A CASE STUDY: Transport and Storage of IM

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1. INTRODUCTION

Minimizing the probability and subsequent consequences of inadvertent initiation of munitions protects our force and reduces the severity of collateral damage. These direct benefits have been achieved thanks to the Insensitive Munitions community.

However not all deploying nations who are co-located with NATO allied forces have procured these safer munitions. Imagine a military base located in an operational theater somewhere in Southwest Asia. This future multi-national camp shares an ammunition holding area with two other nations. The munitions are stored according to NATO Guidelines AASTP-1 with no deviations requiring a waiver. The ammunition holding area footprint is based on the aggregation rules of the standard, i.e., if Hazard Divisions 1.2, 1.3 is mixed with 1.1, the entire explosive quantity is aggregated as HD 1.1. However this future ammunition holding area has no HD 1.1. All main high explosive charges of the munitions present are filled with an insensitive explosive that have passed the sympathetic reaction test. Another allied nation subsequently arrives and wants to store their munitions, but the artillery is filled with TNT and Composition B thus hazard classified as HD 1.1. Aggregating the net explosive quantity as HD 1.1 significantly increases the risk and the Command is not willing to accept it.

How will Insensitive Munitions (IM) change the way we ship and store munitions? This paper will discuss issues related to the strategic and operational storage benefits of IM, but also on the realities of Insensitive Munitions from the perspective of those charged with the storage and movement of stocks.

2. POLICY

Some NATO Member Nations have agreed that all new procurements would be insensitive munitions. Many of these nations have IM policies that require a waiver for any procurement of items that are not IM. Therefore unless there are strong reasons otherwise, all new procurements should be designed to be insensitive munitions.

All legacy munitions which are considered already in use or procured are to be kept under review to identify opportunities to achieve IM compliance. Several nations are proactively setting goals to modify their legacy munitions. The United Kingdom for example has completed an IM assessment of their entire inventory in order to determine where the IM technology gaps are and what the best investment is to get the most benefit. Many workshops have discussed the IM gaps, and where efforts should be concentrated to lessen the risk of collateral damage caused by an event.

The vision for IM is now 20+ years old, and STANAG 4439, Insensitive Munitions was first published in 1998 after years in development. Table 1 below identifies the IM status of NATO member nations. Other Non-NATO Member Nations such as Australia, Finland, South Africa and Sweden identified in Table 2 recognize the benefits of IM and are supportive of IM policies.

NATO Nations	National IM Policy	Ratified STANNAG 4439 Edition 2	Implementation	
			Legacy Munitions	New Munitions
Albania	No	No Response	No	No
Belgium	No	Yes	No	No
Bulgaria	No	Yes	No	No
Canada	Yes	Yes	1	Yes
Croatia	No	No Response	No	No
Czech Republic	No	Yes	No	No
Denmark	Yes	Yes	No	Yes
Estonia	No	Yes	No	No
France	Yes	Yes	Yes	Yes
Germany	Yes	Yes	No	Yes
Greece	No	No Response	No	No
Hungary	No	Yes	No	No
Iceland	No	No Response	No	No
Italy	Yes	Yes	2	2
Latvia	No	No Response	No	No
Lithuania	No	Yes	No	No
Luxembourg	No	No Response	No	No
Netherlands	Yes	Yes	No	Yes
Norway	No	Yes	No	Yes
Poland	No	No Response	No	No
Portugal	No	No Response	No	No
Romania	No	Yes	No	No
Slovakia	No	Yes	No	No
Slovenia	No	Yes	No	No
Spain	No	Yes	No	No
Turkey	No	Yes	No	No
United	Yes	Yes	Yes	Yes
United States	Yes	Yes	Yes	Yes

Table 1. IM Status of NATO Member Nations

[1] *Canada: Legacy Munitions are exempt if service life ends prior to 2020.*
[2] *Italy: Case by Case basis after analyzing the threat.*

Non-NATO Nations	National IM Policy	Ratified STANNAG 4439 Edition 2	Implementation	
			Legacy Munitions	New Munitions
Australia	Yes	4	No	Yes
Finland	Yes	4	Yes	Yes
South Africa	Yes	4	No	Yes
Sweden	Yes	4	No	5

Table 2. IM Status of Global Partner Nations

[4] Non-NATO Member Nations do not ratify NATO documents.
[5] Sweden: MSIAC Member Nation seeking technical guidance.

Much discussion and debate on the operational and logistics benefits from reduced hazard classifications have been heard over the last couple of years. This is often connected with attempts to quantify the benefits of implementing an Insensitive Munitions policy. Recent questions at MSIAC probed the benefits of NATO's storage sub-divisions associated with HD 1.2 and 1.3 particularly the impact that these might have on quantity distances. Although the storage sub-divisions serve as incremental steps in an effort for a nation to produce an insensitive munition, the United Nations for example does not recognize the storage sub-divisions 1.2.1, 1.2.2, 1.2.3, 1.3.1 and 1.3.2. The UN simply classifies the divisions of Hazard Class One into the six divisions, i.e., 1-6. Therefore further hazard classifying munitions to obtain the storage sub-division has not yet been adopted for transportation purposes, however with the continued development of the UN International Ammunition Technical Guidelines (IATG) which does acknowledge the storage sub-divisions, a change to the UN Transport of Dangerous Goods standard becomes more likely.

The standards for storing the munitions hazard classified for storage with these sub-divisions have been evolving in the last several years within the NATO AC/326. This group is responsible for developing the standard and has been working to resolve inconsistencies within the standards AASTP-3, and AASTP-1 for more than 3 years. This may partially explain why there is reluctance by many not to store munitions based on the refined hazard classification that provides a shorter separation distance requirement. Another reason is that mature ammunition storage sites have been planned, sited and licensed based on standards that did not include the storage sub-divisions nor HD 1.6. Additionally the aggregation rules that specify the entire quantity of HD 1.2 and 1.3 when mixed with 1.1 must be aggregated as HD 1.1 remains applicable. Therefore as a consequence, storage benefits from the introduction of Insensitive Munitions may not be fully realized.

3. VULNERABILITY

Direct benefits from using insensitive munitions have recently surfaced in accidents which underscores the need for producing and fielding these munitions. IM that are inadvertently initiated in a fire will have significantly reduced consequences, thus lessens the risk to personnel in a major catastrophe or accident. The high profile accidents often cited and credited as the inspiration leading to the development of Insensitive Munitions (IM) are those of the US Navy Carriers Oriskany, Forrestal and Enterprise of the 1960-1980s. These accidents served well to spur the United States into action. The loss of human life, loss of capability, and the potential to cripple the mission inspired the Navy to engineer an explosive that would perform reliably on demand, but minimize the probability of inadvertent initiation. Those historic accidents involving legacy filled munitions, along with the more recent accidents noted below supports the rational argument to further develop and field IM into the future.

a. United States June 2005 (Figure 1). "About 300 Marine base workers walked shoulder to shoulder through a southern Arizona neighbourhood in search of any stray ammunition from the crash of a bomb-laden Harrier jet that plunged into a backyard while trying to land at Marine Corps Air Station-Yuma, about 185 miles southwest of Phoenix. The pilot ejected safely before the crash, and only one civilian on the ground received a minor injury."[6]

The plane was carrying four each 500-pound bombs that were safely removed. The PBXN-109 explosive filled bombs had devices to prevent detonation if they were to accidentally drop from the aircraft or hit the ground in a crash. All four of the BLU-111/B's buried themselves up to the base plate. They obviously experienced a significant amount of energy upon impact. The M904 nose fuzes were sheared off and the MFMU-139 tail fuzes were unscathed, and the BLU-111/B Bombs mostly disintegrated upon impact. One of the BLU-111/B's caught fire and burnt out like a cigar, while others burned out completely.

Figure 1. Crash Site of Bomb-Laden Harrier Jet

b. United States, September 2009 (Figure 2). A Mine Resistant Armor Protected (MRAP) vehicle in a convoy was destroyed by a very powerful improvised explosive device (IED). The IED ruptured the vehicle's hull and fuel tank, which engulfed the vehicle interior in flames— including 16 each 60mm, M768 (PAX-21) mortar cartridges, hazard classified as 1.2.2, were carried inside the cabin with the 7-man crew. After the MRAP had stopped burning, soldiers found all of the rounds' shell bodies intact, proving that none of them had gone "high order". They also found the remains of the fuzes that had separated from the cartridges, allowing the explosive fill to burn rather than explode.

Although several Soldiers were seriously injured in the ambush, all survived. The M768 cartridge is one of the early success stories in a plan to develop, produce and implement safer ammunition. The M768 incorporates several IM features, including new explosive materials and a plastic fuze adaptor that melts in a fire allowing the fuze to separate from the cartridge. This relieves internal pressure and prevents detonation of the explosive fill. Thanks to the IM features of the M768 cartridges, a much greater disaster was averted.

Figure 2. Interior view of the MRAP after the fire. An unexploded shell body from a M768 cartridge can be seen at the lower left.

c. Afghanistan, May 2009 (Figures 3, 4) A British Harrier jet crashed in Afghanistan according to the Ministry of Defense. The pilot suffered only minor injuries when he ejected from the aircraft before it landed at Kandahar airfield at about 10:30 local time. There were no passengers on board the Harrier and it is believed there were no other casualties. It is thought that the RAF pilot ejected after the Harrier's undercarriage failed to lower as it came in to land. The aircraft, thought to be worth around £20 million was very badly damaged in the crash, but the insensitive filled Paveway IV Guided Bomb did not detonate nor explode, but only burned.

Figure 3. Harrier Jet with Paveway IV Missile before and after the accident.

Figure 4. Ordnance removal after the accident.

By understanding the primary benefit of IM, i.e., minimizing the probability and subsequent consequences of inadvertent initiation as described in the last three recent examples, one will clearly see the operational benefits of transporting IM. Those recent accidents involving a less sensitive main explosive charge are good examples about the reduced reaction level of IM, they also demonstrate the benefits of protecting the force and reducing the severity of collateral damage.

4. SUSCEPTIBILITY

The munition stockpile of all military forces are dominated by legacy filled high explosives such as TNT and Composition B and it will likely continue for the foreseeable future, particularly with multi-national deployments. This leads many to conclude that fielding IM has little benefit in storage and movement of large quantities of bulk stocks due to the aggregation rules discussed above. However it makes perfect sense to consider the value incremental steps can have in order to achieve a fully compliant IM signature.

Table 3 below provides an example of QD siting requirements from AASTP-1 for munitions filled with a legacy filled high explosive charge labelled as HD 1.1. Also included are munitions filled with an insensitive high explosive with significant reduced vulnerability, but which fail to meetss all the IM test requirements. Although inherently difficult to initiate, they do not pass UN Test series 7 therefore at best they can be assigned HD 1.2.1. Munitions that pass all the IM requirements could potentially be hazard classified as HD 1.6. This classification is reserved for munitions which are “extremely insensitive explosives articles” which implies a significantly reduced risk when compared to more conventional munitions. However several PES to ES pairs in table 3 above requires a greater Quantity Distance separation for HD 1.6 than it does for HD 1.2.1.

Another recent change to the NATO storage guidelines in AASTP-1 is the concept of Maximum Credible Event (MCE). This concept applies only to HD 1.2.1, 1.2.3 and 1.6 munitions. In general, the MCE concept applies to Inter-magazine separation distance to offer reduced distances if either the PES or the ES is an earth covered building or a building which can contain the effects generated in an accidental explosion of the HD 1.2 munition. Separation to other facilities, public traffic routes or inhabited buildings are dependent on constructional details of both the PES and ES.

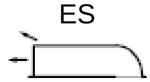
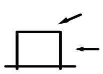
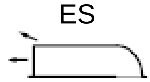
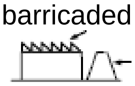
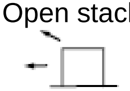
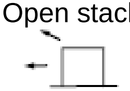
Exposed Site (ES)	Potential Explosion Site (PES)	NEQ [kg]	HD 1.1 [m]	HD 1.2.1 (MCE ≤ 50kg) [m]	HD 1.6[1] [m]
Vulnerable Construction	Earth Covered 	50,000	1650 m	60 m	240 m
IBD – Occupied Housing 	Earth Covered 	50,000	820 m	60 m	240 m
Public Traffic Route	Earth covered Directional effects towards ES 	50,000	Med Density 550 m High Density 820 m	Med Density No QD High Density 60 m	Med Density 107 m High Density 174 m
Open stack, un-barricaded 	Earth Covered Directional effects towards ES 	50,000	Limited Degree of Protection 180 m High Degree 820 m	18 m	60 m
Workshop, no protective roof, barricaded 	Open stack 	4,000	130 m	120 m	80 m
IBD – Occupied Housing 	Open stack 	4,000	400 m	330 m	174 m

Table 3. Example: QD Calculations for various Hazard Divisions

[1] *The separation distances noted for HD 1.6 in Table 8 are greater in most cases than those of 1.2.1, this issue will be addressed with the responsible group to make subsequent and appropriate changes.*

Packaging will also influence the classification, therefore care must be taken to ensure that the correct classification is determined for each configuration in which ammunition and explosives are stored or transported. Since packaging can influence the hazard classification of an article, should the behaviour of munitions inside the storage structure also be considered particularly if the structure can offer a good degree of confinement. Munitions spend nearly all their life in dormancy, therefore a question arises; should a hazard classification system that is based on the munitions reactions to threats during transport determine the most practicable and operationally efficient method for storage?

Maintaining a separation distance that meets the NATO QD guideline for Inter-Magazine Distance (IMD) will prevent immediate propagation, meaning that the explosive quantities in separate locations do not need to be aggregated. Experts agree that damage to stocks in storage from an accidental explosion will vary widely. Hence the NATO ratified guideline for IMD offers three levels of asset protection. These three levels are intended to provide a basis for selecting a particular QD. For example an igloo is designed to resist external blast, primary fragments or secondary projections, thereby by design it ensures that stocks will survive and are expected to remain serviceable. Therefore if the quantity of explosives are limited to the Maximum Credible Event (MCE) that meets IMD, a detonation of all stocks in one igloo will not affect the serviceability of stocks in adjoining locations. A reduction in hazard classification is awarded if the worst reaction to a sympathetic reaction test is a type III response (explosion or better) to a donor's detonation, i.e., an exploding round located adjacent to the donor is considered passing the test. Although the response propagated adjacent rounds, a subsequent detonation is avoided thus qualifying the donor charge with a signature of passing the Sympathetic Reaction Test. The munitions inside the magazine are not likely to be serviceable, but the stocks located at the appropriate Inter-Magazine Distance within an igloo will be according to the various levels of protection.

The following are the three levels of protection offered to ammunition and explosives at the Exposed Sites:

a. <u>Virtually.</u> There is virtually complete protection against practically instantaneous propagation of explosion by ground shock, blast, flame and high velocity projections. There are unlikely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. The stocks are likely to be serviceable. However, ground shock may cause indirect damage and even explosions among especially vulnerable types of ammunition or in conditions of saturated soil.

b. <u>High.</u> There is a high degree of protection against practically instantaneous propagation of explosion by ground shock, blast, flame and high velocity projections. There are occasional fires or subsequent explosions caused by these effects or by lobbed ammunition. Most of the stocks are likely to be serviceable although some are covered by debris.

c. <u>Limited.</u> There is only a limited degree of protection against practically instantaneous propagation of explosion by ground shock, flame and high velocity projections. There are likely to be fires or subsequent explosions caused by these effects or by lobbed ammunition. The stocks are likely to be heavily damaged and rendered unserviceable; they are sometimes completely buried by debris. This level of protection is not recommended for new construction.

Table 4 below is provided to highlight the selection of all 3-levels with a combination pair of a PES to a side exposed ES. One will clearly see that the directional effect from the PES, i.e., rear, side or front can provide a choice on the level of protection desired.

PES ➤ ES ▼	Building with earth on the roof and against three walls. Directional effects through the door and headwall are away from an Exposed Site. (a)	Building with earth on the roof and against three walls. Directional effects through the door and headwall are perpendicular to the direction of an ES. (b)	Building with earth on the roof and against three walls. Directional effects through the door and headwall are towards an Exposed Site (c)
Table 1A HD 1.1 QD Matrix for Earth Covered Storage			
10 Earth-covered building not complying with Part 2, with or without a headwall and door(s) resistant to fire and low velocity projections, (see 1.3.5.6), but the door faces perpendicularly to the direction of a PES.	D6 (49m) Virtually complete protection or D4 (22m) High degree of protection 1.3.3.5 No primary explosives 1.3.5.3 No items vulnerable to spall	D6 (49m) Virtually complete protection or D4 (22m) High degree of protection 1.3.3.5 No primary explosives 1.3.5.3 No items vulnerable to spall	D6 (49m) Limited degree of protection 1.3.5.6 1b Effect of lobbed ammunition

Notes: D4 = $0.8Q^{1/3}$ and D6 = $1.8Q^{1/3}$

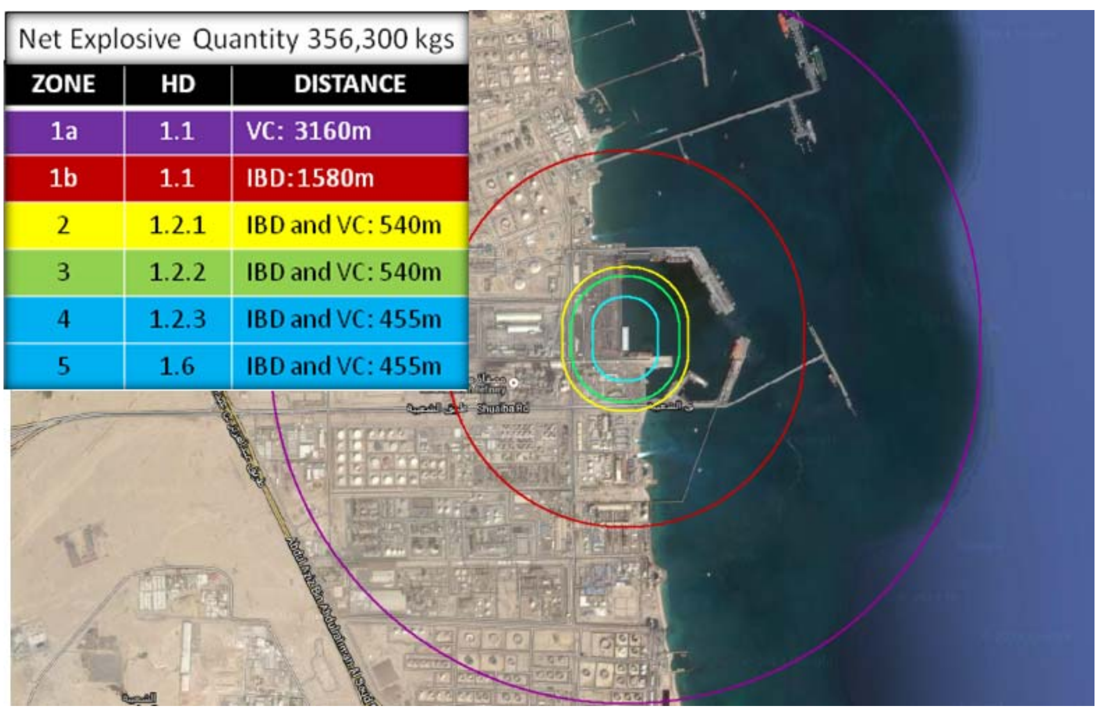
Table 2A(1) SsD 1.2.1 QD Matrix (MCE≤50 kg) <u>for</u> Earth Covered Storage			
10 Earth-covered building not complying with Part 2, with or without a headwall and door(s) resistant to fire and low velocity projections, (see 1.3.5.6), but the door faces perpendicularly to the direction of a PES.	No QD Virtually complete protection	No QD Virtually complete protection	No QD Virtually complete protection
Table 2A(2) SsD 1.2.1 QD Matrix (50kg<MCE≤500kg) for Earth Covered Storage			
10 Earth-covered building not complying with Part 2, with or without a headwall and door(s) resistant to fire and low velocity projections, (see 1.3.5.6), but the door faces perpendicularly to the direction of a PES.	No QD Virtually complete protection	No QD Virtually complete protection	No QD Virtually complete protection

Table 4. QD Selection by Level of Protection for NEQ of 20,000 kilograms.

The HD 1.1 munitions stored at distances meeting virtual complete and high degree of protection will likely remain serviceable, but those provided with a limited degree will not and will likely be covered by debris from the collapsed building. Therefore munitions stored in an Exposed Site meeting a virtual or high level of protection are less susceptible to ground shock, blast, flame and high velocity projections thus the consequences of an event are significantly reduced. Particularly noteworthy is that HD 1.2 munitions regardless of MCE in nearly all IMD combinations offers a virtual level of protection with no QD separation requirement thereby adding another reason to praise the success incremental steps can have, i.e., producing and Hazard Classifying munitions HD 1.2 vice HD 1.1.

Additionally, the QD separation for HD 1.2 is substantially less stringent to Inhabited Buildings and Buildings of Vulnerable Construction (VC) as noted below in figure 5b. Fielding a replacement for the traditional 155mm projectiles, M107 filled with TNT or Comp B and hazard classified as 1.1 has been accomplished. France, Germany and the United States have successfully produced and insensitive filled 155mm projectiles. HE filled Projectiles LU-411-IM, RH-30, and the M795 are hazard classified as HD 1.2.

Figure 5a. Aerial view of Shuaiba Port near Kuwait City.



Net Explosive Quantity 356,300 kgs

ZONE	HD	DISTANCE
1a	1.1	VC: 3160m
1b	1.1	IBD:1580m
2	1.2.1	IBD and VC: 540m
3	1.2.2	IBD and VC: 540m
4	1.2.3	IBD and VC: 455m
5	1.6	IBD and VC: 455m

Figure 5b. IBD and Vulnerable Construction (VC) Quantity Distance Arcs for 50,000 each 155mm HE Projectiles per Hazard Class and Division.

Another incremental step that could be considered is the creation of an "IM Unit/Company/Battalion/Brigade" i.e., fielding a tactical munition stockpile for a military unit, company, battalion or brigade that has an insensitive main high explosive charge thus no items hazard classified as HD 1.1. Prioritization is needed to accomplish this, but the added benefits of IM in a tactical environment reduces the base camp footprint significantly which also lessens the distance to the storage of munitions thereby decreasing exposure necessary to retrieve them, thus reducing risk and improving safety, a.k.a. Force Protection.

Several units in the U.S. Army are typically forward deployed in a location that does not share an ammunition basic load storage area. It is in this case that units can fully benefit from the mitigating effects reduced vulnerability munitions provide in storage planning. The four Units addressed below in Tables 5 through 8 are possibly the most suitable to fully benefit from a stockpile converted to IM.

Hazard Class/Division	NEWQD
1.4	3,436.4
1.3	184,546.7
1.2.2	63.0
1.2.1	107.2
1.1	19,185.6
Total	207,338.9

Table 5. Air Defense Artillery Battalion

Hazard Class/Division	NEWQD
1.4	1,649.2
1.3	533.8
1.2.2	8,037.3
1.2.1	2,708.2
1.1	27,750.9
Total	40,679.4

Table 6. Attack Aviation Battalion

Hazard Class/Division	NEWQD
1.4	12,597.2
1.3	2,913.6
1.2.2	2,431.2
1.2.1	19,572.4
1.1	64,574.5
Total	102,088.9

Table 7. Combat Aviation Brigade

Hazard Class/Division	NEWQD
1.4	13,182.5
1.3	90,208.8
1.2.2	562.6
1.2.1	1,584.7
1.1	331,761.2
Total	437,299.8

Table 8. Field Artillery Brigade

An aspect that EOD and logisticians can appreciate is a change to the NATO marking standard for munitions. Table 9 below is an extract of the NATO standard AOP-2C that identifies the type of ammunition that shall or should be stenciled and stamped with the main high explosive charge nomenclature.

The change request was surfaced by the EOD community to help them quickly assess the disposal technique required, but it also assists logisticians identify the proper munition throughout its lifecycle. Filling this gap helps demonstrate that the IM community is mindful of issues that affect other stakeholders that are far more reaching than reactions to test results.

Serial N°	Type of Ammunition	Caliber or Mass	Model Designation		Lot Designation		Main High Explosive Charge(s)	Remarks
			Complete Round	Single Item	Complete Round	Single Item		
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	Fixed, Semi-fixed Rounds, Mortar Ammunition (Complete Rounds)	X	X	-	X	-	X and O (1)	To be shown on projectile, or cartridge case or both, according to National practice.
2	Separate Projectiles (Gun, Howitzer or Mortar)						X and O (1)	Refers to item issued.
3	Separate Propelling Charges (Cased), Blank Charges (Gun, Howitzer or Mortar)	X or O	-	X	-	X	-	1. Refers to items as issued, blank charges to include the word BLANK in National language. 2. Charge numbers to be marked on each bag, if applicable.
4	Fuzes	-	-	X or O	-	X or O	-	
5	Gun, Howitzer and Mortar Primers	-	-	O	-	O	-	
6	Uncased Propelling Charges (Bagged) for Gun and Howitzer	X	-	X	-	X	-	Charge numbers to be marked on each bag, if applicable.
7	Aircraft Bombs	X	-	X	-	X	X and O (1)	
8	Rocket/Missile with Warhead	X	X	-	X		-	Caliber, if applicable.
9	Rocket/Missile Warhead	X	-	X	-	X	X	Caliber, if applicable.
10	Rocket/Missile Motor	X	-	X		X	-	Caliber, if applicable.
11	Other ammunition	X or O	X	-	X	-	-	

O = permanent markings.
X = stenciled markings.
(1) = 20mm-60mm munitions SHOULD be marked (explosive fill name/official designation), 60mm and above munitions SHALL be marked (explosive fill name/official designation) every 90 degrees on the body.

Table 9. Munitions Marking Guideline from AOP-2C

5. CONCLUSION

The operational and logistic benefits of protecting the force, saving the mission and reducing the severity of collateral damage is difficult to financially quantify, but the consequences avoided such as loss of life noted above are testimonials to the positive impact Insensitive Munitions have already demonstrated.

Efforts to reduce the consequences of an event can make a significant difference throughout the munitions lifecycle from “factory to foxhole.” Eliminating the HD 1.1 aggregation rule from the site planning equation addressed in paragraph 1 is a worthy and achievable goal as evidenced by the successful production of insensitive filled 155mm projectiles now hazard classified as HD 1.2 by France, Germany and the United States.

Survivability[2] is paramount and these incremental steps to improve munitions safety should be embraced as a huge success.

[1] *MSIAC has been an advocate and active supporter of munitions safety with an emphasis on Insensitive Munitions since 1991. “Eliminating hazardous consequences due to unintended reactions of munitions and energetic material throughout their lifecycle” is the strategic objective of MSIAC.*

[2] *Survivability is the capability of system and crew to avoid or withstand a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission [vulnerability and susceptibility are components of survivability].*

6. REFERENCES

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