



U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

NATO Allied Ordnance Publication (AOP-7)

Policy, Data Requirements, and Tests for the
Qualification of Energetic Materials for Military Use

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Distribution A



AOP-7 BACKGROUND

AOP-7 has been used for 30+ years to support energetic material Qualification and munition interoperability across NATO

- Ensure energetic materials (explosives, propellants, and pyrotechnics) meet fundamental safety requirements

Establishes Qualification policy and a standardized assessment approach

- Identifies various stimuli and test procedure requirements for all energetic types
- AOP-7 is used throughout NATO and non-NATO countries for acquisition (contract SOWs) and by national labs performing energetics Qualification

In the U.S., AOP-7 provides the basis for the establishment of DOD and service specific Qualification policy and direction

AOP-7 has not been updated and approved since 2003



QUALIFICATION POLICY SUMMARY

Energetic material Qualification approval is required as part of the process to certify munitions are safe for service use

- Required by numerous safety boards as part of independent approval process for munition certification

Two-phase process

- Initial Qualification phase assesses energetic material characteristics independent of an application
- Final (Type) Qualification phase evaluates energetics behavior in a specific system

Qualification approval or rejection is generally based on an evaluation of all test results in their entirety as opposed to the result of any one test

Qualification approval or rejection in the U.S. is the responsibility of Service Qualification Authorities in either the AF, Army or Navy/Marine Corps

- Delegated from OSD



INITIAL QUALIFICATION PHASE

AOP-7 is primarily focused on the initial Qualification phase

Requirements vary based on the energetic material class

- Explosives (main charge, primary, booster)
- Propellants (gun, solid rocket, liquids)
- Pyrotechnics

Data used to support Qualification:

- Small scale sensitivity test results (impact, friction, ESD, shock, etc.)
- Thermal sensitivity and characterization
- Mechanical property behavior
- Hazard Classification
- Ageing characteristics
- Performance attributes
- Toxicity
- Documentation (specifications, technical reports, certifications)

Multiple test procedures are acceptable and identified for the various stimuli



AOP-7 REVISION APPROACH

Multinational approach with Finland, France, Germany, Netherlands, Norway, Sweden, Turkey, UK, and the U.S. (all services)

AOP-7 has been re-organized to include a main body and three Standards Related Documents (SRDs)

- AOP-7 Main Body; Includes policy, requirements, and tests
- SRD-AOP-7.1; List of Qualified Energetic Materials
- SRD-AOP-7.2; National Test Requirements and Procedures
 - Addendum to AOP-7 requirements unique for each country
- SRD-AOP-7.3; National Authorities responsible for Qualification

SRD Benefits

- NATO revision process for ratifying an AOP or STANAG is fairly tedious
- SRD approval process provides streamlined approach appropriate for documents that require frequent revisions

The current revision process includes updates to AOP-7 and SRD-AOP-7.2 Qualification policy, test requirements, and technical test procedures



MAJOR CHANGES IN AOP-7 (7 DEC 2020 VERSION)

Updated technical requirements

- Revised required sensitivity stimuli, data, and test requirements
- Added new test STANAGs used for Qualification testing
- Updated aging protocol, booster explosive, and liquid propellant Qualification

Added Recommended tests

- Tests and analyses not essential but should be considered for inclusion as part of Qualification
- Support in-depth energetic material characterization
- Provide data supporting ageing or weapon performance

Clarified requirements and definitions for:

- Handling and release of Qualification data, Intellectual Property Rights (IPR) and Non-Disclosure Agreement (NDA) Details
- Qualified energetic materials may need to be re-qualified where new processes, manufacturers, or ingredient sources are introduced
- Added requirement that nations may conduct periodic audits of in-service Qualified energetic materials – this could lead to Qualification cancellation

Updated standard NATO definitions and annexes that provide a recommended Qualification certificate, references, and AOP-7 history



AOP-7 TABLE 1 – GENERAL REQUIREMENTS FOR ENERGETIC MATERIAL QUALIFICATION

Requirement	Type of Information Required
1. Details of the composition and its ingredients per the material specification	Composition ingredients, ingredient percentages in formulation with allowable tolerances, particle size, final product and ingredient sources.
2. Intended role and energetic material type	Main charge high explosive, booster explosive, primary explosive, pyrotechnic composition, gun propellant, solid rocket propellant.
3. Physical form as used in-service and processing characteristics	Method of manufacture. Pressed, melt-cast, cast-cure, extruded, machinability characteristics, specialized handling considerations.
4. Chemical and physical properties	Theoretical maximum density, recommended density for applications, melting point (for melt-cast explosives), growth and exudation properties, chemical characterization and compatibility, hygroscopicity, vapour pressure (for liquids), etc.
5. Sensitivity, mechanical, and thermal characteristics	Sensitivity (impact, friction, ESD, shock), thermal properties (reaction/decomposition temperatures, vacuum stability), mechanical properties.
6. Performance characteristics	Detonation velocity, critical diameter, burning rate, etc.
7. Comparisons to other similar compositions (if any) already in service	Comparisons to energetic materials with a safe history of service use. Includes sensitivity, performance, and mechanical properties.
8. Information about any known incompatible materials	List of substances (e.g., polymers, plasticizer, lacquers, oxidizing agents, etc.) that should not be kept in contact with the energetic material.
9. Toxicity data, environmental safety, and compliance with National Health and Safety requirements	Material Hazard Data Sheet, Safety Data Sheet, Hazard Classification, toxicity information, environmental safety, etc.



AOP-7 TABLE 2 – SPECIFIC QUALIFICATION DATA REQUIREMENTS

Test / Assessment	Explosives			Propellants			Pyro-technics
	Primary	Booster	Main Charge	Gun	Solid Rocket	Liquid	
Sensitivity Testing							
- Impact Sensitivity	M	M	M	M	M	M	M
- Friction Sensitivity	M	M	M	M	M	M	M
- Electrostatic Sensitivity	M	M	M	M	M	M	M
- Shock Sensitivity	R	M	M	R	M	M	
- Adiabatic Compression						M	
Thermal Characterization							
- Thermal Analyses (DSC/DTA/HFC/TGA)	M	M	M	M	M	M	M
- Thermal Stability	M	M	M	M	M	R	M
- Chemical Compatibility	M	M	M	M	M	M	M
- Self-Heating Critical Temperature		M	M			M	
- Auto Ignition Temperature		M	M	M	M		
- Growth/Exudation		M	M				
- Thermal Sensitiveness and Explosiveness		M	M	M	M		M
- Heat Capacity/Thermal Conductivity		R	R	M	R		
- Flash Point/Vapor Phase Ignition						M	

M = Mandatory; R = Recommended

Note: This Table may change slightly in the SRD national sections.



AOP-7 TABLE 2 – SPECIFIC QUALIFICATION DATA REQUIREMENTS

Test/Assessment	Explosives			Propellants			Pyro-technics
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Chemical Characterization	M	M	M	M	M	M	M
Mechanical Property Characterization		M	M	R	M		
Performance Characterization							
- Detonation Velocity		M	M				
- Critical Diameter		M	M	R	M	M	
- Burning Rate				R	R		R
- Unreacted Hugoniot		R	R				
- Run-to-Detonation		R	R				
- Detonation Products Equation-of-State		R	R				
- Detonation Diffusing and Spreading		R	R				
Ageing Protocol, Plan, and Data	M	M	M	M	M	M	M
Hazard Classification	M	M	M	M	M	M	M
Toxicity	M	M	M	M	M	M	M

M = Mandatory; R = Recommended



STANAGS USED FOR QUALIFICATION

Many STANAGs applicable to Qualification testing were developed with the goal of replacing national testing standards

- Numerous test procedure STANAGs exist for sensitivity, thermal, and mechanical property characterization
- Goal was to identify a single test that all nations would perform
- Found to be impractical

Could not accommodate specific national procedures, apparatus, technical limitations, historical data sets, in performing the test

- Unable to make a strong case that any one specific test was superior to others

Multiple test methods for specific stimuli included as a compromise

- Approach is to calibrate test procedures using standard reference materials (ex. RDX)
- Results are also compared to Comparison Energetic Materials with a history of safe in-service use

Agreement within each STANAG is “participating countries.....have decided to accept each test as a standard procedure for determining the XXXX sensitivity”



SRD-AOP-7.2 U.S. SECTION UPDATE (MARCH 2021)

Updated Service Qualification Authorities (SQA)

- Emphasized need to meet with SQA tech reps prior to starting a Qualification program
 - Obtain clarification and guidance on test plan and approach
 - Critical towards developing aging program and need to perform recommended tests
- Emphasized OSD policy emphasizing use of STANAGs/AOPs for acquisition

Updated Qualification technical requirements

Revised Test Procedures – minimize number of tests for each stimuli

- Standardized test procedure format
- Updated existing procedures to include additional test details, configuration, typical results, and references
- Added new procedures that reflect more modern and mature analytical techniques
- Eliminated tests that were obsolete or not relevant to address Qualification requirements
- Updated Comparison Energetic Materials used to compare results from different procedures for the same stimuli

Expansion of ageing protocol, mechanical property, and performance tests details

Updated and clarified booster explosive pass/fail criteria



SRD-AOP-7.2 TEST DESCRIPTION FORMAT

Standardized Format for Test Descriptions

- Type of Test: Describes stimuli being assessed (ex: impact sensitivity)
- Purpose: Top-level explanation of why the test is performed
- Test Background: Historical summary
- Test Arrangement: Detailed description of test apparatus and set-up. Schematics of test configuration provided where appropriate
- Procedures: Specific test procedure
- Results and Data: Common test result observations and reporting requirements
- Supplemental Information
- References

Goal is to develop test procedures that could be used at any facility as written without modification or need to rewrite document

- Provide as much detail as possible

Slight site changes may be required to conform with local requirements (safety, facility layout, personnel requirements, etc.)



TEST REQUIREMENTS SRD-AOP-7.2 (MARCH 2021)

Section 100.1 Impact Sensitivity Tests (4)

- | | | | |
|----------|--------------------|----------|------------------|
| 100.1.01 | ERL Impact | 100.1.02 | Ball Drop Impact |
| 100.1.03 | BAM Impact | 100.1.04 | mBOM Impact |
| 100.1.05 | JANNAF Impact Test | | |

Section 100.2 Friction Sensitivity Tests (2)

- | | | | |
|----------|----------------------|-----------|------------------------------|
| 200.1.01 | ABL Sliding Friction | 201.02.00 | BAM (Julius Peters) Friction |
|----------|----------------------|-----------|------------------------------|

Section 100.3 Electrostatic Sensitivity Tests (1)

- | | |
|----------|-----------------------------|
| 100.3.01 | ABL Electrostatic Discharge |
|----------|-----------------------------|

Section 100.4 Shock Sensitivity Tests (5)

- | | | | |
|----------|-------------------------------|----------|----------------------------|
| 100.4.01 | NOL Small Scale Gap Test | 100.4.02 | NOL Large Scale Gap Test |
| 100.4.02 | Expanded Large Scale Gap Test | 100.4.03 | Super Large Scale Gap Test |
| 100.4.05 | IHE Gap Test | 100.4.06 | Adiabatic Compression |



TEST REQUIREMENTS SRD-AOP-7.2 (MARCH 2021)

Section 200: Thermal Characterization (15 Tests)

- Includes Differential Thermal Analysis (DTA), Differential scanning Calorimetry (DSC), Heat Flow Calorimetry (HFC), etc.

Section 300: Mechanical Property Characterization (6 Tests)

- Uniaxial Compressive Strength, Tensile Strength, Coefficient of Thermal Expansion, etc.

Section 400: Performance Characteristics (8 Tests)

- Detonation Velocity, Critical Diameter, Strand Burning, etc.

Section 500: Physical Properties, Hazard Classification, and Miscellaneous (5 Tests)

- Density, Specific Gravity, Cap Test, etc.

Section 600: Aging Assessment and Evaluation

- Multi-phase approach – still in development
- Will reference test procedures for sensitivity, thermal, and mechanical property characterization



REMAINING SRD TASKS

Finalization of Aging protocol requirements

Review of statistical processes to determine pass/fail criteria for booster explosives

- May be function of specific test procedures

Development of standardized test procedures for Recommended performance tests

Completion of several mechanical property test procedures in conjunction with NATO working group

Review and inclusion of potential changes to standardized shock sensitivity tests



WHAT'S NEXT?

Main body of AOP-7

- Issue next Draft in June 2021 based on Dec 2020 version
- Perform final walk-through at the Fall 2021 AC/326 SG/A meeting
- Incorporate changes in a Final for ratification as part of Spring 2022 AC/326 SG/A meeting

U.S. National Section (SRD-AOP-7.2)

- Adjudicate comments to March 2021 Draft and issue next version in July 2021
- Expect to need one more revision before developing a Final document later in 2021
- Depending on extent of input, goal is to complete the document by the end of CY21

**Additional input from energetics community is
welcome and highly encouraged**