HOW TO FILL ARTILLERY SHELLS AT THE LOWEST COST WITH THE HIGHEST IMNESS USING CAST CURED PBX

R. VENZAC - P. BENHAIM ***Y. GUENGANT - I. BRUN***

EURENCO France
1928 Route d'Avignon - BP 311
84706 SORGUES Cedex
r.venzac@eurenco.com p.benhaim@eurenco.com

SME Environnement
Centre de Recherches du Bouchet
9 rue Lavoisier, 91710 VERT LE PETIT
y.guengant@snpe.com i.brun@snpe.com

ABSTRACT

Use of Cast Cured Plastic Bonded Explosives enables to obtain the Insensitive Munitions signature compliant with STANAG 4439 while preserving high performances. Thus, manufacturing medium and large caliber charges at attractive cost was the project challenge. This has been achieved using a semi-continuous bi component process (EURENCO's Patent). The cast explosive is an RDX – HTPB based composition. Due to maximum explosive quantity allowed in workshop, it was required to demonstrate that Sympathetic Detonation is not possible even for large caliber shells. A full scale test was performed successfully using 155 mm shells in process configuration and on the basis of the safety properties of selected PBX compositions. Through that way, French authorities have classified the manufacturing process in 1.3 HD. This paper describes the main features of this innovative process and the safety aspects.

1. INTRODUCTION

Cast Cured Plastic Bonded Explosives enable to reach the IM/MURAT signature requirements while preserving high performances. At first, only large munitions were concerned but this improvement is possible for all munitions, including tank & artillery shells. However, only first development programs are running today for these shells.

This is due to various reasons; the Navy was the first to request some less vulnerable munitions after the several accidents involving battle ships and especially aircraft carriers; the CBA (Cost Benefit Analysis) has been more convincing with general purpose bombs and other large munitions for the Navy and Air Forces; Nevertheless, the Camp Doha accident has shown the benefit of IM/MURAT introduction for the Army.

So, today it is desirable for customers to obtain Insensitive Munitions filled with Cast Cured PBXs at a price as close as possible to classic munitions containing melt cast or pressed compositions. This challenge has been taken up using a semi-continuous process for shell filling. This is done using the new bi-component technique (EURENCO's Patent) and an integrated workshop.

The integrated workshop designing has been facilitated by the insensitiveness properties of the employed cast Cured PBXs. Indeed, it has been established that no stimulus in process phases can outcome any detonation as by SDT (shock-to-detonation transition) as through DDT (deflagration-to-detonation transition). The remained risk is the PBX combustion with some moderate thermal flux effects. Sufficient convincing demonstrations were done to classify the manufacturing process in 1.3 HD (Hazard Division) by the French Authorities.

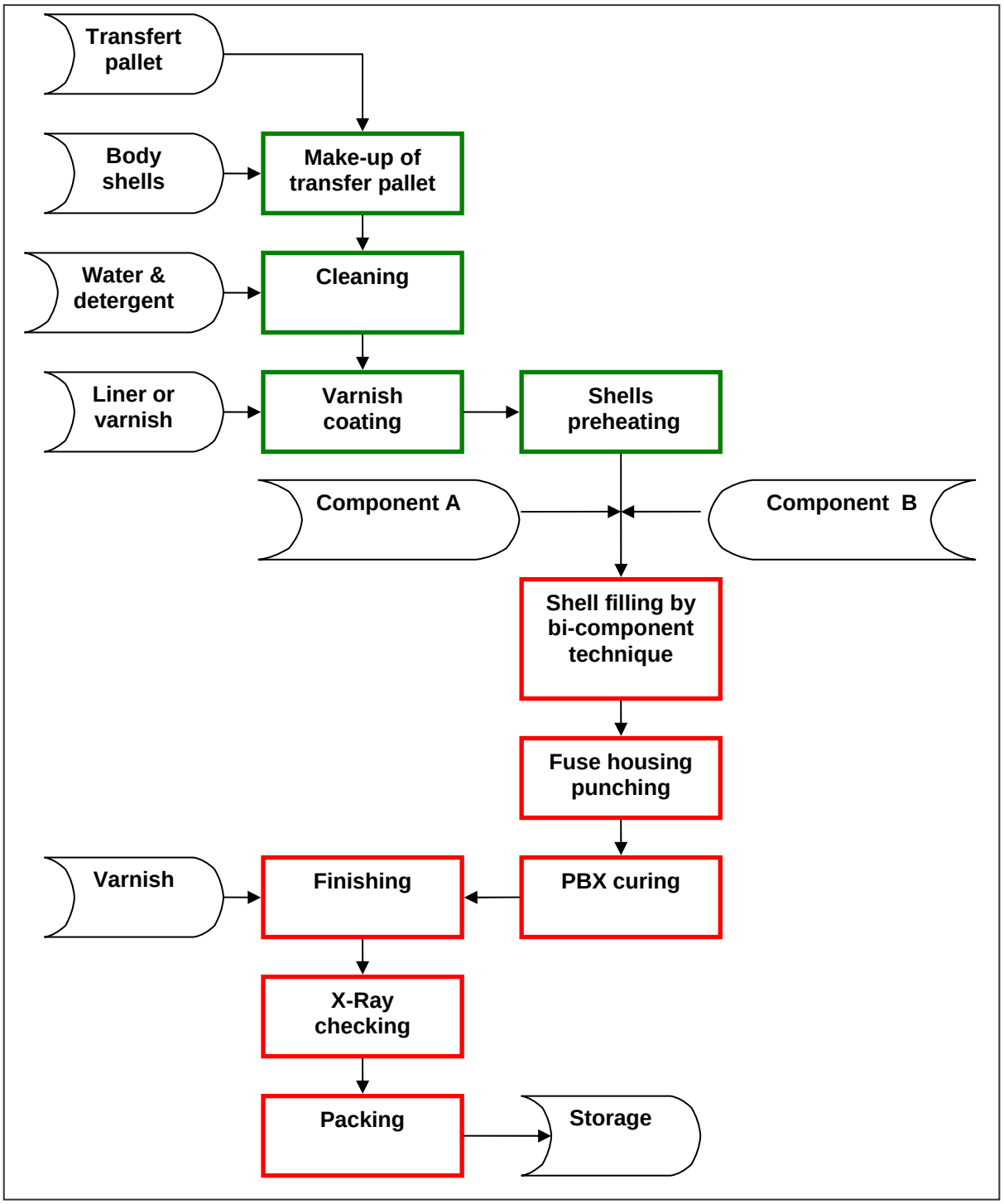
EURENCO Integrated Workshop in Sorgues Plant

2. INTEGRATED WORKSHOP FOR SHELL FILLING

The integrated workshop has 1200 meter square area. The production line is automated from the shell body washing up to final X-Ray control. It allows filling up to 50,000 155 mm shells per year or 100,000 120 mm shells per year. At the same time, it is possible to have in the workshop 200 large caliber shells or 700 medium caliber shells. Larger shells contain around 11 kg and smaller 2.5 kg of PBX.

Internal view of the EURENCO Integrated Workshop (during construction)

The various process phases are summarized on the following picture. At each step, some checks are done to assure the integrity of the explosive charge and to avoid any source of degradation of its properties (shocks, drops, foreign body …). On picture, green boxes correspond to preparation steps, red boxes indicate pyrotechnic phases, and black boxes are the entries & exits of various elements. Manual operations are strongly limited; these are essentially the feeding of production line and the process control.



Synoptic of production line

The component A is brought from another workshop. It is manufactured through classic batch method. Some strong verifications are performed to verify the paste compliance with safety parameters. Indeed, it is necessary to deeply guarantee the absence of possible transition shock-to-detonation (SDT) or deflagration-to-detonation (DDT). The list of such parameters has been defined through a fault tree analysis concerning the whole activities of this integrated workshop.

The shells are filled by the new bi-component technique which has been patented by EURENCO France. This technique enables to achieve the PBX preparation and to fill the shells preserving the high PBX quality: homogeneity, absence of porosity…

	
Internal view of the curing oven	***Handling robot***

This integrated workshop is operated usually by five people team. The support installations are placed closely. These are the local for hand-made touch up or the removal of possible non-conform PBX filling and the waste elimination.

3. CAST CURED PBX PROPERTIES

The Cast Cured PBXs that can be filled in this workshop belong to candidate family for IM/MURAT. So, these are the least vulnerable and the safest compositions. EIDS (Extremely Insensitive Detonative Substance) according to the UN 1.6 Hazard Division is possible only for large caliber [2].

The EIDS can not be initiated directly by classic fuse. The insensitiveness to intense shocks is linked with a large critical diameter. Then, use of large booster is necessary for charge initiation and a minimal munitions size is require getting the stable detonative regime giving the expected performances.

The explosives compositions implemented in this workshop have an inert binder (HTPB, PU …), some explosives charges (RDX or HMX) and possibly some additives (Aluminum…). In the workshop, explosive is present under various forms: pasty in containers, cured in shells, mitigated scraps in bins.

The minimum safety requirements for pasty or cured explosive compositions are listed in the table below:

LIST OF TESTS	MINIMUM REQUIREMENTS
Combustion Propagation in Gutter Test (AFNOR Standard NF T70-507 or AOP7 302.02.001)	**Lower than 50 mm/s**
Large Card Gap Test (40 mm) (AFNOR Standard NF T70-502 or STANAG 4488)	**Lower than 240 cards**
Friction Sensitivity Test (BAM apparatus) (AFNOR Standard NF T70-503 or STANAG 4487)	**Higher than 50 Newton**
Large Scale Electrostatic Discharge Sensitivity Test (AFNOR Standard NF T70-527 or STANAG 4490)	**Not Sensitive**
Friability Test (AFNOR Standard NF T70-524 or UN 7c) ii))	**Lower than 18 MPa/ms at 150 m/s**
Critical Pressure of Combustion under Parallel Layers (SNPE N° 108)	**Higher than 600 MPa**
External Fire Test (AFNOR Standard NF T70-525 or UN 7e))	**No more than burning**

These minimum requirements have been set-up to eliminate any risk of transition-to-detonation, either by SDT (shock-to-detonation transition) or by DDT (Deflagration-to-Detonation transition). The substance characterizations are completed by full scale trials as the UN tests listed in series 6. The various items have passed these tests.

4. HAZARD DIVISION CLASSIFICATION

The various operations conducted in the integrated workshop have been classified under 1.3b Hazard Division by the French Authorities. In France a distinction is done between 1.3a and 1.3b; the first concerns the energetic materials giving considerable thermal flux (i.e. fine gun propellants) and the second concerns mainly rocket propellants. The approval document has been issued by DGA/IPE (French Procurement Agency / Inspectorate for Powders and Explosives) on 2005.

The thought process is that no aggression is able to provoke any SDT, because:

- the Fault Tree Analysis has demonstrated that all possible non-pyrotechnic errors generate some non-dangerous shocks (many times) in comparison with PBX shock sensitivity,

- the preventive measures defined from Fault Tree Analysis are checked according to defined procedures,

- the possible ignition of explosives cannot outcome any violent reaction even for shells, so no DDT is possible and no dangerous fragment can provoke any SDT of neighbouring items.

- Obviously, the fuses are never present in the workshop and even in the whole factory, so, the delivered products are not able to detonate.

These remarks have allowed the 1.3 HD classification of activities which are conducted in the integrated workshop. The QDs are drawn for the whole quantity of explosives inside this workshop (3 tons).

Nevertheless, the DGA/IPE representative was more or less doubtful. So, some complementary trials were requested even if the Fault Tree Analysis had demonstrated that any detonation can be eliminated regarding the listed Cast Cured PBX properties.

The request was to demonstrate the absence of sympathetic detonation between shells on pallets along the production line; even if the donor detonation can not be explained coming from accidental event. This is described in the following paragraph.

Moreover, the event probabilities in integrated workshop were assessed for each operation. The risk of burning is evaluated between 10^{-3} and 10^{-4} annually, except for storage phases in approved package, evaluated lower than 10^{-4} annually.

5. SYMPATHETIC REACTION TRIAL

According to the request from DGA/IPE, it has been necessary to design a pallet allowing guaranteeing the absence of sympathetic detonation. This has been done quite easily through SNPE & EURENCO's knowledge [1].

A specific pallet has been designed using:

- SDT threshold for each studied PBX,
- Numerical simulations though LSDYNA with specific reactive laws of explosives and behavior law of inert materials,
- Preliminary tests in laboratory,
- Full scale tests in standard & hardened conditions to guarantee a safety margin,
- The reference charge is naturally the largest, the 155 mm artillery shell.

The first assessment has shown the necessity to set-up some specific screens between shells of one pallet and between pallets. These screens are made of pressure attenuator materials; the pallet framework is made of steel.

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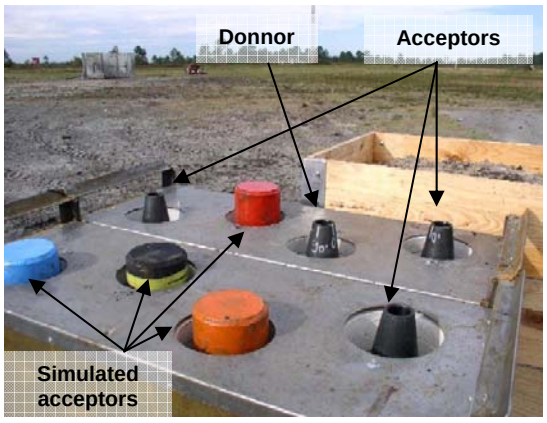
<td> 
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<td>Prototype pallet for SD Test</td>
<td>Recovered 155 mm Shells</td>
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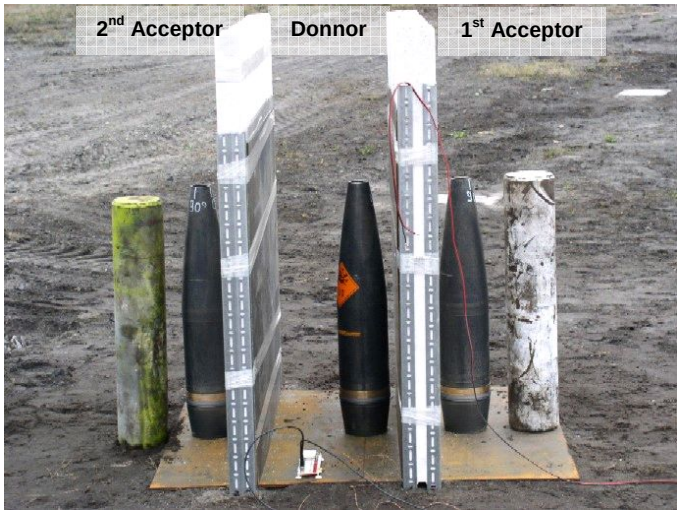
The results have shown the absence of sympathetic detonation in standard conditions between internal items and between pallets. The recovered acceptors are shown on the picture above. The nearest acceptor is partially torn, the two others are intact.

For the trial under hardened conditions, the screen thicknesses have been reduced up to 50%. Through this way, the confidence in the previous result has been completely established. This test has also demonstrated the absence of sympathetic detonation, as shown on the following pictures.



SD Test under hardened conditions

Recovered 155 mm Shells

It is very interesting to note that the acceptors have not detonated even under stronger conditions. The closest acceptor has been torn and the other is pristine except the tracks of fragment impacts. Nevertheless, the projection distances can reach 150 m in open field due to effects of donor detonation. Using the pallets, these distances are shorter.

These tests allow also designing some logistics pallet in order to demonstrate that artillery shells can be classified 1.2 Unit Risk (1.2.3 HD in US & UK) for all logistic phases. According to same issues the MURAT Label 2* would be obtained.

6. CONCLUSIONS

Cast Cured PBXs enables to reach the Insensitive Munitions signatures compliant with STANAG 4439 while preserving high performances. This advantage can be used also during manufacturing phase. Thus, the costs can be attractive and can reinforce the CBA (cost benefit analysis) results.

This is also the outcome of one EURENCO innovation, the semi-continuous process using the bi-component technique. Through that way, the integrated workshop is operated under 1.3 HD due to the demonstrated absence of any detonation risk during these manufacturing phases.

The complementary trials have allowed demonstrating the absence of sympathetic detonation. These artillery & tank shells can be classified clearly 1.2 Unit Risk HD (1.2.3 HD in US & UK) during logistics phases. According to same issues the MURAT Label 2* would be obtained.

7. REFERENCES

[1] Methodology to Predict Sympathetic Detonation between Munitions Stored on a Pallet by Ph. Chabin and M. Dervaux, IM&EMTS 2006

[2] Recommendations on the TRANSPORT OF DANGEROUS GOODS "Manual of Tests and Criteria", ST/SG/AC.10/11/Rev.3.