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BUREAU OTAN DE NORMALISATION
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**STANAG 4560 SGA (EDITION 3) - ELECTRO-EXPLOSIVE DEVICES, ASSESSMENT AND TEST METHODS FOR CHARACTERIZATION - AOP-43 EDITION 3**

References:
A. NSA/1031-JAS/4560, dated 14 December 2006 (Edition 2)
B. NSA/0762(2014)LMC/4560, dated 18 June 2014 (Edition 3) (Ratification Draft 1)

1. The enclosed NATO Standardization Agreement, which has been ratified by nations as reflected in the NATO Standardization Document Database (NSDD), is promulgated herewith.

2. The references listed above are to be destroyed in accordance with local document destruction procedures.

ACTION BY NATIONAL STAFFS

3. National staffs are requested to examine their ratification status of the STANAG and, if they have not already done so, advise the NSO, through their national delegation as appropriate of their intention regarding its ratification and implementation.

4. It should be noted that this standard entered development/ratification under AAP-03(I) and therefore is promulgated in its current format.

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

Enclosure:
STANAG 4560 (Edition 3)

# NORTH ATLANTIC TREATY ORGANIZATION
# (NATO)

# NATO STANDARDIZATION OFFICE
## (NSO)

# STANDARDIZATION AGREEMENT
## (STANAG)

SUBJECT: ELECTRO-EXPLOSIVE DEVICES, ASSESSMENT AND TEST METHODS FOR CHARACTERIZATION - AOP-43 EDITION 3

Promulgated on 21 November 2016

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

## RECORD OF AMENDMENTS

| No. | Reference/Date of amendment | Date entered | Signature |
|---|---|---|---|
| | | | |

## EXPLANATORY NOTES

### AGREEMENT

1. This STANAG is promulgated by the Director NATO Standardization Office under the authority vested in him by the North Atlantic Council.

2. No departure may be made from the agreement without informing the tasking authority in the form of a reservation. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

### RATIFICATION, IMPLEMENTATION AND RESERVATIONS

4. Ratification, implementation and reservation details are available on request or through the NSO websites (internet http://nso.nato.int; NATO Secure WAN http://nso.hq.nato.int).

### RESTRICTION TO REPRODUCTION



### FEEDBACK

6. Any comments concerning this publication should be directed to NATO/NSO – Bvd Leopold III - 1110 Brussels - Belgium.

# NATO STANDARDISATION AGREEMENT
# (STANAG)

## ELECTRO-EXPLOSIVE DEVICE, ASSESSMENT AND TEST METHODS FOR CHARACTERIZATION

Annex A: National Points of Contact.
Annex B: Characterization of Electro-Explosive Devices.
Annex C: BW, FB and CC Characterization Tests.
Annex D: EBW and EFI Characterization Tests.

Referenced documents:

| | |
|---|---|
| STANAG 4147 | Chemical Compatibility of Ammunition Components with Explosives (Non-Nuclear Applications). |
| STANAG 4157 | Fuzing Systems: Test Requirements for Assessments of Safety and Suitability for Service. |
| STANAG 4170 | Principles and Methodology for the Qualification of Explosive Materials for Military use. |
| STANAG 4187 | Fuzing Systems - Safety Design Requirements |
| STANAG 4370 | Environmental Testing |
| AECTP 250 | ELECTRICAL AND ELECTROMAGNETIC ENVIRONMENTAL CONDITIONS |
| AECTP 500 | Electromagnetic Environmental Effects Test & Verification |
| AOP-20 | Manual of Tests for the Safety Qualification of Fuzing Systems |
| AOP-43 | Electro-Explosive Devices; Assessment and Test Methods for Characterization; Guidelines for STANAG 4560 |
| STANAG 4368 | Ignition Systems for Rocket and Guided Missile Motors. Safety Design Requirements |

Related documents:

| | |
|---|---|
| STANAG 4238 | Munition Design Principles, Electromagnetic Environment. |
| AECTP 200 | Environmental Conditions |
| AECTP 230 | CLIMATIC CONDITIONS |
| AECTP 240 | MECHANICAL CONDITIONS |
| AECTP 300 | Climatic Environmental Tests |

| | |
|---|---|
| AECTP 400 | Mechanical Environmental Tests |
| AOP-7 | Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use |
| AOP-16 | Fuzing Systems: Guidelines for STANAG 4187 |

AIM

1. The aim of this agreement is to standardize the methodology and procedures by which Electro-Explosive Devices (EED) are characterized, in order to assist in their assessment for safe and suitable use by NATO forces. It is emphasized that characterization is not qualification but only the data to assist in the overall qualification.

DEFINITIONS

1. The following terms and definitions are used for the purpose of this agreement:

   a. All-fire Threshold (AFT). The level at which there is a 99.9% probability of fire at the 95% upper single sided confidence limit.

   b. Bridge-wire (BW) EED. An EED where the power dissipated by the passage of current through a resistive wire is used to initiate by heating a primary explosive in intimate contact with the wire.

   c. Characterization. The determination of attributes of a component which define its capability to fulfil a particular requirement.

   d. Conducting Composition (CC). An EED where the primary explosive is intimately mixed with a small quantity of conducting material (example graphite and powered metals), which, when placed in a suitable container, allows the flow of an electrical current between two electrodes. As the current flows, sufficient heat is generated to function the composition.

   e. Electrically Initiated Device (EID). Any single shot component initiated by electrical means and having an explosive, pyrotechnic, or mechanical output resulting from an explosive, pyrotechnic, laser or electro-thermal action.

   f. Electro-Explosive Device (EED). A one shot explosive or pyrotechnic device used as the initiating element in an explosive train and which is activated by the application of electrical energy.

   g. Exploding Bridge-wire (EBW). An EED which, when subjected to a high energy, short duration electrical pulse heats up rapidly, partially sublimes and then explodes, projecting high energy particles, causing detonation in a relatively insensitive explosive, which is in direct contact with the bridge-wire.

   h. Exploding Foil Initiator (EFI) (also: Slapper Detonator). An EED with a low resistance bridge which when subjected to a high energy, short duration electrical pulse, converts electrical energy into kinetic energy to project a high velocity flyer plate which, on impact, causes a detonation in a relatively insensitive explosive which is not in direct contact with the bridge.

   i. Film Bridge (FB) EED. An EED where the power dissipated by the passage of current through a resistive vacuum deposited film or foil of very small dimensions is used to initiate by heating a primary explosive which is in intimate contact with the film or foil.

   j. Fireset. For high voltage characterization (> 500 V for fuze application) a fireset is the integral part of a high voltage initiation system designed to produce an electrical pulse with specific characteristics which normally consists of a firing capacitor, triggered high voltage switch and its trigger circuitry.

k. Firing Unit. A firing unit is a combination of power source and safety and trigger switches used to initiate an EED.

l. Maximum Allowable Safe Stimulus (MASS). The projected voltage at which an EFI has a $10^{-6}$ probability to fire with ideal confidence (often referred to as the point estimate).

m. No-fire Threshold (NFT). The level at which there is a 0.1% probability of fire at the 95% lower single sided confidence limit.

n. Qualification. The assessment of an explosive material or EED by the NSAA to determine whether it possesses properties that makes it safe and suitable for consideration for use in its intended role.

o. Semi-conductor Bridge (SCB). An EED containing a heavily doped polysilicon bridge, which when subjected to a pulse of electrical energy produces a plasma discharge initiating an explosive with which it is in contact.

p. Type Qualification. Type (or Final) Qualification relates to the use of a device in a specific application or weapon system. Type Qualification is given when a device has been assessed as part of the design of the specific weapon, and shown to be safe and suitable for military operational or training use in that role. If the same device is used in more than one munition system, then type qualification is required for each munition.

## AGREEMENT

2. Participating nations agree to:

a. Characterize EED in accordance with the methodology and procedures set out in this STANAG.

b. Apply this STANAG to the development and acquisition of EED for use within military weapon systems developed after its promulgation.

c. Provide to the custodian of this STANAG or National Points of Contact (POC) for Safety and Suitability for Service ($S^3$) assessments of EED

d. Safety data developed in accordance with this STANAG shall be made available to other NATO nations participating in a collaborative weapon development or procurement programme upon receipt of a request, submitted through appropriate national channels, from the NSAAs or appropriate authorities as listed in Annex A.

## GENERAL

3. EED currently in general military use include Bridge-Wire (BW) and Film Bridge (FB) devices, Conducting Composition (CC), Semi-Conductor Bridge (SCB), Exploding Bridge-Wire (EBW) and Exploding Foil Initiators (EFI).

4. This STANAG furnishes general requirements to cover the characterization of all EED presently in use in military service and establishes uniform methods for testing electric initiators and electric initiator subassemblies. The purpose of the testing program is to determine the electric characteristics, soundness of mechanical design, output, and resistance to deleterious service environments. It extends the work, previously carried out on a national basis, on BW, FB and CC devices, to also cover EBW and EFI.

5. The term electric initiator does not include complete assemblies, which have electric initiators as subassemblies, but include only the subassemblies themselves. The smallest testable item/subsystem containing one of the above components shall be used for the purposes of characterization.

6. EED are designed to produce a specific output such as shock (detonation), flame, or generate gasses in order to perform a particular task. An explosive reaction process occurs in an EED when the temperature of a small amount of explosive is raised beyond its ignition temperature, due to the heat generated by the input of electrical energy; or when a secondary explosive is detonated following the shock caused by an EBW or by an electrically released flyer. In general, various types of reaction can occur during the ignition and functioning of an explosive composition ranging from burning to full detonation. The reaction will depend upon the type and state of the explosive, the rate of input of energy and the degree of confinement.

7. An EED can be a component of a munition system or subsystems having no separate existence save during manufacture, refurbishment or disposal during the munition life cycle. Alternatively an EED may be fitted into a munition system as it is being deployed, such as an electric detonator fitted to a demolition charge.

8. Primary and secondary explosives, propellants and pyrotechnics may all be used in EED. Generally the primary and secondary explosives will be used to produce a detonation, whilst propellants and pyrotechnics will be used to burn. However, under certain conditions primary and secondary explosives can burn and some propellants can detonate. All explosive materials shall be assessed and/or qualified in accordance with STANAG 4170. Additionally, initiating components shall meet the compatibility requirements of STANAG 4147.

9. The electrical input needed to initiate the EED can be obtained either from sources installed within a munition or from external sources in, for instance, a demolition firing unit or a launching platform connected to the munition through a cable.

10. Characterization of an EED is required to assist a national authority to provide an assessment of the $S^3$ of weapons and those parts of weapon systems and stores in which EED are used. The assessment should cover design and manufacture, including explosive content, initiation and output over a variety of conditions of use. In addition, electric initiators must be safe for handling, transportation, storage and use and must not deteriorate to a degree, which would render their performance or safety doubtful under normal service handling, adverse storage and transportation. RF susceptibility requirements and tests have not been included in this STANAG. It is emphasised that characterisation is not Qualification but only generates the data to assist in the overall Qualification.

11. Re-assessment shall be required whenever component parts of the EED or fireset are

changed.

## DETAILS OF THE AGREEMENT

12. Participating nations agree that:

a. The characterization shall be based on the electrical and environmental tests listed in Annex B.

b. The characterization of BW, FB, SCB and CC devices shall be in accordance with the test procedures described in Annex C or national accepted test procedures listed in AOP 43.

c. For EBW and EFI the characterization shall be in accordance with the test procedures described in Annex D.

d. The NSAA or other appropriate authority shall agree to the selection of tests, sample sizes, and acceptance criteria. At least the minimum number of units as described in Annex C & D shall be used for characterization.

e. As part of the characterization test programme, sequential environmental testing of the EED shall be carried out unless NSAA agree that the environmental aspects are covered by system Qualification tests. These environmental tests shall be in accordance with the guidelines of STANAG 4370 and the appropriate Allied Environmental Conditions and Test Publications (AECTP) and/or STANAG 4157.

(1) Where the EED is transported separate from the receptor explosive charge, the sequential environmental test programme shall include simulation of tactical environments such as ground, sea and air transportation, as applicable.

(2) Where the EED is to be incorporated, at an early stage, into a sub-system or system the EED can be Type Qualified as part of the sub-system or system concerned.

f. The use of an EED in new environmental conditions will require a new appraisal of the relevance of the environmental characterization data.

g. Records, documenting all test specifications, data and results carried out in accordance with this agreement, shall be maintained by participating nations.

## IMPLEMENTATION OF THE AGREEMENT

13. This agreement shall be implemented when ratifying nations have put into place the required national procedures.

**NATIONAL POINTS OF CONTACT**

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NLD Defence Material Organisation
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96 TW / SES
1001 N. 2nd Street, Suite 366
Eglin Air Force Base, FL 32542-6838

## CHARACTERIZATION OF ELECTRO-EXPLOSIVE DEVICES

1. An EED will normally be characterised as a separate item, except for those characteristics that may be more appropriately derived at sub-system level when agreed by the NSAA.

2. The characterization test programme for an EED will consist of a series of electrical tests to establish its electrical parameters and environmental tests that reflect the life cycle of the EED as related to its mode of application. Table 1 shows recommended tests for individual EED.

3. BW, FB, and CC devices have been characterised over the past 35 years using separate national test procedures. These procedures, though different, have normally been considered adequate tests providing the NSAA or other appropriate authority to which the test data should be provided monitors them.

4. With more reliance on manufacturers doing the tests and the need to provide data to other nations when considering overseas sales, it has been considered appropriate to consolidate these tests to provide a single guidance for national defence agencies and contractors. The accepted test procedures are listed in Annex C for BW, FB, CC and SCB.

5. For EFI and EBW the test techniques are identified in Annex D.

6. The list of tests in Table 1 is NOT EXHAUSTIVE. Serials No 2-10 & 19 identify mandatory tests required to provide data to assess the electrical characterization used when assessing the RADHAZ (HERO) of systems/sub systems and functional tests of an EED.

7. Where tests are required to be carried out at cold, ambient, and hot temperatures the following shall be used:

    a. Cold temperature shall be less than or equal to -54° C (- 65°F)

    b. Ambient temperature shall be in the range of +23 ± 10° C (+73 +/- 18°F)

    c. Hot temperature shall be greater than or equal to +71° C (+160°F)

8. After the environmental testing, the EED shall meet all safety and performance requirements, unless specified otherwise.

9. A detailed characterisation test plan shall be developed and approved by the appropriate safety authority prior to starting the characterisation tests. The detailed characterisation test plan shall provide descriptions of the following: visual inspections and examinations, firing unit (fireset), test fixtures, the test firing circuit, and special test equipment that will be used in conducting each test. A detailed test report shall be provided to the design safety authority at the completion of the characterisation testing. As a minimum this report shall include the test data, inspection results, diagnostic records, and explanation of anomalous results.

10. The NSAA or other appropriate national authority should maintain a copy of the test report, along with their electrical and performance characteristics. As a minimum this test report shall include the test data, inspection results, diagnostic records and explanation of anomalous results. Further guidance on assessment and characterisation is contained in AOP 43.

| Series Number | Test | Devices | | |
|---|---|---|---|---|
| | | BW, FB, CC, SCB | EFI | EBW |
| (a) | (b) | (c) | (d) | (e) |
| 1 | Radiographic and/or Visual Inspection | X | X | X |
| | Electrical Tests | | | |
| 2 | Resistance | X | X | X |
| 3 | Insulation Resistance | X | X | X |
| 4 | Firing Properties Test | X | X | X |
| 5 | Malfunction Threshold | | X | X |
| 6 | MAEST | | X | X |
| 7 | Thermal Time Constant(1) | X | X | X |
| 8 | Non-Interrupted Explosive Train Requirement | | X | X |
| 9 | Electrostatic Discharge | X | X | X |
| 10 | Low Power Non-Functioning Test | | | X |
| | Environmental Tests | | | |
| 11 | Vibration | X | X | X |
| 12 | Thermal Shock | X | X | X |
| 13 | Humidity | X | X | X |
| 14 | Leakage | X | X | X |
| 15 | 1.5 m Drop | X | X | X |
| 16 | Mechanical Shock | X | X | X |
| 17 | Thermal Cook-Off(1) | X | X | X |
| 18 | High Temperature(1) | X | | |
| | Function Tests | | | |
| 19 | Performance Tests(2) | X | X | X |
| 20 | Post Environment Firing Properties Test | | X | X |
| 21 | High Voltage | | X | X |

Notes: (1) May not be considered mandatory by the NSAA
(2) Functioned at Cold, Ambient, and Hot

TABLE 1. ELECTRICAL AND ENVIRONMENTAL CHARACTERIZATION TESTS

# BW, FB, CC and SCB CHARACTERIZATION TESTS

## GENERAL

1. BW, FB, CC and SCB devices have been characterised over the past 35 years using separate national test procedures. These procedures, though different, have normally been considered adequate tests providing the NSAA or other appropriate authority has monitored them and been provided with the test data. The documents containing national accepted test procedures are listed in AOP 43.

2. The purpose of the testing program is to establish key initiator characteristics such as the electrical characteristics, soundness of mechanical design, output, basic safety properties and resistance to adverse service environments.

3. The NSAA or other appropriate authority shall approve the test procedures, the tests selected, the number of devices for each test and methods of statistical analysis used and shall specify the appropriate stimulus. Known statistical procedures, which include Bruceton, Langlie, Neyer D-Optimal, One Shot, or Probit, are to be employed.

4. The list of tests is not exhaustive and shall not be considered a substitute for the Qualification of the devices, sub-systems or systems containing the device.

## REQUIRED TESTS

5. Radiographic and/or Visual Inspection. Examination of all initiators shall be made according to the manufacturing inspection criteria and only those meeting the inspection requirements shall be used for the following tests. When considered appropriate by the NSAA each device shall be subjected to radiographic examination such as X-ray, neutron bombardment, gamma rays etc. Radiographic plates and examination acceptance report shall be identified by date, EED part, lot and serial number,

6. Resistance. The purpose of this test is to measure the resistive element of the EED. The resistance of each initiator shall be measured for all devices before any other test is carried out. The resistance shall be measured as follows:

   a. An approved low voltage, low current resistance meter is to be used operating at less than 10% of the designed/estimated NFT current (Typically < 50 mA).

   b. These tests are to be conducted using a DC resistance method at ambient temperature. Measurements shall be recorded and then corrected to ambient temperature (23$^{o}$C) as necessary.

   c. Measuring the initiator bridge resistance or continuity shall not adversely affect the initiator or cause it to dud or fire. In order to reduce errors it is recommended that a four terminal measurement method should be used for devices with low resistance (e.g. < 1 Ω.) (See AOP 43)

7. Insulation Resistance. For devices that are housed in an insulated package the

resistance offered by the insulating members of a component part to an impressed direct voltage shall be measured.

a. Insulation resistance measurements shall be made on an apparatus suitable for the characteristics of the component to be measured such as a megohm bridge, megohm-meter, insulation resistance test set, or other suitable apparatus.

b. For EED with 2 firing leads that are housed in an insulated package, it is a requirement to assure that if 500 V is present anywhere near the initiator it can not inadvertently cause an unacceptable function. All such EED shall be subjected to 500 V dc for 60 s between the initiator that has the input leads shorted and the case prior to the environmental tests. The item under test shall not be damaged, be safe for use and have a leakage current not to exceed 2 μA.

8. Firing Properties Test. It is important to know for both safety and suitability for service ($S^3$) reasons the level of energy or power at which the EED will or will not be initiated. Generally the probability of initiation by the electrical input is assumed to be according to a normal or log normal law. The All-Fire Threshold and the No-Fire Threshold values as defined in clause 2 of this STANAG shall be determined.

a. In addition to reporting the reliability levels, all raw data recorded for the sensitivity tests that comprise the firing properties test shall be reported along with the mean firing stimulus and the associated standard deviation. Known procedures, which include Bruceton, Langlie, Neyer D-Optimal, One Shot, or Probit, are to be employed. These statistical techniques are valid only for those EED whose sensitivity can be approximated by a normal or log-normal distribution. In most instances, conventional EED are “go/no go” devices whose responses are adequately described by a log-normal distribution. Since the all-fire and no-fire levels required are at the “tails” of the distribution, the cost of large numbers of EED prohibit direct determination of these values, and extrapolation from a smaller number of experimental results nearer the middle of the distribution is necessary.

b. AFT and NFT Characteristics. A strategy designed to characterize an EED is to submit each item of a batch of initiators to a series of power/current pulses defined by a statistical method, observe whether the initiator has functioned or not, and determine by calculation the values of AFT and NFT. The firing properties (mean firing stimulus (power/current), standard deviation, minimum all-fire stimulus (power/current), and the maximum no-fire stimulus (power/current)) are determined using the statistical method agreed with the NSAA. (A typical firing strategy is shown in AOP 43, Annex A.)

9. Energy Threshold Assessment for RADHAZ Trials. For pulse sensitive devices, when considered appropriate by the NSAA, evaluate the energy threshold ($E_{th}$) using the statistical method with pulses much less than the estimate of thermal time constant ($\tau$). This will require further devices for sufficient accuracy.

10. Thermal Time Constant. If both the energy and power thresholds have been determined experimentally then evaluate the thermal time constant $\tau$ by dividing $P_{th}$ into $E_{th}$ from paragraphs 8. If the working value of the thermal time constant was large such that only the power threshold assessment has been carried out then the

thermal time constant should be derived from the best available data. This will be the 50% Power level ($P_{50\%}$) from the power threshold assessment and the 50% Energy level ($E_{50\%}$). Other means of determining the Thermal Time Constant can be employed at the discretion of the NSAA.

11. Electrostatic Discharge (25kV). AECTP 250 leaflet 253 defines the maximum personnel electrostatic discharge (PESD) environment likely to be encountered by EED and munition weapon systems containing EED during handling and deployment. The test is to be carried out according to the following:

a. The EED shall not function when subjected to the simulated personnel electrostatic discharge (25 kV) and shall be capable of functioning as designed after having been subjected to the discharge.

b. The test and assessment of the electrostatic discharge susceptibility of the EED shall be conducted in accordance with AECTP 500 leaflet 508-2 and the guidance in AOP-43. All tests on EED shall use only the contact discharge method.

c. The minimum number of devices tested should be agreed with the NSAA or appropriate national authority but shall not be less than 30.

d. Where devices fail the test at the appropriate level, additional testing, if required by the NSAA or appropriate national authority, shall be performed to determine the maximum voltage level at which devices do not fail.

12. Sequential Environmental Testing. For the environmental tests defined in Table 2 the following requirements apply. The sequence of environmental tests and the number of EED per test are at the discretion of the NSAA, as long as all required environmental tests are covered by at least 30 EED each.

13. Vibration. This test is applicable in order to obtain characterisation data about EED to adequately demonstrate their ability to resist a typical environment without unacceptable degradation of their characteristics:

a. The EED shall be subjected to the vibration test as described in STANAG 4157, AOP-20, Test B1 (Transport Vibration (bare fuze); 5-500 Hz sine sweep).

b. On completion of the test the performance of the EED shall be checked for changes in the following:

(1) Physical condition (e.g.by Visual Inspection).

(2) Electrical parameters (bridge resistance, insulation resistance, etc.).

14. Thermal Shock. The objective of the thermal shock test is to determine if an EED is affected as a result of exposure to sudden extreme changes in temperature. The EED shall be tested to the requirements of STANAG 4157, AOP-20, Test C7.

15. Temperature-Humidity. The combined effects of temperature change and humidity can cause degradation to the performance and safety of the EED. The EED shall be tested in accordance with STANAG 4157, AOP 20, Test C1.

   a. Relative humidity (rh) may have a significant influence on some materials during thermal shock test. Where this is considered appropriate the test procedure can be combined with the thermal shock test.

16. Mechanical Shock. The initiator shall be tested to determine if the initiator meets the shock requirements of STANAG 4157, AOP-20, Test A1 (Jolt). The degree of support afforded to the device during the test shall ensure that the full severity of the shock is transferred to the device.

17. 1.5 m Drop. This test simulates severe shocks due to the EED being dropped during accidental mishandling in manufacture, transportation or service use. The initiator shall be tested to determine if the initiator meets the requirements of STANAG 4157, AOP-20, Test A4. Unless required otherwise by the NSAA, 6 unprotected initiators shall be dropped and impacted in each of the following orientations:

   a. 2 unprotected EED nose up

   b. 2 unprotected EED nose down

   c. 2 unprotected EED horizontal.

18. Leakage. The initiator shall be tested in accordance with STANAG 4157, AOP 20, Test C8. This is specifically for hermetically sealed initiators, which shall be tested in accordance with the Fine Leak Test. They are not to exhibit a leak rate in excess of $10^{-5}$ $cm^3/s$ of air at a pressure differential of $0.1 \pm 0.01$MPa.

19. Thermal Cook-off. The maximum temperature to which an initiator can be exposed for a period of one hour without cook-off shall be established (within 10° C).

   a. Using an appropriate pre-test (e.g. using single EED samples), determine the minimum temperature within 10°C at which cook-off occurs within 1 hour.

   b. Five initiators shall be placed in an oven preheated to 10°C below the minimum temperature determined in the pre-test. If cook-off occurs, the temperature shall be decreased 10°C and the test repeated with new initiators. The test shall be repeated in 10°C decrements until cook-off does not occur within a 1-hour period.

   c. The thermal cook-off threshold for a component is the maximum temperature where no cook-off reaction occurs when exposed for a one hour period.

20. High Temperature. This test is to determine if the initiator meets the requirements for high temperature exposure. The maximum temperature (within 10°C) to which an initiator may be exposed for 12 hours and both meet the safety requirements and perform satisfactorily shall be determined.

   a. 10 initiators shall be placed in an oven preheated to a temperature 10°C less than the maximum determined for exposure without cook-off in paragraph 19.

b. The temperature shall be maintained for 12 hours. If no initiator cooks off, the 10 initiators shall be cooled to ambient and functionally tested.

c. If any initiator cooks off, or fails to meet safety or design performance requirements after cooling, the test shall be repeated with additional groups of initiators, decreasing the temperature in increments of 10°C until safety and design performance requirements are met.

Note: This test could be combined with the Thermal Cook-Off test in section 19.

21. Performance Tests. The EED shall be fired and the output recorded when functioned at the minimum firing voltage for an intended application while temperature conditioned:

a. Tests shall be carried out at cold, ambient, and hot temperature conditions.

b. This can be performed on initiators previously stressed during environmental tests.

c. The output characteristics can be determined by tests that reflect the purpose for which the device will be used.

22. Spare. It is advisable to have additional EED in case some tests require repeating.

| **REQUIREMENT** | **PARA** | **MINIMUM QUANTITIES** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **120 A** | **30 B** | **6 C** | **10 D** | **10 E** | **50 F** | **50 G** | **50 H** | **25 I** | **25 J** | **25 K** | **401(3)** |
| Radiographic And/Or Visual Inspection | 5 | X | X | X | X | X | X | X | X | X | X | X | **401** |
| Resistance | 6 | X | X | X | X | X | X | X | X | X | X | X | **401** |
| Insulation Resistance | 7 | X | X | X | X | X | X | X | X | X | X | X | **401** |
| Firing Properties | 8 | X | | | | | | | | | | | **120** |
| Thermal Time Constant(1) | 10 | X | | | | | | | | | | | **120** |
| Electrostatic Discharge | 11 | | X | | | | | | | | | | **30** |
| Vibration (2) | 13 | | | | | | | | | X | X | X | **75** |
| Thermal Shock (2) | 14 | | | | | | | | | X | X | X | **75** |
| Temperature-Humidity (2) | 15 | | | | | | | | | X | X | X | **75** |
| Mechanical Shock (2) | 16 | | | | | | | | | X | X | X | **75** |
| 1.5 Meter Drop | 17 | | | X | | | | | | | | | **6** |
| Leakage (2) | 18 | | | X | | | | | | X | X | X | **81** |
| Thermal Cook-Off (1) | 19 | | | | X | | | | | | | | **10** |
| High Temperature (1) | 20 | | | | | X | | | | | | | **10** |
| Performance Test, Ambient | 21 | | X | X | | | X | | | X | | | **111** |
| Performance Test, Cold | “ | | | | | | | X | | | X | | **75** |
| Performance Test, Hot | “ | | | | | | | | X | | | X | **75** |

Notes: (1) May not be considered mandatory by the NSAA.
(2) See paragraph 12
(3) It is advisable to have additional EED available in case some tests need repeating

TABLE 2. MINIMUM TEST SEQUENCE FOR LOW VOLTAGE EED

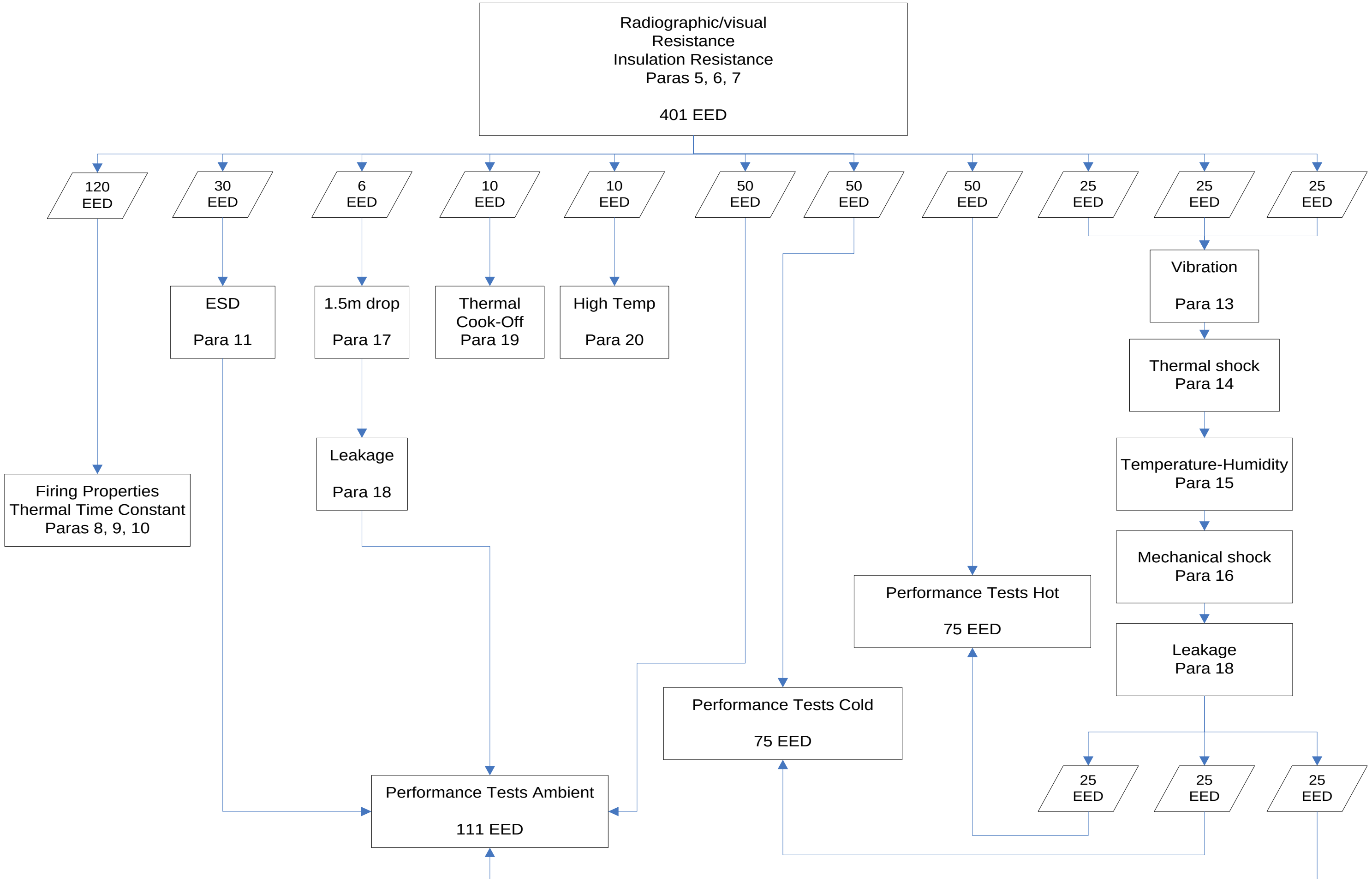


**Figure 1: LOW VOLTAGE EED TEST SEQUENCE**

# EBW AND EFI CHARACTERIZATION TESTS

## GENERAL

1. The tests in this Annex furnish characterization data of electric initiators that are often used in-line for the initiation of safety critical applications. The purpose of the testing program is to establish key initiator characteristics such as the electrical characteristics, soundness of mechanical design, output, basic safety properties and resistance to adverse service environments.

2. As knowledge of the methods for assessing EBW/EFI is still evolving, these tests are considered to be the minimum required. They include those common to the initiator as a device, and those that apply to the initiator and its fire-set. The characterization test programme for an EBW/EFI will consist of a series of electrical tests and when required by the NSAA or appropriate national authority, environmental tests.

3. The minimum test sequence with minimum quantities is given in Table 3. Any variation to the tests given within this Annex to reflect the test item's particular application shall be agreed by the NSAA or other appropriate authority before commencement of the test program.

## REQUIRED TESTS

4. Radiographic and/or Visual Inspection. Examination of all initiators shall be made according to the manufacturing inspection criteria and only those meeting the inspection requirements shall be used for the following tests. When considered appropriate by the NSAA each device shall be subjected to radiographic examination such as X-ray, neutron bombardment, gamma rays etc. Radiographic plates and examination acceptance reports shall be identified by date, EED part, lot and serial number.

5. Resistance. For an initiator, which does not contain a bridge circuit gap the resistance of each initiator shall be measured before the Firing Properties Test is carried out. The resistance shall be measured as follows:

   a. An approved low voltage, low current resistance meter is to be used operating at less than 10% of the designed No Damage or NFT current whichever is the lower.

   b. These tests are to be conducted using the DC resistance method at ambient temperature. Measurements shall be recorded and then corrected to ambient temperature (23ºC) as necessary.

   c. Measuring the initiator bridge resistance or continuity shall not adversely affect the initiator or cause it to dud or fire. In order to reduce errors it is recommended that a four terminal measurement method should be used.

6. Insulation Resistance. For EED that are housed in an insulated package the resistance offered by the insulating members of a component part to an impressed direct voltage shall be measured.

   a. Insulation resistance measurements shall be made on an apparatus suitable for the characteristics of the component to be measured such as a megohm bridge, megohm-meter, insulation resistance test set, or other suitable apparatus.

b. For EED with 2 firing leads that are housed in an insulated package, it is a requirement to assure that if 500 V is present anywhere near the initiator it cannot inadvertently cause an unacceptable function. All such EED shall be subjected to 500 V dc for 60 s between the initiator that has the input leads shorted and the case prior to the environmental tests. The item under test shall not be damaged, be safe for use and have a leakage current not to exceed 2 μA.

7. Firing properties. Since an EBW/EFI operates by application of an input from an external source it is necessary to establish its electrical parameters. The most significant parameters are those, which establish the electrical conditions at which the initiator can and cannot be initiated. The firing properties (mean firing stimulus (voltage/energy), standard deviation, minimum all-fire (voltage/energy), the maximum no-fire (voltage/energy)) and the maximum allowable safe stimulus (MASS) shall be determined by statistical tests as follows:

a. The NSAA or other appropriate authority shall approve the test procedures and methods of analysis used. Known statistical procedures (for example Bruceton, Langlie, Neyer D-Optimal, One Shot, or Probit) are to be employed.

b. These tests are not to be confused with the Performance Tests of paragraph 22 below. Testing the firing properties determines the electrical sensitivity for safety and projected reliability, and provides the user with data to estimate the all-fire/no-fire thresholds and MASS.

c. The firing unit shall use the same circuit components or as close as possible to those used in the intended munition's tactical firing unit (fireset). Due to the possible degradation of the firing pulse because of deterioration of the fireset components, e.g. triggering device and/or firing capacitor, components shall not be used beyond their life ratings.

d. To assure the discharge properties (ring downs) are acceptable, firing units should be calibrated before the first test and on completion, and the subsequent discharges monitored for changes, such as deterioration of components within the firing capacitor discharge unit (fireset).

e. The test shall be carried out at different temperatures and on a minimum sample size for each temperature. Tests shall be completed at cold, ambient, and hot temperatures or at temperatures directed by the possible intended use of the EFI/EBW and fireset. The sample size shall be such that the following two conditions are met:

(1) Not less than 30 initiators at each temperature.

(2) The ratio between the standard deviation and the mean value of the firing voltage (derived from the statistical analysis) shall be not more than 30%.

f. Statistical analysis of the firing properties data shall be used to predict the minimum All-Fire Threshold (AFT), the maximum No-Fire Threshold (NFT) and

MASS of the EFI/EBW at cold, ambient, and hot temperatures. The voltage corresponding to the NFT and the MASS shall be at least 500V.

8. Malfunction Threshold (MFT). Tests are needed to determine the current or power that would be required to cause a malfunction if induced by external effects, such as electromagnetic radiation. A sample of initiators (minimum of 30) shall be subjected to either a functional or inspection approach at ambient temperature to establish the direct current or power that damages the initiator. The inspection approach could provide a lower estimate of maximum no damage level. The results should specify by which test procedure MFT was determined. For Nations considering the safe use of an EFI or EBW it is often appropriate to be aware of the current/power that opens or damages the bridge or wire without detonation or initiation. These tests should be conducted in accordance with the following procedures:

a. Functional Approach. The following test is most suited to EFIs. At present, each NSAA or the appropriate national authority should be consulted with regard to the need to establish the Maximum No-damage Current for EBWs:

(1) Where manufacturers' data is not available, a small sample, no more than 10 devices (not part of the sample size), will be selected and each device subjected to a Direct Current (DC) to determine a mean malfunction level to start the statistical test.

(2) Using the manufacturer's malfunction level, or that established above, as a starting point, the EFI strip line/leads shall be subjected to DC levels in accordance with an acceptable statistical method similar to that used for the firing properties test (e.g. Bruceton, Langlie, or Neyer D-Optimal),

(3) The DC current/power that will cause damage is normally evaluated by applying a test stimulus whose duration is set to be much greater than the time constant. The DC pulse should be applied for >1 minute.

(4) The applied DC shall not overshoot the intended test DC level by more than 5%.

(5) The determination of damage or no-damage after each test shall be determined by the application of the operational voltage from the intended fireset. Failure to detonate shall be considered evidence of damage and detonation shall be considered evidence of no-damage.

(6) If the operational voltage is not known or undefined, the 99.9% AFT level determined in the firing properties test shall be used.

(7) The MFT mean and standard deviation shall be reported.

b. Inspection Approach. The following test can only be used where the bridge is visible for microscope examination:

(1) The DC current shall be applied to the input leads of the initiator, increasing linearly in amplitude, until either a visible change (physical) or measurable change in electrical (resistance) parameters is observed. This will normally be carried out in the absence of any explosive.

(2) The lowest current or power amplitude that damages the initiator and the type

of damage seen shall be reported to the NSAA.

9. Low Power Non-Functioning Test. For EBW, since the explosive is in direct contact with the bridgewire it is necessary to ensure that the device cannot function as a low voltage device. To confirm this, 5 devices shall be tested with a DC power 1 dB below the no damage level determined above (or where not available at a mean no-damage level determined from a sample of 10 devices) and held constant for at least 5 minutes or until the temperature of the EBW has reached an equilibrium (whichever is greater). Any detonation or explosive reaction which would initiate the explosive train shall be deemed a failure and the device shall not be used in an in-line configuration in fuzes or rocket motors. If a reaction occurs the test shall be repeated on further batches of 5 EBWs at a reduced DC level until a threshold value at which no reaction occurs is determined. Any malfunction during this test shall be recorded and the data shall be used to help define the malfunction level required by paragraph 8 above.

10. Thermal Time Constant. For the assessment of device susceptibility in a pulsed rf environment it may be considered appropriate by the NSAA to determine the thermal time constant. The thermal time constant ($\tau$) is the ratio of the electrical energy to the electrical power which causes the same type and intensity of damage to the EFI bridge as the MFT.

a. Perform a wind-up test on a sample of 5 – 10 EFIs starting at a level where no damage is expected and at a pulse width significantly shorter (typically 75 $\mu$s) than the $\tau$. Then increase the pulse amplitude (energy content) in steps until damage meeting the MFT criterion is observed. The mean and standard deviation of the energy to cause a malfunction from the wind-up test indicates the starting level for the Bruceton test

b. A minimum sample of 20 EFIs shall be used for both the short and long pulse Bruceton test.

c. Subject the EFI to the level indicated by the wind-up test (short pulse). Dependent upon whether the MFT is observed, increase or decrease the energy level by 0.125 dB.

d. Repeat a) to c) for the long pulse starting the wind-up test at a level significantly longer (typically 7.5 ms) than the expected $\tau$. Dependent on the observed result of malfunction or not, increase or decrease the level by 0.25 dB. For long pulse measurements the power is calculated from the energy recorded divided by the pulse width.

e. From the Bruceton result determine the 50% MFT energy (short pulse) and power (long pulse) and calculate the $\tau$.

11. Electrostatic Discharge (25 kV). AECTP 250 leaflet 253 defines the maximum Personnel Electrostatic Discharge (PESD) environment likely to be encountered by EED and munition weapon systems containing EED during handling and deployment. The test is to be carried out according to the following:

a. The EFI/EBW shall not function when subjected to the simulated human electrostatic discharge and shall be capable of functioning as designed after having been subjected to the discharge.

b. The test and assessment of the electrostatic discharge susceptibility of the EBW/EFI should be conducted in accordance with AECTP 500 leaflet 508-2 and the guidance given in AOP-43. Tests to EED shall always use the contact discharge method.

c. The minimum number of devices tested shall not be less than 25.

d. Where devices fail the test at the 25 kV level, additional testing, if required by the NSAA or appropriate national authority, shall be performed to determine the maximum pass voltage level.

12. Non-Interrupted Explosive Train Requirement. Where a munition system assembly (such as the warhead section of a missile) contains an EED mounted in a non-interrupted explosive train (e.g. in accordance with STANAG 4187 or STANAG 4368), the NSAA or other appropriate national authority may require an electrical cook-off and Maximum Allowable Electrical Sensitivity (MAES) test to be performed:

a. Electric Cook-Off. The initiator shall not exhibit a functional explosive reaction (including deflagration) from exposure to Alternating Current (AC) and Direct Current (DC) sources up to 500 volts switched directly across the input leads of the device.

Two suggested tests are the 440 VAC (rms) and the 28 VDC tests:

(1) AC Test. The reaction of the bare EED to exposure to a common AC voltage source of 440 VAC shall be determined. An EED will not be considered for qualification for non-interrupted explosive train use if the reaction is a detonation. If the EED is intended for use as a stand alone configuration item, or an application in which the leads of the EED may be externally exposed or accessible, the initiator shall not exhibit a functional explosive reaction (deflagration, explosion, or detonation) during this test.

(a) A special test set is required. The test set must be capable of being controlled to RMS output potential of 440 VAC; further, the test set must be capable of delivering current without throwing the circuit breaker during the course of the test sustaining a short circuit current for five minutes. The output of the test set must be controlled to switch voltage on within 10% of the peak voltage value, with a controlled turn on transient.

(b) The input to the EED shall be energized from a 50 to 60 hertz AC source at 440 VAC (RMS); the power source, including cabling, must be capable of sustaining a minimum short circuit current of 20 amperes to the EED. The minimum open circuit voltage of the source shall be adjusted to within -5 to +15 percent of the required value. EED used for this test shall be temperature conditioned at ambient.

(c) Five EED shall be exposed to the 440 volts RMS for five minutes without additional output impedance being included in the circuit.

(d) The radial confinement used shall be a right circular cylinder constructed from steel. The outside of the cylinder shall have a radius that is at least 50% larger than the radius of the EED being tested. Additionally the cylinder shall have a centre hole to accommodate the EED whose radius is sized such that there is a maximum radial gap of 0,045mm (0.0018”) between the outside surface of the EED and the inside surface of the hole. The radially confined EED shall be mechanically anchored to the dent block to prevent movement should a reaction occur.

(e) For the test, the input voltage shall be switched on either mechanically or electronically, and the onset of voltage shall be controlled. Means of switching power shall be capable of a rise time of 1 microsecond, maximum, to full voltage, with the rise time occurring while the amplitude of the applied voltage is within 10% of the peak value. The reaction of each EED shall be documented. Video or high speed optical recordings shall be used, along, with the dent block condition, to capture response characteristics.

(2) DC Test. The input to the EED shall be energized from a DC source at 28 VDC; the power source must be capable of sustaining a minimum short circuit current of 10 amperes.

(a) Five initiators shall be tested, each for 5 minutes.

(b) The EED will be confined as described in the AC test.

(c) The means of switching power shall be capable of a rise time of 1 microsecond, or less, to full voltage.

(d) The reaction of the device including the occurrence of dudding is to be reported.

b. Maximum Allowable Electrical Sensitivity Test (MAEST). One test considered applicable for EFI is to use a defined standard fireset as described in AOP 43, which would be used by all EFI to establish the NFT and the MASS for an EED with a standard fireset. The standard fireset is not related to the intended-use fireset, and is to be used for this test only. If the intended fireset produces a stimulus, that envelops or exceeds that of the standard fireset, the NSAA may consider that the NFT and MASS determined in the firing properties test can be used instead of the results of the MAEST. The voltage corresponding to the NFT and the MASS for either fireset shall be at least 500V.

13. Sequential Environmental Testing. For the environmental tests defined in Table 3 the following requirements apply. The sequence of environmental tests for each EED and the number of EED per test are to be agreed in advance with the NSAA. (Note that some NSAA accept that all environments shall be covered by at least 30 EED each).

14. Vibration. This test is applicable in order to obtain characterisation data about EFI/EBW to adequately demonstrate their ability to resist a typical environment

without unacceptable degradation of their characteristics:

a. The EED shall be subjected to the vibration test as described in STANAG 4157, AOP-20, Test B1.

b. On completion of the test, the performance of the EFI/EBW shall be checked for changes in the following:

(1) Physical condition, e.g. by visual inspection

(2) Electrical parameters (e.g., bridge resistance, insulation dielectric strength, etc.).

15. Thermal Shock. The objective of the thermal shock test is to determine if an EFI/EBW is affected as a result of exposure to sudden extreme changes in temperature. The EFI/EBW shall be tested to the requirements of STANAG 4157, AOP-20, Test C7.

16. Temperature-Humidity. The combined effects of temperature change and humidity can cause degradation to the performance and safety of the EED. The EED shall be tested in accordance with STANAG 4157, AOP 20, Test C1..

Relative humidity (rh) may have a significant influence on some materials during thermal shock test. Where this is considered appropriate the test procedure can be combined with the thermal shock test.

17. Mechanical Shock. The initiator shall be tested to determine if it meets the shock requirements of STANAG 4157, AOP-20, Test A1 (Jolt). The degree of support afforded to the device during the test shall ensure that the full severity of the shock is transferred to the device.

18. 1.5 m Drop. This test simulates severe shocks due to the EED being dropped during accidental mishandling in manufacture, transportation or service use. The initiator shall be tested to determine if the initiator meets the requirements of STANAG 4157, AOP-20, Test A4. Unless required otherwise by the NSAA, 6 unprotected initiators shall be dropped and impacted in each of the following orientations:

a. 2 unprotected EED nose up

b. 2 unprotected EED nose down

c. 2 unprotected EED horizontal.

19. Leakage. The initiator shall be tested in accordance with STANAG 4157, AOP 20, Test C8. This is specifically for hermetically sealed initiators, which shall be tested in accordance with the Fine Leak Test. They are not to exhibit a leak rate in excess of $10^{-5}$ $cm^3/s$ of air at a pressure differential of $0.1 \pm 0.01$MPa.

20. Thermal Cook-off. The maximum temperature to which an initiator can be exposed for a period of one hour without cook-off shall be established (within 10° C).

a. Using an appropriate pre-test (e.g. using single EED samples), determine the minimum temperature within 10°C at which cook-off occurs within 1 hour.

b. Five initiators shall be placed in an oven preheated to 10°C below the minimum temperature determined in the pre-test. If cook-off occurs, the temperature shall be decreased 10°C and the test repeated with new initiators. The test shall be repeated in 10°C decrements until cook-off does not occur within a 1-hour period.

c. The thermal cook-off threshold for a component is the maximum temperature where no cook-off reaction occurs when exposed for a one hour period.

21. Post Environment Firing Properties Test. In order to confirm that the environmental tests have not compromised the electrical characteristics of the device, the firing properties test of paragraph 7 above shall be repeated on 30 devices at ambient temperature. EED used for the Post-Environment Firing Properties Test are deducted from the performance tests.

22. Performance Tests. The EED shall fire and produce the correct output when functioned at the minimum firing voltage for an intended application, while temperature conditioned:

a. Tests shall be completed at cold, ambient, and hot temperatures.

b. This performance test shall be performed on initiators previously stressed during environmental tests.

c. The output characteristics can be determined by tests which reflect the purpose for which the device will be used.

23. High Voltage. It has been shown that not all EFIs are reliable when exposed to an increased firing voltage. Excessive energy at the bridge of an EFI can cause an incorrect flyer to be released which will not impart enough energy to cause detonation. This test is to assure that the chosen initiator has a reasonable design margin over the minimum firing voltage and that the firing system can operate:

a. The firing unit shall use the same circuit components as used in the munitions firing circuit (fireset).

b. The initiator shall meet the functional requirements when initiated by a firing potential at the limits of the capability of the firing system or 150% of the application specific design firing voltage, whichever is less.

| REQUIREMENT | PARA | MINIMUM QUANTITIES | | | | | | | | | | | | | | 535 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 90 A | 40 B | 30 C | 5 D | 25 E | 30 F | 10 G | 50 H | 50 I | 50 J | 50 K | 50 L | 50 M | 5 N | |
| Radiographic And/Or Visual Inspection | 4 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | **535** |
| Resistance | 5 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | **535** |
| Insulation Resistance | 6 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | **535** |
| Firing Properties | 7 | X | | | | | | | | | | | | | | **90** |
| Malfunction Threshold | 8 | | | X | | | | | | | | | | | | **30** |
| Low Power Non-Functioning Test | 9 | | | | X | | | | | | | | | | | **5** |
| Thermal Time Constant (1) | 10 | | X | | | | | | | | | | | | | **40** |
| Electrostatic Discharge | 11 | | | | | X | | | | | | | | | | **25** |
| Non-Interrupted Explosive Train Requirement | 12 | | | | | | X | | | | | | | | | **30** |
| Vibration(2) | 14 | | | | | | | | | | | X | X | X | | **150** |
| Thermal Shock(2) | 15 | | | | | | | | | | | X | X | X | | **150** |
| Temperature-Humidity(2) | 16 | | | | | | | | | | | X | X | X | | **150** |
| Mechanical Shock(2) | 17 | | | | | | | | | | | X | X | X | | **150** |
| 1.5 Meter Drop(2) | 18 | | | | | | | | | | | X | X | X | | **150** |
| Leakage(2) | 19 | | | | | | | | | | | X | X | X | | **150** |
| Thermal Cook-Off (1) | 20 | | | | | | | X | | | | | | | | **10** |
| Post-Environment Firing Properties | 21 | | | | | | | | | | | X | X | X | | **30** |
| Performance Test, Amb | 22 | | | | | | | | X | | | X | | | | **90** |
| Performance Test, Cold | " | | | | | | | | | X | | | X | | | **90** |
| Performance Test, Hot | " | | | | | | | | | | X | | | X | | **90** |
| High Firing Voltage | 23 | | | | | | | | | | | | | | X | **5** |

Notes: (1) May not be considered mandatory by NSAA
(2) See paragraph 13

TABLE 3. MINIMUM TEST SEQUENCE FOR EFI AND EBW INITIATOR CHARACTERISATION

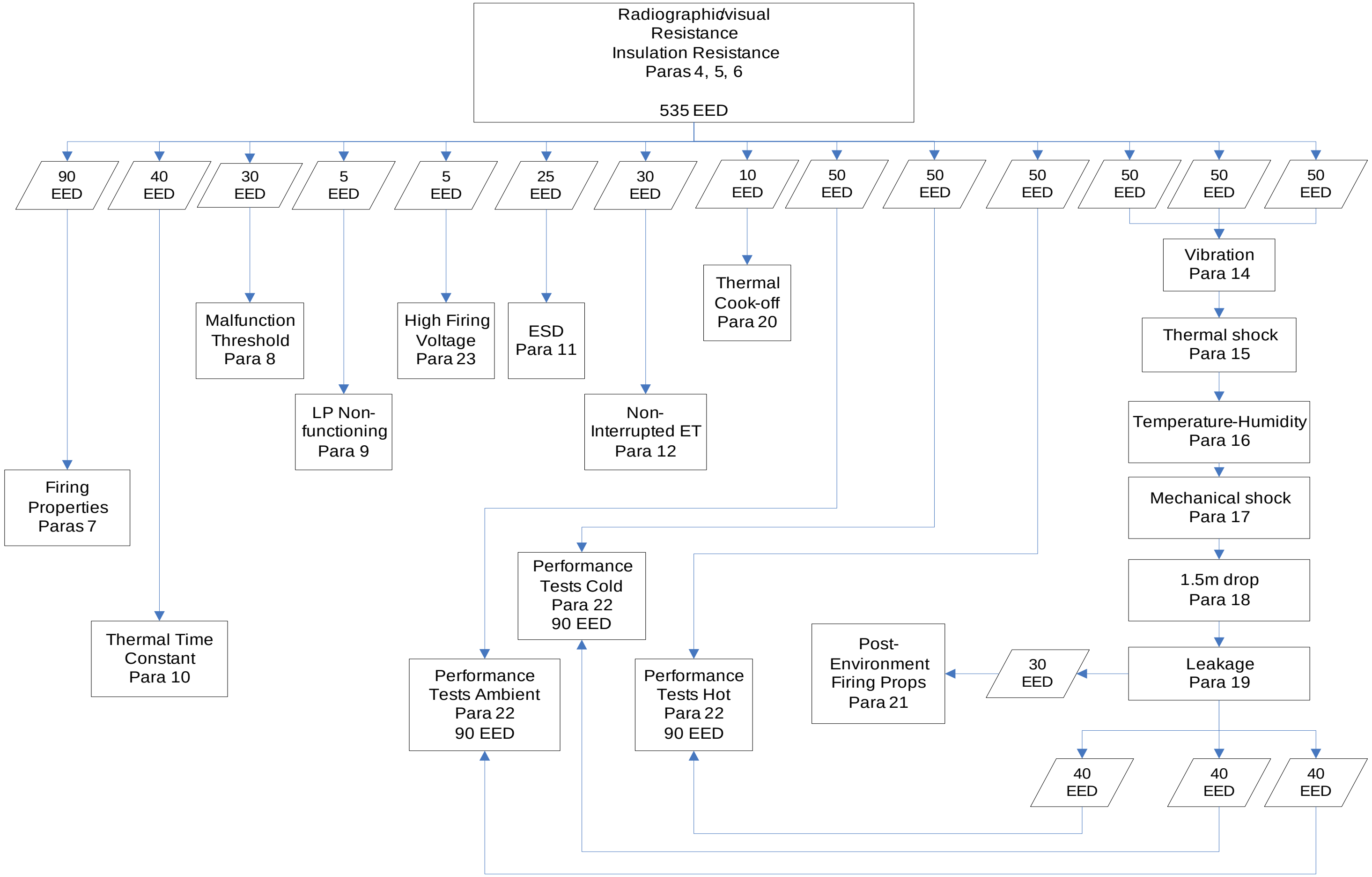


**FIGURE 2: TEST SEQUENCE FOR EBW & EFI**