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Harmonization of Ammunition Qualification

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EUROPEAN NETWORK OF NATIONAL SAFETY AUTHORITIES ON AMMUNITION

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List of Abbreviations and Acronyms

AAS3P	Allied Ammunition Safety and Suitability for Service Publication
ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route
AOP	Allied Ordnance Publication
AECTP	Allied Environmental Conditions Testing Publication
E3	Electromagnetic Environment Effects
EM	Energetic Material
FMECA	Failure Mode, Effects, and Criticality Analysis
HD	Hazard Division
HERO	Hazard of Electromagnetic Radiation to Ordnance
IEC	International Electrical Committee
ISS	In Service Surveillance
LCEP	Life Cycle Expected Profile
NATO	North Atlantic Treaty Organization
pMS	participating Member State
RADHAZ	RADiation HAZard
REACH	Registration, Evaluation, Authorization and restriction of CHemicals
S3	Safety and Suitability for Service
STANAG	STANdardization AGreement
UN	United Nations

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Executive Summary/Abstract

1. INTRODUCTION

Ammunition Safety Qualification is all about assessing the safety and suitability for service (S3) of each particular type of ammunition. This safety and suitability for service assessment is related to a specific design, for an intended use under various environmental conditions (life cycle expected profile - LCEP).

There are differences in the (minimum set of) information needed to actually qualify an ammunition article between nations. Nevertheless there is a common series of tests required by every pMS. The aim of this paper is to suggest best practice recommendations to enhance the possibility of sharing, accepting and adopting other nation's qualification results.

In order to make best use of the results of these common tests, they should be reported in a harmonised way. As qualification reports are written by national test facilities for national safety authorities. The information they provided is specific to the national programme manager's requirements. They also tend to be based on a national web of trust and some "known" technical details can be omitted as the programme manager is only concerned by the overall test result. If these test results were to be more widely disseminated and fully utilised then the technical details would have to be reported in a harmonized way.

2. "Minimum Safety Data Package"

Ammunition safety qualification relies on two main aspects:

- compliance of the design (the ammunition itself or subcomponents) to international standards; and,
- safety assessment covering all aspects of the ammunition use storage/handling/transport and functioning), and conducted according to test standards.

Any shared safety data package provided to a foreign safety authority should include, as a minimum, the following items, covering these two aspects.

Notes:

- pMS have to be aware that ammunition qualification does not cover other (major) concerns which are:
  - production variability (only taken into account through failure mode analysis, using a priori parameters);
  - production evolution (obsolescence);

- use evolutions or national specificities (i.e. own transport means or weapons systems).

Such evolutions are likely to require additional analysis and/or tests to extend the original qualification decision.

2.1. Initiation Systems Qualification

Reference documents: STANAG 4187, STANAG 4368 and STANAG 4157.

Purpose: to provide an acceptable risk level against inadvertent initiation of the payload or of the propulsion components of the ammunition.

Requested data:
- description of the overall architecture and of the design details and compliance matrix with applicable documents for initiation components. The structure of these documents provides all the items to be addressed in this compliance matrix. (STANAG 4187 and STANAG 4368)
- test results of the safety assessment (STANAG 4157).

Notes:
- There are several levels of requirements (mandatory features, design guidelines, etc.).
- Compliance can be achieved by respecting all the design requirements and guidelines (preferred), or by fulfilling the safety objectives (accepted). Considering this last option, the compliance matrix shall be replaced by a complete failure mode, effects, and criticality analysis (FMECA).

Limits: legacy ammunitions or old designs may not be compliant with the last versions of the STANAG. In such cases, additional data should be provided to facilitate a complete risk assessment (design details, compliance matrix to older versions of the documents, etc.).

If the design of initiation components is a major concern, other design compliance requirements can be issued for specific ammunition families, depending on their architecture, e.g. mortar ammunitions (a specific STANAG exists), components such as pressure vessels or rocket motors (pressure burst safety margin) or safety related software…

2.2. Explosive Materials (EM) Qualification Data

Reference documents: STANAG 4170 / AOP-7 (explosive materials characteristics assessment) and STANAG 4147 (explosive materials compatibility).

Purpose: to provide safety and functional characteristics of the EM used in the ammunition. These values allow comparison with in service systems, as well as provide initial data, to be compared with values obtained in production and/or in service surveillance (ISS).

Requested data: performed test types (reference to a standard or complete description of the test, if it is an in-house test) and results (comparison with a well-known EM, using the same test procedures, could be useful).

Notes:

- EM qualification could be regarded as a risk-reduction measure, as it is not directly used for the design of ammunition (it is part of the recorded parameters but is not a functional parameter). In France, there are two main aspects: risk reduction measure (is the EM fit for purpose?) and quality insurance (the ability of the manufacturer to produce the same material consistently; qualification specimens are representative of the mass production items).
- Deficiencies in EM qualification / compatibility testing could be accepted if sufficient feedback is available (ISS during a significant period, proving that there are no critical matters related to materials compatibility or ageing; full IM characteristics of the ammunition or component).
- For small components (like squibs or igniters), a qualification of the component itself can be regarded as more relevant than the qualification of the EM it contains (geometry, powder compression or manufacturing process can lead to significant differences between characteristics of the raw material and of the same material in its “final” configuration).

Limits:

- AOP-7 collates all of the national best practices but without proposing a “standardised” test procedure. EM qualification in an EU country can thus be compliant with the AOP-7 without providing all the data that would be required by another pMS.
- Tests results are not sanctioned by a pass/fail result, as there are no criteria regarding the data gathered during the EM qualification (except for the booster materials). Characteristics of an EM could be regarded as acceptable by a nation (friction or shock sensitivity for instance), and rejected by another.

2.3. Other Components Qualification Data

Reference documents: STANAG 4452 / AOP-52 or IEC standards (software safety), etc.

Requested data: performed test types and tests results or analysis reports.

Notes:

- Except for the ignition devices, there are no real standard documents, and qualification of components, especially the ones using dual (civilian/military) technologies, is bound to be performed using in-house or different standards. For instance, this is the case for software.
- Depending on the industrial organisation, results from tests performed at a component level may be out of requirement.

2.4. Environmental Testing (Climatic and Mechanical)

Reference documents: STANAG 4370 / AECTPs.

Purpose: to provide evidence that the munition will remain safe and function as intended through its operational life, including severe environments (temperature, humidity, shocks and vibrations, etc.).

Requested data: tests plan and reports, both covering the types of environments used to pre-stress the specimens, and the evaluations (functional tests, firings, sectioning) and results, success criteria and rationale.

Notes:

- Most of the ammunition families have dedicated S3 assessment STANAGs (to be replaced by the AAS3P documents). Such STANAGs provide standard test plans, including tests sequence/test description, and dedicated item numbers.

Limits:

- Most of the tests STANAGs allow tailoring of the sequential testing. This tailoring can either alter the test severity (for instance in temperature conditioning) or the number of tests (number of rounds fired in a certain situation, etc.). The rationale behind this tailoring is crucial, as test severity is very difficult to assess without setting the complete design parameters, and the repetition of tests is directly related to the confidence level.

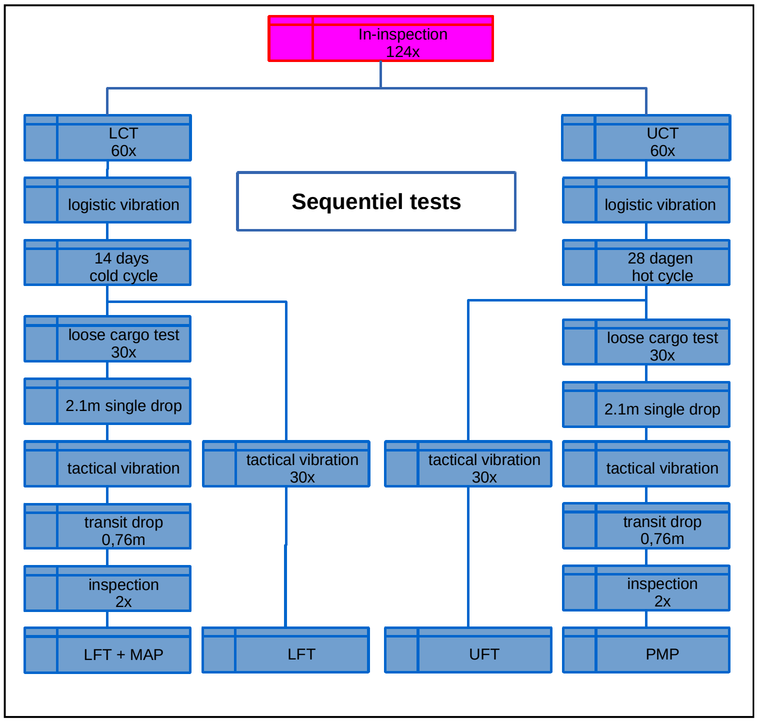

Figure 1: Example of possible sequential test programme according to AAS3P-20

2.5. Electromagnetic Environmental Effects (E3)

Reference documents: STANAG 4370 / AECTP-250 and AECTP-500, STANAG 1397.

Purpose: to provide evidence that a munition sensitive to E3 will remain safe in severe electromagnetic environments (e.g. HERO, lightning and electrostatic discharge).

Requested data: tests set up and results, RADHAZ classification.

Limits:

- Electromagnetic environments effects (E3) assessment is well standardised, but some of its aspects are highly dependent on the combat platform which will use the ammunition. Some specific concerns will require dedicated studies at the integration level (lightning effects, electromagnetic compatibility, munition safety in the induction area of antennas).

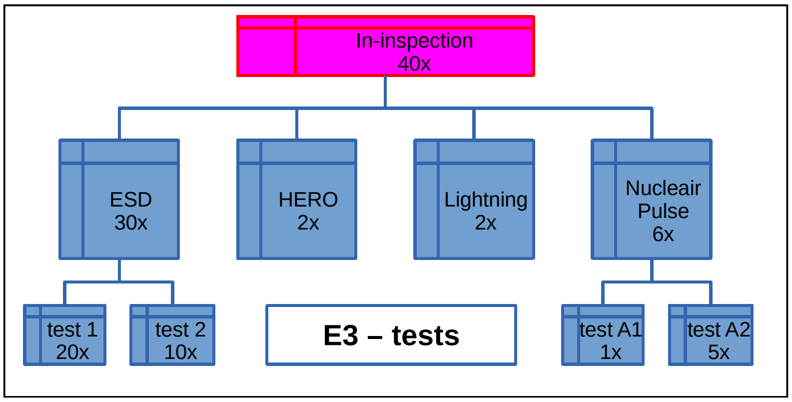

Figure 2: Example of possible E3 test programme

2.6. IM assessment

Reference documents: STANAG 4439 / AOP-39 and relevant test STANAGs.

Purpose: to provide the level of reaction of ammunition to accidental or enemy threats (abnormal thermal or mechanical environments).

Requested data: tests set-up and results reports.

Notes:

- EOD procedure is also of interest, as the low shock sensitivity of the ammunition can lead to difficulties in demi or destruction operations.

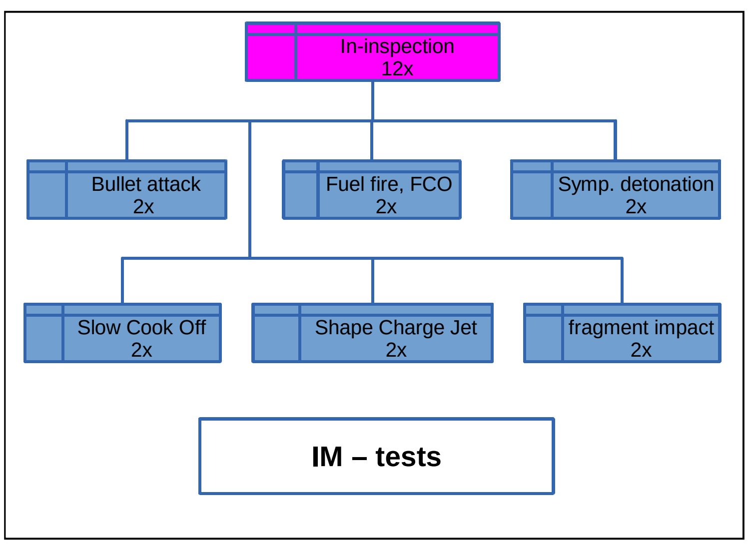

Figure 3: Example of possible IM test programme

2.7. Transportation / storage classification

<u>Reference documents</u>: ST/SG/AC.10/11/Rev.5 “UN Manual of Tests and Criteria” (for transport); STANAG 4123 / AASTP-3.

<u>Requested data</u>: tests set up and results; transport classification certificate issued by the competent national authority.

<u>Notes</u>:
- Most of the countries accept the transport classification issued by a foreign nation (the munition will arrive in the destination country under this certificate).
- Classification according NATO rules is more stringent than the UN ones (i.e. a NATO classification can be used for ADR compliance, but a UN classification cannot be transposed for NATO safety studies, for instance).

2.8. Waivers

All the deviation from requirements or recommendation of the international standards shall be documented:
- Non-compliance with design requirements (design features and/or objectives).
- Non-compliance with the recommended test plans (in terms of test set up, number of tested items, or type of tests).

Documentation should include a detailed description of these differences, and the rationale behind the modifications or the demonstrated safety level.

2.9. Safety Case Report

A summary of all the previous information should be provided in a safety case report, including:
- description of the design of the munition;
- manufacturers (design authority and critical components manufacturers);
- function and use of the munition;
- LCEP and associated environments;
- S3 test plan;
- tests set up and results;
- associated waivers;
- safety analysis (analysis of failure modes and consequences);
- qualification reserves and recommendations.

2.10. Hazard Data Sheet /Material Safety Data Sheet

For operational use, a simple document shall collect all of the relevant safety information, like the NEQ, toxicology of the contained or emitted products (REACH compliance), etc.

3. Harmonised Reporting - Best Practices

3.1. Introduction

Currently, sharing of other nation´s qualification results is difficult, because they lack basic information about the test facilities and the way the actual tests were executed. In most cases, the information provided is insufficient to even be evaluated by another nation's experts. For better cooperation it is necessary to find a common understanding of what is needed.

One step towards this goal is an approach called "Harmonised Reporting", a recommendation for a standardised content of national qualification test reports. Harmonised Reporting will increase the ability to share results, permit more read-across and result in cost reduction.

3.2. Detailed Recommendations

3.2.1. Separation of Safety and Performance Data

It is mandatory to separate safety and performance data into different test reports, because most performance data is classified information. Any test report containing performance related data usually cannot be shared between nations. By limiting the safety test report to safety related data only, the results can be shared more readily.

3.2.2. Design and Test Compliance Matrices

A Compliance Matrix is a table that enables national experts to evaluate another nation´s qualification results. In order to be a handy checklist it should be a short overview of compliance with the requirements. There are two examples in the annexes.

a) In order to allow other nations to understand what design standards were applied and to which degree, a compliance matrix for each applicable design standard should be provided. It should document the compliance for each of the design requirements and how it was achieved. Where design requirements were not followed it should provide a justification. (annex A)
b) In the same way, a compliance matrix for each applicable test standard should be part of the test report. For each test requirement it should state whether the test was carried out or not. For tests executed, the compliance matrix should have a reference to the detailed test report (see also section 3.2.4). For tests not executed, it should provide justification for omission. (annex B)

3.2.3. Waivers

The provision of information on waivers for design and test results is also important for evaluation of the qualification results. It shall be documented which waivers were granted, including the justification for each waiver.

3.2.4. Details of Test Procedures

The complete understanding on how qualification and characterisation tests are executed is of extreme importance in order for other nation's experts to understand how the test results were achieved. Therefore, a report should provide the following information for each and every test:

a) A reference to the respective test standard and procedure in order to allow others to trace back the actual tests to the original test requirements.

b) All test parameters including exact features for each test. This is particularly important for tailorable tests or where multiple sets of parameters are permitted in the test standard. This information allows the other experts to compare the tests executed to their own test requirements and determine if the results can be fully accepted or if there is a gap between the levels at which the tests were executed and their respective national requirements. If the latter applies, additional testing is required, but limiting the tests to some specific conditions may still be possible.

c) A detailed description of the test items. For example, the test item could be an all-up round, an inert round, a dummy of the component under test or the bare component. The test item could also have been conditioned to a certain temperature or modified to host sensors or other test equipment. This information is vital in order to understand the actual test procedure used and the meaning of the results.

d) A detailed description of the test set-up, including the facilities, the tools and support equipment used, the equipment used to measure and document results, the environmental conditions, the weapon used for firing, etc. This information is necessary in order to evaluate the results compared to the national requirements.

e) The number of test items for each test and their individual condition and the tests executed. For example, some items may have been conditioned to certain temperatures or been fired with different weapons or charges.

f) The specific test results for each test item, or group of test items, that were tested in the exact same state and under the exact same conditions. For example, small and medium calibre ammunition usually is tested in groups, whereas high value ammunition may be tested with just one or two items in the exact same configuration, test conditions and pre-conditioning. Only by understanding which results were achieved under which conditions, will the test experts get the full understanding of the overall test results.

3.2.5. Format and Language

It is not intended to impose requirements as to format or language, as this would provide an unnecessary burden. Most people (including most test engineers) don't have a sufficient knowledge of any foreign language to be able to write test reports with the same level of quality in a foreign language as in their own. Therefore, in order to guarantee the highest quality of test reports, they should be written in any language familiar to the author.

Also the national report format should be maintained in order to minimize the additional workload. The burden of translating the test reports into their own language is left with the receiving nation. This seems justified as the receiving nation will save money because fewer tests will have to be undertaken, due to the detailed test reports provided by the other nation.

3.3. Conclusion

The implementation of Harmonised Reporting generates very little additional effort for the respective nation, but should facilitate increased sharing and acceptance of qualification results between interested nations. This will save time and the cost of testing. It will also have the benefit of reducing procurement costs for industry giving them an economic competitive advantage.

Additionally, there are plans to establish regular visits by national experts to partner nation's ammunition test centres. This will enable experts to get a better understanding of another nation's working methods, test standards and test equipment used. Over time, this will build general trust in each other's ability to perform high quality testing.

ANNEXES

ANNEX A Example of Compliance Matrix for a Design Standard

ANNEX B Example of Compliance Matrix for a Test Standard

COMPLIANCE OF THE ABC-FUZE

WITH THE DESIGN REQUIREMENTS OF STANAG 4187

Ser No as per Standard (a)	Design Requirements (b)	Conformity (Yes, No, N/A, open) (c)	Comments (d)
6	**FUNDAMENTAL SAFETY DESIGN REQUIREMENTS**		
	The following safety design requirements should apply to all fuzing systems:		
6.a	Inclusion of Safety Features.		
6.a.(1)	Fuzing systems should include at least two safety features. The control and operation of these safety features are to be functionally isolated from other processes within the munition system and each of which shall prevent unintentional arming of the fuzing system. At least two of the safety features shall be independent and be designed to minimise the potential for common cause failure.	**YES**	The fuze requires two independent environmental stimuli to initiate and complete arming. The rotor is held out of line by the setback device and the jackscrew which is removed after a set number of turbine revolutions.

Ser No as per Standard (a)	**Design Requirements (b)**	**Conformity (Yes, No, N/A, open) (c)**	**Comments (d)**
6.a.(2)	Where it is not technically possible to functionally isolate the safety features, those non-isolated components, including software, used to enable the safety features should be considered part of the fuzing system and must meet the requirements of this STANAG. The reason for not complying with paragraph 6.a.1. and mitigation must be provided to the NSAA that the safety requirements have still been maintained.	**YES**	The safety features are isolated from other components and each other. No software associated logic device is used.
6.a.(3)	At least one of the independent safety features shall prevent arming after launch or deployment until the specified safe separation distance or equivalent delay has been achieved.	**YES**	The second safety features detects the air-stream caused by the velocity in air environment. Due to the mechanical delay caused by the mechanical clockwork, the safety feature is released only after the safe separation distance.
6.b	Operation of Safety Features Using Environmental Stimuli.		
6.b.(1)	The stimuli which enable the independent safety features to operate shall be derived from different environments or different combinations of environments or both; where combinations are used each combination shall be different.	**YES**	The two independent safety features require longitudinal acceleration and a velocity to generate air flow.
…	…	**…**	…

COMPLIANCE OF THE ABC SYSTEM

WITH THE TEST REQUIREMENTS OF

STANAG 4241 - BULLET IMPACT, Munition Test Procedures

Ser No (a)	Test Requirement (b)	Test Applied (Yes, No, Tailored) (c)	Comments (Test Reference or Justification) (d)
1-4	Paragraphs contain no requirements		
5	5. Test Selection. Two test procedures are included in this document. Procedure 1 is a standardised test and intended as a means of jointly assessing Insensitive Munitions (IM) and, Hazard Division (HD) 1.6 requirements (see STANAG 4123, United Nations (UN) document, ST/SG/AC.10/11/ Rev.3/R.256 and STANAG 4439). Procedure 2 is tailorable and its parameters are based on the threat hazard assessment (THA). Either test shall be applied to all munitions containing explosives, propellants or pyrotechnics. When intended to satisfy both IM and Hazard Classification (HC) requirements, the test plans should be coordinated with appropriate authorities in these two areas.	Yes	Test Report: WTD91-300-129/2011 (applicable for whole test) Procedure 1 was selected
6	Conditioning. If the test is to be conducted at temperatures other than ambient, assure the test item is stabilized at the required temperature before conducting the test.	Yes	Ambient temperature was used.

Ser No **(a)**	**Test Requirement** **(b)**	**Test Applied (Yes, No, Tailored)** **(c)**	**Comments (Test Reference or Justification)** **(d)**
7	Impact orientation. The test item shall normally be positioned with its longest axis horizontal, on a suitable stand at a height to facilitate ease of testing, but may be otherwise oriented provided the requirements of paragraph 11 are met. If necessary, the item may be strapped or restrained by other means to prevent it from becoming propulsive, but such restraint should not to interfere with instrumentation, nor affect significantly the ability of the charge or motor case to rupture or fragment.	Tailored	Angle was adjusted to result in highest vulnerability. For details, see test report.
…	….	…	…

Ser No (a)	Test Requirement (b)	Test Applied (Yes, No, Tailored) (c)	Comments (Test Reference or Justification) (d)
12.	Observations and Records: a. The following minimum observations are to be made and records kept: (1) test item identification (model, serial numbers, number of test items, etc.); (2) impact velocity and firing rate (if applicable); (3) blast pressure in two orthogonal directions, three gauges minimum in each direction; (4) witness plates (optional); (5) record of events against time from the order to fire to the end of the trial; (6) the nature of any reactions by the test item; (7) the nature (size) and distribution of residue and debris (fragmap and recovery technique); (8) listing of environmental preconditioning test performed; (9) type of energetic material and weight; (10) the orientation of the test item's longitudinal axis, and layout of the firing area; (11) audio record (in combination with high-speed video recording); (12) indication of propulsion (video or other suitable means);	Yes	

Ser No (a)	Test Requirement (b)	Test Applied (Yes, No, Tailored) (c)	Comments (Test Reference or Justification) (d)
12	b. The following photographic records and videos are to be made: (1) still photographs of the test-item before and after each trial; (2) still photographs of any other residues arising as a result of the trial; (3) colour cine-film or video for the duration of each trial.	(1) Yes (2) Yes (3) No	Video camera broke during trial No. 2; results were still conclusive
…			