2013 Insensitive Munitions and Energetic Materials Technology Symposium,
October 07-10, 2013, San Diego, California.

# SHAPED CHARGE JET STANAG: PROPOSITIONS FOR UPDATED EDITION

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IMEMG is the European Organization assembling leading armament groups working with IM technologies. It aims to express the viewpoint of the armament industry with regards to relevant transnational regulations and requirements. This paper regarding Shaped Charge (SC) Jet STANAG is the result of work carried out by the Hazard Assessment & Classification Expert Working Group. The promulgated STANAG 4526 (ed2), not ratified by all Nations, cannot be used as a standardized reference because the 50 mm Rockeye is not available and its performances are not well defined for determination of an equivalent SC; additionally, test set-up is not clearly defined; Consequently, each test center uses their own SC and procedure. Due to national needs, various standardized SC have been defined: CCEB 62 for France, PG7 Replica for Germany, BRL 81mm for USA. Thus, it is necessary that new edition SCJ STANAG considers theses SC. IMEMG is concerned by the lack of current STANAG consistency and by the numerous SC used by test centers. NATO standards should be agreed and practicable by all member countries and should not rely on self-interpretation or SC not available for all. IMEMG experts intend to support current standardization efforts and wish to stress on the fact that SCJ STANAG should list a very limited umber of approved SC models and test set-up. In any case, each SC referred should have an available and comprehensive technical data pack. This has been presented during 2012 IMEMTS. This new paper develops these issues and proposed some best practices for velocity and diameter determination, some comments about charge diameter on munitions responses. Indeed for the same $V^2d$, responses can differ according to charge diameters. In addition, alternative $V^2d$ values are discussed taking into account the USA standard (141 $mm^3/\mu s^2$). IMEMG Experts propose the value: 60 to 70 $mm^3/\mu s^2$ because this corresponds to the first level of insensitiveness of explosives dedicated to small and medium munitions, and it can correspond to residual $V^2d$ after penetrating a steel plate. This paper could feed discussions for the 2014 MSIAC Workshop dedicated to SCJ STANAG.

# 1 INTRODUCTION

IMEMG is the European Organization assembling leading armament groups working with Insensitive Munitions (IM) technologies. It represents a total of 20 companies from France, United Kingdom, Germany, Italy, Norway and Sweden. It aims to express the viewpoint of the armament industry with regards to transnational regulations and requirements in the field of munitions safety. It is acting as a focal point of contact for members' domestic authorities, EDA (European Defence Agency) and MSIAC. In order to explore technical topics and background from IM signature determination, it has established several EWG (Expert Working Group) dedicated to various point-of-interests:

- Computer Models for IM Performance,
- Cost & Benefit Analysis,
- Fast Cook-off Test Procedure,
- Effects of Ageing,
- Hazard Assessment & Classification.

This paper is the result of feedback and analysis made by experts belonging to the Hazard Assessment & Classification EWG.

The promulgated STANAG 4526 (ed2): SHAPED CHARGE JET – MUNITIONS TEST PROCEDURE, cannot be used as a standardized reference for the following reasons:

- it is not ratified by all Nations;
- the 50 mm Rockeye Shaped Charge is not readily available and its performance is not correctly defined for determination of an equivalent Shaped Charge;
- test set-up is not clearly defined (conditioning plate, target nose, ...);
- each Test Center uses their own Shaped Charge and test procedure.

Recent feedback from Afghanistan and Iraq has led to a Threat Hazard Analysis review. Many National Authorities are choosing / designing specific Standard Shaped Charges which would be representative of numerous RPG7 types:

- France has chosen CCEB 62 Shaped Charge already used for IM design studies,
- Germany has developed a PG-7 replica,
- US MIL-STD-2105(D) specifies a standardized 81mm Shaped Charge.

This IMEMG presentation gives the industrial experts points-of-view to the IM community, IMEMG is concerned by the lack of consistency described above. NATO standards should be agreed and practicable by all member countries and should not rely on self-interpretation or Shaped Charges that are not available for all. IMEMG experts intend to support current standardization efforts and wish to stress the fact that a new STANAG 4526 edition should refer to a very limited number of approved Shaped Charge types and test set-up.

This new paper develops these issues and proposed some best practices for velocity and diameter determination, some comments about charge diameter on munitions responses. Indeed for the same $V^2d$, responses can differ according to charge diameters. In addition, alternative $V^2d$ values are discussed taking into account the USA standard (141 $mm^3/\mu s^2$). IMEMG Experts propose the value: 60 to 70 mm3/µs2 because this corresponds to the first level of insensitiveness of explosives dedicated to small and medium munitions, and it can correspond to residual $V^2d$ after penetrating a steel plate. This paper could feed discussions for the 2014 MSIAC Workshop dedicated to SCJ STANAG.

# 2 CURRENT SITUATION

## *2.1 REFERENCE DOCUMENTS*

STANAG 4439 edition 3 specifies as a threat: Shaped Charge Weapon Attack, with a maximum response, Type III, according to Munition Test Procedure, the STANAG 4526.

AOP 39 edition 3 dictates that:

- the Baseline Threat Range considers shaped charge caliber up to 85 mm diameter,
- for the purpose of IM, shaped charge would be "broadly representative of Rocket Propelled Grenades and top attack bomblets",
- Shaped Charge has to be the 50mm Rockeye or equivalent $V^2d$ charge.

Nevertheless, the use of conditioning plate is not really defined; it can be used to adjust the $V^2d$ value to be compliant with 50mm Rockeye.

## *2.2 STANAG 4526: SHAPED CHARGE JET – MUNITION TEST PROCEDURES*

The STANAG 4526 (ed2) SHAPED CHARGE JET – MUNITIONS TEST PROCEDURE is the current full scale test procedure to characterize munitions responses to shaped charge jet impact, more precisely, according to the standard test procedure; it is designed "for determining the level of reaction of a munition when hit by a typical top attack bomblet shaped charge jet". This STANAG has been promulgated on 10 December 2004; nevertheless it isn't ratified by all NATO nations. It indicates some inconsistent values about Rockeye 50mm; this has been confirmed during an MSIAC workshop (IM Technology Gaps - June 2011).It is presented in Ernest L. Baker's paper "*Rocket Propelled Grenade Shaped Charge Initiation Test Configuration for IM Threat Testing".* Moreover, 50mm Rockeye is not available in many countries, so, it is not used in IMEMG's Nations. Additionally this former charge has poor performances (not straight shaped charge jets) and a rather big scatter in the performance with the consequences of a presumably bad repeatability.

The $V^2d$ value is the current link between different shaped charges. One is allowed to use various shaped charges as long as they have the same $V^2d$ value. But these values noted in Table 1 of STANAG 4526 (see following) are much too high by at least a factor of two.

**Table 1: Standardized $V^2d$ values for a copper jet**

| Threat | Representative $V^2D$ ($mm^3/\mu s^2$) |
|---|---|
| Top Attack Bomblet | 200 |
| SCJ with characteristics of 50mm Rockeye | 360 |
| Rocket Propelled Grenade | 430 |
| Anti-Tank Guided Missile | 800 |

For example, the RPG-7 performances: typical measured values for the jet tip are: V ~ 7.5 mm/µs and d ~ 3 mm which give a $V^2d$ value of ~ 170 $mm^3/\mu s^2$ instead of 430 $mm^3/\mu s^2$ as noted in the STANAG 4526 Table 1, i.e. a factor of 430/170 = 2.5 too large.

That means – because $V^2d$ is the link between different shaped charges - it is very important to define exactly how V and d should be measured. Both numbers V and d are not constant but vary over the SCJ length. Also the scattering within the measurements should be taken into account. That has to be considered for a new STANAG 4526 edition.

In addition, it is indicated that conditioning plate can be used to adjust the $V^2d$ value. Nevertheless, these plates can have two opposite effects: plate debris propelled into tested item generating an additional stimulus, slug of the jet core can be stopped limiting stimulus diameter.

### *2.3 EXAMPLES OF DIFFERENT USES IN IMEMG NATIONS*

Many tests have been conducted in Europe using very large number of different charges from 20 mm sub-munition to 120 mm anti-tank.

Sometimes, tests have been done with a specified shaped charge; more often the main reason for the use of a particular shaped charge was that the charge was available at the date of the test and "compatible" with specifications; Or also, a shaped charge allowing to pass the requirement even if the THA (Threat Hazard Analysis) is not really establish to define this shaped charge.

So, test conditions differ between from test centers to another; no precise rule is defined about the use of conditioning plate, it is often a customer requirement; the distance between charge and specimen is generally the usual stand-off, but it is not sure; it is same for the use (or not) of in-service target nose.

### *2.4 COMPARISON OF IM SIGNATURES*

As is summarized above, lack of precise stimulus and test conditions means that Shaped Charge Jet Impact Tests are performed according to numerous different procedures, the main parameters are listed below:

- Shaped Charges:
  - Diameters can be from 45 mm to 120 mm,
  - In-service charge: with or without target nose,
  - High performance (tapered & fast) jet / un-optimized and cheap charge,
  - Cone material density,
- Conditioning plate use,
- Stand-off value,
- Break-up time,
- Penetration capability

Due to these variations, it is difficult to compare IM Signatures when these are only listed in a table with the AOP39 color-coded boxes; which is the current situation.

## 3 COMMENTS ON CURRENT CHANGES

### *3.1 CURRENT TRENDS IN THREAT DEFINITION*

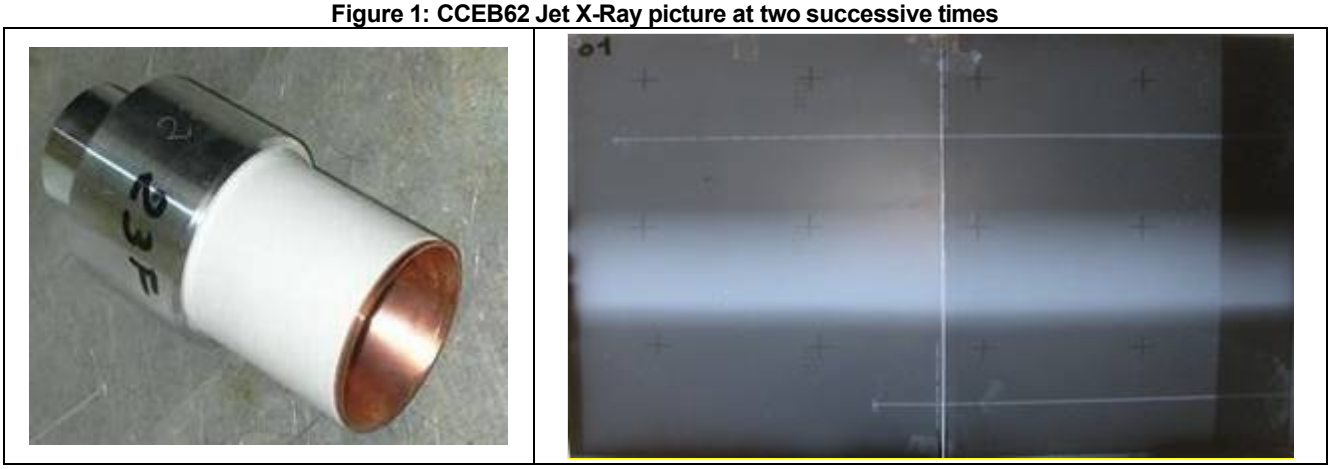
Recent feedback from Afghanistan and Iraq has led to a Threat Hazard Analysis review; RPG-7 is now recognized as the sole / the main shaped charge threat. Due to lack of RPG-7 reliability across various manufacturers, it is necessary to develop a RPG-7 surrogate. Thus, many nations are designing their own RPG-7 surrogate and/or Standardised Shaped Charge, for example:

- France : CCEB 62;
- Germany : 75 mm Shaped Charge "PG-7 German replica";
- USA: LX-14 81mm Shaped Charge (MIL-STD-2105(D) requirement).

### 3.1.1 FRANCE

CCEB 62 is now the French Standardized Shaped Charge for Insensitive Munition Signature assessment in agreement with MoD Instruction N°211893/DEF/DGA/INSP/IPE on 21 July 2011. It is designed to be used to implement STANAG 4526. It is defined in the French Standard Test Procedure: NF T70-511. Its performances characteristics (i.e. $V^2d$) are available (nevertheless new confirmation performance tests are in progress). Good jet quality can be noticed (straightness diameter), picture (figure 4) shows CCEB62 free jet at two successive times.

**Figure 1: CCEB62 Jet X-Ray picture at two successive times**



CCEB 62 (Assessment Shaped Charge) is not equipped with a target nose; conditioning mild steel plates can be used according to THA or for Critical Thickness determination (detonation/no detonation) in relation with V2d.

**Table2: CCEB62 $V^2d$ according to conditioning plate thickness**

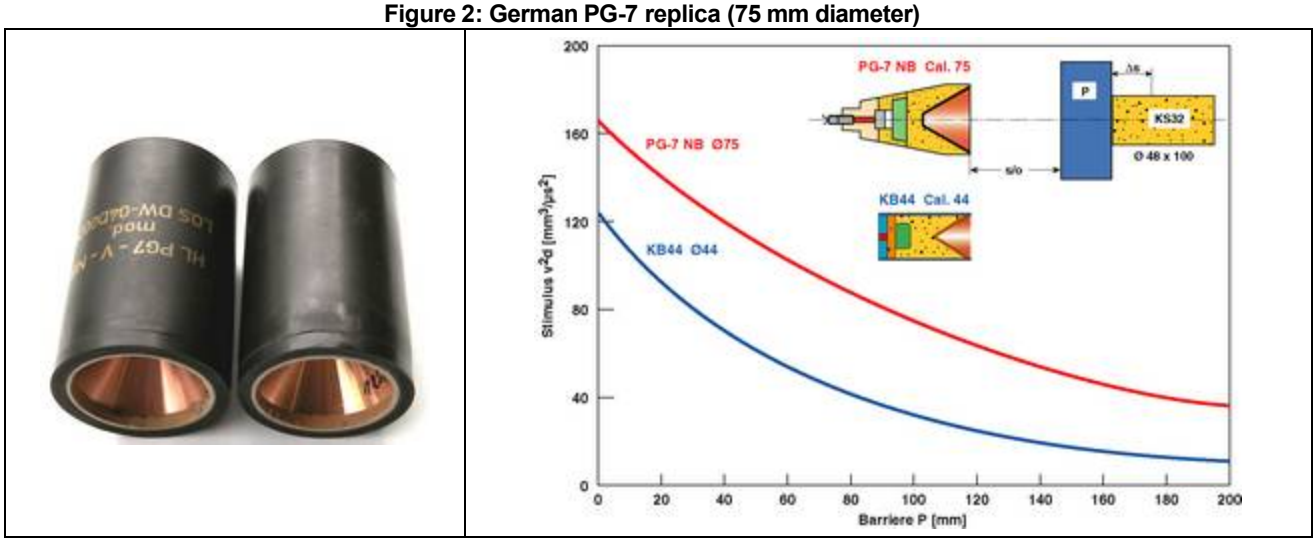
| $V^2d$ ($mm^3/\mu s^2$) | 203 | 103 | 93 | 82.5 | 72 | 62 | 41.5 | 52 | 31 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| Steel Plate thickness (mm) | 0 | 20 | 25 | 40 | 60 | 80 | 110 | 150 | 200 | 280 |

***Confirmation tests are in progress***

### 3.1.2 GERMANY

The Test Procedure in Germany has not yet been defined; it will use a PG 7 surrogate designed by Dynamit Nobel (DND) for the MoD. The test setup will be defined according to the STANAG with a $V^2d$ stimulus according to a THA.

**Figure 2: German PG-7 replica (75 mm diameter)**




### 3.1.3 USA

USA MIL-STD-2105(D) defines LX-14 81mm Shaped Charge (BRL 3.2) as the Standardised Charge for vulnerability assessment. Charge design and performances are available (E. L. Baker's Paper)., Tests seem to always be carried out with a 4" aluminum conditioning block. In that situation, the resultant $V^2d$ is 141 $mm^3/\mu s^2$. Nevertheless, the LX14 explosive charge characteristics are not precisely defined; thus, there is no real guarantee that various LX14 charges manufactured by different producers will have the same performance, thus they should be checked.

## 4 IMEMG's CONCERNS & COMMENTS

### *4.1 HARMONISATION NEEDS*

IMEMG is concerned by the lack of consistency in various test procedures since it leads to increased costs when tests have to be duplicated in the different NATO nations. There are distortions in performance when two comparable munitions can have different IM Signatures due to different test procedures. Finally, it clouds the users' ideas about the real threat that a munition has passed.

Today, it is difficult to compare munitions responses to Shaped Charge Jet attack; NATO standards should be agreed and practicable by all member countries and should not rely on self-interpretation or Shaped Charges not available to all member nations,

IMEMG experts intend to support current standardization efforts and wish to highlight the fact that the next STANAG 4526 edition should list a very limited number of approved Shaped Charge types and test set-ups. In any case, each Shaped Charge referred to must have an available and comprehensive technical data pack available for other nations.

### *4.2 STANDARDISED SHAPED CHARGES*

Standardized shaped charges have been designed to create an accurate RPG-7 surrogate. USA MIL-STD-2105(D) has been firstly designed. It establishes a $V^2d$ reference value equal to 141 $mm^3/\mu s^2$.

Nexter's CCEB62 shaped charge has been selected to be the French standard. Its $V^2d$ can be adjusted to the same value: 141 $mm^3/\mu s^2$ through the use of a conditioning plate.

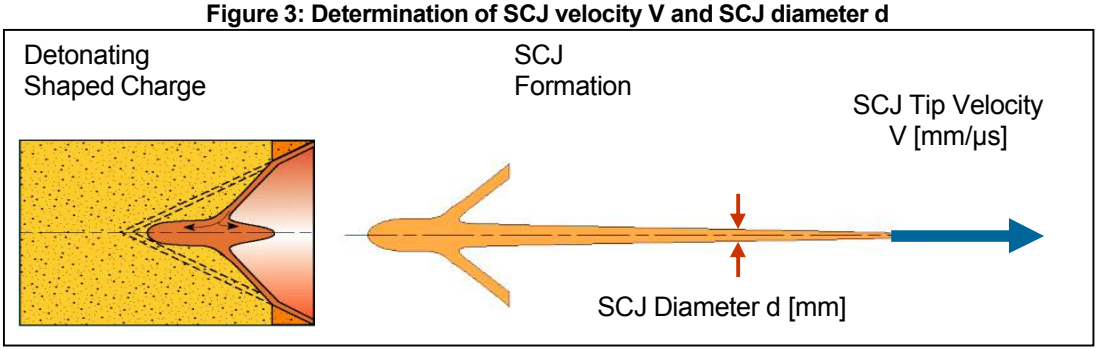
Dynamit Nobel's PG7 surrogate has been chosen to be the German Standard. The $V^2d$ can also be adjusted to the same value: 141 $mm^3/\mu s^2$ through use of a conditioning plate.

Thus, it seems that shaped charge jet harmonization has started, even if charges themselves are different for each nation. Nevertheless, $V^2d$ tolerance has to be specified and charge diameter would be reasonably closed. This is detailed following.

### *4.3 SHAPED CHARGE PERFORMANCE CHARACTERIZATION*

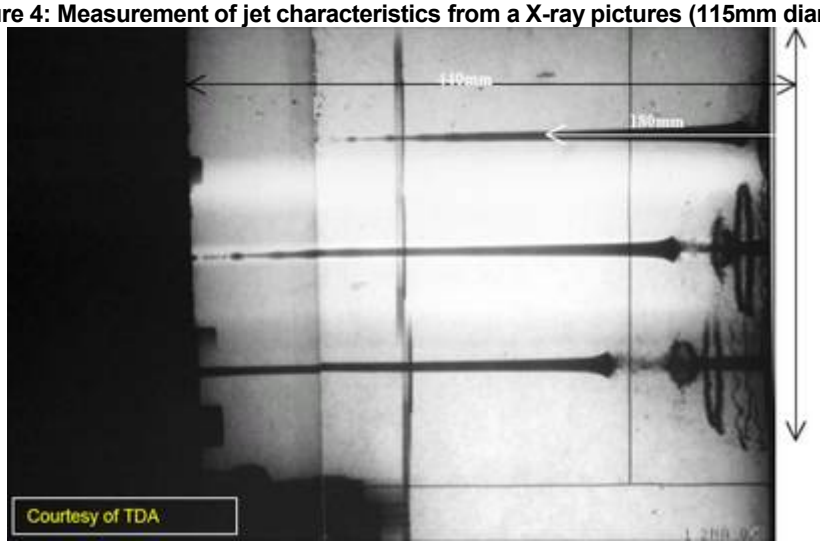
Shaped charge jet characterization is not a simple process. It is illustrated with the incorrect values indicated in STANAG 4526 about the 50 mm Rockeye. This section illustrates the main facts. It is important that the next STANAG 4526 edition should list minimum requirements for shaped charge performance determination.

**Figure 3: Determination of SCJ velocity V and SCJ diameter d**



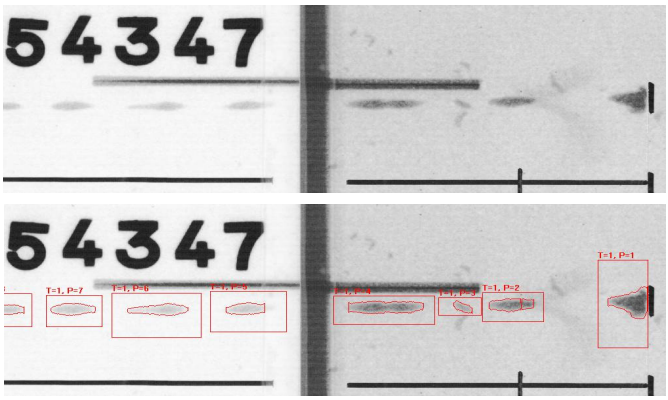

Measuring the $V^2d$ is not easy or trivial. It is done through X-ray pictures (e.g. Figures 3 & 4). Which is diameter value to be considerer; is it the tip diameter? Is it the average diameter between fixed positions? What is the velocity? At which stand-off?

**Figure 4: Figure 4: Measurement of jet characteristics from a X-ray pictures (115mm diameter charge)**



On picture 5, a grey scale value has to be defined to determine where the Shaped Charge jet diameter “ends”. Experiments with different grey scales gave different diameters by almost a factor of two. Also the measuring of the jet velocity behind a steel barrier P is not trivial and can be a source of additional scattering - exacerbated by the squaring of the velocity.

**Figure 5: Measurement of SCJ particles from a X-ray pictures or a rotating mirror camera (MBDA TDW)**

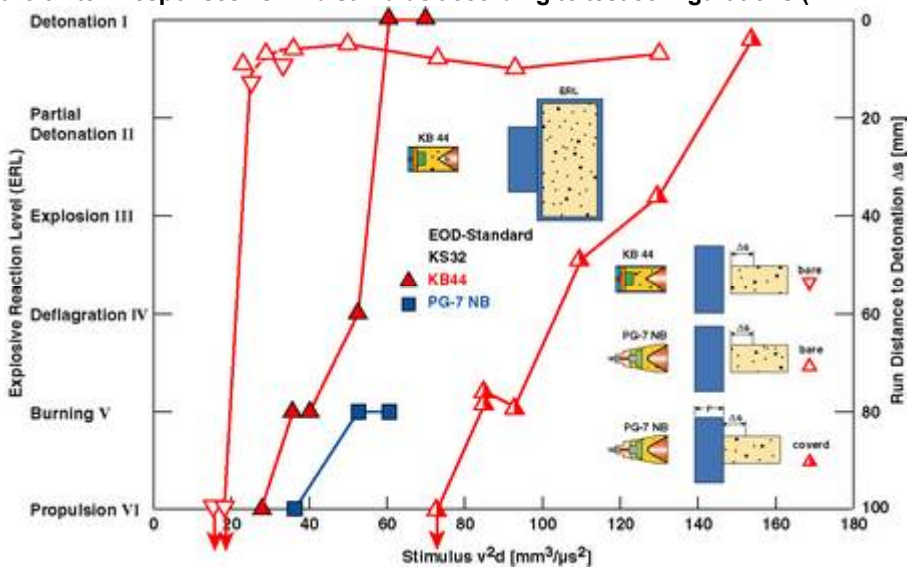



Additionally, the $V^2d$ level tolerance would be specified with reasonable narrow gap. For 141 $mm^3/\mu s^2$ value, this tolerance could be +/- 10 % or +/- 14 $mm^3/\mu s^2$. For each standardized Shaped Charge type, the conditioning plate must be precisely defined, of course the thickness, but also the precise reference of steel or aluminum.

### *4.4 STANDARDISED TEST PROCEDURES*

Test set-up can have a real influence on tested munition response. This is illustrated through the MBDA TDW study summarized below. A generic (or standard) cased (10 mm thick steel) explosive charge filled with PBX was initiated with two different shaped charges jets: KB44 (caliber 44 mm) and PG-7 Replica (caliber 75 mm). The charges responses from Type VI to Type I were evaluated. Results are summarized in figure 8.

**Figure 6: Item responses vs. V2d stimulus according to test configurations (MBDA TDW)**



The filled symbols indicate the tests with the cased generic charge. At a same stimulus of $V^2d$ around 55 / 60 $mm^3/\mu s^2$ (see figure 8):

- a low order “burning” reaction (Explosive Reaction Level = V) is observed if the shoot is done with PG-7 (blue squares),
- But a full detonation (ERL = I) is observed if the KB44 (red triangles) is used.

That could mean not only $V^2d$ is important for the reaction level but also V and d themselves. Conclusion: future standard STANAG Shaped Charge should not vary too much in caliber. That is another reason why it is necessary to standardize the STANAG shaped charge and also the test set-up in the next STANAG 4526 edition

### *4.5 ALTERNATE $V^2D$ VALUE*

Moreover, a V2d stimulus of ~ 141 $mm^3/\mu s^2$ would be much too high (see figure 6); at that stimulus most charges (including small critical diameter insensitive PBX) would detonate; only few EIS (Extremely Insensitive Substance in accordance with UN HD 1.6) would survive. STANAG should define different stimuli according to Life Cycle and Threat Hazard Assessment (comparable to the Fragment impact test STANAG with a defined STANAG projectile and velocities of ~ 1850 m/s or ~ 2500 m/s).

If standard procedure is defined with the stimulus: $V^2d$ is ~ 141 $mm^3/\mu s^2$, then alternative procedure could consider stimulus around 60 / 70 $mm^3/\mu s^2$. This point would be topic to be discussed for next edition of STANAG 4526.

## 5 CONCLUSIONS

This IMEMG's presentation offers the European industrial experts point-of-view to the IM community. IMEMG is concerned by the lack of consistency in specified threat and test procedure. NATO standards should be agreed and practicable by all member countries and should not rely on self-interpretation or Shaped Charges not available to all nations.

Recent feedback from Afghanistan and Iraq has led to a Threat Hazard Analysis review. Many National Authorities are choosing / designing specific Standard Shaped Charges which would be representative of numerous RPG7 types:

- USA MIL-STD-2105(D) specifies a standardized 81mm Shaped Charge.
- France has selected CCEB 62 Shaped Charge already used for IM design studies,
- Germany is developing a PG-7 replica;

IMEMG intends to support current harmonization efforts and wish to highlight the fact that STANAG 4526 should list a very limited number of approved Shaped Charge types and test set-ups:

- Shaped charges diameter would be sufficiently closed generating comparable threats, their performances would be precisely defined,
- Conditioning plate thickness and precise quality must be defined,
- Standardized stimulus: $V^2d$ could be ~ 140 $mm^3/\mu s^2$ , its tolerance would be +/- 10 % or +/- 14 $mm^3/\mu s^2$.
- An optional standardized $V^2d$ would be defined taking into account THA results and existing IM technology, it could be around 60 / 70 $mm^3/\mu s^2$.

In any case, each Shaped Charge referred to must have an available and comprehensive technical data pack including test set-up available for each NATO nation.