NORTH ATLANTIC TREATY ORGANIZATION
ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD

NATO STANDARDIZATION AGENCY (NSA)
AGENCE OTAN DE NORMALISATION (AON)
1110 BRUSSELS

NSA/0190-PPS/4238

25 February 2002

See CNAD AC/310 STANAG distribution

STANAG 4238 PPS (EDITION 1) – MUNITION DESIGN PRINCIPLES, ELECTRICAL/ELECTROMAGNETIC ENVIRONMENTS

Reference: AC/310-D/173, dated 21 Januay 2000

1. The enclosed NATO Standardization Agreement which has been ratified by nations as reflected in page iii is promulgated herewith.

2. The reference listed above is to be destroyed in accordance with local document destruction procedures.

3. AAP-4 should be amended to reflect the latest status of the STANAG.

ACTION BY NATIONAL STAFFS

4. National staffs are requested to examine page iii of the STANAG and, if they have not already done so, advise the Defence Support Division through their national delegation as appropriate of their intention regarding its ratification and implementation.

Jan H ERIKSEN
Rear Admiral, NONA
Director, NSA

Enclosure:
STANAG 4238 (Edition 1)

STANAG 4238
(Edition 1)

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

NATO STANDARDIZATION AGENCY
(NSA)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: MUNITION DESIGN PRINCIPLES, ELECTRICAL/ELECTROMAGNETIC ENVIRONMENTS

Promulgated on 25 February 2002

Jan H ERIKSEN
Rear Admiral, NONA
Director, NSA

RECORD OF AMENDMENTS

No.	Reference/date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Director, NSA under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. 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.

DEFINITIONS

4. Ratification is "In NATO Standardization, the fulfilment by which a member nation formally accepts, with or without reservation, the content of a Standardization Agreement" (AAP-6).

5. Implementation is "In NATO Standardization, the fulfilment by a member nation of its obligations as specified in a Standardization Agreement" (AAP-6).

6. Reservation is "In NATO Standardization, the stated qualification by a member nation that describes the part of a Standardization Agreement that it will not implement or will implement only with limitations" (AAP-6).

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page (iii) gives the details of ratification and implementation of this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions. Page (iv) (and subsequent) gives details of reservations and proprietary rights that have been stated.

FEEDBACK

8. Any comments concerning this publication should be directed to NATO/NSA - Bvd Leopold III, 1110 Brussels - BE.

STANAG 4238
(Edition 1)

NAVY/ARMY/AIR

NATO STANDARDIZATION AGREEMENT
(STANAG)

MUNITION DESIGN PRINCIPLES, ELECTRICAL/ELECTROMAGNETIC ENVIRONMENTS

Annexes:

A. Definitions and Interpretation
B. Design Principles
C. Electromagnetic Environmental Effects
D. Design Guidance in National Documents

Related Documents:

AEP-4	Nuclear Hardening Criteria for Armed Forces Material and Installation
AOP-15	Guidance on the Assessment of the Safety and Suitability for Services of Munitions for NATO Armed Forces.
STANAG 1307	Maximum NATO Naval Operational Electromagnetic Environment Produced by Radio and Radar.
STANAG 4234	Electromagnetic Radiation (Radio Frequency) 200 kHz to 40 GHz, Environment Affecting the Design of Materiel for Use by NATO Forces.
STANAG 4235	Electrostatic Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces.
STANAG 4236	Lightning Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces.
STANAG 4239	Electrostatic Discharge, Munitions Test Procedures.
STANAG 4324	Electromagnetic Radiation (Radio Frequency) Test Information to determine the Safety and Suitability by Service of Electro-explosive Devices and Associated Electronic Systems in Munitions and Weapon Systems.
STANAG 4327	Lightning, Munition Assessment Test Procedures.
STANAG 4416	Nuclear EMP Pulse Testing of Munitions Containing Electro-explosive Devices.

AIM

1. The aim of this agreement is to standardize the design principles which are to be applied to munitions containing Electro-Explosive Devices (EED) and to associated systems to provide the required levels of safety and suitability for service in the electrical/electromagnetic (EM) environments to which those munitions could be exposed in NATO operations.

AGREEMENT

2. Participating nations agree to apply the design principles listed below and expanded in Annex B, to all future developments of electrical circuits in munitions containing EED and to all systems associated with those circuits.

DEFINITIONS

3. The definitions to be used in relation to these principles are contained in Annex A.

DETAILS OF THE AGREEMENT

4. Munitions and sub-systems containing EED shall be designed to operate safely and reliably in any of the specified electrical/electromagnetic environments discussed below.

5. Munitions and sub-systems shall be designed such that no credible single failure or event, including those resulting from the effects produced by the electrical/electromagnetic environment, will initiate an EED or cause a safety feature to be impaired or overridden.

6. Test equipments and their connections interfacing with circuits containing EED shall be designed not to cause an unacceptable increase in the susceptibility of the munition to the effects of the Electrical/EM environment or degrade any safety feature included in the munition.

7. A Hazard Analysis (HA) shall be made on the proposed munition and its associated systems. The HA shall be in accordance with AOP-15 and shall include:

a. Identification and classification of all circumstances which would result in:

(ii) an unintended initiation of an EED;
or (ii) loss/degradation of a safety feature.

from any cause including exposure to the electrical/electromagnetic environment.

8. The resulting hazards should be classified as either having a safety consequence or an unacceptable effect on the operational performance/mission capability of the munition. In identifying and classifying the circumstance/hazard, a simple division between either safety or operational reliability will suffice in most cases. In others, it will be necessary to follow the AOP-15 classifications closely.

a. Where unintended initiation of an EED/loss of a safety feature is judged to have a safety consequence, the probability of the initiation, from all causes, is to be no more than 1×10^{-6} (one in a million). This probability is to be sustained over the time from assembly of the munition to the time when an unintended event is no longer a hazard. This would normally be when the munition has been fired and reached a safe separation from the user, the population or friendly forces. The use of lesser or greater probabilities shall be justified to the relevant National Safety Authority.

b. Where the unintended initiation of an EED is judged to affect only the operational design function and not safety, then the occurrence probability shall be specified from a consideration of the reliability requirements for mission success.

NOTE: The probability of an unintended event quoted above is to include all possible failure modes. Probabilities cannot generally be associated with electrical/EM environmental effects and these are therefore handled as shown in paragraph 9 below.

9. For EED whose inadvertent initiation in their normal mode of operation would result in a safety hazard, a high confidence level is necessary. High confidence levels, against an unintended initiation from an electrical/EM environmental effect, are primarily established from the characterisation of EED no-fire threshold power and/or energy by statistically controlled methods, by good design practice, by adequate system testing and by the application of suitable safety margins. Annex B discusses the approach to setting an appropriate safety margin. The safety margins to be used shall be agreed with the relevant National Safety Authority.

10. For initiation in any abnormal mode of operation, agreement shall be reached with the relevant National Safety Authority on the means of demonstrating that the required confidence level has been achieved.

11. The Electrical/Electromagnetic Environment

a. The maximum electrical/EM environments that the munition and its associated systems may encounter during all relevant phases within the munition life cycle shall be specified by the developing Nation(s). The environment requirements shall be developed from a knowledge of the assembly, testing, transport, storage and operational scenarios likely to be encountered.

b. A complete munition may encounter, at certain phases within its life cycle, RF radiation, Electrostatic charging and discharging, lightning and Nuclear Electromagnetic Pulse (NEMP). Definitions of these external environments are given in STANAGs 4234, 1307, 4235, 4236 and AEP-4. Some or all of these agreements may be relevant to the definition of the environment for a particular munition. Environments produced by the munition itself (internally or externally) or associated platforms shall also be considered. For some munitions, environments created by hostile forces may also need to be taken into account. Annex C includes a description of the potential effects of these environments on systems containing EED.

12. Design, Assessment and Testing

a. Detailed design requirements covering all classes of munition and firing circuit design would be too lengthy for inclusion in this STANAG. However, the general design principles that shall be taken into account by system designers are discussed in Annex B. These are expanded further in the national documents listed in Annex D.

b. The assessment and/or test methods to be adopted for Electrical/EM environmental conditions are given in STANAGs 4239, 4324, 4327 and 4416.

13. The designer shall provide evidence that the design features included in a firing circuit and all associated circuits comply with the agreement in this STANAG. The final assessment report(s) shall contain the evidence gathered in support of compliance with the principles contained in this STANAG. This evidence shall be sufficient to demonstrate the safety and suitability for service of the munition and associated systems in the electrical/EM environments.

IMPLEMENTATION OF THE AGREEMENT

14. This STANAG is considered implemented by a nation when that nation has issued the necessary orders and instructions to the Authorities concerned, putting the Agreement into effect.

DEFINITIONS AND INTERPRETATION

1. Electrical/Electromagnetic (EM) Environment: the totality of electric and electromagnetic phenomena that could be experienced by a munition. These include RF radiation, electrostatic charges/discharges, lightning and NEMP.

   Note: All phenomena do not exist necessarily at the same time or at the same level over a period of time at any given location. The total environment is usually partitioned into individual phenomena of an electrical or electromagnetic nature. The division enables separate assessment of the effect of each phenomenon by analysis or trial. Other EM phenomena, such as LF magnetic radiation may also need to be considered for some systems.

2. Electro-Explosive Device (EED). A one shot explosive or pyrotechnic component used as the initiation element in an explosive or mechanical train which is activated by the application of electrical energy. The term includes, for example, bridge-wire devices, conducting composition devices and exploding foil initiators.

3. Firing Circuit. The complete system including the EED, power supplies and all associated electrical and electronic components and circuitry necessary for normal EED firing.

4. Hardening: The process by which a munition may be protected against the potentially hazardous effects of the electrical/electromagnetic environment by including particular features in the design.

   Note: the main relevant features are:

   a. Shielding or screening, such as metallic enclosures and sheathed cables, containing the EED firing circuits.

   b. Energy diversion by using components such as filters or diodes to limit the effects produced by the environments in the firing circuits.

   c. EED requiring functional energy input of a level or form not likely to be produced through the interaction of the environments with the firing circuit.

5. No-Fire Threshold (NFT). The level of electrical stimulus (power or energy) to an EED at which the probability of firing is acceptably low - generally expressed as 0.1% or 1.0% at the 95% confidence level.

6. Thermal Time Constant. The time the bridge wire, the film or the conductive composition takes to reach 63% of the equilibrium temperature when a step function of power is applied to the leads of the EED.

DESIGN PRINCIPLES

1. INTRODUCTION

1.1 The safety and reliability of systems using EED can only be assured if they are designed to be immune to the effects of the EM environments which they may experience during their life. These effects can occur when the system is unpowered, under test or at any stage of its operational use. Problems found during system tests late in the design phase or in service use are frequently difficult and expensive to solve. In some cases resolution is not practicable leading to restrictions in operational use. It is therefore important that the necessary measures are taken from the start of the design.

1.2 Annex C discusses the potential effects the EM environment may have on firing circuits and EED. In addition to the conduct of hazard analyses to determine the failure modes and probabilities of events which could lead to an unintended initiation, the main design principles which should be followed to avoid the EM effects are:

a. establish an EM immunity design and testing plan to be followed by all system, sub-system and equipment designers including a specification of the environments;

b. use of components with highest intrinsic levels of immunity consistent with required functionality;

c. use of best practice in EMC engineering in terms of safety breaks, circuit design, physical layout, screening, earthing and bonding, and choice of connectors;

d. use of electromagnetic and electrostatic shields;

e. use of RF filters;

f. application of safety margins to provide confidence.

1.3 Each of these areas is discussed further below with specific details relevant to EED and associated circuits.

2. MANAGEMENT OF DESIGN

2.1 An EMC/RADHAZ policy or plan shall be produced at the outset of a project. This plan shall include:

a. a definition of all EM external environments that are expected to be experienced by the system at all stages of its life cycle. The environments should include all those discussed at Annex C and those likely to be generated by the system or its launch platform. When possible the environments expected within each part of the system should be defined taking into account the shielding and screening effects of the structure;

b. a definition of the internal conducted and radiated emissions to be allowed by all elements of the system;

c. the shielding, screening, earthing and bonding rules to be employed in the overall system design and where necessary in relevant sub-systems and equipments;

d. guidelines for choice of components and/or use of particular technologies in terms of their susceptibility to EM effects;

e. the tests to be conducted on each part of the system and at each level of system integration. A test policy is to be produced covering conducted and radiated emission tests leading to full system susceptibility tests, where necessary, for each aspect of the EM environment. The policy should include the test levels and limits and the number of items to be tested;

f. the requirements to be followed to allow the EM aspects of the design to be maintained during the service life of the system;

g. for EED and safety switches the safety margins to be used for determining their safety and reliability when used in the defined environment.

3. CHOICE OF COMPONENTS

3.1 Wherever possible the components used in firing and associated circuits should be those with the lowest practicable sensitivity. This applies in particular to active devices such as semiconductor switches, logic gates and microelectronic circuits. This principle will need to be balanced with the need to reduce power consumption on those munitions with limited power capability.

3.2 In the special case of EED, a device which has as high a NFT as practicable shall be employed. An ideal EED from an EM hazard viewpoint would have a sufficiently high NFT such that no filtering, shielding or restrictions in operational use are necessary. The NFT should be derived by a method approved by the National Acceptance Authority which allows the value to be quoted with high confidence.

3.3 The thermal time constant of the EED shall also be determined so that the potential susceptibility of the EED to single pulses of energy can be determined. Unless there are overriding performance requirements a low voltage EED with a short thermal time constant (i.e. an EED that is sensitive to pulses of the same length as a radar pulse) should not be used.

3.4 To allow optimum use of twisted pair wires double pole EED are preferred when EM hazards are a possible problem.

4. FIRING LINES AND FIRING CIRCUIT DESIGN

4.1 STANAGs 4187 and 4157 shall be followed in respect of particular design and testing requirements for warhead safety and arming units.

4.2 No single component fault or failure shall be capable of firing an EED. This requires firing circuits to be designed such that, when initiation of an EED is unacceptable, there are at least 2 independent circuit breaks, connected in series, between the EED and the source of firing power. These breaks and their control circuits shall be designed to respond only to their intended stimuli and shall be immune to operation by Electromagnetic Interference (EMI) from any source. The safety breaks shall be placed as close as possible (physically) to the EED which they control.

4.3 The use of physical breaks rather than semiconductor breaks is preferred, whenever possible, since they have a much lower self capacitance. Due to the relative sensitivity of electronic circuits consideration should be given to using a dynamic switch in place of a static switch, so that an open or short circuit failure caused by EMI will not cause a safety problem. This type of switch is mandatory for in-line electronic Safety and Arming units.

4.4 Firing Lines. Firing lines shall be kept as short as possible and positioned close to any shielding structure, avoiding apertures likely to be exposed to the EM environment. They shall also be routed separately from lines which carry other electrical services in order to avoid induction of EM energy, and to minimise the risk of an accidental short-circuit to power lines. When it is unavoidable that firing lines share a wiring loom and an electrical connector with other conductors, the connector pins used for the firing lines shall be protected from the electrical services connected to the other pins by an isolating barrier or a ring of earthed pins. If it is possible that electrostatic energy, which exceeds a safe level relative to the NFT of an EED or poses a risk of damage to associated electronics, can be stored on any part of a firing line, electrostatic discharge resistors shall be fitted. Such resistors should consist of parallel pairs to avoid loss of protection if one resistor should fail open-circuit.

4.5 Single-Pole Firing Lines. Single-pole unscreened firing systems are not recommended. Although they can be designed to remain safe and serviceable in a specified RF environment by the application of screening and filtering, safety switches can still be susceptible to voltage breakdown arising as a consequence of the high currents induced into a weapon structure by an EMP or lightning event (see Fig 1). If a single-pole system has to be used, the resistance of the earth, or system ground return, shall be as low as possible and ideally not greater than 50 mΩ. Single-pole firing systems with parallel EED shall not be used in any circumstances since the EED firing circuit can form a circuit loop (see Fig 2) in which the safety switch affords no protection against induced current.

4.6 Double-Pole Firing Lines. In a balanced mode, double-pole circuit EMI shall be reduced by ensuring the wires are kept close together throughout their length and by twisting the individual wires together. A double-pole circuit is best when isolated from ground, particularly at the EED termination, to minimise the effects of common mode pick-up. It is recommended that twisted, or closely laid parallel, screened pairs be used for all double-pole firing systems, in conjunction with double-pole firing and safety switches and overall EM shielding.

4.7 Screening of Firing Lines. Flexible braiding or rigid screening, such as ducting or conduit, placed around the firing lines shall be used to reduce pick-up. The braiding in conjunction with the metal screens of associated junction boxes shall cover the whole installation (including the power supply and all other circuits fed by the power supply) to be fully effective. If firing lines share a wiring loom with other power/signal lines, they shall be separately screened and not share an overall screen. When a system has more than one EED, the firing lines to each EED shall be individually screened to prevent mutual EM coupling.

4.8 To ensure that the effectiveness of the EM shielding is not degraded, the screening braid of firing lines must always make a 360° peripheral contact with the backshell of any connector. The braiding shall not be formed into a pigtail and fed through a plug and socket via one of the pins, as this will reduce the shielding effects. Screening braid should not be formed into a pigtail to make a connection to ground.

4.9 When it is not practicable to screen a complete system, the screening of the firing lines shall commence at the EED shield and extend as far as possible ‘upstream’ towards the power source. For EMC purposes, the screen shall be grounded at the point where the firing lines emerge from the screening. The screening braid of a firing line shall not be used as the return circuit. For this reason coaxial firing lines are not recommended.

4.10 Cables employing double-braided shielding shall be used where the greater attenuation provided is required. Such cables shall have their shields insulated from each other except at their terminations.

4.11 Ribbon or Thin Film Cable. Where firing lines are included in multi-strand ribbon cable the firing lines shall use adjacent conductors and be isolated, on each side, from other power circuits. Thin film cables used to initiate high voltage devices such as EFI shall be kept as short as possible, maintaining low inductance but, due to their low susceptibility to RF, need not be screened.

4.12 Printed Circuit Boards. Wherever practicable firing lines shall not be taken through a printed circuit board (PCB). Where it is not possible to isolate them from a PCB, the firing lines shall be laid as close parallel pairs. The possible coupling from other circuits on adjacent lines and adjacent layers shall be assessed and adequate immunity from coupling assured.

4.13 Electronic Firing Switches. Since semiconductor switches do not provide a high impedance break at RF and may fail short-circuited it is recommended that they are not used directly connected (DC coupled) in series, between an EED and the source of firing power, without incorporating a physical circuit break. This break should be positioned as close as possible to the EED.

4.14 Where a capacitor is used to provide the firing energy to an EED, a duplicated discharge path shall be provided to ensure it is kept in a discharged condition at all times until the charging circuit is enabled by valid arming signals.

4.15 Firing Line Connectors. Electrical connectors employed in firing lines shall be so designed that:

a. the lines to EED are terminated at recessed female pins so that it is not possible for an operator or external structure to accidentally transfer an electrostatic charge;

b. the shells have a good conducting finish and they make connection before any pins;

c. the termination arrangement for cable screening provides a 360° peripheral contact.

4.16 To ensure a sound RF leak-proof connection the mating halves of a connector should be secured by a threaded coupling preferably fitted with RF fingers. Fixed connectors shall make a reliable and consistent contact with the bulkhead to which they are fitted using an effective RF gasket when necessary.

4.17 When a firing line connector is mated in a high intensity RF field, arcing may occur which could result in some rectification of the RF pick-up producing signals within the pass band of any low pass filter. This potential hazard shall be overcome by use of a connector which meets the requirement of para 4.15 b above.

5. ELECTROMAGNETIC AND ELECTROSTATIC SHIELDING

5.1 It will be necessary to enclose some circuits and EED within an overall shield to protect them against one or more of the EM environments. Such a shield shall be constructed of a good conductive material and have no holes, insulating joints or intermittent seams. These defects will introduce frequency selective leakage which can, in extreme cases, enhance the local internal RF field intensity.

5.2 If the system structure is to provide an effective EM shield, continuous conducting contact must be maintained between all joints. Such surfaces must therefore be free of insulating coatings, and be of materials which will resist corrosion in the climatic environment specified for the installation. Alternatively mating surfaces may be protected by an electrically conducting coating. Where contact cannot be maintained, for example due to vibration or structural design, it will be necessary to fit an RF gasket capable of accommodating the distortion. Care should be taken to select materials of compatible contact potentials to avoid corrosion throughout the service life of the installation.

5.3 Where an external structure does not provide sufficient shielding additional protection shall be provided by specially designed enclosures. The principles above concerning full continuous contact around the boundary of the enclosure will still apply. To be effective such enclosures should be well bonded to the system structure.

5.4 Shields intended to attenuate low frequency magnetic fields must necessarily be constructed of magnetic materials having a high permeability.

5.5 A high level of protection against lightning can be afforded to firing circuits provided that the weapon casing or skin in which the circuit is contained has a DC contact impedance between metallic components of less than 0.05 Ω. This impedance needs to be maintained at frequencies up to about 1 MHz and at the current levels likely to be experienced. In addition, double-pole wiring, isolated from ground, should be used. However, there are various mechanisms by which lightning can induce currents on firing lines and the overall hardness of a system, against direct and nearby strikes needs to be assessed in a lightning hazard design assessment in accordance with STANAG 4327.

6. USE OF FILTERS

6.1 Where the use of shielding and screening techniques are not sufficient to provide the required immunity it will be necessary to use RF filters. Filters used in firing lines shall have adequate attenuation over the relevant frequency band and shall be capable of maintaining that attenuation when dissipating the amount of RF energy capable of being induced in the circuit. The RF filter shall be correctly bonded to the enclosure in which it is mounted. RF filters shall be mounted as closely as possible to the EED/circuit being protected.

6.2 In firing circuits incorporating RF filters, semiconductor or rectifying devices shall not be connected in series or parallel with the firing lines between the filter and the last open-circuit break. Such components will rectify any conducted RF signals and may produce a signal for which a low-pass filter will not provide any protection.

6.3 Filtered Connectors/Pins. Filter connector pins may be used as an alternative to discrete filters, particularly where low-frequency attenuation and high power dissipation are not required. This type of connector may also be suitable in multi-way connectors for protecting inputs and outputs associated with the use of electronic devices and microprocessors against the effects of conducted EMI. The means of conducting through life checks on the condition of these pins shall be considered during the design and acceptable arrangements included.

6.4 The inclusion of feed-through pins (i.e. unfiltered pins) will severely reduce the overall effectiveness of a multi-way filtered connector and such pins shall not be used. Filtered connectors which utilise all-metal grounding paths are preferred to those which depend upon metal loaded compounds which may deteriorate with age and introduce increasing RF impedance to ground. For optimum performance the filter-pins shall be in the fixed connector.

7. TEST EQUIPMENT

7.1 Test equipment and any associated cabling and connectors shall be designed such that they do not degrade the EM compatibility of the munition system when used in the EM environment likely to be experienced during all test operations. The test equipment itself should not be possible of providing power to a firing circuit which is greater than the NFT power of the EED. This applies even when any single fault capable of being induced by the EM environment is present.

7.2 The method used for connecting the test equipment shall be such that it is not possible to connect the wrong line or transfer an electrostatic charge to the firing circuits.

8. SAFETY MARGINS

8.1 Since the probability of circuit failure or inadvertent initiation of an EED due to the EM environment cannot practically be calculated, the contribution of such effects to the overall probability of failure of a weapon system is not usually included in failure rate calculations. Instead the principle of using a safety margin between the maximum pick-up level and the susceptibility threshold of the device is used. However, even this principle cannot be applied when it is not possible to measure or calculate the pick-up actually achieved or expected. In such cases confidence in safety has to be derived from go/no-go testing of a sufficient number of samples.

8.2 When deciding what safety margin to use a number of factors need to be taken into account. These are:

a. the method used to derive the NFT threshold of the EED or the switching threshold of an electronic device. A method which uses a statistically meaningful number of devices and establishes the NFT with high statistical confidence will attract a significantly lower safety margin than one which tests only a few devices;

b. where the pick-up level has been calculated from EM theory the safety margin appropriate will depend on the complexity of the system and circuit involved and the method used for undertaking calculations. Such calculations often use worst case assumptions but the difficulties in establishing a fully representative model of the system in all operational modes and orientations mean that considerable simplification is often necessary. Even where worst case assumptions have been used a small safety margin will still be required;

c. where the pick-up level has been derived from measurements on a fully representative system a safety margin will be required to allow for such variabilities as: system orientation with respect to RF fields, number of polarisations and frequencies used, instrumentation method and accuracy, test method (e.g. direct radiation of system or use of bulk current monitoring and injection) and component/system variability

8.3 Lower safety margins can be used for items where failure results only in a reliability as opposed to a safety problem. The overall safety margins to be used shall be agreed with the National Safety Authority. The margins may be different for each environmental effect.

8.4 Where the testing is done by go/no go methods the application of a safety margin is not appropriate unless it is possible to overtest and linearity can be assumed. In such cases multiple samples shall be used. The availability of many complete systems means that this will generally require one or two systems to be tested with EED or other components which may be sensitised by the tests replaced between each evolution. These aspects are discussed further in the test STANAGs 4239, 4324, and 4416.

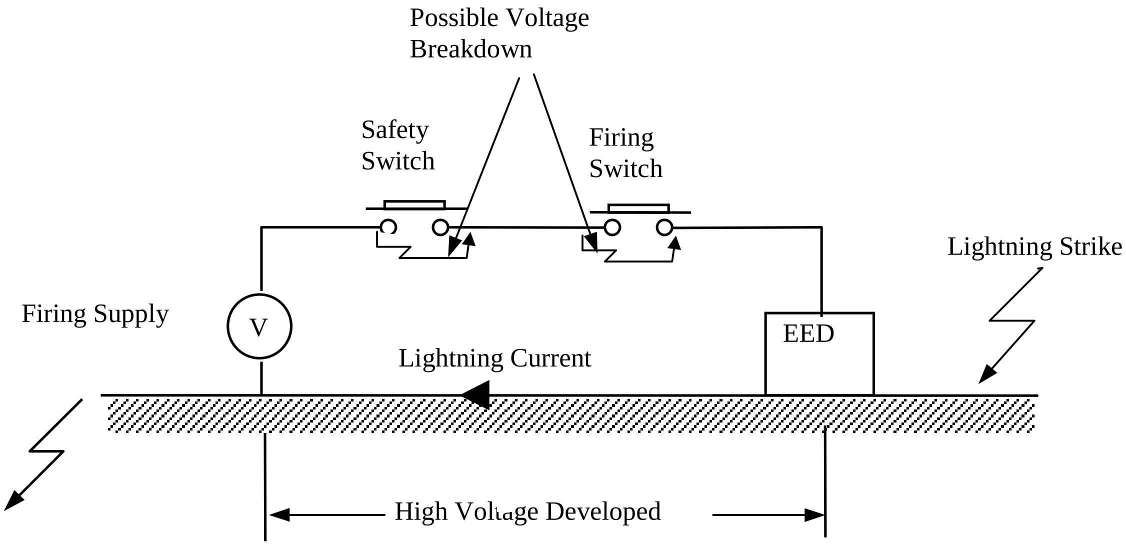

FIG 1. SINGLE POLE GROUND RETURN SYSTEM

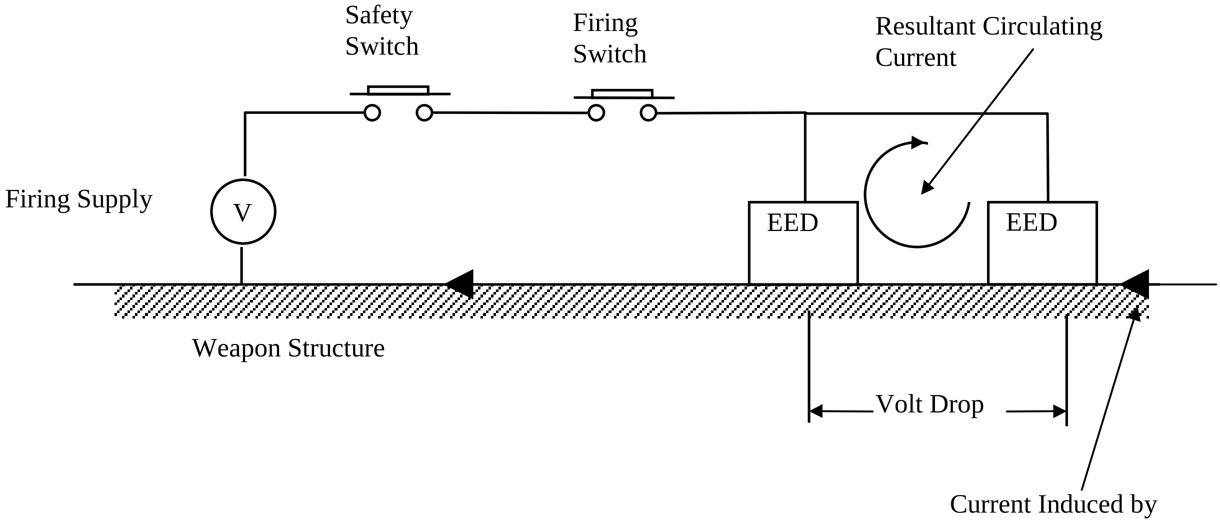

FIGURE 2. The hazard to parallel EED in a single pole ground retu

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

1. ELECTRICAL/ELECTROMAGNETIC ENVIRONMENT

As discussed in the main part of the STANAG there are a number of EM environments which may be experienced by a munition during its life cycle . A number of agreements have been reached in NATO quantifying these environments and these may be considered suitable for defining the levels in which most systems should remain safe and suitable for service. These agreements, however, do not cover such situations as the RF radiation which can be expected in very close proximity to an emitter on a launch or carriage platform, the radiation (internal and external) created by the munition itself or the radiation which may be created by hostile transmitters. The applicable EM environment therefore needs to be established from consideration of the life cycle , from design knowledge and from the operational requirement.
EM environments such as LF or static magnetic fields and the electrostatic charging of the munition itself have not been considered in NATO agreements but may also exist during its life cycle. These shall be considered by designers and assessors when specifying the EM environment.

2. EM ENVIRONMENTAL EFFECTS

2.1 RF Radiation. The high field strengths which can be created by radio and radar transmitters are capable of inducing significant currents into the control and firing circuits of munition systems. These induced currents can be sufficient to either directly initiate an EED or lead to an “indirect” initiation or loss of a safety feature by causing a safety switch or safety break to operate incorrectly. The relatively thin wires in a munition will act as simple linear aerials whose electrical length ranges from very short to very long depending on their physical length and the wavelength of the incident radiation. In a 2-wire circuit both balanced mode and common mode pick-up will occur. The balanced mode current will flow through the circuit load, which if it is an EED, will cause heating of the bridge-wire or other element. Common mode currents will be zero at each end of an isolated line but if the circuit approaches or touches ground a path for the current will be provided. If this path is high impedance (e.g. between pins and case of an EED) a large voltage will be developed which may be sufficient to cause voltage breakdown in the EED filling thus causing abnormal initiation.

2.2 The relatively low switching thresholds of modern semiconductor devices means that they are sensitive to levels of pick-up easily obtained in a poorly designed system. Their fast switching times also mean that they are capable of reacting to RF and the signals modulated onto RF carriers. Moreover, due to the high RF capacitance of semiconductor switches they do not necessarily act as open circuits to RF in the same way as a mechanical switch.

2.3 The above effects are exacerbated if the EM radiation is pulsed with a very high peak power level (e.g. from a radar system). In this case a short duration high instantaneous current may flow or a very high common mode voltage may exist. If the EED or semiconductor device is capable of reacting to these short pulses then unwanted firing/ switching will occur.

2.4 Electrostatic charging/discharging. Whenever a conducting body is placed in an electric field, such as exists between the earth and the ionosphere, a potential will be induced on that body according to its position in the field. This potential becomes considerable at high altitudes or in the proximity of a thunderstorm cloud where voltages of 100 kV, or more, may be induced on a body.

2.5 Engine combustion, the rubbing of dissimilar substances and the blowing of dust, sand, dirt, snow, ice crystals and rain against a body can also generate electrostatic voltages. Packaging materials and the human body are capable of charge accumulation of sufficient energy to cause damage to firing circuits or initiate some EED.

2.6 Electrostatic hazards to electronics and EED generally arise from the sudden discharge of energy from an external body rather than from the relatively slow accumulation of charge. The latter mechanism cannot be dismissed, however, if the firing circuit forms part of the charging circuit. The degree of hazard posed to an EED by a defined level of electrostatic charge depends upon the type of EED and the circuit in which it is connected. System design should always aim to prevent charge accumulation at source.

2.7 An electrostatic charge on the firing lines of some double-pole EED may pose a hazard if allowed to discharge through the EED in the normal or abnormal firing mode although it is unlikely that sections of firing line normally encountered would be able to store sufficient energy to initiate a conventional low voltage bridge-wire EED in the normal firing mode. A discharge from an external source, or from one part of a system structure not well bonded to the rest, could initiate an EED or cause damage to electronic circuits.

2.8 The inclusion of a filter in either a single pole or double pole circuit does not provide automatic protection of an EED from an electrostatic discharge (ESD) since the efficiency of the energy transfer may be increased due to the storage of energy in the capacitor and its relatively slow release to the EED. For this reason discharge resistors should always be included in filtered circuits.

2.9 An ESD of more than a few μJ may damage or cause switching of an electronic firing circuit. All electronic fabrication technologies are susceptible at some level of electrostatic voltage. Some technologies when unprotected may be damaged by a human discharge at as low as 75 V whilst others may be able to withstand up to 15 kV. The latest generations of semiconductor circuits with lower operating voltages are extremely sensitive to ESD and can be permanently damaged by relatively low levels of ESD.

2.10 Lightning. The electrical effects of a lightning strike on a metal structure are primarily determined by the lightning discharge current, its rise time and its duration. The high currents follow the lowest impedance path to ground and in doing so can fuse wires, burn holes in structures and burn out electrical equipments. Any resistance or inductance in the path of this current may cause a high voltage to develop of sufficient amplitude to breakdown insulation and short-circuit to nearby earthed objects or circuits. In addition, magnetic fields produced by the primary current flow may induce secondary currents into adjacent lines of sufficient amplitude to fire an EED directly, or indirectly by operation of safety breaks. Single-pole ‘system-ground’ return circuits are particularly at risk from such currents because of the very high voltages which may be developed between separate grounding points and the resultant possibility of breakdown or coupling across the safety switches.

2.11 A lightning strike also produces a radiated EM field pulse which can induce currents in circuits and structures.

2.12 Nuclear Electromagnetic Pulse (NEMP). The mechanisms by which a nuclear NEMP can subject an EED firing circuit to risk of premature initiation are similar to those described for RF hazards above. The NEMP field couples with the system structure and cables, and high currents may be induced. Additionally, the flow of such large currents may develop potential differences sufficient to cause insulation failure in cables, connectors and switching devices.

2.13 Induced Transient Energy. Electrical transients are generated when circuits are energised or de-energised. The transient consists of damped RF oscillations, the basic frequency of which is dependent upon the length and electrical characteristics of firing and associated lines and components generating the transient. Transients may be conducted along all the electrical circuits of an installation served by a common power supply. In general if the firing lines are less than 0.1 m long or greater than 300 mm from any cable likely to carry significant transients there will be little coupling. For other configurations screening measures will be required.

2.14 Induced Low Frequency Energy. Electromagnetic coupling can occur between firing lines and adjacent lines which carry low frequency power supplies in a manner similar to the induction of transients. The magnitude of the induced signal depends upon the strength of the source signal, the proximity of the lines and the length of the run. When considering electronic firing systems or where large power supplies are involved, particular attention should be given to the possibility of inducing low-frequency EMI into sensitive signal leads irrespective of wiring configuration. Rapid relative movement between an EED circuit and a DC or low frequency magnetic field will also give rise to inductive coupling. This will also occur if a static field suddenly collapses or changes polarity.

2.15 Low frequency induction may be a particular problem for degaussing and deperming cables on ships or submarines. For practical firing circuit designs it is unlikely that such induction will be a hazard to conventional EED but it may cause upset to electronic circuits or devices with magnetically sensitive components.

DESIGN GUIDANCE IN NATIONAL DOCUMENTS

US	MIL STD 464 MIL HDBK 237B
FR	GAM DRAM 01
UK	DEF STAN 08-5 ORDNANCE BOARD PILLAR PROCEEDING P101
GE	VG NORM 95 375 VG NORM 95 376
Others	(to be notified)