2016 Insensitive Munitions and Energetic Materials Technology Symposium,
September12-15, 2016, Nashville, TN, USA.

INSENSITIVE MUNITIONS INDUSTRY CONTRIBUTION FOR STANAG AND AOP IMPROVEMENTS

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ABSTRACT

IMEMG is the European Organization that brings together the twenty-two leading armament manufacturing 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 summarizes the analysis of the AOP 39 ed3 Response Descriptors carried out by the Hazard Assessment & Classification Expert Working Group of IMEMG. It comprises an update of the paper given at the 2015 IMEMTS conference based on feedback from individual companies via a survey of AC326 Sub-Group B workshops and MSIAC documents. As an example, we have reviewed the MSIAC O-167 "Analysis of the IM Type V Response Descriptor" issued on 19 January 2016, which discusses potential changes to the current 20 Joules fragment energy threshold criteria of the current AOP39 ed3. The question is whether, or not, it is pertinent to change to the 79 Joules criterion, which is currently used in NATO safety rules and previously considered in AOP39 ed2, or it is preferable to maintain the 20 Joules threshold? IM requirements should take into account all life cycles phases and relevant hazard management. A meaningful illustration is given by considering the Slow Heating threat which requires a type V response. If we consider that the associated temperature ramp can only be achieved in an enclosed oven (the whole process taking many hours), is the current criteria that the energy of any fragments produced should not exceed 20 Joules at 15 meters range appropriate? Indeed, such propelled pieces cannot even penetrate 2 mm thick aluminum sheets, in which case, a type IV reaction requirement seems to be sufficient. In a similar perspective, it is our view that potential projections should not be taken into account for the Slow Heating threat, or, at least, Response Descriptors should be upgraded to take into account allowed projections. The same analysis can also be conducted for the Fragment Impact Threat. A warhead able to propel a 18.6 gram fragment at 2530 m/s simultaneously generates a potentially fatal blast at least up to 50 meters range. In such circumstances, it is hard to justify the 15 meters threshold for any fragment hazards in which case, a type IV reaction appears to be a much more pertinent requirement. This paper will present the European IM industry comments concerning current discussions for the future AOP 39 ed4, especially regarding Responses Descriptors; test STANAGs; associated AOPs; and potentially feed-back coming from the results / outcomes of the MSAIC Science of Cook-off Workshop.

1 INTRODUCTION

IMEMG is the European Organization assembling leading armament companies working with Insensitive Munitions. It represents a total of 22 companies from Austria, France, Germany, Italy, Norway, Spain, Sweden and United Kingdom. It has been established for 12 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 acts as a focal point of contact for members' National Authorities, the Munition Safety Information and Analysis Center (MSIAC) and the European Defense Agency (EDA). It has established several (currently five) 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 firstly by the Survey Questionnaire on Insensitive Munitions Response Descriptors distributed by the MSIAC. It has given the opportunity to elicit feed-back from IMEMG companies about current AOP 39 ed3 implementation by test centers and national authorities. This has been followed by the MSIAC O-153 "Survey on Insensitive Munitions Responses Descriptors", which raised many interesting points and more recently, the MSIAC O-167 "Analysis of the IM Type V Response Descriptor" issued on 19 January 2016, which discusses potential changes to the current 20 Joules fragment energy threshold criteria in AOP39 ed3.

We have examined the Response Descriptors in conjunction with the mandatory reactions according to the various vulnerability tests. It appears that several questions deal with the Type V Descriptors. For example, in the fragment impact test, the kinetic energy delivered by the fragment equals 60,000 Joules. However, at the same time, the tested munitions shall not eject splinters with an individual kinetic energy exceeding 20 Joules farther than 15 meters. Is such a criterion really relevant given the "aggression" context? A warhead able to propel an 18.6 gram fragment at 2530 m/s simultaneously generates a potentially fatal blast at least up to 50 meters range. In such circumstances, it is hard to justify the 15 meters threshold for any fragment hazards in which case, a type IV reaction appears to be a much more pertinent requirement.

Another example is the slow heating test which requires continuous heating of munitions for many hours in order to reach a "room" temperature exceeding 150°C. Such an event can only occur in a confined space. As currently written in AOP39ed3 it appears necessary to satisfy the propulsion effect or the projection criterion (20 Joules fragment at a distance exceeding 15 meters) inside this confined space to obtain a type V response. It should be noted that the 20Joules fragment is not able to go through a 2 mm thick aluminum sheet as indicated in the UN Orange Book (ST-SG-AC10-11 Rev6) and therefore this criterion appears flawed.

Beyond concerns about personnel safety, the advantages of IM should be easier and more effective demonstrated through the use of Quantitative Risk Assessment (QRA) including platforms survivability. It would be informative if reviews were conducted in order to determine if mandatory responses differed for open battlefield munitions compared to munitions embedded on a platform (tank, battleship, and aircraft). Additionally, ammunition sizes should be taken into account. Type V responses from large munitions (with a weight of active material exceeding a few hundred kilograms) can be much more severe for platforms than, for example, a Type I to III reaction of a hand grenade inside the ship magazine. Does it make sense to use the same Response Descriptors for both cases?

2 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 concerning quantitative criteria, removing values of blast overpressure and radiative heat fluxes. Indeed, it has been considered that measurement interpretations are too dependent on test set-up and munitions architecture.

IMEMG experts have identified several issues with Response Descriptor implementation and, in this paper we propose a few potential improvements. Our main concerns focus on the 20 Joules projection criteria and propulsion effects required for the Type V response. In particular, we have identified the following issues:

- Casing rupture criteria are defined for steel casings and not at all for composite envelopes or even for forged aluminum casings. For example, a forged aluminum casing can fracture due to an impact, which 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 so 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 pressurization of the munitions structure 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. Therefore, the resulting safety assessment report might not take into account such phenomena.

- Munitions can be tested in packaged or unpackaged configurations. If the packaging offers strong confinement, the event may be mitigated. However, if the munition burns, as in aType 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, it is debatable whether or not we consider these projections, as part of the munition response.

- The origin point of the 15 meters distance is not defined in AOP 39 Response Descriptors, for large munitions, it would be logic that this distance would be counted from different edges of munitions. The UN Orange book (ST-SG-AC10-11-Rev6) uses this method for the external fire test for fiery projections, but not for metallic projections. It can be important for munitions a few meters long.

- As stated previously, the size of the munitions should be taken into account. Indeed, Type V response of large munitions (delivered combustion energy of few hundred kilograms) can be much more severe for the platform than, for example, Type I to III reaction of a hand grenade located inside the ship magazine. The question is: do Response Descriptors have to be identical for all munitions sizes?

- Solid propellant motors contain energetic materials designed to burn and generate huge volumes of gases. In this instance, for numerous current rocket motors, the best attainable response is Type IV. Thus, despite the Type V objective, the *"as insensitive as reasonably practicable"* technology may only allow a Type IV response. In which case it may well be virtually impossible to design an Insensitive Solid Propellant Motor to fulfill STANAG 4439 Requirements. This gives birth to resignation in the designer's mind; why expend effort if the result is known in advance i.e. failure to meet IM requirements? It is clear that this is a topic for debate.

3 TYPE V PROJECTION CRITERIA

In previous AOP 39 ed1 or ed2 versions, the projection threshold was 79 Joules beyond 15 meters for Type V response. The 79 Joules energy projection criterion is consistent with AASTP-1; this value is universally used to define Inhabited Building Distance (IBD) in munitions safety regulations.

In current AOP 39 ed3, the projection criterion is fixed at 20 joules for Type V Response This comes from the UN Orange Book External Fire Test distinguishing dangerous goods relevant to Hazard Division 1.2 and 1.3.

There are clearly significant differences between Hazard Classification and IM. These differences between safety regulations trigger several concerns: what is meant by 20 or 79 Joules kinetic energy in regards to lethality and injuries risks by impact? The UN Orange book considers kinetic energy at launch rather than impact. Is seems more appropriate to use energy threshold at impact and a review of this is recommended. Moreover, the question arises of how hit probability is considered? For example, a fragment, which is able to reach 100 meters, generates 3.10^{-5} hit probability when IBD corresponds to a probability below 1% of being hit by a 79 Joules fragment. This corresponds to one dangerous projection at 56 m^2. Thus, the current projection criteria can appear as too strict at 20 Joules. It is recommended that projection criteria should be reviewed before the next release of AOP39 - ed4.

IMEMG has already presented a paper on these issues during 2015 IMEMTS in Rome. Following, this MSIAC's TSO, Martijn van der Voort has produced very interesting report, the O-167 "Analysis of the IM Type V Response Descriptor" issued on 19 January 2016. In his report Martijn includes chapters on: Trajectory Analysis; Distance-Mass Relations; Influence of Projectile Shape and Material; Launch Energy and Impact Energy; Impact Energy at Maximum Distance; Impact Energy after a Vertical Launch[1]; Distance-Mass relations based on impact energy at 15 meters; Prediction of injury and lethality; blunt injury analysis for a person facing the event; hit probability; Possible way forward; MSIAC recommendation. IMEMG experts agree with the technical analysis and take the view that this report constitutes common technical reference for discussions.

[1] In §3.5.2, it is noticed a contradiction with one comment in 2015 IMEMTS IMEMG's paper, in fact our explanation was insufficient: if we consider only the projection distance, this distance can appear as compliant with type V response, but after a vertical launch the kinetic energy at launch and at impact can largely overpass the 20 Joules threshold; that introduces uncertainties between test centers, when the fragment trajectory cannot be recorded;

Here we present the summary extract from the report which, we feel, will support future discussions.

Four possibilities for a way forward have been proposed by Martijn and MSIAC staff:

1. *Maintain distance-mass relation based on 20 J launch energy criterion,*
2. *Change to distance-mass relation based on 20 J impact energy criterion at 15 m,*
3. *Change to distance-mass relation based on 79 J impact energy criterion at 15 m,*
4. *Change to distance-mass relation based on 79 J impact energy criterion at 15 m, combined with a 1% hit probability criterion at 15 m.*

In particular, we would like to draw readers to the MSIAC recommendation:

- *The MSIAC recommendation is to choose option 2, for which we have the following reasons:*
- *It seems reasonable to move from a launch energy criterion to an impact energy criterion at the location of a possibly exposed fire fighter (15m).*
- *Keeping 20J as an energy value is necessary to guarantee non-lethal effects and minimal probability of major injuries for a fire fighter at 15m. This seems, to the author and MSIAC staff, to be consistent with a burn type of response.*
- *To include the hit probability (option 4) causes scaling issues between an IM test, its configuration, and a full scale situation which are not easy to solve. Also, it can be questioned whether it really makes sense to harmonize the IM type V response descriptor with the IBD (Inhabited Building Distance).*

We understand that for Dangerous Goods Transportation in civilian environment (UN Orange Book concern), it is desirable to protect fire fighters at 15 meters if they are not aware of potential explosive hazards. However, IBD allows civilians to be hit by 79 Joules fragment with 1% probability, which makes sense during peacetime.

The preference of IMEMG's experts is the fourth option. Additionally, Martijn has calculated that a 1% hit probability criterion at 15 meters corresponds to 25 projections. Feedback shows that number of projection is below this value for burning reaction. So, with 2 to 5 projections, the hit probability is from 1 to 2.10^{-3} which is an improvement.

4 PROPULSION EFFECT ASSESSMENT

The propulsion effect assessment is a usual topic of discussion with test centers, the discussion being sometimes quite difficult. Indeed, both in the table and text, the propulsion effect is not well enough 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 real plume) is observed through the nozzle, even if this flame is not energetic enough to shift the motor.

Propulsion definition is not accurate enough. Indeed, the standard definition is not sufficient to define that propulsion for a Type V reaction as *"There is no evidence of thrust capable of propelling the munitions beyond 15m"* and this does not fit with the criterion given in the table *"for rocket motor a significantly longer reaction time than if initiated in its design mode"*. Thus, information concerning platform survivability assessment is missing given that potential consequences induced by a 20 meters movement or a 2 kilometer flight (compared with a 40 kilometers range motor) can be quite different.

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

- People's safety: munitions movement is tolerable beyond 15 meters because the probability to be injured is quite similar at 10 meters or at 30 meters, the victim being hit by the projectile or not. This probability is not a monotonous decreasing function with the distance contrary to the blast overpressure effect for example.

- Platform survivability: the question concerns the mechanical and thermal damages generated by the munitions shifting. Inside a warship magazine, or a storage igloo, the question is more about possible exit of the munitions. 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.

- Fire propagation: this is relevant in the case of an internal storage igloo. However if the munition has been impacted by a 0.5" bullet or a 18.6g fragment, burning is a likely outcome. Furthermore, ammunition boxes are generally closer than 15 meters, and the domino effect is independent of potential propulsion farther than 15 meters.

Moreover, separate testing of the motor of a cruise missile may result in a propulsion effect, which is insufficient to move the complete missile. In this case it would be mandatory to check this effect on the complete missile to justify IM requirements.

So, with the aim of launching debate, the following statement is proposed: *"Munitions movement should be limited to around 30 meters to obtain a Type V response as for energetic material projections"*. This is similar to the maximum distance for energetic materials projection distance. Moreover, it would be preferable to indicate “m” for moving associated to Type IV reaction it would be more explicit to explain the Type IV hazard in that case.

The final question consist to define precise method allowing to assess this moving or shifting effect up to 15 or 30 meters. Today, it is not clear in AOP 39 ed3 and in test AOPs or SRD.

5 HARMONISATION WITH STANAG 4439 ed3 REQUIREMENTS

In Table 1 below, we state the current threats that need to be considered in IM assessment and the required munition response. If we consider current response descriptors of AOP 39 ed3, it appears that the STANAG is over prescriptive for slow heating and fragment impact threat.

Table 1 IM threats and requirements

THREAT	REQUIREMENT	BASELINE THREAT RANGE
Magazine/store fire or aircraft/vehicle fuel fire (Fast Heating)	No response more severe than Type V (Burning)	Average temperature between 550ºC and 850ºC until all munitions reactions completed. 550ºC reached within 30s from ignition.
Fire in an adjacent magazine, store or vehicle (Slow Heating)	No response more severe than Type V (Burning)	Between 1ºC and 30ºC per hour heating rate from ambient temperature.
Small arms attack (Bullet Impact)	No response more severe than Type V (Burning)	From one to three 12,7mm AP round, velocity from 400 m/s to 850m/s.
Fragmenting munitions attack (Fragment Impact)	No response more severe than Type V (Burning)	Steel fragment from 15 g with velocity up to 2600m/s and 65 g with velocity up to 2200m/s.
Shaped charge weapon attack (Shaped Charge Jet Impact)	No response more severe than Type III (Explosion)	Shaped charge caliber up to 85 mm.
Most severe reaction of same munition in magazine, store, aircraft or vehicle (Sympathetic Reaction)	No propagation of reaction more severe than Type III (Explosion)	Detonation of donor in appropriate configuration.

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

- For example, the Slow Heating requires a thermal confinement of the munitions (igloo, vehicle, magazine, navy gun turret …) in order to reach temperatures ranging from 150 to 200°C (300 to 400°F) with a progressive ramp (the whole process taking many hours). Is the current criterion that the energy of any fragments produced should not exceed 20 Joules beyond 15 meters range appropriate?

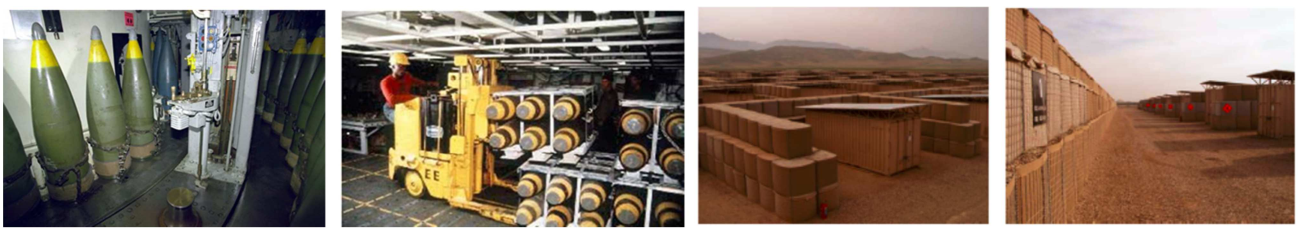
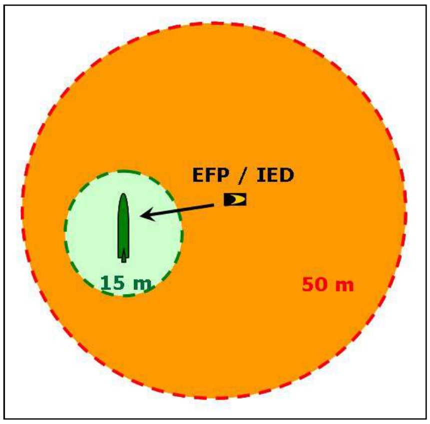


Figure 1 Type IV Response appears as sufficient because walls stop projections

- In such a configuration, a Type V requirement seems pointless given that the walls, which inevitably surround the munitions, will easily stop potential fragments from the envelope of the munition. Indeed, such propelled pieces cannot even penetrate 2 mm thick aluminum sheets as indicated in the UN Orange Book (ST-SG-AC10-11 Rev6). Consequently, a Type IV requirement could be sufficient (see Figure 1).

- When a weapons platform is attacked by an IED (Improvised Explosive Device, see Figure 2) or by one specific missile able to propel 18.6g fragment @ 2530 m/s (8300 ft/s), blast and fragments they generate can provoke severe damage and lethal injuries to persons up to 50 meters away. It is the same for the alternate fragment speed (1830 m/s). Large artillery shells or general purpose bombs generate such fragment, with lethal effects (blast & primary fragments) beyond 50 meters.



➔ 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)

Figure 2: Example to illustrate excessive severity of criteria

- In such a case, is it really necessary to require, a Type V response for the "acceptor" munition, and no-injuries farther than 15 meters? In comparison with the violence of the stimulus, the "contribution" of the impacted munition seems secondary if limited to Type V, IV or even III levels of response. In comparison, the sympathetic detonation scenario, which is finally quite similar, requires only a Type III mandatory response.

6 CONCLUSIONS AND PERSPECTIVES

IMEMG experts have reviewed the current AOP39 descriptors and highlighted discrepancies. We suggest that the issues raised should be discussed by AC326 SGB National Experts. In particular, we suggest the following.

For the AOP 39 ed4:

- Review projection criterion for the Type V response, according to the fourth option proposed by MSIAC in the O-167 report "Analysis of the IM Type V Response Descriptor", this option is *“Change to distance-mass relation based on 79 J impact energy criterion at 15 m, combined with a 1% hit probability criterion at 15 m”;*

- Review propulsion effect assessment for the Type V response, it could be *"Munitions movement would be limited to around 30 meters to respect Type V response as for energetic material projections”.* In addition, we believe it is necessary to indicate how to evaluate propulsion distance in test AOPs or in SRDs. In addition, in the case of a propulsion effect resulting in a Type IV reaction, it is preferable to indicate “m” (moving) in substitution to “p” because, it is more explicit to describe this effect.

For the next edition of STANAG 4439 we recommend the following changes, especially if the projection criterion is maintained at 20 joules and propulsion effect at 15 meters:

- Move the maximum response allowed in slow heating from Type V to Type IV. Since munitions effects are contained within a magazine, storage or vehicle and anyone within such a confined space would survive the stimulus.

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

For industry, IM development is a difficult and costly challenge. It is important that both manufacturers and users gain benefits from reduction of logistical costs as well as improvements in terms of people's safety and platform survivability. For that, it is necessary to have good clarity about IM or near-IM advantages.