



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 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 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 any hazardous effect is admitted farer 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 AASTP1 & 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 groups working with Insensitive Munitions (IM) technologies. It represents a total of 20 companies from France, United Kingdom, Germany, Italy and Norway. 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 (EWGs) 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 have said *"IM are more expensive, less efficient and in addition there is no-logistic gain"*, for IMEMG members it is difficult to heard 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 of 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 several questions are about the Type V Descriptors. In 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. In example, about the slow heating threat, if an accidental scenario is able to heat munitions many hours, higher than 150 to 200°C, this scenario requires confined space; is it really necessary to respect strictly type V requirements on propulsion effect or about the 20J at 15 m projection inside this confined space, what are external effects ?

So, beyond concerns about the only 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 would be considered, Type V response of large munitions (delivered combustion energy of few hundred kilograms) can be more severe for platform than, in example, Type I to III reaction of hand grenade inside ship magazine. Do Response Descriptors have to be identical for whole 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 closed to the ideal requirements.

According to the STANAG 4439 definitions, we can read: "Insensitive Munitions (IM) / MUnitions à Risques ATtenués (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, some requirements and response descriptors could be adjusted to be more pragmatic:

- In 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. Is Type IV sufficient requirement for a such threat, isn't it?
- 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 farer than 15 meters, isn't it? It is unimportant that the acceptor munitions response be either Type V or IV or III. Apart for some simple types of ammunitions, this response will be very hard to attain for most Insensitive Munitions. This event scenario can be compared with sympathetic detonation, but for this trial the mandatory response is only Type III.

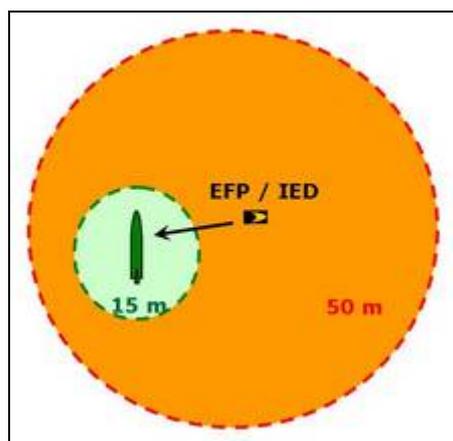


FIGURE 1:
Example to illustrate excessive severity of criteria
Primary Fragments Injuries Distance for 1kg
Explosive Charge with 2mm thick case: 50m
In comparison with :
Maximum Projections Distance to pass Type V
Response: 15 m

3 FEW GENERAL COMMENTS ABOUT RESPONSE DESCRIPTORS

AOP 39 ed1 has been 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 measurements and data interpretations are too dependant of test set-up and munition architecture.

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

Other difficulties are listed following:

- The casing rupture criteria are defined for steel case and not at all for composite envelope or even for forged aluminum case. In 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. That outcomes that it is desirable, but expensive, to perform tests on inert items in the aim to determine aggression effects on the sole munition casing.
- The multi-components munitions responses is 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 farer than 15 meters (Type IV response) due to the sole pneumatic burst of this structure. This is practically ignored for Insensitive Munitions award because sub-system are tested separately, of course, would can be considered through safety assessment report, it isn't sure.
- Munitions can be tested packaged or unpackaged: if the package is strong, the aggression may be mitigated but on an over hand, if munition burns (Type V response) and if it pressurizes the package generating package projections farer than 15 meters, how do we have to consider these projections, as munition response or not?
- As already said in introduction, munition size would be considered, Type V response of large munitions (delivered combustion energy of few hundred kilograms) can be more severe for platform than, in example, Type I to III reaction of hand grenade inside ship magazine. Do Response Descriptors have to be identical for whole munitions sizes?
- Solid propellant motors contain energetic materials designed to burn and generating large gases quantities, today for numerous motors, the best response is Type IV, despite Type V objective, it corresponds to the "*as insensitive as reasonably practicable*" technology, so it is practicably impossible to design Insensitive Solid Propellant Motors according to STANAG 4439 Requirements. This outcomes resignation of designer, why to do efforts if the result is known in advance, failed to IM requirements? It is a topic for discussions.

4 THE "20 JOULES" PROJECTION CRITERIA

In pervious AOP 39 ed 1 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 universality used to define Inhabited Building Distance (IBD) which corresponds to less than 1% likelihood to be hit by such hazardous fragment, it correspond to one dangerous projection for 56 m².

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

- The 20J kinetic energy in the starting energy and not the impact energy against potential victims. This in is illustrated in the table below, so this criteria is stricter than generally considered, 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.

- At the opposite, heavier pieces (100 to 200g) can respect the maximum distances (35 to 20m) with an impact energy reaching 100J due to a bell trajectory after a quasi-vertical starting. This introduces uncertainties between trials, due to projection distance criteria, a munition response can be declared Type IV or V independently of the real physical effects.
- The 20J kinetic energy seems to be considered as the safety limit for projections, but this value is the impact energy against potential victims. It is, in example, considered 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 is 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 m², 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 softball gamers are playing with gas guns able to propel 0.68" projectiles with 20, 30 or even 40 Joules starting energies, of course players wear face protections, but injuries aren't frequent. That allows comparison in terms of projection energy especially for non metallic scraps.
- Illustrating difficulties to mitigate responses about projections, IMEMG paper has been presented during 2010 IMEMTS, it reports that 3 liters water in 220 liters barrels submitted to UN fast heating has to be assign to type IV, because cover plate (2.5 kg) has been propelled too far (22 meters).

So, in the aim to start debate, it is proposed to move Type V projection criterion to:

*"Only few projections (around 10) farther than 15 m
with moderate mass (around 1000g)
are admitted for the Type V Response".*

Indeed, in example, it seems as tolerable to observe 12 projections (about 100 g) at 40 meters or 8 projections (about 300 g) at 20 meters or only 1 projection (about 3kg) at 25 meters. It is coherent with other qualitative criteria and National Authorities can take into account of munition architecture influence on the response and also can consider projection materials (steel, aluminum, composite, plastic ...).

5 PROPULSION EFFECT ASSESSMENT

The propulsion effect assessment is a usual topic of discussion with test centers, discussions are sometimes quite difficult. Indeed in the table and in the text the propulsion effect is not enough well define and because there is often a lack of instrumentation (thrust transducer). Some Test centers declare "propulsion effect" since a flame (not a plume) is observed through the nozzle, even if this flame is not able to shift the motor.

Propulsion definition 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 motors range).

It is necessary to clarify which is the feared propulsion effect: against person, for platform survivability, and for fire propagation/

- About person 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 meet munition or not. Likelihood isn't monotonous decreasing function with the distance contrary, in example, to the blast overpressure effect.
- About platform survivability, the question is about the mechanical and thermal damages generated the munition shifting. Inside battleship magazine, or storage igloo, the question is more about possible exit of the munition and the 15 meters shifting of unattached item is too strict. On aircraft

carrier deck, in example when we consider Forrestal disaster, it appears that the main factor of damages is kerosene leakage on the deck and rocket explosion is only secondary factor.

- About fire propagation, it is a parameter if it is inside storage igloo, but if your munition has been attacked by 0.5" bullet or 18.6g fragment, you have already a big problem, and your munition boxes are generally closer than 15 meters, and the domino effect is independent of a potential shifting farther than 15 meters. Moreover, for

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 about the complete missile to justify IM requirements.

So, in the aim to start debate, it is proposed to change:

*"Munitions shifting would be limited to around 30 meters
to respect Type V response like 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"*

6 CONCLUSIONS AND PERSPECTIVES

IMEMG experts offer as topic of discussion to AC326 SGB National Experts:

- Move from Type V to Type IV, the maximum response to slow heating *"Fire in an adjacent magazine, store or vehicle"*, because munitions effects are contained inside such 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 farer 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 like for energetic material projections. Munitions response generating strong propulsion effect with a potential flight farer than few hundred meters would be identified to feed quantitative risk assessment and/or be assigned to type III 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 the source of improvements.

For industry IM development is difficult challenge, because after their designing *"as insensitive as reasonably practicable"*, it is absolutely necessary to sold them. So, buyers must gain benefits coming from reduction of logistical costs additionally of increasing platform survivability and person safety. For that, it is necessary to have good clarity about IM or near-IM advantages.

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