

NATO STANDARD

AOP-4241

**BULLET IMPACT
TEST PROCEDURES FOR MUNITIONS**

Edition A, Version 2

MARCH 2022



NORTH ATLANTIC TREATY ORGANIZATION

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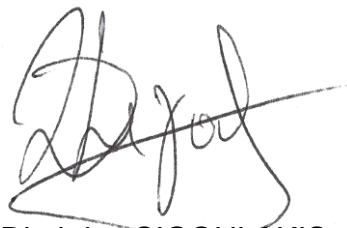
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4 March 2022

1. The enclosed Allied Ordnance Publication AOP-4241, Edition A, Version 2, BULLET IMPACT TEST PROCEDURES FOR MUNITIONS, which has been approved by the nations in the CNAD AMMUNITION SAFETY GROUP (CASG – AC/326), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4241.
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Dimitrios SIGOULAKIS
Major General, GR (A)
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CHAPTER 1 INTRODUCTION

When reviewing requirements for this test, SRD AOP-39.1 should first be read for guidance in the organization, responsibilities and conduct of full-scale testing.

1.1 ANNEXES

- A. Best Practices
- B. Historical Overview

1.2 RELATED DOCUMENTS

STANAG 4439	Policy for Introduction and Assessment of Insensitive Munitions (IM)
AOP-39	Policy for Introduction and Assessment of Insensitive Munitions (IM)
SRD AOP-39.1	Guidance on the Organization, Conduct and Reporting of Full-scale Tests
STANAG 4241	Bullet Impact Test Procedures for Munitions
AASTP-03	Manual of NATO Safety Principles for the Hazard Classification of Military Ammunition and Explosives
United Nations	Manual of Tests and Criteria (ST/SG/AC.10/11)

1.3 AIM

The aim of this AOP is to specify the test requirements and procedures to provide evidence of the response of munitions and weapon systems to the threats represented from being impacted by small arms projectile(s).

1.4 AGREEMENT

1. Participating nations agree that the requirements and methods incorporated in this AOP will be used for determining the response of munitions and weapon systems to bullet impact represented by 12.7 mm Armor Piercing (AP) projectile or more appropriate threat.
2. Participating nations further agree that national standards, orders, manuals and instructions implementing this AOP will include a reference to the STANAG 4241 for purposes of identification.

3. No departure may be made from this agreement without consultation with the NATO Tasking Authority. Nations may propose changes at any time to the NATO Tasking Authority where they will be processed in the same manner as the original agreement.

1.5 DEFINITIONS

For the purpose of this document, definitions of terms to be used to describe test details and events are given in the NATO Terminology Database (NATOTerm) that is available by reference for all Allied Publications.¹

1.6 GENERAL

1. Effort to minimize the violence of the reaction of munitions impacted by small arms projectiles is a continuing commitment of weapons designers in order that the safety of personnel and materiel will not be unduly jeopardized.

2. This AOP addresses the situation where munitions and weapon systems are impacted by bullet(s). This can occur in peacetime as the result of an accident, dissident/saboteur activity, or on operations as a consequence of enemy action, which can result in a significant compromise of safety.

3. The objective of the Bullet Impact Test is to determine the response of the munition(s) when subjected to bullet impact(s).

4. This test may also be used for Hazard Classification (HC) as required by AASTP-03 and UN Document ST/SG/AC.10/11 and any amendments thereto, and other applications not covered by these documents where the response of a munition to bullet impact is required to be known or assessed. If a test is to be used for Hazard Classification, an agreement must be reached between Hazard Classification and Safety Authorities on the required test, number of test items, their configuration (e.g. packaged or unpackaged), and the number of tests to be performed.

1.7 TEST LIMITATIONS

1. The Bullet Impact Test is only designed to simulate the most violent response that a viable bullet impact threat would produce.

2. This test only represents a particular set of conditions as it is not possible to cater to the wide range of weapons, sizes of bullets, strike velocities or angles of attack in the real world.

¹ <https://nso.nato.int/natoterm/>

CHAPTER 2 TEST SPECIFICATIONS

2.1 TEST ITEM CONFIGURATION

1. The test item configuration shall be the final production standard and in accordance with the condition as appropriate to the life cycle phase represented by the test, or representative as approved by the National Authority.
2. Guidance on variations to the production standard and condition (e.g. live vs inert, pre-conditioning, packaged vs unpackaged, single vs multiple test items, All-Up-Round vs component level) as given in SRD AOP-39.1 Annex B shall be considered.

2.2 TEST DETAILS

2.2.1 Test Methods

There are three methods for performing the Bullet Impact Test for Munitions:

- a. Method 1 (Standard) for determining the response of a munition when hit by three 12.7 mm Armor Piercing (AP) projectiles;
- b. Method 2 (Primary Alternative) for determining the response of a munition when hit by one 12.7 mm AP projectile;
- c. Method 3 (Tailorable Alternative) for determining the response of a munition when hit by one or more projectiles that are typical of those determined by means of a threat hazard assessment (THA).

2.2.2 Test Requirements

- a. For Method 1 and 2 the standard attack munition (threat) is a 12.7 mm AP M2 round, fired from a rigidly mounted gun. Comparable projectiles are acceptable if they fulfil the specifications below in paragraph b. Both munition and gun shall be selected to fulfil these specifications for Method 1 and 2:
 - (1) Impact velocity: 850 ± 20 m/s;
 - (2) Rate of fire: 600 ± 50 rounds per min (only Method 1)
 - (3) Size: 12.7 x 99 mm
- b. For Method 1 and 2 the projectile shall fulfil the specifications listed below. Examples of compliant 12.7 mm munitions can be found in Annex A.

- (1) Weight of projectile: > 40 g (617.3 grain) and < 50 g (771.6 grain)
 - (2) Hardness of core: > 750 HV (61.2 HRC) or comparable
 - (3) Material of core: Steel
 - (4) May contain tracer: No
 - (5) May contain incendiary composition: No
 - (6) May contain pyrotechnics: No
 - (7) May contain high explosives: No
- c. For all methods, the shots have to hit a target area consisting of a circle with 5 cm diameter. The aiming point is the center of the target area.
- d. To meet the requirements for the target and for reaching the rate of fire, the use of three remotely controlled guns is recommended for Method 1. For Method 3, parameters should be as determined by the THA and approved by the National Authority.
- e. Methods shall be established to assure the bullet is aimed at the selected aimpoint and that it follows the desired path through the munition.

2.2.3 Test Set-Up

1. The test item condition and orientation shall be applied in coherence with the life cycle phase represented by the test, or representative as approved by the National Authority.
2. The range from gun to target is to be determined by the test authorities, depending on accuracy and safety aspects. In most cases, a range between 15 and 30 m is recommended. A larger or shorter range may be appropriate, if demanded for performing the test and agreed by the National Authority.
3. Additional guidance on variations to the test conditions (positioning/orientation, aim-point/shot-line, restraints, conditioning, marking, reuse, etc.) as given in SRD AOP-39.1 Annex B shall be considered.

2.2.4 Number of Tests

Any of the selected test methods shall be carried out twice; once against the main charge filling and once against the most sensitive component/energetic material (e.g. motor igniter, warhead booster). 'Most sensitive component' means the component which, if exposed to the threat, is likely to lead to the most violent response of the munition.

2.3 DOCUMENTATION AND COMPLIANCE

1. A test directive, test plan and test report shall be produced and shall be agreed by the National Authority. Guidance on completion of documentation, responsibilities for completion and review are discussed in detail in SRD AOP-39.1.
2. It is essential that the test is conducted in accordance with the Test Directive; one of the responsibilities of the Project Team is to confirm compliance.
3. Where deviations from the agreed Test Directive and Test Plan, or the procedure agreed upon at the Trial Readiness Review prove necessary, these must be approved on behalf of the review body by the appropriate Project Team representative, taking advice as necessary from the safety advisor and technical specialists.

2.4 OBSERVATIONS AND RECORDS

Guidance on specific aspects of the conduct of testing, observations and data recording is discussed in more detail in SRD AOP-39.1. Unless noted as “optional”, for IM purposes, the following minimum observations shall be made and records kept. Test recommendations, records and observations for HC testing and assessment are included in the UN Manual of Tests and Criteria and the Globally Harmonized System of Classification and Labelling of Chemicals, and are not optional.

- a. Test item identification and configuration (model, serial numbers, number of test items, etc.); Type of energetic material and weight; Listing of environmental preconditioning tests performed; Spatial orientation of the test item.
- b. Test setup/configuration: type of procedure; Details of weapon(s) and munition used; Number of rounds; Distance between weapon(s) and test item; Method of mounting and/or restraint; Distances from the test item to any protective wall or enclosure; Identification and location of any other instrumentation if used.
- c. Record of events versus time, from the order to fire to the end of the test.
- d. Record of aim point(s) selected, hit point(s) (if possible) and whether the bullet(s) exited from the test item or remained within it (if possible).
- e. Impact velocity of each bullet, firing rate (if applicable) and method of determination.
- f. Accuracy at impact(s); Estimated measurement uncertainties for: (a) the impact velocity and (b) impact location.
- g. Nature of any reactions by the Test Item.

- h. Photo Imagery of the Test Item and the Test Setup before and after performing the test.
- i. Nature and distribution of remains/residue and debris including: range, position, photographs, identification (as possible), and mass of each piece.
- j. Meteorological data (wind speed, direction) during the test.
- k. Indication of propulsion (video or other suitable means).
- l. Audio and video records: A recording device shall be placed near the trial site to record all audio and enable correlation between visible events and indicated time.
- m. Suitable Blast or overpressure gauges should be positioned around the test item to record pressure-time history with a record of gauge location and height.
- n. Witness plates and screens (optional) as a measure of projection severity; Photographs of witness plates and screens (if used); Number and depth of penetrations in fragment recovery panels (if used).
- o. A complete data record shall be compiled to include pressure, sound, imagery, fragmentation, debris and propulsion information.

2.5 EVALUATION OF TEST RESULTS

Policy and procedures for evaluation of test results are given in:

- a. AOP-39, Policy for Introduction and Assessment of Insensitive Munitions (IM);
- b. AASTP-03, Manual of NATO Safety Principles for the Hazard Classification of Military Ammunition and Explosives.

ANNEX A BEST PRACTICES**A.1 EXAMPLES OF COMPLIANT 12.7 MM AP PROJECTILES**

The following munitions fulfill the requirements of this AOP and are approved for use in the context of this AOP.

Table A-1

Model	Manufacturer	Weight of Projectile	Hardness of Core
DM51	n/a	About 618 grain About 40 g	n/a
M2 AP	Various	695 grain 45 g	780 HV 63.3 HRC
AP-M8	Various		

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ANNEX B HISTORICAL OVERVIEW

B.1 REVISION PROCESS**B.1.1 IM Test AOP Standardization Working Group (2020-2021) [1]**

1. In the time between April 2020 and April 2021, AOP-39, -39.1, -4240, -4241, -4382, -4396, -4496, and -4526 have been revised. The objectives of these revisions, executed by the IM Test AOP Standardization Working Group, were:
 - a. Fix grammatical and spelling mistakes, clerical errors, and enforce a uniform structure, format, and wording across all AOPs for the sake of readability and ease-of-use.
 - b. Ensure that the AOPs only contain requirements.
2. Altering any technical content was not permitted, because the group aspired to merely update each AOP's Version and not release entirely new Editions.
3. To achieve the second goal, guidance and best practices were to be moved into the SRD AOP-39.1. However, accomplishing this was not entirely possible. It was agreed that all AOP-specific guidance remains in each AOP's Annex A, while all guidance that applied to two or more AOPs was marked to be moved into the SRD.
4. The IM Test AOP Standardization Working Group also made notes about topics that could potentially be discussed at future gatherings of each AOP's respective Custodian Working Group.
5. A total of 26 meetings took place, all of them virtually. The involved people were the Custodians of the various documents as well as representatives of MSIAC and AC/326 SG/B.

B.1.2 Creation of AOP-4396 Edition A (2010-2018)

1. In 2010 NATO's Ammunition Safety Group (AC/326) empowered their munition Subgroup B (Ammunition Systems Design & Assessment) to establish Custodian Working Groups for each of the IM related STANAGs as a means of reviewing and updating the IM test requirements where needed. Several nations participated in these Working Groups to address the individual IM test requirements in succession, including Fast Heating, Bullet Impact, Shaped-Charge Jet Impact, Fragment Impact, Slow Heating and finally Sympathetic Reaction. Each topic required multiple meetings to produce the desired end product – a draft AOP document that contained the revised, updated test requirements. These new AOPs would then become companion documents to their respective STANAGs with the STANAG as the lead or referencing document only.

2. TTCP recommended to review STANAG 4241 Ed. 2 because the then current requirements were difficult to consistently fulfill. For instance, many Bullet Impact Tests were ruled to have been executed wrongly, because the bullet velocity was below the lower limit of 850 ± 20 m/s [2].

3. To see how large of an issue this was and what other problems or recommendations the partner nations had, the revision process began in January 2013 with a survey on how they perform the Bullet Impact Test and what experiences they have made with the requirements that existed back then. The results can be found in the MSIAC report O-152. It was concluded that most nations comply with the velocity requirement, but there were still enough unanswered question to warrant the establishment of a Custodian Working Group [3, 4].

4. There were two Bullet Impact Custodian Working Group (BI CWG) meetings during the period September 2014 – September 2015. These meetings were conducted to review and update the test requirements of STANAG 4241 and create AOP-4241. The BI CWG deliberations included very lengthy discussions, sometimes supported by detailed technical investigations, on many topics related to this test and its procedural requirements. A long period of discourse per e-mail followed, during which AOP-4241 Edition A Version 1 was finalized. The final draft was finished near the end of 2017 and came into effect November 2018. The following topics were addressed during the entire revision process:

- a. Bullet Velocity
 - (1) Guidance on velocity measurement
 - (2) How to counter wear of the barrel
 - (3) How to adjust bullet velocity (e.g. alter propellant amount, heat / cool propellant)
- b. Test Methods
 - (1) Whether the 3-round burst or single-shot is the standard method
- c. Projectile Type
 - (1) Whether to stick to .50
 - (2) Whether only the M2 or bullets similar to it are allowed
- d. Aim Point & Shot Line
 - (1) Whether to aim at the booster
 - (2) Definition of “most shock sensitive component that leads to worst response when hit”

- (3) Target circle of 5 cm; whether it can be hit reliably
- (4) Impact angle
- (5) Whether to avoid shot lines that can seriously alter the velocity and path of projectile
- e. Gun Set-Up
 - (1) Recommendation for three individual guns
- f. Test Item Orientation & Configuration
 - (1) Whether to only allow horizontal positions
 - (2) Whether dummies that replace inert parts must be thermally representative
 - (3) What parts must be present
- g. Harmonization Between BI for IM and BI for HC
 - (1) Was agreed to make a new AOP that disregards the HC requirements
 - (2) Was agreed that harmonizing just for HD 1.6 was unnecessary
- h. Need for High-Speed-Video
- i. Need for an SRD
- j. Need for Witness Plates
- k. Mounting Height of Blast Gauges

B.1.3 Changes from STANAG 4241 Edition 2

Several changes were made in AOP-4241 Ed A V1 compared to STANAG 4241 Ed 2. The largest ones are listed below.

- a. General Changes
 - (1) The format was updated to fit the standards of the time.
 - (2) The wording of various sections was edited to clear up misunderstandings and to make the AOPs more uniform and consistent.
 - (3) A table of contents was added.

- b. Aim and Agreement
- (1) Any mention of the test methods was removed to clarify that the aim of the AOP is to provide evidence of the response of a munition and/or weapon system to the threat Bullet Impact.
 - (2) The agreement to develop tests for other bullet attack weapons was removed.
- c. Definitions
- (1) A reference to the NATO Terminology Management System replaced the references to AOP-38, -39 and STANAG 4439.
- d. Test Procedures/Methods
- (1) A third test method was established as a primary alternative, to allow partner nations to fire a singular bullet instead of a three round burst:

“A primary alternative test procedure (Method 2) for determining the reaction, if any, of a munition an impact of one 12.7 mm AP projectile”
 - (2) This method was introduced to examine the response of munition to an impact of a single bullet. One reason for this could be that the impact of three bullets in the small target area is of sufficient low probability. Another reason could be that the impact of the second and third bullet of a round would provide additional damage to the energetic material that was already damaged by the first bullet. So the response might be worsened by this.
 - (3) The order of the test methods was established as follows:
 - (a) Method 1: standard, 3-round-burst
 - (b) Method 2: primary alternative, singular shot
 - (c) Method 3: tailorable alternative, requirements based on THA
 - (4) The recommendation to use three remotely controlled guns for Method 1 was added.
- e. Attack Munition
- (1) A cal. 50 bullet remained the standard threat.

- (2) Comparable projectiles to that of the M2 cal .50 AP round were made acceptable. A set of criteria, which projectiles must fulfill to be usable for the Bullet Impact Test, was determined and added. A list of available bullets that already fulfill these criteria was added as well.
 - (3) Guidance on how to achieve the required impact velocity was added.
- f. Aim Point & Shot Line
 - (1) The requirement to exclude the booster when determining the most shock-sensitive explosive component in a munition was removed. Instead, the booster was added to the list of valid aim points.
 - (2) The requirement that the “impact shall be approximately perpendicular to the long axis of the test item” was removed. Instead, guidance was given on shotlines that likely lead to the most violent response of the munition.
- g. Test Documentation
 - (1) A “Documentation and Compliance” section was added that cites Test Directive, Test Plans and reporting and refers to SRD AOP-39.1 for details.
- h. Observation and Records, Instrumentation
 - (1) It was specified that the impact velocity of each bullet has to be measured.
 - (2) Information and requirements regarding test instrumentation and test data that are unique for this test were added in the “Observations and Records” section. A hint that more guidance on instrumentation can be found in SRD AOP-39.1 was added as well.

B.2 BACKGROUND AND TEST ORIGIN

Not used.

B.3 REFERENCES

[1] D. Pudlak, K. Tomasello, "Revisions and Improvements to the NATO Insensitive Munitions Test Doctrine Portfolio", NATO AC326 SG/B Spring Meeting, April 15-16, 2021

[2] "Lessons learned from the use of the new response descriptors", Stuart Blashill, TTCP WPN TP-4, February 2012

[3] "STANAG 4241 Review of the Bullet Impact Test", Emmanuel Schultz, in AC/326 SG/B, September 2013

[4] "An International Review of the Bullet Impact Test" (O-152), Emmanuel Schultz, Brussels, Belgium, August 2013

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