QUALIFICATION OF MALLEABLE PLASTIC EXPLOSIVE HEXOMAX AND ITS APPLICATION IN A FLEXIBLE LINEAR SHAPED CHARGE SYSTEM

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ABSTRACT

Based on his know-how on cast-cure compositions, EURENCO developed several years ago a new generation of malleable plastic explosive blocks, called Hexomax [1]. Since 2014 the product has further been improved to meet the highest levels of requirements of Armies in term of performances, safety and malleability, and the French Army qualified Hexomax in 2016.

Thanks to its constant properties on the large range of temperatures recognized by the French Forces, Hexomax has been recently qualified by the French Army in the system Supraflex, a flexible linear shaped charge, designed and supplied by SUPRAMECA. Moreover, the preliminary test results, performed with Hexomax blocks combined with the specifically designed logistical box, demonstrated that a type VI reaction against the sympathetic reaction is achievable.

This paper presents available results in term of characteristics, performances and vulnerability of this improved Hexomax in tactical and logistical configurations.

INTRODUCTION

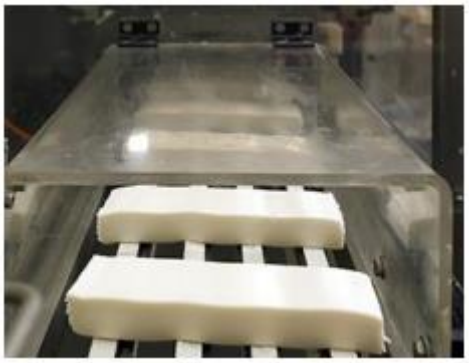
As leader in energetic materials, EURENCO develops and supplies IM solutions, from IM high explosive (HE) compositions to cast-cure compositions.
Based on its know-how on the cast-cure technology, EURENCO developed 10 years ago a new plastic explosive, containing RDX and an inert binder, in order to replace the previous PETN based plastic explosive known as PLASTRITE. Hexomax fulfills the Montreal Convention requirements. The development strategy was presented in 2012 at IMEMTS symposium in Las Vegas.
Since then, continuous works have been performed to further improve the material so that it now meets the highest requirements for military use in hot and cold countries.
Hexomax has been selected and qualified by the French Ministry of Defense to equip the French Forces. The Ministry of Defense has even extended the range of qualification of the product: Hexomax is now qualified to be used as the main explosive charge in the flexible linear shaped system Supraflex which is supplied by the French company SUPRAMECA, expert in designing and supplying shaped charges and breaching systems.

Latest results obtained with improved Hexomax will be presented in this paper.
First, the properties of this plastic explosive, in term of performances, malleability and insensitivity will be described, as well as the effect of ageing. Regarding IM tests, preliminary tests undertaken with Hexomax blocks combined with the specifically designed logistical box Supracase, designed by SUPRAMECA, to reduce the sympathetic reaction between blocks, will be especially outlined. Moreover, environment tests performed on the product will be described. Then, the main performance results of the system Supraflex with Hexomax will be presented.

[1] A new generation of malleable plastic explosive blocks, B. Mahé, IMEMTS, 2012

1. PROPERTIES OF HEXOMAX

Hexomax is a malleable plastic explosive containing more than 85% RDX, maximum 14% inert binder and 1% tagging agent.
100 g to 1000 g blocks are produced at industrial scale. The cast-cure explosive composition is extruded, cut at the desired size and wrapped into a specific plastic film.



Picture 1: blocks on the production line

1.1. Performances

Using a detonator Nr 8 (or containing 800 mg PETN) is the easiest way to initiate Hexomax. The detonation velocity and critical diameter were measured. The detonation pressure was evaluated based on the measured density 1.56. The results are given in the following table.

Detonation velocity	7780 m/s
Critical diameter	~2 mm
Density	1.56
Detonation pressure (calculated)	>23GPa

Table 1: Detonation performance results

1.2. Sensitivity

Hexomax is fully qualified according to the STANAG 4170. In table 2 are reported the sensitivity data of the product against required tests.

	Results	Test references
Friction sensitivity	11+/30 at 353N	STANAG 4487 - annex A
Impact sensitivity	37 J	STANAG 4489 - annex C
Shock sensitivity (card gap test)	190 cards	STANAG 4488 - annex B

Table 2: Friction, impact and shock sensitivity results

These results are comparable with the values of the typical cast-cure composition B2238 used as booster in IM warheads (Impact sensitivity: 41J ; shock sensitivity : 180 cards).

In addition, Hexomax does not react against the 12m drop test and it is a good insulating material against electrostatic discharges: no reaction occurred when 300 kV was applied directly on the product (56 tests realized according to AECTP 250 method 253).

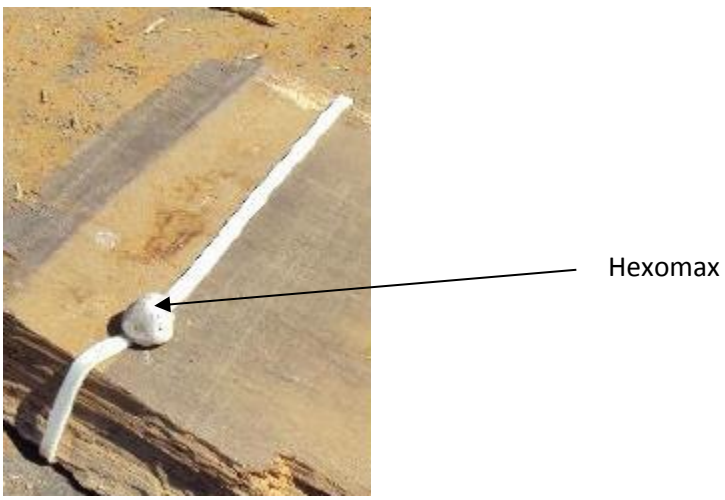
Regarding the stability in temperature, the self-ignition temperature by progressive heating is 214°C, this temperature corresponding to the RDX decomposition. Therefore, Hexomax is stable.

These results demonstrate that Hexomax is insensitive towards standard aggressions.

1.3. Malleability

Hexomax is very malleable on the complete range of temperature [-21°C;+55°C] and this characteristic is recognized by the French Forces. Therefore it can be used in various situations : around any round element to be destroyed or opened, as a booster to initiate another charge.

Picture 2: Hexomax in various situations
(Courtesy of the Technical Service of French Army)



Picture 3 : Hexomax used as booster

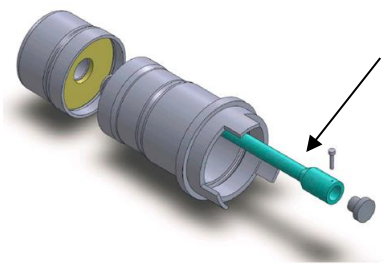


Figure 1 : Hexomax in modified fuze for test centers

1.4. Ageing effect

Blocks have been stored during 16.5 months at 60°C, which is equivalent to 22 years at 20°C according to Arrhénius law.

Characterizations were performed by DGA Techniques Terrestres on aged Hexomax and the results are compared with the initial product in the table 3.

	T0	After ageing
Self-ignition temperature by progressive heating	214°C	211°C
Impact sensitivity (BAM)	37 J	36 J
Friction sensitivity (BAM)	11+/30 at 353 N	0+/30 at 353 N

Table 3: Characterizations after ageing

Therefore, Hexomax remains safe for handling after more than 20 years ageing.

Moreover, it keeps its malleability property as shown in the picture 4.

Picture 4: Hexomax after ageing

1.5. IM properties

Fuel fire, slow cook off, bullet impact and fragment impact were performed on Hexomax. Three of them were presented in 2012 [1]. Hexomax blocks were placed in a logistic plywood box to realize the tests. As this type of box does not lead to any confinement, the results can be applied to Hexomax.

1.5.1. Fuel fire

The test was performed according to the STANAG 4240. The combustion of Hexomax was observed ➔ type V.

Beginning of the test

End of the fuel fire

Picture 5 : Fuel fire

1.5.2. Slow cook off

The test was performed according to the STANAG 4382. The combustion of Hexomax was observed ➔ type V.

Picture 6: Hexomax in logistic plywood box after slow cook off

1.5.3. Bullet impact

The test was performed according to the STANAG 4241 (12,7 mm diameter bullet). No reaction was observed ➔ type VI.

Picture 7: Hexomax after the bullet impact

1.5.4. Fragment impact

The test was performed according to the STANAG 4496: the mass of the fragment was 18,6g and the measured velocity 1830 m/s.
Hexomax reacted and a type I reaction was observed.

1.5.5. Sympathetic reaction

In 2012, the performed tests showed that the reaction between 2 blocks is type I. Works were in progress to determine a design which guaranteed a non-transmission of detonation.

The French company SUPRAMECA has designed and developed a specific logistic box named Supracase which avoid the sympathetic reaction between Hexomax blocks by absorbing the detonation pressure.

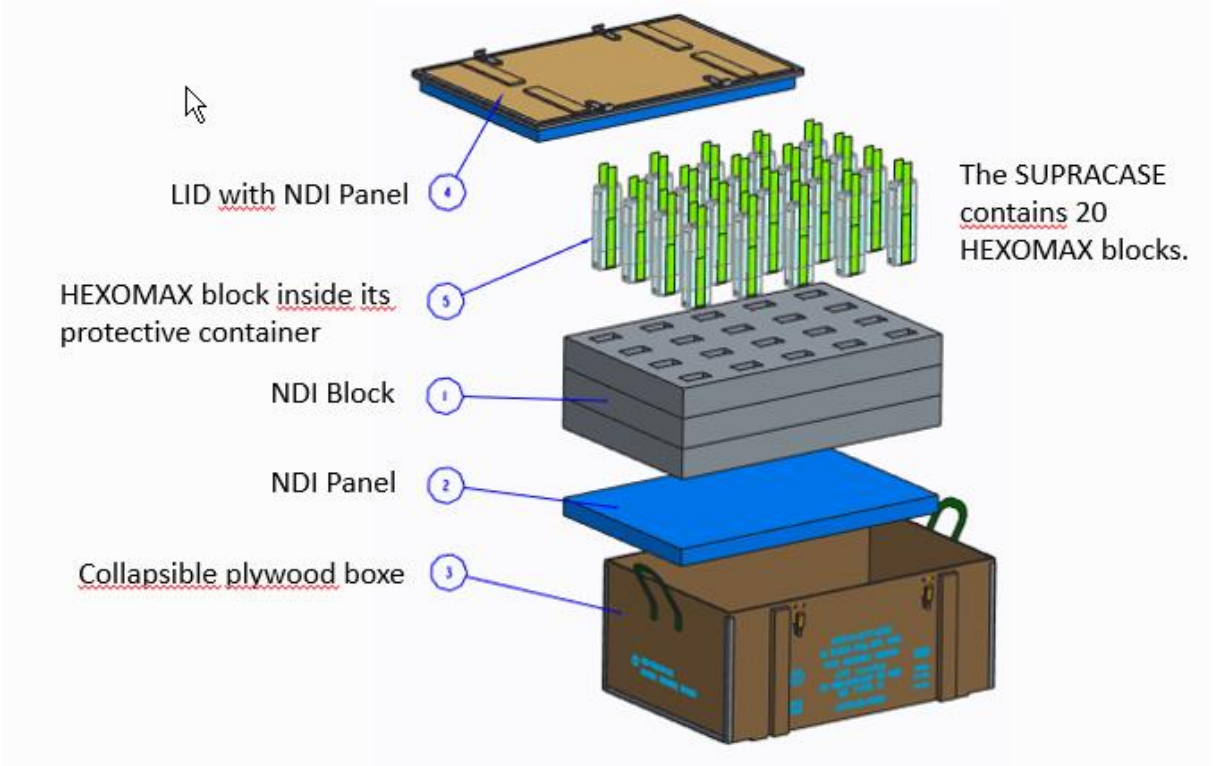


Figure 2: Description of Supracase

Preliminary tests were performed at EURENCO plant by measuring first the detonation over pressure of one block alone and then the detonation over pressure of blocks in Supracase.

Test 1 : Live blocks were inside the box which was placed on the wooden pallet. One block was initiated.

Figure 3: Configuration of the sympathetic test N°1

The measured detonation over pressure proves that only the initiated block detonated.

Test 2 : 4 boxes Supracase placed on a wooden pallet. Boxes 1 and 2 had live Hexomax blocks, while 3 and 4 had 1/5 live blocks (inert blocks for 4/5). Live blocks were placed close to the boxes 1 and 2. One block in box 1 was initiated.

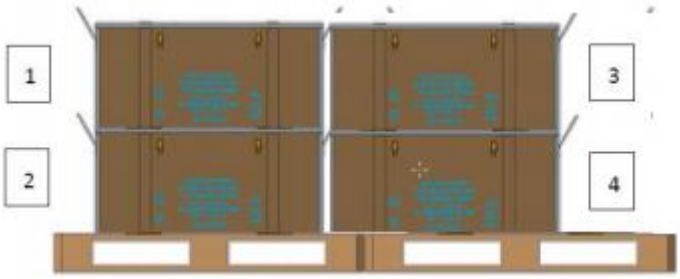


Figure 4: Configuration of the sympathetic test N°2

After the test, the box 1 was completely destroyed but the blocks close to the initiated one did not react. Boxes 3 and 4 were not destroyed. Box 2 remained at its place and it was partially damaged but the live blocks are still inside.
These both results demonstrate that a type VI is achievable when Hexomax is placed in the Supracase.

1.5.6. Summary of IM behaviour

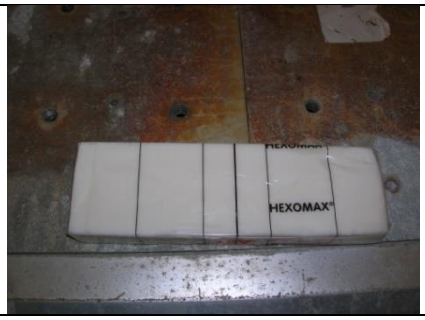
Tests	Reference	Results
Fuel fire	STANAG 4240	Type V
Slow cook off	STANAG 4382	Type V
Bullet Impact	STANAG 4241	Type VI
Sympathetic reaction		Type VI achievable by using Supracase
Fragment impact	STANAG 4496	Type I
Heavy fragment impact		Type I (assumption made according to other results)
Shaped charge		Type I (assumption made according to other results)

Table 4: IM signature

1.6. Environment testing

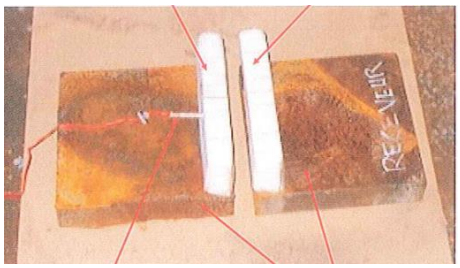
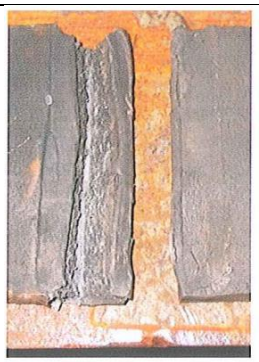
In the way of the qualification Hexomax has been tested under various environments it can face during its life. Environment tests were performed according to the standards AECTP 300 and 400.

- Storage and transport :
  - Land transport vibrations
  - Aircraft and Helicopter vibrations and accelerations up to 40g

	
After accelerations	After vibrations at -21°C

Pictures 8: Hexomax after accelerations and vibrations induced by transport

  - Thermal shocks
  - Humid/hot/cold environments from -40°C to +71°C (5 cycles A1, 10 cycles A2 and 4 cycles B3 then 4 days at -40°C)
  - Solar radiations
- Use :
  - Salted atmosphere
  - Rain
  - Dust wind
  - Temperatures from -21°C to +55°C ; the ignitation of the block has even been demonstrated until -40°C

	
Ignitiation of the block at the left at -40°C	Witness sheet after detonation

Picture 9: Ignitiation of Hexomax at -40°C

All the results demonstrate that Hexomax keeps its properties after long storage worldwide and transport phases and it can be used in any of these environments.
Moreover, Hexomax can be deployed under water.

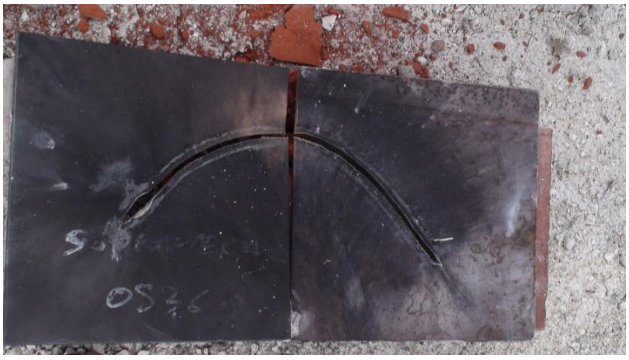
2. QUALIFICATION IN THE SUPRAFLEX SYSTEM

Thanks to its performance, insensitivity and unique malleability and modeling, Hexomax can be used as the explosive charge for any system like Supraflex.

Supraflex has been designed by the French company SUPRAMECA to be able to cut large steel thicknesses. An adhesive is under the charge so that it sticks directly on the target during 30 min. Moreover, the system can be easily initiated thanks to the booster developed by SUPRAMECA, which can be placed anywhere along the charge. This ensures a reliable ignition.
Hexomax blocks are unwrapped and placed by modeling into the linear charge.

Picture 10: Hexomax into Supraflex

Picture 11: Supraflex on steel plate


Picture 12: Cut steel plate after ignition

The desired cutting form is obtained.

Based on the achieved performances, Supraflex 10, 25 and 40 combined with Hexomax have been qualified in 2017 by the French Ministry of Defense for breaching applications (walls, etc).

As described in the following table, the cutting performance in steel varies according to the type of Supraflex:

Type	Weight of explosive	Cut thickness in steel
Supraflex® 10	190 g/m	10 mm
Supraflex® 25	1161 g/m	25 mm
Supraflex® 40	2953 g/m	40 mm

Table 5: Performance of Supraflex

CONCLUSION

Hexomax is safe for handling, transport and use in the complete range of temperature and keeps its properties after 20 years ageing.
The IM properties of the product can be improved by using the logistic box Supracase as experimentaly demonstrated: type VI is achievable for sympathetic reaction.
Its unique malleability allows Hexomax to be used alone for any cutting, opening or destruction operation. For more specific cutting work, it can be placed into any pre-formed shape, like the flexible linear shaped charge Supraflex. The French Ministry of Defense has qualified the product for these applications and further uses are already foreseen.