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TEMPER simulations for 120 mm IM HE-T

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English summary

Three of the IM threats, bullet impact, fragment impact and sympathetic reaction, have been studied by simulations with the MSIAC software TEMPER. TEMPER has been used to calculate the IM responses of 120 mm IM HE-T filled with PAX-48/MCX-8100 with different properties. NominalPAX-48/MCX-8100 NTO/DNAN/HMX (53/35/12) with both theoretical (calculated) and measured properties have been studied. In addition, the shock sensitivity has been varied. Three different values have been included. In total four sets of properties for PAX-48/MCX-8100 fillings have been studied.

Bullet Impact simulations have been performed with one shot with the test specification in STANAG 4241. The results show *no reaction* responses for all four filler properties included in this study.

The fragment impact test according to STANAG 4496 with a conical NATO fragment at 2530 m/s shows that a shell filled with PAX-48/MCX-8100 having shock sensitivity 54.6 kbar gives a *detonation* response for shell thicknesses of 5 and 6 mm. With the most sensitive composition, 45 kbar, a shell thickness of 9 mm is required to get a *no reaction* response.

For sympathetic reaction tests according to STANAG 4396 procedure, the response depends on both donor and acceptor properties. The following combinations of donor and acceptor properties will give ***detonation*** of acceptor listed below:

1. Acceptor/donor with shock sensitivity 54.6 kbar and calculated properties.
    a. Acceptor shell thickness 5 mm – donor shell thicknesses 5-7 mm.

2. Acceptor/donor with shock sensitivity 54.6 kbar and measured properties.
    a. Acceptor shell thickness 6 mm – donor shell thicknesses 5-7 mm.
    b. Acceptor shell thickness 5 mm – donor shell thicknesses 5-9 mm

3. Acceptor/donor with shock sensitivity 50.0 kbar and measured properties.
    a. Acceptor shell thickness 7 mm – donor shell thicknesses 5-8 mm.
    b. Acceptor shell thickness 6 mm – donor shell thicknesses 5-10 mm.
    c. Acceptor shell thickness 5 mm – donor shell thicknesses 5-12 mm.

4. Acceptor/donor with shock sensitivity 45.0 kbar and measured properties.
    a. Acceptor shell thickness 9 mm – donor shell thickness 5 mm.
    b. Acceptor shell thickness 8 mm – donor shell thicknesses 5-10 mm.
    c. Acceptor shell thicknesses 5-7 mm – donor shell thicknesses 5-12 mm.

The required response in sympathetic reaction in STANAG 4439 is a *type III*, *deflagration* or better to obtain IM compliance. The obtained responses to fulfilling the IM requirements in STANAG 4439 for PAX-48/MCX-8100 filled shells in bullet impact, fragment impact and sympathetic reaction tests require a shock sensitivity of 50.0 kbar or better. For these three IM threats no mitigation is necessary as long as the fillings are of good quality

Sammendrag

Tre av IM-truslene kuletreff, fragmenttreff og sympatetisk reaksjon har vært studert ved bruk av MSIAC simuleringsverktøyet TEMPER. Ved bruk av TEMPER har vi beregnet IM-responsen til 120 mm IM HE-T for sprengstoffyllinger med PAX-48/MCX-8100 med ulike egenskaper. Benyttet sammensetning av PAX-48/MCX-8100 var nominell 53/35/12 (NTO/DNAN/HMX), med beregnete og målte egenskaper. Tre verdier for sjokkfølsomheten ble benyttet. Totalt inkluderte studien fire sett med egenskaper for PAX-48/MCX-8100.

Kuletreffsimuleringer med ett skudd er utført med testbetingelsene gitt i STANAG 4241. Resultatet viser en *ikke reaksjon* respons for alle kombinasjoner av egenskaper til sprengstoffyllingen inkludert i denne studien.

I simuleringene av fragmenttreff, iht STANAG 4496, med et konisk NATO fragment med hastighet på 2530 m/s vil granater med PAX-48/MCX-8100 fyllinger med sjokkfølsomhet 54.6 kbar gi *detonasjon* respons med veggtykkelser på 5 og 6 mm. For fyllinger med den mest følsomme komposisjonen, 45 kbar, kreves en veggtykkelse på 9 mm eller mer for å oppnå en *ikke reaksjon* respons.

Responsen i sympatetisk reaksjon er avhengig av egenskapene til både donor og akseptor. For følgende kombinasjoner av donor og akseptoregenskaper oppnås en ***detonasjon*** respons:

1. Akseptor/donor med beregnete egenskaper og sjokkfølsomhet 54.6 kbar.
    1. Akseptor veggtykkelse 5 mm – donor veggtykkelse 5-7 mm.

2. Akseptor/donor med målte egenskaper og sjokkfølsomhet 54.6 kbar.
    1. Akseptor veggtykkelse 6 mm – donor veggtykkelse 5-7 mm.
    2. Akseptor veggtykkelse 5 mm – donor veggtykkelse 5-9 mm.

3. Akseptor/donor med målte egenskaper og sjokkfølsomhet 50.0kbar.
    1. Akseptor veggtykkelse 7 mm – donor veggtykkelse 5-8 mm.
    2. Akseptor veggtykkelse 6 mm – donor veggtykkelse 5-10 mm.
    3. Akseptor veggtykkelse 5 mm – donor veggtykkelse 5-12 mm.

4. Akseptor/donor med målte egenskaper og sjokkfølsomhet 45.0 kbar.
    1. Akseptor veggtykkelse 9 mm – donor veggtykkelse 5 mm.
    2. Akseptor veggtykkelse 8 mm – donor veggtykkelse 5-10 mm.
    3. Akseptor veggtykkelse 5-7 mm – donor veggtykkelse 5-12 mm

Kravet i STANAG 4439 til respons for å tilfredsstille kravet til IM i sympatetisk reaksjon er en Type III reaksjon, deflagrasjon eller mildere.

Utfra simuleringsresultater vil en 120 mm granat kunne oppnå IM-klassifisering med en PAX-48/MCX-8100 fylling med en sjokkfølsomhet på 50 kbar eller bedre. Dette kravet er oppnåelig med en fylling av god kvalitet. For de tre truslene studert i denne rapporten kreves ingen formildende tiltak for å tilfredsstille kravet til IM-egenskaper.

Contents

Abbreviations

BI	Bullet Impact
DNAN	2,4-dinitroanisole
FI	Fragment Impact
HDPE	High Density PolyEthylene
HE	High Explosive
HMX	Octogen/1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane
IM	Insensitive Munitions
MCX	Melt Cast Explosive
MCX-8100	NTO/DNAN/HMX (53/35/12)
NTO	3-Nitro-1,2,4 Triazol 5-one
PAX-48	NTO/DNAN/HMX (53/35/12)
SR	Sympathetic Reaction
STANAG	Standardization Agreement
TEMPER	**T**oolbox of **E**ngineering **M**odels for **P**rediction of **E**xplosive **R**eactions
TMD	Theoretical Maximum Density

1 Introduction

The 120 mm IM HE-T shell filled with PAX-48 was developed some years ago. The qualification of the shell resulted in an IM compliant product. IM compliance is obtained mainly through the properties of the main explosive filling and the attachment of the fuze. Although the product to day performs as expected several modifications to obtain a better product have been and will be considered.

The IM requirements and signature for the 120 mm IM HE-T as presented in reference (1) for the original design with a HDPE venting sleeve are summarized in Table 1.1. These test results were achieved by performing full scale IM tests according to accompanying test STANAGs for 5 of the threats specified in STANAG 4439 Ed. 3 (2). Test results obtained for the original design fulfill the requirements in STANAG 4439 Ed. 3 for IM compliance.

IM Test	Response Type: *Required*	Response type: Obtained for IM HE-T Warhead
Liquid Fuel/External Fire, Munitions test **STANAG 4240**	5	5
Slow Heating, Munitions test **STANAG 4382**	5	5
Bullet Impact, Munitions test **STANAG 4241**	5	5
Shaped Charge Jet, Munitions test **STANAG 4526**	3 or better	4
Sympathetic Reaction, Munitions test **STANAG 4396**	3 or better	NR (no reaction)

Table 1.1 IM requirements and responses in IM tests for 120mm IM HE-T warhead (1).

The PAX-48 composition is developed and qualified in US (3). The composition contains three different ingredients, a binder DNAN melting at 95°C and two solid fillers HMX and NTO with some solubility in melted DNAN. The solubility of HMX is higher than of NTO. DNAN when going from liquid to solid, has a volume decrease of 13.59 volume % (4), when it melts the volume increase is 15.72 volume %. A special cooling procedure is necessary during the casting process to obtain an acceptable quality of the cast. This gives rise to sedimentation due to density differences specially between NTO $\rho(s) = 1.91$ g/cm^3 and DNAN $\rho(l)=1.336$ g/cm^3. A corresponding composition to PAX-48 is produced by Chemring Nobel, named MCX-8100 53/35/12 (NTO/DNAN/HMX). The last one was characterized with regard to properties as detonation velocity and pressure in reference (5). Results obtained were in the same range as those US obtained for PAX-48 during the qualification. With these experimental results and properties calculated by use of Cheetah 2.0 (6) we have performed simulations with TEMPER for studies of the responses in the IM-tests, Cook-off tests are not included. The motivation for these simulations was to study the effects of changes in filler properties and design on the response in IM-tests. One of the questions of special interest was whether it would be possible to fulfil the IM-requirements for threats as BI, FI and SR without using a HDPE sleeve.

2 EXPERIMENTS

In reference (5) we determined detonation velocity and pressure for MCX-8100. These results and properties calculated by use of Cheetah 2.0 (6) are summarized in Table 2.1. The table contain also a summary of the properties required to perform simulations with the MSIAC software TEMPER (7) to study the responses for the IM-threats BI, FI and SR. Fragmentations for different generic warheads at different envelope thicknesses were included.

Cheetah Calculations for PAX-48/MCX-8100 with BKWC Product Library and Experimental Measured Properties			
		Nominal	**Experimental**
TMD	**(g/cm^3)**	**1.7650**	
Measured density	**(g/cm^3)**		**1.72**
Pressure	**(GPa)**	24.19	21.00
Velocity	**(m/s)**	7612	7100
Gamma		3.227	3.227
Gurney Cooper	**(m/s)**	2563	2391
Mott constant	**($kg^{1/2}m^{-7/6}$)**	3.159	3.727
C_o	**(m/s)**	2922	2557
S		1.60	1.83
Number of fragments			
Envelop thickness 8 mm		**5690**	**4088**
Envelop thickness 9 mm		**4638**	**3332**
Envelop thickness 10 mm		**3859**	**2773**

Table 2.1 Measured and calculated properties of PAX-48/MCX-8100.

2.1 Hugoniot

The NEWGATES V.1-10 (8) has been used to calculate the Sound velocity and Slope of D=f(u) curve needed for the material properties to perform the simulations of SR. Determination of values used for NTO and DNAN is described in reference (9).

Data to fill
Calculated Hugoniot
Details on calculations

Calculation of Mixture Hugoniot

Run | Hugoniot Database | Charts | Implement | Copy Results | Clear Sheet

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,764	2,941	1,60	1,764	0,0%	2,0	6,0	0,3	0,8

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,760	2,905	1,62	1,764	0,2%	2,0	6,0	0,3	0,8

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,750	2,815	1,68	1,764	0,8%	2,0	6,0	0,3	0,8

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,740	2,730	1,74	1,764	1,4%	2,0	6,0	0,3	0,8

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,730	2,649	1,78	1,764	1,9%	2,0	6,0	0,4	0,8

Ingredient	Name	Weight %	Density (g/cm³)	C_0 (km/s)	s (-)	Material Number
1	NTO	53,0%	1,910	2,780	1,78	9
2	DNAN	35,0%	1,546	3,180	1,31	15
3	HMX	12,0%	1,903	3,200	1,52	4

	Density (g/cm³)	C_0 (km/s)	s (-)	TMD (g/cm³)	Porosity (%)	Pmin (GPa)	Pmax (GPa)	umin (km/s)	umax (km/s)
Mixture	1,720	2,572	1,83	1,764	2,5%	2,0	6,0	0,4	0,8

Ingredient	Weight %
1	53,0%
2	35,0%
3	12,0%
4	0,0%
5	0,0%

Density (g/cm³)	Pmin (GPa)	Pmax (GPa)
1,720	2,0	6,0

Figure 2.1 Calculated Hugoniots for PAX-48/MCX-8100 with 0-2.5% porosity.

2.1.1 Nominal content

Figure 2.1 shows the calculated Hugoniot values for different porosities of PAX-48/MCX-8100 with nominal content. The nominal content of these two compositions is 12 wt. % HMX, 35 wt. % DNAN and 53 wt. % NTO, and NEWGATES gives a TMD (Theoretical Maximum Density) of 1.764 g/cm³.

2.2 Materials

2.2.1 Inert material

2.2.1.1 Steel-NoName

```
Inert Material
Rho, 7850
C0, 4570
S, 1.49
Lambda, 50
CP, 0.477e3
CJ Gamma, 1.93
```

2.2.2 Reactive material

For PAX 48 C the properties are calculated from nominal content with a value from (3) for the shock sensitivity. For material PAX 48 EXP the properties are measured and the value for the shock sensitivity is taken from (3), the same as for PAX 48 C. For PAX 48 EXP 50 and PAX 48 EXP 45 the shock sensitivity has been changed to 50 and 45 kbar.

2.2.2.1 PAX 48 C

```
Reactive Material
Rho, 1765
C0, 2941
S, 1.60
Lambda,
CP,
CJ Pressure, 24190000000
CJ Shock, 7610
CJ Gamma, 3.227
LSGT Threshold Pressure, 5460000000
A Modified Jacobs-Roslund,
```

2.2.2.2 PAX 48 EXP 1

```
Reactive Material
Rho, 1720
C0, 2572
S, 1.83
Lambda,
CP,
CJ Pressure, 2100000000
CJ Shock, 7100
CJ Gamma, 3.227
LSGT Threshold Pressure, 5460000000
A Modified Jacobs-Roslund,
```

2.2.2.3 PAX 48 EXP 50

```
Reactive Material
Rho, 1720
C0, 2572
S, 1.83
Lambda,
CP,
CJ Pressure, 2100000000
CJ Shock, 7100
CJ Gamma, 3.227
LSGT Threshold Pressure, 5000000000
A Modified Jacobs-Roslund,
```

2.2.2.4 PAX 48 EXP 45

```
Reactive Material
Rho, 1720
C0, 2572
S, 1.83
Lambda,
CP,
CJ Pressure, 2100000000
CJ Shock, 7100
CJ Gamma, 3.227
LSGT Threshold Pressure, 4500000000
A Modified Jacobs-Roslund,
```

2.3 Stimulus

2.3.1 120 mm PAX- 48 C

```
Outer-diameter, 0.120
Inner-diameter, 0.100
Case-length, 0.326
Case-thickness, 0.010
Gurney-constant, 2563
Mott-B-constant, 3.159
M-over-C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC
```

2.3.2 120 mm PAX 48 EXP 1

```
Outer-diameter, 0.120
Inner-diameter, 0.100
Case-length, 0.326
Case-thickness, 0.010
Gurney-constant, 2391
Mott-B-constant, 3.727
M-over-C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP1
```

2.3.3 120 mm PAX 48 50

```
Outer-diameter, 0.120
Inner-diameter, 0.100
Case-length, 0.326
Case-thickness, 0.010
Gurney-constant, 2391
Mott-B-constant, 3.727
M-over-C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP50
```

2.3.4 120 mm PAX 48 45

```
Outer-diameter, 0.120
Inner-diameter, 0.100
Case-length, 0.326
Case-thickness, 0.010
Gurney-constant, 2391
Mott-B-constant, 3.727
M-over-C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45
```

2.4 Structures

2.4.1 PAX 48 C

```
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC
```

2.4.2 PAX 48 EXP 1

```
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP1
```

2.4.3 PAX 48 EXP 50

```
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP50
```

2.4.4 PAX 48 EXP 45

```
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45
```

2.5 Scenarios

2.5.1 Bullet Impact

2.5.1.1

```
Scenario]
[Stimulus]
Flat End Rod
Diameter, 0.0127
Velocity, 850
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC
```

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 64 Variable1,
Stimulus. Velocity Variable2,
Structure. Thickness

850;0.005	900;0.008	950;0.011	1050;0.006	1100;0.009	1150;0.012
850;0.006	900;0.009	950;0.012	1050;0.007	1100;0.010	1200;0.005
850;0.007	900;0.010	1000;0.005	1050;0.008	1100;0.011	1200;0.006
850;0.008	900;0.011	1000;0.006	1050;0.009	1100;0.012	1200;0.007
850;0.009	900;0.012	1000;0.007	1050;0.010	1150;0.005	1200;0.008
850;0.010	950;0.005	1000;0.008	1050;0.011	1150;0.006	1200;0.009
850;0.011	950;0.006	1000;0.009	1050;0.012	1150;0.007	1200;0.010
850;0.012	950;0.007	1000;0.010	1100;0.005	1150;0.008	1200;0.011
900;0.005	950;0.008	1000;0.011	1100;0.006	1150;0.009	1200;0.012
900;0.006	950;0.009	1000;0.012	1100;0.007	1150;0.010	
900;0.007	950;0.010	1050;0.005	1100;0.008	1150;0.011	

2.5.1.2

[Scenario]
[Stimulus]
Flat End Rod
Diameter, 0.0127
Velocity, 850
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45

[Model]
MSIAC Jacobs-Roslund Vlim

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

0.005;600	0.015;600	0.025;600	0.035;600	0.045;600	0.055;600
0.005;800	0.015;800	0.025;800	0.035;800	0.045;800	0.055;800
0.005;1000	0.015;1000	0.025;1000	0.035;1000	0.045;1000	0.055;1000
0.005;1200	0.015;1200	0.025;1200	0.035;1200	0.045;1200	0.055;1200
0.005;1400	0.015;1400	0.025;1400	0.035;1400	0.045;1400	0.055;1400
0.005;1600	0.015;1600	0.025;1600	0.035;1600	0.045;1600	0.055;1600
0.005;1800	0.015;1800	0.025;1800	0.035;1800	0.045;1800	0.055;1800
0.005;2000	0.015;2000	0.025;2000	0.035;2000	0.045;2000	0.055;2000
0.005;2200	0.015;2200	0.025;2200	0.035;2200	0.045;2200	0.055;2200
0.005;2400	0.015;2400	0.025;2400	0.035;2400	0.045;2400	0.055;2400
0.005;2600	0.015;2600	0.025;2600	0.035;2600	0.045;2600	0.055;2600
0.01;600	0.02;600	0.03;600	0.04;600	0.05;600	0.06;600
0.01;800	0.02;800	0.03;800	0.04;800	0.05;800	0.06;800
0.01;1000	0.02;1000	0.03;1000	0.04;1000	0.05;1000	0.06;1000
0.01;1200	0.02;1200	0.03;1200	0.04;1200	0.05;1200	0.06;1200
0.01;1400	0.02;1400	0.03;1400	0.04;1400	0.05;1400	0.06;1400
0.01;1600	0.02;1600	0.03;1600	0.04;1600	0.05;1600	0.06;1600
0.01;1800	0.02;1800	0.03;1800	0.04;1800	0.05;1800	0.06;1800
0.01;2000	0.02;2000	0.03;2000	0.04;2000	0.05;2000	0.06;2000
0.01;2200	0.02;2200	0.03;2200	0.04;2200	0.05;2200	0.06;2200
0.01;2400	0.02;2400	0.03;2400	0.04;2400	0.05;2400	0.06;2400
0.01;2600	0.02;2600	0.03;2600	0.04;2600	0.05;2600	0.06;2600

2.5.1.3

[Scenario]
[Stimulus]
Flat End Rod
Diameter, 0.0127
Velocity, 850
Inert Material, Steel-NoName

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 96
Variable1, Stimulus. Diameter
Variable2, Structure. Thickness

0.005;0.005	0.015;0.005	0.025;0.005	0.035;0.005	0.045;0.005	0.055;0.005
0.005;0.006	0.015;0.006	0.025;0.006	0.035;0.006	0.045;0.006	0.055;0.006
0.005;0.007	0.015;0.007	0.025;0.007	0.035;0.007	0.045;0.007	0.055;0.007
0.005;0.008	0.015;0.008	0.025;0.008	0.035;0.008	0.045;0.008	0.055;0.008
0.005;0.009	0.015;0.009	0.025;0.009	0.035;0.009	0.045;0.009	0.055;0.009
0.005;0.010	0.015;0.010	0.025;0.010	0.035;0.010	0.045;0.010	0.055;0.010
0.005;0.011	0.015;0.011	0.025;0.011	0.035;0.011	0.045;0.011	0.055;0.011
0.005;0.012	0.015;0.012	0.025;0.012	0.035;0.012	0.045;0.012	0.055;0.012
0.01;0.005	0.02;0.005	0.03;0.005	0.04;0.005	0.05;0.005	0.06;0.005
0.01;0.006	0.02;0.006	0.03;0.006	0.04;0.006	0.05;0.006	0.06;0.006
0.01;0.007	0.02;0.007	0.03;0.007	0.04;0.007	0.05;0.007	0.06;0.007
0.01;0.008	0.02;0.008	0.03;0.008	0.04;0.008	0.05;0.008	0.06;0.008
0.01;0.009	0.02;0.009	0.03;0.009	0.04;0.009	0.05;0.009	0.06;0.009
0.01;0.010	0.02;0.010	0.03;0.010	0.04;0.010	0.05;0.010	0.06;0.010
0.01;0.011	0.02;0.011	0.03;0.011	0.04;0.011	0.05;0.011	0.06;0.011
0.01;0.012	0.02;0.012	0.03;0.012	0.04;0.012	0.05;0.012	0.06;0.012

2.5.2 Fragment Impact

2.5.2.1 PAX 48 C

[Scenario]
[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, 0.010
Characteristic_ dimension, 0.10
Initial_ temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC

```
[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 8
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
0.010; 0.01556
0.011; 0.01556
0.012; 0.01556
```

2.5.2.2 PAX 48 EXP 1

```
[Scenario]
[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, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP1

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 8
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
0.010; 0.01556
0.011; 0.01556
0.012; 0.01556
```

2.5.2.3 PAX 48 EXP 50

[Scenario]
[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, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP50

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 8
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
0.010; 0.01556
0.011; 0.01556
0.012; 0.01556

2.5.2.4 PAX 48 EXP 45

[Scenario]
[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, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45

```
[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 8
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
0.010; 0.01556
0.011; 0.01556
0.012; 0.01556
```

2.5.3 One-on-One Simulations

Simulations of sympathetic reaction have been performed with the MSIAC TEMPER software. Stimulus was the One-on-One Warhead model (7). The case thicknesses of both the acceptor and the donor have been varied from 5 to 12 mm. This variation covers the case thicknesses for a 120 mm IM HE-T shell with a margin of 1 mm.

2.5.3.1 PAX 48 C

```
[Scenario]
[Stimulus]
One On One Warhead
Outer diameter, 0.120
Inner diameter, 0.100
Case length, 0.326
Case thickness, 0.010
Gurney constant, 2563
Mott B constant, 3.159
M over C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC

[Mitigation]
Air
Thickness, 0.155

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameC
```

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 64
Variable1, Stimulus. Case thickness
Variable2, Structure. Thickness

0.005;0.005	0.006;0.010	0.008;0.007	0.009;0.012	0.011;0.009
0.005;0.006	0.006;0.011	0.008;0.008	0.010;0.005	0.011;0.010
0.005;0.007	0.006;0.012	0.008;0.009	0.010;0.006	0.011;0.011
0.005;0.008	0.007;0.005	0.008;0.010	0.010;0.007	0.011;0.012
0.005;0.009	0.007;0.006	0.008;0.011	0.010;0.008	0.012;0.005
0.005;0.010	0.007;0.007	0.008;0.012	0.010;0.009	0.012;0.006
0.005;0.011	0.007;0.008	0.009;0.005	0.010;0.010	0.012;0.007
0.005;0.012	0.007;0.009	0.009;0.006	0.010;0.011	0.012;0.008
0.006;0.005	0.007;0.010	0.009;0.007	0.010;0.012	0.012;0.009
0.006;0.006	0.007;0.011	0.009;0.008	0.011;0.005	0.012;0.010
0.006;0.007	0.007;0.012	0.009;0.009	0.011;0.006	0.012;0.011
0.006;0.008	0.008;0.005	0.009;0.010	0.011;0.007	0.012;0.012
0.006;0.009	0.008;0.006	0.009;0.011	0.011;0.008	

2.5.3.2 PAX 48 EXP 1

Scenario]
[Stimulus]
One On One Warhead
Outer diameter, 0.120
Inner diameter, 0.100
Case length, 0.326
Case thickness, 0.010
Gurney constant, 2391
Mott B constant, 3.727
M over C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP1

[Mitigation]
Air
Thickness, 1000e-3

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP1

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 64
Variable1, Stimulus. Case thickness
Variable2, Structure. Thickness

0.005;0.005	0.006;0.010	0.008;0.007	0.009;0.012	0.011;0.009
0.005;0.006	0.006;0.011	0.008;0.008	0.010;0.005	0.011;0.010
0.005;0.007	0.006;0.012	0.008;0.009	0.010;0.006	0.011;0.011
0.005;0.008	0.007;0.005	0.008;0.010	0.010;0.007	0.011;0.012
0.005;0.009	0.007;0.006	0.008;0.011	0.010;0.008	0.012;0.005
0.005;0.010	0.007;0.007	0.008;0.012	0.010;0.009	0.012;0.006
0.005;0.011	0.007;0.008	0.009;0.005	0.010;0.010	0.012;0.007
0.005;0.012	0.007;0.009	0.009;0.006	0.010;0.011	0.012;0.008
0.006;0.005	0.007;0.010	0.009;0.007	0.010;0.012	0.012;0.009
0.006;0.006	0.007;0.011	0.009;0.008	0.011;0.005	0.012;0.010
0.006;0.007	0.007;0.012	0.009;0.009	0.011;0.006	0.012;0.011
0.006;0.008	0.008;0.005	0.009;0.010	0.011;0.007	0.012;0.012
0.006;0.009	0.008;0.006	0.009;0.011	0.011;0.008	

2.5.3.3 PAX 48 EXP 50

[Scenario]
[Stimulus]
One On One Warhead
Outer diameter, 0.120
Inner diameter, 0.100
Case length, 0.326
Case thickness, 0.010
Gurney constant, 2391
Mott B constant, 3.727
M over C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP50

[Mitigation]
Air
Thickness, 0.155

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP50

[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 64
Variable1, Stimulus. Case thickness
Variable2, Structure. Thickness

0.005;0.005	0.006;0.010	0.008;0.007	0.009;0.012	0.011;0.009
0.005;0.006	0.006;0.011	0.008;0.008	0.010;0.005	0.011;0.010
0.005;0.007	0.006;0.012	0.008;0.009	0.010;0.006	0.011;0.011
0.005;0.008	0.007;0.005	0.008;0.010	0.010;0.007	0.011;0.012
0.005;0.009	0.007;0.006	0.008;0.011	0.010;0.008	0.012;0.005
0.005;0.010	0.007;0.007	0.008;0.012	0.010;0.009	0.012;0.006
0.005;0.011	0.007;0.008	0.009;0.005	0.010;0.010	0.012;0.007
0.005;0.012	0.007;0.009	0.009;0.006	0.010;0.011	0.012;0.008
0.006;0.005	0.007;0.010	0.009;0.007	0.010;0.012	0.012;0.009
0.006;0.006	0.007;0.011	0.009;0.008	0.011;0.005	0.012;0.010
0.006;0.007	0.007;0.012	0.009;0.009	0.011;0.006	0.012;0.011
0.006;0.008	0.008;0.005	0.009;0.010	0.011;0.007	0.012;0.012
0.006;0.009	0.008;0.006	0.009;0.011	0.011;0.008	

2.5.3.4 PAX 48 EXP 45

[Scenario]
[Stimulus]
One On One Warhead
Outer diameter, 0.120
Inner diameter, 0.100
Case length, 0.326
Case thickness, 0.010
Gurney constant, 2391
Mott B constant, 3.727
M over C,
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45

[Mitigation]
Air
Thickness, 0.155

[Structure]
Covered Plane Explosive
Thickness, 0.010
Characteristic dimension, 0.10
Initial temperature, 298
Inert Material, Steel-NoName
Reactive Material, PAX-48-NoNameEXP45

```
[Model]
MSIAC Jacobs-Roslund Vlim

[Simulation Parameters]
Number of points, 64
Variable1, Stimulus. Case thickness
Variable2, Structure. Thickness

0.005;0.005   0.006;0.010   0.008;0.007   0.009;0.012   0.011;0.009
0.005;0.006   0.006;0.011   0.008;0.008   0.010;0.005   0.011;0.010
0.005;0.007   0.006;0.012   0.008;0.009   0.010;0.006   0.011;0.011
0.005;0.008   0.007;0.005   0.008;0.010   0.010;0.007   0.011;0.012
0.005;0.009   0.007;0.006   0.008;0.011   0.010;0.008   0.012;0.005
0.005;0.010   0.007;0.007   0.008;0.012   0.010;0.009   0.012;0.006
0.005;0.011   0.007;0.008   0.009;0.005   0.010;0.010   0.012;0.007
0.005;0.012   0.007;0.009   0.009;0.006   0.010;0.011   0.012;0.008
0.006;0.005   0.007;0.010   0.009;0.007   0.010;0.012   0.012;0.009
0.006;0.006   0.007;0.011   0.009;0.008   0.011;0.005   0.012;0.010
0.006;0.007   0.007;0.012   0.009;0.009   0.011;0.006   0.012;0.011
0.006;0.008   0.008;0.005   0.009;0.010   0.011;0.007   0.012;0.012
0.006;0.009   0.008;0.006   0.009;0.011   0.011;0.008
```

3 RESULTS

3.1 Fragmentation

3.1.1 Nominal content-calculated properties

The explosive properties given in Table 2.1 have been used to calculate fragmentation with a module in TEMPER. Table 3.1 summarizes the input parameters used for a shell filled with MCX-8100/PAX-48. Theoretical performance properties have been used to calculate the properties of the Worst Credible fragment for different envelope thicknesses. The results of the calculations are shown in Table 3.11.

Outer diameter	**(m)**	0.12
Case length	**(m)**	0.326
Gurney constant	**(m/s)**	2563
Mott B constant	**($kg^{1/2}m^{-7/6}$)**	3.159
Explosive density	**(g/cm^3)**	1.765

Table 3.1 Properties of the 120 mm donor shell used in this study.

Table 3.2 summarizes the values used as input for the calculations of number of fragments for envelop thicknesses from 8 to 10 mm. Table 3.5 gives the obtained fragment distribution.

Envelope thickness (mm)	**8**	**9**	**10**
M0 (Total mass in kg)	9.32	9.32	9.32
m50 [kg]	0.0016	0.0020	0.0024
Number of fragments	**5690**	**4638**	**3859**

Table 3.2 Input and fragmentation results for different envelop thicknesses.

3.1.2 Measured properties

The measured explosive properties given in Table 2.1 have been used to calculate fragmentation with a module in TEMPER. Table 3.3 summarizes the input parameters, and the results of the calculations are shown in Table 3.14.

Outer diameter	**(m)**	0.12
Case length	**(m)**	0.326
Gurney constant	**(m/s)**	2391
Mott B constant	**($kg^{1/2}m^{-7/6}$)**	3.727
Explosive density	**(g/cm^3)**	1.72

Table 3.3 Properties of the 120 mm donor shell used in this study.

Envelope thickness	**(mm)**	**8**	**9**	**10**
M0	(Total mass in kg)	9.32	9.32	9.32
m50	[kg]	0.0023	0.0028	0.0034
Number of fragments		**4088**	**3332**	**2773**

Table 3.4 Input and fragmentation results for different envelop thicknesses.

Fragmentation with theoretically calculated properties of MCX-8100/PAX-48						
Total number of fragments	8 mm envelope		9 mm envelope		10 mm envelope	
	5690		4638		3859	
Fragment mass (g)	Number of Frag. Above	Fragment %	Number of Frag. Above	Fragment %	Number of Frag. Above	Fragment %
0.05	4444.22	21.892	3710.949	19.996	3148.768	18.412
0.5	2604.76	54.221	2290.815	50.612	2027.902	47.455
2	1192.43	79.043	1131.381	75.609	1065.559	72.390
3	839.28	85.250	823.937	82.237	797.919	79.325
4	624.20	89.030	630.659	86.404	625.255	83.799
7	305.80	94.626	331.130	92.861	347.406	90.998
10	172.80	96.963	197.785	95.736	217.115	94.374
13	105.88	98.139	127.095	97.260	145.043	96.242
16	68.48	98.797	85.747	98.151	101.297	97.375
19	46.06	99.191	59.939	98.708	73.072	98.107
22	31.93	99.439	43.060	99.072	54.041	98.600
25	22.68	99.601	31.618	99.318	40.773	98.944
28	16.43	99.711	23.639	99.490	31.272	99.190
31	12.11	99.787	17.944	99.613	24.320	99.370
34	9.05	99.841	13.800	99.702	19.140	99.504
37	6.86	99.880	10.734	99.769	15.220	99.606
40	5.25	99.908	8.434	99.818	12.214	99.684
45	3.43	99.940	5.752	99.876	8.615	99.777
50	2.30	99.960	4.005	99.914	6.192	99.840
55	1.57	99.972	2.838	99.939	4.523	99.883
60	1.09	99.981	2.042	99.956	3.350	99.913
65	0.77	99.986	1.490	99.968	2.512	99.935
70	0.55	99.990	1.100	99.976	1.905	99.951
75	0.40	99.993	0.820	99.982	1.458	99.962
80	0.29	99.995	0.618	99.987	1.126	99.971
85	0.21	99.996	0.470	99.990	0.876	99.977
90	0.16	99.997	0.360	99.992	0.687	99.982
95	0.12	99.998	0.277	99.994	0.542	99.986
100	0.090	99.998	0.216	99.995	0.431	99.989
105	0.069	99.999	0.168	99.996	0.344	99.991
110	0.053	99.999	0.132	99.997	0.276	99.993
115	0.041	99.999	0.105	99.998	0.223	99.994
120	0.031	99.999	0.083	99.998	0.181	99.995
125	0.025	100.000	0.066	99.999	0.147	99.996
130	0.019		0.053	99.999	0.120	99.997
135	0.015		0.043	99.999	0.099	99.997
140	0.012		0.035	99.999	0.081	99.998
145	0.009		0.028	99.999	0.067	99.998
150	0.008		0.023	100.000	0.056	99.999
155	0.006		0.019		0.046	99.999
160	0.005		0.015		0.039	99.999
165	0.004		0.013		0.032	99.999
170	0.003		0.010		0.027	99.999
175	0.003		0.009		0.023	99.999
180	0.002		0.007		0.019	100.00
185	0.002		0.006		0.016	
190	0.001		0.005		0.014	
195	0.001		0.004		0.012	
200	0.001		0.003		0.010	
205	0.001		0.003		0.008	

Table 3.5 Fragment distribution calculated with theoretically determined properties of MCX-8100/PAX-48.

Fragmentation with experimentally measured properties of MCX-8100/PAX-48						
Total number of fragments	8 mm envelope		9 mm envelope		10 mm envelope	
	4088		3332		2773	
Fragment mass (g)	Number of Frag. Above	Fragment %	Number of Frag. Above	Fragment %	Number of Frag. Above	Fragment %
0.05	3315.34	18.90	2758.25	17.23	2333.33	15.84
0.5	2107.96	48.43	1832.59	45.01	1606.97	42.04
2	1087.04	73.41	1007.80	69.76	931.40	66.41
3	807.17	80.25	770.28	76.88	728.89	73.71
4	628.02	84.64	614.11	81.57	592.79	78.62
7	343.01	91.61	355.70	89.33	360.23	87.01
10	211.45	94.83	229.82	93.10	241.85	91.28
13	139.61	96.58	157.98	95.26	171.81	93.80
16	96.49	97.64	113.17	96.60	126.74	95.43
19	68.94	98.31	83.55	97.49	96.09	96.53
22	50.54	98.76	63.12	98.11	74.41	97.32
25	37.82	99.07	48.58	98.54	58.60	97.89
28	28.78	99.30	37.97	98.86	46.80	98.31
31	22.22	99.46	30.06	99.10	37.82	98.64
34	17.37	99.58	24.06	99.28	30.87	98.89
37	13.72	99.66	19.45	99.42	25.42	99.08
40	10.94	99.73	15.85	99.52	21.10	99.24
45	7.64	99.81	11.46	99.66	15.69	99.43
50	5.44	99.87	8.43	99.75	11.86	99.57
55	3.93	99.90	6.30	99.81	9.09	99.67
60	2.89	99.93	4.76	99.86	7.05	99.75
65	2.15	99.95	3.65	99.89	5.52	99.80
70	1.62	99.96	2.82	99.92	4.37	99.84
75	1.23	99.97	2.20	99.93	3.48	99.87
80	0.941	99.977	1.73	99.95	2.80	99.90
85	0.727	99.982	1.37	99.96	2.26	99.92
90	0.566	99.986	1.09	99.97	1.84	99.93
95	0.444	99.989	0.877	99.974	1.51	99.95
100	0.350	99.991	0.708	99.979	1.24	99.96
105	0.278	99.993	0.575	99.983	1.02	99.96
110	0.222	99.995	0.469	99.986	0.850	99.969
115	0.178	99.996	0.384	99.988	0.709	99.974
120	0.143	99.996	0.316	99.991	0.593	99.979
125	0.116	99.997	0.261	99.992	0.498	99.982
130	0.094	99.998	0.216	99.994	0.420	99.985
135	0.077	99.998	0.180	99.995	0.355	99.987
140	0.063	99.998	0.150	99.995	0.301	99.989
145	0.052	99.999	0.126	99.996	0.256	99.991
150	0.043	99.999	0.106	99.997	0.219	99.992
155	0.035	99.999	0.089	99.997	0.187	99.993
160	0.029	99.999	0.075	99.998	0.161	99.994
165	0.024	99.999	0.064	99.998	0.138	99.995
170	0.020	100.000	0.054	99.998	0.119	99.996
175	0.017	100.000	0.046	99.999	0.103	99.996
180	0.014	100.000	0.039	99.999	0.089	99.997
185	0.012	100.000	0.034	99.999	0.077	99.997
190	0.010	100.000	0.029	99.999	0.067	99.998
195	0.009	100.000	0.025	99.999	0.058	99.998
200	0.007	100.000	0.021	99.999	0.051	99.998
205	0.006	100.000	0.018	99.999	0.044	99.998

Table 3.6 Fragment distribution calculated with experimentally measured properties of MCX-8100/PAX-48.

Input values and the results of calculated number of fragments and size/size distribution for envelop thicknesses from 8 to 10 mm are summarized in Table 3.4 and Table 3.6.

The obtained fragment distribution shows strong dependence of the properties of the explosive filling. Theoretically calculated properties give more fragments than the experimentally measured properties for equal envelope thickness. Our measured properties are slightly below the properties obtained by ARDEC during qualification of PAX-48 (3). For a filling with production quality the fragmentation results will be between the two results given in Table 3.5 and 3.6.

3.2 Bullet Impact

STANAG 4241(10) sets the requirements for performing the BI-test. The bullet shall have diameter 12.7 mm and impact velocity shall be 850 m/s. In the simulation with TEMPER we can perform only one firing on virgin material. The STANAG 4241 gives a test requirement of three hits within a diameter of 50 mm. However, since we have no properties of damaged material, we have not the option to perform simulation with 3 hits.

The most important property of the explosive filling in BI-test is the shock sensitivity. For the two alternatives of filling we have studied, with theoretical calculated and experimentally measured properties, we have no own measured shock sensitivity data. We have used 54.6 kbar,

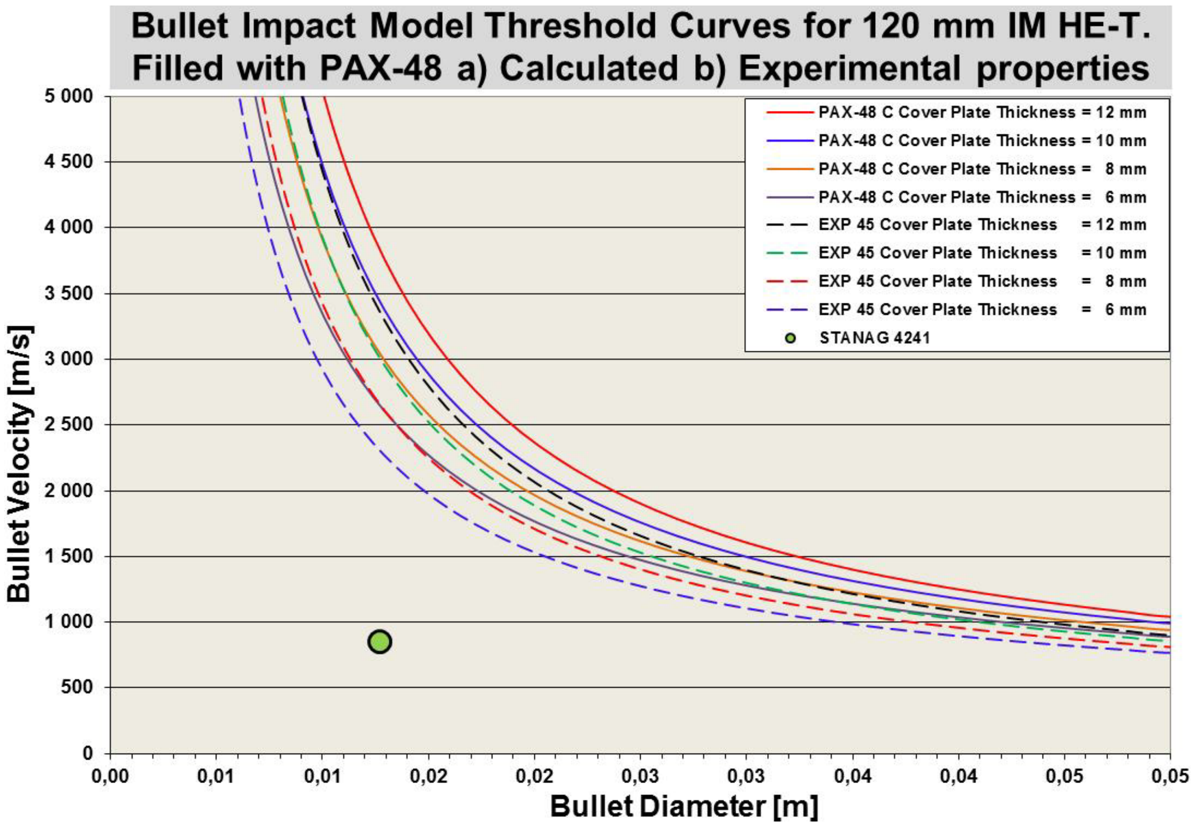
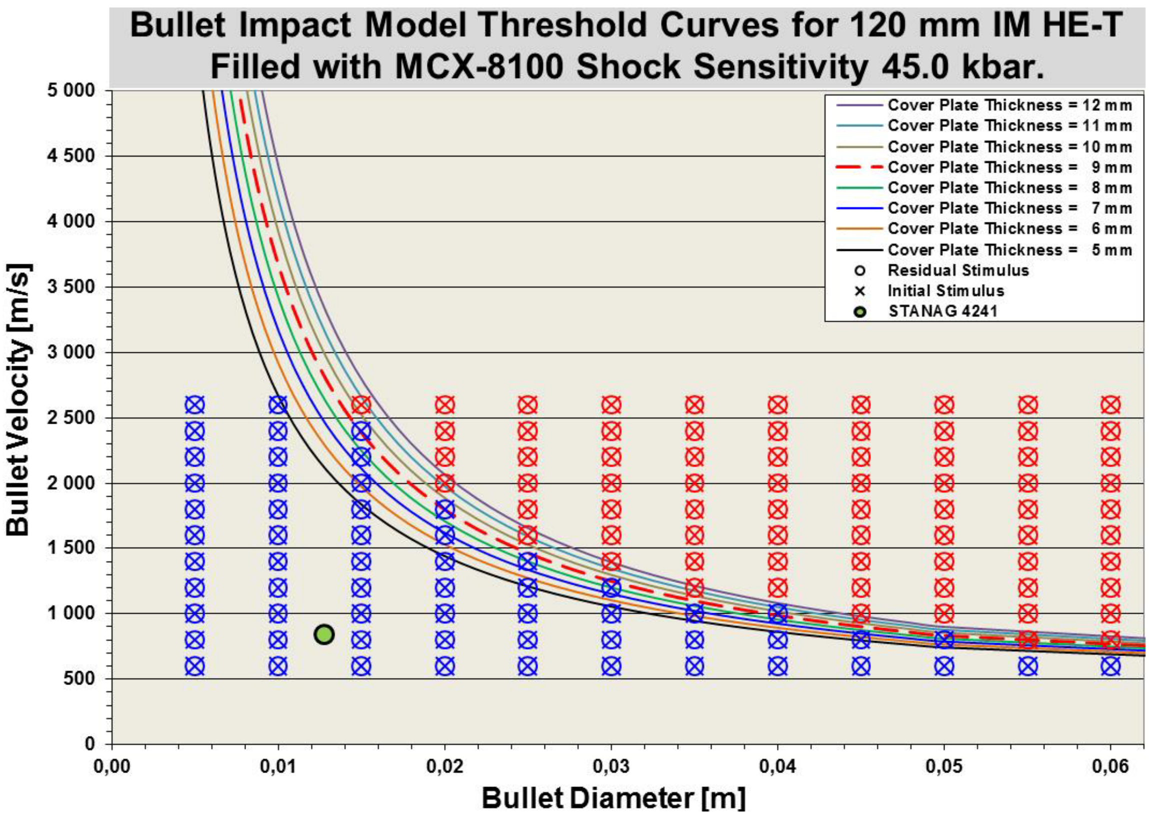


Figure 3.1 Model threshold curves for PAX-48 with calculated properties and MCX-8100 with experimental properties. The PAX-48 filling has a shock sensitivity of 54.6 kbar and the MCX-8100 filling a shock sensitivity of 45 kbar.

taken from the qualification report of PAX-48 (3). In addition we have chosen two shock sensitivity values, 50 and 45 kbar, as examples of sensitivity for fillings with sedimentation and/or pores/voids. The results in Figure 3.1 show that the position of the bullet is far from all threshold curves for both PAX-48 and MCX-8100 filled acceptors.



The colour code for the bullets is for shell thickness 10 mm. **Blue** ***No Reaction***, **Red** ***Detonation***.

Figure 3.2 Model threshold curves for MCX-8100 with experimental properties and a shock sensitivity of 45 kbar, and the response of bullet with diameter from 5 to 60 mm in step of 5 mm with velocity from 600 to 2600 m/s in step of 200 m/s.

Figure 3.2 gives the threshold curves for a shell filled with MCX-8100 with experimentally measured properties and a shock sensitivity of 45 kbar. This is the most sensitive filling we have included in this report. The properties of the threat bullet have been varied with diameter from 5 to 60 mm in steps of 5 mm and velocity from 600 to 2600 m/s in steps of 200 m/s. With a position of the bullet above the threshold curve a detonation (red) response will occur and below no reaction (blue) response. The threat specified in STANAG 4241 to a 120 mm shell filled with PAX-48/MCX-8100 filling will, with high probability, respond with a reaction not more severe than a *no reaction* or *type V* response. This will probably be true even for a three bullet hit.

3.3 Fragment Impact

3.3.1 PAX 48 C

STANAG 4496 (11) defines the threat in fragment impact test. The threat is a fragment with diameter 14.3 mm, velocity of 2530 m/s and weight of 18.6 g. The fragment impact threat is a more energetic threat than the bullet impact. Figure 3.3 shows threshold curves for a shell filled with PAX-48 with calculated properties and a shock sensitivity of 54.6 kbar for shell thicknesses from 5 to 12 mm. The fragment is positioned above the threshold curves for 5 and 6 mm shell thicknesses implying that to avoid a *detonation* response the shell thickness should be at least 7 mm.

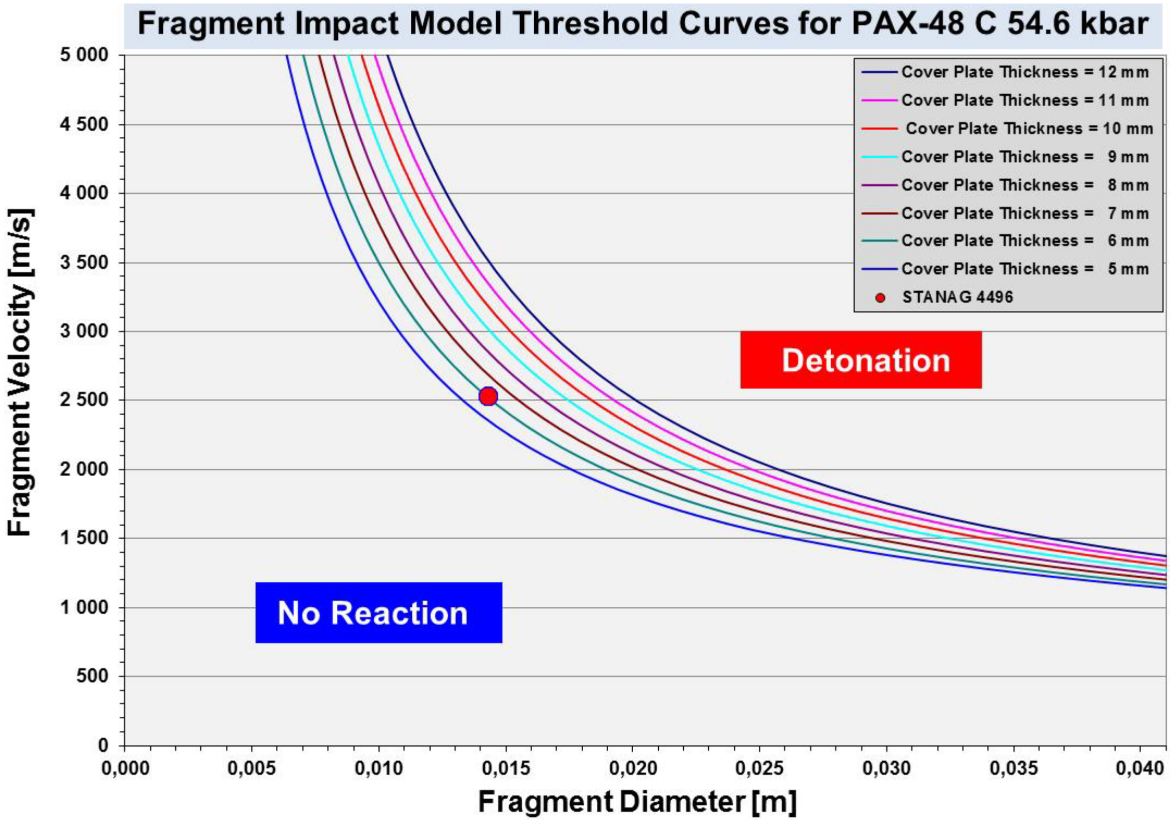


Figure 3.3 Model threshold curves for a 120 mm shell filled with PAX-48 C 54.6 kbar and the position of the fragment threat.

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

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

Table 3.7 Response in an acceptor filled with PAX-48 with Cheetah 2.0 BKWC calculated properties and shock sensitivity 54.6 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

3.3.2 PAX 48 EXP 1

In this simulation we used a PAX-48/MCX-8100 filling with experimentally measured properties and a shock sensitivity of 54.6 kbar. The response of this acceptor doesn't deviate from what we obtained with calculated properties and as Figure 3.4 and Table 3.8 show. For a 120 mm shell with thicknesses 5 and 6 mm a hit will give a *detonation* response.

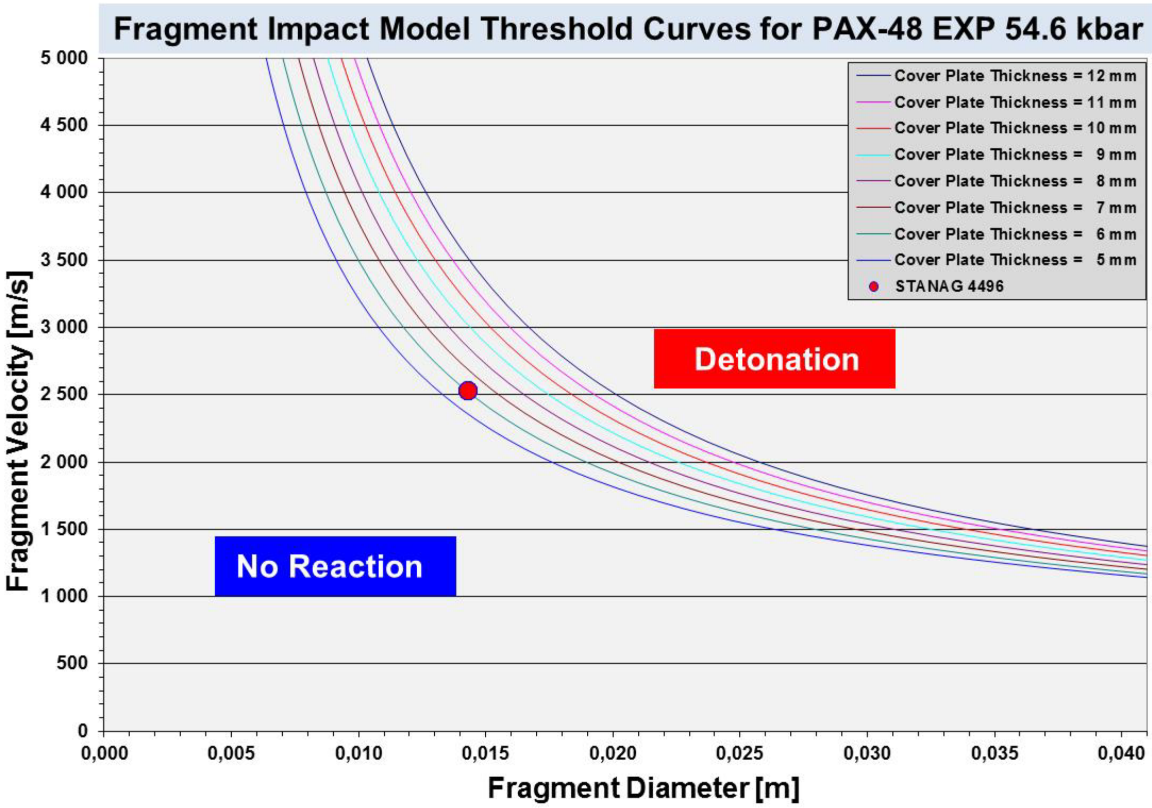


Figure 3.4 Model threshold curves for 120 mm shell filled with PAX-48 EXP 54.6 kbar, and the position of the fragment threat.

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

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

Table 3.8 Response in acceptor filled with PAX-48 with measured properties and shock sensitivity 54.6 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

3.3.3 PAX 48 EXP 50

In this simulation we used a PAX-48/MCX-8100 filling with experimentally measured properties and a shock sensitivity of 50 kbar. The response of this acceptor is slightly different from the former as the position of the fragment moves up approximately one mm, but as Table 3.9 shows, the response for shell thickness 7 mm is still a *no reaction* response.

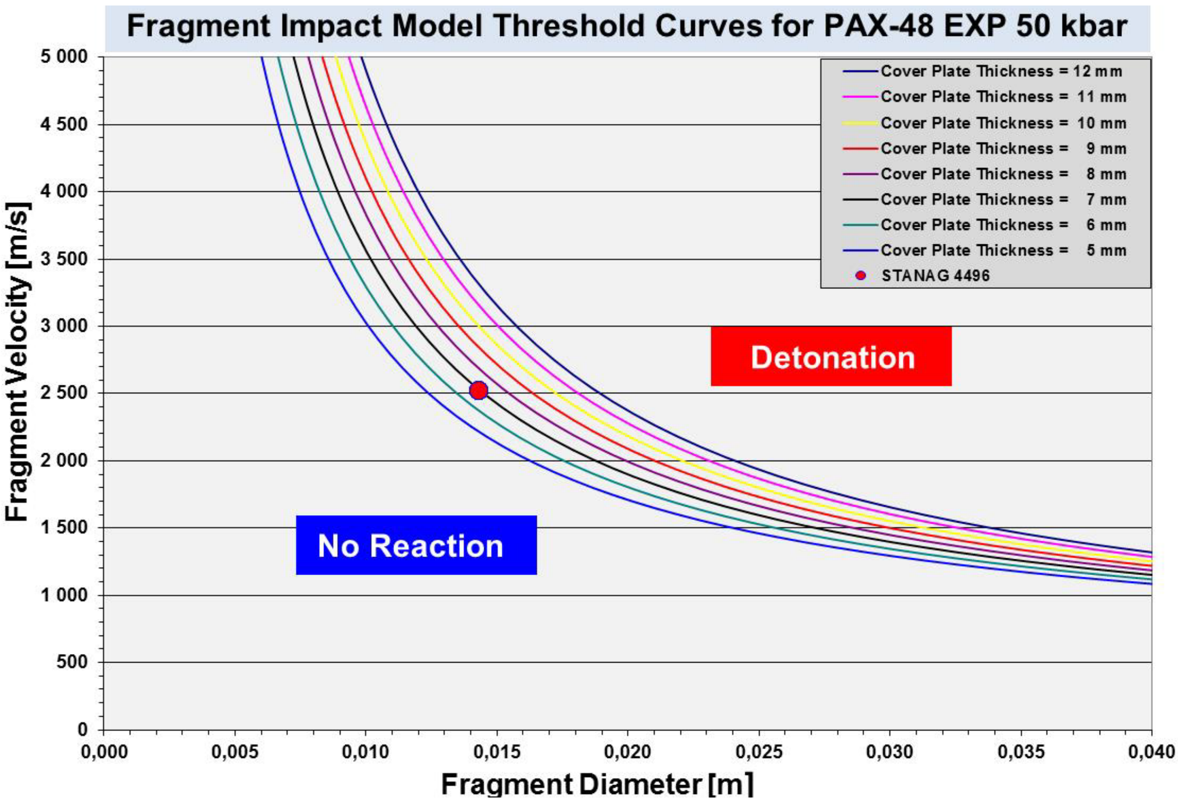


Figure 3.5 Model threshold curves for 120 mm shell filled with PAX-48 EXP 50 kbar, and the position of the fragment threat.

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

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

Table 3.9 Response in a 120 mm acceptor shell filled with PAX-48/MCX-8100 with experimental properties and shock sensitivity 50 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

3.3.4 PAX 48 EXP 45

The last simulation of fragment impact test was with a PAX-48/MCX-8100 explosive filling with shock sensitivity 45 kbar and experimentally measured properties. The response of this acceptor changes compared with the three former simulations. The fragment position moves to above the threshold curve for 8 mm shell thickness, see Figure 3.6. For shell thicknesses from 5 to 8 mm the shell will respond with a *detonation* response. With a shell thickness of 9 mm or more the response will be a *no reaction* response.

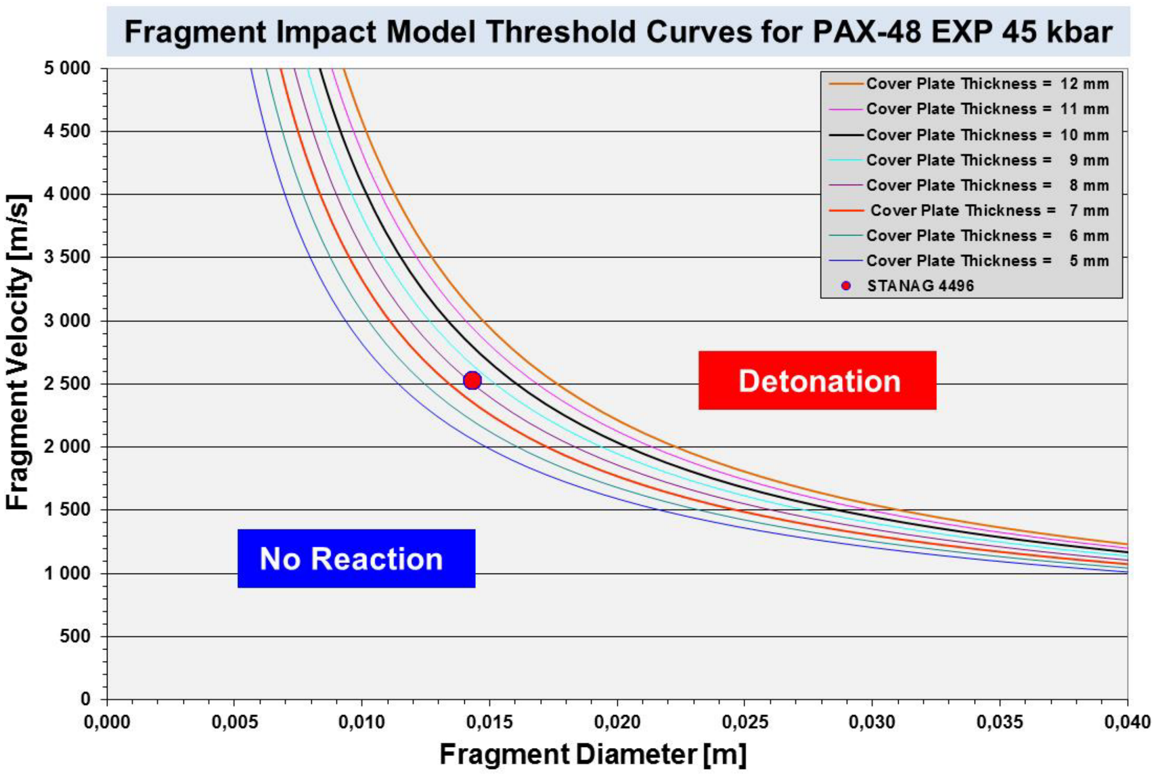


Figure 3.6 Fragment impact threshold curves for PAX-48 EXP 45 kbar.

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

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

Table 3.10 Response in acceptor filled with PAX-48 with experimental properties and shock sensitivity 45 kbar when hit by a conical NATO fragment with a velocity of 2530 m/s.

The STANAG 4439 requirement for fragment test is a *Type V* or *no reaction* response for IM compliance. To fulfil this requirement a PAX-48/MCX-8100 filling in a 120 mm shell should have a shock sensitivity of 50 kbar or better.

3.4 Sympathetic Reaction "One-on-One"

Simulations of sympathetic reaction (12) have been performed with TEMPER and the One-on-One warhead model for four different scenarios. In all simulations the donor and the acceptor have the same explosive filling properties. The PAX-48/MCX-8100 filler have either calculated or experimentally measured properties. The content in both alternatives is the nominal. Included shock sensitivities are a value of 54.6 kbar taken from reference (3), and two selected values of 50 and 45 kbar. The last two values represent fillings with some porosity and/or sedimentation. Both are phenomena often observed for this kind of melt-casted explosive fillings.

3.4.1 PAX-48 C

The first simulation was with an acceptor and a donor having PAX-48 filling with calculated properties and a shock sensitivity 54.6 kbar. Figure 3.7 shows acceptor threshold curves and Worst Credible (WC) fragments coming from 5 to 12 mm donor shell thicknesses. Table 3.11 gives the properties of these WC-fragments in form of mass, dimensions and velocity in addition to equivalent diameter for different envelope thicknesses.

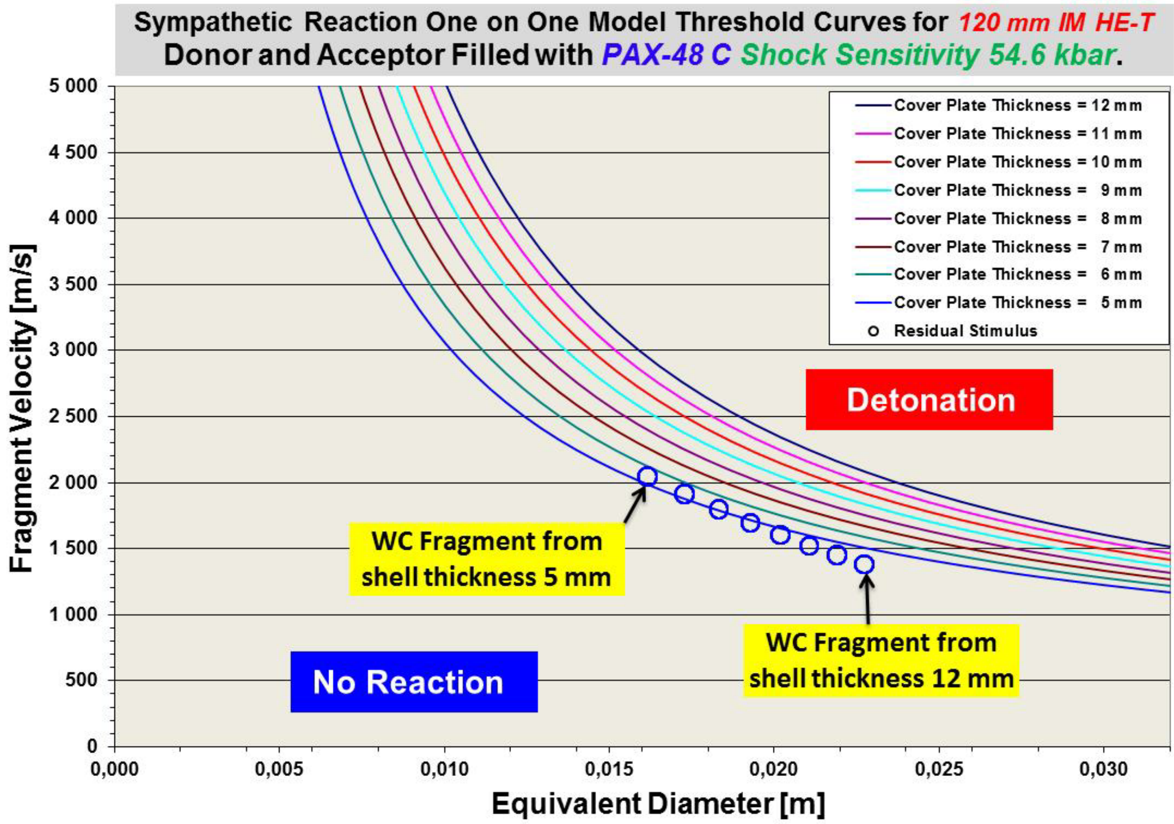


Figure 3.7 Detonation threshold curves for an acceptor filled with PAX-48/MCX-8100 composition with calculated properties and shock sensitivity 54.6 kbar, and worst credible fragments for the donor shell filled with PAX-48/MCX-8100 composition with calculated properties and shock sensitivity 54.6 kbar.

From Figure 3.7 it can be seen that only two of the worst credible fragments are positioned above the threshold curve for 5 mm acceptor shell thickness. These two fragments will give a *detonation* response in the acceptor shell. For all other WC-fragments there will be a *no reaction* response. Table 3.12 and 3.13 show the same results. Main observation for this simulation is that only for fragments and shell thicknesses outside those found in 120 mm IM HE-T result in a *detonation* response. To pass the IM requirement in STANAG 4439 (2) for SR-test a *type III* or *deflagration* response is required.

Envelop thickness [mm]	Velocity [m/s]	m50 [g]	Frag mass [g]	Thickness [mm]	Length [mm]	Width [mm]	Eq. Diameter [mm]
5	2043.9	**0.73**	7.76	3.04	25.50	12.75	**16.16**
6	1910.9	**1.00**	10.59	3.63	27.26	13.63	**17.29**
7	1795.6	**1.30**	13.80	4.21	28.89	14.44	**18.32**
8	1694.2	**1.64**	17.37	4.79	30.41	15.20	**19.28**
9	1603.8	**2.01**	21.31	5.35	31.85	15.92	**20.19**
10	1522.5	**2.41**	25.61	5.91	33.22	16.61	**21.06**
11	1448.7	**2.86**	30.28	6.46	34.55	17.28	**21.90**
12	1381.1	**3.33**	35.32	7.01	35.84	17.92	**22.72**
13	1318.9	**3.84**	40.75	7.54	37.10	18.55	**23.52**
14	1261.2	**4.39**	46.56	8.07	38.34	19.17	**24.31**
15	1207.4	**4.98**	52.78	8.59	39.57	19.79	**25.09**
16	1157.1	**5.60**	59.41	9.10	40.79	20.39	**25.86**

Table 3.11 Properties of worst credible fragments from 120 mm IM HE-T donor with PAX-48 C filling.

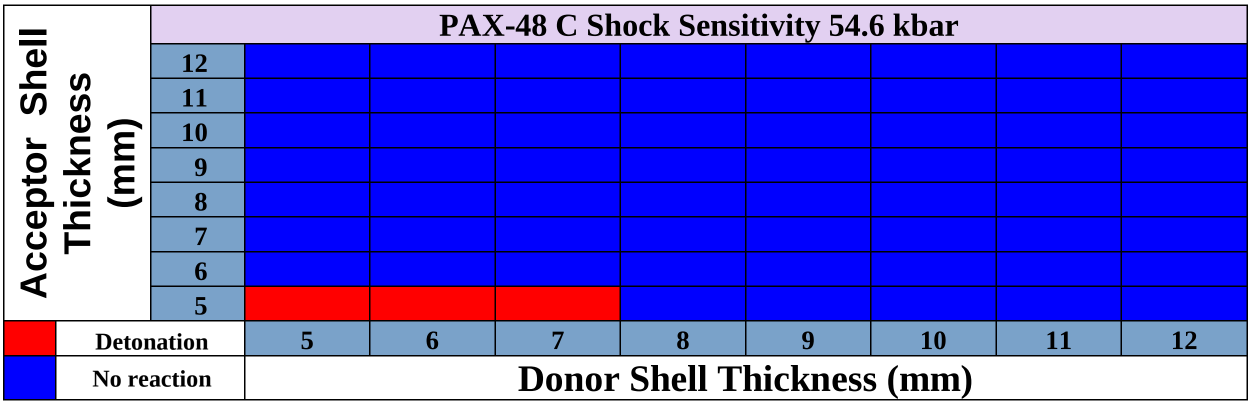


Table 3.12 Responses for 120 mm shells filled with PAX-48 C with shock sensitivity 54.6 kbar depending on shell thicknesses in both donor and acceptor.

PAX-48 C – Shock sensitivity 54.6 kbar											
Donor	Acceptor	Fragment		Donor	Acceptor	Fragment		Donor	Acceptor	Fragment	
Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity
mm	mm	mm	m/s	mm	mm	mm	m/s	mm	mm	mm	m/s
5	5	16.16	2043.9	7	11	18.32	1795.6	10	9	21.06	1522.5
5	6	16.16	2043.9	7	12	18.32	1795.6	10	10	21.06	1522.5
5	7	16.16	2043.9	8	5	19.28	1694.2	10	11	21.06	1522.5
5	8	16.16	2043.9	8	6	19.28	1694.2	10	12	21.06	1522.5
5	9	16.16	2043.9	8	7	19.28	1694.2	11	5	21.90	1448.7
5	10	16.16	2043.9	8	8	19.28	1694.2	11	6	21.90	1448.7
5	11	16.16	2043.9	8	9	19.28	1694.2	11	7	21.90	1448.7
5	12	16.16	2043.9	8	10	19.28	1694.2	11	8	21.90	1448.7
6	5	17.29	1910.9	8	11	19.28	1694.2	11	9	21.90	1448.7
6	6	17.29	1910.9	8	12	19.28	1694.2	11	10	21.90	1448.7
6	7	17.29	1910.9	9	5	20.19	1603.8	11	11	21.90	1448.7
6	8	17.29	1910.9	9	6	20.19	1603.8	11	12	21.90	1448.7
6	9	17.29	1910.9	9	7	20.19	1603.8	12	5	22.72	1381.1
6	10	17.29	1910.9	9	8	20.19	1603.8	12	6	22.72	1381.1
6	11	17.29	1910.9	9	9	20.19	1603.8	12	7	22.72	1381.1
6	12	17.29	1910.9	9	10	20.19	1603.8	12	8	22.72	1381.1
7	5	18.32	1795.6	9	11	20.19	1603.8	12	9	22.72	1381.1
7	6	18.32	1795.6	9	12	20.19	1603.8	12	10	22.72	1381.1
7	7	18.32	1795.6	10	5	21.06	1522.5	12	11	22.72	1381.1
7	8	18.32	1795.6	10	6	21.06	1522.5	12	12	22.72	1381.1
7	9	18.32	1795.6	10	7	21.06	1522.5				
7	10	18.32	1795.6	10	8	21.06	1522.5				

Table 3.13 Responses for worst credible fragments of different diameters and velocities. ***Red colour*** *gives a* ***detonation*** *response in the acceptor.* ***Blue colour*** *gives a* ***no reaction*** *response in the acceptor.*

3.4.2 PAX-48 EXP

The second simulation was with an acceptor and a donor having PAX-48/MCX-8100 filling with experimentally measured properties and a shock sensitivity 54.6 kbar. Figure 3.8 shows acceptor threshold curves and Worst Credible (WC) fragments from 5 to 12 mm donor shell thicknesses. Table 3.14 gives the properties of these fragments in form of mass, dimensions and velocity in addition to equivalent diameter for different envelope thicknesses.

Figure 3.8 shows that five of the worst credible fragments have a position above one or more acceptor threshold curves giving *detonation* responses in the acceptor. The same results are shown in Table 3.15 and 3.16. For the WC-fragments coming from donor envelope thicknesses of 5 and 6 mm the acceptor shell needs 7 mm or thicker steel casing protection to respond with *no reaction* responses. For WC-fragments coming from donor shell thicknesses of 8 and 9 mm the acceptor shell thickness needed for protection is reduced to 5 mm. For WC-fragments coming from donor shell thickness 10 mm or thicker *no reaction* response is observed. The observed difference in response between PAX-48/MCX-8100 filling with calculated and experimentally measured properties is because the latter produces larger WC-fragments. PAX-48/MCX-8100 is not an ideal explosive, so in the real life the measured performance properties will be lower than for the calculated. How large these differences will be are determined by the quality of the casted fillings.

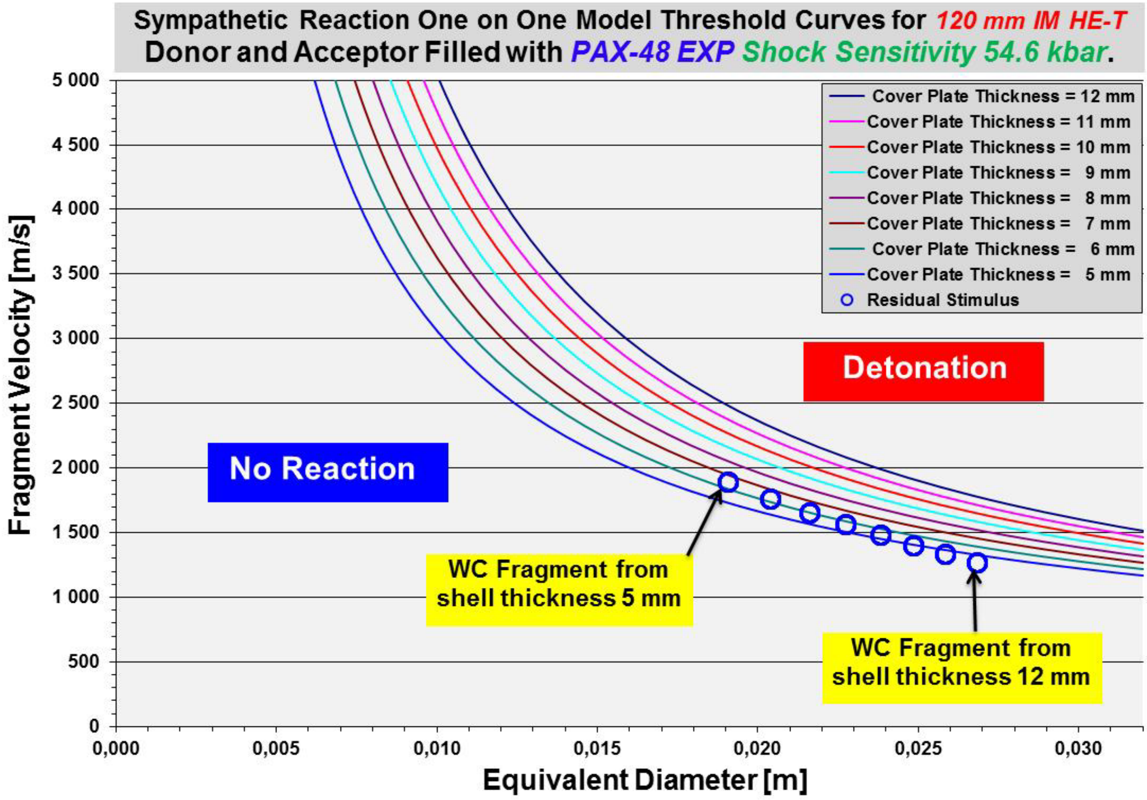


Figure 3.8 Detonation threshold curves for an acceptor filled with PAX-48/MCX-8100 composition with experimentally measured properties with shock sensitivity 54.6 kbar, and worst credible fragments from a donor shell filled with PAX-48/MCX-8100 composition with experimentally measured properties with shock sensitivity 54.6 kbar.

Envelop thickness [mm]	Velocity [m/s]	m50 [g]	Frag mass [g]	Thickness [mm]	Length [mm]	Width [mm]	Eq. Diameter [mm]
5	1891.3	1.02	10.81	3.04	30.08	15.04	19.07
6	1767.1	1.39	14.75	3.63	32.17	16.08	20.39
7	1659.7	1.81	19.21	4.21	34.08	17.04	21.61
8	1565.3	2.28	24.18	4.79	35.88	17.94	22.74
9	1481.3	2.80	29.66	5.35	37.57	18.79	23.82
10	1405.8	3.36	35.64	5.91	39.20	19.60	24.85
11	1337.3	3.97	42.15	6.46	40.76	20.38	25.84
12	1274.6	4.64	49.17	7.01	42.29	21.14	26.81
13	1216.9	5.35	56.72	7.54	43.77	21.89	27.75
14	1163.5	6.11	64.81	8.07	45.24	22.62	28.68
15	1113.8	6.93	73.47	8.59	46.69	23.34	29.60
16	1067.2	7.80	82.70	9.10	48.12	24.06	30.51

Table 3.14 Properties of worst credible fragments from 120 mm IM HE-T donor with PAX-48/MCX-8100 EXP filling.

PAX-48/MCX-8100 EXP – Shock sensitivity 54.6 kbar											
Donor	Acceptor	Fragment		Donor	Acceptor	Fragment		Donor	Acceptor	Fragment	
Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity
mm	mm	mm	m/s	mm	mm	mm	m/s	mm	mm	mm	m/s
5	5	19.07	1891.3	7	11	21.61	1659.7	10	9	24.85	1405.8
5	6	19.07	1891.3	7	12	21.61	1659.7	10	10	24.85	1405.8
5	7	19.07	1891.3	8	5	22.74	1565.3	10	11	24.85	1405.8
5	8	19.07	1891.3	8	6	22.74	1565.3	10	12	24.85	1405.8
5	9	19.07	1891.3	8	7	22.74	1565.3	11	5	25.84	1337.3
5	10	19.07	1891.3	8	8	22.74	1565.3	11	6	25.84	1337.3
5	11	19.07	1891.3	8	9	22.74	1565.3	11	7	25.84	1337.3
5	12	19.07	1891.3	8	10	22.74	1565.3	11	8	25.84	1337.3
6	5	20.39	1767.1	8	11	22.74	1565.3	11	9	25.84	1337.3
6	6	20.39	1767.1	8	12	22.74	1565.3	11	10	25.84	1337.3
6	7	20.39	1767.1	9	5	23.82	1481.3	11	11	25.84	1337.3
6	8	20.39	1767.1	9	6	23.82	1481.3	11	12	25.84	1337.3
6	9	20.39	1767.1	9	7	23.82	1481.3	12	5	26.81	1274.6
6	10	20.39	1767.1	9	8	23.82	1481.3	12	6	26.81	1274.6
6	11	20.39	1767.1	9	9	23.82	1481.3	12	7	26.81	1274.6
6	12	20.39	1767.1	9	10	23.82	1481.3	12	8	26.81	1274.6
7	5	21.61	1659.7	9	11	23.82	1481.3	12	9	26.81	1274.6
7	6	21.61	1659.7	9	12	23.82	1481.3	12	10	26.81	1274.6
7	7	21.61	1659.7	10	5	24.85	1405.8	12	11	26.81	1274.6
7	8	21.61	1659.7	10	6	24.85	1405.8	12	12	26.81	1274.6
7	9	21.61	1659.7	10	7	24.85	1405.8				
7	10	21.61	1659.7	10	8	24.85	1405.8				

Table 3.15 *Responses for worst credible fragments of different diameters and velocities. **Red colour** gives a **detonation** response in the acceptor. **Blue colour** gives a **no reaction** response in the acceptor.*

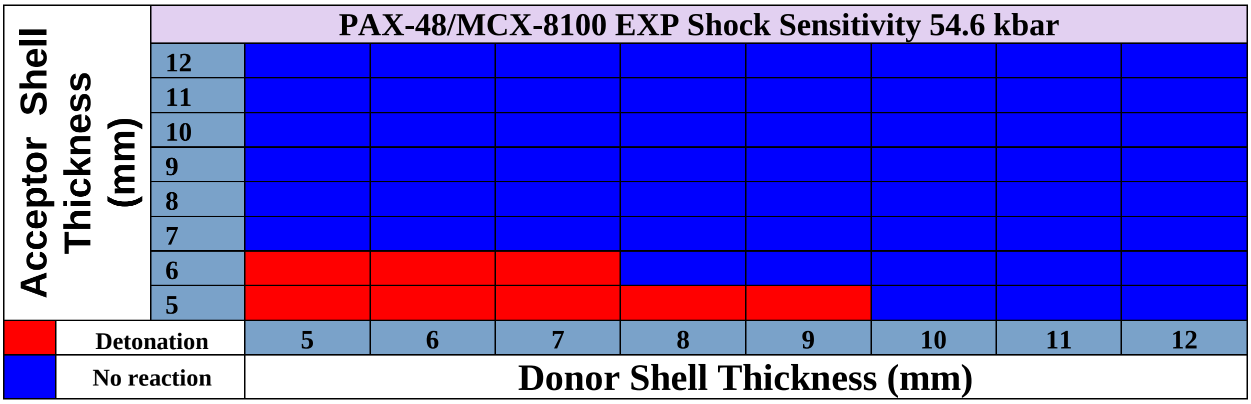


Table 3.16 *Responses for 120 mm shells filled with PAX-48/MCX-8100 EXP shock sensitivity 54.6 kbar depending on shell thicknesses in both donor and acceptor.*

3.4.3 PAX-48 EXP 50

The third simulation was with an acceptor and a donor having PAX-48/MCX-8100 fillings with experimentally measured properties and a shock sensitivity 50 kbar. Figure 3.9 shows acceptor threshold curves and Worst Credible (WC) fragments from 5 to 12 mm donor shell thicknesses. Table 3.14 gives the properties of these fragments in form of mass, dimensions and velocity in addition to equivalent diameter for different envelope thicknesses.

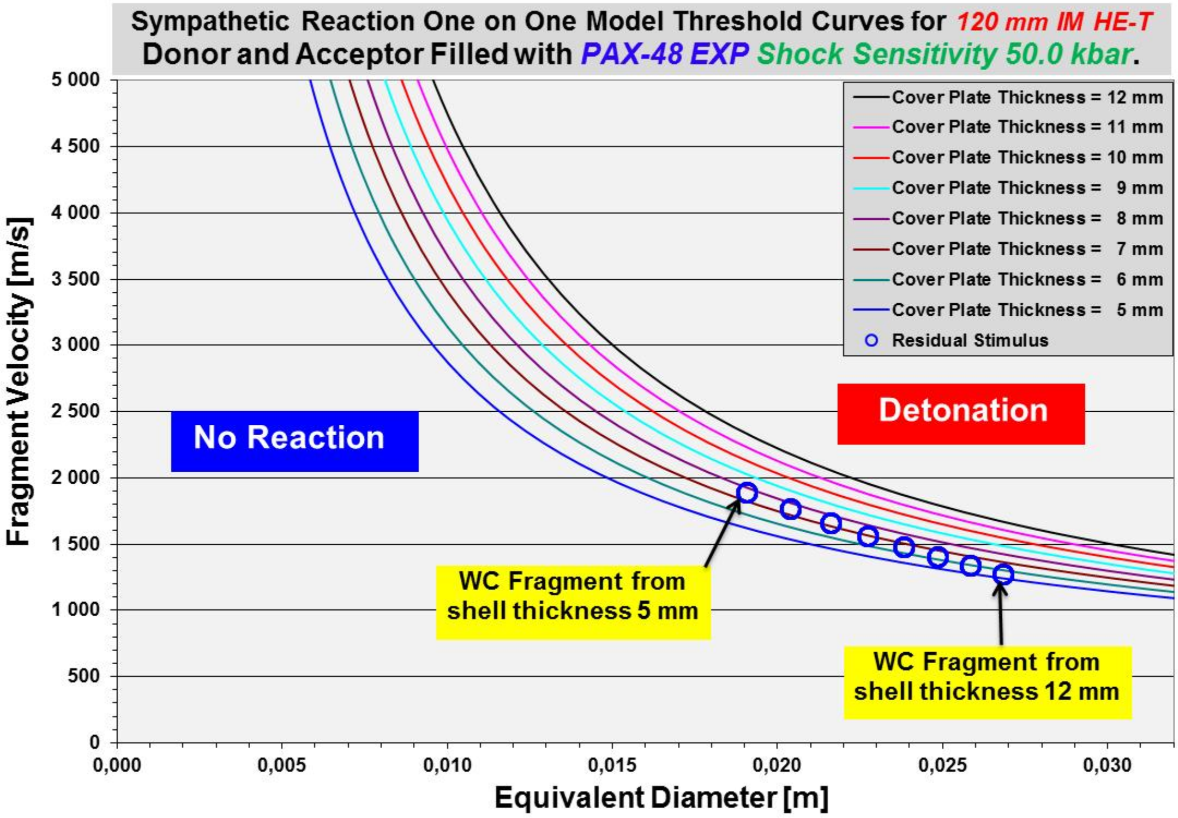


Figure 3.9 Detonation threshold curves for an acceptor filled with PAX-48/MCX-8100 composition with experimentally measured properties, and worst credible fragments for the donor shell filled with MCX-8100 composition with experimentally measured properties. Both shells have shock sensitivity 50 kbar.

Figure 3.9 shows that all the WC-fragments are positioned above one or more acceptor threshold curves giving *detonation* responses. From Table 3.17 and 3.18 we see that there are many more red numbers or squares for this simulation than for the two former simulations.

PAX-48/MCX-8100 EXP – Shock sensitivity 50 kbar											
Donor	Acceptor	Fragment		Donor	Acceptor	Fragment		Donor	Acceptor	Fragment	
Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity
mm	mm	mm	m/s	mm	mm	mm	m/s	mm	mm	mm	m/s
5	5	19.07	1891.3	7	11	21.61	1659.7	10	9	24.85	1405.8
5	6	19.07	1891.3	7	12	21.61	1659.7	10	10	24.85	1405.8
5	7	19.07	1891.3	8	5	22.74	1565.3	10	11	24.85	1405.8
5	8	19.07	1891.3	8	6	22.74	1565.3	10	12	24.85	1405.8
5	9	19.07	1891.3	8	7	22.74	1565.3	11	5	25.84	1337.3
5	10	19.07	1891.3	8	8	22.74	1565.3	11	6	25.84	1337.3
5	11	19.07	1891.3	8	9	22.74	1565.3	11	7	25.84	1337.3
5	12	19.07	1891.3	8	10	22.74	1565.3	11	8	25.84	1337.3
6	5	20.39	1767.1	8	11	22.74	1565.3	11	9	25.84	1337.3
6	6	20.39	1767.1	8	12	22.74	1565.3	11	10	25.84	1337.3
6	7	20.39	1767.1	9	5	23.82	1481.3	11	11	25.84	1337.3
6	8	20.39	1767.1	9	6	23.82	1481.3	11	12	25.84	1337.3
6	9	20.39	1767.1	9	7	23.82	1481.3	12	5	26.81	1274.6
6	10	20.39	1767.1	9	8	23.82	1481.3	12	6	26.81	1274.6
6	11	20.39	1767.1	9	9	23.82	1481.3	12	7	26.81	1274.6
6	12	20.39	1767.1	9	10	23.82	1481.3	12	8	26.81	1274.6
7	5	21.61	1659.7	9	11	23.82	1481.3	12	9	26.81	1274.6
7	6	21.61	1659.7	9	12	23.82	1481.3	12	10	26.81	1274.6
7	7	21.61	1659.7	10	5	24.85	1405.8	12	11	26.81	1274.6
7	8	21.61	1659.7	10	6	24.85	1405.8	12	12	26.81	1274.6
7	9	21.61	1659.7	10	7	24.85	1405.8				
7	10	21.61	1659.7	10	8	24.85	1405.8				

Table 3.17 Responses for worst credible fragments of different diameters and velocities. ***Red colour*** *gives a* ***detonation*** *response in the acceptor.* ***Blue colour*** *gives a* ***no reaction*** *response in the acceptor.*

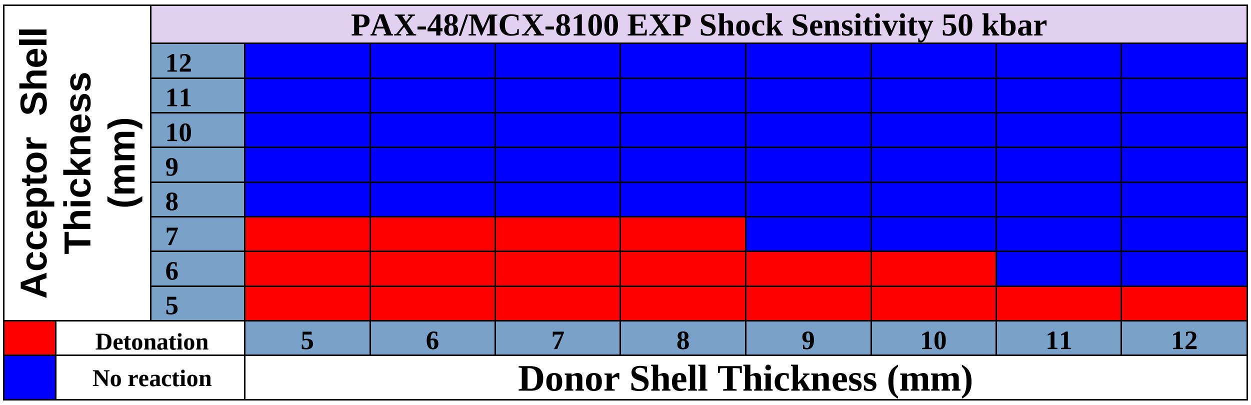


Table 3.18 Responses for 120 mm shells filled with PAX -48/MCX-8100 EXP with shock sensitivity 50 kbar depending on shell thicknesses in both donor and acceptor.

3.4.4 PAX-48 EXP 45

The last simulation was with an acceptor and a donor having PAX-48/MCX-8100 fillings with experimentally measured properties and a shock sensitivity 45 kbar. Figure 3.10 shows acceptor threshold curves and Worst Credible (WC) fragments from 5 to 12 mm donor shell thicknesses. Table 3.14 gives the properties of these fragments in form of mass, dimensions and velocity in addition to equivalent diameter for different envelope thicknesses.

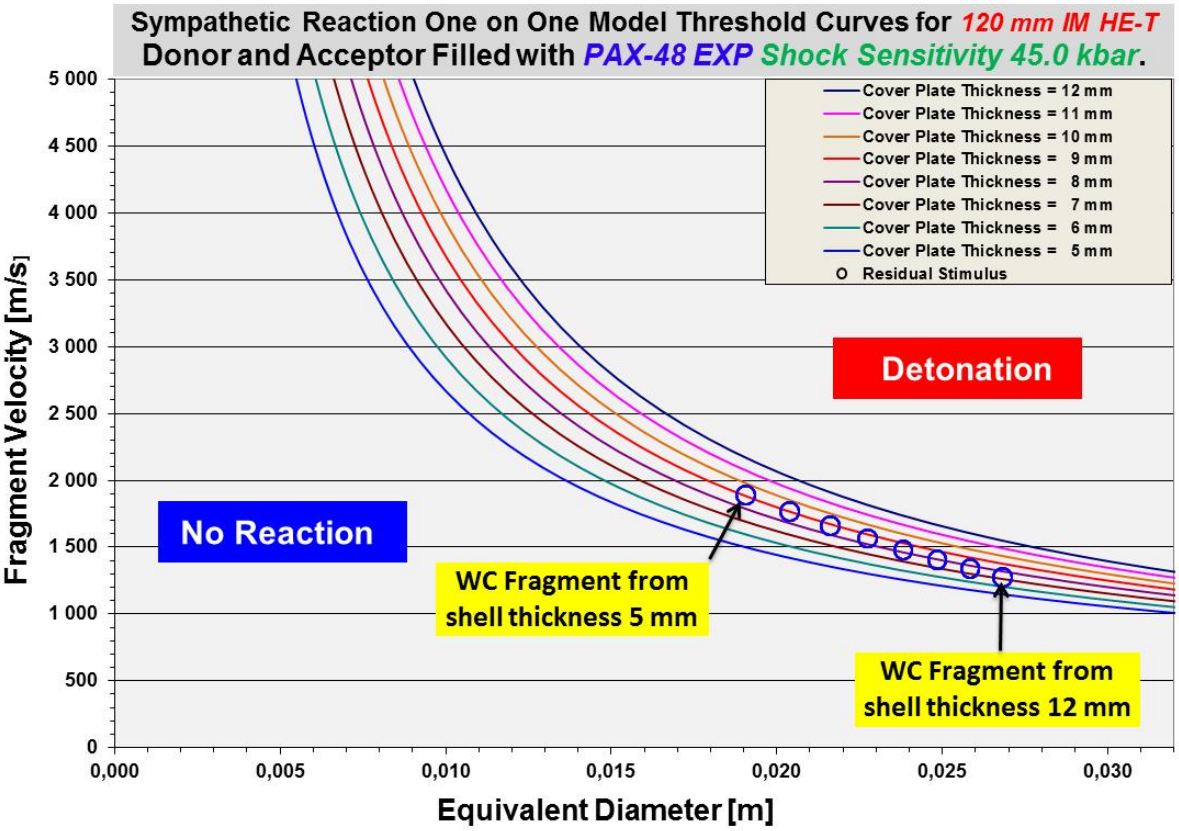


Figure 3.10 Detonation threshold curves for an acceptor filled with PAX-48/MCX-8100 composition with experimentally measured properties and shock sensitivity 45 kbar, and worst credible fragments for the donor shell filled with PAX-48/MCX-8100 composition with experimentally measured properties and shock sensitivity 45 kbar.

Figure 3.10 shows that all the WC-fragments are positioned above three or more acceptor threshold curves giving *detonation* responses. From Table 3.17 and 3.18 we see that there are significantly more red numbers or red squares in these tables than in the equivalent tables for the two first simulations.

The WC-fragment from donor shell thickness 5 mm will give *detonation* response in the acceptor if the shell is thinner than 10 mm. The WC-fragments from donor shell thicknesses from 6 mm to 10 mm will give *detonation* responses in the acceptors if the shell is thinner than 9 mm. The WC-fragments from donor shell thicknesses 11 mm and 12 mm will give *detonation* responses in the acceptors if the shell is thinner than 8 mm.

PAX-48/MCX-8100 EXP – Shock sensitivity 45 kbar											
Donor	Acceptor	Fragment		Donor	Acceptor	Fragment		Donor	Acceptor	Fragment	
Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity	Shell Thickness		Equivalent Diameter	Velocity
mm	mm	mm	m/s	mm	mm	mm	m/s	mm	mm	mm	m/s
5	5	19.07	1891.3	7	11	21.61	1659.7	10	9	24.85	1405.8
5	6	19.07	1891.3	7	12	21.61	1659.7	10	10	24.85	1405.8
5	7	19.07	1891.3	8	5	22.74	1565.3	10	11	24.85	1405.8
5	8	19.07	1891.3	8	6	22.74	1565.3	10	12	24.85	1405.8
5	9	19.07	1891.3	8	7	22.74	1565.3	11	5	25.84	1337.3
5	10	19.07	1891.3	8	8	22.74	1565.3	11	6	25.84	1337.3
5	11	19.07	1891.3	8	9	22.74	1565.3	11	7	25.84	1337.3
5	12	19.07	1891.3	8	10	22.74	1565.3	11	8	25.84	1337.3
6	5	20.39	1767.1	8	11	22.74	1565.3	11	9	25.84	1337.3
6	6	20.39	1767.1	8	12	22.74	1565.3	11	10	25.84	1337.3
6	7	20.39	1767.1	9	5	23.82	1481.3	11	11	25.84	1337.3
6	8	20.39	1767.1	9	6	23.82	1481.3	11	12	25.84	1337.3
6	9	20.39	1767.1	9	7	23.82	1481.3	12	5	26.81	1274.6
6	10	20.39	1767.1	9	8	23.82	1481.3	12	6	26.81	1274.6
6	11	20.39	1767.1	9	9	23.82	1481.3	12	7	26.81	1274.6
6	12	20.39	1767.1	9	10	23.82	1481.3	12	8	26.81	1274.6
7	5	21.61	1659.7	9	11	23.82	1481.3	12	9	26.81	1274.6
7	6	21.61	1659.7	9	12	23.82	1481.3	12	10	26.81	1274.6
7	7	21.61	1659.7	10	5	24.85	1405.8	12	11	26.81	1274.6
7	8	21.61	1659.7	10	6	24.85	1405.8	12	12	26.81	1274.6
7	9	21.61	1659.7	10	7	24.85	1405.8				
7	10	21.61	1659.7	10	8	24.85	1405.8				

Table 3.19 Responses for worst credible fragments of different diameters and velocities. ***Red colour*** *gives a* ***detonation*** *response in the acceptor.* ***Blue colour*** *gives a* ***no reaction*** *response in the acceptor.*

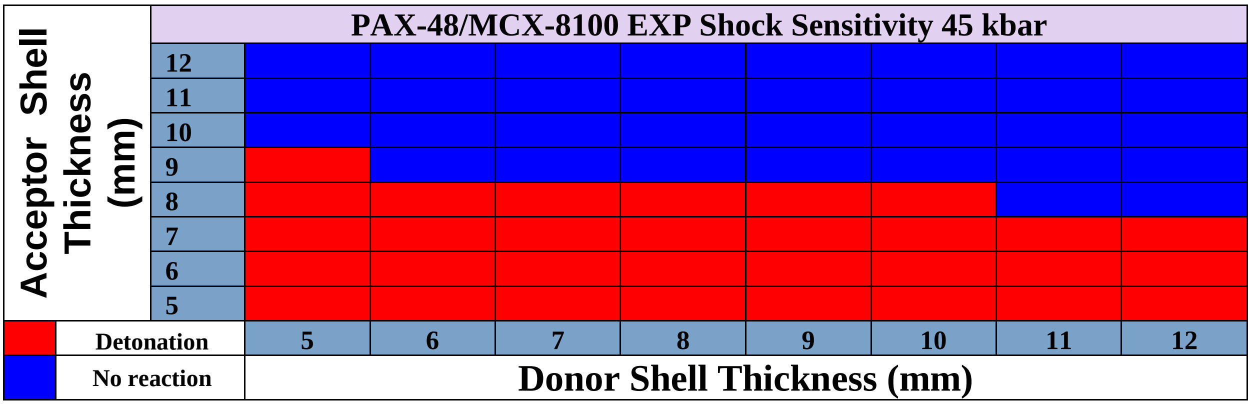


Table 3.20 Responses for 120 mm shells filled with PAX-48/MCX-8100 EXP with shock sensitivity 45 kbar depending on shell thicknesses in both donor and acceptor.

Sympathetic Reaction test according to STANAG 4439 requires a *type III, deflagration* reaction or better, as response to pass the IM-requirement. For PAX-48/MCX-8100 fillings this requirement is fulfilled with low shock sensitivity, but can be hard to obtain for the most sensitive compositions having shock sensitivity of 50 kbar or less.

4 Summary

TEMPER has been used to study IM-responses for 120 mm IM HE-T for different properties of the main explosive filling. Simulations for nominal content with theoretically calculated properties and experimentally measured properties of PAX-48/MCX-8100 have been performed. Shock sensitivity has been varied.

Bullet Impact simulations with one shot threat with the requirements in STANAG 4241 show *No Reaction* response for all combinations of properties included in this study.

Fragment Impact test according to, STANAG 4496, with a conical NATO fragment at a velocity of 2530 m/s, gives a *Detonation* response for shell thicknesses of 5-6 mm. For the most sensitive composition, 45 kbar, a shell thickness of 9 mm is needed to get a *No Reaction* response.

For Sympathetic Reaction munitions test procedures according to STANAG 4396, the response depends upon both donor and acceptor properties. The following combinations of donor and acceptor properties will give ***Detonation*** responses:

1. Acceptor/donor with shock sensitivity 54.6 kbar and calculated properties.
   a. Acceptor shell thickness 5 mm - Donor shell thicknesses 5-7 mm.

2. Acceptor/donor with shock sensitivity 54.6 kbar and measured properties.
   a. Acceptor shell thickness 6 mm - Donor shell thicknesses 5-7 mm.
   b. Acceptor shell thickness 5 mm - Donor shell thicknesses 5-9 mm

3. Acceptor/donor with shock sensitivity 50.0 kbar and measured properties.
   a. Acceptor shell thickness 7 mm - Donor shell thicknesses 5-8 mm.
   b. Acceptor shell thickness 6 mm - Donor shell thicknesses 5-10 mm.
   c. Acceptor shell thickness 5 mm - Donor shell thicknesses 5-12 mm.

4. Acceptor/donor with shock sensitivity 45.0 kbar and measured properties.
   a. Acceptor shell thickness 9 mm - Donor shell thickness 5 mm.
   b. Acceptor shell thickness 8 mm - Donor shell thicknesses 5-10 mm.
   c. Acceptor shell thicknesses 5-7 mm - Donor shell thicknesses 5-12 mm.

The required response in Sympathetic Reaction in STANAG 4439 is a *type III* reaction, *deflagration* or better to obtain IM-compliance.

The response according to STANAG 4439 in Sympathetic Reaction requires a *type III reaction, deflagration* or better, to obtain IM-compliance.

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