



**MINISTÈRE
DES ARMÉES**

*Liberté
Égalité
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The study of the compatibility of energetic materials

STANAG 4147 Ed 3 - AOP 4147 Ed A
Compatibility guidelines MAN CAT 17501

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Overview

STANAG 4147 and Guidelines 17501

General considerations

Compatibility tests

French process

Requirements

French standards

GUIDE MAN CAT N°17501

Guide pour la détermination de la compatibilité des matières énergétiques avec les matériaux en contact

1^{ère} édition

(Les dates précises d'approbation et de publication sont accessibles dans SysMan)

Document entretenu par DGA/DIE/ST/IP/MAN/PES



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STANAG 4147 – AOP 4147 Guidelines 17501

Compatibility is required for the qualification of ammunition (NATO standard : STANAG 4297 – AOP 15)

Guidelines 17501:

- French application document for STANAG 4147

- Signed by the French Authority

- Must be applied for all ammunition qualification for the French forces

- DGA verifies that it is applied

- Contains: General observations on compatibility

 - Process on program

 - Particularities

 - Lab tests and French standards

What is an incompatibility reaction ?

Chemical reaction at the interface of two materials in contact

Can change the chemical and mechanical properties, the ageing of both materials...



New thermal protection (left) and after ageing (right). The change is caused by an incompatibility between the glue and the propellant.

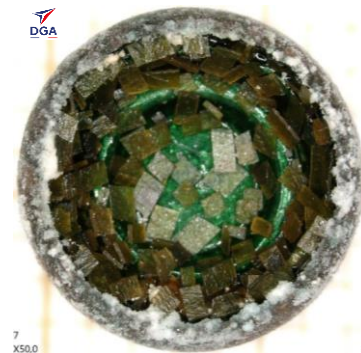
Why do we verify compatibility ?

There could be an impact on the energetic material and the ammunition

2 types:

- Safety issue
- Reliability issue

The absence of justification could lead to restriction of use (climates, shelf life, periodic inspection...)



Incompatibility between a propellant and a lacquer in an initiator

When do we check compatibility ?

At the conception of the ammunition

After any changes in the material (inert and energetic)

Exceptionally, RETEX can be used instead of compatibility test (same materials, used for more than 10 years in the French army at a large scale)

Different types of contact

Direct:

Materials physically in contact, share an interface

Indirect:

Materials in contact by vapor phase, migration of liquids (nitroglycerin...)

Possible:

Could happen during the life of the ammunition (migration of solids...)

Compatibility matrix

Table with couples energetic/inert et energetic/energetic

Must show:

- List of energetic materials
- Types of contact
- Precise materials + surface treatments
- Reference of tests

rep	designation	material	surface treatment	shell	propellant	glue	xx
1	shell	xxx	xxx				
2	propellant	xxx	-	CD_1			
3	glue	xxx	-	-	CI_4		
4	xx	xxx	-	-	CP_5	-	
5	xx	xxx	xxx	-	CD_6	-	-

Principle of compatibility tests

« Chemical reaction detector »

Compare the reactivity of the materials alone and together

It cannot predict the effect of the incompatibility reaction, or its kinetics

1:1 ratio to represent the interface

Apply a time/temperature couple "representative" enough to highlight reactions

It doesn't represent the real conditions lived by the object, it is used to accelerate the incompatibility reaction and able us to detect them through the duration of the test

Why use several methods ?

A chemical reaction can manifest in different ways :

- Mass loss / gassing
- Chemical alteration of the material
- Heating

We have to study the right marker

Example : study of the compatibility of a gun propellant with a lacquer:

Element 1	Element 2	Analysis	Test verdict	Final decision
Gun propellant	Paint	Method 1	Compatible	Incompatible
		Method 2	Compatible	
		Method 3	Incompatible	

Which analysis methods ?

Mass loss:

Vacuum stability (VST)

Thermogravimetry (TGA)

Gravimetry ("FOA")

Chemical modifications:

Differential scanning calorimetry (DSC)

Infrared spectroscopy

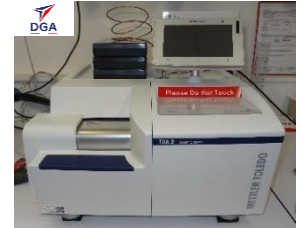
Stabilizer depletion

Heat:

Heat flow calorimetry (HFC)



Differential scanning
calorimetry



Thermogravimetry

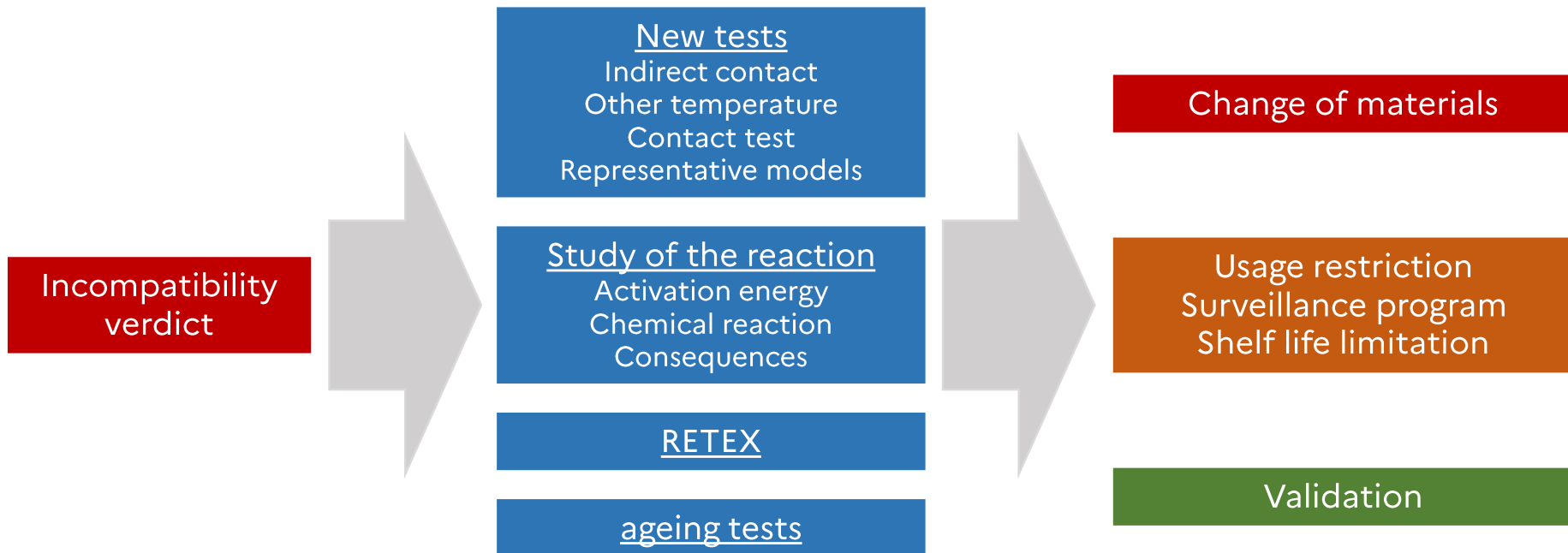


Heat flow calorimetry

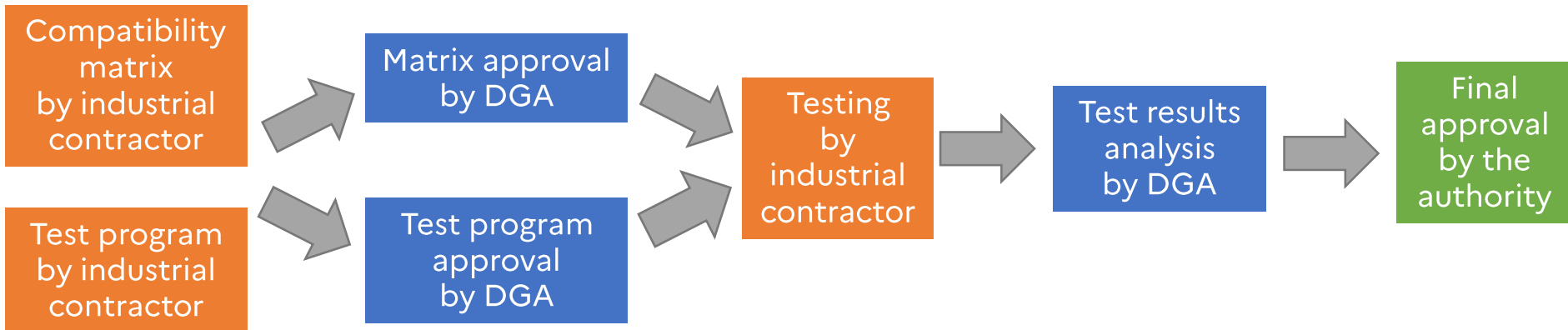


Vacuum stability

What if an incompatibility is detected ?



Compatibility verification at DGA



Requirements for compatibility verification by DGA

Matrix:

matrix

list of elements present in the ammunition

list of energetic materials, of new materials

physical state of the materials, surface treatments...

test program

plans and references, 3D representations...

Results:

complete test reports (test conditions, sampling, pictures, curves)

RETEX justification

French standards



French standardization group for defense energetic materials
(Groupe d'étude des modes opératoires)

Stability and compatibility group with all industrial and state actors

NF T70-517: vacuum stability (200 h)

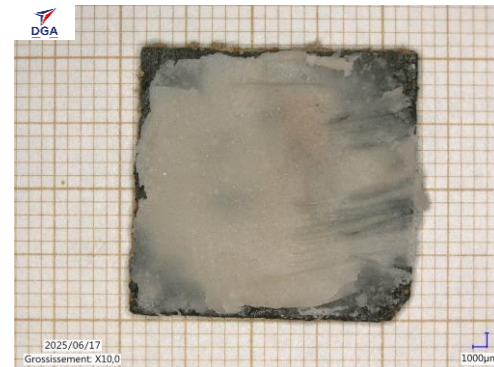
NF T70-535: DSC (no ageing)

NF T70-538: TGA (no ageing)

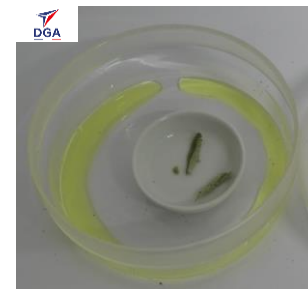
STC-500: gravimetry

STC-700: compatibility with surface (paints, surface treatments)

STC-701: compatibility with liquids and indirect contacts (project)



STC-700



STC-701

Incompatibility (gas release)

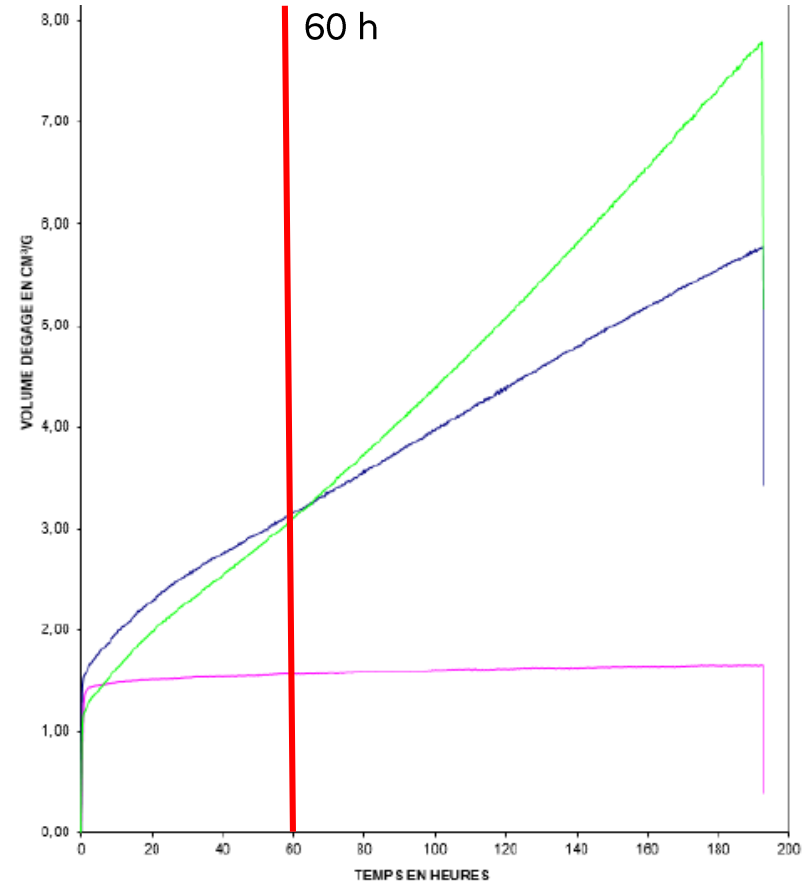
NF T70-517: vacuum stability (200 h)

Blue : glue

Pink : propellant

Green : mix

Incompatibility after 60 h



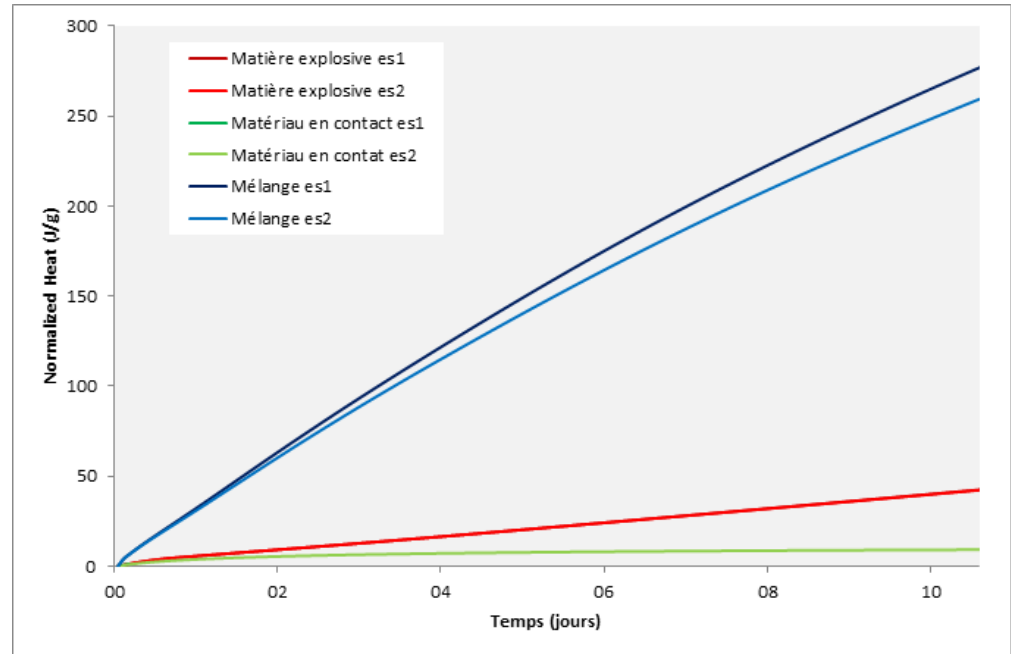
Incompatibility (heat release)

Red : explosive
Green : laquer
Blue : mix



Before test

After test

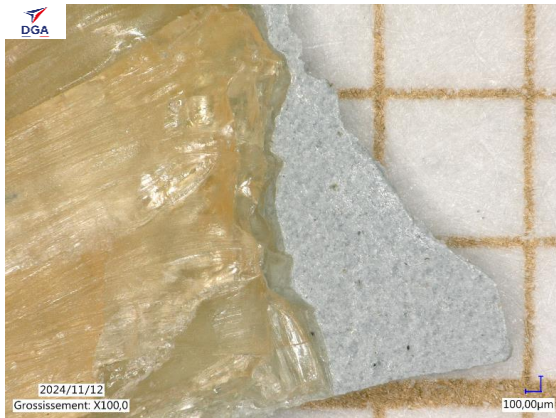


Incompatibility (chemical modification)

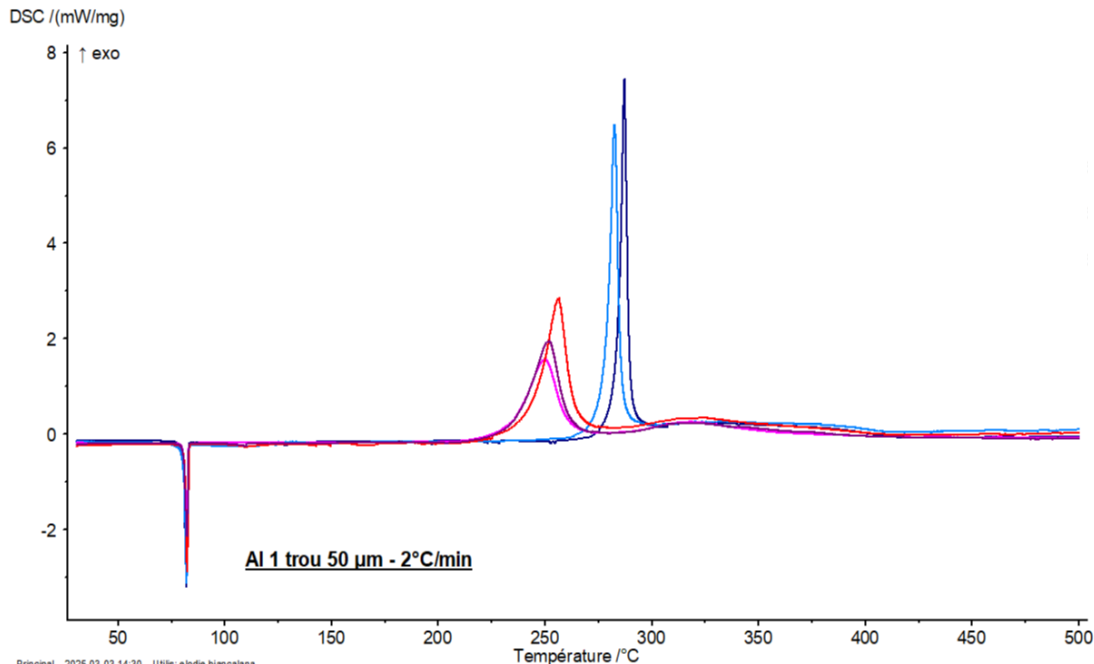
Blue: explosive

Pink/red: explosive after aging in contact
of a paint

32 °C shift



STC-700



Incompatibility (chemical modification)

The stabilizer is consumed more than twice as fast when in contact with the other propellant



Before test



After test

	Stabilizer (%)
Propellant 1	1,17
Propellant 1 aged alone	0,98
Propellant 1 aged with propellant 2 (10:1)	0,73

 **Thank you, questions ?**

Incompatibility (chemical modification)

Pink: liquid

Green: explosive aged alone

Red: explosive aged immersed in liquid

