevation is altered but it is also changed by altering the charge of the grenade. Altering the charge is done by removing or adding charge rings which are placed on the lower part of the grenade (see Figure 10).

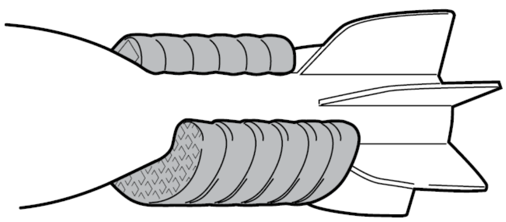

Figure 10. Charge rings on 80RÖKVINGGR 10 [7]

2.1.1 GRK m/41

The Swedish 120 mm mortar system (see Figure 11) is called 120 mm Grk m/41 and is a muzzle loaded mortar. It was manufactured by the Finnish company Tampella and a total of 219 mortars has been delivered to FM. It is transported on a trailer and the setup consists of the barrel, a bipod and a baseplate just as the Stokes mortar. For a weapon-system it is mechanically very simple and robust.

Figure 11. 120 mm GRK m/41 in Armemuseum, Stockholm

The current regulations of ear protectors for 120mm Grk m/41 are illustrated in Figure 12. Closest to the mortar and up to 25m from the mortar it is mandatory with double ear protectors and between 25m to 100m is it sufficient with single ear protectors.

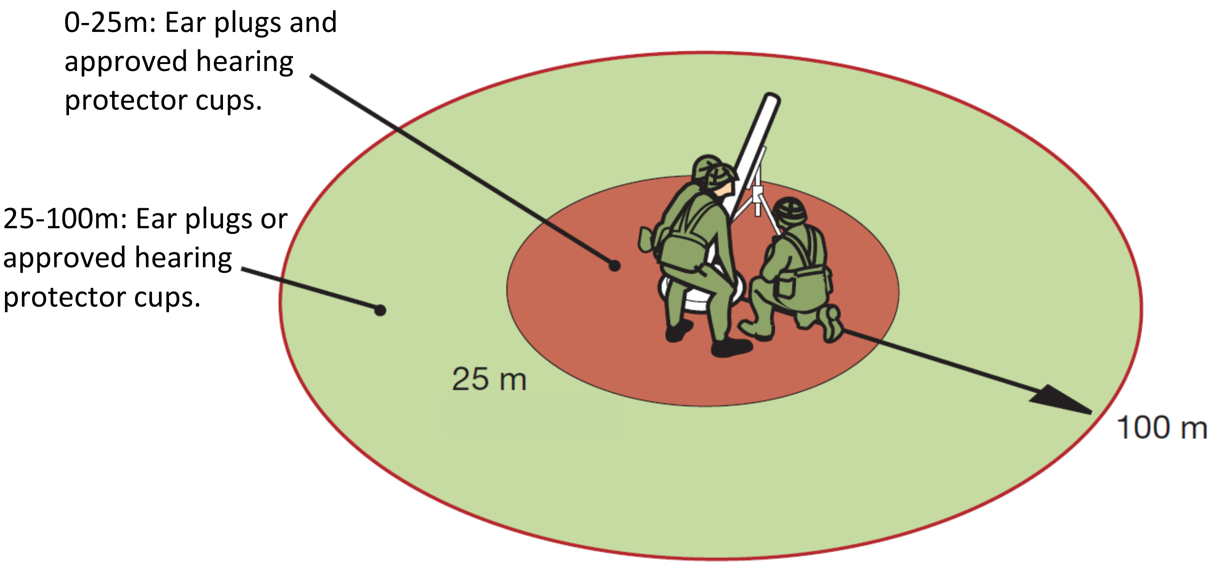

Figure 12. Regulations regarding ear protection for GRK m/41 [8]

Previous tests of the sound pressure levels when firing m/41 showed the results displayed in Table 1.

Table 1 Open field measurement on grk m/41 [9]

	MP1 Mean/Max [dB(C)]	MP2 Mean/Max [dB(C)]	MP3 Mean/Max [dB(C)]	MP4 Mean/Max [dB(C)]
$L_{p,C1s}$	146.4/147.3	143.4/143.9	145.2/145.8	144.5/144.9
$L_{pC,Peak}$	179.5/ 181.0	176.4/ 176.9	177.8/ 178.3	176.9/ 177.5

2.2 Ear protections

There are several methods for describing sound attenuation levels for ear protection systems and those interesting for this project is the HML-method and the SNR method, both of them are briefly described below and followed by a table (Table 2) presenting the attenuation values for those ear protectors currently used by the Swedish Armed forces. The methods are described fully in ISO 4869-2 [10].

2.2.1 HML

The H- M- and L-values are calculated using eight different reference noises and the values are then calculated from the attenuation for different octave bands. The three values are for High-, Middle- and Low-frequencies.

2.2.2 Single number rating (SNR)

For the calculating SNR-value the ear protector is exposed to a pink noise spectrum and then the SNR-value are calculated from the sound level reduction for the different octave bands.

Table 2. Sound attenuation for ear protectors currently used by the Swedish Armed Forces

	H	M	L	SNR
ComTac XP + Earplug Classic	36	38	36	39
ComTac	32	24	17	27
ComTac XP	31	25	16	28
Earplug Classic	30	24	22	28
Telehelmet 9A with Active Noise Reduction	25	27	30	N/A
Telehelmet 9A without Active Noise Reduction	25	23	30	N/A

2.3 Regulation for measurements

The regulation used to regulate the measurement of impulse sounds used by FM and FMV is the *HKV 14990:7816 Försvarsmaktens regler för mätning av impulsljud från vapen och sprängning i fritt fält, i fordon och i bebyggelse* [11] and is based on the standards *AFS 2005:16* [12], *ISO 4869-2* [10] and *SS-ISO 10843* [13]. The standard describes the measurement procedure and how it is supposed to be reported. It states where probes are to be placed and the allowed error of the measurements.

The regulation stipulates that a minimum of three firings should be conducted for every case and if the C-weighted peak pressure level ($L_{pC,Peak}$) for the three measurements vary more than 3 dB, more firings shall be performed until the variation in dB is less than the number of firings.

The microphones are to be placed as displayed in Figure 13 with the addition of probes at ear height in the crew’s positions inside the vehicle.

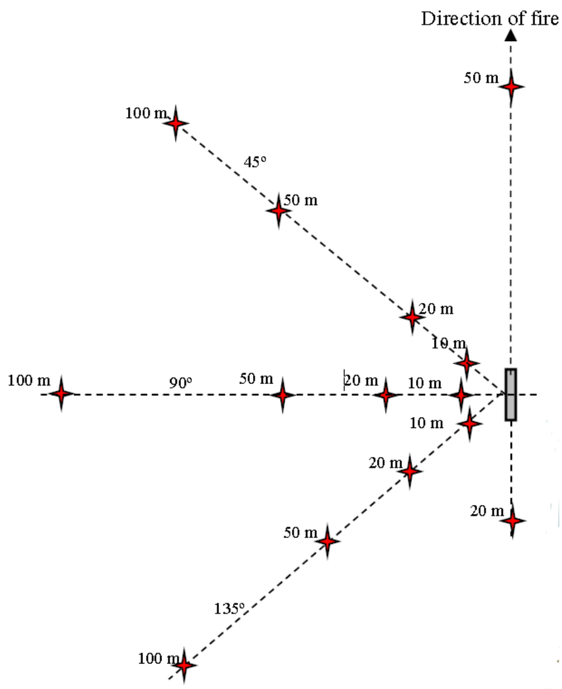

Figure 13. Regulated placement of microphones

The outcome of the test should be presented in a report where the data shall be presented as;

- A-weighted energy equivalent for a 8 hour exposure ($L_{EX,8h}$)
- C-weighted peak pressure level ($L_{pC,Peak}$) regulated by SS-ISO 10843
- C-weighted energy equivalent for a sequence lasting 1 second ($L_{pC,1sEq}$) regardless of measuring time
- Calculated permissible number of firings if required (see 2.4)
- Additional data depending on the sort of measurement performed

In the report it is also required to present the complete test setup with measurement instruments, a weather report, a presentation of test location, involved persons, description of test object and regulatory document.

2.4 Regulation for hearing protectors

The regulations for use of ear protectors are set by the *HKV 14990:59497 Försvarsmaktens regler för hörselskydd mot impulsljud vid skjutning med vapen och sprängning* [14] and it states how to choose ear protectors, permissible number of firings per day and maximum exposure levels. The requirements are:

- If the impulse peak value ($L_{pC,Peak}$) is below or equal to 140 dB(C) then no ear protectors are required.
- If the impulse peak value ($L_{pC,Peak}$) is below or equal to 165 dB(C) single ear protectors are required.
- If the impulse peak value ($L_{pC,Peak}$) is over 165 dB(C) double ear protectors are required.
- The impulse peak value under double ear protectors (L'_{pC}) must not exceed 160 dB(C).
- If the impulse peak value under the ear protectors (L'_{pC}) exceeds 140 dB(C), the number of firings per day will be limited (see 2.4.1 Permissible number of firings per day).

The impulse peak value under the ear protectors (L'_{pC}) are calculated in accordance to

$$L'_{pC} = L_{pC,Peak} - d_m \tag{1}$$

Where d_m is chosen from the ear protectors HML-values depending of the impulse noise type as shown in Table 3.

Table 3. Modified sound attenuation value [15]

Impulse noise type	d_m[dB]
1: Lower frequency range exposure (punch press, jolt squeeze, explosives**)**	L-5
2: Medium-high frequency range exposure (nail gun, hammer, rifle)	M-5
3: High frequency range (pistol)	H

The workflow of the evaluation of testdata and determining required ear protectors are shown as a flow chart in Figure 14 below.

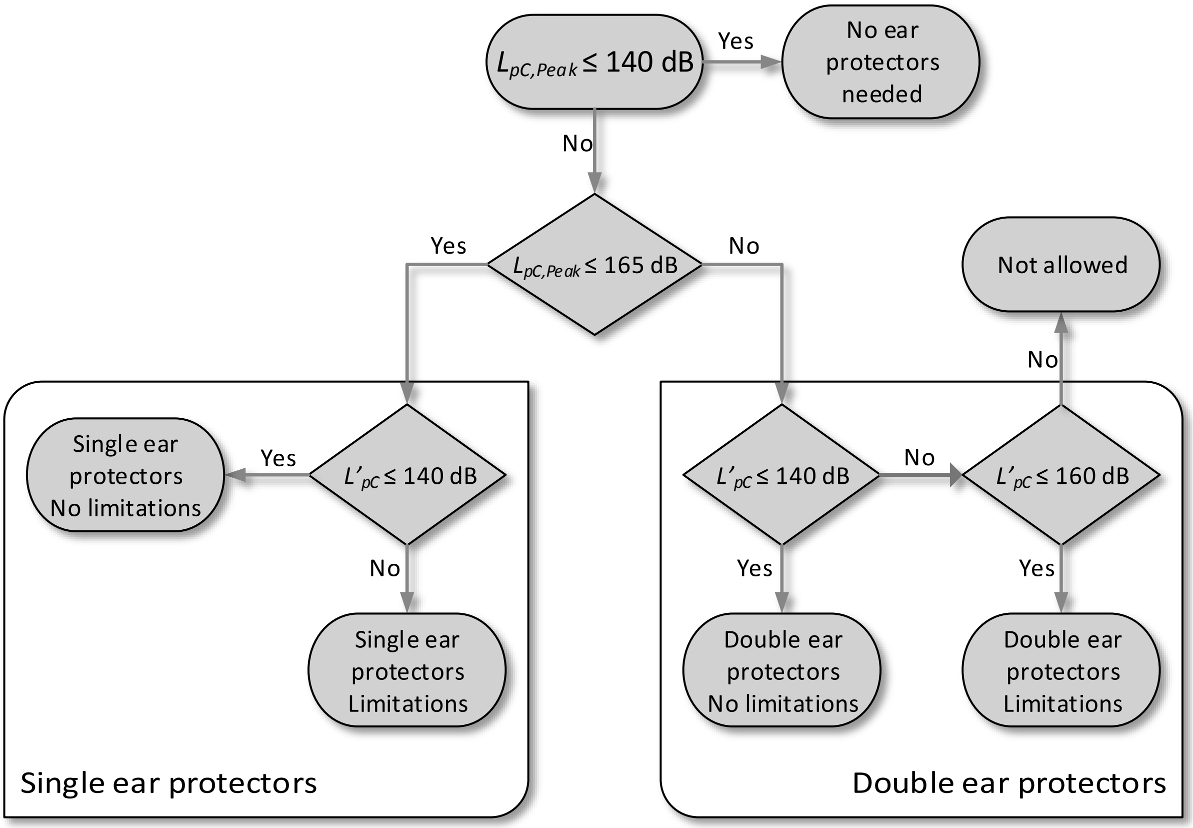

Figure 14 Workflow for evaluating sound pressure and choosing ear protectors

2.4.1 Permissible number of firings per day

To calculate the number of permissible firings per day when needed, the equation (2) is used and the condition is that $L_{ex,8h}$ must not exceed 85 dB(A).

$$L_{ex,8h} = L'_{Ax} - 45 + 10lgN \tag{2}$$

where

$$L'_{Ax} = L_{pC,1sEq} - SNR \tag{3}$$

This gives that the maximum number of firings are

$$N = 10^{\left(\frac{85 - L_{pC,1sEq} + SNR + 45}{10}\right)} \tag{4}$$

3.1 Testing

To reach the goal of the project, a test shooting is conducted. Instead of using a real CV90, a mock-up chassis was used. The mock-up was built from a chassis used to test mine protection and now had served its cause (see Figure 8). The chassis was altered in accordance to drawings supplied by BAE Systems Hägglunds which is the manufacturer of the CV90-system.

Figure 15. CV90 Mock-up

The alterations made included making a hole in the roof and attaching roof hatches, adding a rear door, making the chassis dividable and removing the floor so the mortar would stand directly on the ground. The removing of the floor was problematic due to the mine protection and the solution demanded removing part of the walls and rebuilding it with new sheet metal. The alterations are displayed in Figure 16. The alterations where all made by Försvarets verkstäder (FSV) in Karlsborg.

Figure 16. Mock-up after alterations

The reason why the chassis was made dividable was for safety reason. If a grenade would fail to launch the chassis would be removed without the mortar being affected and making it easier to perform actions for failing grenades. The measurements of the chassis are displayed in Figure 17 and Figure 18.

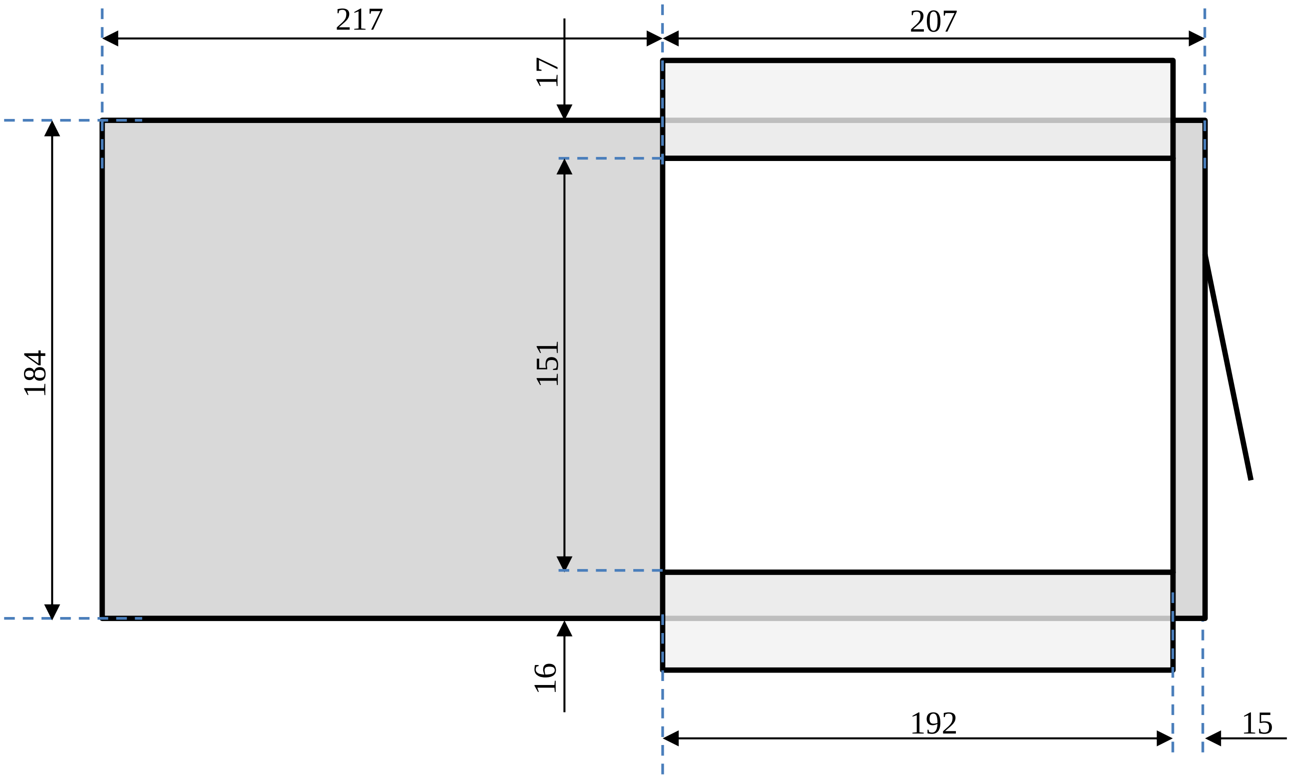

Figure 17. Top-view measurements in centimeters (not to scale) [16]

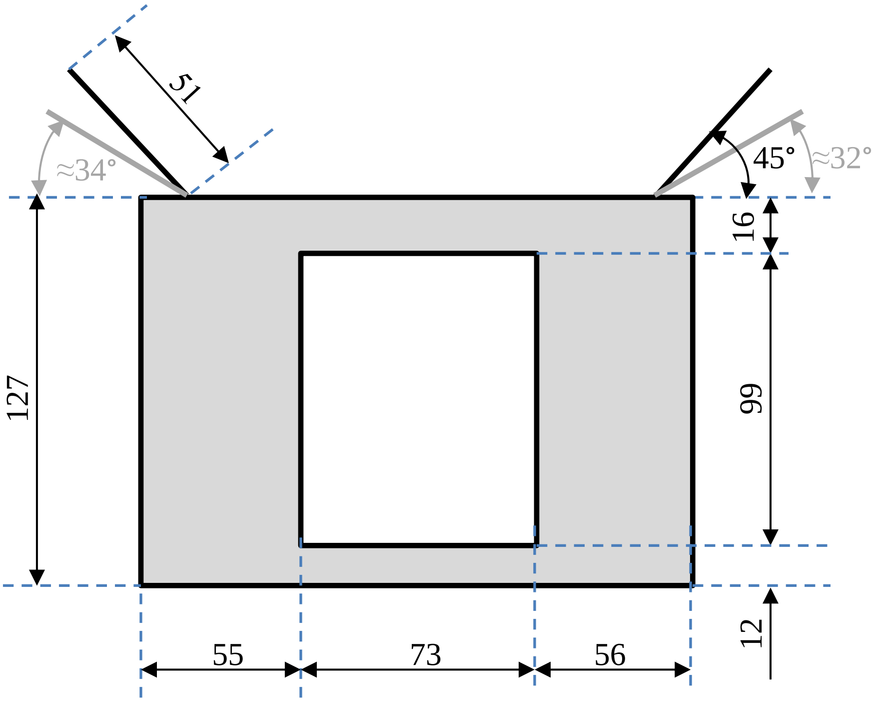

Figure 18. Rear-view measurements in centimeters (not to scale) [16]

3.2 Parameters to investigate

3.2.1 Elevation

The test of different elevations is of the utmost importance since it is used to determine the range of the grenade and limitations of the elevation would also limit the range of the grenades in a way that render this solution useless. The elevation should be 45° to 85° to be effective. And the chosen levels for this parameter will be three levels of 45°, 75° and 85°. The use of 75° elevation is due to previous tests which have been done in open field and thereby adding the possibility to compare with those.

3.2.2 Charge

To use different charge to the grenade affects the range along with the elevation. The most probable effect from this parameter is that the highest charge will give highest sound pressure and it can therefore be argued if investigating this parameter is necessary. However there might be some effects that occur for lower charges that won't occur for the maximum charge. The chosen levels for this parameter is the three levels; charge 9 (the maximum charge), charge 7 and charge 5.

3.2.3 Direction

When looking at other vehicles with this solution there has been solutions both with the barrel directed to the rear (i.e. M1129) and directed forwards (i.e. BMP 1). It is of interest which solutions are possible in the CV90 case or if it might be possible with a 360° aiming field. It is therefore a parameter to be investigated and the three levels of this parameter are; Forwards (0°), Backwards (180°) and Side (90°).

3.2.4 Rear door

It is of interest to investigate if the rear door (see Figure 19) needs to be open during firing or if it can be left closed. A closed hatch provides more protection for the personnel but for the case with the US army they leave it open. One of the reason is that they supply the mortar with grenades from the outside instead of using the grenades from the vehicle; this is when it is used in situations when time to deploy is not crucial. The obvious levels for this parameter is "Open" and "Closed".

Figure 19. Rear door

3.2.5 Roof hatches

When looking at other solutions (i.e M1129), their roof hatches when open is at a 45° angle. It has not been investigated if this is an optimum solution with regards to the sound pressure. This parameter will be tested for the normal 45° angle (Figure 20, left picture) as well as for the 30° angle (Figure 20, right picture).

Figure 20. Different angle of the roof hatches (left: 45°, right: 30°)

3.2.6 Elevation of the chassis

If the chassis is elevated while the mortar is still on the ground level, the height of the muzzle over the roof can be investigated to see how this affects the sound pressure levels inside the vehicle. The chassis is elevated with wooden blocks (see Figure 21) and heightened with about 40 cm.

Figure 21. Elevation of the chassis with wooden blocks

3.2.7 Blast Attenuator Device (BAD)

One of the most interesting parameters in this test is the BAD (see Figure 22, middle picture) which is a funnel made to decrease the sound pressure levels by directing the sound pressure away from the personnel. This product comes from the company Elbit Systems and is designed for their 120mm mortar called Cardom. The Cardom-system as well as the BAD is widely used and one of the largest customers is the US army and is the system used in the M1064 Mortar

Carrier. Previous tests of the BAD has shown large reduction of the sound pressure levels and is therefore of great interest for this system and the result from this test might also lead to investigations if the BAD might be implemented to the existing Swedish mortar system. The levels of this parameter are the two levels “With BAD” and “Without BAD”.

Figure 22. Left: Alteration of the barrel to fit the BAD. Middle: BAD. Right: BAD-mounted on the barrel

The BAD is not designed for the Swedish mortar 120mm Grk m/41 which required alterations to be made on the barrel in form of turning on the muzzle (see Figure 22, left picture).

3.3 Test plan

The ideal test would be to perform a full factorial design test which would give the possibility to analyse all sorts of interaction effects of the parameters but this would also result in an unreasonable amount of tests (432 scenarios with a minimum of 3 tests/scenario results in 1290 grenades) and it is unlikely that there are any interaction over three degrees that are of interest. Therefore the test plan was designed as such as interaction effect could be calculated for some of the parameters whilst other parameters just can be evaluated for their main effect. The reasoning behind this is that some of the parameters are of more importance for the functioning of the system whilst other parameters are investigated as potential measures for increasing the number of permissible firings. One might say that there are two parts in the test, one for basic functioning of the mortar and one for testing attenuation measures.

A test plan was developed and the scenarios were set in different priorities which would simplify any alterations that needed to be made during the test shooting and to easier know which scenarios to add would there be time for more. The test plan as a whole is presented in APPENDIX A TEST PLAN. The most high priority scenarios are set in backwards direction since it is more widely used and the prioritized scenarios in forward and side directions are scenarios that can be compared to the backwards scenarios. A summary of the levels are presented in Table 4

Table 4. Parameters of interest and their levels

Parameter	+	0	-
Elevation	80°	75°	50°
Charge	Max(9)	Mean(7)	Min(5)
Direction	Forwards	Backwards	Side
Rear door	Closed	-	Open
Roof hatches	45°	-	30°
Chassis elevation	0	-	+40 cm
BAD	With	-	Without

3.4 ANOVA

Since the test plan is designed in a way that allows the scenarios to be compared not only with main effects but also with the possibility to investigate interacting effects the ANOVA method will be applied to easier look at the effects of the parameters and conclude if it is of statistical significance. The ANOVA is performed with the use of MATLAB and the code used is presented in APPENDIX D MATLAB-CODE.

3.5 Test Setup

The test setup differs from the regulatory setup [11] since this is just a prestudy of the system and the test was focused on the environment inside the vehicle making it unnecessary to rig all microphones outside the vehicle.

Outside the rig four probes where placed at 10m as shown in Figure 23. These were not necessary for the purpose of the project but were placed for future references. A camcorder was also placed outside the rig to record the testing for quality assurance.

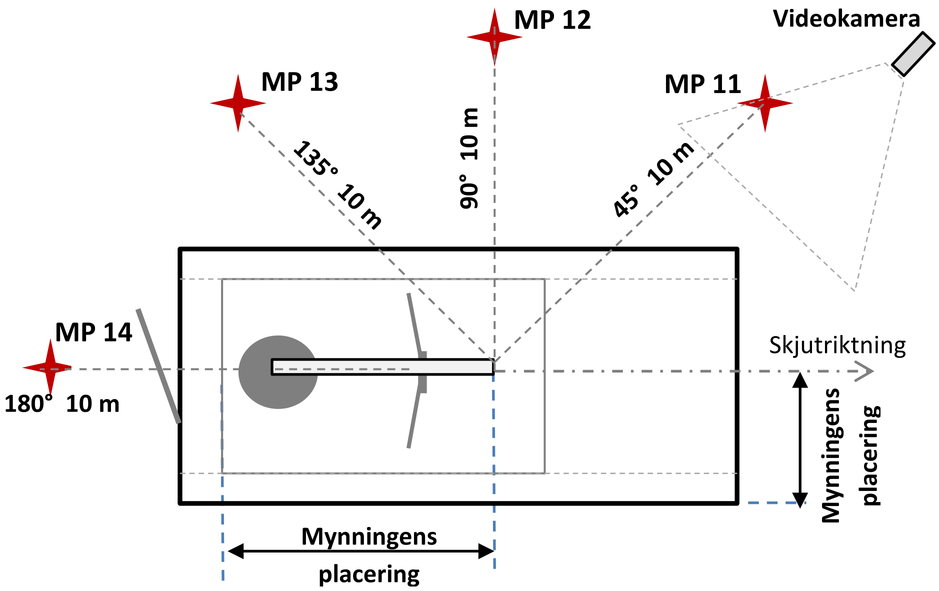

Figure 23. Top-view outer test-setup (measurements in centimeters, not to scale) [16]

Inside the rig six probes were placed which would record the sound pressure levels. They are defined as MP1-MP6 and placed as shown in Figure 24 and Figure 25.

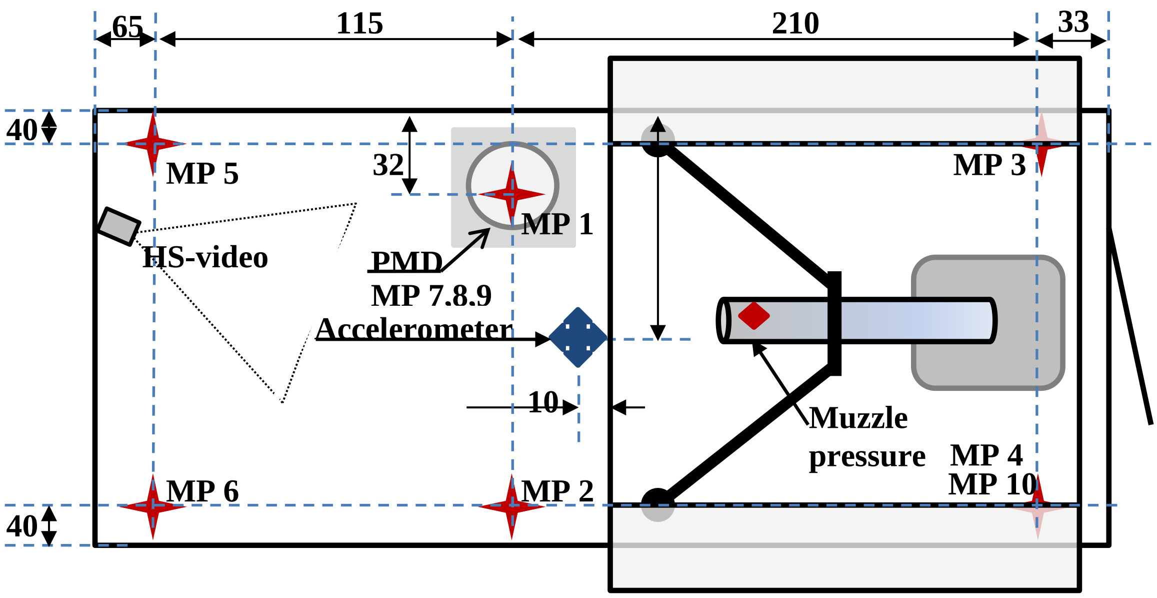

Figure 24. Top-view inner test-setup (measurements in centimetres, not to scale) [16]

On the barrel, near the muzzle, a pressure sensor was placed to monitor the internal pressure in the barrel. It was also used to trigger the recording device thus supplying synchronization for all measurement data.

On the front wall, a high-speed camera was mounted and aimed at the mortar. The purpose of the camera was to monitor if any smoke entered the vehicle after firing which could be a health hazard for the personnel.

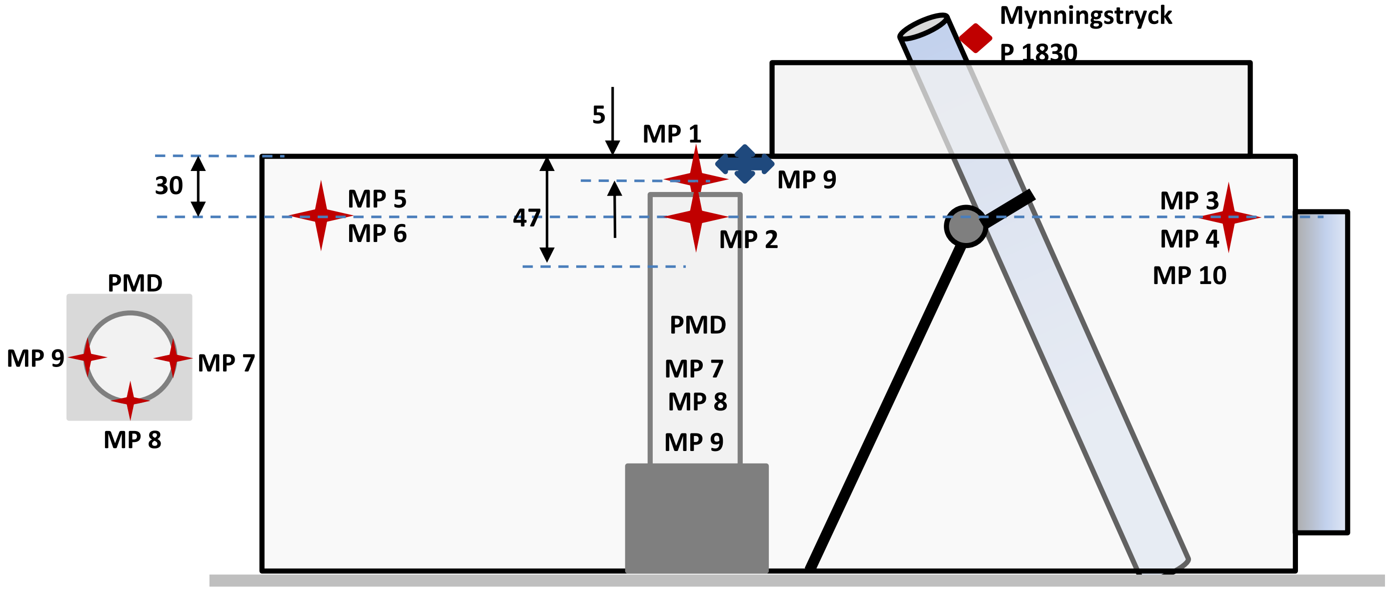

Figure 25. Side-view inner test-setup (measurements in centimetres, not to scale) [16]

Inside the rig a device called Pressure Measurement Device (PMD) was placed on the right side and contained the pressure sensors MP7-MP9. These together with the pressure sensor MP10 are used to calculate Chest Wall Velocity Predictor (CWVP) which is used to predict if there is any risk for damages on internal organs. Figure 26 displays the placements and attachments of some of the sensors.

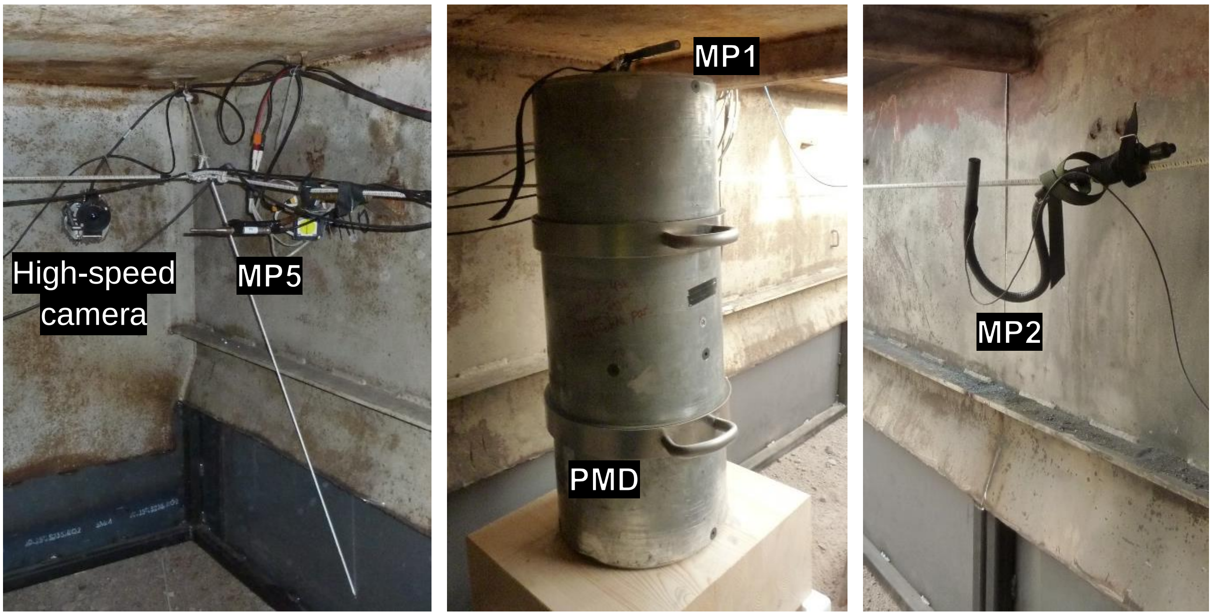

Figure 26 Placement of measurement devices

4.1 Testing

The test was initially scheduled for week 10 (4/3-8/3) but was postponed due to problems with the alterations of the mock-up. Fortunately there was an opening in the schedule for T&E the week after. The test was performed during week 11 (11/3-15/3) and a total of 104 grenades were launched, testing 29 different scenarios which was a great success since it was estimated that time would allow a maximum of 70 grenades. The tested scenarios are presented in Table 5, Table 6 and Table 7. It was a priority to do most test backwards since that solution is most widely used. Test to the side was least prioritized. All of the highest priority scenarios where performed except two which was the test with different angle of the roof hatches, the test was however performed but in the forward direction instead.

Table 5. Tested scenarios, backwards

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
1	75°	Backwards	0	Closed	Min(5)	Without	45°
2	75°	Backwards	0	Closed	Mean(7)	Without	45°
3	75°	Backwards	0	Closed	Max(9)	Without	45°
5	45°	Backwards	0	Closed	Max(9)	Without	45°
6	85°	Backwards	0	Closed	Max(9)	Without	45°
7	75°	Backwards	0	Opened	Max(9)	Without	45°
8	45°	Backwards	0	Opened	Max(9)	Without	45°
9	85°	Backwards	0	Opened	Max(9)	Without	45°
13	75°	Backwards	0	Closed	Min(5)	With	45°
14	75°	Backwards	0	Closed	Mean(7)	With	45°
15	75°	Backwards	0	Closed	Max(9)	With	45°
16	45°	Backwards	0	Closed	Max(9)	With	45°
17	85°	Backwards	0	Closed	Max(9)	With	45°
18	75°	Backwards	0	Opened	Max(9)	With	45°
23	75°	Backwards	+40 cm	Closed	Max(9)	Without	45°
24	75°	Backwards	+40 cm	Closed	Max(9)	With	45°

Table 6. Tested scenarios, side

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
57	75°	Side	0	Closed	Max(9)	Without	45°
61	75°	Side	0	Opened	Max(9)	Without	45°
69	75°	Side	0	Closed	Max(9)	With	45°
72	75°	Side	0	Opened	Max(9)	With	45°

Table 7. Tested scenarios, forwards

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
30	75°	Forwards	0	Closed	Max(9)	Without	45°
32	45°	Forwards	0	Closed	Max(9)	Without	45°
33	85°	Forwards	0	Closed	Max(9)	Without	45°
34	75°	Forwards	0	Opened	Max(9)	Without	45°
42	75°	Forwards	0	Closed	Max(9)	With	45°
43	45°	Forwards	0	Closed	Max(9)	With	45°
45	75°	Forwards	0	Opened	Max(9)	With	45°
53	75°	Forwards	0	Closed	Max(9)	Without	30°
54	75°	Forwards	0	Opened	Max(9)	Without	30°

4.2 C-weighted peak pressure level ($L_{pC,Peak}$)

In Table 8, the mean and max values of $L_{pC,Peak}$ for the tested scenarios in backwards direction are presented. A test result for every scenario is presented in APPENDIX B. MP5 and MP6 displayed the lowest values of the measuring points and they displayed values over 165 dB for all scenarios where the BAD was not used and when the BAD was used most scenarios recorded a peak value under 165 dB.
MP3 and MP4 recorded the highest peak values for most of the scenarios, especially for backwards fired scenarios, with the highest value recorded for scenario 23 by MP4 with a value of 184.6 dB which was the scenario with elevated chassis.

Table 8. Mean/Max $L_{pC,Peak}$, backwards

ID	MP1 Mean/Max [dB(C)]	MP2 Mean/Max [dB(C)]	MP3 Mean/Max [dB(C)]	MP4 Mean/Max [dB(C)]	MP5 Mean/Max [dB(C)]	MP6 Mean/Max [dB(C)]
1	169.4/169.9	170.8/171.5	175.9/176.6	175.2/175.3	167.9/168.7	168.0/168.9
2	172.0/172.8	173.3/175.5	178.3/179.4	177.6/178.5	169.2/169.8	168.9/170.8
3	173.1/174.9	171.5/171.8	178.1/179.5	175.8/176.8	166.2/167.2	167.8/169.1
5	172.6/173.7	174.0/175.3	179.6/181.1	180.9/181.9	167.3/168.4	167.6/168.5
6	170.2/171.5	172.6/173.5	176.8/178.4	175.8/176.2	166.8/168.0	168.6/170.5
7	172.3/173.2	170.4/172.0	178.6/179.6	176.5/176.6	166.6/167.3	165.8/166.5
8	173.2/173.7	174.8/177.0	178.3/179.3	180.6/182.7	169.0/169.3	168.7/169.6
9	171.4/173.4	172.9/173.9	177.5/178.3	175.8/177.0	166.4/167.3	167.0/167.5
13	164.7/167.2	163.2/165.2	164.9/168.2	164.3/167.1	159.3/162.1	158.6/162.7
14	166.6/167.3	167.7/169.9	169.2/170.3	170.0/170.7	162.0/162.7	163.7/165.1
15	170.6/172.0	166.8/167.4	170.9/172.6	170.5/172.4	163.7/165.8	163.4/164.7
16	169.5/171.5	167.3/168.4	171.9/172.2	171.2/172.1	165.0/166.1	165.4/166.8
17	164.9/165.4	164.0/164.6	170.2/171.9	169.5/172.3	160.9/161.8	162.8/164.3
18	169.9/171.5	167.6/169.0	169.7/171.5	170.3/172.1	161.7/163.0	164.3/165.5
23	172.8/174.5	175.3/177.3	180.7/181.5	183.6/184.6	168.9/171.8	170.7/171.4
24	167.3/170.0	168.1/169.5	171.4/173.2	173.3/174.6	164.2/165.9	165.6/167.9

4.3 L'_{pC}

The sound pressure level under the ear protectors calculated from equation (1) and using sound impulse type 1 from Table 3 and with attenuation data for ComTac XP + Earplug Classic and the mean and max values for the tested scenarios in backwards direction are presented in Table 9. A test result for every scenario is presented in APPENDIX B. No scenario reached a value over 160 dB(C) which means that no scenario is prohibited, however a lot of the scenarios reached a value over 140 dB(C) in one or more measuring points. This means that it is necessary to limit the number of firings.

Table 9. Mean/Max L'_{pC}, backwards

ID	MP1 Mean/Max [dB(C)]	MP2 Mean/Max [dB(C)]	MP3 Mean/Max [dB(C)]	MP4 Mean/Max [dB(C)]	MP5 Mean/Max [dB(C)]	MP6 Mean/Max [dB(C)]
1	138.4/138.9	139.8/140.5	144.9/145.6	144.2/144.3	136.9/137.7	137.0/137.9
2	141.0/141.8	142.3/144.5	147.3/148.4	146.6/147.5	138.2/138.8	137.9/139.8
3	142.1/143.9	140.5/140.8	147.1/148.5	144.8/145.8	135.2/136.2	136.8/138.1
5	141.6/142.7	143.0/144.3	148.6/150.1	149.9/150.9	136.3/137.4	136.6/137.5
6	139.2/140.5	141.6/142.5	145.8/147.4	144.8/145.2	135.8/137.0	137.6/139.5
7	141.3/142.2	139.4/141.0	147.6/148.6	145.5/145.6	135.6/136.3	134.8/135.5
8	142.2/142.7	143.8/146.0	147.3/148.3	149.6/151.7	138.0/138.3	137.7/138.6
9	140.4/142.4	141.9/142.9	146.5/147.3	144.8/146.0	135.4/136.3	136.0/136.5
13	133.7/136.2	132.2/134.2	133.9/137.2	133.3/136.1	128.3/131.1	127.6/131.7
14	135.6/136.3	136.7/138.9	138.2/139.3	139.0/139.7	131.0/131.7	132.7/134.1
15	139.6/141.0	135.8/136.4	139.9/141.6	139.5/141.4	132.7/134.8	132.4/133.7
16	138.5/140.5	136.3/137.4	140.9/141.2	140.2/141.1	134.0/135.1	134.4/135.8
17	133.9/134.4	133.0/133.6	139.2/140.9	138.5/141.3	129.9/130.8	131.8/133.3
18	138.9/140.5	136.6/138.0	138.7/140.5	139.3/141.1	130.7/132.0	133.3/134.5
23	141.8/143.5	144.3/146.3	149.7/150.5	152.6/153.6	137.9/140.8	139.7/140.4
24	136.3/139.0	137.1/138.5	140.4/142.2	142.3/143.6	133.2/134.9	134.6/136.9

4.4 Number of permissible firings with double ear protectors

Since almost every scenario tested resulted in a C-weighted peak value above 165 dB(C) it is required for the personnel to wear double ear protectors and therefore the permissible number of firings are evaluated from the SNR value of the ComTac XP + Earplug Classic(see Table 2). Table 10 presents the limitation of firings for backwards firing and when restrictions are not required it says Unl (Unlimited). A test result for every scenario is presented in APPENDIX B. MP5 and MP6 have no restrictions for every scenario except for the minimum value on scenario 23(elevated chassis). Scenario 23 results in the lowest permissible amount of firings for the whole test with 30 firings per day for MP4. Most scenarios shows a limitation of 30-50 firings without the BAD and with the bad the restrictions are about 100-110 firings.

Table 10. Permissible number of firings, backwards

ID	MP1 Min/Max	MP2 Min/Max	MP3 Min/Max	MP4 Min/Max	MP5 Min/Max	MP6 Min/Max
1	Unl/Unl	149/Unl	73/82	80/94	Unl/Unl	Unl/Unl
2	81/Unl	99/115	46/92	49/93	Unl/Unl	Unl/Unl
3	68/Unl	84/111	58/63	75/84	Unl/Unl	Unl/Unl
5	53/Unl	51/78	59/64	47/57	Unl/Unl	Unl/Unl
6	89/Unl	99/119	59/79	67/91	Unl/Unl	Unl/Unl
7	77/Unl	99/Unl	66/89	83/111	Unl/Unl	Unl/Unl
8	50/72	46/78	49/81	38/71	Unl/Unl	Unl/Unl
9	81/Unl	86/Unl	76/104	89/126	Unl/Unl	Unl/Unl
13	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl
14	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl
15	125/Unl	Unl/Unl	171/Unl	178/Unl	Unl/Unl	Unl/Unl
16	104/Unl	Unl/Unl	109/167	140/Unl	Unl/Unl	Unl/Unl
17	Unl/Unl	Unl/Unl	193/Unl	160/Unl	Unl/Unl	Unl/Unl
18	153/Unl	Unl/Unl	190/unl	203/Unl	Unl/Unl	Unl/Unl
23	85/Unl	62/78	32/45	30/44	89/Unl	143/Unl
24	Unl/Unl	Unl/Unl	116/Unl	140/Unl	Unl/Unl	Unl/Unl

4.5 ANOVA

A value under 0.05 indicates difference in the means with a 95% significance level and are highlighted in the tables.

4.5.1 Charge – BAD

The first ANOVA investigates the parameters charge and BAD and the scenarios used are presented in Table 11. This test is done for scenarios with the mortar directed backwards and with an elevation of 75°. This test is full factorial and interaction effects can be calculated.

Table 11 Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
1	75°	Backwards	0	Closed	Min(5)	Without	45°
2	75°	Backwards	0	Closed	Mean(7)	Without	45°
3	75°	Backwards	0	Closed	Max(9)	Without	45°
13	75°	Backwards	0	Closed	Min(5)	With	45°
14	75°	Backwards	0	Closed	Mean(7)	With	45°
15	75°	Backwards	0	Closed	Max(9)	With	45°

The result from the ANOVA is presented in Table 12 and Table 13 and shows the probability for the measurement points for the different sources.
The ANOVA tables 18 and 19 indicate an overall effect both for the main effects as well as interacting effects. In Figure 27 and Figure 28 the effects are easier to interpret. Without the use of BAD the highest charge does not give the highest peak levels or $L_{pC,1sEq}$ but with the use of BAD the highest charge gives the highest values. The effect of the bad itself shows an attenuation of 5-11 dB(C) for the peak values as well as the $L_{pC,1sEq}$.

Table 12 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Charge	0.003	0.001	0.000	0.030	0.015	0.071
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Charge*BAD	0.248	0.162	0.006	0.002	0.035	0.042

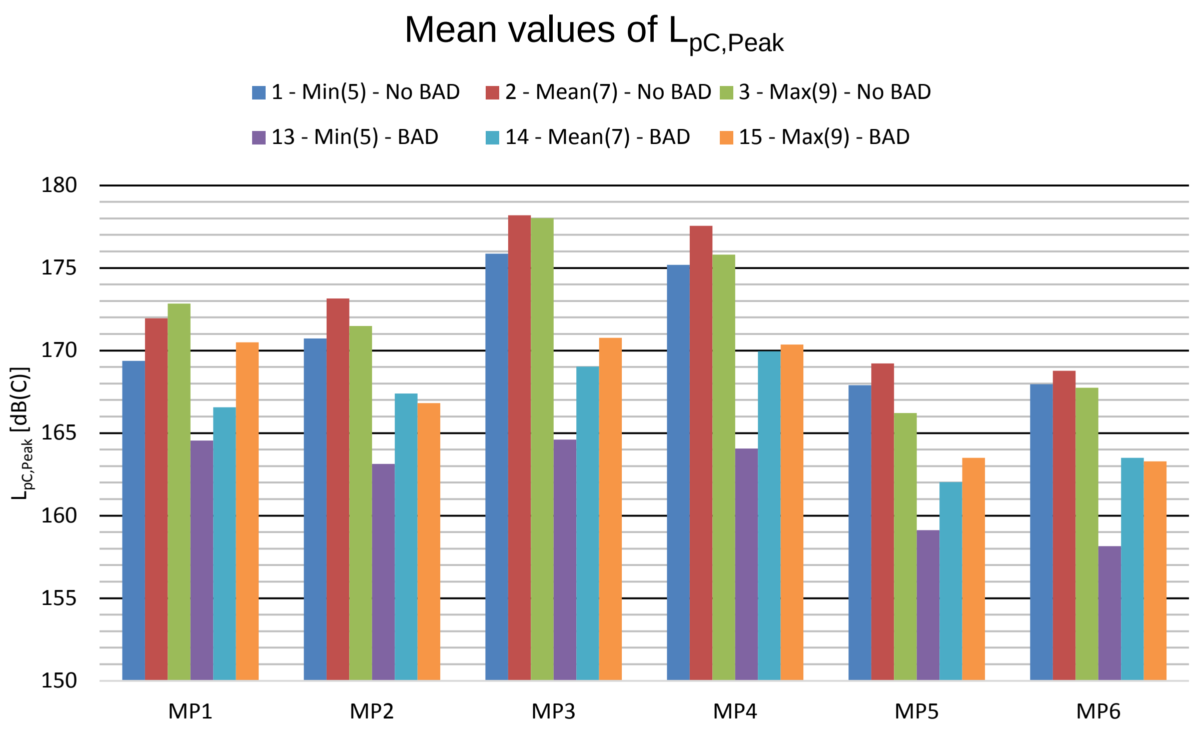

Figure 27 Mean values for the tested scenarios divided by the measurement points

Table 13 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Charge	0.000	0.000	0.001	0.027	0.017	0.000
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Charge*BAD	0.294	0.016	0.008	0.002	0.003	0.001

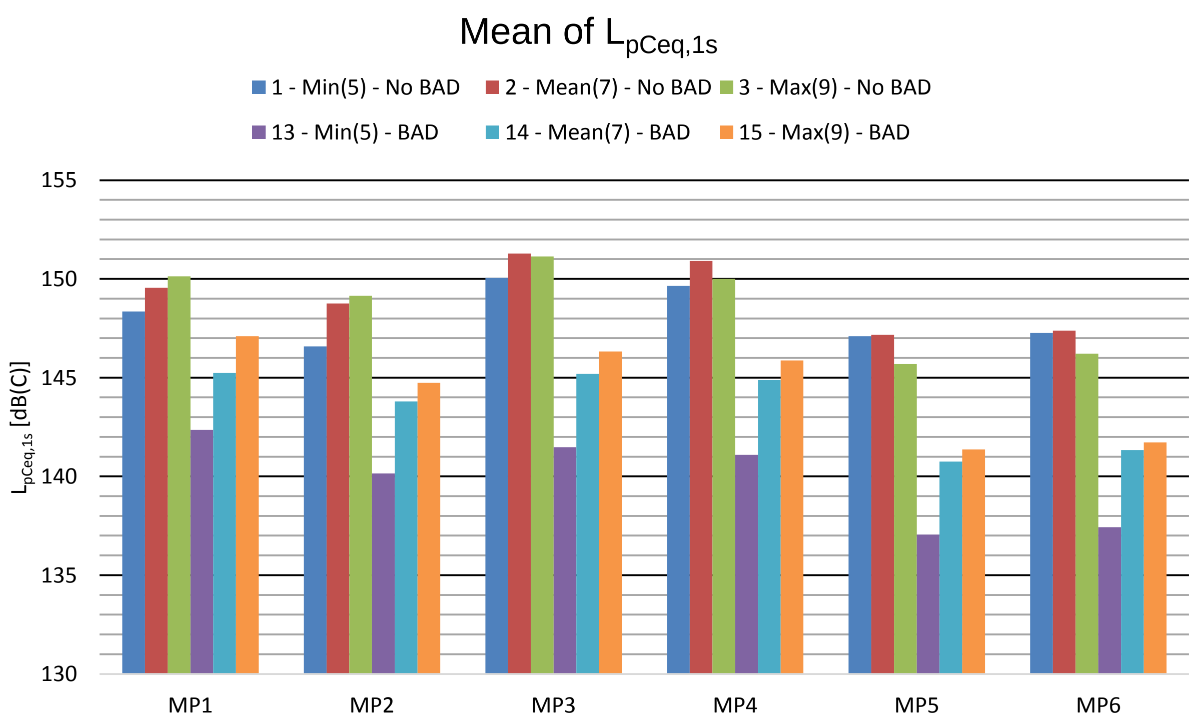

Figure 28 Mean values for the tested scenarios divided by the measurement points

4.5.2 Elevated chassis – BAD

In this test the ANOVA investigates the elevated chassis and the BAD. It is a full factorial test and interactions can be calculated. The used scenarios are presented in Table 13.

Table 14. Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
3	75°	Backwards	0	Closed	Max(9)	Without	45°
15	75°	Backwards	0	Closed	Max(9)	With	45°
23	75°	Backwards	+40 cm	Closed	Max(9)	Without	45°
24	75°	Backwards	+40 cm	Closed	Max(9)	With	45°

An interesting aspect with this test is to conclude if the effect of the BAD is due to its design or just that it moves the muzzle away from the vehicle. The muzzle heights for the scenarios are presented in Table 15 and it shows that with the elevated chassis and with the BAD (ID 24) the muzzle is closer to the vehicles roof then for ID 3. If the effect of the BAD is only due moving the muzzle ID 24 would show higher levels than ID 3

Table 15. Muzzle height over roof

ID	3	15	23	24
Muzzle height over roof (cm)	74	89	36	55

Table 17 and Table 16 shows an overall effect of both the elevated chassis and the BAD which also can be seen in Figure 29 and Figure 30 it also shows that ID 3 has higher values than ID 24 which indicates that it is the design of the BAD that gives the effect.

Table 16 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevated chassis	0.001	0.042	0.000	0.098	0.005	0.068
BAD	0.000	0.000	0.000	0.002	0.000	0.000
Elevated chassis*BAD	0.047	0.161	0.010	0.310	0.592	0.837

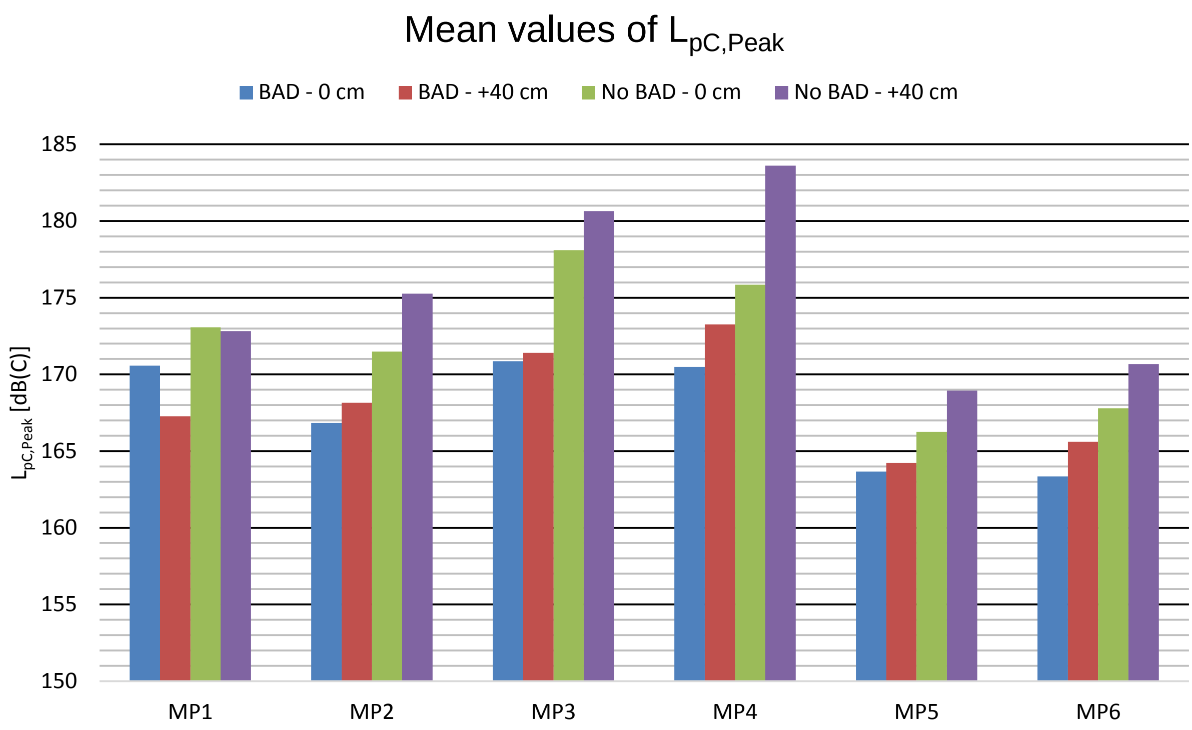

Figure 29 Mean values for the tested scenarios divided by the measurement points

Table 17 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevated chassis	0.022	0.000	0.000	0.071	0.007	0.000
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Elevated chassis*BAD	0.437	0.289	0.002	0.355	0.454	0.397

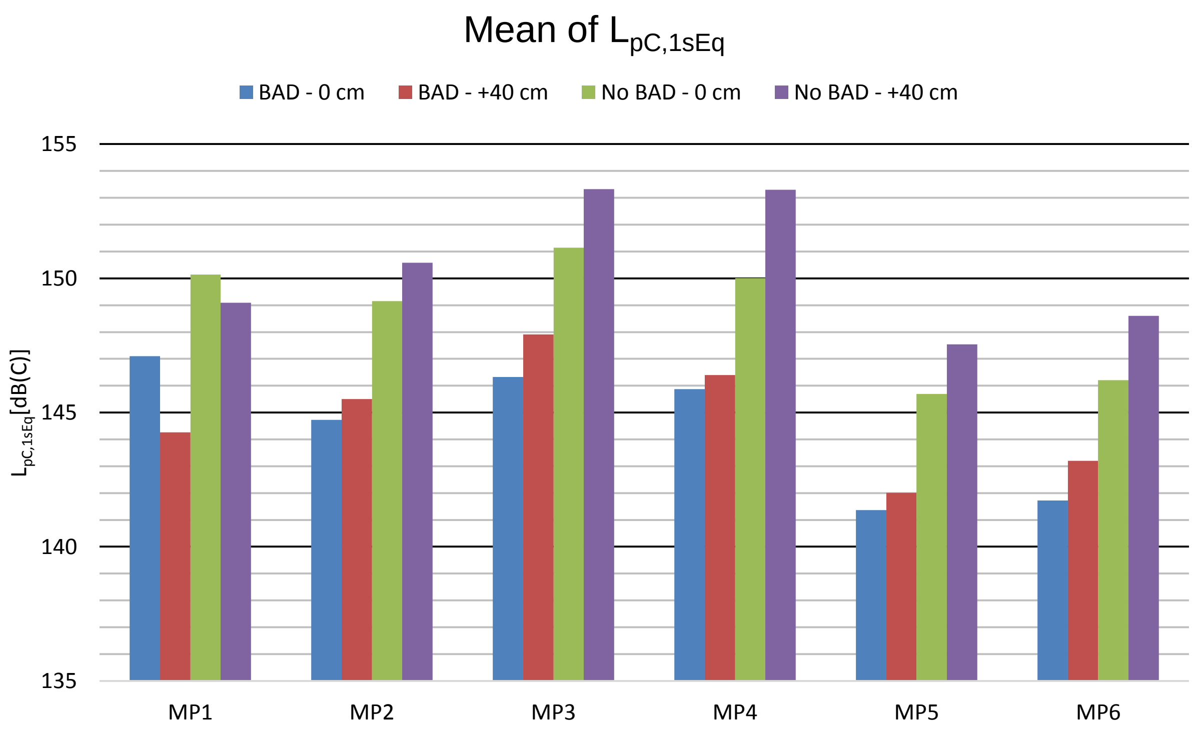

Figure 30 Mean values for the tested scenarios divided by the measurement points

4.5.3 Roof hatches – Rear door

The testing or roof hatches and rear door is part of the investigation of potential measures that could lower the exposure to the personnel. The test is full factorial and interacting effects can be calculated. The used scenarios are presented in Table 18.

Table 18 Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
30	75°	Forwards	0	Closed	Max(9)	Without	45°
34	75°	Forwards	0	Opened	Max(9)	Without	45°
53	75°	Forwards	0	Closed	Max(9)	Without	30°
54	75°	Forwards	0	Opened	Max(9)	Without	30°

The results of this ANOVA test is presented in Table 20 and Table 19 and it shows some effects on some of the measuring points but no overall effects. Figure 31 and Figure 32 shows that the effects are insignificant (<3dB(C)).

Table 19 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Rear hatch	0.287	0.994	0.057	0.767	0.285	0.365
Roof hatches	0.006	0.334	0.274	0.996	0.162	0.001
Rear hatch*Roof hatches	0.687	0.338	0.345	0.320	0.798	0.186

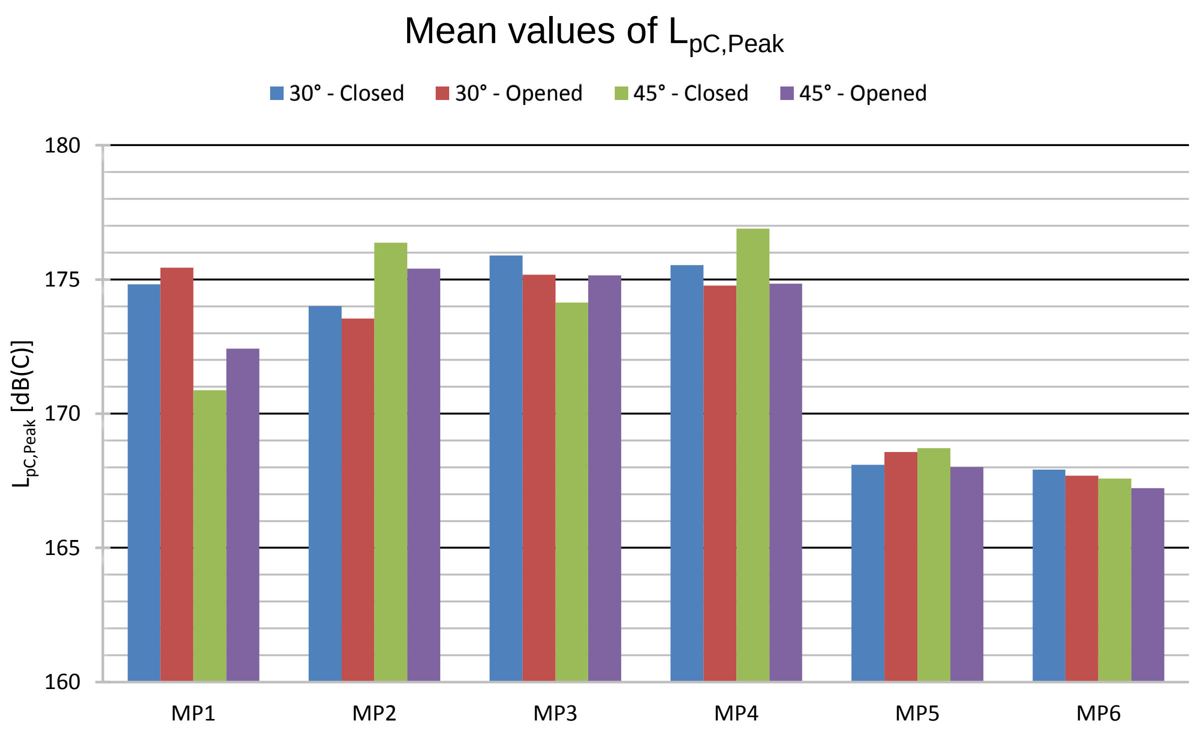

Figure 31 Mean values for the tested scenarios divided by the measurement points

Table 20 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Rear hatch	0.640	0.013	0.066	0.310	0.050	0.647
Roof hatches	0.027	0.002	0.039	0.052	0.084	0.175
Rear hatch*Roof hatches	0.581	0.374	0.584	0.035	0.055	0.667

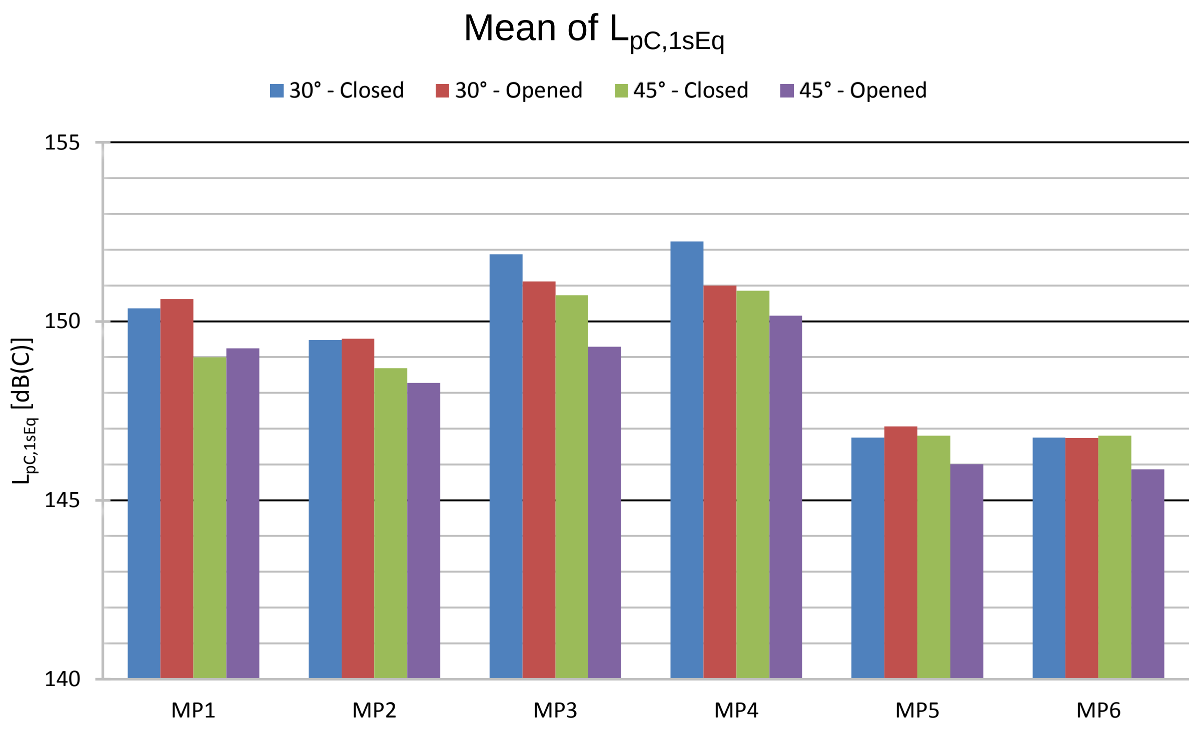

Figure 32 Mean values for the tested scenarios divided by the measurement points

4.5.4 Elevation - BAD

The test of elevation and BAD was performed using the scenarios presented in Table 21. It is a full factorial test and interactions can be calculated. It was of great importance to see if any elevation was prohibited.

Table 21 Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
3	75°	Backwards	0	Closed	Max(9)	Without	45°
5	45°	Backwards	0	Closed	Max(9)	Without	45°
6	85°	Backwards	0	Closed	Max(9)	Without	45°
15	75°	Backwards	0	Closed	Max(9)	With	45°
16	45°	Backwards	0	Closed	Max(9)	With	45°
17	85°	Backwards	0	Closed	Max(9)	With	45°

The results from the test are presented in Table 23 and Table 22 and they show an overall effect both from the elevation as well as the BAD. Some of the measuring points also indicated interacting effects. Figure 33 and Figure 34 visualizes the effects and shows that the BAD gives the effect of up to 10 dB(C) while the elevation only gives up to 4 dB(C).

Table 22 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevation	0.008	0.037	0.002	0.015	0.360	0.004
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Elevation*BAD	0.018	0.815	0.057	0.033	0.069	0.124

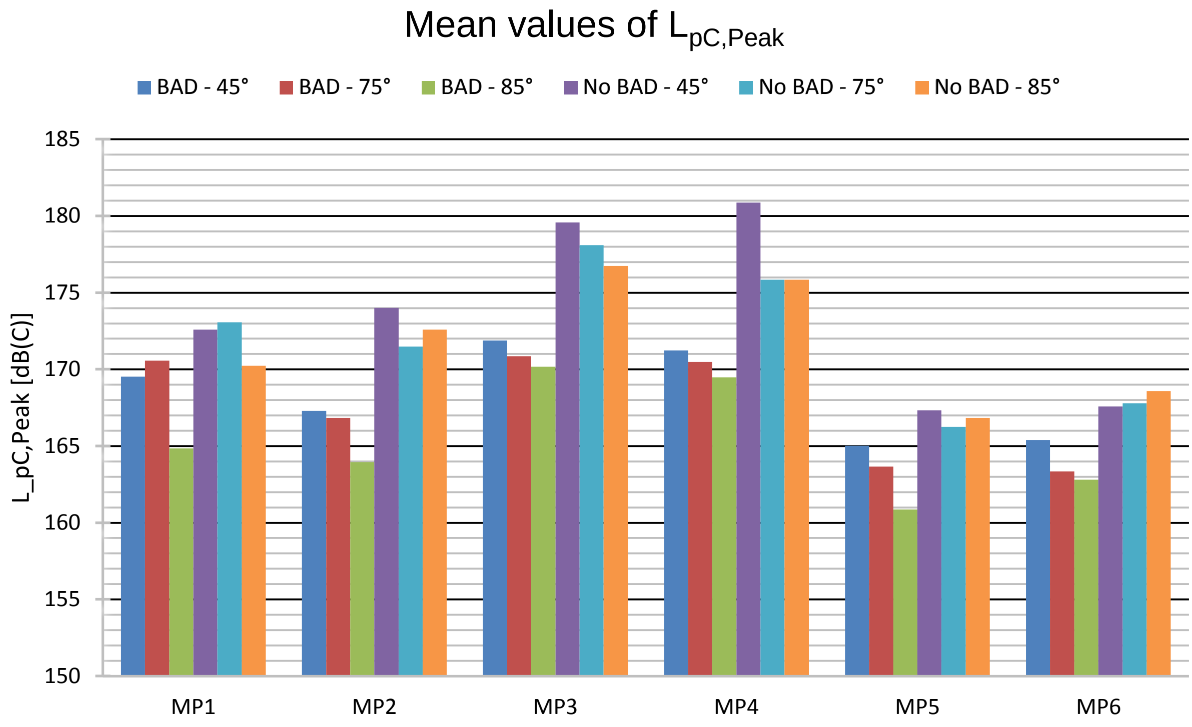

Figure 33 Mean values for the tested scenarios divided by the measurement points

Table 23 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevation	0.000	0.031	0.000	0.002	0.001	0.000
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Elevation*BAD	0.336	0.187	0.458	0.008	0.004	0.006

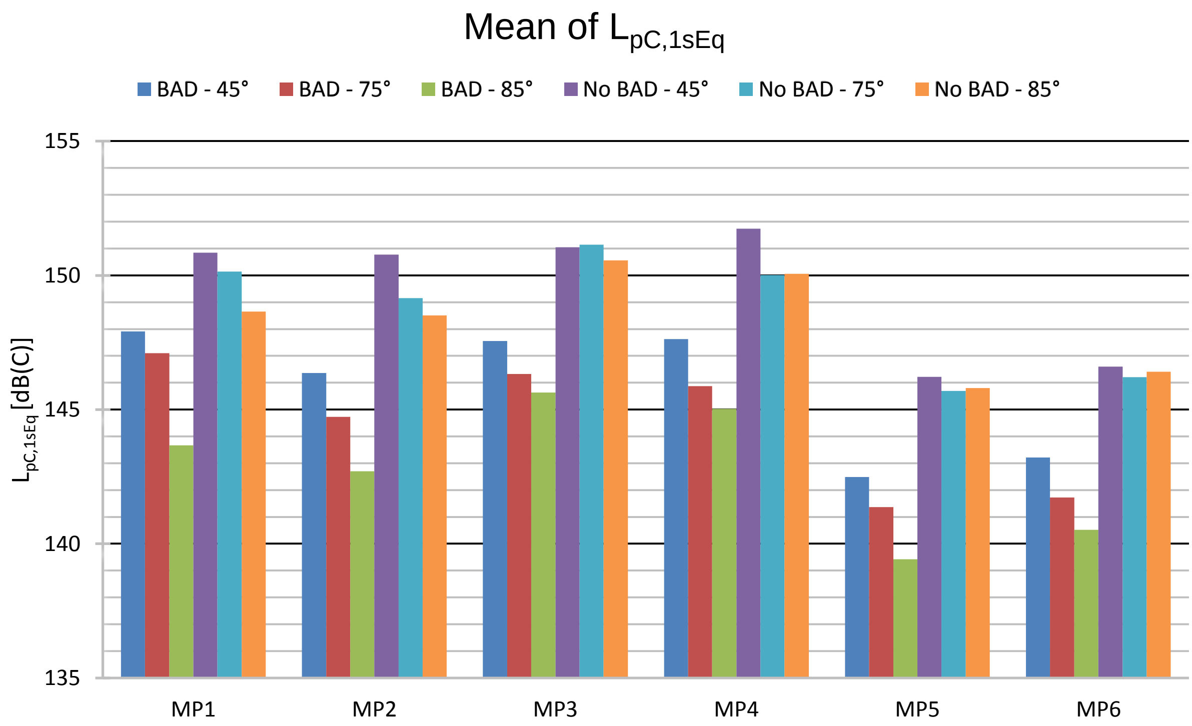

Figure 34 Mean values for the tested scenarios divided by the measurement points

4.5.5 Elevation - Direction

The elevation and direction test is more or less the core test for this investigation. It shows if the basic use of the mortar is possible. The used scenarios are presented in Table 24 and it is a full factorial.

Table 24 Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
3	75°	Backwards	0	Closed	Max(9)	Without	45°
5	45°	Backwards	0	Closed	Max(9)	Without	45°
6	85°	Backwards	0	Closed	Max(9)	Without	45°
30	75°	Forwards	0	Closed	Max(9)	Without	45°
32	45°	Forwards	0	Closed	Max(9)	Without	45°
33	85°	Forwards	0	Closed	Max(9)	Without	45°

The results from the test are reported in scenarios divided by the measurement points

Table 26 and Table 25. They show no overall effect from the main effects but indicate that there are interacting effects. Figure 35 and Figure 36 shows that for backwards firing the low elevation gives highest values but for forwards firing the highest values are recorded for the highest elevation.

Table 25 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevation	0.031	0.776	0.178	0.639	0.877	0.028
Direction	0.119	0.000	0.022	0.082	0.122	0.001
Elevation*Direction	0.000	0.001	0.000	0.038	0.337	0.006

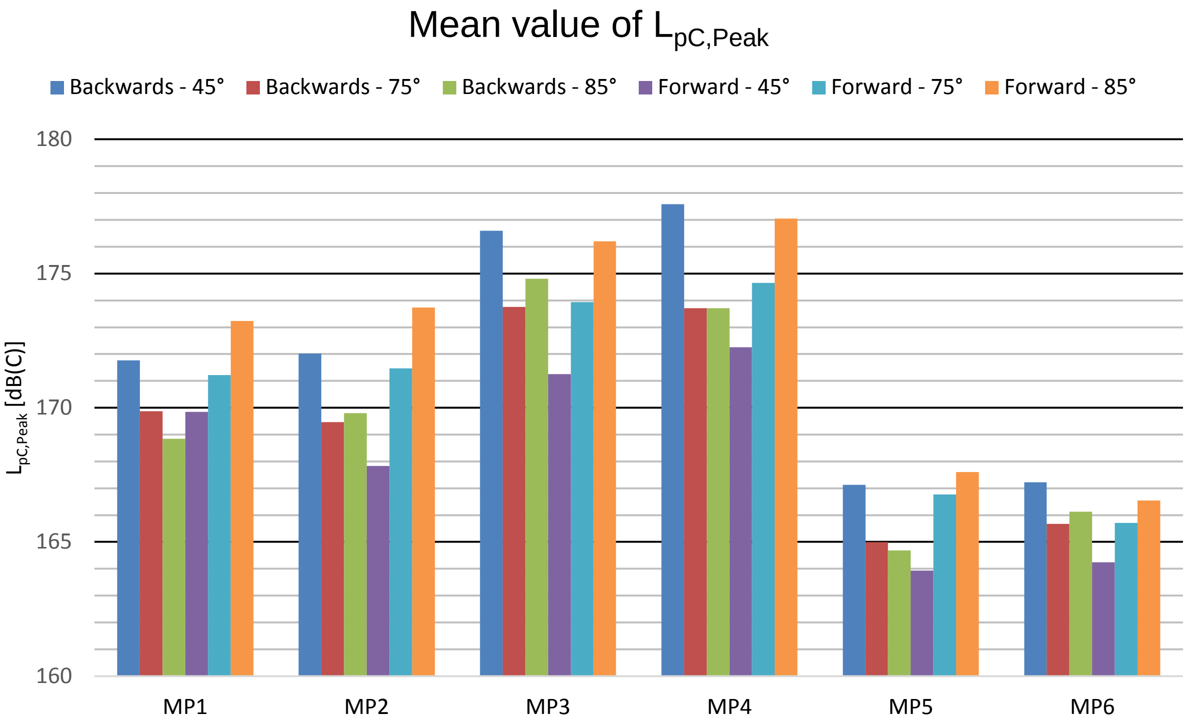

Figure 35 Mean values for the tested scenarios divided by the measurement points

Table 26 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
Elevation	0.000	0.027	0.530	0.129	0.154	0.293
Direction	0.005	0.012	0.059	0.232	0.121	0.008
Elevation*Direction	0.249	0.007	0.000	0.003	0.015	0.000

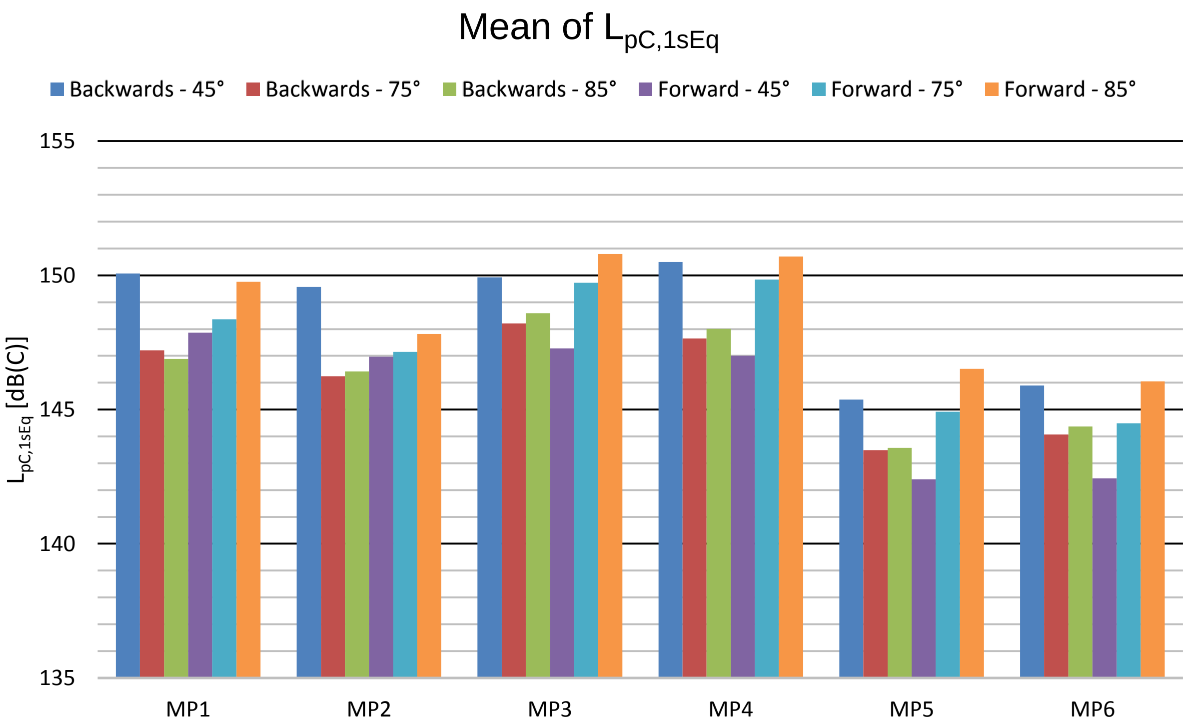

Figure 36 Mean values for the tested scenarios divided by the measurement points

4.5.6 Direction - Rear door – BAD

For testing all of the three directions, rear door and BAD the scenarios used are described in Table 27 it is a full factorial and the only test performed that can show three level interacting effects.

Table 27 Scenarios used for ANOVA-test

ID	Elevation	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches
3	75°	Backwards	0	Closed	Max(9)	Without	45°
7	75°	Backwards	0	Opened	Max(9)	Without	45°
15	75°	Backwards	0	Closed	Max(9)	With	45°
18	75°	Backwards	0	Opened	Max(9)	With	45°
30	75°	Forwards	0	Closed	Max(9)	Without	45°
34	75°	Forwards	0	Opened	Max(9)	Without	45°
42	75°	Forwards	0	Closed	Max(9)	With	45°
45	75°	Forwards	0	Opened	Max(9)	With	45°
57	75°	Side	0	Closed	Max(9)	Without	45°
61	75°	Side	0	Opened	Max(9)	Without	45°
69	75°	Side	0	Closed	Max(9)	With	45°
72	75°	Side	0	Opened	Max(9)	With	45°

The results from the test is presented in Table 29 and Table 28 and it clearly shows that the BAD has effect on the results both the peak value as well as $L_{pCeq,1s}$. It also shows that the direction has effect and also the direction interacting with the BAD. The rear door appears to have effect for the peak level but as shown in Figure 37 and Figure 38 the effect is not very significant (<2 dB(C)).

Table 28 Result from ANOVA of $L_{pC,Peak}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Rear hatch	0.993	0.658	0.980	0.130	0.042	0.270
Direction	0.044	0.120	0.198	0.007	0.009	0.011
BAD*Rear hatch	0.178	0.470	0.797	0.158	0.936	0.406
BAD*Direction	0.000	0.000	0.184	0.640	0.008	0.001
Rear hatch*Direction	0.819	0.564	0.679	0.993	0.751	0.883
BAD*Rear hatch*Direction	0.402	0.614	0.462	0.633	0.074	0.967

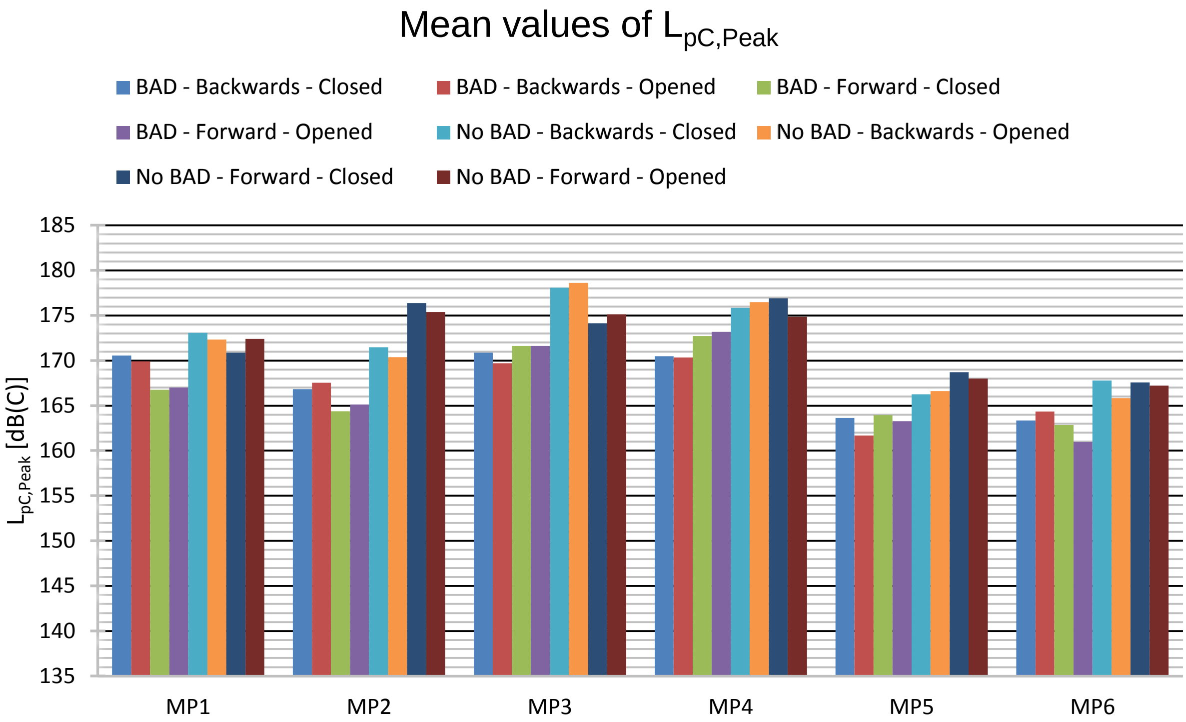

Figure 37 Mean values for the tested scenarios divided by the measurement points

Table 29 Result from ANOVA of $L_{pC,1sEq}$

Source	MP1	MP2	MP3	MP4	MP5	MP6
BAD	0.000	0.000	0.000	0.000	0.000	0.000
Rear door	0.884	0.002	0.040	0.043	0.016	0.997
Direction	0.042	0.080	0.001	0.000	0.012	0.000
BAD*Rear door	0.508	0.533	0.595	0.464	0.321	0.611
BAD*Direction	0.186	0.000	0.185	0.100	0.001	0.001
Rear door*Direction	0.701	0.811	0.597	0.886	0.371	0.754
BAD*Rear door*Direction	0.592	0.175	0.505	0.190	0.076	0.942

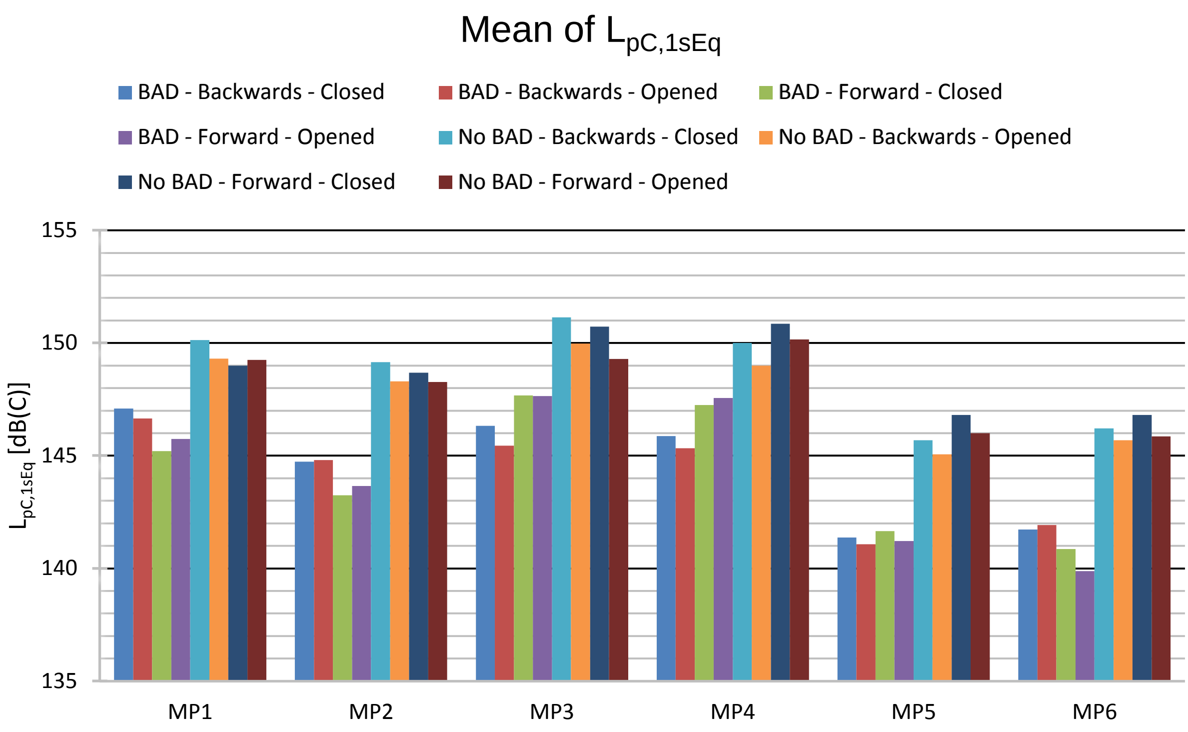

Figure 38 Mean values for the tested scenarios divided by the measurement points

5 DISCUSSION AND CONCLUSIONS

5.1 Discussion

5.1.1 Errors

The baseplate was during the test pressed down into the ground by the recoil force (see Figure 39). This led to the baseplate being lowered almost 20 cm from the 105 grenades fired. This led to the muzzle height over the roof differs and as a result of this the comparisons for direction can be misleading.

Figure 39 Baseplate pressed down in the ground by the recoil force

The results from the use of ANOVA should be considered guiding results and not definitive. ANOVA assumes that the test series are a good representation of the whole population and three tests/scenario is a bit too few to ensure a correct result.

5.1.2 Open field vs. contained area

A comparison between a previous open field test and the concept test was performed. The measurement points for the different tests were not the same but the measuring points compared are all in the vicinity of the mortar (<2m). The open field test was performed in 2000 and is described in the report from T&E [9] and summarized in Table 1. A representable time-sound pressure level graph is presented in Figure 40 for open field and Figure 41 shows for the vehicle mounted mortar test. The both show a sequence of ~0,3 seconds and it clearly shows the effect of having a mortar in a confined space; it requires 4-5 times as long to settle.

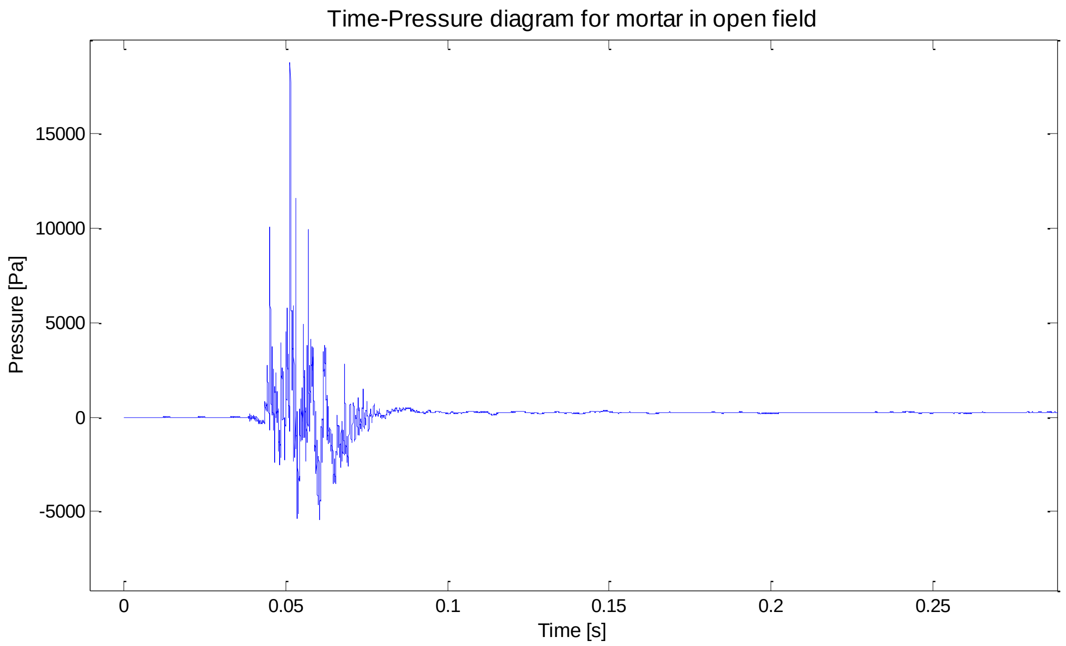

Figure 40 Representable graph from open field test

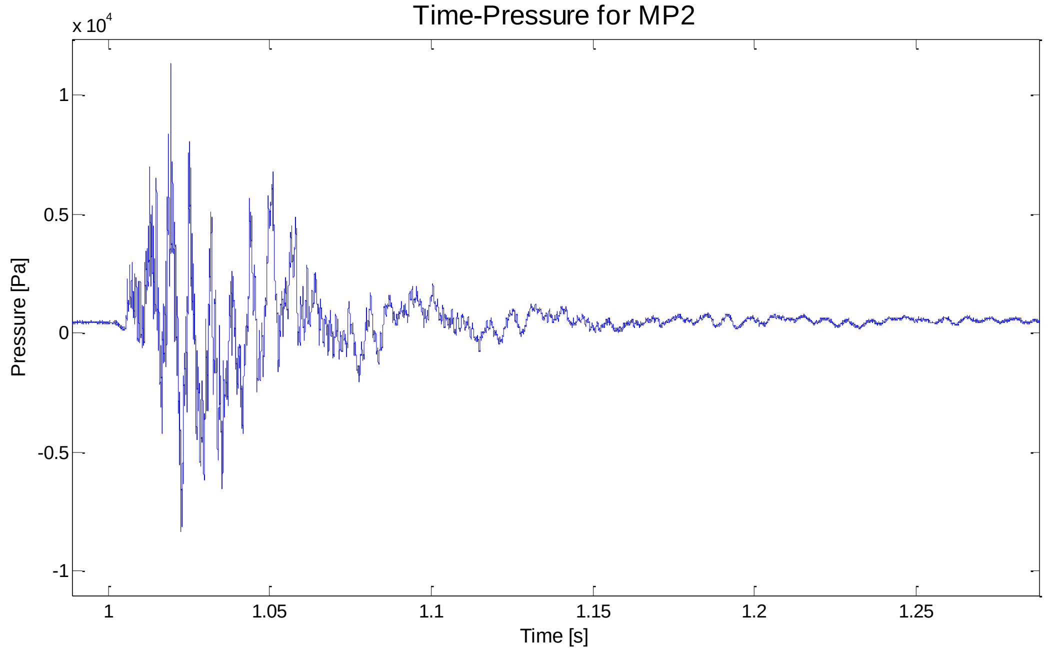

Figure 41 Representable graph from concept test

A comparison of data in Table 1, Table 8 and Table 9 shows that the open field test has higher peak value but it can be explained by some of that measuring points being placed higher from the ground than in the concept test. The comparison also shows that the concept test has higher values of the $L_{pC,1sEq}$ (149-151 dB) than the open field test (143-147 dB) this is most likely due to the longer settling time.

5.1.3 Elevation

It proved to be a problem to have the mortar in 45° elevation due to the limited space, this led the lowest elevation to be 55.8°.

The effect of the elevation proved to be dependent of which direction the mortar was directed to. When fired in backwards direction the highest levels were recorded for lowest elevation but in forward direction it was the 85° elevation which resulted in highest levels. In backwards direction the elevations 75° and 85° showed very little difference (<2dB) while in forward direction they differed more (1-3dB). The difference for the highest and lowest values was maximum 6 dB.

5.1.4 Charge

The test with different charges was performed in 75° elevation, in backwards direction and the results was somewhat surprising since it was assumed that the highest charge would also give the highest sound pressure levels and this was basically the case when the BAD was used but without the BAD the highest charge gave lower values for most probes. This is most likely due to the flow velocity directing the pressure wave propagation, and requires more investigations in fluid mechanics to explain. The problem with this results is that almost every scenario was performed with the highest charge and therefore it is possible for most scenarios to have up to 3 dB lower peak value and 1,5 dB lower $L_{pC,1sEq}$. It is also possible that a charge of 6 or 8, which was not tested, would give the highest values. However the difference was below 3 dB which is within the measurement error and to draw conclusions from this, a test with more than three tests/scenario would be required.

5.1.5 Direction

As already discussed in 5.1.3 the direction proved to interact with the elevation. Noteworthy is that the highest and lowest values recorded was almost the same (<2dB) regardless of direction. None of the directions showed values that would prohibit use in that direction it is therefore most likely that it is possible with a 360° aiming area around the vehicle.

5.1.6 Rear door

The effect of having the rear door open or closed could not be statistically proven. The ANOVA only showed effects in a few cases and for only a few measuring point and the effect was at max 2 dB. Therefore it should not be required to regulate if the door needs to be open or closed.

5.1.7 Roof hatches

The test of different angles did not show any significant effect. ANOVA showed effect for MP1-MP3. For MP1 having the roof hatches in 30° showed 4 dB higher levels and MP2 showed 2 dB lower and MP3 recorded less than 1 dB lower for the peak values. The angle did not give an overall positive effect in the vehicle mock-up.

5.1.8 Elevated chassis

The elevated chassis increased the levels significantly; 3-8 dB without BAD and 0.5-3 dB with the BAD for the peak value, 1-3.5 dB without BAD and 0.5-2 dB with the BAD for $L_{pC,1sEq}$. The use of the BAD made the system less sensitive for altering the muzzle height over the roof.

5.1.9 BAD

The results showed that the use of the BAD significantly lowered both $L_{pC,Peak}$ and $L_{pC,1sEq}$ with between 5 and 11 dB . Figure 42 shows two snapshots from the video recorded by the camcorder placed outside the test-rig for two similar scenarios which only differed in the use of BAD. As it clearly shows the BAD directs the pressure wave propagation efficiently away from the personnel.

The test with the elevated chassis excluded that the effect would be due to the muzzle being moved away from chassis. However the elevated chassis test changed the volume of the interior which could give some effects.

Figure 42 Difference in fire bolt; Left; without BAD, Right; with BAD

5.1.10 Other investigated risks

T&E investigated other potential risks during the test. They concluded that smoke only entered the vehicle for one scenario and that it was not any substantial quantity. The test of the chest wall velocity predictor (CWVP) showed a maximum of 0.7 m/s which is well below the limit of 3.6 m/s. The result and conclusions from T&E are presented fully in their report [16].

5.1.11 Updated ear protectors and regulations

At FMV there are projects active with the purpose of purchasing new ear protector systems with improved properties compared to the ones currently in service with features as active noise reduction (ANR) and ear plugs with integrated speakers for improved communications. The outcome of those projects can prove to be advantageous for the investigated concept.

The current regulations for use of ear protectors was updated in 2012 and at the present a project is revising these regulations, which probably will result in more restrictions and most likely $L_{pC,1sEq}$ will be restricted to a maximum of about 150 dB which in that case would prohibit some of the scenarios tested.

5.2 Conclusion

- The concept is a feasible solution with regard to the sound pressure levels
- The solution will most likely have a firing limitation of about 30-50 firings per day
- With the use of the BAD the limitation would increase to over 100 firings per day
- It is possible to fire the mortar forwards, backwards and to the side
- It is possible to use the highest charge

6 RECOMMENDATIONS AND FUTURE WORK

6.1 Recommendations

It is recommended to proceed with the development of this concept. None of the result has in any way shown that this concept will be prohibited regarding sound pressure levels. The limitation of 30 -50 firings per day might be a bit too few but the test shows that improvements can be made and the test-rig is not fully representable for an end product. A more thorough test with interior will give a more certain limitation.

6.2 Future work

6.2.1 Prototype testing

The test-rig used was similar to the CV90 in many ways but was also different in some aspects. The interior of the test-rig was bare metal and without the ballistic lining protection that a CV90 has. The rig was not equipped with seats, electronic devices, supplies and personal equipment which the final solution would have. All these things will change the soundscape inside the vehicle, not so much for the peak value but definitely for the reflective waves, which can lower the $L_{pC,1sEq}$. Next step should this solution be selected would be to create a more realistic prototype not just to investigate sound pressure but also the placement of the personnel when firing, which directions and elevations and placement of the mortar, all the parameters that was undecided when this test was made and thereby perform a more directed test.

6.2.2 BAD

The BAD proved to be very useful and effective and it is of great interest to further investigate the possibility to implement it, not only for the self-propelled mortar but also for use with the m/41 in standard use. What needs to be investigated is;

1. Which dimensions are most suitable for the Swedish use
2. How does it affect the grenades and their trajectory
3. Comparative test between BAD and adding an elongation of the barrel corresponding to the length of the barrel+BAD
4. At which degree it increases the recoil forces

6.2.3 Shorter and recoiling barrel

For implementing the open hatch solution, using the existing mortar m/41 would not be an optimal solution since it requires the chassis to absorb the recoil forces and it became obvious that it requires more space than the CV90 can provide. It is most likely that this concept will require a new weapon system. Most new mortars that are suitable for this task has a shorter barrel then the m/41 and also have the ability to absorb the recoil forces. If a shorter, recoiling barrel is to be used it requires investigations of how it affects the use with the grenades currently in service by the Swedish Armed Forces. A shorter barrel also requires further testing of the sound pressure level if this information is not supplied by the manufacturer.

6.2.4 Fluid mechanics

As can be seen in Figure 42 the flow is very different for the two scenarios. It is a possibility that further investigations on how to affect this flow can come up with new solutions and designs of the BAD and perhaps also for the barrel. It would also be interesting to study the flow for the different charges and see if that can explain why the highest charge did not give the highest sound pressure levels

7 REFERENCES

[1] Markstridsskolan, ”Battaljons artilleriet i morgondagens insatsförband,” Försvarsmakten , 2012.

[2] 12 cm granatkastare m/41 E-F - Instruktionsbok, Stockholm: Försvarets Materielverk, 2010.

[3] A. Säljö, F. Arrhen, H. Bolouri, M. Mayorga och A. Hamberger, ”Neuropathology and Pressure in the Pig Brain Resulting from Low-Impulse Noise Exposure,” *JOURNAL OF NEUROTRAUMA*, vol. 25, pp. 1397-1406, 2008.

[4] I. V. Hogg, Mortars, Ramsbury: The Crowood Press Ltd, 2001.

[5] ”firstworldwar.com,” [Online]. Available: http://www.firstworldwar.com/weaponry/mortars.htm. [Använd 25 05 2013].

[6] ”Army Training Network,” Department of the Army, 07 12 2007. [Online]. Available: https://rdl.train.army.mil/catalog/view/100.ATSC/079D2132-7C40-4E1A-ACA9-CC84C594234C-1300505809048/3-22.91/chap2.htm. [Använd 25 05 2013].

[7] 80 rökvinggranat 10 - Instruktionsbok, Stockholm: Försvarets Materielverk, 2011.

[8] "SäkI Art Grk Krb CAS," FMV, Stockholm, 2013.

[9] T&E, ”Impulsljudsundersökning GRK m/41,” FMV, Karlsborg, 2000.

[10] "SS-EN ISO 4869-2 Acoustics - Hearing protectors - Part 2 Estimation of effective A-weighted sound pressure levels when hearing protectors are worn," Standardiseringen i Sverige (SIS), Stockholm, 1994.

[11] "HKV 14990:7816 Försvarsmaktens regler för mätning av impulsljud från vapen och sprängning," Försvarsmakten - Högkvarteret, Stockholm, 2012.

[12] ”AFS 2005:16 Buller,” Arbetsmiljöverket, Stockholm, 2005.

[13] "ISO 10843:1997 Acoustics - Methods for description and physical measurements of single impulses or seris of impulses," The International Organization for Standardization, Genevé, 1997.

[14] "HKV 14990:59497 Försvarsmaktens regler för hörselskydd mot impulsljud vid skjutning med vapen och sprängning," Försvarsmakten - Högkvarteret, Stockholm, 2012.

[15] ”SS-EN 458:2005 Hörselskydd - Rekommendatioer för val, användning, skötsel och underhåll - Vägledande dokument,” Swedish Standards Institute (SIS), Stockholm, 2005.

[16] ”13FMV1227-3:1 Förstudie av impulsljud vid skjutning med strf-monterad GRK,” FMV Test and Evaluation Centre Karlsborg, Karlsborg, 2013.

[17] SäkI Gemensam 13, Stockholm: FMV, 2013.

ID number	Prio	Elevation	Side aiming	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches	Grenade
1	1	75°	0	Backwards	0	Closed	Min(5)	Without	45°	m/58
2	1	75°	0	Backwards	0	Closed	Mean(7)	Without	45°	m/58
3	1	75°	0	Backwards	0	Closed	Max(9)	Without	45°	m/58
4	0	75°	0	Backwards	0	Closed	Max(9)	Without	45°	m/86
5	1	45°	0	Backwards	0	Closed	Max(9)	Without	45°	m/58
6	2	85°	0	Backwards	0	Closed	Max(9)	Without	45°	m/58
7	1	75°	0	Backwards	0	Opened	Max(9)	Without	45°	m/58
8	1	45°	0	Backwards	0	Opened	Max(9)	Without	45°	m/58
9	2	85°	0	Backwards	0	Opened	Max(9)	Without	45°	m/58
10	1	75°	Max	Backwards	0	Closed	Max(9)	Without	45°	m/58
11	2	45°	Max	Backwards	0	Closed	Max(9)	Without	45°	m/58
12	2	85°	Max	Backwards	0	Closed	Max(9)	Without	45°	m/58
13	1	75°	0	Backwards	0	Closed	Min(5)	With	45°	m/58
14	1	75°	0	Backwards	0	Closed	Mean(7)	With	45°	m/58
15	1	75°	0	Backwards	0	Closed	Max(9)	With	45°	m/58
16	1	45°	0	Backwards	0	Closed	Max(9)	With	45°	m/58
17	2	85°	0	Backwards	0	Closed	Max(9)	With	45°	m/58
18	1	75°	0	Backwards	0	Opened	Max(9)	With	45°	m/58
19	2	45°	0	Backwards	-1	Closed	Max(9)	Without	45°	m/58

A2

ID number	Prio	Elevation	Side aiming	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches	Grenade
20	2	75°	0	Backwards	-1	Closed	Max(9)	Without	45°	m/58
21	2	85°	0	Backwards	-1	Closed	Max(9)	Without	45°	m/58
22	1	45°	0	Backwards	40 cm	Closed	Max(9)	Without	45°	m/58
23	1	75°	0	Backwards	40 cm	Closed	Max(9)	Without	45°	m/58
24	2	75°	0	Backwards	40 cm	Closed	Max(9)	With	45°	m/58
25	2	85°	0	Backwards	40 cm	Closed	Max(9)	Without	45°	m/58
26	2	75°	0	Backwards	0	Closed	Max(9)	Without	30°	m/58
27	2	75°	0	Backwards	0	Opened	Max(9)	Without	30°	m/58
28	2	75°	0	Forward	0	Closed	Min(5)	Without	45°	m/58
29	2	75°	0	Forward	0	Closed	Mean(7)	Without	45°	m/58
30	1	75°	0	Forward	0	Closed	Max(9)	Without	45°	m/58
31	0	75°	0	Forward	0	Closed	Max(9)	Without	45°	m/86
32	1	45°	0	Forward	0	Closed	Max(9)	Without	45°	m/58
33	2	85°	0	Forward	0	Closed	Max(9)	Without	45°	m/58
34	1	75°	0	Forward	0	Opened	Max(9)	Without	45°	m/58
35	2	45°	0	Forward	0	Opened	Max(9)	Without	45°	m/58
36	2	85°	0	Forward	0	Opened	Max(9)	Without	45°	m/58
37	2	75°	Max	Forward	0	Closed	Max(9)	Without	45°	m/58
38	3	45°	Max	Forward	0	Closed	Max(9)	Without	45°	m/58
39	2	85°	Max	Forward	0	Closed	Max(9)	Without	45°	m/58
40	2	75°	0	Forward	0	Closed	Min(5)	With	45°	m/58
41	2	75°	0	Forward	0	Closed	Mean(7)	With	45°	m/58

ID number	Prio	Elevation	Side aiming	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches	Grenade
42	1	75°	0	Forward	0	Closed	Max(9)	With	45°	m/58
43	2	45°	0	Forward	0	Closed	Max(9)	With	45°	m/58
44	2	85°	0	Forward	0	Closed	Max(9)	With	45°	m/58
45	1	75°	0	Forward	0	Opened	Max(9)	With	45°	m/58
46	3	45°	0	Forward	-1	Closed	Max(9)	Without	45°	m/58
47	3	75°	0	Forward	-1	Closed	Max(9)	Without	45°	m/58
48	3	85°	0	Forward	-1	Closed	Max(9)	Without	45°	m/58
49	3	45°	0	Forward	40 cm	Closed	Max(9)	Without	45°	m/58
50	3	75°	0	Forward	40 cm	Closed	Max(9)	Without	45°	m/58
51	3	75°	0	Forward	40 cm	Closed	Max(9)	With	45°	m/58
52	3	85°	0	Forward	40 cm	Closed	Max(9)	Without	45°	m/58
53	3	75°	0	Forward	0	Closed	Max(9)	Without	30°	m/58
54	3	75°	0	Forward	0	Opened	Max(9)	Without	30°	m/58
55	3	75°	0	Side	0	Closed	Min(5)	Without	45°	m/58
56	3	75°	0	Side	0	Closed	Mean(7)	Without	45°	m/58
57	1	75°	0	Side	0	Closed	Max(9)	Without	45°	m/58
58	0	75°	0	Side	0	Closed	Max(9)	Without	45°	m/86
59	1	45°	0	Side	0	Closed	Max(9)	Without	45°	m/58
60	3	85°	0	Side	0	Closed	Max(9)	Without	45°	m/58
61	1	75°	0	Side	0	Opened	Max(9)	Without	45°	m/58
62	3	45°	0	Side	0	Opened	Max(9)	Without	45°	m/58
63	3	85°	0	Side	0	Opened	Max(9)	Without	45°	m/58

A4

ID number	Prio	Elevation	Side aiming	Direction	Elevated chassis	Rear door	Charge	BAD	Roof hatches	Grenade
64	2	75°	Max	Side	0	Closed	Max(9)	Without	45°	m/58
65	3	45°	Max	Side	0	Closed	Max(9)	Without	45°	m/58
66	3	85°	Max	Side	0	Closed	Max(9)	Without	45°	m/58
67	3	75°	0	Side	0	Closed	Min(5)	With	45°	m/58
68	3	75°	0	Side	0	Closed	Mean(7)	With	45°	m/58
69	1	75°	0	Side	0	Closed	Max(9)	With	45°	m/58
70	3	45°	0	Side	0	Closed	Max(9)	With	45°	m/58
71	3	85°	0	Side	0	Closed	Max(9)	With	45°	m/58
72	1	75°	0	Side	0	Opened	Max(9)	With	45°	m/58
73	3	45°	0	Side	-1	Closed	Max(9)	Without	45°	m/58
74	3	75°	0	Side	-1	Closed	Max(9)	Without	45°	m/58
75	3	85°	0	Side	-1	Closed	Max(9)	Without	45°	m/58
76	3	45°	0	Side	40 cm	Closed	Max(9)	Without	45°	m/58
77	3	75°	0	Side	40 cm	Closed	Max(9)	Without	45°	m/58
78	3	75°	0	Side	40 cm	Closed	Max(9)	With	45°	m/58
79	3	85°	0	Side	40 cm	Closed	Max(9)	Without	45°	m/58
80	3	75°	0	Side	0	Closed	Max(9)	Without	30°	m/58
81	3	75°	0	Side	0	Opened	Max(9)	Without	30°	m/58

$L_{pC,Peak}$

ID	MP1				MP2				MP3			
	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min
1	169.4	169.9	168.9	1.0	170.8	171.5	169.4	2.0	175.9	176.6	175.4	1.2
2	172.0	172.8	171.0	1.8	173.3	175.5	172.0	3.6	178.3	179.4	176.4	3.0
3	173.1	174.9	170.0	4.9	171.5	171.8	171.0	0.8	178.1	179.5	176.7	2.9
5	172.6	173.7	170.7	3.0	174.0	175.3	171.5	3.8	179.6	181.1	178.6	2.5
6	170.2	171.5	168.6	2.9	172.6	173.5	171.6	1.9	176.8	178.4	175.5	2.9
7	172.3	173.2	170.9	2.3	170.4	172.0	168.9	3.1	178.6	179.6	177.8	1.8
8	173.2	173.7	172.3	1.4	174.8	177.0	172.0	4.9	178.3	179.3	176.8	2.5
9	171.4	173.4	169.9	3.6	172.9	173.9	170.4	3.5	177.5	178.3	176.5	1.9
13	164.7	167.2	162.3	4.9	163.2	165.2	161.8	3.4	164.9	168.2	162.6	5.6
14	166.6	167.3	165.3	2.0	167.7	169.9	163.6	6.3	169.2	170.3	165.6	4.7
15	170.6	172.0	168.9	3.1	166.8	167.4	166.0	1.5	170.9	172.6	169.4	3.2
16	169.5	171.5	168.3	3.2	167.3	168.4	166.6	1.9	171.9	172.2	171.3	0.8
17	164.9	165.4	164.3	1.1	164.0	164.6	162.3	2.3	170.2	171.9	167.9	4.0
18	169.9	171.5	168.9	2.5	167.6	169.0	166.5	2.5	169.7	171.5	167.9	3.5
23	172.8	174.5	170.3	4.1	175.3	177.3	173.8	3.5	180.7	181.5	180.1	1.4
24	167.3	170.0	164.1	5.9	168.1	169.5	167.3	2.2	171.4	173.2	169.8	3.4
30	170.9	172.7	169.6	3.2	176.4	177.3	175.1	2.2	174.1	174.5	173.8	0.7
32	172.3	173.4	171.2	2.2	170.3	170.7	169.8	0.9	172.6	174.2	171.6	2.5
33	173.2	174.5	171.7	2.8	173.7	174.3	173.0	1.4	176.2	176.5	176.0	0.6
34	172.4	173.2	170.8	2.4	175.4	176.3	174.7	1.6	175.1	176.5	172.5	4.0
42	166.8	168.4	165.1	3.3	164.4	165.7	163.4	2.4	171.6	172.7	169.4	3.3
43	167.4	167.9	166.8	1.2	165.4	166.8	164.1	2.7	169.9	171.2	168.4	2.8
45	167.0	168.5	166.0	2.5	165.1	165.6	164.8	0.8	171.6	172.4	170.5	1.9
53	174.8	177.6	172.0	5.6	174.0	175.6	172.3	3.3	175.9	176.4	174.4	2.0
54	175.4	177.7	173.1	4.5	173.5	174.6	172.2	2.4	175.2	177.4	173.2	4.1
57	171.6	172.8	170.6	2.2	173.5	174.9	172.2	2.7	174.5	175.0	174.2	0.8
61	171.5	173.2	170.0	3.3	174.0	175.0	173.4	1.6	173.5	174.4	171.8	2.6
69	167.7	169.8	165.4	4.4	165.9	167.9	163.1	4.8	173.3	175.8	170.5	5.3
72	168.3	170.5	165.7	4.7	165.9	167.6	163.4	4.2	172.7	174.6	170.7	3.9

$L_{pC,Peak}$

ID	MP4				MP5				MP6			
	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min
1	175.2	175.3	175.1	0.2	167.9	168.7	167.3	1.4	168.0	168.9	167.4	1.5
2	177.6	178.5	175.9	2.6	169.2	169.8	168.1	1.7	168.9	170.8	167.1	3.7
3	175.8	176.8	175.1	1.7	166.2	167.2	165.2	2.0	167.8	169.1	167.1	2.0
5	180.9	181.9	179.5	2.5	167.3	168.4	166.2	2.3	167.6	168.5	167.0	1.5
6	175.8	176.2	175.1	1.1	166.8	168.0	165.8	2.2	168.6	170.5	167.4	3.1
7	176.5	176.6	176.3	0.4	166.6	167.3	166.2	1.1	165.8	166.5	165.1	1.3
8	180.6	182.7	178.9	3.9	169.0	169.3	168.8	0.5	168.7	169.6	167.7	1.9
9	175.8	177.0	174.5	2.5	166.4	167.3	164.9	2.4	167.0	167.5	166.8	0.7
13	164.3	167.1	161.9	5.2	159.3	162.1	156.7	5.3	158.6	162.7	156.3	6.4
14	170.0	170.7	169.4	1.4	162.0	162.7	161.7	1.1	163.7	165.1	160.7	4.3
15	170.5	172.4	168.2	4.1	163.7	165.8	161.9	3.9	163.4	164.7	162.0	2.7
16	171.2	172.1	170.7	1.4	165.0	166.1	164.2	1.9	165.4	166.8	164.6	2.2
17	169.5	172.3	167.9	4.5	160.9	161.8	159.9	1.9	162.8	164.3	161.8	2.5
18	170.3	172.1	168.7	3.4	161.7	163.0	160.5	2.5	164.3	165.5	163.0	2.5
23	183.6	184.6	181.7	2.9	168.9	171.8	166.6	5.1	170.7	171.4	169.6	1.8
24	173.3	174.6	170.5	4.1	164.2	165.9	162.8	3.1	165.6	167.9	163.7	4.2
30	176.9	177.2	176.3	0.9	168.7	169.7	168.1	1.6	167.6	168.0	167.3	0.7
32	174.4	175.4	173.0	2.4	166.6	167.3	165.8	1.5	167.1	167.5	166.2	1.3
33	177.0	178.7	174.7	4.1	167.6	168.4	166.4	1.9	166.5	167.8	164.7	3.1
34	174.8	176.1	174.1	2.0	168.0	169.6	166.7	3.0	167.2	167.8	166.4	1.3
42	172.7	174.4	171.6	2.9	164.0	166.1	162.2	3.9	162.8	163.7	161.2	2.4
43	170.2	173.2	167.8	5.4	161.3	162.2	159.9	2.3	161.4	162.6	159.9	2.7
45	173.2	173.8	171.8	2.0	163.3	166.1	161.1	5.0	161.0	162.0	158.9	3.1
53	175.5	177.0	173.7	3.3	168.1	168.5	167.4	1.1	167.9	168.4	167.3	1.0
54	174.8	176.3	172.8	3.5	168.6	170.0	167.5	2.5	167.7	168.1	167.2	0.9
57	176.5	178.0	175.0	3.0	168.4	169.7	166.3	3.4	167.7	168.4	167.2	1.2
61	177.4	178.8	176.5	2.4	168.5	168.9	168.1	0.9	167.2	167.9	166.6	1.3
69	172.6	176.2	168.2	8.0	165.3	166.2	164.0	2.2	166.1	167.0	164.9	2.1
72	172.7	175.9	168.2	7.7	163.9	165.3	160.5	4.9	164.9	167.6	160.2	7.5

$L_{pC,1s}$

ID	MP1				MP2				MP3			
	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min
1	148.4	148.7	147.8	0.9	146.6	147.3	146.2	1.1	150.1	150.3	149.9	0.5
2	149.5	149.9	149.2	0.7	148.8	149.0	148.4	0.7	151.3	152.3	149.4	3.0
3	150.1	150.6	149.8	0.9	149.1	149.7	148.5	1.2	151.1	151.3	151.0	0.3
5	150.8	151.7	149.9	1.8	150.8	151.9	150.0	1.8	151.0	151.2	150.9	0.3
6	148.7	149.5	148.2	1.3	148.5	149.0	148.2	0.8	150.6	151.3	150.0	1.3
7	149.3	150.1	148.4	1.7	148.3	149.0	147.4	1.6	150.0	150.7	149.5	1.2
8	151.4	152.0	150.4	1.6	151.6	152.3	150.0	2.3	151.2	152.0	149.9	2.1
9	148.3	149.9	147.5	2.4	148.0	149.6	147.1	2.5	149.6	150.2	148.8	1.4
13	142.4	145.0	140.9	4.1	140.1	143.4	137.8	5.6	141.5	144.2	139.9	4.3
14	145.2	145.8	145.0	0.8	143.8	143.9	143.6	0.3	145.2	145.5	144.9	0.5
15	147.1	148.0	146.4	1.6	144.7	146.4	143.8	2.6	146.3	146.7	145.8	0.8
16	147.9	148.8	147.0	1.8	146.4	147.4	145.5	1.8	147.6	148.6	146.8	1.9
17	143.7	144.8	143.1	1.7	142.7	144.3	141.7	2.5	145.6	147.0	144.5	2.5
18	146.6	147.3	146.0	1.2	144.8	145.5	144.3	1.2	145.4	146.2	144.8	1.4
23	149.1	149.7	148.0	1.7	150.6	151.1	150.0	1.0	153.3	153.9	152.5	1.4
24	144.3	145.4	143.2	2.3	145.5	146.5	144.7	1.8	147.9	148.3	146.9	1.4
30	149.0	149.3	148.8	0.5	148.7	149.0	148.2	0.8	150.7	151.9	150.0	1.9
32	150.0	150.3	149.8	0.5	149.2	149.5	148.7	0.8	148.7	148.8	148.5	0.3
33	149.8	150.1	149.2	0.9	147.8	148.4	147.1	1.3	150.8	151.6	149.9	1.7
34	149.2	149.6	148.8	0.8	148.3	149.0	147.7	1.3	149.3	149.3	149.2	0.1
42	145.2	145.9	144.8	1.1	143.2	143.8	142.4	1.4	147.7	148.0	147.2	0.7
43	145.7	146.4	145.0	1.3	144.8	145.7	143.6	2.1	145.9	146.9	145.2	1.7
45	145.7	147.0	145.1	1.9	143.7	145.2	142.8	2.5	147.7	148.8	147.0	1.8
53	150.4	151.5	149.5	2.0	149.5	150.3	148.6	1.7	151.9	152.4	151.6	0.9
54	150.6	151.6	149.7	1.9	149.5	150.3	148.6	1.8	151.1	152.2	150.3	1.9
57	149.6	150.6	148.9	1.8	147.4	148.2	146.5	1.7	149.5	150.0	148.9	1.2
61	149.8	150.7	149.2	1.5	147.9	148.5	147.4	1.1	149.2	149.8	148.9	0.9
69	146.6	147.4	145.3	2.1	144.0	145.0	143.0	2.1	147.7	149.0	146.9	2.1
72	146.9	148.8	144.7	4.1	144.0	146.1	141.4	4.7	146.6	148.3	145.3	3.1

$L_{pC,1s}$

ID	MP4				MP5				MP6			
	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min	Mean	Max	Min	Max-Min
1	149.6	150.0	149.3	0.7	147.1	147.5	146.8	0.7	147.3	147.7	147.0	0.8
2	150.9	152.1	149.3	2.8	147.2	148.3	145.8	2.5	147.4	148.5	146.0	2.4
3	150.0	150.2	149.7	0.5	145.7	146.2	145.3	1.0	146.2	146.6	145.8	0.8
5	151.7	152.2	151.4	0.8	146.2	146.8	145.6	1.2	146.6	147.0	146.0	1.0
6	150.1	150.7	149.4	1.3	145.8	146.1	145.4	0.6	146.4	146.7	146.1	0.5
7	149.0	149.8	148.5	1.3	145.1	145.4	144.8	0.6	145.7	146.0	145.4	0.6
8	152.1	153.1	150.5	2.7	147.4	147.7	147.0	0.7	147.9	148.4	147.6	0.7
9	148.9	149.5	148.0	1.5	145.5	145.7	145.2	0.5	146.2	146.6	145.8	0.8
13	141.1	143.7	139.3	4.4	137.1	140.1	135.4	4.7	137.4	140.7	135.6	5.1
14	144.9	145.6	144.2	1.4	140.7	142.1	139.7	2.4	141.3	142.7	140.4	2.3
15	145.9	146.5	145.3	1.2	141.4	142.7	140.7	2.0	141.7	142.6	141.1	1.5
16	147.6	147.8	147.5	0.3	142.5	143.0	141.9	1.1	143.2	144.1	142.4	1.7
17	145.0	146.9	143.8	3.1	139.4	140.4	138.6	1.8	140.5	140.9	140.1	0.8
18	145.3	145.9	144.9	1.0	141.1	141.5	140.4	1.2	141.9	142.6	141.5	1.1
23	153.3	154.2	152.5	1.7	147.5	149.5	146.2	3.3	148.6	150.5	147.4	3.0
24	146.4	147.5	145.6	1.9	142.0	144.3	141.0	3.2	143.2	145.5	142.0	3.5
30	150.9	151.8	149.9	1.9	146.8	147.2	146.6	0.6	146.8	147.3	146.5	0.8
32	148.3	148.5	147.9	0.7	145.2	145.4	145.0	0.3	145.2	145.6	145.0	0.6
33	150.7	151.9	149.8	2.1	146.5	147.4	146.0	1.4	146.1	147.1	145.3	1.7
34	150.2	150.8	149.6	1.1	146.0	146.4	145.6	0.8	145.9	146.1	145.7	0.4
42	147.2	147.7	146.5	1.2	141.7	143.9	140.3	3.6	140.9	143.5	139.5	4.0
43	145.7	146.6	144.8	1.8	139.6	140.7	138.8	1.9	139.6	141.0	138.8	2.2
45	147.6	148.4	147.0	1.4	141.2	142.2	140.6	1.6	139.9	140.4	139.5	0.9
53	152.2	152.8	151.5	1.3	146.8	147.2	146.2	1.0	146.7	147.1	146.2	0.9
54	151.0	152.1	149.4	2.7	147.1	147.6	146.6	1.0	146.7	147.2	146.2	1.0
57	150.2	150.6	149.6	1.0	146.7	147.2	145.9	1.3	145.9	146.3	145.4	0.9
61	149.7	149.9	149.5	0.4	146.9	147.3	146.6	0.6	146.1	146.4	145.8	0.6
69	147.9	149.4	146.7	2.7	144.4	146.0	143.0	3.0	144.1	145.8	142.7	3.1
72	146.7	149.0	144.5	4.4	142.6	144.3	140.5	3.8	141.8	143.0	139.6	3.3

Permissible number of firings

ID	MP1 Min/Max	MP2 Min/Max	MP3 Min/Max	MP4 Min/Max	MP5 Min/Max	MP6 Min/Max
1	Unl/Unl	149/Unl	73/82	80/94	Unl/Unl	Unl/Unl
2	81/Unl	99/115	46/92	49/93	Unl/Unl	Unl/Unl
3	68/Unl	84/111	58/63	75/84	Unl/Unl	Unl/Unl
5	53/Unl	51/78	59/64	47/57	Unl/Unl	Unl/Unl
6	89/Unl	99/119	59/79	67/91	Unl/Unl	Unl/Unl
7	77/Unl	99/Unl	66/89	83/111	Unl/Unl	Unl/Unl
8	50/72	46/78	49/81	38/71	Unl/Unl	Unl/Unl
9	81/Unl	86/Unl	76/104	89/126	Unl/Unl	Unl/Unl
13	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl
14	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl	Unl/Unl
15	125/Unl	Unl/Unl	171/Unl	178/Unl	Unl/Unl	Unl/Unl
16	104/Unl	Unl/Unl	109/167	140/Unl	Unl/Unl	Unl/Unl
17	Unl/Unl	Unl/Unl	193/Unl	160/Unl	Unl/Unl	Unl/Unl
18	153/Unl	Unl/Unl	190/unl	203/Unl	Unl/Unl	Unl/Unl
23	85/Unl	62/78	32/45	30/44	89/Unl	143/Unl
24	Unl/Unl	Unl/Unl	116/Unl	140/Unl	Unl/Unl	Unl/Unl
57	68/Unl	121/177	78/102	68/86	Unl/Unl	Unl/Unl
61	67/Unl	111/145	83/103	82/89	Unl/Unl	Unl/Unl
69	Unl/Unl	Unl/Unl	100/Unl	91/Unl	Unl/Unl	Unl/Unl
72	Unl/Unl	Unl/Unl	116/Unl	100/Unl	Unl/Unl	Unl/Unl
30	92/Unl	99/Unl	51/79	52/82	Unl/Unl	Unl/Unl
32	74/83	Unl/Unl	104/111	111/129	Unl/Unl	Unl/Unl
33	77/95	115/154	55/81	51/83	Unl/Unl	Unl/Unl
34	87/Unl	99/135	92/95	66/86	Unl/Unl	Unl/Unl
42	Unl/Unl	Unl/Unl	129/Unl	133/176	Unl/Unl	Unl/Unl
43	Unl/Unl	Unl/Unl	163/Unl	174/Unl	Unl/Unl	Unl/Unl
45	Unl/Unl	Unl/Unl	105/Unl	114/158	Unl/Unl	Unl/Unl
53	56/89	74/110	45/55	41/56	Unl/Unl	Unl/Unl
54	54/84	73/110	47/74	49/91	Unl/Unl	Unl/Unl

Charge – BAD ($L_{pC,Peak}$)

MP1 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	42.13	2	0	21.07	8.55	0.003
BAD	194.86	1	0	194.86	79.07	0.000
Charge*BAD	7.51	2	0	3.76	1.52	0.248
Error	39.43	16	0	2.46		
Total	299.00	21	0			

MP2 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	67.82	2	0	33.91	10.10	0.001
BAD	459.58	1	0	459.58	136.93	0.000
Charge*BAD	13.74	2	0	6.87	2.05	0.162
Error	53.70	16	0	3.36		
Total	617.79	21	0			

MP3 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	69.96	2	0	34.98	17.98	0.000
BAD	350.25	1	0	350.25	179.99	0.000
Charge*BAD	28.11	2	0	14.05	7.22	0.006
Error	31.14	16	0	1.95		
Total	506.81	21	0			

MP4 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	16.76	2	0	8.38	4.43	0.030
BAD	209.30	1	0	209.30	110.51	0.000
Charge*BAD	34.34	2	0	17.17	9.07	0.002
Error	30.30	16	0	1.89		
Total	307.12	21	0			

MP5 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	38.20	2	0	19.10	5.53	0.015
BAD	228.63	1	0	228.63	66.15	0.000
Charge*BAD	28.91	2	0	14.45	4.18	0.035
Error	55.30	16	0	3.46		
Total	366.29	21	0			

MP6 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	23.58	2	0	11.79	3.14	0.071
BAD	244.60	1	0	244.60	65.12	0.000
Charge*BAD	29.25	2	0	14.62	3.89	0.042
Error	60.09	16	0	3.76		
Total	348.68	21	0			

C2

Charge – BAD ($L_{pC,1s}$)

MP1 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	50.21	2	0	25.11	17.71	0.000
BAD	149.96	1	0	149.96	105.76	0.000
Charge*BAD	3.75	2	0	1.87	1.32	0.294
Error	22.69	16	0	1.42		
Total	236.32	21	0			

MP2 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	35.16	2	0	17.58	15.11	0.000
BAD	227.84	1	0	227.84	195.91	0.000
Charge*BAD	12.60	2	0	6.30	5.42	0.016
Error	18.61	16	0	1.16		
Total	306.37	21	0			

MP3 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	30.49	2	0	15.24	11.92	0.001
BAD	210.17	1	0	210.17	164.42	0.000
Charge*BAD	16.84	2	0	8.42	6.59	0.008
Error	20.45	16	0	1.28		
Total	291.67	21	0			

MP4 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	14.01	2	0	7.01	4.54	0.027
BAD	259.34	1	0	259.34	168.07	0.000
Charge*BAD	28.70	2	0	14.35	9.30	0.002
Error	24.69	16	0	1.54		
Total	338.45	21	0			

MP5 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	16.19	2	0	8.10	5.30	0.017
BAD	248.59	1	0	248.59	162.64	0.000
Charge*BAD	26.10	2	0	13.05	8.54	0.003
Error	24.46	16	0	1.53		
Total	326.41	21	0			

MP6 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Charge	19.43	2	0	9.72	14.17	0.000
BAD	132.13	1	0	132.13	192.67	0.000
Charge*BAD	14.82	2	0	7.41	10.81	0.001
Error	10.97	16	0	0.69		
Total	185.49	21	0			

Elevated chassis - BAD ($L_{pC,Peak}$)

MP1 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	22.78	1	0	22.78	21.40	0.001
BAD	127.30	1	0	127.30	119.59	0.000
Elevated chassis*BAD	5.34	1	0	5.34	5.02	0.047
Error	11.71	11	0	1.06		
Total	178.80	14	0			

MP4 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	9.31	1	0	9.31	3.27	0.098
BAD	48.88	1	0	48.88	17.17	0.002
Elevated chassis*BAD	3.23	1	0	3.23	1.13	0.310
Error	31.32	11	0	2.85		
Total	97.53	14	0			

MP2 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	9.31	1	0	9.31	5.31	0.042
BAD	253.89	1	0	253.89	144.75	0.000
Elevated chassis*BAD	3.96	1	0	3.96	2.26	0.161
Error	19.29	11	0	1.75		
Total	300.15	14	0			

MP5 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	23.51	1	0	23.51	12.31	0.005
BAD	86.63	1	0	86.63	45.36	0.000
Elevated chassis*BAD	0.58	1	0	0.58	0.30	0.592
Error	21.01	11	0	1.91		
Total	139.96	14	0			

MP3 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	101.51	1	0	101.51	43.15	0.000
BAD	232.62	1	0	232.62	98.88	0.000
Elevated chassis*BAD	22.76	1	0	22.76	9.67	0.010
Error	25.88	11	0	2.35		
Total	412.50	14	0			

MP6 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	14.97	1	0	14.97	4.08	0.068
BAD	173.40	1	0	173.40	47.31	0.000
Elevated chassis*BAD	0.16	1	0	0.16	0.04	0.837
Error	40.31	11	0	3.66		
Total	238.84	14	0			

 C3

Elevated chassis – BAD ($L_{pC,1s}$)

MP1 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	4.52	1	0	4.52	7.16	0.022
BAD	83.29	1	0	83.29	132.09	0.000
Elevated chassis*BAD	0.41	1	0	0.41	0.65	0.437
Error	6.94	11	0	0.63		
Total	99.59	14	0			

MP4 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	5.73	1	0	5.73	4.01	0.071
BAD	89.58	1	0	89.58	62.72	0.000
Elevated chassis*BAD	1.33	1	0	1.33	0.93	0.355
Error	15.71	11	0	1.43		
Total	117.88	14	0			

MP2 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	13.09	1	0	13.09	47.97	0.000
BAD	96.70	1	0	96.70	354.46	0.000
Elevated chassis*BAD	0.34	1	0	0.34	1.24	0.289
Error	3.00	11	0	0.27		
Total	120.01	14	0			

MP5 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	13.77	1	0	13.77	10.85	0.007
BAD	90.13	1	0	90.13	70.99	0.000
Elevated chassis*BAD	0.76	1	0	0.76	0.60	0.454
Error	13.97	11	0	1.27		
Total	125.62	14	0			

MP3 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	13.43	1	0	13.43	32.13	0.000
BAD	112.45	1	0	112.45	269.04	0.000
Elevated chassis*BAD	7.12	1	0	7.12	17.03	0.002
Error	4.60	11	0	0.42		
Total	147.37	14	0			

MP6 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Elevated chassis	8.88	1	0	8.88	25.55	0.000
BAD	39.86	1	0	39.86	114.76	0.000
Elevated chassis*BAD	0.27	1	0	0.27	0.78	0.397
Error	3.82	11	0	0.35		
Total	56.33	14	0			

Rear Hatches – Roof Hatches ($L_{pC,Peak}$)

MP1 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	1.65	1	0	1.65	1.27	0.287
Roof hatches	15.74	1	0	15.74	12.09	0.006
Rear hatch*Roof hatches	0.22	1	0	0.22	0.17	0.687
Error	13.02	10	0	1.30		
Total	30.49	13	0			

MP4 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.10	1	0	0.10	0.09	0.767
Roof hatches	0.00	1	0	0.00	0.00	0.996
Rear hatch*Roof hatches	1.22	1	0	1.22	1.09	0.320
Error	11.19	10	0	1.12		
Total	12.44	13	0			

MP2 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.00	1	0	0.00	0.00	0.994
Roof hatches	2.57	1	0	2.57	1.03	0.334
Rear hatch*Roof hatches	2.53	1	0	2.53	1.01	0.338
Error	24.99	10	0	2.50		
Total	30.15	13	0			

MP5 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.30	1	0	0.30	1.28	0.285
Roof hatches	0.54	1	0	0.54	2.28	0.162
Rear hatch*Roof hatches	0.02	1	0	0.02	0.07	0.798
Error	2.39	10	0	0.24		
Total	3.24	13	0			

MP3 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	7.03	1	0	7.03	4.61	0.057
Roof hatches	2.04	1	0	2.04	1.34	0.274
Rear hatch*Roof hatches	1.50	1	0	1.50	0.98	0.345
Error	15.25	10	0	1.53		
Total	25.05	13	0			

MP6 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	1.39	1	0	1.39	0.90	0.365
Roof hatches	35.13	1	0	35.13	22.81	0.001
Rear hatch*Roof hatches	3.10	1	0	3.10	2.01	0.186
Error	15.40	10	0	1.54		
Total	55.73	13	0			

C6

Rear Hatches – Roof Hatches ($L_{pC,1s}$)

MP1 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.12	1	0	0.12	0.23	0.640
Roof hatches	3.54	1	0	3.54	6.74	0.027
Rear hatch*Roof hatches	0.17	1	0	0.17	0.33	0.581
Error	5.25	10	0	0.53		
Total	9.05	13	0			

MP4 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.20	1	0	0.20	1.14	0.310
Roof hatches	0.86	1	0	0.86	4.84	0.052
Rear hatch*Roof hatches	1.06	1	0	1.06	5.96	0.035
Error	1.77	10	0	0.18		
Total	3.78	13	0			

MP2 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	4.15	1	0	4.15	9.22	0.013
Roof hatches	7.55	1	0	7.55	16.75	0.002
Rear hatch*Roof hatches	0.39	1	0	0.39	0.86	0.374
Error	4.51	10	0	0.45		
Total	16.33	13	0			

MP5 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.78	1	0	0.78	4.98	0.050
Roof hatches	0.57	1	0	0.57	3.68	0.084
Rear hatch*Roof hatches	0.74	1	0	0.74	4.74	0.055
Error	1.56	10	0	0.16		
Total	3.46	13	0			

MP3 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	3.18	1	0	3.18	4.25	0.066
Roof hatches	4.23	1	0	4.23	5.65	0.039
Rear hatch*Roof hatches	0.24	1	0	0.24	0.32	0.584
Error	7.49	10	0	0.75		
Total	15.47	13	0			

MP6 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
Rear hatch	0.10	1	0	0.10	0.22	0.647
Roof hatches	0.98	1	0	0.98	2.13	0.175
Rear hatch*Roof hatches	0.09	1	0	0.09	0.20	0.667
Error	4.61	10	0	0.46		
Total	5.82	13	0			

Direction - Rear door - BAD ($L_{pC,Peak}$)

MP1 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	598.44	1	0	598.44	373.73	0.000
Rear hatch	0.00	1	0	0.00	0.00	0.993
Direction	11.08	2	0	5.54	3.46	0.044
BAD*Rear hatch	3.04	1	0	3.04	1.90	0.178
BAD*Direction	94.08	2	0	47.04	29.38	0.000
Rear hatch*Direction	0.64	2	0	0.32	0.20	0.819
BAD*Rear hatch*Direction	3.01	2	0	1.50	0.94	0.402
Error	49.64	31	0	1.60		
Total	748.64	42	0			

MP2 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	598.44	1	0	598.44	373.73	0.000
Rear hatch	0.00	1	0	0.00	0.00	0.993
Direction	11.08	2	0	5.54	3.46	0.044
BAD*Rear hatch	3.04	1	0	3.04	1.90	0.178
BAD*Direction	94.08	2	0	47.04	29.38	0.000
Rear hatch*Direction	0.64	2	0	0.32	0.20	0.819
BAD*Rear hatch*Direction	3.01	2	0	1.50	0.94	0.402
Error	49.64	31	0	1.60		
Total	748.64	42	0			

MP3 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	210.47	1	0	210.47	52.55	0.000
Rear hatch	0.00	1	0	0.00	0.00	0.980
Direction	13.69	2	0	6.85	1.71	0.198
BAD*Rear hatch	0.27	1	0	0.27	0.07	0.797
BAD*Direction	14.34	2	0	7.17	1.79	0.184
Rear hatch*Direction	3.15	2	0	1.57	0.39	0.679
BAD*Rear hatch*Direction	6.35	2	0	3.17	0.79	0.462
Error	124.16	31	0	4.01		
Total	387.93	42	0			

MP4 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	185.42	1	0	185.42	78.54	0.000
Rear hatch	5.71	1	0	5.71	2.42	0.130
Direction	27.82	2	0	13.91	5.89	0.007
BAD*Rear hatch	4.95	1	0	4.95	2.10	0.158
BAD*Direction	2.14	2	0	1.07	0.45	0.640
Rear hatch*Direction	0.03	2	0	0.02	0.01	0.993
BAD*Rear hatch*Direction	2.19	2	0	1.10	0.46	0.633
Error	73.19	31	0	2.36		
Total	309.10	42	0			

C8

MP5 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	185.42	1	0	185.42	78.54	0.000
Rear hatch	5.71	1	0	5.71	2.42	0.130
Direction	27.82	2	0	13.91	5.89	0.007
BAD*Rear hatch	4.95	1	0	4.95	2.10	0.158
BAD*Direction	2.14	2	0	1.07	0.45	0.640
Rear hatch*Direction	0.03	2	0	0.02	0.01	0.993
BAD*Rear hatch*Direction	2.19	2	0	1.10	0.46	0.633
Error	73.19	31	0	2.36		
Total	309.10	42	0			

MP6 Peak

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	505.64	1	0	505.64	130.06	0.000
Rear hatch	4.91	1	0	4.91	1.26	0.270
Direction	40.75	2	0	20.37	5.24	0.011
BAD*Rear hatch	2.76	1	0	2.76	0.71	0.406
BAD*Direction	75.59	2	0	37.79	9.72	0.001
Rear hatch*Direction	0.98	2	0	0.49	0.13	0.883
BAD*Rear hatch*Direction	0.26	2	0	0.13	0.03	0.967
Error	120.52	31	0	3.89		
Total	752.23	42	0			

Direction - Rear door - BAD ($L_{pC,1s}$)

MP1 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	182.64	1	0	182.64	180.47	0.000
Rear hatch	0.02	1	0	0.02	0.02	0.884
Direction	7.13	2	0	3.57	3.52	0.042
BAD*Rear hatch	0.45	1	0	0.45	0.45	0.508
BAD*Direction	3.60	2	0	1.80	1.78	0.186
Rear hatch*Direction	0.73	2	0	0.36	0.36	0.701
BAD*Rear hatch*Direction	1.08	2	0	0.54	0.53	0.592
Error	31.37	31	0	1.01		
Total	225.92	42	0			

MP3 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	106.52	1	0	106.52	130.82	0.000
Rear hatch	3.73	1	0	3.73	4.58	0.040
Direction	14.92	2	0	7.46	9.16	0.001
BAD*Rear hatch	0.24	1	0	0.24	0.29	0.595
BAD*Direction	2.91	2	0	1.45	1.78	0.185
Rear hatch*Direction	0.85	2	0	0.43	0.52	0.597
BAD*Rear hatch*Direction	1.14	2	0	0.57	0.70	0.505
Error	25.24	31	0	0.81		
Total	164.34	42	0			

MP2 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	96.63	1	0	96.63	169.84	0.000
Rear hatch	6.89	1	0	6.89	12.12	0.002
Direction	3.12	2	0	1.56	2.75	0.080
BAD*Rear hatch	0.23	1	0	0.23	0.40	0.533
BAD*Direction	13.86	2	0	6.93	12.18	0.000
Rear hatch*Direction	0.24	2	0	0.12	0.21	0.811
BAD*Rear hatch*Direction	2.10	2	0	1.05	1.84	0.175
Error	17.64	31	0	0.57		
Total	148.51	42	0			

MP4 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	178.32	1	0	178.32	192.63	0.000
Rear hatch	4.12	1	0	4.12	4.45	0.043
Direction	25.60	2	0	12.80	13.83	0.000
BAD*Rear hatch	0.51	1	0	0.51	0.55	0.464
BAD*Direction	4.59	2	0	2.29	2.48	0.100
Rear hatch*Direction	0.23	2	0	0.11	0.12	0.886
BAD*Rear hatch*Direction	3.24	2	0	1.62	1.75	0.190
Error	28.70	31	0	0.93		
Total	247.94	42	0			

 C9

C10

MP5 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	197.33	1	0	197.33	229.41	0.000
Rear hatch	5.60	1	0	5.60	6.51	0.016
Direction	8.83	2	0	4.41	5.13	0.012
BAD*Rear hatch	0.88	1	0	0.88	1.02	0.321
BAD*Direction	14.74	2	0	7.37	8.57	0.001
Rear hatch*Direction	1.76	2	0	0.88	1.02	0.371
BAD*Rear hatch*Direction	4.82	2	0	2.41	2.80	0.076
Error	26.67	31	0	0.86		
Total	254.32	42	0			

MP6 EQ

Source	Sum Sq.	d.f.	Singular?	Mean Sq.	F	Prob>F
BAD	145.38	1	0	145.38	270.66	0.000
Rear hatch	0.00	1	0	0.00	0.00	0.997
Direction	10.71	2	0	5.36	9.97	0.000
BAD*Rear hatch	0.14	1	0	0.14	0.26	0.611
BAD*Direction	9.66	2	0	4.83	8.99	0.001
Rear hatch*Direction	0.31	2	0	0.15	0.28	0.754
BAD*Rear hatch*Direction	0.06	2	0	0.03	0.06	0.942
Error	16.65	31	0	0.54		
Total	181.78	42	0			

APPENDIX D MATLAB-CODE DATA ANALYZE

```
function varargout = testgui(varargin)
global p_ref
p_ref = 2*10^-5;   %[Pa];
% TESTGUI MATLAB code for testgui.fig
%      TESTGUI, by itself, creates a new TESTGUI or raises the existing
%      singleton*.
%
%      H = TESTGUI returns the handle to a new TESTGUI or the handle to
%      the existing singleton*.
%
%      TESTGUI('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in TESTGUI.M with the given input arguments.
%
%      TESTGUI('Property','Value',...) creates a new TESTGUI or raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before testgui_OpeningFcn gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to testgui_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help testgui

% Last Modified by GUIDE v2.5 13-Feb-2013 15:31:09

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @testgui_OpeningFcn, ...
                   'gui_OutputFcn',  @testgui_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before testgui is made visible.
function testgui_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to testgui (see VARARGIN)

% Choose default command line output for testgui
handles.output = hObject;
```

```
% Update handles structure
guidata(hObject, handles);

% UIWAIT makes testgui wait for user response (see UIRESUME)
% uiwait(handles.figure1);


% --- Outputs from this function are returned to the command line.
function varargout = testgui_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;


% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global d0 dx p y_unit x_unit t L_p names data p_ref
[filename, pathname] = ...
     uigetfile({'*.mat';'*.*'},'File Selector');
 set(handles.text1,'String',[pathname,'\', filename])
 data = load([pathname,filename]);
 names = fieldnames(data);
  p_ref = 2*10^-5;
  for loopIndex = 1:numel(names)
      temp_data = data.(names{loopIndex});
      ch_title{loopIndex} = temp_data.Channels.ChannelInfos.ChannelInfo.Name;
  end

  set(handles.popupmenu1,'String',ch_title)

  for loopIndex = 1:numel(names)
      loopIndex
      temp_data = data.(names{loopIndex});
      %x_unit = temp_data.xUnits;
      d0 = temp_data.Channels.Segments.Data.dX0;
      dx = temp_data.Channels.Segments.Data.dXstep;
      size temp_data.Channels.Segments.Data.Samples
      p.(names{loopIndex}) = temp_data.Channels.Segments.Data.Samples;
      x_unit.(names{loopIndex}) = temp_data.xUnits;
      y_unit.(names{loopIndex}) =
temp_data.Channels.ChannelInfos.ChannelInfo.YUnits;
      t.(names{loopIndex}) = 0:dx:(length(p)-1)*dx;
      L_p.(names{loopIndex}) =
10*log10((p.(names{loopIndex}).^2)./(p_ref.^2));
      %L_p(loopIndex,:) = 10*log10((p.^2)./(p_ref.^2));
      size t
  end
```

```
% --- Executes on selection change in popupmenu1.
function popupmenu1_Callback(hObject, eventdata, handles)
% hObject    handle to popupmenu1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns popupmenu1
contents as cell array
%        contents{get(hObject,'Value')} returns selected item from popupmenu1
global d0 dx p y_unit t ch_title



% --- Executes during object creation, after setting all properties.
function popupmenu1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to popupmenu1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end


% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global d0 dx p y_unit x_unit t L_p names data p_ref
MP =get(handles.popupmenu1,'Value')
for loopIndex = MP
      loopIndex
      temp_data = data.(names{loopIndex});
      d0 = temp_data.Channels.Segments.Data.dX0;
      dx = temp_data.Channels.Segments.Data.dXstep;
      p= temp_data.Channels.Segments.Data.Samples;
      x_unit = temp_data.xUnits;
      y_unit = temp_data.Channels.ChannelInfos.ChannelInfo.YUnits;
      t = 0:dx:(length(p)-1)*dx;
      L_p = 10*log10((p.^2)./(p_ref.^2));
      ch_title = temp_data.Channels.ChannelInfos.ChannelInfo.Name;
      axes(handles.axes1)
      Fs=1/dx;
      figure(10)
plot(t,p)
title(ch_title)
    xlabel(['Time [s]'])
    ylabel([' Pressure [Pa]'])
    axes(handles.axes2)

plot(t,L_p)
title(ch_title)
    xlabel(['Time [s]'])
    ylabel([' Pressure [dB]'])
%     axes(handles.axes3)
%     spectrogram(p,256,250,256,Fs)
    L=length(p);
```

```
    NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(p,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2+1);

% Plot single-sided amplitude spectrum.
axes(handles.axes4)
figure(20)
plot(f,2*abs(Y(1:NFFT/2+1)))
title('Single-Sided Amplitude Spectrum of y(t)')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
end

set(handles.text2,'String',[num2str(max(p)) ' [Pa]'])
set(handles.text3,'String',[num2str(max(L_p)) ' [dB]'])


% --- If Enable == 'on', executes on mouse press in 5 pixel border.
% --- Otherwise, executes on mouse press in 5 pixel border or over
popupmenu1.
function popupmenu1_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to popupmenu1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)



function edit1_Callback(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit1 as text
%        str2double(get(hObject,'String')) returns contents of edit1 as a
double


% --- Executes during object creation, after setting all properties.
function edit1_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

APPENDIX E MATLAB-CODE ANOVA

```
%% Examensarbete FMV
%  Simon Hallin
%  2013-04-16
%  simonhal@kth.se
%
%  Funktionen tar in värden från excel-fil och gör en Anovan
 clc, clear all, close all hidden
 set(0,'DefaultFigureWindowStyle','docked')
format long
warning off
time = clock;
%% Inställningar
% Skapa Excelfil
MakeXls = 1; % 0=Nej 1=Ja
FileName = ['FMV_Anova (' date ' kl. ' num2str(time(4)) '.' num2str(time(5))
').xlsx'];

% Anova - Visa tabeller
Tabell = 'on';
model=1;            % Antal interaktioner beräknade

%% Läsa in Excelfil
[ndata_Eq1s, text_Eq1s, alldata] = xlsread('Resultat
Analys.xlsx','Lcw,Eq1s');
[ndata_Peak, text_Peak, alldata] = xlsread('Resultat Analys.xlsx','Lcw,Max');
grubrik = text_Eq1s(1,1:12);
Pp_rubrik=text_Peak(1,28:33);
PEq_rubrik=text_Eq1s(1,13:18);


g3i = alldata(2:end,3);g3i=cell2mat(g3i);
%% Fastställa scenarion

% Riktning-Tratt-Bakre lucka
% Id=[3 7 15 18 30 34 42 45 57 61 69 72];

% Alla
Id=[1 2 3 5 6 7 8 9 13 14 15 16 17 18 23 24 30 32 33 34 42 43 45 53 54 57 61
69 72];
groups= [4 5 6 7 8 9 10];

% Bakåt
% Id=[1 2 3 5 6 7 8 9 13 14 15 16 17 18 23 24];
% groups = [4 6 7 8 9];

% Elevation-Bakre lucka-tratt (Bakåt)OK
% Id=[3 5 6 7 8 9 15 16 17 18];
% groups = [4 7 9];

% Tratt-Laddning (Bakåt) (inlagd)OK
% Id=[1 2 3 13 14 15];
% groups = [8 9];

% Tratt-Laddning-Baklucka
% Id=[1 2 3 7 13 14 15 18];
% groups = [7 8 9];
```

```
% Tratt-elevated chassis(inlagd)
% Id=[3 15 23 24];
% groups = [6 9];

% Roof hatches - Rear door (inlagd)
% Id=[30 34 53 54];
% groups = [7 10];

% Direction - Rear door - BAD (inlagd)
% Id= [3 7 15 18 30 34 42 45 57 61 69 72];
% groups = [9 7 5];

% Elevation - BAD (inlagd)
% Id= [3 5 6 15 16 17];
% groups = [4 9];

% Elevation - Direction
% Id= [3 5 6 30 32 33];
% groups = [4 5];

% Elevation - Rear door
% Id= [3 5 6 7 8 9];
% groups = [4 7];


iii=1;
for i=1:length(Id)
    for ii=1:length(g3i)
        if Id(i)==g3i(ii)
            index(iii)=ii;
            g(iii,1) = alldata(ii+1,1);
            g(iii,2) = alldata(ii+1,2);
            g(iii,3) = alldata(ii+1,3);
            g(iii,4) = alldata(ii+1,4);
            g(iii,5) = alldata(ii+1,5);
            g(iii,6) = alldata(ii+1,6);
            g(iii,7) = alldata(ii+1,7);
            g(iii,8) = alldata(ii+1,8);
            g(iii,9) = alldata(ii+1,9);
            g(iii,10) = alldata(ii+1,10);
            g(iii,11) = alldata(ii+1,11);
            g(iii,12) = alldata(ii+1,12);
            Pp(iii,:)=ndata_Peak(ii,28:33);
            PEq(iii,:)=ndata_Eq1s(ii,13:18);

            iii = iii+1;
        end
    end
end

t1 = [grubrik Pp_rubrik PEq_rubrik];
t2 = [g];
t3 = num2cell([Pp PEq]);

table= [t1;t2 t3];


%% ANOVA
```

```
for ind=1:length(groups)

group{:,ind}=g(:,groups(ind));
names(ind)=grubrik(groups(ind));
end


[P1_Eq.p,P1_Eq.table,P1_Eq.stats]=anovan(PEq(:,1),group,'model',model,'displa
y',Tabell,'varnames',names);
set(1,'name','P1_Eq')
[P2_Eq.p,P2_Eq.table,P2_Eq.stats]=anovan(PEq(:,2),group,'model',model,'displa
y',Tabell,'varnames',names);
set(2,'name','P2_Eq')
[P3_Eq.p,P3_Eq.table,P3_Eq.stats]=anovan(PEq(:,3),group,'model',model,'displa
y',Tabell,'varnames',names);
set(3,'name','P3_Eq')
[P4_Eq.p,P4_Eq.table,P4_Eq.stats]=anovan(PEq(:,4),group,'model',model,'displa
y',Tabell,'varnames',names);
set(4,'name','P4_Eq')
[P5_Eq.p,P5_Eq.table,P5_Eq.stats]=anovan(PEq(:,5),group,'model',model,'displa
y',Tabell,'varnames',names);
set(5,'name','P5_Eq')
[P6_Eq.p,P6_Eq.table,P6_Eq.stats]=anovan(PEq(:,6),group,'model',model,'displa
y',Tabell,'varnames',names);
set(6,'name','P6_Eq')

[P1_Peak.p,P1_Peak.table,P1_Peak.stats]=anovan(Pp(:,1),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(7,'name','P1_Peak')
[P2_Peak.p,P2_Peak.table,P2_Peak.stats]=anovan(Pp(:,2),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(8,'name','P2_Peak')
[P3_Peak.p,P3_Peak.table,P3_Peak.stats]=anovan(Pp(:,3),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(9,'name','P3_Peak')
[P4_Peak.p,P4_Peak.table,P4_Peak.stats]=anovan(Pp(:,4),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(10,'name','P4_Peak')
[P5_Peak.p,P5_Peak.table,P5_Peak.stats]=anovan(Pp(:,5),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(11,'name','P5_Peak')
[P6_Peak.p,P6_Peak.table,P6_Peak.stats]=anovan(Pp(:,6),group,'model',model,'d
isplay',Tabell,'varnames',names);
set(12,'name','P6_Peak')



%% Spara ANOVA till xlsx
if MakeXls==1
xlswrite(FileName,table,'Scenario')
xlswrite(FileName,P1_Eq.table,'P1_Eq')
xlswrite(FileName,P1_Peak.table,'P1_Peak')
xlswrite(FileName,P2_Eq.table,'P2_Eq')
xlswrite(FileName,P2_Peak.table,'P2_Peak')
xlswrite(FileName,P3_Eq.table,'P3_Eq')
xlswrite(FileName,P3_Peak.table,'P3_Peak')
xlswrite(FileName,P4_Eq.table,'P4_Eq')
xlswrite(FileName,P4_Peak.table,'P4_Peak')
xlswrite(FileName,P5_Eq.table,'P5_Eq')
xlswrite(FileName,P5_Peak.table,'P5_Peak')
```

```
xlswrite(FileName,P6_Eq.table,'P6_Eq')
xlswrite(FileName,P6_Peak.table,'P6_Peak')
disp(['Excelfil skapad: ' FileName])
else
    disp('Ingen Excelfil skapad!')
end
```