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RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE LA DÉFENSE

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N° 0260

FRENCH NATIONAL DOCTRINE
WITH REGARDS TO LESS HAZARDOUS MUNITIONS

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CONTENTS

WARNING

Nuclear weapons are out of the scope of this doctrine.

1. PURPOSE

The purpose of this document is to set forth the French doctrine with regards to less hazardous munitions (munitions à risques atténués or MURAT). It defines the MURAT Standard concept and specifies the methods, means and procedures for the assignment of these Standards.

2. DEFINITION

Less hazardous munition (in French : Munitions à risques atténués – MURAT) : munition which satisfy the conditions required in terms of performance, availability and operating but for which the probability of inadvertent initiation as well as, the violence of the reaction and the collateral damage likely to result from accidental stimuli have been reduced to a minimum.

The delay of appearance of dangerous phenomena is also taken into consideration.

It is the munition, in its various logistic and operational conditions, which is considered in terms of how it reacts to accidental stimuli. However, the use of specially designed protection may justify the assignment of different standards to a munition according to its logistic or operational situations (bare or in container, for instance).

3. METHODES AND MEANS

The production of a MURAT requires the carefully balanced combination of methods and means.

Mention could be made of :

- the application of quality assurance rules in force for the production of equipment for the French Armed Forces and, more generally, « good working practices »,
- the choice of defence energetic materials having a low sensitivity to the accidental stimuli considered,
- specific design choices such as the installation of protection, venting systems, multiple barriers, less sensitive and secured initiation devices, etc.
- the choice of packaging methods, secured container, etc.

Particular attention must be paid to the risks of unexpected functioning. The use of initiation devices with two independent safety features is required. The insertion of mechanical barriers in the initiation train is conditioned by the initiation principles used.

The use of low-sensitivity defence energetic materials is not a sufficient condition of obtain MURAT. It is only imposed for the MURAT*** Standard and only downstream from the safety barriers of the initiation train.

In addition, the utilisation rules have a significant impact on the safety of weapon systems which can be considerably improved, for instance through:

- the choice of suitable storage and transport methods, the installation of screens
- the establishment of operating rules which can be evolved with the hazards associated with the environment.

4. ENVIRONNEMENT, CONSIDERED THREATS/STIMULI AND FEARED EVENTS

4.1. Environment

4.1.1. Normal environment

The normal environment is the field in which the weapon system has been defined through its specifications. In that field, safety should be maintained at he highest level and nominal performance should be guaranteed.

An extension of that field to the reasonable limits foreseeable within the capabilities of the system is planned.

It is then accepted that correct functioning is no longer guaranteed and, anyhow, that performance is deteriorated; but safety should be maintained at the same level as before.

The list of stimuli of that entire field is defined through the environmental specifications and by the normal conditions and rules for use of the munition and the weapon system.

4.1.2. Accidental environment

During its logistical and operational lifetime at peacetime an times of crisis, the munition may be subjected to an accidental environment outside its normal environment.

This is the peripheral field of the previous one ; it is practically unlimited ; it is the one in which the equipment may be found for instance during the course of an accident.

It is accepted that in that field, or after passing through that field :

- safety cannot be guaranteed with the same level as previously,
- the equipment should not be used without a prior expertise.

MURAT is a munition designed to react in the most moderate possible way when subjected to accidental stimuli.

4.2. Threats/Stimuli

The accidental threats to be considered may be classified in three categories of stimuli :

- thermal stimuli
- mechanical stimuli
- electrical or electromagnetic stimuli

Those stimuli may be combined.

The list, which is not fully exhaustive, of the types of stimuli to which munitions may be subjected, is presented hereafter.

4.2.1. Thermal stimuli

This category of stimuli is the most probable at peacetime; three types of thermal stimuli are considered :

- a source of heat typical of a liquid fuel: heating is fast and temperatures are high; durations are average. The temperature and the duration of the fire depend, in particular, on the fire-fighting system.
- source of heat leading to slow heating, such as the remote effect of an undetected or badly controlled fire, or the steam jet of a burst pipe. The heating rate is of a few degrees per hour. The durations are long.
- very violent, short-duration source of heat created, for instance, by a munition fire or the combustion of explosives.

4.2.2. Mechanical stimuli

Generally, five types of mechanical stimuli are considered :

- drop from a great height corresponding to a handling accident,
- of small arms projectiles impact,
- very fast, light fragment impacts, representative of the threat of anti-aircraft fragmentation warhead or shell.
- heavy fragment impacts representative of the threat of anti-ship missiles, bombs or large-calibre shells.
- anti-tank type shaped-charge jet impact.

The following are also considered for some applications :

- kinetic energy projectile or self forging fragment impact,
- fall of an object on to the munition during handling or transport,
- projection of fragments consequent to the explosion of pressurised containers (e.g. fire extinguishers).
- secondary fragments or spall impact such as, for instance, fragments of armour impacted by a shaped charge.

4.2.3. Electrical or electromagnetic stimuli

In general, the following are considered where they have not been taken into account already in the normal environment:

- electrostatic discharges,
- direct lightning strikes and electromagnetic fields radiated near by lightning strikes,
- radiation emitted by various radar or radio transmitters (HERO effect),
- electromagnetic pulse following the explosion of a nuclear warhead.

4.2.4. Combined stimuli

- Sympathetic detonation or functioning. This threat is due to nominal or non nominal functioning of identical munition nearby.
- detonation of non-identical munition nearby.

The events, which may be of different types depending on the munitions considered, may have combined the stimuli of thermal flux, shock-wave, air overpressure and fragment impacts.

- combined stimuli such as those resulting from a crash of an aircraft for instance.

- etc…

4.3. Selected types of stimuli

Since it is impossible to deal with the full range of possible stimuli in each category, a selection of stimuli which are representative of the threats the munitions could face in their various phases of life cycle, had to be done.

Nine types of stimuli, which enable the behaviour of the munitions to be predicted, are considered for the assignment of the MURAT standards; they are listed hereafter :

1 severe electrical or electromagnetic stimuli,

2 drop,

3 external fire (Fast cook off),

4 slow heating,

5 bullet impacts,

6 sympathetic reaction,

7 light fragment impacts,

8 heavy fragment impact,

9 shaped-charge jet impact.

4.4. Events feared and types of reaction

Stimuli suffered by the munition may lead to events whose effects, more or less violent, are listed in types of reaction. Their precise description, which is acknowledged by the international organisations, as well as a summary table indicating the behaviour of the munition for each type of reaction and the effects expected on the environment, are given in appendix 1. The concept of no-reaction presents an original character which may be considered as specific to the MURAT. These elements are briefly summarised hereafter.

Type I :

Blast effect (or shock wave) and fragmentation typical of complete detonation.

Type II :

Blast effect (or shock wave) and fragmentation typical of partial detonation. Effect proportional to the quantity of energetic materials which detonate, sometimes producing large fragments.

Type III :

Violent bursting of the casing with corresponding effects, shock wave less intense than that which would result from a detonation, projection of large fragments, projection of unburned energetic materials, fire and smoke.

Type IV :

Non violent production of gases: the casing may burst without production of fragment; possible projection of energetic materials and end caps ; no blast or fragmentation; emission of heat and smoke; possible propulsion leading to significant movement of the article.

Type V :

Non propulsive combustion, non violent opening of the casing, no dangerous projection beyond 15 metres, smooth release of gases.

No reaction :

In this case, the concept of no-reaction only concerns the safety aspect. If an explosive event, which takes place following stimuli suffered by the munition, remains non-perceptible and is of non danger for the environment, even the immediate surroundings, this event shall be considered as a “no-reaction”.

Some national or international rules may impose a total lack of explosive reaction.

Although it is acknowledged at international level, the definition of those types of reaction does not have a definitive character. A study of this subject has started in the NATO AC/310 Group on the basis of the table in appendix 1. It should lead to the adoption of an official definition of he different types of reaction which could affect the munition.

5. THE MURAT STANDARD

In order to obtain a MURAT STANDARD the reactions of the munition with respect to the nine type of selected stimuli must be analysed.

The scope to be taken into account for each of those type of stimuli are shown in appendix 2.

For a given munition, the tables “stimuli/types of reaction” given in paragraph 5 are used to define its level of “MURATIZATION” represented by the MURAT*, MURAT** and MURAT*** standards.

The procedures used to assign a standard are described in paragraph 7.

When the effects specific to a stimuli are much more significant than those potentially generated by the munition to be examined, this will not be taken into account (so it would be ridiculous to expose a 5.56 cartridge to a shaped charge jet. On the other hand, it could be pertinent to examine the effects of the same stimuli on a container filled with this type of cartridge).

The MURAT standard enable to assess the behaviour of munitions when subjected to typical stimuli. However, under no circumstances does this rule out an hazard analysis under the planned conditions of use; nor does knowledge of the hazard division for storage and transport rule out specific studies in terms of the conditions of use.

6. STIMULI/REACTIONS FOR THE MURAT STANDARDS

The tables presented hereafter define the type of acceptable reaction for each type of stimuli selected.

As a reference, the stimuli/acceptable reactions table, which defines the munition classified 1.6, is given in appendix 3.

It should be noted that :

- no typical test for electrical stimuli, light fragments, heavy fragments and shaped charge jet is taken into consideration in the context of the rules for definition of class 1.6;

- MURAT** have the same type of acceptable reactions as 1.6 munitions for their common basis of selected stimuli; on the other hand, the clause concerning extremely insensitive detonating substances (EIDS) is not required for MURAT**; however, reactions to stimuli which are not taken into consideration for the 1.6 class, such as light fragments, heavy fragments or shaped charge jet impacts, are examined.

Stimuli / reactions table
MURAT* standard

Reaction / Stimuli	NR	V	IV[1]	III	II	I
1 – Electrical	X					
2 – Drop	X[2]					
3 – External fire	X	X	X			
4 – Slow heating	X	X	X	X		
5 – Bullets	X	X	X	X		
6 – Sympathetic reaction	X	X	X	X		
7 – Light fragments	X	X	X	X	X	X
8 – Heavy fragments	X	X	X	X	X	X
9 – Shaped charge jet	X	X	X	X	X	X

Stimuli / reactions table
MURAT** standard

Reaction / Stimuli	NR	V	IV[1]	III	II	I
1 – Electrical	X					
2 – Drop	X[2]					
3 – External fire	X	X[3]				
4 – Slow heating	X	X				
5 – Bullets	X	X	X	X		
6 – Sympathetic reaction	X	X	X	X		
7 – Light fragments	X	X	X	X		
8 – Heavy fragments	X	X	X	X		
9 – Shaped charge jet	X	X	X	X	X	X

Stimuli/reactions table
MURAT*** standard

Reaction / Stimuli	NR	V	IV[1]	III	II	I
1 – Electrical	X					
2 – Drop	X[2]					
3 – External fire	X	X[3]				
4 – Slow heating	X	X				
5 – Bullets	X	X				
6 – Sympathetic reaction	X	X	X			
7 – Lights fragments	X	X				
8 – Heavy fragments	X	X	X			
9 – Shaped charge jet	X	X	X	X		

NOTA : defence energetic materials will be of the EIDS (extremely insensitive detonating substance) type with the exception of those located upstream of shutters when such features are in the initiation train.

Key : X accepted reaction

[1] non propulsion
[2] evacuation of the article must be possible with no risk
[3] at earliest, 5 minutes after the start of the fire

7. CONSEQUENCES OF THE MURAT CHARACTER OF MUNITIONS ON RULES TO BE APPLIED FOR STORAGE AND TRANSPORT

7.1 - Disregarding the classification specific to storage and transport resulting from strict application of UN procedures, the table given hereafter indicated the rules to be applied in this matter for MURAT. They reflect the hazard analysis of munitions subjected to the selected types of stimuli.

The information given in the « assimilation classification » column is used to calculate hazard zones as defined in force regulations.

7.2 - The munitions which consist of more than 200 kg of detonation substances must be classified in hazard division 1.1 according to the results of test a) of UN serie 6. However, since there is no propagation of the reaction, the weight of energetic materials to be taken into account for application of the storage and transport rules may be limited to that of a single article.

7.3 - The very small articles which benefit by special packaging are often classified 1.4; due to the variety of these articles, general rules can not be laid down.

The following simple rules, applicable to the storage and transport of homogenous batches, result from an analysis of the possible « assimilation classifications » disregarding :

- very large articles with a weight of detonating substances > 200 Kg cf. § 6.2
- very small article which benefit by special packaging cf. § 6.3

MURAT standard	Maximum acceptable events	Assimilation classification
MURAT *	- detonation of a single article through the effect of its initiation device or due to an external cause - progressive reaction of the whole stack with projection of fragments due to an external cause	1.2
MURAT **	- detonation of a single article through the effect of its initiation device or a shaped charge - progressive reaction of the whote stack with projection of fragments due to an external cause - combustion of the whole stack in a fire	1.2 / 1.3 Assimilation classification 1.2 or 1.3 results from a detailed analysis of effects on the environment of the reactions to the various stimuli
MURAT ***	- detonation of a single article through the effect of its initiation device - combustion of the whole stack due to an external cause	1.3

8. PROCEDURES

A MURAT standard can only be given to specific munitions which have been designed, developed, qualified an manufactured according to the quality rules applicable to this type of equipment for the French Armed Forces.

The procedures to be applied, which enable the assignment of a MURAT standard to a munition, are as follows :

8.1 - An analysis enables to check the compliance with the design principles and rules imposed on munitions applying for a MURAT standard.

8.2 - The MURAT standard will be granted by the competent authority on the basis of a files consisting of :

- theoretical analyses of the predictable behaviour of the munition in regard to various stimuli,
- modelling,
- extrapolations of know reactions,
- tests results.

The various elements of the file will demonstrate that, for the nine types of selected stimuli, the reaction level does not exceed that which is indicated in the “Stimuli/reactions tables”.

1 provide all the pertinent elements enabling the assessment of the guarantee given by the demonstration for the whole scope of stimuli.

The necessary trials will be carried out according to the following procedures :
- UN, when applicable,
- NATO when UN is not applicable,
- National, when there are no NATO procedures.

The use of any other method should be subject to explicit justification.

APPENDIX I
DESCRIPTION OF REACTIONS

TYPE I REACTION

The most violent type of explosive event. A supersonic reaction propagates through the energetic material to produce an intense shock in the surrounding medium (e.g., air or water) and a very rapid plastic deformation of metallic cases followed by extensive fragmentation. All energetic materials will be consumed. The effects will include large ground craters for munitions on or close to the ground, perforation, plastic deformation or fragmentation of adjacent metal plates and blast overpressure damage to nearby structures.

TYPE II REACTION

The second most violent type of explosive event. some but not all of the energetic materials react as in a Type I reaction. An intense shock occurs; a part of the case is broken into small fragments; a ground crater can be produced, the adjacent metal plates can be damaged as in a Type I reaction and there will be blast overpressure damage to nearby structures. A Type II reaction can also produce large case fragments as in a violent pressure (brittle fracture). The amount of damage, relative to a Type I reaction, depends on the portion of material that detonates.

TYPE III REACTION

The third most violent type of explosive event. Ignition and rapid burning of the confined energetic material build up high local pressures leading to violent pressure rupture of the confining structure. Metal cases are fragmented (brittle fracture) into large pieces that are often propelled long distances. The unreacted and/or burning energetic material is also scattered about. Air shocks are produced that can cause damage to nearby structures. Fire and smoke hazards will exist. The blast and high velocity fragments can cause minor ground craters and damage (break-up, tearing, gouging) to adjacent metal plates. Blast pressures are lower than for Type I or Type II reactions.

TYPE IV REACTION

The fourth most violent type of explosive event. Ignition and burning of the confined energetic materials lead to nonviolent pressure release as a result of a low strenght case or venting through the case walls (outlet gap, initiation capsule, etc…) The case may rupture but does not fragment; orifice covers may be expelled and unburnt or burning energetic material may be scattered about and spread the fire. Pressure releases may propel an unsecured test item causing an additional hazard. No blast effect or significant fragmentation damage to the surroundings, only heat and smoke damage from the burning energetic material.

RÉACTION DE TYPE V

The least violent of explosive event. The energetic material ignites and burns non propulsively. The case may split up non-violently; it may melt or weaken sufficiently to allow slow release of combustion gases; the case covers may be dislodged by the infernal pressure. Debris stays in the area of the fire although covers may be thrown up to 15 meters. These debris are unlikely to cause fatal wounds to personnel.

PROPULSION

A reaction whereby adequate force is produced to impart flight to the test item.

DEFINITION OF NATO REACTIONS (PROPOSED MODIFICATIONS)

REACTION	MUNITION BEHAVIOUR		EFFECTS			
	Energetic materials	**Case**	**Blast**	**Projection of energetic materials**	**Projection of fragments**	**Miscellaneous**
I	- detonation - supersonic decomposition reaction	- very fast plastic deformation - total fragmentation	- intense shock wave - damage to neighbouring structures	- all the materials react	- perforation, plastic deformation or fragmentation of adjacent metal plates	- larges craters in the ground
II	- partial detonation	- partial fragmentation + large fragments	- ditto	- ditto	- ditto	- ditto - proportional to % of detonating material
III	- fast combustion of confined material (explosion) - local pressure build up	- violent breaking into large fragments	- blast effect < detonation - damage to neighbouring structures - P > 50 mbar at 15 m (1) (2)	- scattering of burning materials - risk of fire, smoke	- long-range projection - damage to metal plates (breacks, rips, outs)	- small craters in the ground
IV	- combustion/deflagration - non violent pressure release	- breaks but does not fragment into more than 3 parts - expulsion of end caps - gases release through opening	- Reaction noted IV s - blast effect limited to P < 50 mbar à 15 m (1) (2)	- Reaction noted IV i - scattering of materials - risk of fire	- Reaction noted IV m - expulsion of end caps and large structural parts - no significant damage	- Reaction noted IV p - damage caused by heat and smoke - propulsion of unattached sample
V	- combustion	- splits in a non-violent way - smooth release of gases - separation of end caps	blast effect limited to P < 50 mbar à 15 m (1) (2)	- energetics materials remain nearby (< 15 m) (2)	- debris remains, except covers - no fragment of more than 79J (3) or more than 150 g beyond 15m (2)	- heat flow < 4 kw/m^2 à 15 m (2)

(1) French Instruction of May 8. 1981

(2) UN – Transport of dangerous goods: test 6(c) (3) MIL-STD-2105A: Hazardous fragment

APPENDIX II

SCOPE OF SELECTED STIMULI
Characteristics of the scope of stimuli to be taken into account for assigning standards

In order to simplify demonstration of the compliance with the reaction levels for each type of stimuli, restricted scopes have been defined, for which this demonstration will be required.

A priori, these scopes constitute representative limits of the types of selected stimuli.

In most cases, these scopes have a range of variation of one or more parameters.

The demonstration should be based on both the data corresponding to the most penalising values of the parameters for the considered article an don analyses which enable to extend those particular results to the entire scope.

Characteristics of the stimuli

CATEGORY OF STIMULI	TYPE OF SELECTED STIMULI	SCOPE TO BE TAKEN INTO ACCOUNT FOR THE ASSIGNMENT OF STANDARD
Electrical or electromagnetic	1 Severe electrical or electromagnetic stimuli	- electrical or electromagnetic radiation: scope defined in GAM DRAM 01 02 - static electricity: scope defined in STANAG 4235 - lightning: scope defined in STANAG 4236 excluding direct lightning strike
Mechanical	2 Drop	- Heights of O to 12 m on flat steel surface
Thermal	3 External fire	- Liquid hydrocarbon Kerosene type fuel combustion. No limitation in time
Thermal	4 Slow heating	- Steady heating rate of 3 to 60°C per hour starting from ambient temperature. - No limitation in time
Mechanical	5 Bullet impacts	- 12,7 amour-piercing bullets - 1 to 3 bullets in burst - Impact velocity of 0 to 850 m/s
Mechanical	6 Sympathetic reaction	- The most penalising reaction (nominal or not) of identical munitions in the most detrimental for safety configuration
Mechanical	7 Light fragments impacts	- 20g cubic steel fragments - 3 simultaneous fragments - Impact velocities of 0 to 2000 m/s
Mechanical	8 Heavy fragment impacts	- 250 g parallelepipedic steel fragment - Only one fragment - Impact velocity of 0 to 1650 m/s
Mechanical	9 Shaped charge jet impact	- Residual jet of a shaped charge capable of nominal perforation of 300 mm thick steel plate.

APPENDIX III

TABLE OF STIMULI/ACCEPTABLE REACTIONS FOR 1.6 HAZARD DIVISION

Reaction / Stimuli	NR	V	IV	III	II	I
1 – Electrical [1]	X	X	X	X	X	X
2 – Drop	X					
3 – External fire	X	X				
4 – Slow heating	X	X				
5 – Bullets	X	X	X	X		
6 – Sympathetic reaction	X	X	X	X		
7 – Light fragments [1]	X	X	X	X	X	X
8 – Heavy fragments [1]	X	X	X	X	X	X
9 – Shaped charge jet [1]	X	X	X	X	X	X

[1] this type is not taken into consideration for 1.6 classification

Key : X accepted reaction

NOTE : an article classified in 1.6 hazard division only contains “extremely insensitive detonating substances” (EIDS).