A NEW PROPOSAL HELPING US
TO QUANTIFY REACTION TYPES

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The GEMO (French committee tests procedures) is a working group treating tests standards on defense explosives. It is under the autority of the DGA (French procurement agency of the French Ministry of Defense) and it regroups experts from the Ministry of Defense and from Armament Industries.

The scopes treated by the GEMO cover the statistics methods and metrology, the explosives propertiesand the physico-chemical analysis, the security and the vulnerability, and finally the ammunitions performances.

The vulnerability working group of the GEMO convenes program services of the DGA, four tests centers of the DCE (The Systems Evaluation and Test Directorate) and all the armament industries concerned by the vulnerability of the ammunitions. Apart from the fact that the members of this working group cover all the profession, they also cover the whole explosives and french ammunitions (explosive, powder, propellant, bomb, warhead, shell, rocket motor, ...).

This organisation allows to have the most objective and broad french opinion as possible about the vulnerability standards. After 10 years, this working group writed eight standards to carry out tests on models and seven definition documents of these models.

These works allow France to have, in the vulnerability tests scope, all the necessary documents to study the behaviour of new explosives, confined or not in models. The tests on full scale ammunitions derive also benefit from these works.

Two years ago, these documents were french standards.

And for that, it had been necessary that our working group examines again all the documents which had been writen for many years.

Over and above standards and models definition documents, the GEMO also writed a document which defines the reaction types of ammunitions under different vulnerability tests.

This document takes up the definitions expressed by the NATO working groups again. But it also takes up a table imagined by the armament programm services of the French Procurement Agency and some french armament Industrialists at the beginning of the 90's.

This table has been accepted by the National Competent Authority of the Fench Procurement Agency in 1993 and it is approved by the french MURAT doctrine.

The goal of this table is to take much of the reaction type classification of vulnerability tests results.

Indeed the official definitions, provided in the NATO documents for example, are not precise enough and they are particularly arguable.

This doesn't allow to warrant the objectivity of the classification which is made.

Now the tests results are often difficult to interpret and the frontier between two reaction types seems to be often slight.

Here below are some examples which were carried out by the French MOD/DGA/DCE/CAEPE.

Two fast cook off tests (870°C fuel fire tests) carried out on an air to air missile rocket motor were setted out.

They fit into the less vulnerability framework of ammunitions which have to take aboard french navy aircraft carriers.

These tests were carried out according to the STANAG 4240, and the measures made were the following ones :

- fire temperatures
- rocket motor behaviour
- blast pressure
- video and audio records

The results of the first test were given below :

- <u>overpressure</u>
    - ↳ 10 mbar at 10 m and 7 mbar at 15 m

- <u>video records</u>
    - ↳ initiation of the propellant
    - ↳ a lot of fragments throwed outside the tank

- <u>observations in the area after the test</u>

    - ↳ no structural fragment outside the tank
    - ↳ unburned propellant (1 % of the total mass) up to 8 m
    - ↳ burning propellant up to 18 m
    - ↳ the item was cut in two main parts

To conclude, we can say that was not a severe reaction, only a fire spreading threat which could endanger the navy platform.

Between a type V and a type IV, we decided to choose a **type IV.**

The results of the second test were the following ones :

- <u>overpressure</u>
    - ↳ 45 mbar at 10 m and 31 mbar at 15 m

- <u>video records</u>
  - ↳ a lot of fragments (structure and burning propellant) throwed away
  - ↳ combustion of propellant fragments occured during 24 s

- <u>observations in the area after the test</u>

  - ↳ 14 fragments in the tank, that is to say 8,5 % of the propellant and 62 % of the structure
  - ↳ 18 fragments outside the tank (one piece of propellant, 8 %, at 27 m and 30 % of the structure up to 60 m) and burning propellant fragments up to 20 m

To conclude, we can say that were not only local damages, fire spreading threat but the overpressure levels were not too severe (inapropriate to a partial detonation).

Between a type IV and a type III, we decided to choose a **type III.**

We could easily note on these two examples that the reaction type classification is proving often difficult.

Neither the industrial desire to reduce the effects of the reaction obtained to meet requirements of its contract and nor the propensity of safety team to often see great danger even when it's not true, it's delicate to reach a decision for the state tests center.

As it has to remain the most objective as possible, the official definitions on which it leans and which are today very arguable, as we said before, are not be really of any use to it.

A last example, about a slow cook off test, confirmes this difficulty.

It was also carried out by the French MOD/DGA/DCE/CAEPE on an air to air missile rocket motor in a climatic facility at 3,3°C / h.

It fet into the less vulnerability framework of ammunitions which have to take aboard french navy aircraft carriers.

This test were carried out according to the STANAG 4382, and the measures made were the following ones :

- temperatures in the test facility and on the item
- rocket motor behaviour
- blast pressure
- video and audio records

The results of the first test were given below :

- overpressure
  - ↳ equivalent to the detonation of 8 % of the energetic material

- video records
  - ↳ initiation of the propellant
  - ↳ a lot of fragments throwed away

- observations in the area after the test

  - ↳ the front face was still on the test stand
  - ↳ 14 item fragments (75 % of the total structural mass) up to 62 m, 10 of them at a distance inferior to 15 m
  - ↳ 6 pieces of the test facility up to 100 m : only one at a distance inferior to 15 m

To conclude, we can say there were propulsion and no plastical damage of the mechanical stand. A large part of the rocket motor was not destroyed and the test facility was cut in large pieces.

Even then the overpressure analysis seemed to indicate a partial detonation, we decided to choose a **type III**, because the elements given by observations of damage are inconsistent with this partial detonation.

To facilitate this classification, France therefore writed at the beginning of the 90's the below table on the next page.

This table contains for each reaction type, from type I to type V, informations about the energetic material and ammunition case behaviours, but also about the measures (overpressure, flux, length of projection, ...) made on these tests.

Relating to these measures, some quantitative values have been added to the corresponding NATO definitions about each reaction type.

As a matter of fact, the informations provided in these definitions have been taken again in this table, but to facilitate the experimenter work in his choice of a reaction type and especially to avoid as many as possible all kind of interpretation.

So, different reaction types were often chose for reactions were yet similar.

These quantitative values come from the below official documents :

- MIL-STD-2105A : « Hazardous fragment »
- UN - Dangerous goods transport : 6 C test
- French explosive safety document :

  N° 1196, ISBN 2-11-072 726-8, ISSN 0767-4538

■ according to official descriptions ■ added by the National Competent Authority of the French ProcurementAgency

RESPONSE TYPE	MUNITION BEHAVIOUR		EFFECTS			
	Energetic materials	Case	Blast	Energetic materials projection	Projection of fragments	Others
I	- detonation - supersonic decomposition reaction	- very fast plastic deformation	- intense shock wave - damage to neighbouring structures	- all the materials react	- perforation, plastic deformation or adjacent metal plates fragmentation	- large craters in the ground
II	- partial detonation	- partial fragmentation + large fragments	- ditto	- ditto	- ditto	- ditto - proportional to % of detoning material
III	- fast combustion of confined material (explosion) - local pressure build up	- violent breaking into large fragments	- blast effect < detonation - damage to neighbouring structures - $\Delta P > 50$ hPa at 15 m (1) (2)	- scattering of burning materials - risk of fire smoke	- long-range projection - damage to metal plates (breaks, rips, cuts)	- small craters in the ground
IV	- combustion/deflagration - non-violent pressure release	- breaks but does not fragment into more than 3 parts - covers expulsion - gases release through openings	- blast effect limited to $\Delta P < 50$ hPa at 15 m (1) (2)	- scattering of materials - risk of fire	- expulsion of covers and large structural parts - no significant damage	- damage caused by heat and smoke - propulsion of unattached sample
V	- combustion	- splits in a non-violent way - smooth release of gases - separation of end caps	- blast effect limited to $\Delta P < 50$ hPa at 5 m (1) (2)	- energetic materials remain nearby (< 15 m) (2)	- débris remain in place except covers - no fragments of more than 79 J (3) or more than 150 g beyond 15 m (2)	- heat flow < 4 KW/m² at 15 m (2)

(1)French explosive safety document, " Circulaire du 8 Mai 1981: § C2" (2) UN - Dangerous materials transport : 6 C test (3) MIL-STD-2105A : "Hazardous fragment"

The seven values which therefore come from these documents and which explicit the different levels are listed below with their justification :

- 100 hPa ➔ criterion for limit between medium damages and small damages to nearby structures in the french document
- 50 hPa ➔ criterion for limit between small damages and very small damages to nearby structures in the french document
- 79 J ➔ criterion for energy of a hazardous fragment according to the MIL-STD-2105A
- 150 g ➔ criterion for hazardous fragment according to UN 6C test (bonfire test)
  (for example, the projection of a 150 g more fragment at more than 15 m be followed by a 1.2 division classification)
- 4 kW/m² ➔ criterion for hazardous thermal flux according to UN 6C test
  (for example, a thermal flux of more than 4kW/m² at 15 m be followed by a 1.3 division classification)
- 5 m ➔ normal distance of intervention for firemen around a fire of 1.4 ammunition (essentially civil ammunition)
- 15 m ➔ normal distance of intervention for firemen around a fire of other ammunition (essentially military ammunition)

At that time, we have at disposal a table which has been most certainly improved, but it still contains near some clear and necessary descriptions of reaction types some arguable ones which can't be used to easily differentiate the levels of reaction between them.

A new improved table could thus be created. It should be divided in three parts and it should only contain clear and measurable informations permitting to choose a reaction type, and also for each of them some informations came from the NATO definitions about the tested ammunition behaviours and others unmeasurable effects.

The last informations are only in this table to help us for the choice of reaction type and they are not necessary and sufficiently.

For the ammunition behaviour informations, they are in this table to closely bound up with the NATO definitions, but not to differentiate the levels between them with objectivity.

IMPROVED TABLE

<table>
<tr><th>RESPONSE TYPE</th><th colspan="2">MUNITION BEHAVIOUR</th><th colspan="4">MESURABLE EFFECTS</th><th>OTHERS EFFECTS</th></tr>
<tr><th></th><th>Energetic materials</th><th>Case</th><th>Blast</th><th>Energetic materials projection</th><th>Projection of fragments</th><th>Witness plate</th><th>Caracteristic effects</th></tr>
<tr><td>I</td><td colspan="2" rowspan="5">Informations about the behaviour of the munition

These informations, coming from the NATO definitions, which can't be used to choose a reaction type</td><td colspan="4" rowspan="5">Effects to measure to be able to differentiate
and to choose a reaction type

We only considere here the effects, indicated in the NATO definitions, which can really be measure</td><td rowspan="5">Other effects which can help you to differentiate reaction types, but not really necessary (also indicated in the NATO definitions)</td></tr>
<tr><td>II</td></tr>
<tr><td>III</td></tr>
<tr><td>IV</td></tr>
<tr><td>V</td></tr>
</table>

A proposal of this new table is given in the last page.

There is only a proposal expressed by the GEMO vulnerability working group.

Nevertheless, it is certain that the actual official definitions are not precise as sufficient : arguable criterions and unmeasurable values.

This has two main consequences.

First, for an ammunition vulnerability test, the work of tests teams is really difficult and can't be guarantee.

Secondly, and it is the most important, the chose reaction type can differ according to the efficiency of the experimenter (between different tests centers in the same country for example), or according to particular interests (between different countries, at the international level, for example).

And it is not acceptable when we talk about safety level !

IMPROVED TABLE

RESPONSE TYPE	MUNITION BEHAVIOUR		MESURABLE EFFECTS				OTHER EFFECTS
	Energetic materials	**Case**	**Blast**	**Energetic materials projection**	**Projection of fragments**	**Witness plate**	**Caracteristic effects**
I	- detonation - supersonic decomposition reaction	- very fast plastic deformation into a lot of small fragments	- shock wave above 90 % of the munition equivalent weight of TNT	- absence of energetic materials	observation of small fragments	- drilled	- large craters in the ground - perforation, plastic deformation or adjacent metal plates fragmentation - damage to neighbouring structures
II	- partial detonation	- fragmentation into small and large fragments	- shock wave between 10 % and 90 % of the munition equivalent weight of TNT	aimless	observation of small fragments	- stamped (going up to the perforation) and/or deformed	- idem above but it is dependant upon the percent of energetic materials which detonate
III	- fast combustion of confined material (explosion) - local pressure build up	- violent breaking into large fragments	- $\Delta P > 100$ mbar (1) à 15 m (2)	aimless	- long range projection of large fragments	aimless	- small craters in the ground - damage to metal plates (breaks, rips, cuts) - scattering of burning materials - risk of fire and smoke - damage to neighbouring structures
IV	- combustion / deflagration - non-violent pressure release	- it could break into large parts - covers expulsion - gases release through openings	- $\Delta P < 100$ mbar (1) à 15 m (2)	aimless	- expulsion of covers and large structural parts - propulsion of the tested munition	aimless	- scattering of materials - risk of fire and smoke
V	- combustion	- splits in a non-violent way - smooth release of gases - separation of end caps	- $\Delta P < 50$ mbar (1) à 15 m (2)	- energetic materials remain nearby (<15 m) (2)	- debris remain in place except covers (< 15 m)	aimless	

(1) French explosive safety document, "Circulaire du 8 Mai 1981: § C2"   (2) UN - Transport des matières dangeureuses : épreuve 6 C