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Presentation of the Nexter Munitions' systems approach of demilitarization for IM melt-cast ammunition

NEXTER Munitions

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1. Introduction

Nexter Munitions is well known for studies held in the field of melt-cast processes, and in the field of developing Insensitive Munitions, which are filled with low sensitive explosive compositions based on TNT. Recent concerns address the desire to develop ammunition with the respect of the sustainable development. This new challenge is defined as a new requirement to develop products with environmental, social and economic well-being for today and tomorrow. This approach is motivated by three main areas of action: actual stockpile of ammunition, by thinking the end of life of ammunition and potential benefits in terms of economic aspect. The key of the success of the sustainable development approach resides by the simultaneous approach in terms of environmental aspect and economic benefits, which is of course, the main driver for the improvement. This paper present the works performed by Nexter Munitions in order to demonstrate the leadership of melt-cast technology and the commitment to the sustainable development.

2. Actual situation

The life cycle of munitions can be described by the following synoptic. In the past, ammunition was designed without taking account the recycling concern. Indeed some technical solutions were currently used for shell body like crimping, welding and irreversible energetic materials like plastic bonded explosive for the main charge.

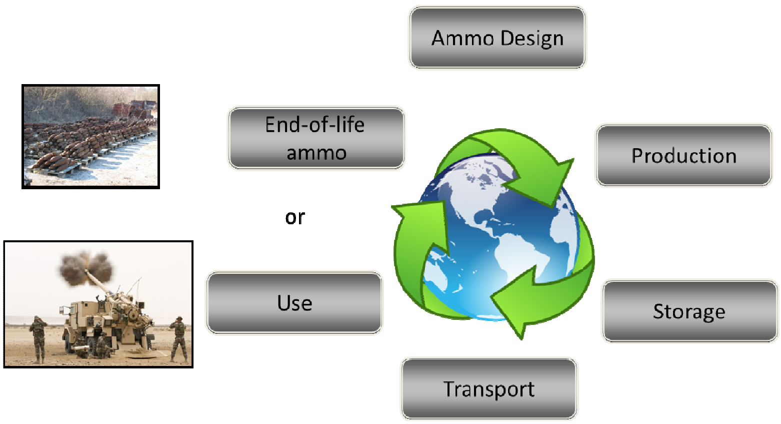

Figure 1: Life Cycle of ammunition

Nowadays there is a growing understanding of the need to minimize environmental impacts from all sectors, including military defense. Armies have large amounts of ammunition in store, which were produced during a time when demilitarization was not considered. As explained in the life cycle of ammunition, sooner or later munitions cannot be used or stored any longer then must be therefore destroyed. For example actual situation for the French army is that a quantity of 90% till 30% of stored ammunition will be dedicated to destruction.

2.1. State of the Art regarding the Demil

Today the treatment of the end-of-life ammunition or deteriorated ammunition can be sum up by the following processes.

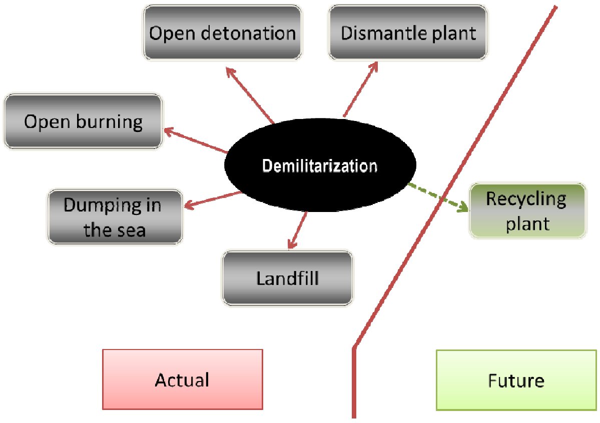

Figure 2: State of the art regarding the demil

As shown in the figure, all methods used today are destructive operations without recycling any part of ammunition. Nowadays in the frame of the sustainable development the recycling becomes mandatory by the customers in order to bring real advantage and of course to lead to cost effective solutions during the life cycle.

2.2. Ammunition end-of-life processing

The treatment of ammunition is performed by different ways. In the greatest majority of cases, the last performed operation includes an open burning or an open detonation (methods used for small components or for deteriorated ammunition).
These methods generate different pollutions: metallic or plastic fragments on the ground, noise, harmful gases. The ammunition dumps in the sea and the landfill were admitted during 50 years, as mentioned in Figure 2, but now it is forbidden. This technique created environmental pollution by releasing chemicals.
Since several years, industries have developed specialized processes to treat or “demil” the end-of-service ammunition. Different techniques have been developed before burning them. The following paragraphs present an overview of most common methods. For more information see [4].

2.3. Preparation steps for burning solution

The following figures show the process to prepare “not deteriorated” ammunition, in order to be destroyed. In the most common case, ammunition is cut into pieces before entering in burning chamber. Pictures extracted from industry websites illustrate the existing methods to dismantle ammunition.

Figure 3: Cutting with a circular saw or sawing by water jet

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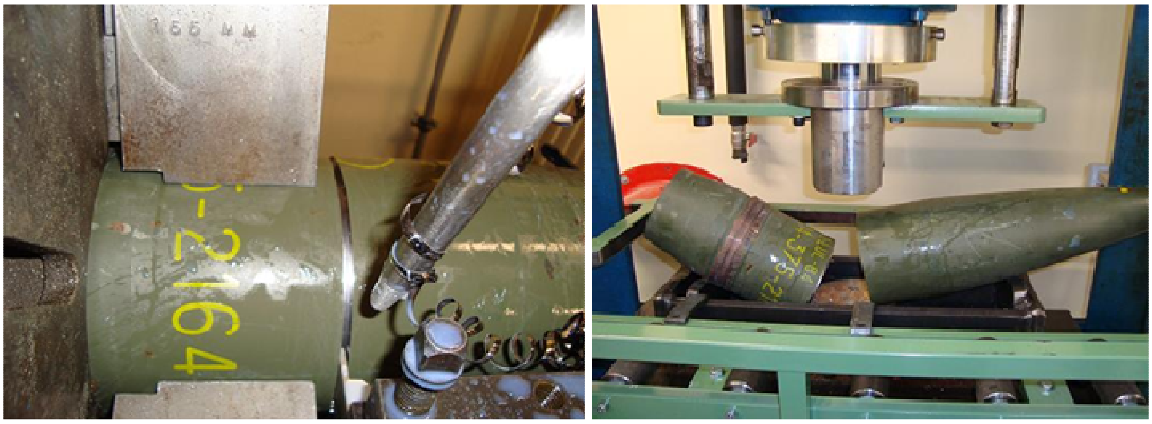

Figure 4: Milling and pressed

The aim of the preparation is to obtain limited mass of energetic materials ready to be burned. Then the “pellets” of shells are burned in the oven. This technique is dedicated to calibre from 155 mm till 60 mm.

2.4. Burning part

Once the pieces of ammunition are ready prepared to be disposing, the burning phase is running. As for samples preparation, numerous data are available in open literature to describe the burning equipment and the associated gases treatment apparatus. The following pictures present some equipment described in the literature or in the web.

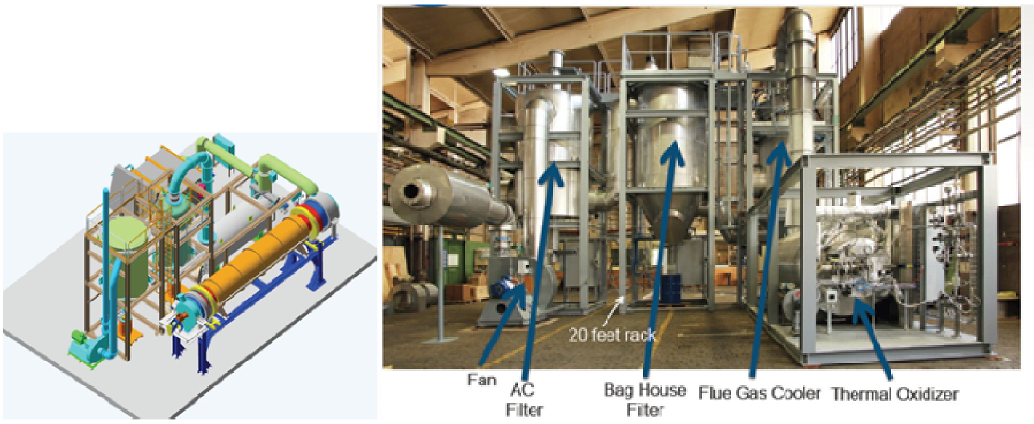

Figure 5: Burning part with gas treatment

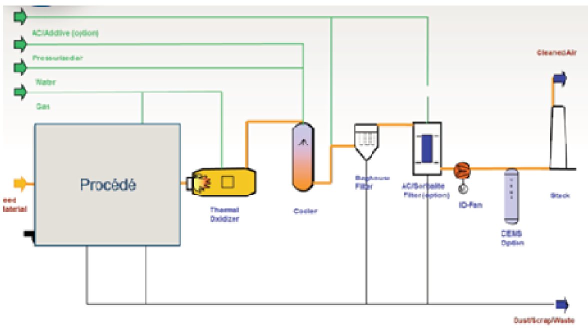

Figure 6: Schematic view of burning equipment

As previously presented, there is increasingly important interest for alternative solution which allows reducing the environmental impact. Indeed, the legislation becomes more and more drastic in terms of level of pollution and industrial must be take into account this aspect when they develop plant to treat the ammunition or when they need to add a filtration device to treat the burning gases in order to release “green gases” in the atmosphere.
Some publication described briefly the different steps **[2]**: the gas treatment is divided into four steps. Firstly, post-combustion is running where the gas are co-fired. In this part, volatile organic compounds, hydrocarbons, CO, dioxins and furans, selective catalytic reduction, gas scrubbers and adsorption are treated. After cooling, gas selective reduction works in order to remove NO_x by adding urea solution. Then gas scrubbers’ works in three iterative steps to remove heavy metal and particles, to neutralize pH and to filter gases (SO_2, SO_3, HCl,

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HF and thin particles). Finally adsorption step is performed using zeolites. The publication does not detail the treatment for produced waste liquids by these different phases.

2.5. Recent studies in the field of Life Cycle Assessment LCA [2]

University of Coimbra (Portugal) has published in Propellants, Explosives, Pyrotechnics (PEP) an article regarding the life cycle assessment of ammunition demilitarization. The University focuses only on one part of the whole life cycle Assessment. They compared the impact of the demilitarization of ammunition by discharging and the disposal of energetic materials by using a static kiln.

The dismantling and discharging were performed by using a temperature around 400 à 600°C. The incineration and gas treatment were made with an efficient treatment of gases in order to release “green gases”.

The main conclusions of the study were the following one. The part, which impacts the Human & Earth resources, was the incineration and gas treatment. The following graph built with the data extracted from the article shows the comparison between dismantling / discharging and incineration / gases treatment, according to the 10 categories taken into account in the software used by the University.

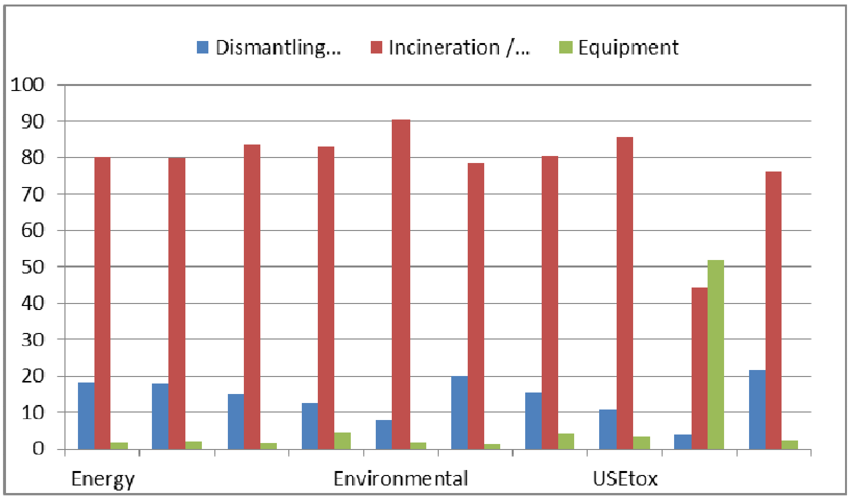

Figure 7: Comparison of impact of dismantling versus Incineration on different environmental categories

In terms of primary energies (CED Cumulative Energy Demand, included renewable and non-renewable energy), it appears that incineration contributes for the major impact due to the high quantity of consumed energy to reach incineration temperature.

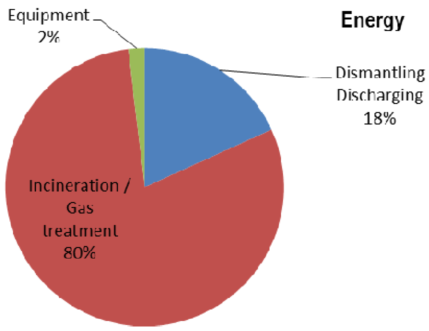

Figure 8: LCA of ammunition demilitarization - Energy impact

In terms of environmental impact categories (abiotic depletion, acidification, eutrophication, global warming, ozone layer depletion, photochemical oxidation), it appears also that incineration participates as the main contributor.

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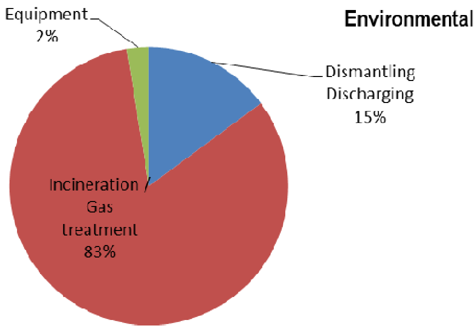

Figure 9: LCA of ammunition demilitarization - Environmental impact

Finally, in terms of toxicological impact (USEtox which includes human toxicity-cancer, human toxicity-non-cancer and ecotoxicity), incineration is still the major contributor for toxicological impact, by releasing toxic chemicals.

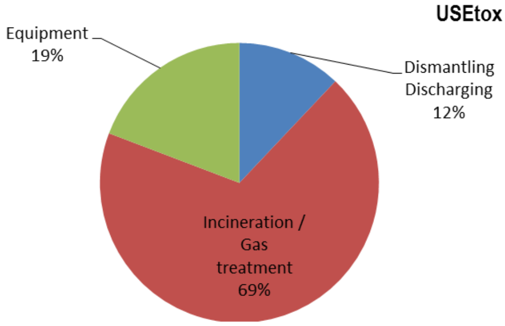

Figure 10: LCA of ammunition demilitarization - toxicological impact

It appears clearly that "green" incineration of energetic material costs to the Earth's resources. This solution works but it is not acceptable for the environmental aspect. It is not an eco-friendly process, in spite of gases treatment. Moreover the University of Coimbra shown that equipment needed for this treatment creates pollution in another part of the life cycle. Moreover the life-time of burning chamber is evaluated at 10 years. It seems that it not a pertinent solution for the future.

2.6. Where we are today

R&D department are working on alternative solutions which join economic and ecologic aspects, the first one being of course the most important.

2.6.1. Reusing artillery shell casing [1]

Recent article in the press relates the fact that it is possible to reduce the cost of ammunition by reusing some part of it. US Army ammunition plant has developed a process to recover the 155mm shell [*ed: shells filling with explosive composition based on fusible matrix TNT*] in order to reuse these rounds for training only. The shell is filled with explosive composition IMX-101, for the half price of standard ammunition. US Army saves about $79 million annually by the environmentally friendly way! In fact reusing parts of ammunition seem to be the admitted solution to fulfill the economic and ecologic aspects, instead of destroying them. For this solution the labor cost should be considered.

2.6.2. Energetic materials extracted from explosive composition [6]

A publication has been already presented during ICT conference in 2011, by Defence R&D Valcartier regarding the extraction of most valuable ingredients in main charge of 105 mm shell. Two types of explosive compositions have been tested: Composite and TNT-based explosive compositions. Explosive compositions were easily extracted (by water jet for composite and by re-melting the TNT). The TNT-based explosive composition was the only energetic material able to be reuse, in comparison with composite sludge. The extraction of energetic materials from a shell is possible. The conclusion of this article is that the reuse and recycling explosives can save money.

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2.6.3. Filling shell with flakes of explosive composition

Explosive compositions based on fusible matrix, like TNT or DNAN, are easily reused in the form of flakes. Some companies are able to provide flakes of energetic explosives compositions like Nexter Munitions or BAE Holston [7]. Following pictures show some details of “flakes” manufacture process at Nexter Munitions.

Figure 11: XF®11585 flakes – TNT based explosive composition – XF®PREMIX

Nexter Munitions has performed a comparative study between these two explosives compositions (IMX-104 and XF®11585), regarding the process parameter to re-implement in the filling tank and regarding the detonics and vulnerability performances of these explosive compositions. Results of evaluation of melt-cast explosive compositions based on TNT and DNAN are available in literature [5]. Moreover, the low vulnerability explosive composition XF®11585 is fully qualified by French MoD according to the STANAG 4170, and already used in Insensitive Munitions (120 mm tank and mortar, 76 mm Navy ammunition) [9]. This solution meets the requirement of the STANAGs 4439 and 4224.

3. Processes of demilitarization – implementation at lab scale

In order to have an economic and an ecologic benefit by using IM munitions. For more 10 years Nexter Munitions has developed basic technological bricks in order to dismantle the IM ammunition that it produces, anticipating requirements from customers or MoD. In fact, by recovering “waste”, i.e. ammunition shell body, energetic materials, instead of burning it with the ecologic impact described previously (§ 2.5), Nexter Munitions gives the opportunity to be compliant with ecologic and economic approaches. Of course, Nexter Munitions ensures that ecologic cannot leave without economic aspect.

3.1. Insensitive Munitions: complex and cost effective components

The demilitarisation is a recent concern for ammunition which includes high technology in order to be compliant with STANAG 4439 and STANAG 4224, is confirmed by the presentation of the plenary session of IMEMTS 2012 [8]. Indeed, concerning the main charge, low sensitivity explosive composition must be used in order to achieve STANAG requirements. Moreover, insensitive molecules (NTO for example), more expensive than conventional molecules, must be added to the explosive formulation (i.e. Comp B). Ammunition design includes specific mechanical parts in order to be compliant with STANAG requirements. This ammunition which contains high technology merits a possibility to recycle the maximum parts of it.
In the most common case, the end-of-service ammunition is cut and energetic material is burned. That is not a satisfactory solution, see § 2.5, for an explosive composition with a high technology which includes some time expensive components; it is not economically-responsible. One way will be to reuse the energetic material and if possible some metallic parts. Nexter munitions carried out different technologies in order to ensure an economic and ecologic end-of-service.

3.2. Dismantling techniques used by Nexter Munitions

Nexter Munitions challenge was to develop procedure in order to recover expensive material. Nexter Munitions considers 2 approaches.

- The case of complete round, i.e. a cartridge,
- The case of shell with fuze

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3.2.1. Case of complete round

The dismounting is performed by using a traction device in order to separate the shell from the cartridge.

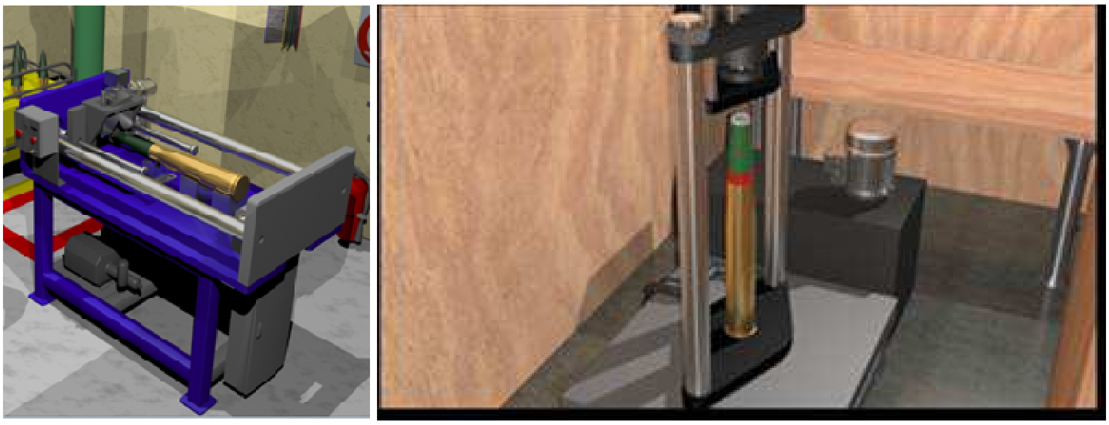

Figure 12: cartridge dismantling

Then, the cartridge is emptied and could be revalorized or reused with new propellant. The shell is dismantled using the following procedure.

3.2.2. Case of shell with fuze

Tail, fuze, sealing ring and other parts of the shell can be unscrewed by using specific equipment.

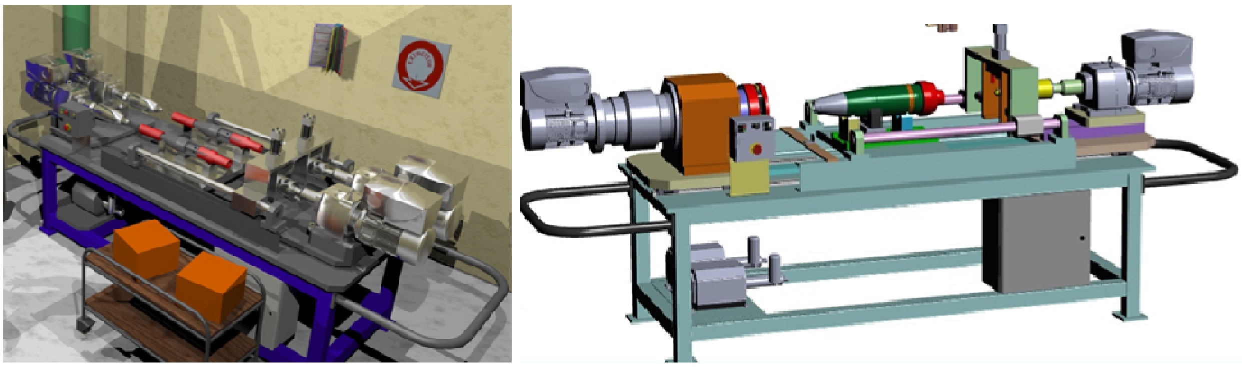

Figure 13: Shell opening

After the previous machining part 2 different cases can occur: firstly the explosive composition is available and the shell can be discharged. Secondly one, the explosive composition is not available and the shell must be treated by traditional ways of demilitarisation (see §2.3).

3.3. Ammunition discharging by Nexter Munitions

Explosive composition based on fusible matrix has a real cost effective solution for the end-of-life thanks to its reversible property.

3.3.1. Methods

After fuze removing, shell body is heated above the melt cast temperature of TNT. Then, 2 methods can be used, reversal discharging or by using the patented method developed by Nexter Munitions, see figures above with box around.

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Figure 14: Methods to discharge shell

Unfortunately there are traces of explosive inside the cavity of shell body, as illustrated by the Figure 15.

Figure 15: traces of explosive in the cavity of the shell after discharging

3.3.2. Example of shell cleaning

The treatment of dirty shell body was performed by using stream water jet as described in the Figure 16.

Figure 16: Shell body cleaning by water jet

3.4. Reused energetic materials in form of flakes

It exists two major ways: the first one is to burn the waste of energetic materials; the second one is to be eco-friendly by reusing the flakes of energetic materials. It is proven that is possible to fill with flakes of energetic materials ammunition whatever calibres. Nexter Munitions has filled ammunition with XF® flakes. These flakes have been obtained after discharging, as shown in Figure 14, and transformed in re-useable flakes by the process illustrated in Figure 11.

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Figure 17: re-implementation of flakes into industrial tank or into laboratory reactor [5]

Trials performed with ammunition filled with this reusable flakes fulfil the Nexter Munitions requirements. To conclude, this part dedicated to available process of demilitarisation, Nexter Munitions is able to perform a non-destructive process of the end-of-service ammunition, which fulfils duality between ecologic and economic approaches. To go further, Nexter Munitions applied this approach to the industrial scale.

4. Insensitive Munitions loaded with recovered energetic materials

Nexter Munitions has already demonstrated the feasibility of this approach. The following paragraphs present the results obtained by applying technologies described previously.

4.1. Implementation in industrial scale

Flakes of energetics materials have been re-implemented in industrial equipment, following the standard procedure. However for the explosive composition in flakes forms, there is no need to perform preliminary step of mixing different components.

Figure 18: Industrial equipment for shell filling, and Specific separable shell body of 155 mm LU211

In order to confirm the feasibility Nexter Munitions has loaded 155 mm LU-211 with XF® Premix. To achieve the filling quality, specific separable shell bodies have been added in the production trolley, see Figure 18.

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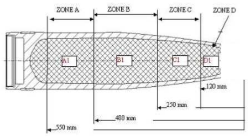
4.2. Characterisation of shell loaded with re-covered explosive composition

Once the 155 mm LU211 loaded with flakes of XF®, characterizations have been performed. The following table sum up the results obtained.

Table 1: characterisations of shells filled with XF® Premix

Procedure	STANAG or tolerances	Results	Conformity with specification
Basic pyrotechnics tets	STANAG 4489 STANAG 4487 STANAG 4490	0% à 50J 0% à 353 N >736 mJ	✓
X-Ray analyses	Control – 2 sides	No defect	✓
Destructive expertise: longitudinal sawing		0 defects (bubble, cracks, voids, shrinkage)	✓
Chemical analyses	NTO 48±2% TNT 31±2% Alu 13.5±2% Wax 7.5±2% Density 1.75 g/cm³	NTO 46.6 – 49.4 TNT 30.2 – 32.8 Alu 12.5 – 13.5 Wax 5.9 – 7.6 Density 1.75 – 1.76	✓
Mechanical properties NF T70-314		ε = 20 MPa	✓
Exudation		Procedure C-01-2 : no exudation	✓
Safety and suitability for service Evaluation	STANAG 4224	Compliant with specifications for 155 mm LU211 IM	✓

4.3. Detonics performances of ammunition filled with XF®PREMIX

Nexter Munitions has performed detonics performance tests with the shells loaded with re-covered XF®. All the tests performed confirm equivalent performances to those observed with original shell. The following pictures present the witness plate of ignition trial. Tests have been performed at different temperature: -40°C, room temperature and +63°C.

Figure 19 : witness plate at ambient, +63°C and -40°C

Nominal detonations of 155 mm LU211 filled with recovered XF® were observed whatever the temperature of test.

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5. Conclusion

For more than 10 years Nexter Munitions has developed basic technological bricks in order to dismantle the "IM" ammunition that it produces, anticipating the future needs from customers or MoD. Current industrial solutions for disposal ammunition are very mainly divided into 3 phases: dismantling ammunition, burning the pellets of ammunition and treatment of gases. As described in this paper, incineration phase is not eco-friendly and it will probably evolve due to the hardening of the legislation. However, it is necessary to maintain open burning for ammunition which are in bad state of preservation; specific case aside it is important to propose cost effective solutions for ammunition which have been stored in appropriate and known conditions of storage.

Nexter Munitions has exposed alternative approaches to fulfil duality between ecologic and economic approaches. As mentioned these technologies are very interesting for explosive composition with a low vulnerability implemented in "IM" ammunition. Indeed these explosive compositions ask advanced formulation technologies, and the fact that we can reuse the explosive compositions instead of burning them; it is a real cost effective solution of using melt-cast formulations. Moreover discharging ammunition could be a complicated operation in case of presence of additional booster / or complementary charge, Nexter Munitions' explosive composition XF®11585 don't require booster thereby facilitating dismantling.

This paper presents the work performed in the field of Insensitive Munitions, but all the procedure could be applied for conventional ammunition filled with Compo B or TNT.

This approach could be considered at the moment slightly premature or innovative but we have to go ahead and take into account the following preoccupation regarding the Earth's resources preservation and the long-term consumption.

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