Insensitive Munitions and Energetic Materials Technology Symposium
24-28th April 2006 - Bristol, UK

Insensitive Munitions European Manufacturers Group (IMEMG) www.imemg.org

IMEMG aims for Harmonisation in Insensitive Munitions Assessment

Authors: Members of IMEMG Expert Working Group on IM Policies

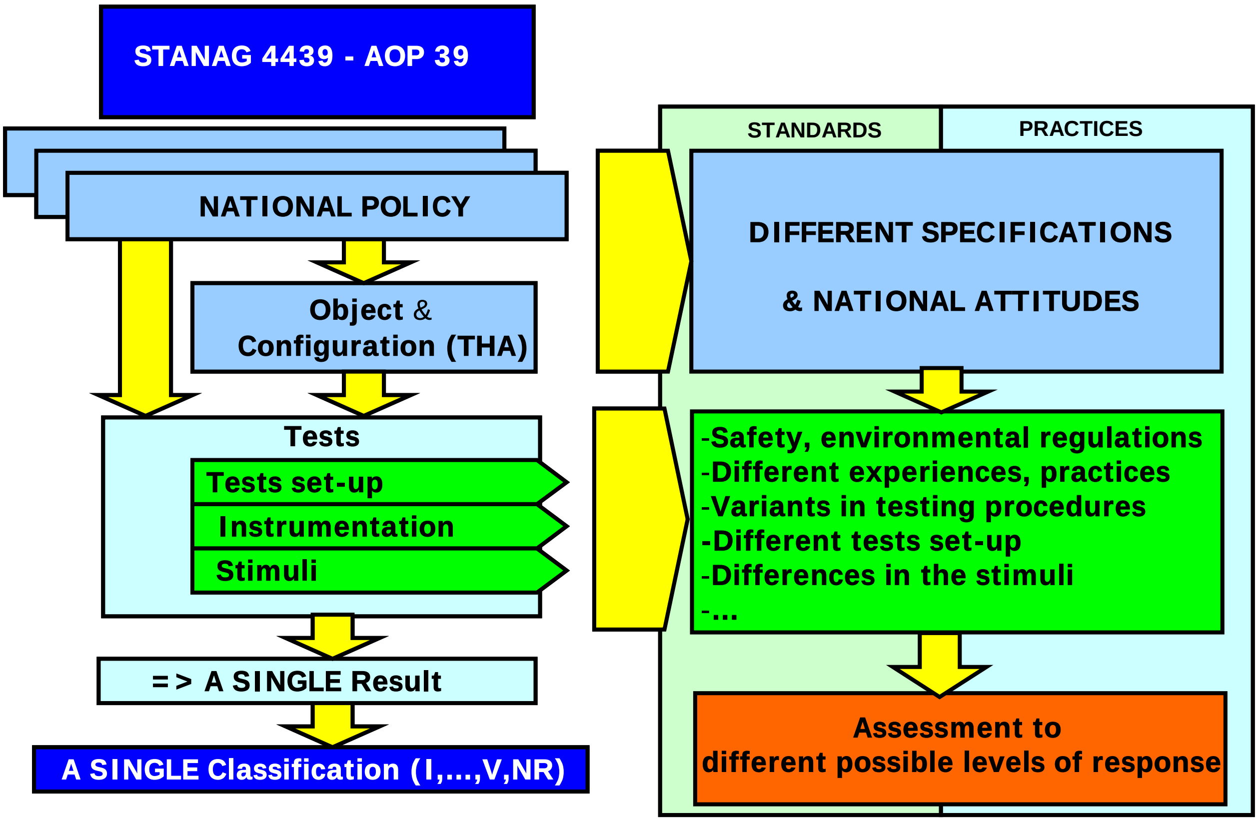
Giat Industries; Regis AUMASSON – **TDA**; Joel FERRON – **EURENCO France**; Yves GUENGUANT – **BAE SYSTEMS**; Ron E HOLLANDS – **RHEINMETALL**; Ms Almuth KEßLER, Gerhard HUBRICHT – **MBDA.UK;** Ron SCOTT – **ROXEL**; Hakim TAAZIBT – **AWE**; Mike TILL – **Snecma Propulsion Solide**; Jean-Pierre VIDAL - **MBDA.F**; Michel VIVES – **PROTAC**; Didier ZANELLI

I - SUMMARY.

The Insensitive Munitions European Manufacturers Group (IMEMG) has created an Expert Working Group (EWG) comprising representatives from the Industry. The activities of the EWG have involved the review and comparison of national IM policies, paying special attention to munition assessment procedures and also a technical analysis of the testing practices and methodologies adopted by each country.
The overall aims of this EWG are to identify areas where testing practices in France, Germany and the United Kingdom differ and to propose ways in which, national requirements can be harmonised, making recommendations to the appropriate National Authorities.
This paper presents the first results of this joint work, it shows how inconsistencies and lack of definition in the current STANAG 4439 associated testing procedures and supporting AOP 39 document can lead to differences in interpretation by those conducting the trial.

II - ACTUAL PROBLEMS OF THE TEST STANAGs IN THE IM ASSESSMENT LOGIC.

The following flowchart summarises the process and logic from STANAG 4439, the NATO standardisation agreement about policy for introduction and assessment of insensitive munitions, for the munitions classification to a given stimuli.



Flowchart 1: Position of the IM test STANAGs in the IM assessment logic.

Most of the OCCAR countries have established their own IM national policy which details the application methods and some specific requirements. These policies encompass the national needs and also results from different past experiences. For the munitions classification to a given stimuli, all these IM policies refer to the process and logic from STANAG 4439, the NATO STANdardisation AGreement about policy for introduction and assessment of Insensitive Munitions. Of course, countries that do not have their own policy may find support in the existing ones and also in STANAG 4439 itself.

These differences in national policies have resulted in different munitions requirements, also in different test specifications and often in different test configurations. One can also argue that munitions life cycles could differ from one nation to another or from one user to another.

The testing establishment defines the test set-up and the instrumentation in accordance with the test STANAGs and also the local regulations (health and safety, environment). Test STANAGs provide very good and essential support, but sometimes it is difficult to distinguish what is mandatory and what is recommended or simply proposed. Additionally, each specifying authority, each test establishment has its own experiences, its own practices.
Also, the degrees of freedom offered in STANAG requirements have to be defined more precisely in order to be able to perform the test or to avoid discrepancies due to the physical characteristics of the stimuli itself. These different allowed ways for performing the tests according to the STANAG induce consequences in the test results. (for example, the distance from surface of the fuel to the axis of the specimen).

Of course, everyone understands that these differences could lead to different test results and test analysis. As examples: a vertical mock –up at testing may not exhibit the same debris map as a horizontal one, a given bench may restrict the spread of fragments or an oven body may modify air blast pressure measurements…

Finally, the classification authority establishes the level of response based upon the results that are observed and measured. As mentioned, AOP 39 defines quite accurately the boundaries between each of the successive levels of reaction, but boundaries between the levels of reaction tend to remain imprecise areas, where there is still room for interpretation.

Of course the harmonisation process has been launched and future revisions of STANAGs will significantly contribute to it. All this represents an important contribution towards standardisation by the involved organizations, such as AC 326, National Safety Authorities or MSIAC.
However on the other side, the increasing need of interoperability requires reliable exchanges of information and also shows the limitations of the present situation. Everyone would expect a unique classification of munitions response to a standardised stimulus whatever were the test centre or the nation or etc. Unfortunately for the time being this is not always the case.
This led the IMEMG Board to create the IM Policies Expert Working Group with the terms of references presented earlier.

III - OBJECTIVE OF THE IMEMG Expert Working Group

EWG work set up a database of top level national policy documentation and has offered a greater mutual understanding of the advantages and disadvantages of the various national approaches to be developed.
This work has highlighted the important support of the National Authority publications and in the MSIAC documents.

This in turn may give rise to variation in results and IM signatures which could preclude the NATO inter-operability goals. The EWG has tackled its tasks by making a detailed review of the STANAG test methods and associated procedures; They address:

Liquid Fuel / external fire (FCO),	STANAG 4240 ed 2
Slow Heating (SCO)	STANAG 4382 ed 2,
Bullet Impact (BI),	STANAG 4241 ed 2
Sympathetic Reaction (SR),	STANAG 4386 ed 2
Fragment Impact (FI)	STANAG 4496 ed 1, draft
Shaped Charge Jet Impact (SCJI)	STANAG 4526 ed 1.

Main areas of the text, open to interpretation through lack of clarity, have been identified and the ways in which each nation interprets these requirements have been compared with the objective of specifying best practice.
The goal is to review the IM test STANAGs to see how tests can be conducted to give results which can be shared with confidence between national agencies thereby avoiding questions over interoperability.

IV - TESTS STANAG ANALYSES

In the following parts, are presented, for each STANAG, the main results of the IMEMG EWG analysis comparing the different testing procedures of United Kingdom, Germany, France, where first hand experience can be utilised.

IV – A – STANAG 4240; LIQUID FUEL FIRE.

IV –A1 - Main points of interpretation.

The test arrangement is not described accurately enough and without acceptance criteria, misunderstandings on the result can arise.

IV – A2 - National approaches and practices.

United Kingdom:

Option sometimes taken to use mini-fuel fire procedure given in OB Pillar Proceeding P103; 4th February 1992.

Some munitions exceed size limitation in mini-fuel fire so a decision needs to be made whether to use mini or large scale test.

Four thermocouples are stipulated; positioning of further thermocouples added at discretion; generally two more thermocouples are used.

The type of blast gauge used and positioning can vary according to the test establishment.

Germany:

As for Hazard Classification and in an effort to protect the environment, wood is also used in place of kerosene as fuel.

Generally the 4 stipulated thermocouples are used. A blast gauge with an electric transducer is used; the position depends on the requirements.

Height above fuel is chosen according to the STANAG requirement.

The configuration of the mini fuel fire is sometimes also taken. Additionally in the past also the bonfire testing (with wood instead of kerosene) was used in Germany for some selected features

France:

France now only performs the fuel fire test according to STANAG 4240 and not according to the previous French technical specification (IT 9282-1)

The mini fuel fire test is not performed because it is considered that the standard configuration is able to cover all the cases. The mini fuel test is just considered as an example for of a particular configuration.

The minimum number of thermocouples specified is considered insufficient to characterise the fire so more than 4 are used.

The level of reaction may be demonstrated reading across from similar weapons or moke-up, modelling and analysis, energetic material characterisation, laboratory scale and small scale tests.

IV – A3 – Remarks.

The fuel fire test procedures performed in the three countries are very similar. Nevertheless, the test arrangement is not described precisely enough in the STANAG, for example the type of the blast gauge or the height of the fuel / maximum time of burning.

The positioning of the test item is not specified and can lead to variability in height above the fuel level. The minimum height above the fuel is the only one specified and no maximum is defined.
For a better comparison and an appraisal of the results, it would be helpful to describe the detailed test items in the testing report and to avoid misinterpretations, the test arrangements should also be precisely described.
The minimum acceptable temperature of the fire was decreased in edition 2 of the STANAG but this low temperature can lead to instabilities in the fuel fire which could induce discrepancies in the test result. Today, most of the database has been compiled with fires close to 1000°C and these disparate conditions could make it difficult to implement homogeneous databases.

VI – B – STANAG 4382; SLOW HEATING.

V –B1 - Main points of interpretation.

Two optional very different gradients of heating are possible for performing the test; 3.3 °C/hr or a gradient of heating determined by the Threat Hazard Analysis with a default rate of 25 °C/hr.
The possible thermal gradient in temperature observed in the oven (should not be > 5 °C) can modify the level of reaction according to various test set up and specially the orientation of the munitions. In fact a thermal gradient in the oven can modify the point where the article under test will be ignited and thus lead to a more or less severe reaction.

V – B2 - National approaches and practices.

United Kingdom:
The availability of the THA from Customer is often in question.
In the absence of THA the standard 3.3°C/h condition is used.
Number of thermocouples and positioning can vary compared with the minimum of four as stipulated.
Germany:
The gradient of heating is generally 3.3°C/h; depending on the ammunition, preconditioning is usual.
The air exchange is illustrated with a diffuser. As a result of the test arrangement blast measurement is not feasible.
5 thermocouples are normally used.
France:
The option invariably taken is to perform the test at 3.3°C/h. This covers all the possible cases as it is considered to be the more severe configuration.
Different heating systems are used with a natural or a forced convection according to the orientation of the munition in the furnace.

V – B3 – Remarks.

The test set up inducing different thermal exchanges (natural or forced convection, conduction) can lead to a thermal gradient inside the oven. The thermal gradient in the furnace should be not greater than 5°C but may not be detected by the thermocouples and can modify the level of reaction according to the starting point of ignition.

In some case, the munition can stand up in a vertical position or in a container which is not fully detailed by the STANAG. The requirements on these points are not well defined. Today most of the databases haves been built with test results obtained at 3.3 °C/h and with such disparate test conditions, it is difficult to compile a homogeneous database.
The heating rate, 3.3°C/h is not considered to be a realistic case but certainly it covers all the worst cases and if a specimen does not pass at 3.3 °C/h test, then the chances of success at 25°C/h are very weak.
Without clear acceptance criteria for the test set up and a detailed report it is difficult to have a clear understanding of the test results.

VI – C - STANAG 4241; BULLET IMPACT.

VI –C1 - Main points of interpretation.

STANAG 4241 Edition 2, promulgated in April 2003, offers some degree of freedom or interpretation for setting up the test or for performing instrumentation.

The main points identified are:

- Initially the choice of the type of test procedure between two options, procedure 1 or procedure 2, which could lead to results that are not comparable. The reasons are that Procedure 1 is a standardized test intended as a means of jointly assessing Insensitive Munitions and Hazard Division (HD 1.6) requirements. The test Procedure 2 is a flexible test that can be tailored to take into account the threat Hazard Assessment, the round burst and the type of projectile.
- Secondly, the allowed range of temperature of the item could introduce misinterpretations in the test results and perhaps its reaction level could also be different according to the sensitiveness of the energetic components and the properties of non explosive sections.
- Thirdly, the test item configuration could also cause misunderstanding in the test results based on potential discrepancies between packaged or unpackaged ammunition and all-up-round test that contains more than one major pyrotechnic component which may be tested either individually or as all-up-round.

VI – C2 - National approaches and practices.

United Kingdom:
The UK approaches and practices are the following:
If there is no doubt concerning the definition of the bullet, the lack of THA availability means that the Procedure 1 is usually taken.
The round velocity requirement stated in the STANAG (850 +/- 20 m/s) enforces conditioning at low temperature of the M2 0.5in AP projectile.
For Procedure 1, a three round burst is specified in the aim of the STANAG but not mentioned elsewhere in the other part of the document. All trials carried out by Land Systems involve single shots.
For Procedure 1, two tests are required, one aiming at the main explosive component and the other at the most shock-sensitive explosive component excluding the booster. It is not clear what is meant by “booster” in this case.
Germany:
Procedure 1 is also usually chosen with the M2 0.5 in AP projectile but the three round burst is not applied and the trials carried out by testing centres involve two shots performed with 2 different weapons due to the rate of fire and the precision of the impact.

The three other difficulties observed by the testing centres for the test set-up and the instrumentation are the determination of the blast pressure, the very low tolerance of the bullet impact velocity and the respect of the target area (5 cm circle).

France:

Procedure 1 is also mainly used with the standard attack munition M2.

Procedure 2 is sometimes used. In such case, to fulfil the requirement the velocity of the bullet impact must be adapted and determined for staying in the body. The case where the bullet stops inside the ammunition is considered as the worst case for the item.

Most trials carried out by the French MOD involve single shots instead of a three shot burst.

VI – C3 – Remarks.

The points of interpretation described above lead each country to adopt national practices according to their own experience and expertise.

National practices analysis shows that the standard Procedure 1 is usually chosen rather than Procedure 2.

The two procedures do not cover all the possible mechanisms of reaction with a such threat (SDT, DDT, XDT) and are so different in the test configuration and in the stimuli reaction that they should lead to two separate STANAGs.

VII – D - STANAG 4386; SYMPATHETIC REACTION.

VII –D1 - Main points of interpretation.

According to the text, there are at least 2 different objectives for this test; one is the Hazard Classification and the other the assessment of IM in accordance with STANAG 4439. This can result in different test arrangements and, for that reason, different results. A discussion could be initiated to see how it is possible to harmonize the protocol.

As the STANAG 4439 does not describe a precise test arrangement, the interpretation of the results are, may be very ambiguous.

VII – D2 - National approaches and practices.

United Kingdom:

The diagram of stack vague.

No mention of inclusion of boxes or containers.

No mention of shaped charge. Munitions usually initiated by L2A1 detonator onto booster pellet.

Is “in the design mode” the same as “the normal means of initiation”?

Germany:

Test configuration like in storage. It depends on the type of munition and their requirements.

France:

The worst configuration in terms of safety (French regulation)

Distance between the munitions determined from logistics requirements and this distance may depend upon users

A single test is performed. The purpose (§ 7.a) requests the most likely in-service situation for the test. Why do two tests have to be performed (§ 9.b.3)?

VII – D3 – Remarks.

The requirement regarding the external confinement is very vague.
As donor, "to initiate the rocket motor with a credible threat"? What is credible and how to manage the effects of the "credible threat" upon the acceptor.
Type of ignition (ignition chain) is not a realistic threat. Ignition i.e. with a shaped charge attack is more realistic.

VIII – E - STANAG 4496 ed 1 draft; FRAGMENT IMPACT.

VIII – E1 - Main points of interpretation.

This new STANAG (first edition in ratification process) can be analysed but no feed-back can be produced. Remarks given come from experience with other standards (Mil-Std 2105B, French MURAT Doctrine,…) and study output like the excellent L86 NIMIC Report.
The STANAG defines precisely the fragment mass, nevertheless the steel grade is not specified the projectile drawing is confusing. The projectile shape (l=d) appears as inappropriate to guarantee a stable flight and the impact incidence angle would be variable.
This STANAG is open to interpretation about the impact velocity, the aiming point, the method of item restraint, and other parameters.

VIII – E2 - National approaches and practices.

United Kingdom:
No minimum Brinell hardness given for projectile; suggested range 150-270.
Currently the projectile velocity given in Procedure 1 (2530 m/s) cannot be achieved. A new trials gun is being manufactured in the UK.
THA often not available.
Method of restraint open to interpretation.
STANAG does not state that tests should be carried out on separate munitions. Land Systems use separate munitions, eg one shell for each shot.
Germany:
As defined
Generation of fragment high velocity is expensive and they are not considered a threat for gun ammunition.
France:
France performs two types of fragment impact test:
A light impact test with a simultaneous burst of 3 steel cubes up to 2000m/s
France has got a lot of experience with the heavy impact test witch (?) uses a 250g steel sphere up to 1650m/s. The sphere geometry allows for a wide and reliable modelling data base.
The velocity of the bullet impact has to be adapted and determined according to the worst case for the item.

VIII – E3 – Remarks.

The change of the STANAG for using a spherical fragment will give a higher repeatability of the stimulus (dispersion due to the impact angle). In all cases, the definition of the projectile has to be better specified. (Projectile geometry on drawing, tolerances on the dimensions, angles have to be specified in a better way, grade of steel defined).

In general, the lack of a real specification for fragment velocity can induce some misinterpretation on IM signature. The examination of the “degree of confidence in the results” through computer modelling and the probabilistic approach is interesting. Nevertheless, no method (or reference) is indicated.
We do not find in this document elements of standardisation which will lead to comparable test results.

IX – F - STANAG 4526; SHAPED CHARGE JET IMPACT.

IX –F1 - Main points of interpretation.

The stimulus is not very well defined, mainly if you do not use “Rock-eye” warhead.
The equivalence to the Rock-eye shaped charge is not quite evident .

IX – F2 - National approaches and practices.

United Kingdom:
Rock-eye (or equivalent) specified in Mil Standard is used. Land Systems have used IBL 755 (50mm) rounds but are now moving to M42 (MLRS bomblet; approx 34mm).
THA not always available.
Germany:
DM 1383 bomblet is used; if necessary with shielding.
Shell in configuration with its booster/fuze
France:
France performs the test with a 62 or a 80mm shaped charge without shields.
According to the French application document of the STANAG, the residual jet must be able to pierce 300 mm of steel

IX – F3 – Remarks.

Ed1 not ratified
The main part of the text is very ambiguous, with conflicting recommendations.
Why include “sympathetic reaction” comments inside this STANAG?
The test procedures are not sufficiently specified. The threat is realistic but for a comparative test it is essential to have a standardized stimulus. The studies of the last decades have proved that the influential parameters are the diameter, the velocity and the material of the jet. So it seems necessary to define the characteristics of the jet.
When including the SR-Test, the initiation of the shell is more realistic than in the STANAG 4396 (see SR)

X – CONCLUSIONS and RECOMMENDATIONS.

The maximisation of benefits to be gained from IM is an International concern which requires common means of interpretation.
Despite the progress in harmonizing the test STANAGs with reference to STANAG 4439, these documents are still not precise enough to ensure full interoperability with no misunderstanding.

The IMEMG analysis, from an Industrial point of view are limited at the moment to three involved countries as outlined the main point of interpretation for each test and the general remarks are:

- A lack of clear acceptance criteria for any tests, no tolerances are given for measurement properties, few items appears as mandatory,
- We have the choice between various threat levels (according to THA …), that is consistent if the munitions life cycle is always the same or equivalent in the different forces. In the contrary case, the IM signature cannot be used as an interoperability parameter. If for a warhead the THA specifies that the maximum impact velocity is 1800m/s and that it does not detonate at this velocity but it detonates for a higher impact velocity, what is its IM signature in a one for one applications?
- Requirements and procedures are mixed together which could result in serious misinterpretations within the documents,
- To avoid misinterpretation the test arrangement should be described very precisely in the test report.

Facing this situation IMEMG EWG suggestions are :

* To define for every test what are the critical parameters open to interpretation,
* To specify the boundary conditions for test/stimuli parameters in relation to acceptance criteria,
* To describe the test arrangement precisely in the test report to avoid misinterpretation of results,
* To harmonise UN Hazard Classification and IM testing by choosing a single test variant, the more severe one.

In order to facilitate full interoperability IMEMG should request AC/326 and working groups partners (MSIAC) to harmonise IM tests STANAGs in line with those proposals. IMEMG embrace these goals and is ready to participate in this effort.

REFERENCES:

1 - STANAG 4439 ed 1 Policy for introduction, assessment and testing for insensitive munitions (MURAT)
2 - AOP 39 Guidance on the assessment and testing for insensitive munitions ed 1; 06/97
3 - STANAG 4382 ed 2 Slow Heating
4 - STANAG 4240 ed 2 Liquid Fuel / external fire
5 - STANAG 4241 ed 2 Bullet Impact
6 - STANAG 4386 ed 2 Sympathetic Reaction
7 - STANAG 4496 ed 1 Fragment Impact
8 - STANAG 4526 ed 1 Shaped Charge Jet Impact
9 - ONU recommendations for transportation ST/SG/AC.10/1/Rev 13
10 - Manuel of NATO principles for the hazard classification of military ammunition and explosives AASTP3
11 - French implementing document: instruction n°260 DGA/IPE; (ed 04/08/93)
12 - MIL-STD-2105 C Hazard assessments tests for non nuclear munitions; 12/01/03

13 - Fragment impact testing; NIMIC's review and proposal, NIMIC L86 report ;M Ficher – F Peugeot, 30/04/2002
14 - The use of small-scale testing and modelling in IM assessment; NIMIC L83 M Sharp; 8/02/2002
15 - IM signatures, Hazard Division and Labelling; NIMIC L84 P Marchandin; 30/01/2002
16 - Workshop on Sympathetic Reactions; NIMIC-S-374-95; June 1995.