

2019 Insensitive Munitions & Energetic Materials Technology Symposium  
Seville, Spain

**NATO AC326 Subgroup B Ammunition Systems Design and Assessment –  
Insensitive Munitions Test STANAG updates**

Ken Tomasello  
*IM Office, Naval Ordnance Safety and Security Activity, Indian Head, MD, USA*

Christophe Jacq  
*DGA Missiles Testing (French MoD), France*

Ernest Baker, Michael Sharp  
*Munitions Safety Information Analysis Center (NATO), Brussels, Belgium*

During the past three years all seven of the Insensitive Munitions (IM) test STANAGs and Allied Publications (AP) have been updated. Each document has been updated to the current NATO standardization requirements spelled out in AAP-03K as well as brought up to current best practice and testing methods agreement between the NATO nations. The overarching IM test documents STANAG 4439 and AOP-39 for Policy on the Development and Assessment of Insensitive Munitions were part of the update. This included a full reorganization of AOP-39 and the creation of a new Standards Related Document (SRD) SRD AOP-39.1. The reorganization of the AOP and addition of the SRD greatly simplifies and removes redundancy from all of the IM test standards. The guidance provided by the updated standards will ensure more consistent testing and evaluation of ordnance hazard assessment testing for all NATO and partner nations. This paper describes the background, changes and status of the updates.

## **INTRODUCTION**

International policy, guidance, protocols and assessment on Insensitive Munitions (IM) are mandated or discussed and detailed in NATO policy documents. NATO overarching IM policy document is STANAG 4439, Policy for the Introduction and Assessment of Insensitive Munitions (IM). Under direction of the NATO CNAD Ammunition Safety Group, a number of Custodian Working Groups have been reviewing and updating the NATO full-scale test STANAGs and changing the document structure and organization to reflect a change in approach to development and maintenance of NATO Standards. Working Groups have completed reviews of STANAG 4439, as well as the Bullet Attack, Fragment Attack, Fast Heating, Shaped Charge Jet and Slow Heating full-scale test STANAGs, creating an AOP under the cover of each of the test STANAGs. A Working Group is currently nearing completion reviewing the Sympathetic Reaction Test STANAG. In addition, an update of AOP-39 has been completed, but limited to the Response Descriptors (Annex I) and full-scale testing (Annex H). The review of Annex H has rebalanced the text and requirements between this and the full-scale test documents. The review and update of Annex I has looked at the Response Descriptors and reviewed assessment criteria.

## **BACKGROUND**

Prior to the start of the review of AOP-39, Annex H, MSIAC was tasked by the document Custodian, France, to undertake a review of all the full-scale testing requirements and guidance in the relevant documents. Figure 1 shows the timeline for promulgation of previous and planned future NATO IM, as well as HC, related documents. Of note is that the last update of any the full-scale test policy documents was in 2006 with the majority last updated in 2004. STANAG 4439 has been updated twice since the last full-scale test STANAG was promulgated, which included additional

requirements and guidance with respect to test conduct that should have resulted in consequential changes for the full-scale testing STANAGs.

As a result, a lack of consistency has developed between the policy in STANAG 4439 and the full-scale test STANAGs. As a consequence, Edition 3 of AOP-39 (Annex H) updated requirements and guidance for the conduct of all the full-scale tests were often overlooked as they were not referenced by the full-scale test STANAGs, or other relevant NATO documents (including AASTP-3 on HC).

A number of other factors also led to the current review of all test related standards and guidance. There have been pressures to change full-scale test procedures to reflect more efficient testing methods and to take into account our improved understanding of threats and munition response. Recent changes in approach and policy on NATO documents led to an opportunity to review and restructure all the IM policy documents. A review was also undertaken of the Response Descriptors detailed in AOP-39 and the UN Recommendations on the Transportation of Dangerous Goods – Manual of tests and Criteria (ST/SG/AC.10/11/Rev.6 Appendix 8) back in 2013. This provided an opportunity to determine whether earlier changes made in 2009 had satisfactorily addressed needs by analyzing experience by nations conducting subsequent assessments.

The updated full-scale test Standards have, or are being written to comply with NATO policy consisting of a covering STANAG and an associated AOP for each full-scale test. All the full-scale test documents are developed to have a consistent structure and standard. A new class of NATO document, a Standards Related Document (SRD) allows all common information to be contained in a single reference document. It was decided by the Custodian and working group that an SRD would be drafted to support STANAG 4439 and AOP-39. This resulted in creation of AOP.39.1 Guidance on the Organization, Conduct and Reporting of Full Scale Tests, Edition A Version 1, May 2018. This was undertaken to also address the concern that AOP-39 – Annex H was being overlooked and it was the intention that test guidance be removed from AOP-39 into this new document. It is noted that the removal of this Annex has yet to be completed resulting in some duplication of guidance. It is intended that this will be addressed as part of the IM/HC Harmonization effort referred to later in this paper.

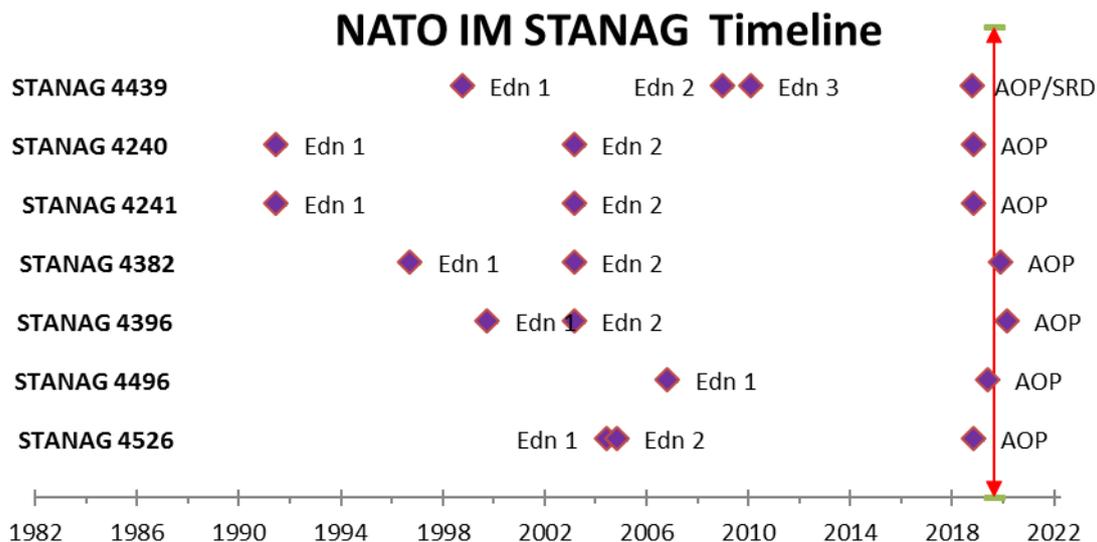


Figure 1. IM STANAG and AOP Timeline

### NATO DOCUMENTATION POLICY

NATO documentation is structured hierarchically as follows and shown in Figure 2:

- Covering Document (only STANAG or STANREC).
- Allied Publication (NATO or Civil standards, AOP, AASTP).
- Standards-related document (SRD).

Each has different principles and processes associated with them.

STANAG. A STANAG is:

- A stand-alone document that covers one or several subject-related Allied Standards.
- Has to be ratified and then promulgated.

Allied Publication (AP). Where it relates to interoperability is promulgated with a covering STANAG. Other aspects are:

- A stand-alone document.
- Only required to be promulgated.
- Requirements based

Standards-Related Document (SRD). A document that supports one or more Allied Standards to support understanding and may provide additional data and information. Examples of an SRD may include User Manuals, Handbooks, Catalogues and Implementation Guides.

Other aspects of an SRD are:

- Will not contain policy requirements.
- Approved and promulgated under a silence procedure.

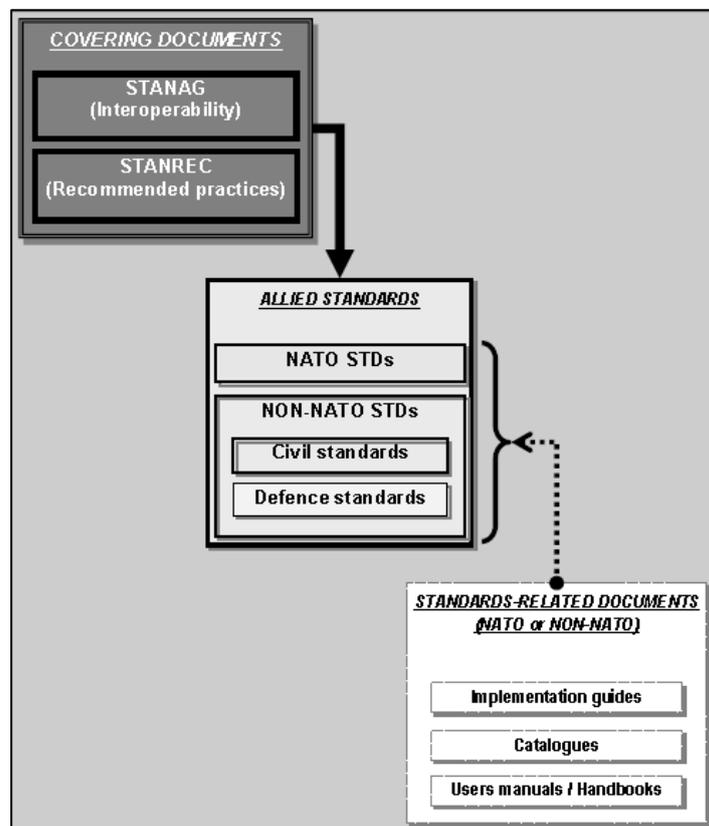


Figure 2. NATO Documentation Levels (AAP-03(K))

Allied Standards and SRDs have more flexibility with respect to updating and amendment than a Covering Document and allow for more frequent, minor updates. Minor changes can be implemented without the need for Ratification of the covering STANAG, major changes however require Ratification which is usually a lengthier process.

### NATO IM POLICY DOCUMENT STRUCTURE AND CONTENT

Based on the MSIAC observations and recommendations, the Custodian and AOP-39 Working Group made a decision on the intended future structure of NATO IM policy and full-scale testing documents. This is shown at Figure 3; changes are as follows:

- STANAG 4439 continues to cover AOP-39.
- There is no substantive change to AOP-39 except the current review of the Response Descriptors (Annex I).
- Each full-scale test STANAG is a covering document with all the test requirements contained in a new AOP, numbered to mirror the covering STANAG.
- The new SRD AOP-39.1 supports all the full-scale test STANAGs and AOPs with common aspects of full scale testing such as reporting, documenting, data collection.

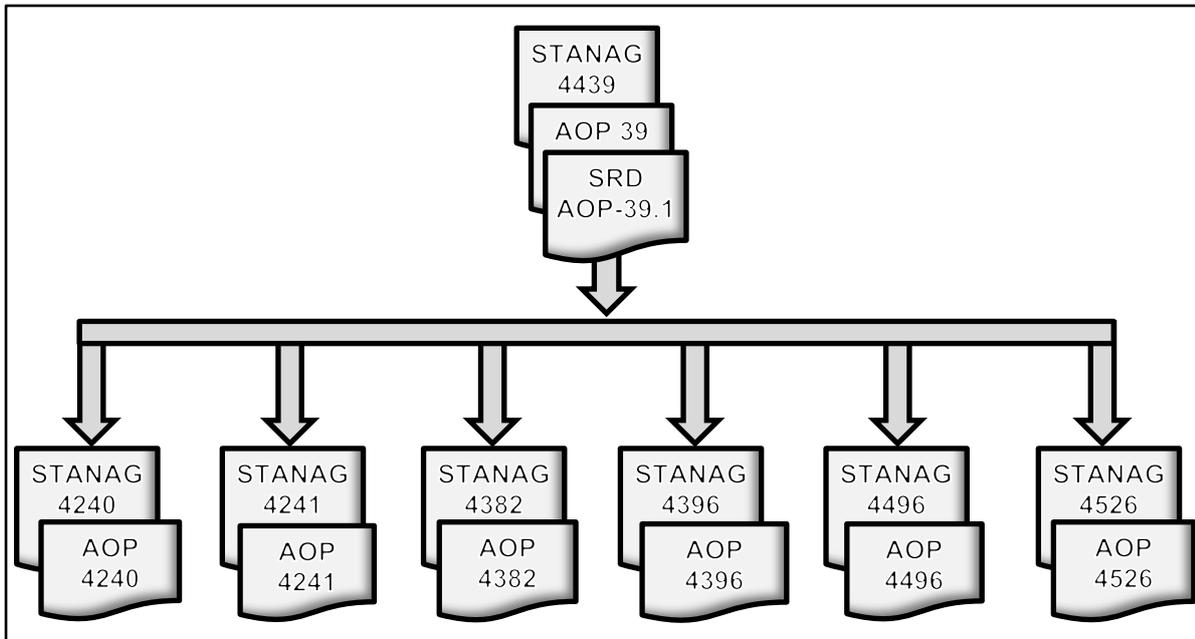


Figure 3. New IM Policy Document Structure

The structure and adjustment of the content is considered in more detail below.

Annex H to AOP-39 is the only part of STANAG 4439 affected by a review of the requirements and guidance for full-scale testing. An outline of the current structure of Annex H and the decision on changes is as follows:

- Annex H retained and revised outlining the structure and relationship between the AOP full-scale test AOPs and the SRD.
- Specific text on the Fast Heating, Bullet Impact and Shaped Charge full scale testing was removed, as this is now included in the associated promulgated AOPs. It is anticipated that the specific text on Fragment Impact, Slow Heating and Sympathetic Reaction will be removed in a further update of AOP-39.
- Appendices 1 – 5 covering generic aspects of full-scale test conduct are now incorporated into the SRD. This covers the following topics:
  - Appendix 1 – Trial Framework.
  - Appendix 2 – Trial Conduct.
  - Appendix 3 – Test Programme.
  - Appendix 4 – Trial Reporting.
  - Appendix 5 – Test Report Template.
- Appendix 6 - no longer relevant.
- Appendices 7 – 12:
  - Generic aspects of full-scale test planning, documentation, data collection and reporting are also incorporated into the SRD.
  - Specific technical aspects of full-scale testing are now incorporated into the full-scale test AOPs.
  - Specific aspects of full-scale test monitoring or reporting are now incorporated into the new full-scale test AOP.

The full-scale test AOP working group reviews have also had the opportunity to input into the content of the SRD and adjust their drafts in line with the future IM policy document structure.

### FULL-SCALE TESTING STANDARDS RELATED DOCUMENT

The key aspect of the SRD is that it contains no policy statements or requirements. The document details guidance or recommendations on best practice to help ensure consistency of data collection between tests and nations. The requirement for what aspects of the guidance in the SRD are to be adopted for each full-scale test will be specified and referenced in the Test Directive sent to the Trials Agency.

The current layout of SRD AOP-39.1 is as follows:

- Test framework, organisation and responsibilities.
- Test programme.
- Test planning and guidance.
- Test specific considerations.
- Documenting.
- Test conduct.
- Reporting.

For consistency of approach, reference terminology has been in the documents for organisations involved in developing, conducting and reporting a full-scale test as follows:

- **Test Programme.** Details all testing to be conducted and is normally produced by the Project or Programme Team. This will include requirements for all safety testing including full-scale testing.
- **Test Directive.** Specifies in detail the requirements for each Individual full scale test.
- **Test Plan.** Details how the test is to be conducted and is normally produced by the Test Agency.

Terms are used generically and there may well be some national differences.

### CHANGES TO FULL-SCALE TESTING

Below is a synopsis of the content of the new full-scale test AOPs. A more detailed description of the working groups review process, resulting changes and reasoning for the changes is contained in [1]. The working Groups have concluded their technical review of the content and detail of the test methods and the major changes as summarized in table 1.

Test	Summary of Major Changes
<b>All standards</b>	Standards have been structured and formatted to meet the new NATO standards requirements
<b>AOP-4240 – Fast Heating</b>	<p>Introduction of new test method to allow other fuels to be used.</p> <p>Introduction of Heat Flux Measurement: a requirement to reach 80 kW/m<sup>2</sup>, and the need to characterise alternative heat sources</p> <p>Improvements in instrumentation</p>

Test	Summary of Major Changes
<b>AOP-4241 – Bullet Impact</b>	Introduction of Test Method 2 recognising that many nations conduct a single bullet impact test. Introduction of alternative 12.7 mm AP projectiles which meet a defined specification
<b>AOP-4382 – Slow Heating</b>	Selection of a new heating rate of 15°C/hour Improvements in instrumentation Improved guidance and requirements on preconditioning (included how to calculate soak times)
<b>AOP-4396 – Sympathetic Reaction (on-going discussion)</b>	Improved definitions to remove differences in interpretations: <ul style="list-style-type: none"> <li>• Confined vs unconfined</li> <li>• Definition of the test item (box vs munition)</li> <li>• Mode of initiation</li> </ul> Recognition of the importance of a calibration shot
<b>AOP-4496 – Fragment Impact</b>	Improved guidance on fragment orientation at impact and the aiming point Additional requirements for a minimum Brinell hardness of the fragment of 190 HB
<b>AOP-4526 – Shaped Charge Jet</b>	Agreement on the threat characteristics for the standard test RPG 61 mm and 95 mm. Agreement on threat specification range: required jet diameter at the target of 2.5 - 3.5 mm, and Held's criteria ( $V^2d$ ) at the target between 120 – 140 mm <sup>3</sup> /μs <sup>2</sup> Identification of new test SCs Agreement on use of jet conditioning plates

Table 1. Summary of the key testing changes.

## RESPONSE DESCRIPTORS

The AOP-39 Working Group reviewed the contents and structure of Annex I to AOP-39 covering Response Descriptors. The review was based on an MSIAC questionnaire and report [2] [3] and subsequent discussions focused on interpretation and clarification of a number of aspects of test conduct, which included:

**Fragment Criteria.** The working group reviewed various aspects such as fragment material density and energy. One of the findings of this work was that the criteria were based on launch energy and not impact energy as originally presumed [4] [5]. Another aspect discussed was consistency in use of fragment energy criteria for IM and UN Hazard Classification (HC) requirements (20J vs. 79J). The working group decided to keep 20J as the hazard metric, but changed it to a 20J impact at 15m criterion, with a different curve for each of several fragment densities.

Each curve indicates conditions where the criterion is exceeded, the point at which a person standing at 15m would be hit with a 20J or more impact energy.

**Primary and Secondary Evidence.** Despite some nations concerns with the Primary and Secondary approach, the response descriptors table retains this approach to account for situations where primary and secondary evidence are not consistent (for example due to scaling effects).

**Articles Under Test.** Guidance is now included on how this should be properly defined for a packaged configuration.

**Propulsion.** A better definition and clarification is now provided. There is now delineation between a Type IV assignment based on a deflagration response vs propulsive event.

**Calibration Tests.** Guidance on the role and purpose of calibration tests is now included.

## FUTURE CHANGES

The work of updating the IM standards to address the lack of consistency is nearly completed. However, these documents should continue to be reviewed on a regular basis to ensure that they reflect best practice. In the meantime, other work is on-going under NATO AC326 aimed at harmonizing the approach to IM and HC and this work will likely result in some consequential changes for tests standards in the coming years.

The goal of this activity is to address some long running concerns, in particular, that we not duplicate effort in assessing IM response and when assigning UN Hazard Division. To address this and other concerns AC/326 Main Group (MG) approved the creation of a Working Group (WG) to review NATO policy and guidance on IM and HC to assess opportunities for harmonisation. Motivations for this work are wide and included the following.

- Nations sometimes classify/assess munitions differently (HC/IM)
- There is a recognized need to exploit available resources and expertise while minimizing duplication of effort
- IM HC assessment and assignment could better support situation specific risk assessment
- The UN manual of tests and criteria development on UN TS 6 are driven by the civil side and could be seen as not fully representative of the military environment. There is a need to develop improved guidance for military munitions.
- There is a perceived need to improve confidence in correctly recognizing the hazard posed by munitions

The working group will also look at using the IM 'Whole Body of Evidence' approach to exploit the wider knowledge for HC purposes. A final objective of the work is to migrate NATO's policy into United Nations (UN) as a revision for UN TS 7, which could ultimately allow the assignment of 1.1, 1.2, 1.3, 1.4 and 1.6 hazard divisions. This paper does not cover the details of this effort but it is worth noting that the following activities will likely impact testing related documentation:

- The effort to harmonize the approach to IM and HC will result in a review of AOP39.1 "Guidance on the Organization, Conduct and Reporting of Full Scale Tests" to ensure that it covers all the UN TS 6 and TS 7 requirements for HC. This document will likely move in the document hierarch to be called up by a new STANAG covering both IM and HC.
- The test STANAGS will be reviewed to ensure that they employ instrumentation required for HC, plus the opportunity will be taken to enhance this and reporting requirements to better capture explosive effect to assist risk assessment.
- Improved guidance on assignment of a Mass Explosion Hazard is required to ensure consistency in the assignment of HC between nations and services. This may result in consequential changes to the SR and FH test standards to ensure this can be determined.

Other requirements to more accurately quantify explosive effects to support explosive storage safety requirements (application of quantity distances) may also result in changes.

## **CONCLUSIONS**

The overarching IM policy documents STANAG 4439 and AOP-39, Policy on the Development and Assessment of Insensitive Munitions, were included as part of this extensive update plan. This included reorganization of AOP-39 test related information and the creation of a new Standards Related Document (SRD) SRD AOP-39.1.

All seven of the IM test STANAGs and Allied Publications (AP) have also been updated. Each document has been brought in line with the current NATO standardization requirements detailed in AAP-03K. The nations have also agreed and introduced best practice with respect to testing methods. The reorganization of the AOP and addition of the SRD greatly simplifies and removes redundancy from the IM test standards. The guidance provided helps ensure a more consistent approach to testing and IM assessment and hazard classification assignment between NATO and partner nations.

Updated versions of STANAG 4439 and AOP-39, as well as the Bullet Attack, Fragment Attack, Fast Heating and Shaped Charge Jet full-scale test STANAGs and associated AOPs have now been promulgated and those involved in testing should ensure that they are now working to the latest standards.

The updated Slow Heating (currently in ratification) and Sympathetic Reaction STANAGs and associated AOPs are nearing completion. A further update of AOP-39 Appendix H is anticipated to remove the specific testing guidance on Fragment Impact, Slow Heating and Sympathetic Reaction, as these descriptions are included in the new test AOPs. Ongoing work is now aimed at harmonizing HC and IM testing into a combined standard structure.

## **ACKNOWLEDGEMENTS**

We would like to acknowledge the STANAG custodians and the Custodian Working Groups for their work in reviewing and updating the IM standards.

## **REFERENCES**

1. Jacq, C., K. Tomasello, E. Baker and M. Sharp, "Review and Update of Insensitive Munitions Test Procedures", Insensitive Munitions & Energetic Materials Technology Symposium, Seville, Spain, 21-24 October 2019.
2. Eich, T., B. Halls, S. Bordachar, M. Sharpe and T. Swierk, "IM Response Descriptors – An Update for Assessment Processes", Insensitive Munitions & Energetic Materials Technology Symposium, Tuscon, AZ, USA, 12-14 May 2009.
3. Sharp, M., "Survey on Insensitive Munitions (IM) Response Descriptors", MSIAC Report O-153, August 2013.
4. Miers, K.T., D.J. Puklak, B.E. Fuchs, "Ballistic Trajectory Modeling for the Insensitive Munitions Type IV/V Hazardous Fragment Threshold", International Explosives Safety Symposium & Exposition, San Diego, CA, USA, 6-9 August 2018.
5. van der Voort, M.M., E.L. Baker, E. Schultz and M.W. Sharp, "Projection Criteria for Insensitive Munitions and Hazard Classification", Insensitive Munitions & Energetic Materials Technology Symposium, Nashville, TN, USA, 2016.