Qualification of an Enhanced Blast Explosive (DPX-6)

According to STANAG 4170

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DPX-6

- DPX-6 contains
  - HMX ca 50 %
  - Aluminum ca 46 %
  - HyTemp ca 1 %
  - DiOctylAdipate. ca 3 %
- Developed for use in M72-ASM-RC (M72-Anti Structure Munition, Reduced Caliber).

Test Program - STANAG 4170

1.	Stability & Thermal Characterization	STANAG 4515/4556
2.	Compatibility	STANAG 4147
3.	Ignition Temperature	STANAG 4515/4491
4.	Explosive Response when Ignited	STANAG 4491
5.	Electrostatic Discharge	STANAG 4490
6.	Impact	STANAG 4489
7.	Friction	STANAG 4487
8.	Shock	STANAG 4488
9.	Critical Diameter	AOP-7
10.	Detonation Velocity	AOP-7
11.	Mechanical/Rheological Properties	4525/4540/4443
12.	Variation of Properties with Age	AOP-7

Accelerated Ageing Program

	Ageing time at 71 ºC (days)		0	30	60	120	180
	Test	**Reference**					
Tested at powder	Composition	Internal procedure	X	X	X	X	X
	DSC (Differential Scanning Calorimetry)	STANAG 4515	X	X	X	X	X
	Vacuum Thermal Stability	STANAG 4556	X	X	X	X	X
	Temperature of ignition. (woods metal bath)	STANAG 4491	X	X	X	X	X
	BAM Impact Sensitivity	STANAG 4489	X	X	X	X	X
	BAM Friction Sensitivity	STANAG 4487	X	X	X	X	X
Tested at pressed charges	Uniaxial Compressive test.	STANAG 4443	X	X	X	X	X
	Small scale GAP-test (21 mm test)	STANAG 4488	X				X
	Density	Internal procedure	X	X	X	X	X
	Weight loss	Internal procedure	X	X	X	X	X

1. & 2. Stability and Compatibility

	STANAG	T=0	30 d 71 °C	30 d 71 °C	30 d 71 °C	30 d 71 °C
DSC	4515	Exotherm at 279°C	Exotherm at 281°C	Exotherm at 279°C	Exotherm at 280°C	Exotherm at 280°C
VTS	4556 100°C/40h	0.08 ml/g	0.06 ml/g	0.07 ml/g	0.06 ml/g	0.04 ml/g

Compatible: Al, Steel, Epoxy/carbon fiber & RTV rubber

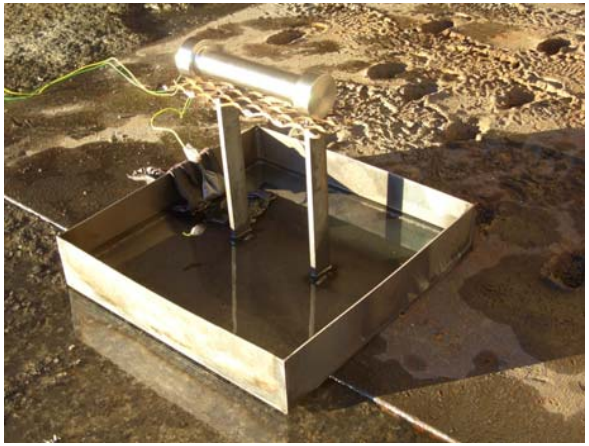
Uncertain: Glass fiber, DP 460 & Polyurethane

3. Ignition Temperature

Test / STANAG	Not aged	30 days @ 71 ºC	60 days @ 71 ºC	120 days @ 71 ºC	180 days @ 71 ºC
Temp. of Ignition STANAG 4491 B1	279 ºC	N/A	N/A	N/A	N/A
Woods metal bath STANAG 4491 B2	264 ºC	267 ºC	267 ºC	267 ºC	267 ºC
DSC STANAG 4515	Exo at 279 ºC	Exo at 281 ºC	Exo at 279 ºC	Exo at 280 ºC	Exo at 280 ºC

- The measured values are as expected for HMX-based compositions.
- No changes can be observed for the ignition temperature properties after aging for 180 days at 71 ºC.

4. Fast Cook off, Tube test STANAG 4491

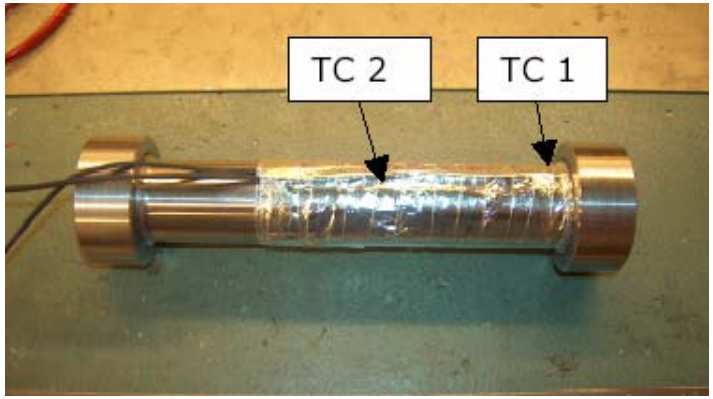





4. Fast Cook off , Tube test STANAG-4491.

Test	Reaction Category	Time to Event
1	1 (Deflagration)	310 seconds
2	1 (Deflagration)	260 seconds
3	1 (Deflagration)	275 seconds

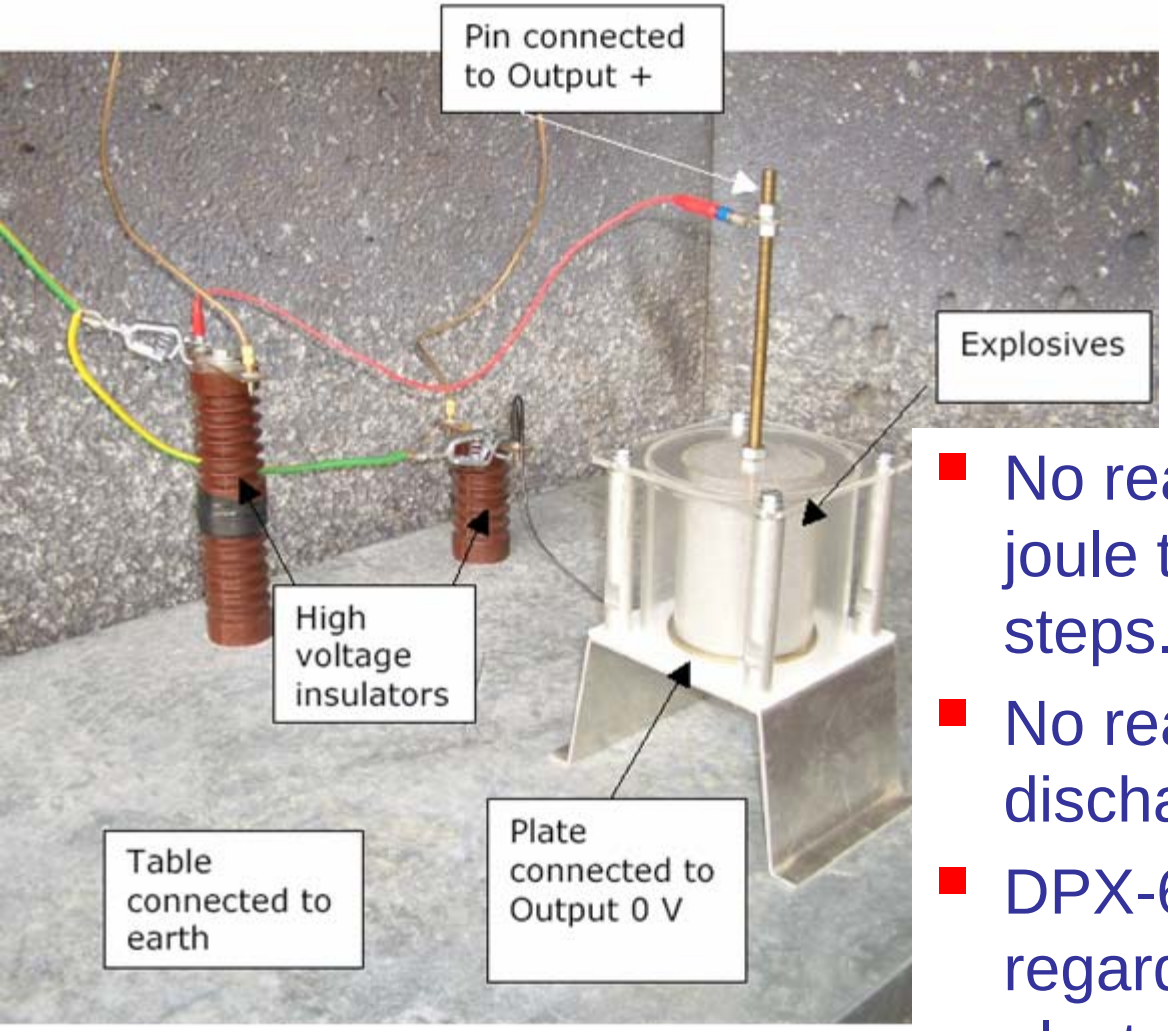
4. Slow Cook-off, Tube test



4. Slow Cook-off, Tube test STANAG-4491.

Test No.	Heating rate	Reaction Category	TC 1	TC 2
1	10 °C/hour	1 (Deflagration)	195 °C	203 °C
2	60 °C/ hour	1 (Deflagration)	208 °C	224 °C
3	300 °C/ hour	1 (Deflagration)	200 °C	246 °C

5. Electrostatic Discharge Test



- No reaction observed from 5 joule to 15.6 joule in one joule steps.
- No reaction observed for 30 discharges at 15,6 Joule.
- DPX-6 granules can be regarded as insensitive to electrostatic discharge

6 & 7 Impact and Friction Sensitivity

Test	T=0	30 days @ 71 ºC	60 days @ 71 ºC	120 days @ 71 ºC	180 days @ 71 ºC
BAM impact STANAG 4489	7.74 J	7.65 J	10.68 J	8.86 J	6.95 J
BAM friction STANAG 4487	179 N	188 N	177 N	191 N	204 N

- Acceptable impact and friction sensitivity
- Expected values for HMX/Hytemp compositions.
- Within the reproducibility of the tests there are no changes over time when aged at 71 ºC for 180 days.

8. Shock sensitivity, STANAG 4489

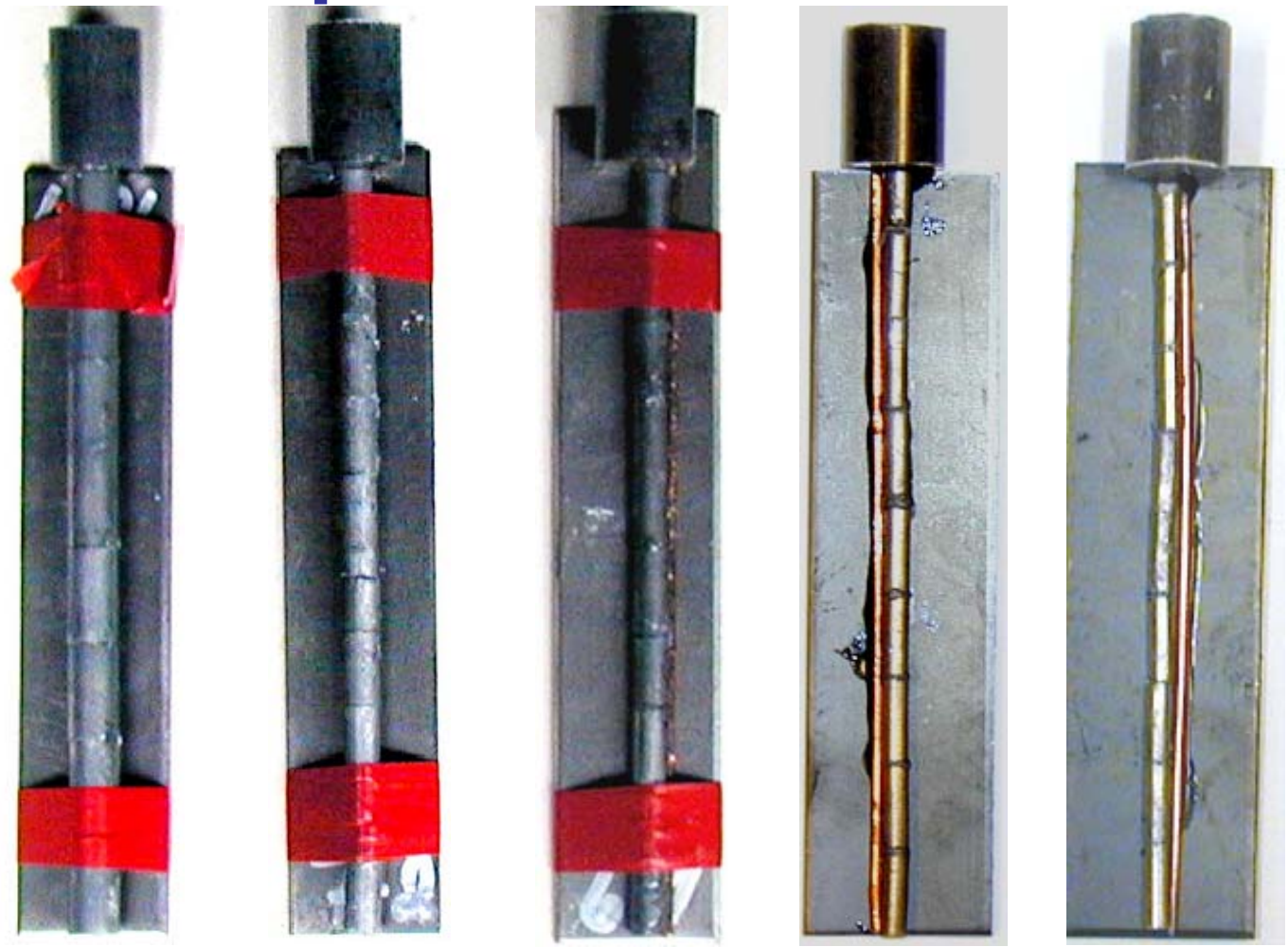
Test	Material	Density	Not aged	180 days @ 71 ºC
Small scale water GAP-test (50 % point)	DPX-6	2.05	16.94 mm 22.5 kBar	16.92 mm 22.5 kBar
BICT Water GAP test. Typical results	*PBXW-11 (ref)*	*≈98 % TMD*	*18 – 20 mm* *20.9 –18.4 kBar*	*N/A*

- The shock sensitivity is acceptable and in the same range as for other HMX based pressable compositions.
- Slightly better shock sensitivity than PBXW-11 (PBXN-11)
- No change in shock sensitivity after aging for 180 days at 71 ºC.

9. Critical Diameter

- This test should be done according to AOP-7.
- FFI have experience with a test that is similar to a test described for UK in AOP-7.
- The FFI test was performed for several diameters between 4.11 mm to 9.97 mm

9. Setup for various diameters



9.97 mm 7.16 mm 6.53 mm 5.03 mm 4.11 mm

9. Critical diameter

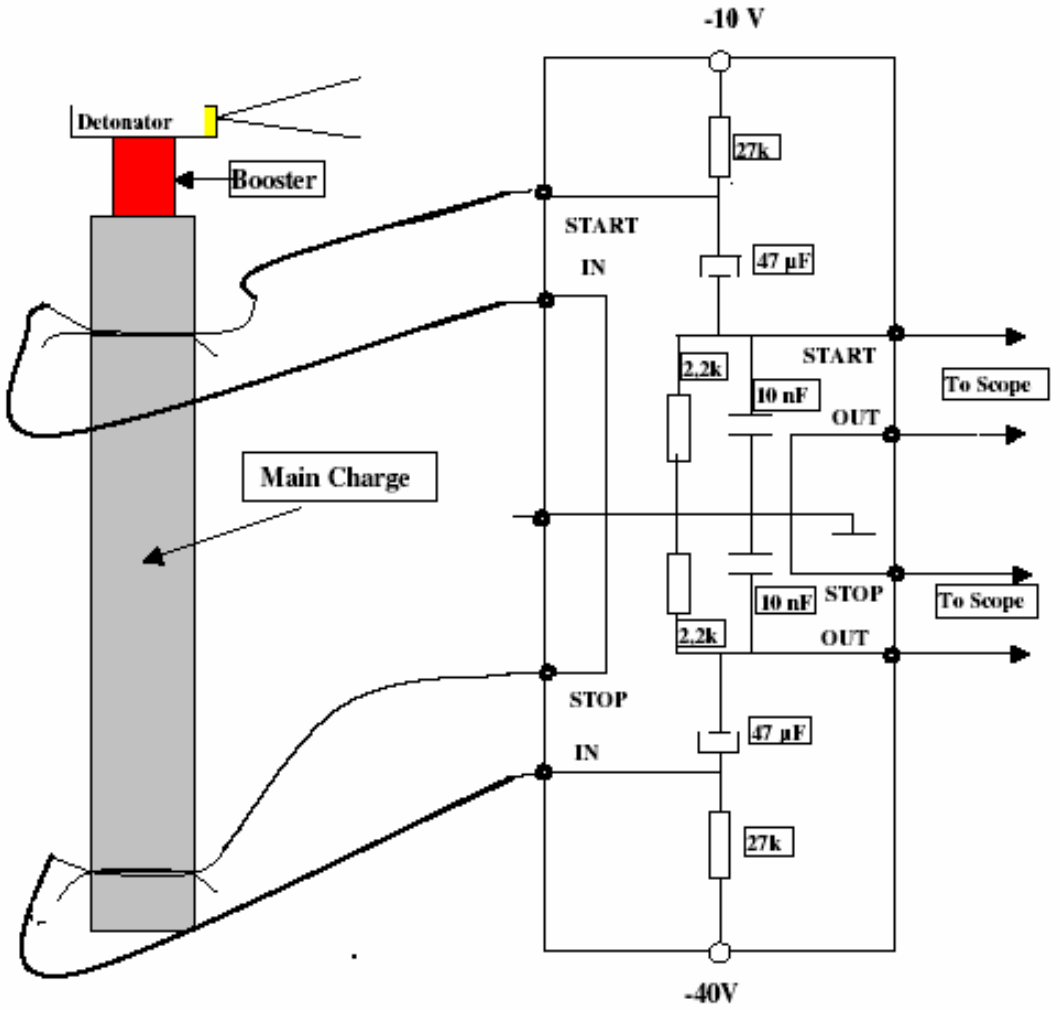
Diameter	Density	1. parallel	2. parallel	3. parallel
12.7 mm	2.05 g/cm^3	Detonation	Detonation	N/A
9.97 mm	2.05 g/cm^3	Detonation	Detonation	Detonation
7.16 mm	2.04 g/cm^3	Detonation	Detonation	Detonation
6.53 mm	2.06 g/cm^3	Partly stopped.	Detonation	Detonation/ burning/ detonation
5.03 mm	2.06 g/cm^3	Detonation	Detonation	Detonation
4.11 mm	2.06 g/cm^3	Detonation	Detonation stopped	Detonation stopped

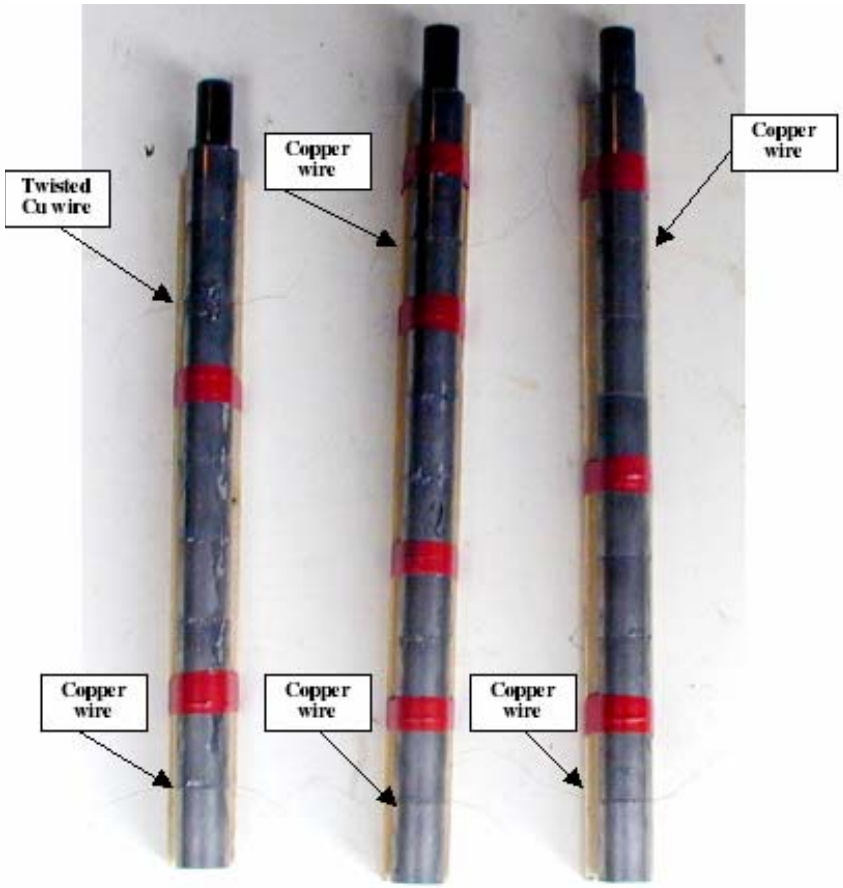
- The critical diameter for DPX-6 is *maximum* 5 mm.
- The charges will be several times larger than 5 mm.

10. Detonation velocity

- This test should be done according to AOP-7.
- FFI have experience with a test that is similar to tests described for several countries in AOP-7.
- The test was performed at charges with 25.4 mm diameter.

10. Setup for the Charges





10. Detonation velocity

Number of pellets	Start/stop distance	Measured time (µs)	Detonation velocity
9	23.521 cm	29.9 µs	7867 m/s
10	27.393 cm	34.9 µs	7849 m/s
10	27.465 cm	35.0 µs	7847 m/s
Average detonation velocity for DPX-6			**7850 ± 11 m/s**

- The detonation velocity for DPX-6 is 7850 m/s

11. Mechanical / Rheological Properties.

- Tests performed according to STANAGs 4540 and 4443:
  - **Glass Transition Temperature** (T_g) have been measured for the **binder** with a DSC method.
  - Tests performed for DPX-6 directly have been unsuccessful due to a to low binder content.
    - However, solid materials such as aluminum and HMX will not affect the glass transition temperature for the binder.
  - **Mechanical properties** have been characterized by using Uniaxial compressive test.

11.1 Glass Transition Temperature

Material	Filler	HyTemp (%)	DOA (%)	Amount	T_g(°C)	Comment
DPX-6	HMX/Al 50/46	1	3	Max. amount	n/a	No signal observed
PBXW-11	96% HMX	1	3	35.3 mg	-94/ -99	Weak transition
PBXN-9	92% HMX	2	6	49.9 mg	-101	Strong transition
Binder	--	24	76	12.5 mg	-100	Strong transition

- T_g for DPX-6 is close to –100 ºC.
- Low service temperature should not be a problem for DPX-6

11.2 Uniaxial Compressive Test

Period of Ageing	Test temperature (ºC)	Peak-Stress (σ_m) (MPa)	Strain at Peak-Stress (ε_m) (%)	Modulus of elasticity (E_0) (MPa)
T=0	- 52 ºC	45.6 ± 0.4	5.0 ± 0.1	1618 ± 6
	14 ºC	10.2 ± 0.2	4.0 ± 0.2	440 ± 6
	60 ºC	7.4 ± 0.7	4.2 ± 0.2	360 ± 32
Aged 180 days @ 71 ºC	- 50 ºC	44.0 ± 0.5	5.5 ± 0.1	1410 ± 41
	14 ºC	11.9 ± 0.1	4.5 ± 0.2	440 ± 8
	40 ºC	9.7 ± 0.3	4.2 ± 0.1	390 ± 11
	60 ºC	8.8 ± 0.2	4.12 ± 0.07	360 ± 12

- The mechanical behavior of DPX-6 is comparable with other pressable compositions.
- Aging shows no significant effect on the mechanical properties

12. Variation of Properties with age

	T=0	30 days 71°C	60 days 71°C	120 days 71°C	180 days 71°C
% HMX	48.9	49.7	50.0	50.0	50.2
% Al	46.8	46.0	45.8	45.9	45.7
% Hytemp	1.1	1.1	1.1	1.1	1.1
% DOA	3.2	3.2	3.1	3.0	3.0
Weight loss (mg)		5.5±0.5	3.1±0.3	4.2±0.1	6.2±0.4
Density change (g/cm^3)		-0.001 ±0.003	0.005 ±0.003	0.004 ±0.002	0.001 ±0.004

12. Variation of Properties with age

- No significant changes in the composition after ageing
- No significant weight loss or density changes after ageing.
  - The weight losses are less than 0.04 % and the density changes are less than 0.3 %.
- No significant changes for any of the tests as described earlier in this presentation.

Overall Summary and Conclusions

- Qualification program according to STANAG 4170 successfully completed for DPX-6
  - The explosive is safe to handle.
  - Obtained information on critical parameters
- All the sensitivity tests are as good as expected or better than for similar well-known compositions.
- None of the results obtained in this study show any unexpected negative behavior.
- No significant changes when exposed to accelerated ageing at 71 ºC for 180 days.