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STANAG 4439 MANDATORY REACTIONS & AOP39 RESPONSE DESCRIPTORS: FEED-BACK AND CONSIDERATIONS FROM IM INDUSTRY

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ABSTRACT

IMEMG is the European Organization assembling leading armament companies working with Insensitive Munitions. It aims to express the viewpoint of the armament industry with regards to relevant transnational regulations and requirements. This paper is the result of the work carried out by the Hazard Assessment & Classification Expert Working Group regarding the STANAG 4439 ed3 mandatory reactions and AOP 39 ed3 Response Descriptors. It collects the experts feed-back and considerations of the 20 companies belonging to IMEMG. It points out some difficulties to reach full IM Signature with the maximum allowed reactions according to stimuli and response descriptors criteria according to munitions characteristics. For example: Type V is required to fragment impact test (18.6g @ 2530 m/s), that seems too severe taking into account credible threats; Indeed the IED, EFP or specific warheads being able to generate such a stimulus, generate also dangerous effects up to 50 m, or more, whereas no hazardous effect is admitted farther than 15 meters for the Type V response. For fragment impact threat, response type should be type III or IV with the current descriptors. More generally, response descriptors for type V reaction appear as too strict for fragments, especially about 20 Joules criteria, previously (AOP39 ed2), it was 79 Joules; this value is universally used for injuries-to-people, i.e. to define IBD according to AASTP-1 & 4; why shall this same energy still not be used to define Type V reactions? General analysis of response descriptors has been done by IMEMG's experts in conjunction with the Survey on Insensitive Munitions Response Descriptors done by the MSIAC. This paper sets-up the review of current response descriptors with the IM industry experiences. It is designed to feed reflections of AC326 SGB experts.

1 INTRODUCTION

IMEMG is the European Organization assembling leading armament companies working with Insensitive Munitions. It represents a total of 20 companies from France, United Kingdom, Germany, Italy, Norway, and Sweden. It has been established for 9 years and can be traced back to the foundation of "Club MURAT" in 1991. 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' National Authorities, MSIAC and EDA. It has established several Expert Working Groups (EWG) in order to explore technical topics. This paper is a result analysis work prepared by the Hazard Assessment & Classification EWG.

This work has been initiated by two events: the first was the Questionnaire for Survey on Insensitive Munitions Response Descriptors distributed by the MSIAC, this has been the opportunity to set-up current feed-back coming from the 20 IMEMG companies about the AOP 39 ed3 implementation by test centers and national authorities; the second was a question coming from audience during the last MSIAC Activities Presentation Meeting in Paris, a French Army Officer has said *"IM are more expensive, less efficient and in addition there is no-logistic gain"*, for IMEMG members it is difficult to hear that in 2013.

Thus, we have thought on this problem that we have had already identified. It is very difficult to pass the complete STANAG 4439 requirements due to current available techniques and because Energetic Materials are naturally energetic. Numerous munitions are partially compliant to STANAG 4439 and they fulfill the development program requirements which take into account the Threat Hazard Assessment according to the life cycle, but they are not real IM, and it is very difficult to gain any IMness benefits during transport and storage phases.

We have examined the Response Descriptors in conjunction with the mandatory reactions according to the various vulnerability tests. It appears that several questions are about the Type V Descriptors. For example, the fragment impact delivers 60,000 Joules kinetic energy, while it is forbidden, for the tested munition, to have only one 20 Joules projection at 15 meters; is it really pertinent? Moreover, it seems that Type V Response Descriptors are essentially designed for person safety and not for platform survivability concerns, which is solid advantage for IM.

Moreover some requirements could be discussed. For example, about the slow heating threat, if an accidental scenario is able to heat munitions for many hours, the resulting temperature reaching 150 to 200°C, this scenario requires a confined space; is it really necessary to respect strictly type V requirements on the propulsion effect or the 20J at 15 m projection inside this confined space, what are the external effects? It is reminded that the 20J fragment isn't able to go through a 2 mm thick aluminum sheet (UN Orange Book ST-SG-AC10-11 Rev5).

So, beyond concerns only the person safety, a Quantitative Risk Assessment (QRA) including platforms survivability, the demonstration of IM advantages should be easier and more effective. Perhaps, it is possible to examine if mandatory responses would be different for open battlefield munitions and embedded munitions on platform (tank, ship, and aircraft). Additionally munition size should be considered, Type V response of large munitions (delivered combustion energy of few hundred kilograms) can be more severe for platform than, for example, Type I to III reaction of hand grenade inside ship magazine. Do Response Descriptors have to be identical for all munitions sizes?

2 FEW REMARKS ABOUT STANAG 4439 ed3

STANAG 4439 ed3 states that ratifying nations agree to *"develop and/or introduce into service munitions that are as insensitive as reasonably practicable"*, and it is written that *"to be considered insensitive, a munition in a particular configuration shall meet the requirements of Table 1"* or *" a munition is considered IM compliant for a given life cycle if, for each considered threat, it meets the requirements expressed in Table 1 for any relevant configuration(s)"*.

Table 1

Threat	Requirement
Magazine/store fire or aircraft/vehicle fuel fire	No response more severe than Type V (Burning)
Fire in an adjacent magazine, store or vehicle	No response more severe than Type V (Burning)
Small arms attack	No response more severe than Type V (Burning)
Fragmenting munitions attack	No response more severe than Type V (Burning)
Shaped charge weapon attack	No response more severe than Type III (Explosion)
Most severe reaction of same munition in magazine, store, aircraft or vehicle	No propagation of reaction more severe than Type III (Explosion)

Practically, a given munition is Insensitive or it is not, even if it is "as insensitive as reasonably practicable", and this for all threats independently of its life cycle. Thus, if a munition meets 80% of IM requirements, it is not an IM and it is not possible to gain any advantage as promised in STANAG *"In addition, IM provide for more cost effective and efficient transport, storage and handling of munitions. These benefits could be realized through assignment of a more favorable hazard classification".* It is true that some dedicated regulations exist: the NATO Sub-Storage Division 1.2.3 or the French 1.2 Unitary Risk Division, but these divisions often bring only some virtual gains and beside, the UN 1.6 Hazard Division is an unreachable objective unless for few exceptions (Has one been already awarded ?). That means it would be fruitful for the various stakeholders concerned by IM that pragmatic Requirements and Response Descriptors allow declaring as IM some practicably insensitive munitions close to the ideal requirements.

According to the STANAG 4439 definitions, we can read: *"Insensitive Munitions (IM) / MUnitions à Risques ATténués (MURAT). Munitions which reliably fulfill their performance, readiness and operational requirements on demand and which minimize the probability of inadvertent initiation and severity of subsequent collateral damage to weapon platforms, logistic systems and personnel when subjected to selected accidental combat threats"* and also *"Introduction of IM/MURAT into service enhances the survivability of logistical and tactical combat systems, platforms and stockpiles, and minimizes the risk of injury to personnel. It accomplishes this significantly reducing the potential for the inadvertent reaction of a munition to occur; the scope and/or violence of a reaction, if it were to occur; and the consequences from such a reaction"*.

These points drive us to think, that some requirements and response descriptors could be adjusted to be more pragmatic:

- For example about the Slow Heating corresponding to *"Fire in an adjacent magazine, store or vehicle"*, if an accidental scenario is able to heat munitions many hours, higher than 150 to 200°C (or 300 to 400°F), this scenario requires a confined space, is it really necessary to respect the Type V requirements inside this confined space. It is reminded that the 20J fragment isn't able to go through only 2 mm thick aluminum sheet. While typical walls of warships ammunition stores are some 8 mm thick steel sheets. Type IV is a sufficient requirement for such threat.

- If a weapons platform is attacked by an IED (Improvised Explosive Device) or by one specific missile able to propel 18.6g fragment @ 2530 m/s (8300 ft/s), blast and fragments can provoke severe damages and injuries to persons up to 50 meters, is it really necessary to require Type V response and no-injuries farther than 15 meters? It is unimportant that the acceptor munitions response shall be either Type V or IV or III. Apart for some simple types of ammunitions, this response will be very hard to reach for most Insensitive Munitions. This event scenario can be compared with sympathetic detonation, but for this trial the mandatory response is only Type III.

FIGURE 1: IEDs

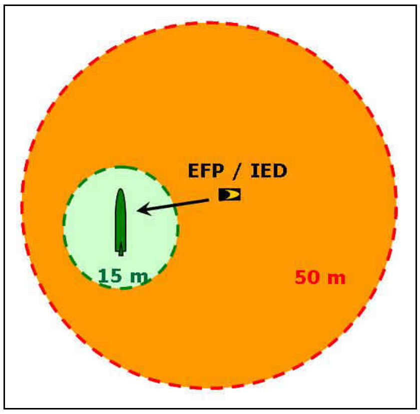

FIGURE 2:
Example to illustrate excessive severity of criteria:
➔ Primary Fragments Injuries Distance for 1kg Explosive Charge with 2mm thick case: 50m (orange zone)
➔ In comparison with :Maximum Projections Distance to pass Type V Response: 15 m (green zone)

3 FEW GENERAL COMMENTS ABOUT RESPONSE DESCRIPTORS

AOP 39 ed1 was issued in 1998 following the 1997 NIMIC IM Testing Workshop. Response Descriptors have been improved through the second and the third editions, especially about quantitative criteria, removing values of blast overpressure and radiative heat fluxes. Indeed, it has been considered that measurements and data interpretations are too dependant from test set-up and munition architecture.

IMEMG experts have identified some difficulties for Response Descriptor implementation and they have proposed some potential improvements. The main concerns are about 20 Joules Projection criteria and the propulsion effects assessment for the Type V response. These topics are analyzed in following paragraphs.

Other difficulties are listed below:

- Casing rupture criteria are defined for steel casings and not at all for composite envelopes or even for forged aluminum casings. For example, the sole forged aluminum fracture due to an impact can correspond to type III or IV response descriptor even if the energetic material doesn't react. It highlights the fact that it is desirable, but expensive, to perform preliminary tests on inert items, nevertheless that aggression effects on the sole munition casing might be determined.

- The multi-components munitions responses are not really considered; sub-systems can deliver Type V effects if tested alone (smooth release of combustion gases) but munition structure pressurization can propel pieces farther than 15 meters (Type IV response) due to its sole pneumatic burst. This is practically ignored for Insensitive Munitions assessments because sub-systems are tested separately. As a consequence, the resulting safety assessment report might not take into account such phenomena.

- Munitions can be tested in packaged or unpackaged configurations. On the one hand, if the package is strong, the aggression may be mitigated but on the over hand, if the munition burns (Type V response), it can pressurize the package until it bursts into fragments. These fragments are likely to be projected at distances exceeding 15 meters. In this particular case, how do we have to consider these projections, as the munition response or not?

- As already said in introduction, munition size should be considered, Type V response of large munitions (delivered combustion energy of few hundred kilograms) can be more severe for the platform than, for example, Type I to III reaction of a hand grenade located inside the ship magazine. Do Response Descriptors have to be identical for all munitions sizes?

- Solid propellant motors contain energetic materials designed to burn and generate huge amount of gases. As a consequence, the best response is Type IV for numerous current rocket motors. But, despite Type V objective, it corresponds to the *"as insensitive as reasonably practicable"* technology, so that it might be virtually impossible to design Insensitive Solid Propellant Motors fulfilling to STANAG 4439 Requirements. This gives rise to resignation of designers' mind, why doing efforts if the result is known in advance, i.e. failure to IM requirements? It is a topic for discussions.

4 THE "20 JOULES" PROJECTION CRITERIA

In previous AOP 39 ed1 or ed2, for Type V response, projection limit was 79 Joules (or 150 gram beyond 15 meters). The 79J energy projection criteria is consistent with AASTP-1, this value is universally used to define Inhabited Building Distance (IBD) which corresponds to a probability below 1% of being hit by such a hazardous fragment (it corresponds to one dangerous projection for 56 m^2).

The 20 Joules Projection Criteria for Type V Response, coming from UN Orange Book 6c Test, triggers several concerns:

- The 20J kinetic energy in the initial energy and not the energy at impact on potential victims. This is illustrated in the table below, showing that this criterion is stricter than usually admitted, if we consider the impact energy.

Table 2

UN 6c test / AOP39 ed3		**IMEMG Calculation**		
Mass	**20J Projection Distance**	**20J Initial Velocity**	**Projection Distance**	**Impact Energy**
(g)	**(m)**	**(m/s)**	**(m)**	**(J)**
25	**83.6**	**40.0**	**85**	**7**
50	**58.4**	**28.3**	**58**	**11**
75	**44.4**	**23.0**	**44**	**13.5**
100	**35.6**	**20.0**	**35**	**15**
125	**29.8**	**17.9**	**29**	**16**
150	**25.6**	**16.3**	**25**	**17**
175	**22.43**	**15.1**	**22**	**17**
200	**20**	**14.1**	**19**	**17,5**
277 (*)	***15***	***12.0***	***14***	***18***
300	**13.9**	**11.5**	**13**	**18.5**
400	**10.9**	**10.0**	**10**	**19**
500	**8.9**	**8.9**	**8**	**19**

(*) Calculated value for projection at 15 meters.

- On the opposite, for example, 100g pieces can respect the AOP39 maximum distances (35 m) with an impact energy reaching 100J, it is due to a bell trajectory effect after a quasi-vertical launching and falling, in that case, and it is not a 20J initial energy projection. At the end, this introduces uncertainties between trials, due to projection distance criteria; a munition response can be declared Type IV or V without taking into account the real physical effects.

- The 20J kinetic energy seems to be considered as the safety limit for projections, but this value is the energy at impact on potential victims. It is considered, for example, in the SAFER software as indicated in AASTP-4 ed1 November 2008 (II-150 fig 63) while in the ASSTP-1 ed1 change 3 April 2010, it is still the table [5-15] which is referred as presented below. The 20J criteria in not considered as a critical kinetic energy.

Table 3

LETHALITY DUE TO IMPACT ENERGY				
LETHALITY (p in %)	IMPACT ENERGY / KINETIC ENERGY (Joule)			
	HEAD	CHEST	ABDOMEN	LIMBS
1	55	58	105	155
5	65	90	140	240
20	79	140	200	380
50	100	230	280	620
99	200	850	850	2500

- Moreover, the Inhabited Building Distances (IBD) defines safety distance according to projection density: no more than one 79J projection for 56 m^2, as indicated in AASTP-1 ed1 change 3 April 2010. Thus, if it is admitted to expose civilians to some 79J projections, is the 20J criterion still pertinent for the Response Descriptors?

- In leisure world, Paintball or Airsoft gamers are playing with gas guns able to propel 0.68" projectiles with 10, 20, 30 or even 40 Joules launching energies. Of course, players wear face protections, but injuries aren't frequent. This allows comparison in terms of projection energy especially for non metallic fragments.

FIGURE 3: Paintball and Airsoft players

- Illustrating difficulties to mitigate responses about projections, IMEMG paper has been presented during 2010 IMEMTS event, it reports that 3 liters of water in 220 liters barrels submitted to UN fast heating has to be assigned to a Type IV response given that the cover plate (2.5 kg) has been propelled too far (22 meters).

FIGURE 4: UN 6c test
3 liters of water in 220 liters barrels

So, in order to launch the debate, it is proposed to make the Type V projection criterion evolve to the following statement:

*"Only few projections farther than 15 m
with a moderate mass are accepted for the Type V Response*."

Indeed, for example, it seems as tolerable to observe 12 projections (around 100 g) at 40 meters or 8 projections (around 300 g) at 20 meters or only 1 projection (about 3kg) at 25 meters. It is consistent with other qualitative criteria and National Authorities to take into account consideration both the influence of the munition architecture on the response and the type of material which is propelled (steel, aluminum, composite, plastic …).

5 PROPULSION EFFECT ASSESSMENT

The propulsion effect assessment is a usual topic of discussions with test centers, these discussions being sometimes quite difficult. Indeed, both in the table and text, the propulsion effect is not enough well defined. Furthermore, there is often a lack of instrumentation (thrust transducer). Some Test centers state a "propulsion effect" as soon as a flame (not a plume) is observed through the nozzle, even if this flame is not able to shift the motor.

Propulsion definition is not sufficiently defined, It is not consistent to define that propulsion is *"Type V: There is no evidence of thrust capable of propelling the munition beyond 15m"* and in the table *"for rocket motor a significantly longer reaction time than if initiated in its design mode"*. So, information for platform survivability assessment is missing, it is different if propulsion effect is a 20 meters shifting or 2 kilometers flight (in comparison with a 40 kilometers range motors).

It is necessary to clarify which is the feared event about propulsion effects: traumatic effects against personnel, for platform survivability concerns, or fire propagation:

- Concerning people's safety, munition shifting is tolerable beyond 15 meters because the likelihood to be injured is quite similar at 10 meters or at 30 meters, the victim is hit by the projectile or not. This likelihood isn't a monotonous decreasing function with the distance contrary to the blast overpressure effect for example.

- Concerning the platform survivability, the question is about the mechanical and thermal damages generated by the munition shifting. Inside a warship magazine, or a storage igloo, the question is more about possible exit of the munition. Thus, the 15 meters shifting of unattached item is too strict. On an aircraft carrier deck, if we consider the Forrestal disaster example, it appears that the main factor of damages were kerosene leakages on the deck, rocket explosion being just a secondary factor.

- About fire propagation, this parameter is relevant in the case of an internal storage igloo, however if your munition has been attacked by 0.5" bullet or 18.6g fragment, you have already a big problem. Furthermore, ammunition boxes are generally closer than 15 meters, and the domino effect is independent of a potential shifting farther than 15 meters.

Moreover, when a cruise motor is tested separately, it is possible to observe propulsion effect which is insufficient to move the complete missile. It would be mandatory to check this point on the complete missile so as to justify IM requirements.

So, in the aim to launch debate, it is proposed to change for the following statement:

"Munitions shifting should be limited to around 30 meters
to respect Type V response as for energetic material projections".

or

"Munitions response generating strong propulsion effect
with a potential flight farther than few hundred meters
would be identified to feed quantitative risk assessment
and/or be assigned to type III response

or

""Munitions response generating strong propulsion effect
with a potential flight farther than few hundred meters
would be identified to feed quantitative risk assessment
and/or be assigned to a new type VII or "V + Propulsion" response"

6 CONCLUSIONS AND PERSPECTIVES

IMEMG experts offer as a topic of discussion to AC326 SGB National Experts the following proposals:

- Move from Type V to Type IV, the maximum response allowed to slow heating *"Fire in an adjacent magazine, store or vehicle"*, because munitions effects are contained inside such a magazine, store or vehicle and because nobody can survive to the aggression itself.

- Move from Type V to Type III (or IV), the maximum response to fragment impact because hazardous effects of the threat itself largely overpass all tolerated effects of Type V response.

- Review projection criterion for the Type V response, it could be: *"Only few projections farther than 15m with moderate mass are admitted for the Type V Response ".*

- Review propulsion effect assessment for the Type V response, it could be: *"Munitions shifting would be limited to around 30 meters to respect Type V response as for energetic material projections. Munitions response generating strong propulsion effect with a potential flight farther than few hundred meters would be identified to feed quantitative risk assessment and/or be assigned to type III response and/or new type VII or "V & Propulsion" response.*

Of course, some others changes are desirable like precision about the packaging, multi-component munitions responses, etc. The MSIAC Survey on Insensitive Munitions Response Descriptors is also a source of improvements.

For industry IM development is a difficult challenge, munitions designed to be "*as insensitive as reasonably practicable",* have to be sold necessarily. So, buyers must gain benefits coming from reduction of logistical costs in addition to improvements in terms of platform survivability and people's safety. For that, it is necessary to have good clarity about IM or near-IM advantages.

In terms of Quantitative Risk Assessment, main threats are Fast Heating, Bullet Impact and Sympathetic Reaction. So the proposed evolution about the maximum response to Slow Heating and Fragment Impact seems quite reasonable. The proposed reviewing in Response Descriptors corresponds to the same objective, because the current response descriptors appear too strict about 20J projection and propulsion effect.