Insensitive Explosives: Minimizing the Consequences of Unplanned Events

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ABSTRACT

Within the scope of application orientated explosive developments safety remains a vital aspect that can never be ignored. Considering the diversity of the explosives application environment, the safety topic can become very environment specific. Considering only two distinct fields of application, military and commercial, we can see how this can come to pass. In the past two decades the developments of insensitive munitions, and more specifically insensitive explosives formulations, were the focus of many development projects. Previous accidents, like the well-known USS Forestall incident, highlighted the importance of weapon platform survivability, own forces protection and more. A lot of progress has been made in the development of insensitive explosive formulations guided by NATO standards like STANAG 4439. Commercial explosives developments in the same time period were more focussed on cost and application rather than the inherent safety characteristics of the explosives formulations. Transport, storage and handling safety are very important and is governed by several local and international standards, and in isolated cases user requirements. Frequent SAFEX incident reports suggest that these standards are seen as minimum safety requirements and not as a motivation to develop safer explosives formulations. This paper will ask the question whether the time is not right for the current commercial explosive safety focus, being mainly basis of safety and good explosives practise related, be expanded to include insensitive explosive formulation development for commercial applications. Advantages of this approach will be discussed using recent incidents and the subsequent consequence management.

1. BACKGROUND

Munitions are, by their very nature, hazardous items and the dangers associated with them are always of concern to their users throughout the munitions life cycle [Boulay, 1999]. Past advances in military technology required munitions with improved performance, leading weapon designers to focus on cost- effective performance on target. This continued for most of the previous century and led to a number of accidents, a few of which are listed below.

At a Royal Air Force Depot in 1944, 3500 tons of bombs exploded leaving 68 people dead. In 1967, on board an United States aircraft carrier, the USS Forestall, the accidental launch of a rocket injured 161 people and killed 134. An explosion of a surface storage depot in Pakistan, in 1988, caused the death of 1000 people. In 1999, in Kuwait, an explosion in a US Army vehicle storage depot, injured 50 people and caused the death of two persons [Freché, 2001].

In all these accidents, munitions were involved, either as the origin of the damage or as an increasing factor that contributed to the magnitude of these catastrophes. The life cycle of munitions includes the production, transport, storage and operational use of the munitions. Hazardous stimuli that can result in such catastrophes, as given above, may be experienced throughout the entire life cycle of munitions.

Over the past decade, a determined attempt has been made by military services of most major western nations to reduce the vulnerability of their munition platforms [Lamy, 1994]. This was done by the launching of research to develop Low Vulnerability Ammunition (LOVA) and to identify the technology requirements for the production and procurement of Insensitive Munitions (IM) for service use [Derbyshire, 1998].

Figure 1: Forestall incident

Figure 2: Ammunition Depot – Turkey 2012

The development of IM technology was a significant step in the energetic materials area during the last few decades [Mandelbaum, 2000]. The term insensitive munitions evolved from the United States Navy. It was used to describe the attributes associated with reduced combat vulnerability of warships. This resulted by deploying on board munitions having relatively benign response to severe accident and combat stimuli [NIMIC, 1996].

To some extent, this terminology has had misleading implications for the uninitiated, since the explosiveness of munitions is invariably associated with the concept of damage to the target. It should, therefore, be emphasised that the "insensitiveness" of an IM applies to its behaviour with respect to accidents (during peace or war time) or combat stimuli and its requirement to respond with minimal damage effects to the surroundings. However, it does not refer to the munitions behaviour when deliberately functioned in the design mode. This is clearly given by the definition of IM, as we know it today:

"Munitions which reliably fulfil their performance, readiness and operational demand, but which minimise the probability of inadvertent initiation and the severity of collateral damage to weapon platforms, logistic systems and personnel" [NIMIC, 1996]

Thus, the introduction of IM is aimed at enhancing defence preparedness via improved system survivability and operational safety [RSA DoD 3/99, 1999].

2. ACHIEVING IM

To achieve IM, the desired approach is to design certain characteristics into munitions, and this is certainly appropriate for new munitions. Technological advances in the design of the explosive ordnance make this possible. Some of the methods that are available and are proven for munitions, and particularly for their associated energetic materials, are as follows:

2.1.1. Munitions (Excluding Energetic Materials)

The methods below can be implemented to enhance the IM characteristics of ammunition. These methods do not include changes to explosive formulations.

- Techniques to protect against thermal threats.
- Protection techniques against shock, impact and sympathetic detonation.
- Prevention techniques to avoid catastrophic pressure build-up whatever the initial stimuli.
- Techniques to prevent premature initiation from in-line explosive trains of fuse systems.

2.1.2. ENERGETIC MATERIALS.

Methods used to obtain IM characteristics by changing the explosive formulations are:

- Techniques to reduce the sensitiveness of explosives.
- Techniques to reduce the mechanical sensitiveness of explosives.
- Introducing engineering design into the configuration of explosives.

2.1.3. STANDARDS, POLICIES AND LABELS

Fulfilling IM specifications is a systems approach and requires taking into account the entire armament system, including packaging. Standards, policies and labels have been issued and define the IM objectives and what is necessary for compliance verification within those objectives. These standards, labels and policies include Standard NATO agreements (STANAG's), United States Military Standards (MIL-STD'S), Munitions á Risques Atténué (MURAT one star, two star and three star labels). MURAT is the French description for IM. Many countries and the most NATO countries have adopted IM policies for their armament [Freché, 2000].

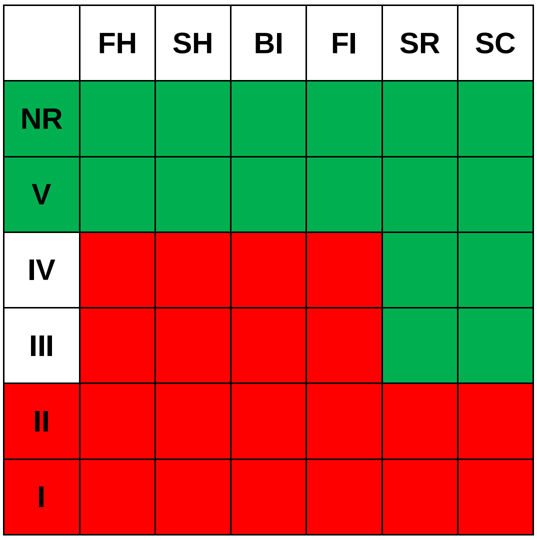
Weapon designers and scientists use these standards, policies and labels as guidelines to design weapons, packaging and energetic materials that exhibit IM characteristics. These documents not only provide guidelines to identify the technology requirements for production, but also for procurement of insensitive munitions.

IM STANAG 4439 and Allied Ordnance Proceeding 39 (AOP 39) are two such documents, and calls for nations ratifying these documents to provide the results of any threat hazard assessment be made public and the methodology used to be described. FitzGerald-Smith (1999) states that whereas AOP 39 outlines threat hazard assessments, it does not give any guidance on how such assessment should be conducted. The term "threat hazard assessment" (THA) has different interpretations depending on its use either by the military or industry or simply because of national perspective. Therefore the following definition was agreed upon by the NATO Insensitive Munitions Information Centre (NIMIC) member nations, when this terminology is applied to munitions:

"A threat hazard assessment is an assessment of the threats to a munition throughout its life cycle followed by an assessment of the likely hazard from the munition and their consequence to the surrounding environment, resulting from each of the individual tests. Its specific objectives are to identify every threat which may affect a munition at any point in its life cycle and identifying every hazard arising from each threat".
[FitzGerald - Smith, 1999]

Once these threats have been identified, STANAG 4439 can be used to identify the tests that must be conducted as well as the results that must be achieved in order to conform to IM characteristics. It is also important to remember that when a new energetic material is developed, it must still be subjected to the relevant explosive characterisation tests as specified by local authorities. IM characterisation tests must then be done in addition to the explosive characterisation tests.

A key aspect to note here is the reference to the entire life cycle of the munition. This usually includes storage, transport and handling in many different areas e.g. manufacturing, depot storage, operational storage areas and operational platforms.



	FH	SH	BI	FI	SR	SC
NR	🟩	🟩	🟩	🟩	🟩	🟩
V	🟩	🟩	🟩	🟩	🟩	🟩
IV	🟥	🟥	🟥	🟥	🟩	🟩
III	🟥	🟥	🟥	🟥	🟩	🟩
II	🟥	🟥	🟥	🟥	🟥	🟥
I	🟥	🟥	🟥	🟥	🟥	🟥

Figure 3: STANAG 4439 Test and acceptable response criteria.

(FH = Fast Heating test; SH = Slow Heating test; BI = Bullet impact test; FI = Fragment Impact; SR = Sympathetic reaction test; SC = Shaped Charge Jet Impact test. I = Detonation Reaction; II = Partial detonation reaction; III = Explosion reaction; IV = Deflagration reaction; V = Burning; NR = No Reaction)

(Green Areas represent the desired response)

3. COMMERCIAL EXPLOSIVES

By their nature commercial explosives are (main charge explosives e.g. slurries, emulsions and ANFO) significantly less sensitive than their military counter parts. Initiating systems and accessories like boosters can be regarded as being similar with regards to sensitivity and response behaviour. Looking at incidents and accidents involving commercial explosives it can be concluded that even though commercial explosives are less sensitive explosives compositions ,the frequency of unintended events are much higher than for military explosives. An obvious reason can simply be related to the volumes of explosives that are manufactured annually. But is it as simple as blaming volumes of manufacture on frequency of incidents.

Figure 4:ANFO Explosion

Figure 5: Train truck fire

3.1. STANDARDS, POLICIES AND LABELS

There are currently hundreds of specifications that can be used to test specific characteristics of commercial explosives. These include national and international specifications and in some cases commercial explosives are tested against local military specifications. These specifications and standards provide guidelines for testing of explosives for specific conditions and often pass fail criteria and or basic acceptance criteria.

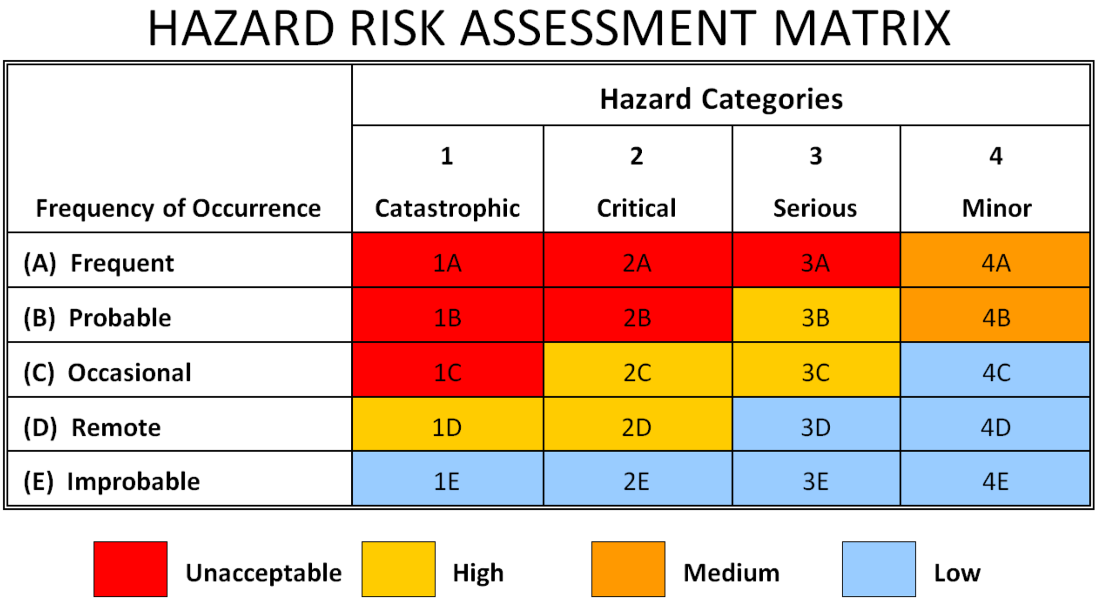
Selected tests are enforced by legislative authorities to allow manufacture, transport, storage , use and destruction of commercial explosives. This approach is not out of the ordinary and is also followed by military industry. What is however different is that there are no common efforts towards establishing a globally accepted standard for moving towards safer commercial explosives and ultimately moving towards a 1.6 classification.

The Hazard Risk Assessment Matrix is derived from MIL-STD-882B. The matrix provides a systematic method for assigning a hazard level to a failure event based on the severity and frequency of the event.

The hazard level consists of one number and one letter. The number represents the severity of the event. The numbers represent: (1) Death, system loss, or irreversible environmental damage; (2) Severe injury, occupational illness, major system damage, or reversible severe environmental damage; (3) Injury requiring medical attention, illness, system damage, or mitigable environmental damage; (4) Possible minor injury, minor system damage, or minimal environmental damage.

The letter of the hazard level represents the Frequency of Occurrence. The letters represent: (A) Expected to occur frequently; (B) Will occur several times in the life of an item; (C) Likely to occur sometime in the life of an item; (D) Unlikely, but possible to occur in the life of an item; (E) So unlikely, it can be assumed occurrence may not be experienced.

As can be seen from the table, each hazard level is associated with a risk category. Risk categories assist risk-management team members in differentiating credible high-hazard threats that may result in loss of life and property from less probable risks, therefore aiding management in risk vs. cost decisions.



HAZARD RISK ASSESSMENT MATRIX

	Hazard Categories			
Frequency of Occurrence	1 Catastrophic	2 Critical	3 Serious	4 Minor
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

🟥 Unacceptable 🟨 High 🟧 Medium 🟦 Low

Figure 6: THA Matrix

This hazard risk assessment (including variations thereof) is well known and widely used in the explosives industry. Although task specific it does not allow for proper consequence assessment and can also be very idiosyncratic with the outcome very much related to the experience of the individuals around the table. The approach to minimize consequences to unplanned events is also very circumstance depended. No holistic approach is followed and cost is always a factor.

Maybe it’s time to change

4. INSENSITIVE COMMERCIAL EXPLOSIVES (ICE)

The question “Why would this be feasible?” Is one of many legitimate questions that can be asked? Let us look at some of the advantages that insensitive munitions bring to the military industry:

- Weapon platform survivability (huge financial benefit)
- Safety of own forces (minimising injury and loss of life)
- Reduced safety distances (enhanced process safety and increased storage capacity as well as reduced footprint)

These benefits are achieved by optimising and developing:

- Less sensitive explosives formulations

- Implementing mitigation systems into the actual munition system
- Evolving packaging technology

All of these are brought together by a global standardisation body. In short one set of rules applicable to everybody.

Lets now look at some of the advantages ICE can bring to the commercial environment:

- Reduced safety distances
- Alternative modes of transportation can be considered (Air)
- Alternative manufacturing and application technology
- Safety to civilians (close to factories and on transport routes)

These benefits are achieved by optimising and developing:

- Less sensitive explosives formulations
- Implementing mitigation systems into the actual systems (explosives systems, transport containers)
- Evolving packaging technology

4.1. What is needed

To successfully reap the benefits of ICE the following is needed:

- A legally recognised global body that can develop, compile and enforce compliance to standards
- Willingness of legislators to accept change and set realistic requirements for ICE.
- Identification of specific tests to be conducted and define compliance criteria in order to proof insensitive characteristics of explosives.

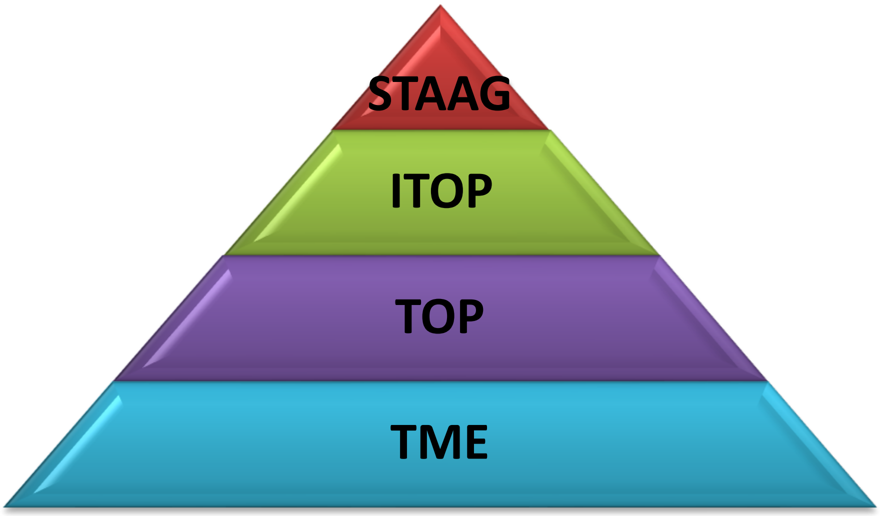


Figure 7: Standardization Approach

(STAAG – Standard Allied Agreement, ITOP – International Test Operation Procedure, TOP – Test Operation Procedure, TME – Test Method Establishment)

Figure 7 shows a standardization approach that could be followed to ensure global alignment of tests and test methods. Related to this is the standardisation of risk assessment and hazard identification techniques and systems.

5. CONCLUSIONS

Whether it is directly or indirectly, explosives incidents and accidents are more often than not related to human interaction. Common outcomes of accident investigations are changes in operating instructions, process conditions, training regimes, etc. This approach leads to the adoption of the "shifting baseline syndrome" in many manufacturing companies. This means that safety targets for next year is set based on the performance of this year. The implication of this approach is that safety targets quickly become unrealistic and consequently people perceive such targets as just another number on a piece of paper.

A standardised approach leading the development of insensitive commercial explosives can open a new era in the commercial explosives industry. Technological advances are taking the world by storm and if we do not acknowledge this and adapt accordingly the future could prove to be bleak. IM developments prove that explosives safety can be achieved in multi-disciplinary facets. Science can give the commercial explosives industry:

"explosives which reliably fulfil their performance, readiness and operational demand, but which minimise the probability of inadvertent initiation and the severity of collateral damage to manufacturing and application platforms, logistic systems and personnel".

6. TAKE HOME MESSAGE

Learn from the past but embrace the future.

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