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English summary

IM classification of munitions requires testing according to STANAG 4439 (1). All tests have to be performed unless the Threat Hazard Analysis shows that specific threats in the STANAG do not exist for the life cycle of the specific munition. In some nations a full scale test may be replaced by small scale testing accompanied with simulations. In this report results from small scale testing of the explosive composition MCX-6100 have been used as input for simulations of Bullet Impact (BI) and Fragment Impact (FI) tests with the MSIAC TEMPER software. The munitions we have studied are 155 mm shells. MCX-6100 is a melt-cast composition to be used in this munition.

The TEMPER simulations of BI test with flat end rod on shell filled with MCX-6100 CH 6027/14 compositions show a *no reaction* response for the three shock sensitivities studied in this report. With TEMPER we have studied impact by only one bullet. The STANAG 4241(2) requires hit by three bullets. Shock properties of damaged explosive are not available for the MCX-6100 compositions. However, nothing in the obtained simulation results indicate problems to achieve a *no reaction* response in BI tests for a 155 mm shell filled with MCX-6100. The requirement in STANAG 4439 for the BI test to fulfill the IM requirements is a *type V reaction, no response more severe than burning.*

Simulations of FI test with a conical NATO fragment and the test conditions given in STANAG 4496 (3) have been performed on different shell thicknesses of shells filled with MCX-6100 having three different shock sensitivities. With a MCX-6100 filling with a shock sensitivity of 58.5 kbar, a shell thickness of 6 mm or more gives a *no reaction* response. With a MCX-6100 filling with a shock sensitivity of 47.5 kbar, a shell thickness of 8 mm or more gives a *no reaction* response. For MCX-6100 fillings with a shock sensitivity of 36.4 kbar, a shell thickness of 11 mm or thicker gives a *no reaction* response. The requirement in STANAG 4439 for the FI test to fulfill the IM requirements is a *type V reaction, no response more severe than burning.*

The simulations with TEMPER of both bullet and fragment impact tests show that the requirements in STANAG 4439 can be fulfilled. For the fragment impact test, however, the shock sensitivity of the MCX-6100 composition should be 50 kbar or better to obtain a *type V response*.

Sammendrag

For å oppnå IM-klassifisering av ammunisjon er det i STANAG 4439 (1) krav til testing. Disse testene må utføres med mindre en trusselvurdering viser at truslene i STANAG 4439 ikke forekommer i ammunisjonens livsløp. Fullskalatesting kan i noen nasjoner erstattes med småskalatester i kombinasjon med simuleringer. I denne rapporten er resultater fra småskalatesting av sprengstoffkomposisjonen MCX-6100 benyttet som inndata for simuleringer av testene «Bullet Impact» (BI) og «Fragment Impact» (FI) med MSIAC TEMPER-programvaren. Ammunisjonen vi har studert, er en 155 mm granat. MCX-6100 er en smeltestøpkomposisjon til bruk i denne ammunisjonstypen.

TEMPER-simuleringene av beskytning med en sylindrisk kule på en MCX-6100 CH 6027/14 fylt granat viser en *ikke-reaksjon*-respons for de tre sjokkfølsomhetene studert i denne rapporten. Treff av kun én kule er studert. Kravet i STANAG 4241 (2) er at målet skal treffes av tre kuler innenfor en radius på 50 mm. Sjokkfølsomhetsegenskapene til skadede MCX-6100-komposisjoner er ukjent. Ingenting i de oppnådde simuleringsresultatene tyder imidlertid på at ikke en *type V*-respons i BI-test kan oppnås med en MCX-6100-fylling. Kravet i STANAG 4439 for BI-test for å tilfredsstille kravet til IM er en *type V-respons, brann*.

Simuleringene av fragmentanslag med et konisk NATO-fragment under testbetingelser gitt i STANAG 4496 (3) er gjennomført mot en granat fylt med MCX-6100-komposisjoner med tre forskjellige sjokkfølsomheter. Variabelen er veggtykkelsen til granaten. For MCX-6100-fyllingen med sjokkfølsomhet 58.5 kbar gir en granatveggtykkelse på 6 mm eller mer en *ikke-reaksjon*. For MCX-6100-fyllingen med sjokkfølsomhet 47.5 kbar gir en granatveggtykkelse på 8 mm eller mer en *ikke-reaksjon*. Og for MCX-6100-fyllingen med sjokkfølsomhet 36.4 kbar kreves en veggtykkelse på 11 mm eller mer for å gi en *ikke-reaksjon*. Kravet i STANAG 4439 til FI for å tilfredsstille kravet til IM er en *type V-respons, brann*.

Simuleringen med TEMPER av kule- og fragmentanslagstest viser at for begge testene er kravene til IM i STANAG 4439 med en *type V*-respons oppnåelig. Men for fragmentanslagstesten bør det stilles krav til sjokkfølsomheten for MCX-6100-fyllingen. For å oppnå en *ikke-reaksjon*-respons bør sjokkfølsomheten til MCX-6100-fyllingen være +50 kbar.

Contents

Abbreviations

DNAN	2,4-dinitroanisole
BI	**B**ullet **I**mpact
FI	**F**ragment **I**mpact
IM	**I**nsensitive **M**unitions
IM HE-ER	**I**nsensitive **M**unitions High **E**xplosive **E**xtended **R**ange
IMX-104	NTO/DNAN/RDX (53/31.7/15.3) (5)
MCX	**M**elt **C**ast **E**xplosive
MCX-6100	NTO/DNAN/RDX (53/32/15)
MSIAC	**M**unitions **S**afety **I**nformation **A**nalysis Center
NTO	3-Nitro-1,2,4 triazole-5-one
NOL LSGT	**N**aval **O**rdnance **L**ab **L**arge **S**cale **G**ap **T**est
RDX	hexogen/1,3,5 -trinitro-1,3,5-triazacyclohexane
STANAG	Standardization Agreement
TEMPER	**T**oolbox of **E**ngineering **M**odels for **P**rediction of **E**xplosive **R**eaction
TMD	**T**heoretical **M**aximum **D**ensity
WC	**W**orst **C**redible

1 Introduction

MCX-6100 has been selected as main filling for a new 155 mm shell. MCX-6100 is a melt-cast composition containing DNAN as binder with NTO and RDX as filler. The nominal content is 32/53/15 (DNAN/NTO/RDX). The composition is manufactured by Chemring Nobel AS, and is under final qualification according to STANAG 4170 (4). MCX-6100 is based on the same ingredients as the US composition IMX-104 (5).

The composition was selected as main filler due to its low shock sensitivity and high potential to achieve a 155 mm shell with IM properties. The composition contains three different ingredients, a binder DNAN melting at 95°C and two solid fillers RDX and NTO with some solubility in melted DNAN. The solubility of RDX is higher than of NTO. DNAN, when going from liquid to solid has a volume decrease of 13.59 volume % (6), when it melts the volume increases by 15.72 %. A special cooling procedure is necessary during the casting to obtain an acceptable quality of the cast. This gives rise to sedimentation due to density differences specially between NTO (ρ(s) = 1.91 g/cm^3) and DNAN (ρ(l)=1.336 g/cm^3).

The sedimentation of MCX-6100 fillings was studied for different samples casted with different cooling procedures in plastic cylinders, gap test steel tubes and also 155 mm shells. Compositions for these test items as bared charges were analysed after removal of the moulds and the steel body of the 155 mm shells. The content and density in the top, middle and bottom of these fillings have been analysed and measured. The results have been used to determine porosity in longitudinal direction and theoretical performance by use of Cheetah 2.0 (7). These results were used to study the effect of sedimentation on reaction response in Sympathetic Reaction (8, 9).

In this report we have studied the effects differences in shock sensitivity of MCX-6100 fillings have on response of a 155 mm shell in Bullet Impact (BI) and Fragment Impact (FI). The BI and FI simulations have been performed with experimentally measured properties of the Acceptor. All simulations have been performed with TEMPER 2.2.2 (**T**oolbox of **E**ngineering **M**odels for **P**rediction of **E**xplosive **R**eactions) (10). The shock sensitivities of the acceptors included in this study are 36.4, 47.5 and 58.5 kbar. The low, 58.5 kbar (11), and high, 36.4 kbar (12) shock sensitivities must be seen as upper and lower limits of shock sensitivity for MXC-6100 depending on casting quality. 47.5 kbar is the average of the two tests. In (5) they operate in NOL LSGT with barrier from 106 up to 127 cards, or shock sensitivity from 55.2 to 48.2 kbar. In reference (13) for comparison, LSGT card gap value for regular flake IMX-104 melt casted is measured to120 cards (49.6 kbar), and the 50% point between go and no go for granulated IMX-104 baseline (ρ=1.66) is 155 cards (36.1 kbar).

BI simulations have been carried out with bullets with diameter from 5mm to 60 mm and velocity from 600 to 2600 m/s. The IM requirement is a 12.7 mm bullet at 850±20 m/s shall give a *Type V reaction*: No response more severe than burning. For FI-test the requirement for the NATO fragment with diameter 14.3 mm at 2530 m/s shall respond with a *Type V reaction*: No response more severe than burning.

2 Experiments

All simulations have been performed with TEMPER 2.2.2. For Bullet Impact (BI) bullets with different diameter from 5 mm to 60 mm in steps of 5 mm and velocity ranging from 600 m/s to 2600 m/s in steps of 200 m/s have been included in the study. In addition the required test conditions in STANAG 4241 (2) of 12.7 mm and 850 m/s have been included. The simulations for Fragment Impact have been with the standard conical NATO fragment. This fragment has diameter 14.3 mm and shall have a velocity of 2530 m/s, STANAG 4496 (3). For both tests the acceptor shell thickness has been varied from 5 to 20 mm.

2.1 Reactive material properties

The properties for the MCX-6100 explosive filling in the acceptor were all experimentally measured (7). The only variable for the acceptor explosive filling has been the shock sensitivity. Three different values for shock sensitivity have been used. Low shock sensitivity, 58.5 kbar obtained from a test series of CH 6079/13 initiated from the bottom (11), high shock sensitivity 36.5 kbar obtained by initiating a test series of CH 6027/14 from the top (12), and finally 47.5 kbar, the average value of these two experimentally obtained values. 2.1.1 – 2.1.3 show the material properties for the 155 mm acceptor shells we have used in the simulations both for BI and FI test.

2.1.1 MCX-6100-EXP high shock sensitivity - 36.4 kbar

```
Reactive Material
Rho, 1740
C0, 2730
S, 1.72
Lambda,
CP,
CJ Pressure, 20700000000
CJ Shock, 7420
CJ Gamma, 3.228
LSGT Threshold Pressure, 3640000000
A Modified Jacobs-Roslund, 0
```

2.1.2 MCX-6100-EXP average shock sensitivity – 47.5 kbar

```
Reactive Material
Rho, 1740
C0, 2730
S, 1.72
Lambda,
CP,
CJ Pressure, 20700000000
CJ Shock, 7420
CJ Gamma, 3.228
```

```
LSGT Threshold Pressure, 4750000000
A Modified Jacobs-Roslund, 0
```

2.1.3 MCX-6100-EXP low shock sensitivity – 58.5 kbar

```
Reactive Material
Rho, 1740
C0, 2730
S, 1.72
Lambda,
CP,
CJ Pressure, 20700000000
CJ Shock, 7420
CJ Gamma, 3.228
LSGT Threshold Pressure, 5850000000
A Modified Jacobs-Roslund, 0
```

2.2 Scenarios – Bullet Impact Test

Two separate runs are needed since we want to study three variables and TEMPER only can handle two variables in one run. In the first run at a constant velocity of 2000 m/s the diameter of the bullet was varied from 5 to 60 mm and the thickness of the steel cover plate from 5 mm to 20 mm. In the second run the cover plate thickness was constant at 15 mm, while the bullet diameter (5-60 mm) and the bullet velocity (600 m/s to 2600 m/s) were the two variables.

2.2.1 High shock sensitivity – 36.4 kbar

2.2.1.1 Variables - bullet diameter and cover plate thickness

```
[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 36

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 192
Variable1, Stimulus. Diameter
Variable2, Structure. Thickness

0.005;0.005   0.005;0.01    0.005;0.015   0.005;0.02    0.01;0.009
0.005;0.006   0.005;0.011   0.005;0.016   0.01;0.005    0.01;0.01
0.005;0.007   0.005;0.012   0.005;0.017   0.01;0.006    0.01;0.011
0.005;0.008   0.005;0.013   0.005;0.018   0.01;0.007    0.01;0.012
0.005;0.009   0.005;0.014   0.005;0.019   0.01;0.008    0.01;0.013
```

0.01;0.014	0.02;0.016	0.03;0.018	0.04;0.020	0.055;0.006
0.01;0.015	0.02;0.017	0.03;0.019	0.045;0.005	0.055;0.007
0.01;0.016	0.02;0.018	0.03;0.020	0.045;0.006	0.055;0.008
0.01;0.017	0.02;0.019	0.035;0.005	0.045;0.007	0.055;0.009
0.01;0.018	0.02;0.02	0.035;0.006	0.045;0.008	0.055;0.010
0.01;0.019	0.025;0.005	0.035;0.007	0.045;0.009	0.055;0.011
0.01;0.02	0.025;0.006	0.035;0.008	0.045;0.010	0.055;0.012
0.015;0.005	0.025;0.007	0.035;0.009	0.045;0.011	0.055;0.013
0.015;0.006	0.025;0.008	0.035;0.010	0.045;0.012	0.055;0.014
0.015;0.007	0.025;0.009	0.035;0.011	0.045;0.013	0.055;0.015
0.015;0.008	0.025;0.01	0.035;0.012	0.045;0.014	0.055;0.016
0.015;0.009	0.025;0.011	0.035;0.013	0.045;0.015	0.055;0.017
0.015;0.01	0.025;0.012	0.035;0.014	0.045;0.016	0.055;0.018
0.015;0.011	0.025;0.013	0.035;0.015	0.045;0.017	0.055;0.019
0.015;0.012	0.025;0.014	0.035;0.016	0.045;0.018	0.055;0.020
0.015;0.013	0.025;0.015	0.035;0.017	0.045;0.019	0.06;0.005
0.015;0.014	0.025;0.016	0.035;0.018	0.045;0.02	0.06;0.006
0.015;0.015	0.025;0.017	0.035;0.019	0.05;0.005	0.06;0.007
0.015;0.016	0.025;0.018	0.035;0.02	0.05;0.006	0.06;0.008
0.015;0.017	0.025;0.019	0.04;0.005	0.05;0.007	0.06;0.009
0.015;0.018	0.025;0.02	0.04;0.006	0.05;0.008	0.06;0.010
0.015;0.019	0.03;0.005	0.04;0.007	0.05;0.009	0.06;0.011
0.015;0.02	0.03;0.006	0.04;0.008	0.05;0.01	0.06;0.012
0.02;0.005	0.03;0.007	0.04;0.009	0.05;0.011	0.06;0.013
0.02;0.006	0.03;0.008	0.04;0.010	0.05;0.012	0.06;0.014
0.02;0.007	0.03;0.009	0.04;0.011	0.05;0.013	0.06;0.015
0.02;0.008	0.03;0.010	0.04;0.012	0.05;0.014	0.06;0.016
0.02;0.009	0.03;0.011	0.04;0.013	0.05;0.015	0.06;0.017
0.02;0.01	0.03;0.012	0.04;0.014	0.05;0.016	0.06;0.018
0.02;0.011	0.03;0.013	0.04;0.015	0.05;0.017	0.06;0.019
0.02;0.012	0.03;0.014	0.04;0.016	0.05;0.018	0.06;0.020
0.02;0.013	0.03;0.015	0.04;0.017	0.05;0.019	
0.02;0.014	0.03;0.016	0.04;0.018	0.05;0.020	
0.02;0.015	0.03;0.017	0.04;0.019	0.055;0.005	

2.2.1.2 Variables - bullet diameter and bullet velocity

```
[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 36

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 132
Variable1, Stimulus. Diameter
Variable2, Stimulus. Velocity
```

0.005;600	0.005;1800	0.01;800	0.01;2000	0.015;1000
0.005;800	0.005;2000	0.01;1000	0.01;2200	0.015;1200
0.005;1000	0.005;2200	0.01;1200	0.01;2400	0.015;1400
0.005;1200	0.005;2400	0.01;1400	0.01;2600	0.015;1600
0.005;1400	0.005;2600	0.01;1600	0.015;600	0.015;1800
0.005;1600	0.01;600	0.01;1800	0.015;800	0.015;2000

0.015;2200	0.025;2000	0.035;1800	0.045;1600	0.055;1400
0.015;2400	0.025;2200	0.035;2000	0.045;1800	0.055;1600
0.015;2600	0.025;2400	0.035;2200	0.045;2000	0.055;1800
0.02;600	0.025;2600	0.035;2400	0.045;2200	0.055;2000
0.02;800	0.03;600	0.035;2600	0.045;2400	0.055;2200
0.02;1000	0.03;800	0.04;600	0.045;2600	0.055;2400
0.02;1200	0.03;1000	0.04;800	0.05;600	0.055;2600
0.02;1400	0.03;1200	0.04;1000	0.05;800	0.06;600
0.02;1600	0.03;1400	0.04;1200	0.05;1000	0.06;800
0.02;1800	0.03;1600	0.04;1400	0.05;1200	0.06;1000
0.02;2000	0.03;1800	0.04;1600	0.05;1400	0.06;1200
0.02;2200	0.03;2000	0.04;1800	0.05;1600	0.06;1400
0.02;2400	0.03;2200	0.04;2000	0.05;1800	0.06;1600
0.02;2600	0.03;2400	0.04;2200	0.05;2000	0.06;1800
0.025;600	0.03;2600	0.04;2400	0.05;2200	0.06;2000
0.025;800	0.035;600	0.04;2600	0.05;2400	0.06;2200
0.025;1000	0.035;800	0.045;600	0.05;2600	0.06;2400
0.025;1200	0.035;1000	0.045;800	0.055;600	0.06;2600
0.025;1400	0.035;1200	0.045;1000	0.055;800	
0.025;1600	0.035;1400	0.045;1200	0.055;1000	
0.025;1800	0.035;1600	0.045;1400	0.055;1200	

2.2.2 Average Shock Sensitivity - 47.5 kbar

2.2.2.1 Variables - bullet diameter and cover plate thickness

[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 47

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 192
Variable1, Stimulus. Diameter
Variable2, Structure. Thickness

0.005;0.005	0.01;0.005	0.015;0.005	0.02;0.005	0.025;0.005
0.005;0.006	0.01;0.006	0.015;0.006	0.02;0.006	0.025;0.006
0.005;0.007	0.01;0.007	0.015;0.007	0.02;0.007	0.025;0.007
0.005;0.008	0.01;0.008	0.015;0.008	0.02;0.008	0.025;0.008
0.005;0.009	0.01;0.009	0.015;0.009	0.02;0.009	0.025;0.009
0.005;0.010	0.01;0.010	0.015;0.010	0.02;0.010	0.025;0.010
0.005;0.011	0.01;0.011	0.015;0.011	0.02;0.011	0.025;0.011
0.005;0.012	0.01;0.012	0.015;0.012	0.02;0.012	0.025;0.012
0.005;0.013	0.01;0.013	0.015;0.013	0.02;0.013	0.025;0.013
0.005;0.014	0.01;0.014	0.015;0.014	0.02;0.014	0.025;0.014
0.005;0.015	0.01;0.015	0.015;0.015	0.02;0.015	0.025;0.015
0.005;0.016	0.01;0.016	0.015;0.016	0.02;0.016	0.025;0.016
0.005;0.017	0.01;0.017	0.015;0.017	0.02;0.017	0.025;0.017
0.005;0.018	0.01;0.018	0.015;0.018	0.02;0.018	0.025;0.018
0.005;0.019	0.01;0.019	0.015;0.019	0.02;0.019	0.025;0.019
0.005;0.020	0.01;0.020	0.015;0.02	0.02;0.020	0.025;0.02

0.03;0.005	0.035;0.012	0.04;0.019	0.05;0.010	0.055;0.017
0.03;0.006	0.035;0.013	0.04;0.02	0.05;0.011	0.055;0.018
0.03;0.007	0.035;0.014	0.045;0.005	0.05;0.012	0.055;0.019
0.03;0.008	0.035;0.015	0.045;0.006	0.05;0.013	0.055;0.020
0.03;0.009	0.035;0.016	0.045;0.007	0.05;0.014	0.06;0.005
0.03;0.010	0.035;0.017	0.045;0.008	0.05;0.015	0.06;0.006
0.03;0.011	0.035;0.018	0.045;0.009	0.05;0.016	0.06;0.007
0.03;0.012	0.035;0.019	0.045;0.010	0.05;0.017	0.06;0.008
0.03;0.013	0.035;0.02	0.045;0.011	0.05;0.018	0.06;0.009
0.03;0.014	0.04;0.005	0.045;0.012	0.05;0.019	0.06;0.010
0.03;0.015	0.04;0.006	0.045;0.013	0.05;0.020	0.06;0.011
0.03;0.016	0.04;0.007	0.045;0.014	0.055;0.005	0.06;0.012
0.03;0.017	0.04;0.008	0.045;0.015	0.055;0.006	0.06;0.013
0.03;0.018	0.04;0.009	0.045;0.016	0.055;0.007	0.06;0.014
0.03;0.019	0.04;0.010	0.045;0.017	0.055;0.008	0.06;0.015
0.03;0.020	0.04;0.011	0.045;0.018	0.055;0.009	0.06;0.016
0.035;0.005	0.04;0.012	0.045;0.019	0.055;0.010	0.06;0.017
0.035;0.006	0.04;0.013	0.045;0.020	0.055;0.011	0.06;0.018
0.035;0.007	0.04;0.014	0.05;0.005	0.055;0.012	0.06;0.019
0.035;0.008	0.04;0.015	0.05;0.006	0.055;0.013	0.06;0.020
0.035;0.009	0.04;0.016	0.05;0.007	0.055;0.014	
0.035;0.010	0.04;0.017	0.05;0.008	0.055;0.015	
0.035;0.011	0.04;0.018	0.05;0.009	0.055;0.016	

2.2.2.2 Variables - bullet diameter and bullet velocity

[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 47

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 192
Variable1, Stimulus. Diameter
Variable2, Structure. Thickness

0.005;0.005	0.01;0.006	0.015;0.007	0.02;0.008	0.025;0.009
0.005;0.006	0.01;0.007	0.015;0.008	0.02;0.009	0.025;0.01
0.005;0.007	0.01;0.008	0.015;0.009	0.02;0.01	0.025;0.011
0.005;0.008	0.01;0.009	0.015;0.01	0.02;0.011	0.025;0.012
0.005;0.009	0.01;0.01	0.015;0.011	0.02;0.012	0.025;0.013
0.005;0.01	0.01;0.011	0.015;0.012	0.02;0.013	0.025;0.014
0.005;0.011	0.01;0.012	0.015;0.013	0.02;0.014	0.025;0.015
0.005;0.012	0.01;0.013	0.015;0.014	0.02;0.015	0.025;0.016
0.005;0.013	0.01;0.014	0.015;0.015	0.02;0.016	0.025;0.017
0.005;0.014	0.01;0.015	0.015;0.016	0.02;0.017	0.025;0.018
0.005;0.015	0.01;0.016	0.015;0.017	0.02;0.018	0.025;0.019
0.005;0.016	0.01;0.017	0.015;0.018	0.02;0.019	0.025;0.02
0.005;0.017	0.01;0.018	0.015;0.019	0.02;0.02	0.03;0.005
0.005;0.018	0.01;0.019	0.015;0.02	0.025;0.005	0.03;0.006
0.005;0.019	0.01;0.02	0.02;0.005	0.025;0.006	0.03;0.007
0.005;0.02	0.015;0.005	0.02;0.006	0.025;0.007	0.03;0.008
0.01;0.005	0.015;0.006	0.02;0.007	0.025;0.008	0.03;0.009

0.03;0.01	0.035;0.016	0.045;0.006	0.05;0.012	0.055;0.018
0.03;0.011	0.035;0.017	0.045;0.007	0.05;0.013	0.055;0.019
0.03;0.012	0.035;0.018	0.045;0.008	0.05;0.014	0.055;0.02
0.03;0.013	0.035;0.019	0.045;0.009	0.05;0.015	0.06;0.005
0.03;0.014	0.035;0.02	0.045;0.01	0.05;0.016	0.06;0.006
0.03;0.015	0.04;0.005	0.045;0.011	0.05;0.017	0.06;0.007
0.03;0.016	0.04;0.006	0.045;0.012	0.05;0.018	0.06;0.008
0.03;0.017	0.04;0.007	0.045;0.013	0.05;0.019	0.06;0.009
0.03;0.018	0.04;0.008	0.045;0.014	0.05;0.02	0.06;0.01
0.03;0.019	0.04;0.009	0.045;0.015	0.055;0.005	0.06;0.011
0.03;0.02	0.04;0.01	0.045;0.016	0.055;0.006	0.06;0.012
0.035;0.005	0.04;0.011	0.045;0.017	0.055;0.007	0.06;0.013
0.035;0.006	0.04;0.012	0.045;0.018	0.055;0.008	0.06;0.014
0.035;0.007	0.04;0.013	0.045;0.019	0.055;0.009	0.06;0.015
0.035;0.008	0.04;0.014	0.045;0.02	0.055;0.01	0.06;0.016
0.035;0.009	0.04;0.015	0.05;0.005	0.055;0.011	0.06;0.017
0.035;0.01	0.04;0.016	0.05;0.006	0.055;0.012	0.06;0.018
0.035;0.011	0.04;0.017	0.05;0.007	0.055;0.013	0.06;0.019
0.035;0.012	0.04;0.018	0.05;0.008	0.055;0.014	0.06;0.02
0.035;0.013	0.04;0.019	0.05;0.009	0.055;0.015	
0.035;0.014	0.04;0.02	0.05;0.01	0.055;0.016	
0.035;0.015	0.045;0.005	0.05;0.011	0.055;0.017	

2.2.3 Low shock sensitivity - 58.5 kbar

2.2.3.1 Variables - bullet diameter and cover plate thickness

[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 58

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 192
Variable1, Stimulus. Diameter
Variable2, Structure. Thickness

0.005;0.005	0.005;0.018	0.01;0.015	0.015;0.012	0.02;0.009
0.005;0.006	0.005;0.019	0.01;0.016	0.015;0.013	0.02;0.01
0.005;0.007	0.005;0.02	0.01;0.017	0.015;0.014	0.02;0.011
0.005;0.008	0.01;0.005	0.01;0.018	0.015;0.015	0.02;0.012
0.005;0.009	0.01;0.006	0.01;0.019	0.015;0.016	0.02;0.013
0.005;0.01	0.01;0.007	0.01;0.02	0.015;0.017	0.02;0.014
0.005;0.011	0.01;0.008	0.015;0.005	0.015;0.018	0.02;0.015
0.005;0.012	0.01;0.009	0.015;0.006	0.015;0.019	0.02;0.016
0.005;0.013	0.01;0.01	0.015;0.007	0.015;0.02	0.02;0.017
0.005;0.014	0.01;0.011	0.015;0.008	0.02;0.005	0.02;0.018
0.005;0.015	0.01;0.012	0.015;0.009	0.02;0.006	0.02;0.019
0.005;0.016	0.01;0.013	0.015;0.01	0.02;0.007	0.02;0.02
0.005;0.017	0.01;0.014	0.015;0.011	0.02;0.008	0.025;0.005

0.025;0.006	0.03;0.016	0.04;0.01	0.045;0.02	0.055;0.014
0.025;0.007	0.03;0.017	0.04;0.011	0.05;0.005	0.055;0.015
0.025;0.008	0.03;0.018	0.04;0.012	0.05;0.006	0.055;0.016
0.025;0.009	0.03;0.019	0.04;0.013	0.05;0.007	0.055;0.017
0.025;0.01	0.03;0.02	0.04;0.014	0.05;0.008	0.055;0.018
0.025;0.011	0.035;0.005	0.04;0.015	0.05;0.009	0.055;0.019
0.025;0.012	0.035;0.006	0.04;0.016	0.05;0.01	0.055;0.02
0.025;0.013	0.035;0.007	0.04;0.017	0.05;0.011	0.06;0.005
0.025;0.014	0.035;0.008	0.04;0.018	0.05;0.012	0.06;0.006
0.025;0.015	0.035;0.009	0.04;0.019	0.05;0.013	0.06;0.007
0.025;0.016	0.035;0.01	0.04;0.02	0.05;0.014	0.06;0.008
0.025;0.017	0.035;0.011	0.045;0.005	0.05;0.015	0.06;0.009
0.025;0.018	0.035;0.012	0.045;0.006	0.05;0.016	0.06;0.01
0.025;0.019	0.035;0.013	0.045;0.007	0.05;0.017	0.06;0.011
0.025;0.02	0.035;0.014	0.045;0.008	0.05;0.018	0.06;0.012
0.03;0.005	0.035;0.015	0.045;0.009	0.05;0.019	0.06;0.013
0.03;0.006	0.035;0.016	0.045;0.01	0.05;0.02	0.06;0.014
0.03;0.007	0.035;0.017	0.045;0.011	0.055;0.005	0.06;0.015
0.03;0.008	0.035;0.018	0.045;0.012	0.055;0.006	0.06;0.016
0.03;0.009	0.035;0.019	0.045;0.013	0.055;0.007	0.06;0.017
0.03;0.01	0.035;0.02	0.045;0.014	0.055;0.008	0.06;0.018
0.03;0.011	0.04;0.005	0.045;0.015	0.055;0.009	0.06;0.019
0.03;0.012	0.04;0.006	0.045;0.016	0.055;0.01	0.06;0.02
0.03;0.013	0.04;0.007	0.045;0.017	0.055;0.011	
0.03;0.014	0.04;0.008	0.045;0.018	0.055;0.012	
0.03;0.015	0.04;0.009	0.045;0.019	0.055;0.013	

2.2.3.2 Variables - bullet diameter and bullet velocity

[Stimulus]
Flat End Rod
Diameter, 0.010
Velocity, 2000
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 58

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 132
Variable1, Stimulus, Diameter
Variable2, Stimulus, Velocity

0.005;600	0.01;1200	0.015;1800	0.02;2400	0.03;800
0.005;800	0.01;1400	0.015;2000	0.02;2600	0.03;1000
0.005;1000	0.01;1600	0.015;2200	0.025;600	0.03;1200
0.005;1200	0.01;1800	0.015;2400	0.025;800	0.03;1400
0.005;1400	0.01;2000	0.015;2600	0.025;1000	0.03;1600
0.005;1600	0.01;2200	0.02;600	0.025;1200	0.03;1800
0.005;1800	0.01;2400	0.02;800	0.025;1400	0.03;2000
0.005;2000	0.01;2600	0.02;1000	0.025;1600	0.03;2200
0.005;2200	0.015;600	0.02;1200	0.025;1800	0.03;2400
0.005;2400	0.015;800	0.02;1400	0.025;2000	0.03;2600
0.005;2600	0.015;1000	0.02;1600	0.025;2200	0.035;600
0.01;600	0.015;1200	0.02;1800	0.025;2400	0.035;800
0.01;800	0.015;1400	0.02;2000	0.025;2600	0.035;1000
0.01;1000	0.015;1600	0.02;2200	0.03;600	0.035;1200

```
0.035;1400
0.035;1600
0.035;1800
0.035;2000
0.035;2200
0.035;2400
0.035;2600
0.04;600
0.04;800
0.04;1000
0.04;1200
0.04;1400
0.04;1600
0.04;1800
0.04;2000
0.04;2200
0.04;2400
0.04;2600
0.045;600
0.045;800
0.045;1000
0.045;1200
0.045;1400
0.045;1600
0.045;1800
0.045;2000
0.045;2200
0.045;2400
0.045;2600
0.05;600
0.05;800
0.05;1000
0.05;1200
0.05;1400
0.05;1600
0.05;1800
0.05;2000
0.05;2200
0.05;2400
0.05;2600
0.055;600
0.055;800
0.055;1000
0.055;1200
0.055;1400
0.055;1600
0.055;1800
0.055;2000
0.055;2200
0.055;2400
0.055;2600
0.06;600
0.06;800
0.06;1000
0.06;1200
0.06;1400
0.06;1600
0.06;1800
0.06;2000
0.06;2200
0.06;2400
0.06;2600
```

2.3 Scenarios Fragment Impact Test

In FI-test the stimulus, or threat, is a conical NATO fragment with diameter 14.3 mm with a velocity of 2530 m/s. Appendix A gives specification of the fragment. The acceptor is filled with MCX-6100 CH 6027/14 with experimentally obtained properties. Three different shock sensitivities of the filling have been studied. The properties of the fillings are given in 2.1.1 – 2.1.3. The shell or cover plate thickness, has been varied from 5 to 20 mm in all simulations.

2.3.1 High shock sensitivity - 36.4 kbar

```
[Stimulus]
Conical Fragment
Diameter, 0.0143
Length, 0.01556
Velocity, 2530
Cone angle, 160
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 36

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 16
Variable1, Structure. Thickness
Variable2, Stimulus. Length
0.005;0.01556
0.006;0.01556
0.007;0.01556
0.008;0.01556
0.009;0.01556
0.01;0.01556
0.011;0.01556
0.012;0.01556
0.013;0.01556
0.014;0.01556
```

```
0.015;0.01556
0.016;0.01556
0.017;0.01556
0.018;0.01556
0.019;0.01556
0.02;0.01556
```

2.3.2 Average shock sensitivity - 47.5 kbar

```
[Stimulus]
Conical Fragment
Diameter, 0.0143
Length, 0.01556
Velocity, 2530
Cone angle, 160
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 47

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 16
Variable1, Structure. Thickness
Variable2, Stimulus. Length
0.005;0.01556
0.006;0.01556
0.007;0.01556
0.008;0.01556
0.009;0.01556
0.01;0.01556
0.011;0.01556
0.012;0.01556
0.013;0.01556
0.014;0.01556
0.015;0.01556
0.016;0.01556
0.017;0.01556
0.018;0.01556
0.019;0.01556
0.02;0.01556
```

2.3.3 Low shock sensitivity - 58.5 kbar

```
[Stimulus]
Conical Fragment
Diameter, 0.0143
Length, 0.01556
Velocity, 2530
Cone angle, 160
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3
```

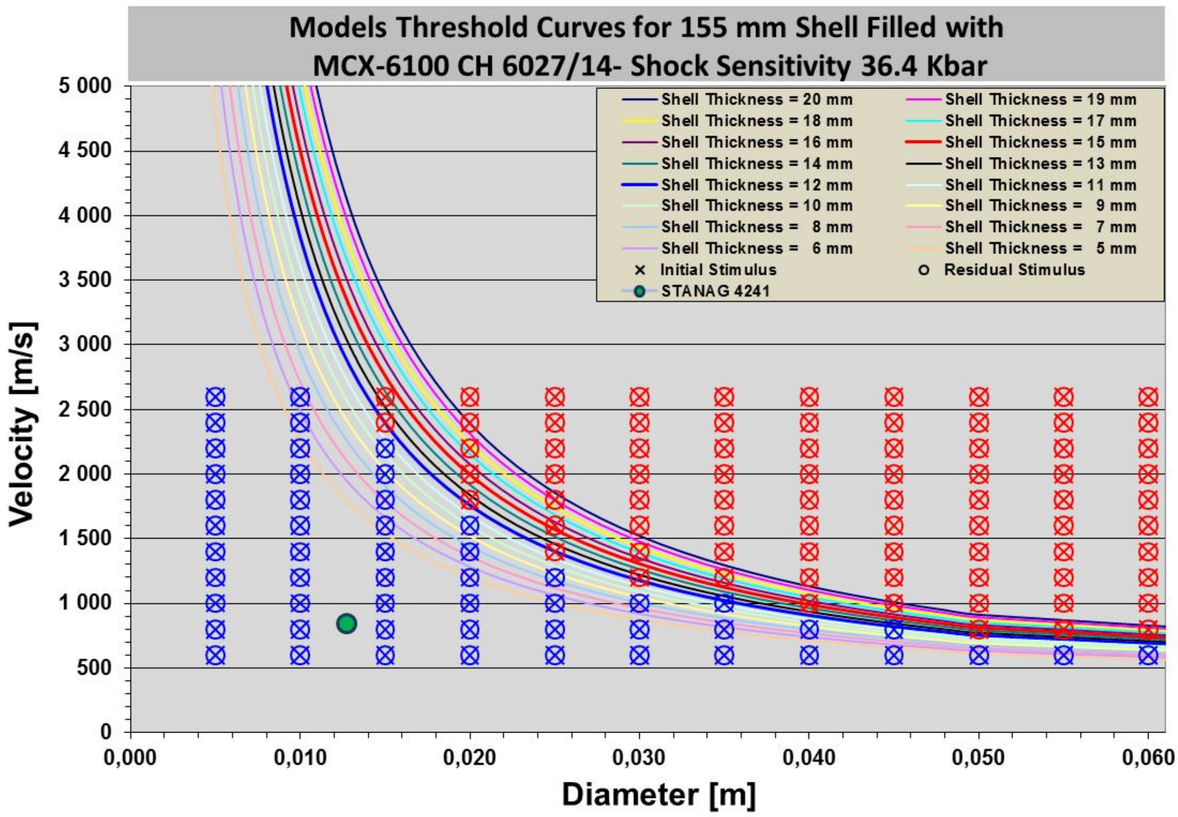
```
[Structure]
Covered Plane Explosive
Thickness, 0.015
Characteristic dimension, 015
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, MCX-6100-EXP-NoName 58

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 16
Variable1, Structure. Thickness
Variable2, Stimulus. Length
0.005;0.01556
0.006;0.01556
0.007;0.01556
0.008;0.01556
0.009;0.01556
0.01;0.01556
0.011;0.01556
0.012;0.01556
0.013;0.01556
0.014;0.01556
0.015;0.01556
0.016;0.01556
0.017;0.01556
0.018;0.01556
0.019;0.01556
0.02;0.01556
```

3 Results

3.1 Bullet Impact

3.1.1 High shock sensitivity – 36.4 kbar

Figure 3.1 gives the responses for acceptor shells filled with MCX-6100 CH 6027/14 with shock sensitivity of 36.4 kbar. Variables for the threat are bullet diameter (5 to 60 mm) in steps of 5 mm and bullet velocity (600 – 2600 m/s) in steps of 200 m/s. For the acceptor the variable is cover plate or shell thickness from 5 mm to 20 mm.



Threats (bullet diameter/velocity points) positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm.

Figure 3.1 Threshold curves for MCX-6100 CH 6027/14 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats.

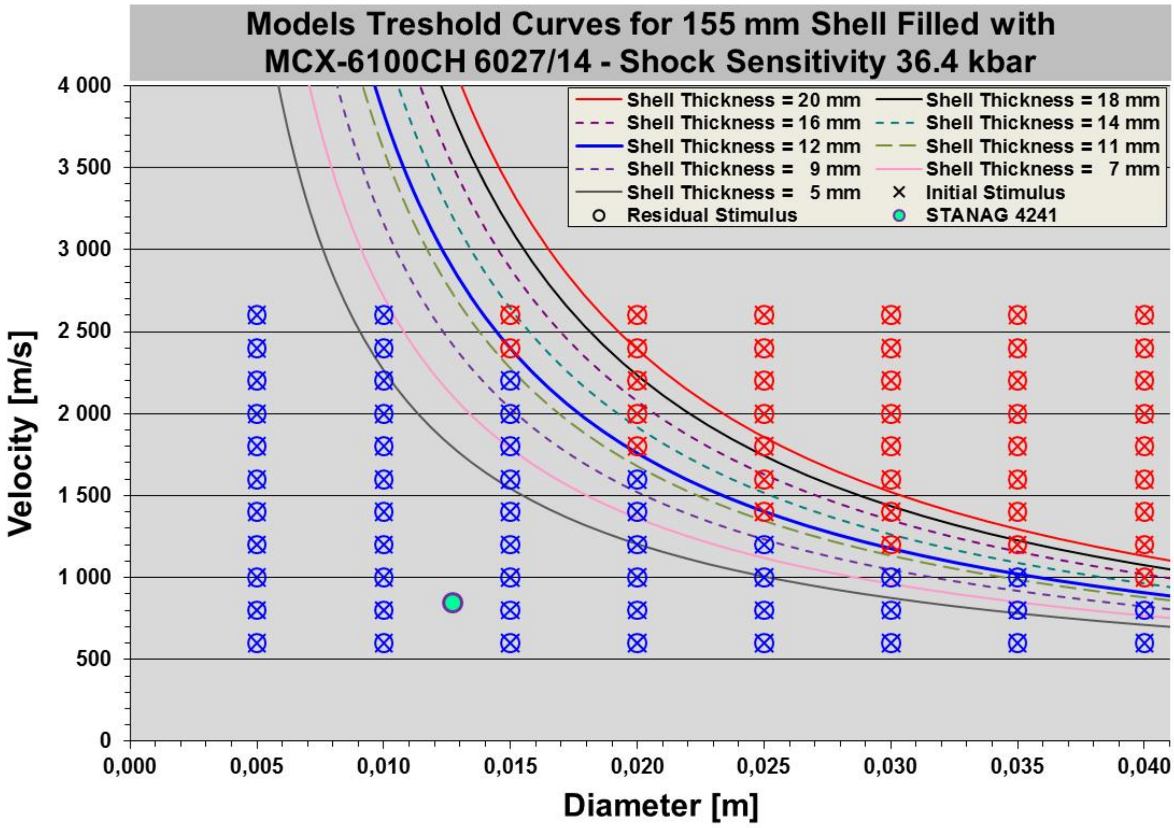
Figure 3.1 shows threshold curves and threats with the response for 12 mm shell thickness. Red colour is a detonation response and blue colour for a no reaction response. Table 3.1 and Table 3.2 show diagrams with the responses for all combinations of threat properties (bullet diameter and velocity) and acceptor shell thicknesses. Bullets with diameter 5 mm is removed from the Table 3.1 since they for all velocities included in this study responded with a no reaction response.

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10	1400	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2400	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2600	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
15	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2200	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue
20	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
25	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
30	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
35	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

*Table 3.1 Responses for different threats (bullet sizes and velocities) for different shell thicknesses for MCX-6100 CH 6027/14 filling having shock sensitivity 36.4 kbar. (**Red** – detonation, **blue** – no reaction)*

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
40	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
45	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
50	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
55	600	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
60	600	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

*Table 3.2 Responses for different threats (bullet sizes and velocities) for different shell thicknesses for MCX-6100 CH 6027/14 filling having shock sensitivity 36.4 kbar. (**Red** – detonation, **blue** – no reaction)*



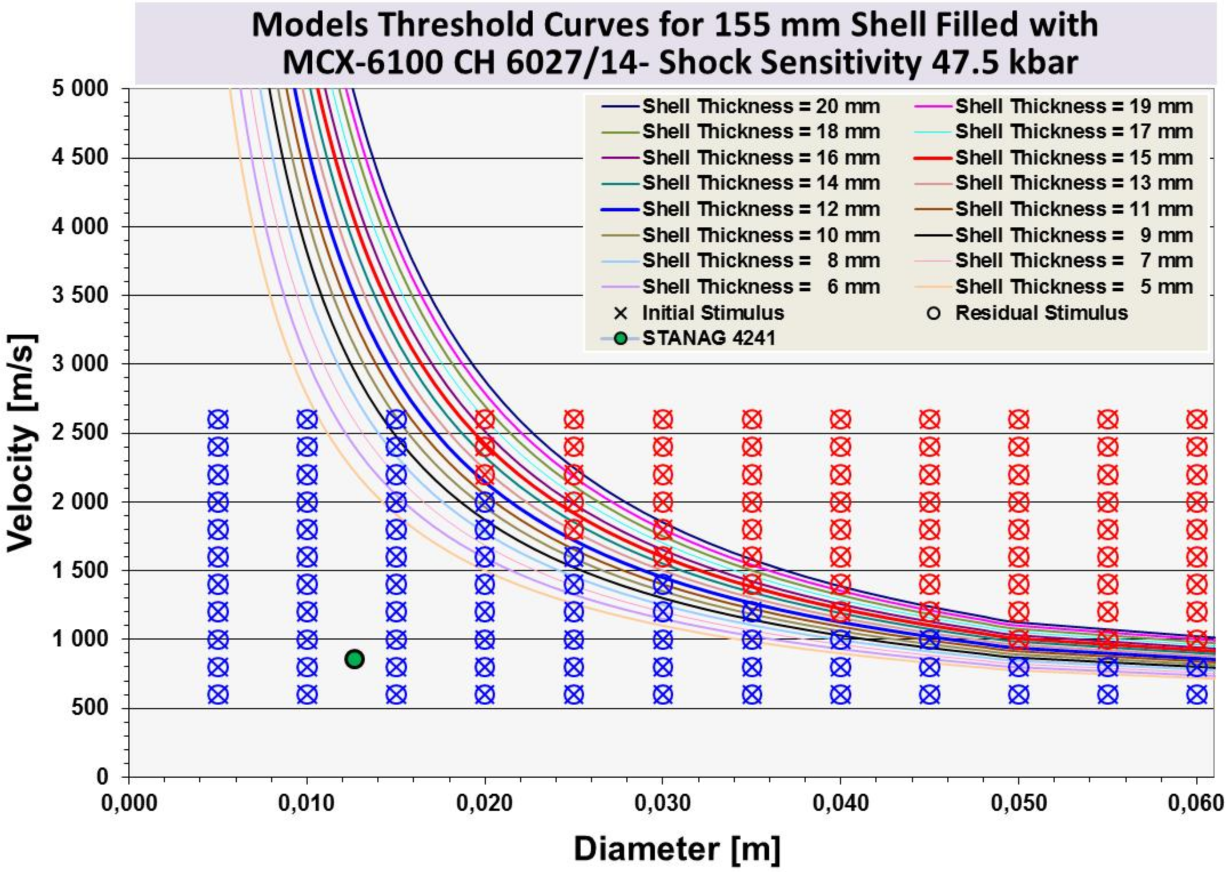
Threats (bullet diameter/velocity points) positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm.

Figure 3.2 Threshold curves for MCX-6100 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats.

Figure 3.2 is a simplified version of Figure 3.1, where bullets with diameter above 40 mm and some of the threshold curves have been removed. In addition the bullet with the diameter and velocity required in the STANAG 4241 has been plotted. The position and response of this bullet shows that a 155mm shell filled with MCX-6100 CH 6027/14 composition under all circumstances will pass the STANAG requirement for one bullet hit. However, the result says nothing about what will happen when the shell is hit by three bullets. However, the margins from no reaction response to a detonation response are large.

3.1.2 Average shock sensitivity - 47.5 kbar

Figure 3.3 gives the results for acceptor shells filled with MCX-6100 CH 6027/14 with measured shock sensitivity 47.5 kbar. Variables for the threat are bullet diameters in steps of 5 mm from 5 mm to 60 mm and bullet velocities in steps of 200 m/s from 600 m/s to 2600 m/s. For the acceptor the variable is the cover steel plate or shell thickness (5-20 mm). Tables 3.3 and 3.4 show diagrams with the responses for all combinations of bullet diameters and velocities of acceptors protected by steel plate or shell of different thicknesses.



Threats (bullet diameter/velocity points) positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm.

Figure 3.3 Threshold curves for MCX-6100 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats.

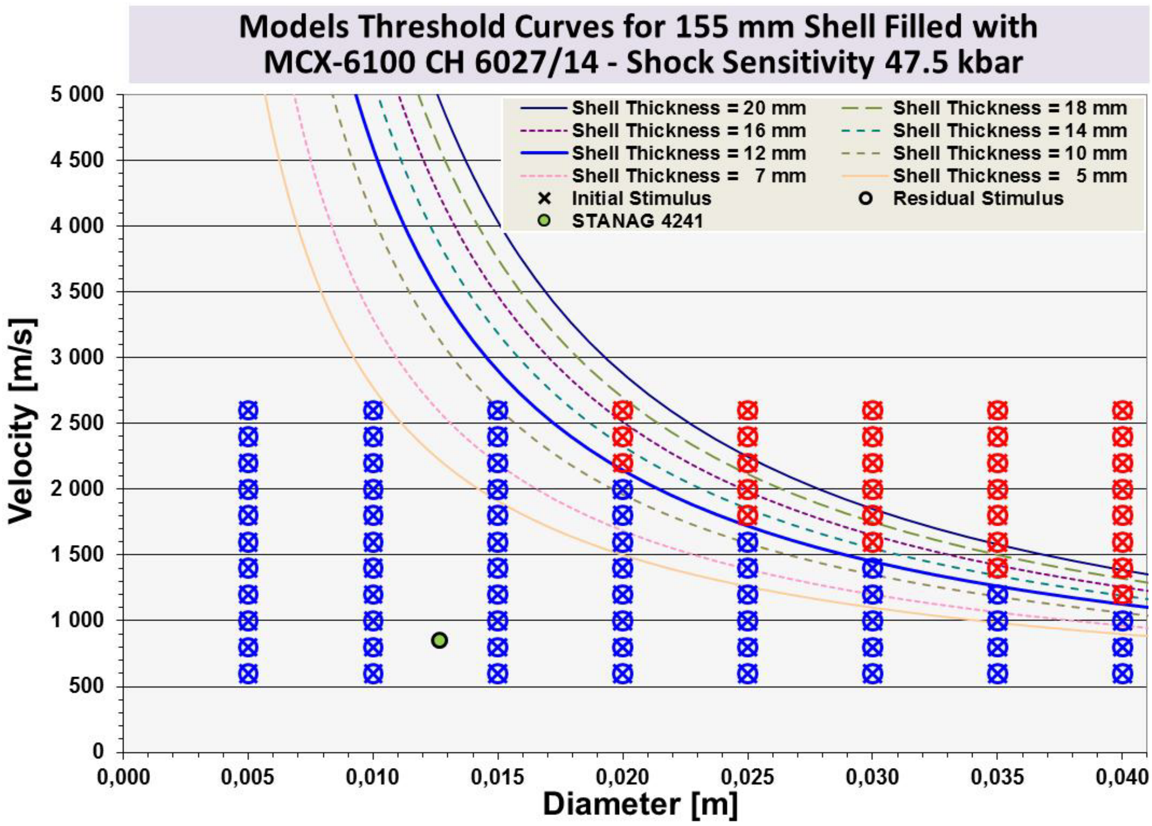
Bullets with diameter 5 and 10 mm are removed from the Table 3.3, since they for all velocities included in this study respond with a no reaction response.

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
15	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1400	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	2000	R	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	2200	R	R	R	B	B	B	B	B	B	B	B	B	B	B	B	B
	2400	R	R	R	R	B	B	B	B	B	B	B	B	B	B	B	B
	2600	R	R	R	R	R	R	B	B	B	B	B	B	B	B	B	B
20	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1400	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1600	R	R	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1800	R	R	R	R	B	B	B	B	B	B	B	B	B	B	B	B
	2000	R	R	R	R	R	R	B	B	B	B	B	B	B	B	B	B
	2200	R	R	R	R	R	R	R	R	B	B	B	B	B	B	B	B
	2400	R	R	R	R	R	R	R	R	R	R	B	B	B	B	B	B
	2600	R	R	R	R	R	R	R	R	R	R	R	R	R	B	B	B
25	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1400	R	R	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1600	R	R	R	R	R	B	B	B	B	B	B	B	B	B	B	B
	1800	R	R	R	R	R	R	R	R	R	B	B	B	B	B	B	B
	2000	R	R	R	R	R	R	R	R	R	R	R	R	B	B	B	B
	2200	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	B
	2400	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
30	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	R	R	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1400	R	R	R	R	R	R	B	B	B	B	B	B	B	B	B	B
	1600	R	R	R	R	R	R	R	R	R	R	B	B	B	B	B	B
	1800	R	R	R	R	R	R	R	R	R	R	R	R	R	B	B	B
	2000	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2200	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2400	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
35	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	R	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	R	R	R	R	R	R	B	B	B	B	B	B	B	B	B	B
	1400	R	R	R	R	R	R	R	R	R	R	B	B	B	B	B	B
	1600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	1800	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2000	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2200	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2400	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
40	600	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	800	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	1000	R	R	R	B	B	B	B	B	B	B	B	B	B	B	B	B
	1200	R	R	R	R	R	R	R	R	R	B	B	B	B	B	B	B
	1400	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	1600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	1800	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2000	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2200	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2400	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2600	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Table 3.3 *Responses of different threats (bullet diameter and velocity) for MCX-6100 filled acceptor with different shell thicknesses. (**Red** – detonation, **blue** – no reaction)*

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
45	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
50	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
55	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
60	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

*Table 3.4 Responses of different threats (bullet diameter and velocity) for MCX-6100 CH 6027/14 filled acceptor with different shell thicknesses. (**Red** – detonation, **blue** – no reaction)*



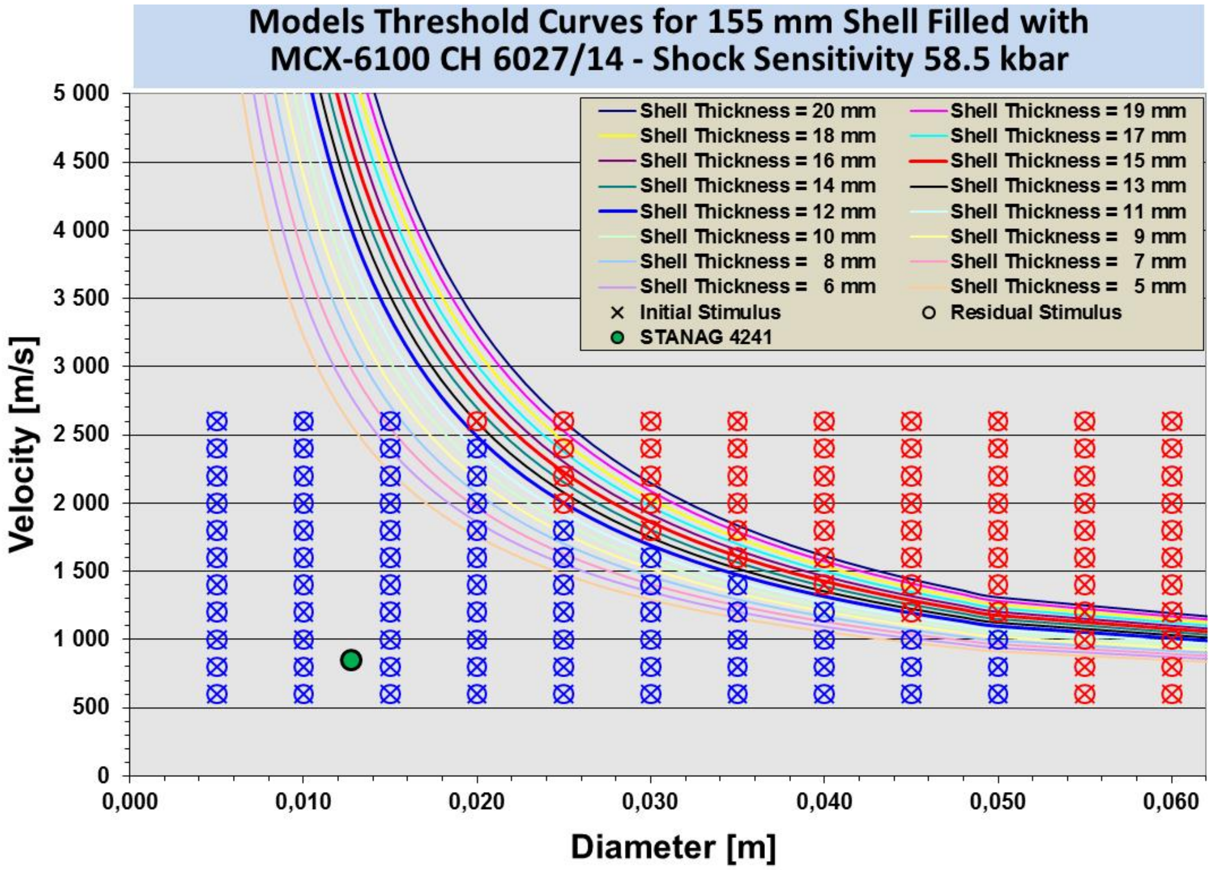
Threats (bullet diameter/velocity points) positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm

Figure 3.4 Threshold curves for MCX-6100 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats. The actual responses are for shell thickness12 mm

Figure 3.4 is a simplified version of Figure 3.3 where some of the threshold curves and bullets with diameter above 40 mm have been removed. In addition the bullet with the dimension and velocity test requirement in the STANAG 4241 has been plotted. The position and response of this bullet shows that a 155mm shell under all circumstances will pass the STANAG requirement for one bullet hit. For the requirement in STANAG 4241of hit by three separate bullets the results say nothing. However, the margin from no response to a detonation response is large.

3.1.3 Low shock sensitivity - 58.5 kbar

Figure 3.5 gives the results for an acceptor shell filled with MCX-6100 CH 6027/14 with experimentally determined properties including a measured shock sensitivity of 58.5 kbar. Threat variables are bullet diameter (5 to 60 mm) and bullet velocity (600 – 2600 m/s). Acceptors have cover plate thickness varying from 5-20 mm. Tables 3.5 and 3.6 show diagrams with the responses for all threats (combinations of bullet diameter and velocity) for acceptors filled with MCX-6100 CH 6027/14 having shock sensitivity 58.5 kbar and protected by steel plates of different thicknesses.



Threats (bullet diameter/velocity points) positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm.

Figure 3.5 Threshold curves for MCX-6100 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats.

Bullets with diameter 5 and 10 mm are removed from Table 3.5 since they for all velocities included in this study responded with a *no reaction* response.

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
15	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2400	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2600	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
20	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2200	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2400	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue
25	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue
30	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
35	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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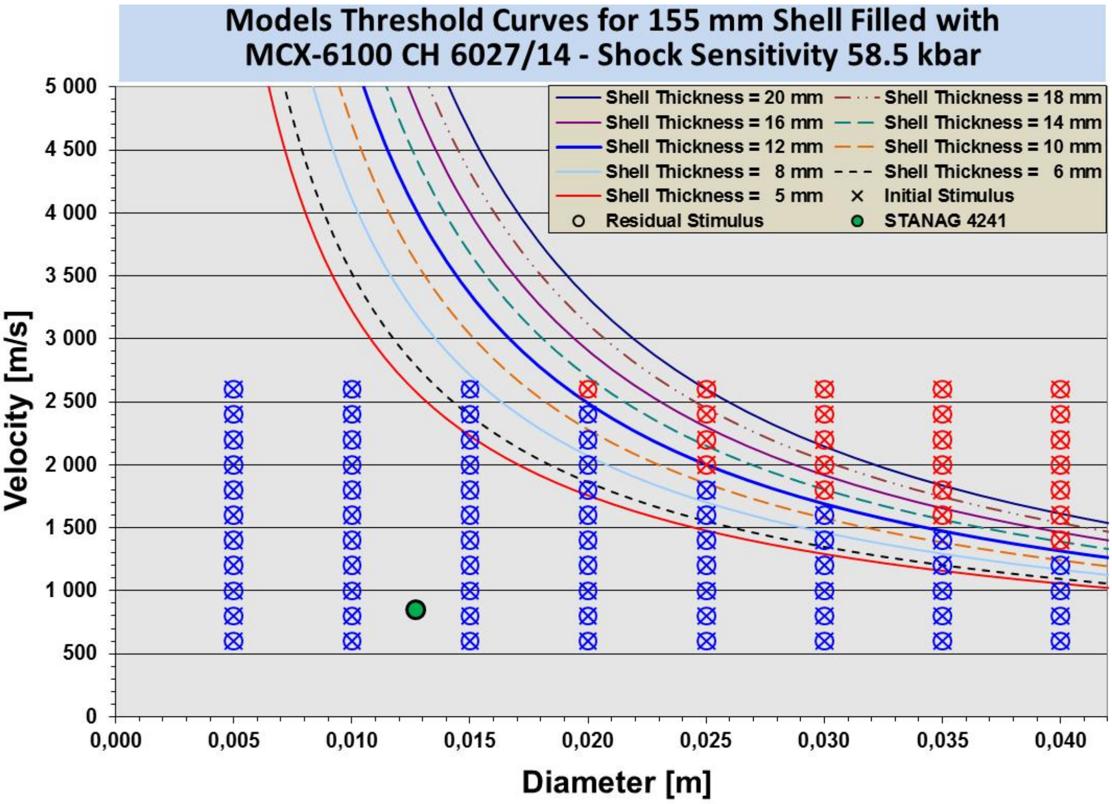
	1400	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

*Table 3.5 Responses for different threats (bullet size and velocity) for different shell thicknesses for MCX-6100 CH 6027/14 filling having shock sensitivity 58.5 kbar. (**Red** – detonation, **blue** – no reaction)*

Bullet Diameter (mm)	Bullet Velocity (m/s)	Shell thickness (mm)															
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
40	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
45	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
50	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
55	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
60	600	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	800	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1000	Red	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	1200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	1800	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2000	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2200	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2400	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2600	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

*Table 3.6 Responses for different threats (bullet size and velocity) for different shell thicknesses for MCX-6100 CH 6027/14 filling having shock sensitivity 58.5 kbar. (**Red** – detonation, **blue** – no reaction)*



Threats (bullet diameter/velocity points)positioned above the cover plate threshold curve give a detonation (red) response, positioned below give a no reaction response (blue). The colour code is only valid for cover plate thickness 12 mm.

Figure 3.6 Threshold curves for MCX-6100 fillings covered by steel plate with thickness from 5 to 20 mm and the responses of different threats.

Figure 3.6 shows the same results as Figure 3.5, but some of the threshold curves and bullets with diameter above 40 mm have been removed. In addition the bullet with the dimension and velocity required in the STANAG 4241 has been plotted. The position and response of this bullet show that a 155 mm shell under all circumstances will pass the STANAG requirement for one bullet hit. For the requirement in STANAG 4241of hit by three separate bullets the results say nothing. However, the margins from no reaction response to a detonation response are large even for the area with thin shell thicknesses in the top of the shell.

3.2 Fragment Impact

For the conical NATO fragment at velocity 2530 m/s fragment impact simulations have been performed against acceptors filled with MCX-6100 CH 6027/14 with determined properties including the shock sensitivity (7, 11, and 12). Three values of shock sensitivity 36.4, 47.5 and 58.5 kbar have been included. The only variable for these simulations is the steel cover plate thickness of the acceptor. The thickness has been varied from 5 to 20 mm in steps of 1 mm.

3.2.1 High shock sensitivity - 36.4 kbar

The first run was with an acceptor having shock sensitivity of 36.4 kbar. The obtained responses are shown in Table 3.7. For MCX-6100 CH 6027/14 covered with a steel plate of 12 mm thickness or more shows a no reaction response, blue colour. With a thinner protection the response is a detonation.

Acceptor	THREAT –NATO Fragment	
Shell thickness (mm)	Diameter (mm)	Velocity (m/s)*
5	14.3	2530
6	14.3	2530
7	14.3	2530
8	14.3	2530
9	14.3	2530
10	14.3	2530
11	14.3	2530
12	14.3	2530
13	14.3	2530
14	14.3	2530
15	14.3	2530
16	14.3	2530
17	14.3	2530
18	14.3	2530
19	14.3	2530
20	14.3	2530

***Red colour detonation – blue colour no reaction in acceptor.**

Table 3.7 Responses in acceptors filled with MCX-6100 CH 6027/14 having a shock sensitivity of 36.4 kbar hit by a conical NATO fragment with a velocity of 2530 m/s.

3.2.2 Average shock sensitivity - 47.5 kbar

The second run was with an acceptor having shock sensitivity of 47.5 kbar. The obtained responses are shown in Table 3.8. For MCX-6100 CH 6027/14 having shock sensitivity 47.5 kbar a steel plate with thickness 8 mm or more is necessary to obtain a no reaction. With thinner steel protection the response is a detonation.

Acceptor	THREAT –NATO Fragment	
Shell thickness (mm)	Diameter (mm)	Velocity (m/s)*
5	14.3	2530
6	14.3	2530
7	14.3	2530
8	14.3	2530
9	14.3	2530
10	14.3	2530
11	14.3	2530
12	14.3	2530
13	14.3	2530
14	14.3	2530
15	14.3	2530
16	14.3	2530
17	14.3	2530
18	14.3	2530
19	14.3	2530
20	14.3	2530

***Red colour detonation – blue colour no reaction in acceptor.**

Table 3.8 Response in acceptors filled with MCX-6100 with shock sensitivity of 47.5 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

3.2.3 Low shock sensitivity - 58.5 kbar

The third and last run was with an acceptor having shock sensitivity of 58.5 kbar. The obtained

Acceptor	THREAT –NATO Fragment	
Shell thickness (mm)	Diameter (mm)	Velocity (m/s)*
5	14.3	2530
6	14.3	2530
7	14.3	2530
8	14.3	2530
9	14.3	2530
10	14.3	2530
11	14.3	2530
12	14.3	2530
13	14.3	2530
14	14.3	2530
15	14.3	2530
16	14.3	2530
17	14.3	2530
18	14.3	2530
19	14.3	2530
20	14.3	2530

***Red colour detonation – blue colour no reaction in acceptor.**

Table 3.9 Response in acceptors filled with MCX-6100 with shock sensitivity of 58.5 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

responses are shown in Table 3.9. For a 155 mm shell filled with MCX-6100 CH 6027/14 composition a 6 mm thick steel plate or more is necessary to obtain a no reaction. For thinner protection is the response a detonation.

3.2.4 Comparison of threshold curves

In Figure 3.7 the threshold curves for the three different shock sensitivities included in this study have been plotted for three different cover plate thicknesses (6, 12, 18 mm). Selected thicknesses are representative for the thickness in the top, middle and bottom of a 155 mm shell.

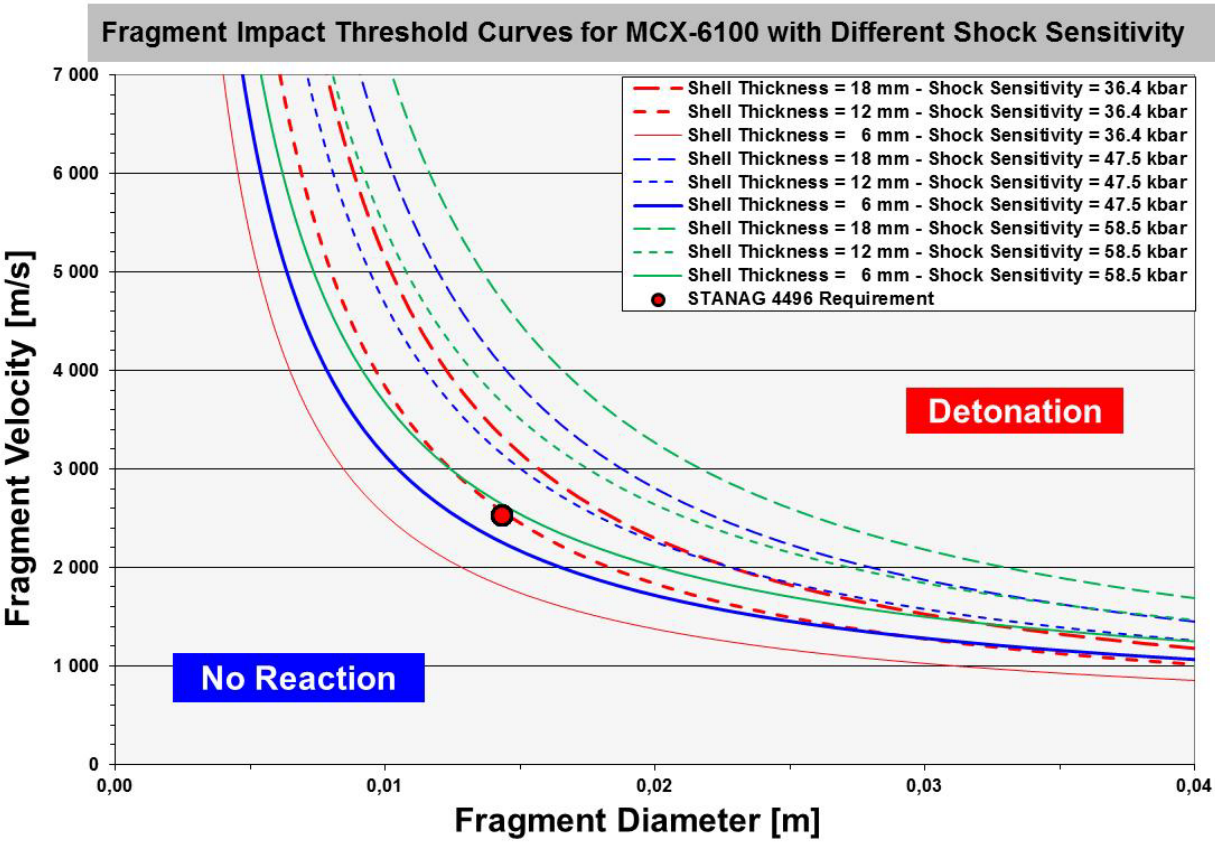


Figure 3.7 Threshold curves for MCX-6100 CH 6027/14 filled shells having three different shock sensitivities protected by three different shell thicknesses.

STANAG 4439 (1) requires a type III response for FI test according to STANAG 4496 to fulfil the IM requirement. Figure 3.7 shows that for MCX-6100 fillings with low sensitivity (58.5 kbar) protection with 6 mm steel or thicker will give a *no reaction* response. Even for the most sensitive filling (36.4 kbar) a protection of 12 mm steel gives a *no reaction* response.

In conclusion, it should be possible for a MCX-6100 filling with shock sensitivity of 50 kbar or lower to pass the IM requirements. The impact point of the hit will be important for the reaction response. For all three shock sensitivities studied in this report a hit of the shell in the middle or below will be mild. The most critical impact point will be close to the fuze well, which for the most sensitive filling could result in a detonation response.

4 Summary

The TEMPER simulations of bullet impact tests with flat end rod on shells filled with MCX-6100 CH 6027/14 compositions show *no reaction* response for the three shock sensitivities studied in this report. With TEMPER we have studied impact by only one bullet. The STANAG 4241 requires hit by three bullets. Shock properties of damaged explosive are not available for MCX-6100 compositions. However, nothing in the BI test simulations indicates that a *no reaction* response will occur with a MCX-6100 filling. The requirement in STANAG 4439 for FI test to fulfill the IM requirement is a *type V reaction, No response more severe than burning*.

Simulations of fragment impact with a conical NATO fragment and test conditions given in STANAG 4496 have been performed on different shell thicknesses filled with MCX-6100 having three different shock sensitivities. With a MCX-6100 filling with shock sensitivity 58.5 kbar a shell thickness of 6 mm or thicker gives a *no reaction* response. With a MCX-6100 filling with a shock sensitivity of 47.5 kbar a shell thickness of 8 mm or thicker gives a *no reaction* response. For MCX-6100 fillings with a shock sensitivity of 36.4 kbar a shell thickness of 11 mm or thicker gives a *no reaction* response. The requirement in STANAG 4439 for FI test to fulfill the IM requirement is a *type V reaction, No response more severe than burning*.

References

(1) STANAG 4439 JAS Ed.3: Policy for Introduction and Assessment of Insensitive Munitions (IM), NATO Standardization Agency (NSA), NSA/0337(2010)-JAS/4439, 17 March 2010.

(2) STANAG 4241 Ed 2: Bullet Impact, Munitions Test procedure, NATO/PfP Unclassified, 15 April 2003.

(3) STANAG 4496 JAS Ed. 1 "Fragment Impact, Munitions Test Procedure", NATO Standardization Agency (NSA), NSA/1025(2010)-JAS/4496, 13 December 2006.

(4) STANAG 4170 JAIS (Edition 3): principles and methodology for the qualification of explosive materials for military use. NSA/0135(2008)-JAIS/4170, 4 February 2008.

(5) Leila Zunino: IMX-104 Characterization for DoD Qualification, Insensitive Munitions & Energetic Materials Technology Symposium, 14-17 May 2012, Las Vegas.

(6) MSIAC Data Sheet for 2, 4-Dinitroanisole (DNAN), January 18, 2007.

(7) Gunnar Ove Nevstad: MCX-6100 CH 6027/14 Characterization, FFI-rapport 2015/02185, 18 November 2015.

(8) Gunnar Ove Nevstad: TEMPER Simulations of MCX-6100 filled 155 mm Shells – Experimental Properties. Sympathetic Reaction and Fragmentation Studies, FFI-rapport 2015/01916, 22 October 2015.

(9) Gunnar Ove Nevstad: Sympathetic Reaction TEMPER Simulations of 155 mm Shell Filled with MCX-6100 Composition, FFI -rapport 2015/01915, 22 October 2015.

(10) Emmanuel Lapébie and Pierre-François Péron: TEMPER User's Manual, MSIAC Unclassified report L-139 Edition 2, May 2011 TEMPER v2.2.1 User, Material database. MSIAC 2012. Pierre-François Péron: TEMPER V2.2 Tutorial, MSIAC Unclassified Report L-137 Edition 2, May 2011.

(11) Gunnar Ove Nevstad: Intermediate Scale Gap Test of MCX-6100, FFI-rapport 2015/2183, 18 November 2015.

(12) Gunnar Ove Nevstad: Intermediate Scale Gap Test of MCX-6100 CH 6027/14, FFI- rapport 2015/02180, 16 December 2015.

(13) Anthony Di Stasio: Characterization of Granular IMX-104, Insensitive Munitions & Energetic Materials Technology Symposium, 18-21 May 2015. Rome, Italy.

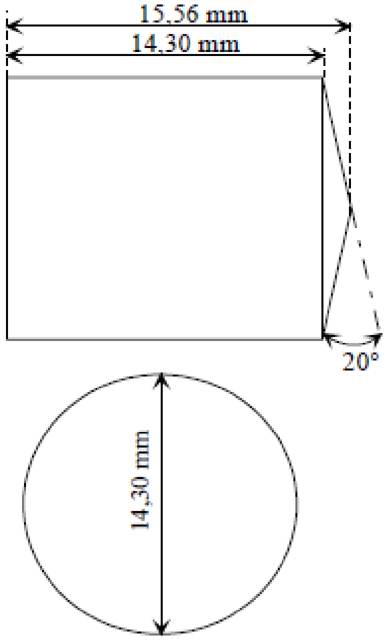
(14) Philip Samuels, Anthony di Stasio, Leila Zunino, Daniel Zaloga, Charlie Patel, Sanjev K. Singh, Amy Chau: IM Results Comparison for DNAN Based Explosives, MSIAC IM Technology Gaps Workshop, 20-24 June 2011, the Hague, The Netherlands.

Appendix A NATO fragment

Annex A from STANAG 4496 (3) is given below, describing the dimensions of a standard NATO fragment.

NATO/PFP UNCLASSIFIED

ANNEX A
STANAG 4496
(Edition 1)



Notes:

Shape ⇨ a conical ended cylinder with the ratio $\frac{\text{L (length)}}{\text{D (diameter)}} > 1$ for stability;

Tolerances : ± 0,05 mm and ± 0°30'
Fragment Mass: 18,6 g
Fragment material: Fragment Material: A mild, carbon steel with a Brinell Hardness (HB) less than 270.

Annex A: Standard Fragment