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THE EFFECTS OF ENERGETICS MATERIALS AGEING ON SYSTEM IM RESPONSE

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The Insensitive Munitions European Manufacturers Group (IMEMG) is a European organisation which assembles leading European armament groups working with IM Technologies: ammunition, energetic materials & components. 20 member companies from France, Germany, Italy, Norway, Sweden and the United Kingdom combine their efforts through IMEMG. At a time when national administrations in Europe are gradually adopting IM policies for their armament procurement, the main European manufacturers combine their expertise to promote and implement standard rules regarding ammunition requirements. In particular, IMEMG members work together to demonstrate that new developments in munitions safety do exist: technologies and techniques for mitigating the hazard presented by munitions are operational and in force.

An Expert Working Group (EWG) was established in 2011 to consider the effects of age on the IM response of munitions. It was quickly recognised that this is a very diverse and challenging subject; for that reason the group decided to focus their initial efforts on the effects of cast-cure PBX formulations on IM response.

The following terms of reference were agreed:-

- Analyse how energetic materials degradation can affect munitions IM response
  - Perform a Fault Tree Analysis (FTA)
  - Perform a Failure Modes and Effects Analysis (FMEA)

- Establish state-of-the art with respect to ageing of energetic materials:-
  - Review International standards (including Draft STANAG 4666)
  - Review and collate published test data for aged energetic materials, e.g. chemistry, kinetics etc. (including the European collaboration on KS-32 ageing)
  - Identify situations where ageing has affected IM properties

- Identify data with which to validate the proposed failure modes
- Identify gaps in data and knowledge
- Write a final report & make recommendations on future work

It was noted by the group that various classes of energetic materials would need to be considered. These are:-

- Cast-cure PBXs
- Composite propellants
- Melt-cast IM formulation (TNT based)
- Pressed compositions
- Gun propellants

It was also agreed that certain classes of energetic materials would be excluded from investigation. These are:-

- Primary explosives
- Double based propellants

Initial Output – Cast-cure PBXs

The group have focused their efforts on cast-cure PBXs by creating a logic diagram in the format of a Fault Tree Analysis (FTA). This analysis considers a higher order reaction to IM stimulus to be the overall effect and establishes the links between the higher order response and (i) charge-scale effects (e.g. increased likelihood of SDT or DDT) and (ii) energetic material-scale effects (e.g. cracked explosive, changes to binder system). The logic diagram enables the links between munitions/charge-scale tests & explosive charge/energetic materials tests to be made. It is noted that the logic diagram is constructed from an unbiased hierarchy of likely failure modes and the probability of individual events occurring has not yet been formally considered.

The benefits of the logic diagram are:-

- Provides an overview of effects of energetic materials properties on IM response
- Collates International test methods and specifications
- Identifies which tests offer the most value (i.e. most frequent occurrence in logic diagram)
- Provides opportunities to influence test programmes for life extension and in-service support
- Highlights gaps in test programmes and test data
- Illustrates the true value of individual test data when trying to understand the 'bigger picture'
- Provides a useful tool for assessing the effects of explosives ingredient or process changes in addition to ageing effects

Initial Conclusions

The approach used by the EWG for cast-cure PBXs is generic and it can be applied to other classes of energetic materials such as melt-cast and pressed PBXs or composite propellants. The 'logic diagram' establishes the links between the properties of energetic materials and the system level response in IM tests. Furthermore, links are made to the tests that are actually performed.

The tests that offer significant value to surveillance programmes can be easily identified using this approach and those materials/charge-scale failure modes that could cause system IM response to change can be identified. The 'fault tree' format could also be used to prioritise any mitigating action to protect against particular failure modes.
A preliminary conclusion of this initial investigation is that cast-cured PBXs are known to be chemically and physically stable materials. The magnitude of age-related changes to cast-cure PBX properties is generally small and it is difficult to envisage a situation where this class of energetic material would cause IM response to change dramatically.