

# MUNITIONS VULNERABILITY ASSESSMENT ALONG THEIR LIFE CYCLE - METHODS & RESULTS -

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# INTRODUCTION

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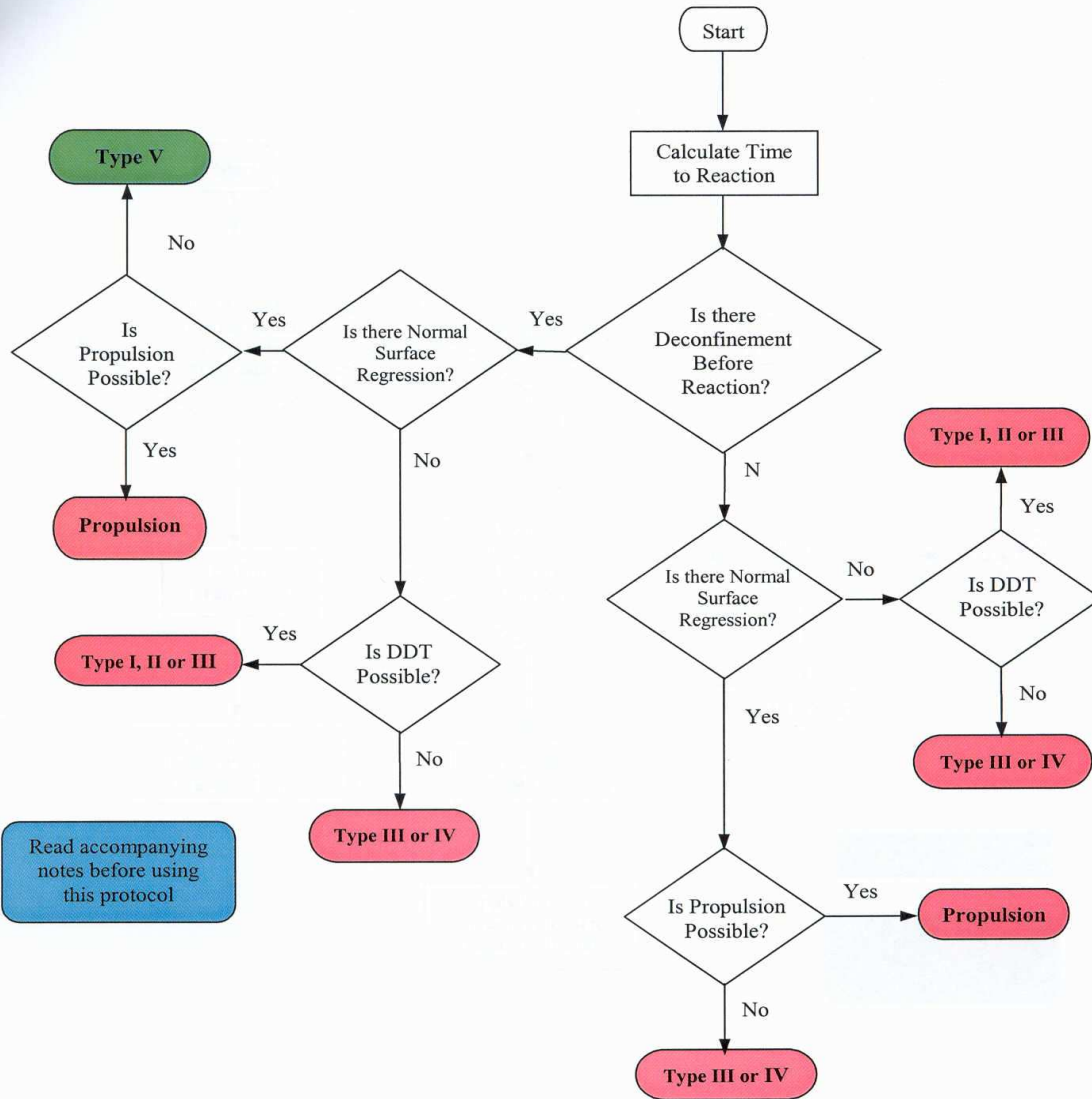
- The required service can reach 20 years for munitions (warheads, bombs, shaped charges, torpedoes, underwater mines, etc...).
- This paper aims at giving methodological tools and examples for IMness assessment according to their life cycle.
- Only few specific studies have been conducted to detect potential changes on IM signature.
- Some results are available concerning Cast Cured PBXs which are manufactured by EURENCO France.
- Two ageing conditions were used: 20 & 60°C during 11 & 8 years respectively.

# PREDICTIVE METHODOLOGIES AND ANALYSIS TOOLS <sub>1</sub>

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- The predictive methodologies are based on small scale trials and on databases associated to numerical simulations.
- It is done in the aim to reduce the number of full scale tests and to increase confidence in their results by the influence analysis of parameters.
- They are more or less precise according to the state-of-art, but they have been validated up to the full scale test for each vulnerability threat.
- These methodologies are recognized by French authorities DGA / IPE through vulnerability reports issued to obtain the MURAT Labels: 1, 2 or 3 stars (the 3 stars label is compliant with full requirements of STANAG 4439).

# PREDICTIVE METHODOLOGIES AND ANALYSIS TOOLS <sub>2</sub>



These methodologies are conceived to answer to all questions.

For example, "is DDT possible?" forces to consider when an EM grain is damaged by threat:

- Which is its specific surface?
- Which is its burning surface?
- Which is pressure increasing rate?
- Which is confinement pressure burst? - ...

# VULNERABILITY MONITORING PARAMETERS <sub>1</sub>

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- Previous protocol shows that it is necessary to have the knowledge of each elementary mechanism concerning EM reactivity and case properties in the aim to predict munitions responses.
- Fault Tree Analysis is useful to list these "vulnerability monitoring parameters".
- When this work has been achieved, it is possible to determine on samples the effect of ageing and to extrapolate to munitions IM signature.

# VULNERABILITY MONITORING PARAMETERS<sub>2</sub>

| Munitions parts  | Monitoring Parameters   | Comments                            |
|--|---|-------------------------------------|
| <b>Munitions case</b>                                      | Thermal conductivity  | Thermal aspects                     |
|  | Radiative emissivity  | Especially for Fast Cook-off        |
|  | Pressure burst at high loading rates according to temperature | For all threats                     |
|  | Shock Hugoniot  | For intense shocks                  |
|  | Melt temperature  | Especially for Fast Cook-off        |
| <b>Thermal insulation / liner</b>                          | Specific heat   | Thermal aspects                     |
|  | Shock Hugoniot  | For intense shocks                  |
|  | Melt temperature  | Especially for Fast Cook-off        |
|  | Flammability temperature                                      | Especially for Fast Cook-off        |
|  | Pyrolysis kinetic   | Thermal aspects                     |
| <b>Energetic materials<br/>(main charge, booster, ...)</b> | Density   |                                     |
|  | Pressure / Time threshold for detonation                      | For intense shocks                  |
|  | Detonation critical diameter                                  | For intense shocks                  |
|  | Friability  | For all threats                     |
|  | Pyrolysis kinetic   | Thermal aspects                     |
|  | Self-heating kinetic  | For slow cook-off                   |
|  | Pressure / Damage dependant burning rate                      | For all threats                     |
|  |   |                                     |
| <b>Architecture parameters</b>                             | Sticking resistance (case, thermal insulation, EM grain...)   |                                     |
|  | Liquid tightness  | Especially for melt cast explosives |
|  | Protective cap characteristics                                | Nozzle, venting device              |
|  | Characteristics of mitigant devices                           | Functioning guarantee               |
|  | Characteristics of Ignition / initiation devices              | Under all aspects                   |

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>1</sub>

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These characterizations were focused on classic mechanical properties and main safety characteristics as requested in NATO standards AOP 7 & 15.

The only vulnerability trials were the Bullet Impact tests which have been conducted on SNPE's vehicle (1.1 litres).

The ageing conditions were 20 & 60°C during up to 11 & 8 years respectively.

The PBX blocks were packaged in closed plastic bags.

Before experiments, samples were extracted by machining from block, avoiding to use the layers near from grain surface.

For Bullet impact tests the explosive grains were set up directly.

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>2</sub>

## Studied compositions :

| Purpose                     | Reference | Filler content | Binder | Filler (s)    | Density | D (m/s) | EIDS |
|-----------------------------|-----------|----------------|--------|---------------|---------|---------|------|
| Booster                     | B2188A    | 84             | HTPB   | HMX/PETN      | 1.62    | 7900    | No   |
|                             | B2238A    | 78             | HTPB   | RDX           | 1.57    | 8040    | No   |
| Blast or underwater effects | B2211D    | 88             | HTPB   | RDX/AP/AI     | 1.81    | 5500    | Yes  |
|                             | B2245B    | 88             | HTPB   | RDX/NTO/AP/AI | 1.81    | 5150    | Yes  |
| Ballistic effects           | ORA86B    | 86             | PU     | HMX           | 1.70    | 8360    | No   |
|                             | B2214B    | 84             | HTPB   | HMX/NTO       | 1.63    | 7450    | Yes  |
|                             | HBu88A    | 88             | HTPB   | RDX           | 1.63    | 8110    | No   |



# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>3</sub>

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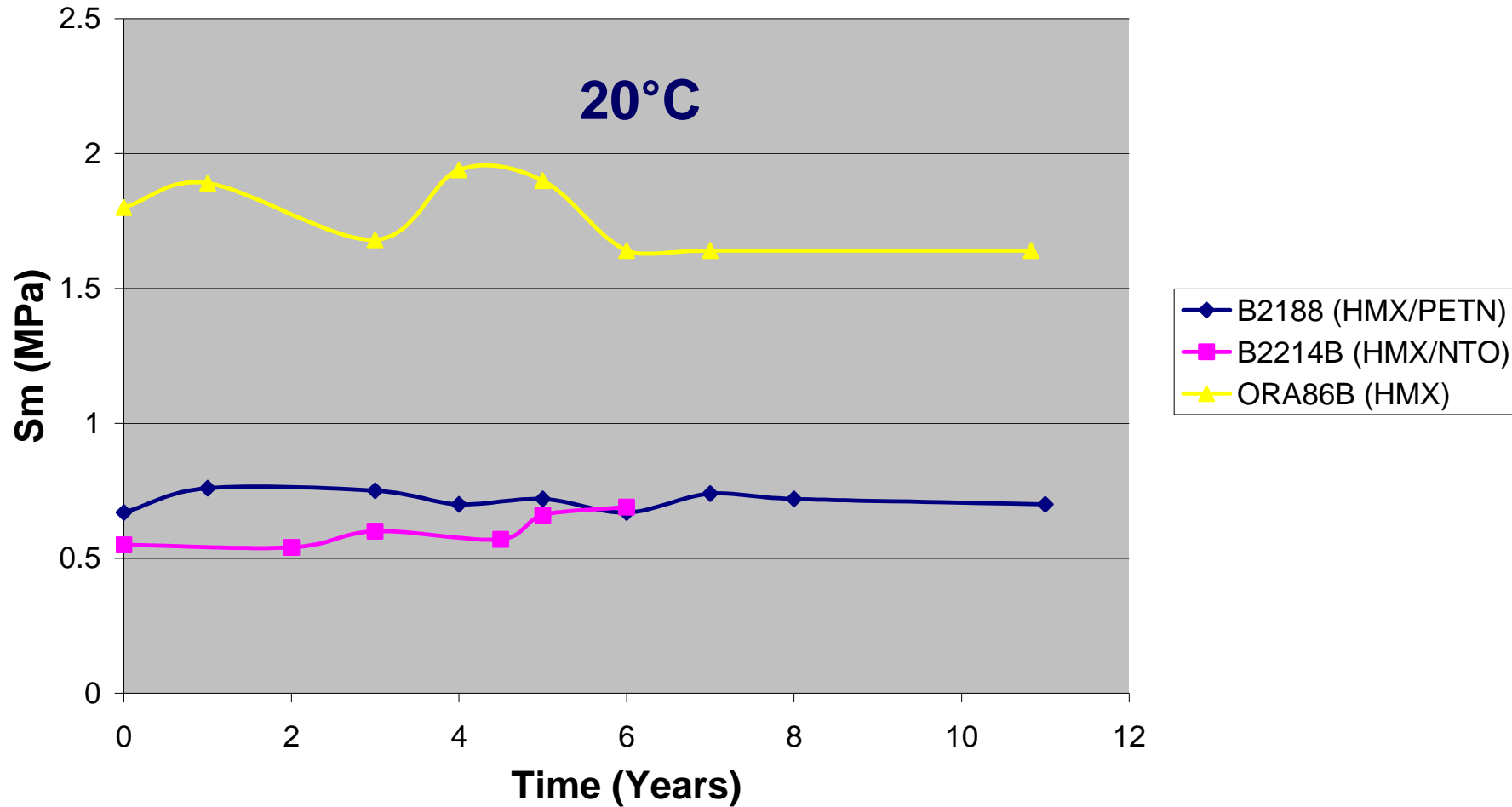
## Mechanical properties :

Uniaxial tensile according to AOP 7 STANAG 4506 with "dog bone" samples, crosshead of 50 mm/min, temperature 20°C.

Uniaxial compression according to AOP 7 STANAG 4443 with cubic samples (10 mm x 10 mm x 10 mm), crosshead of 1 mm/min, temperature 20°C.

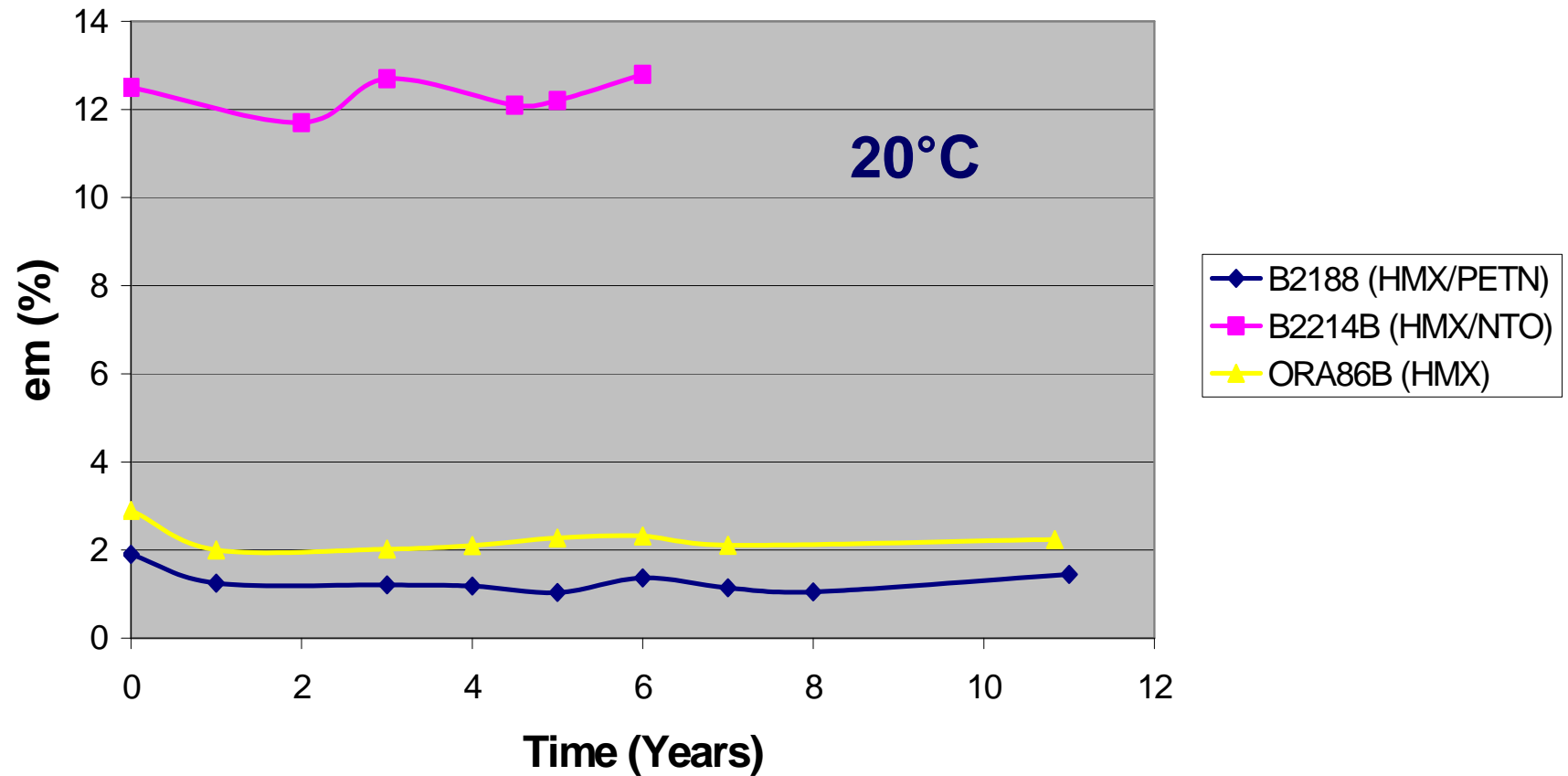
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>4</sub>

## MECHANICAL PROPERTIES: TENSILE TEST Maximum stress versus time



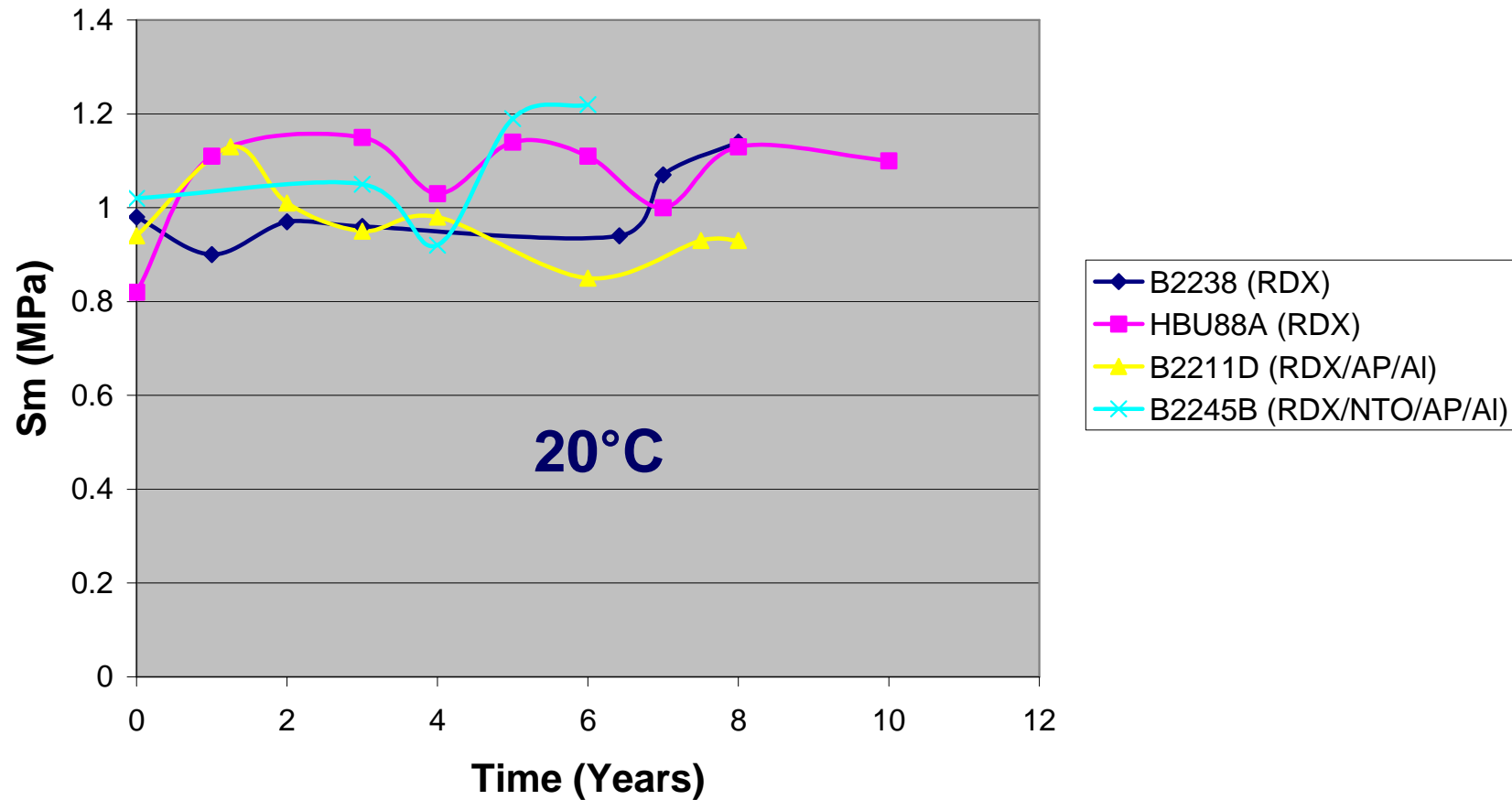
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>5</sub>

## MECHANICAL PROPERTIES: TENSILE TEST Deformation at maximum stress versus time



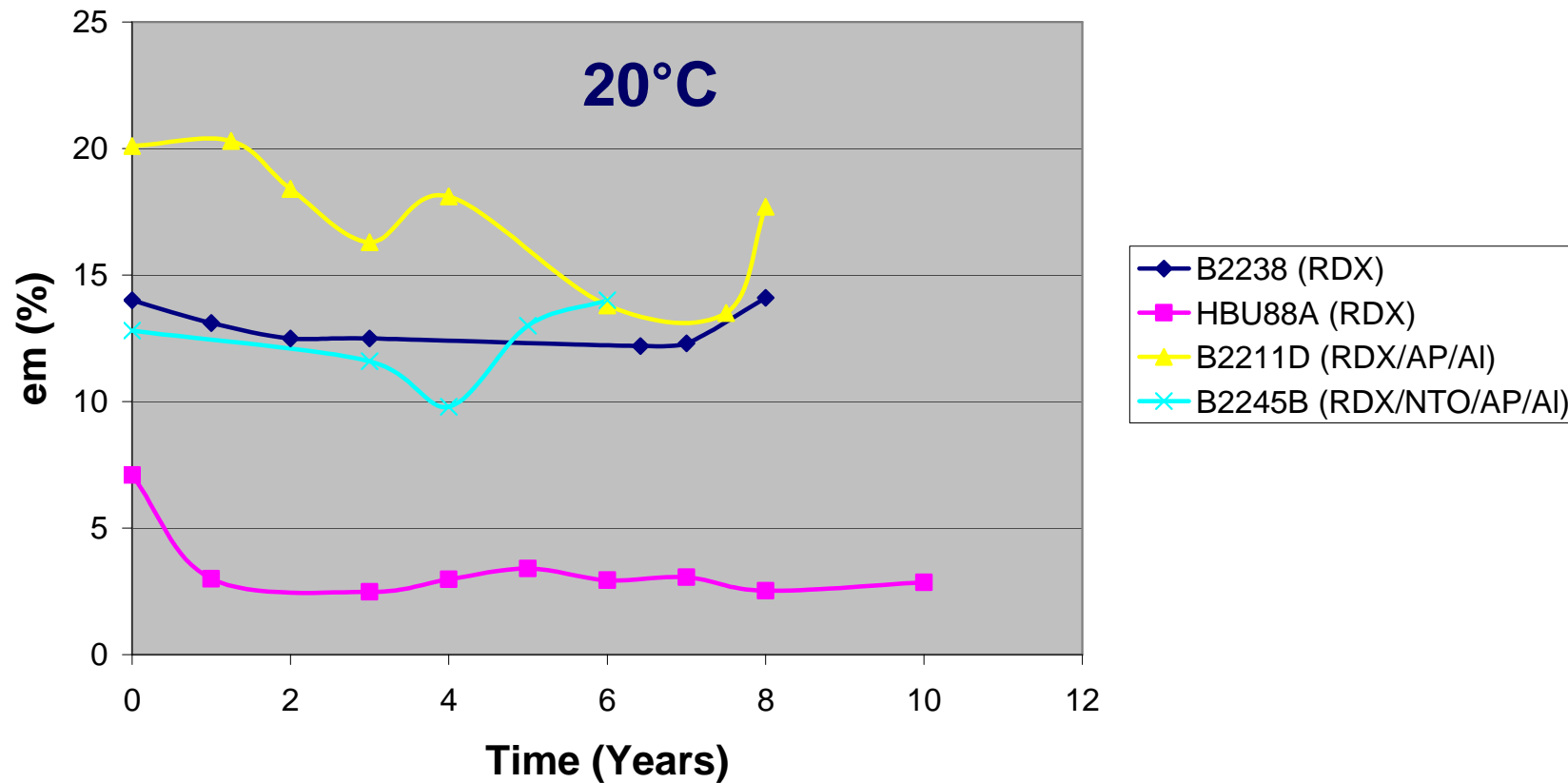
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>6</sub>

## MECHANICAL PROPERTIES: TENSILE TEST Maximum stress versus time



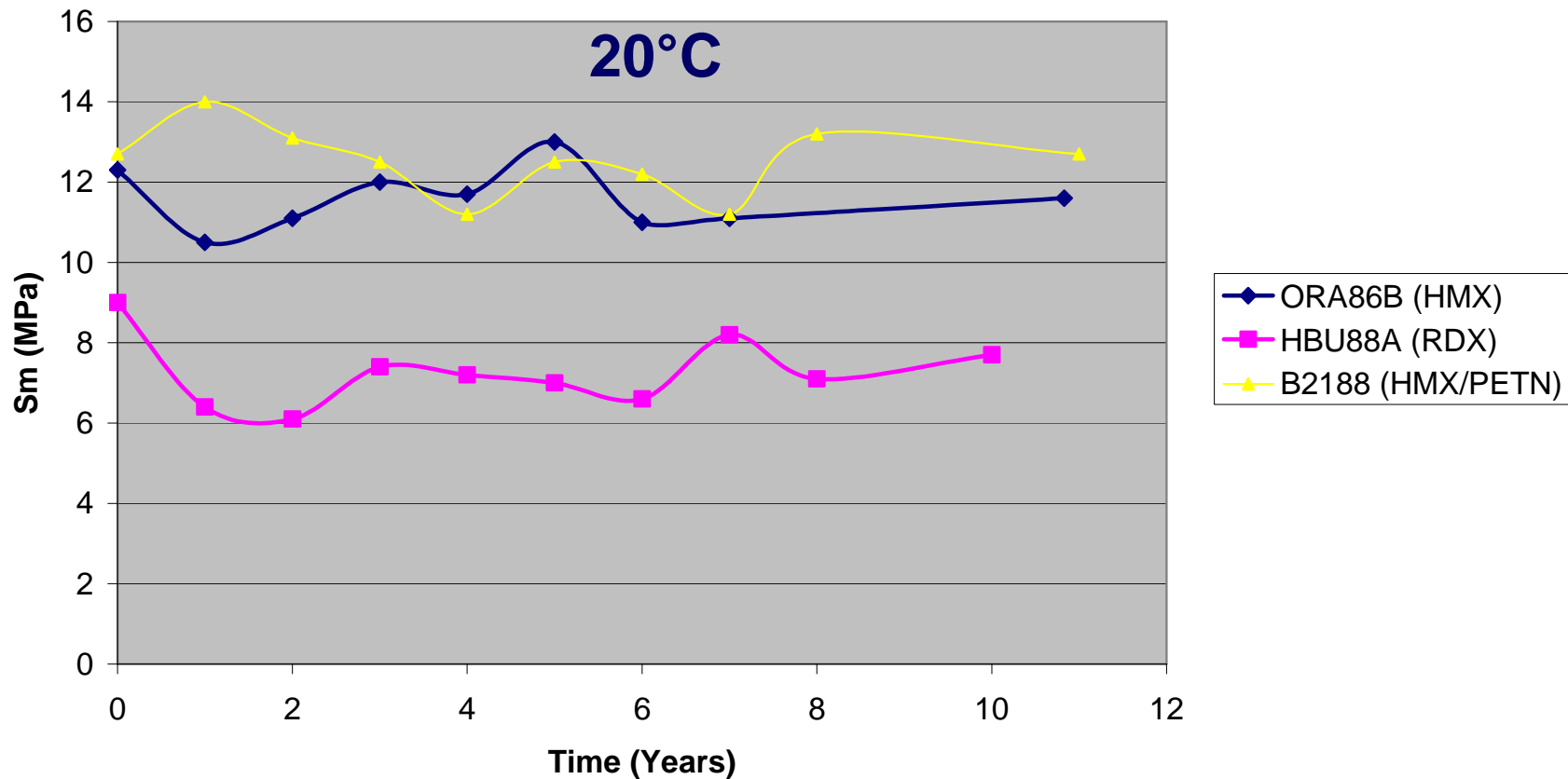
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>7</sub>

## MECHANICAL PROPERTIES: TENSILE TEST Deformation at maximum stress versus time



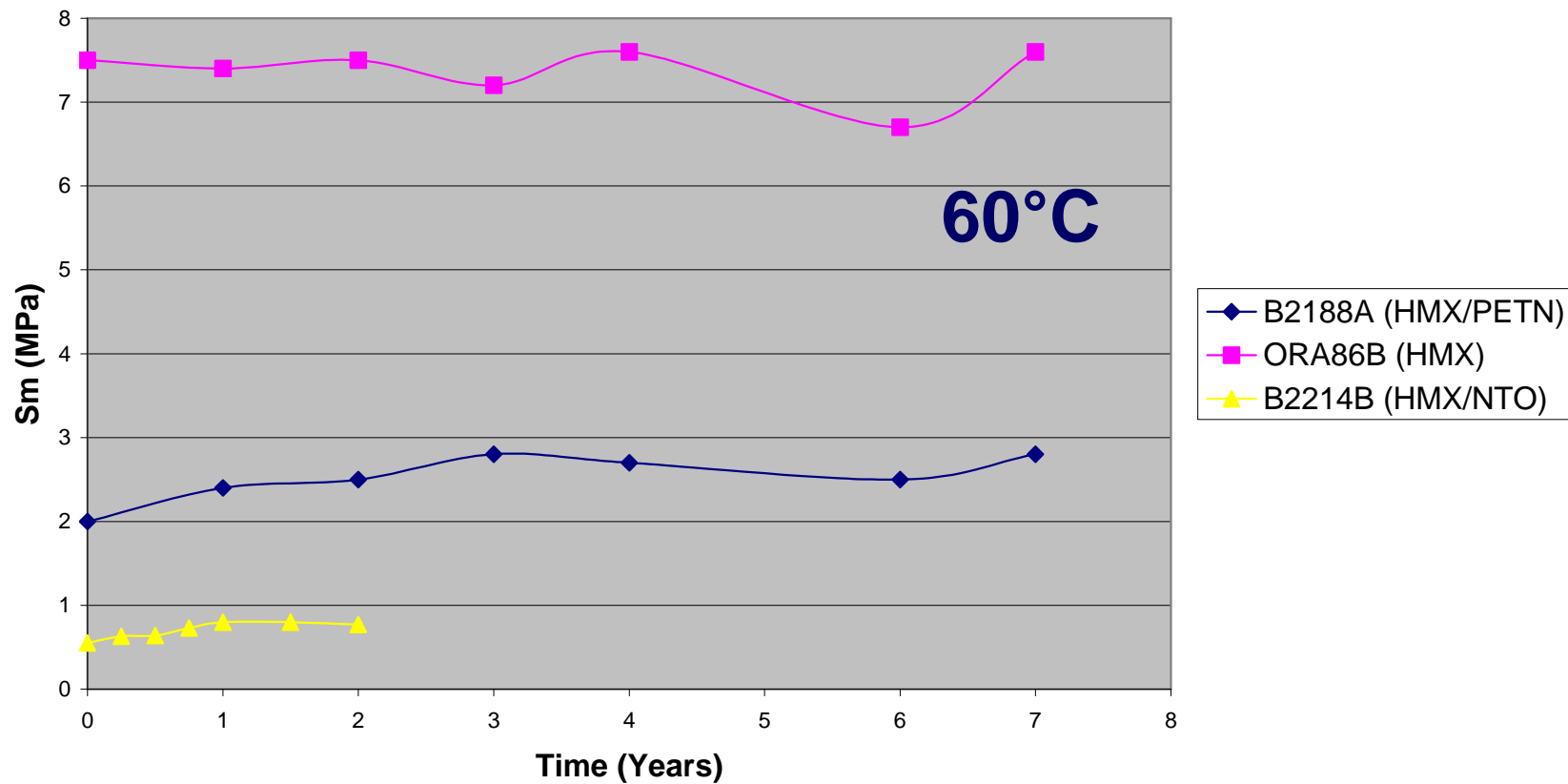
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>8</sub>

## MECHANICAL PROPERTIES: COMPRESSION TEST Maximum stress versus time



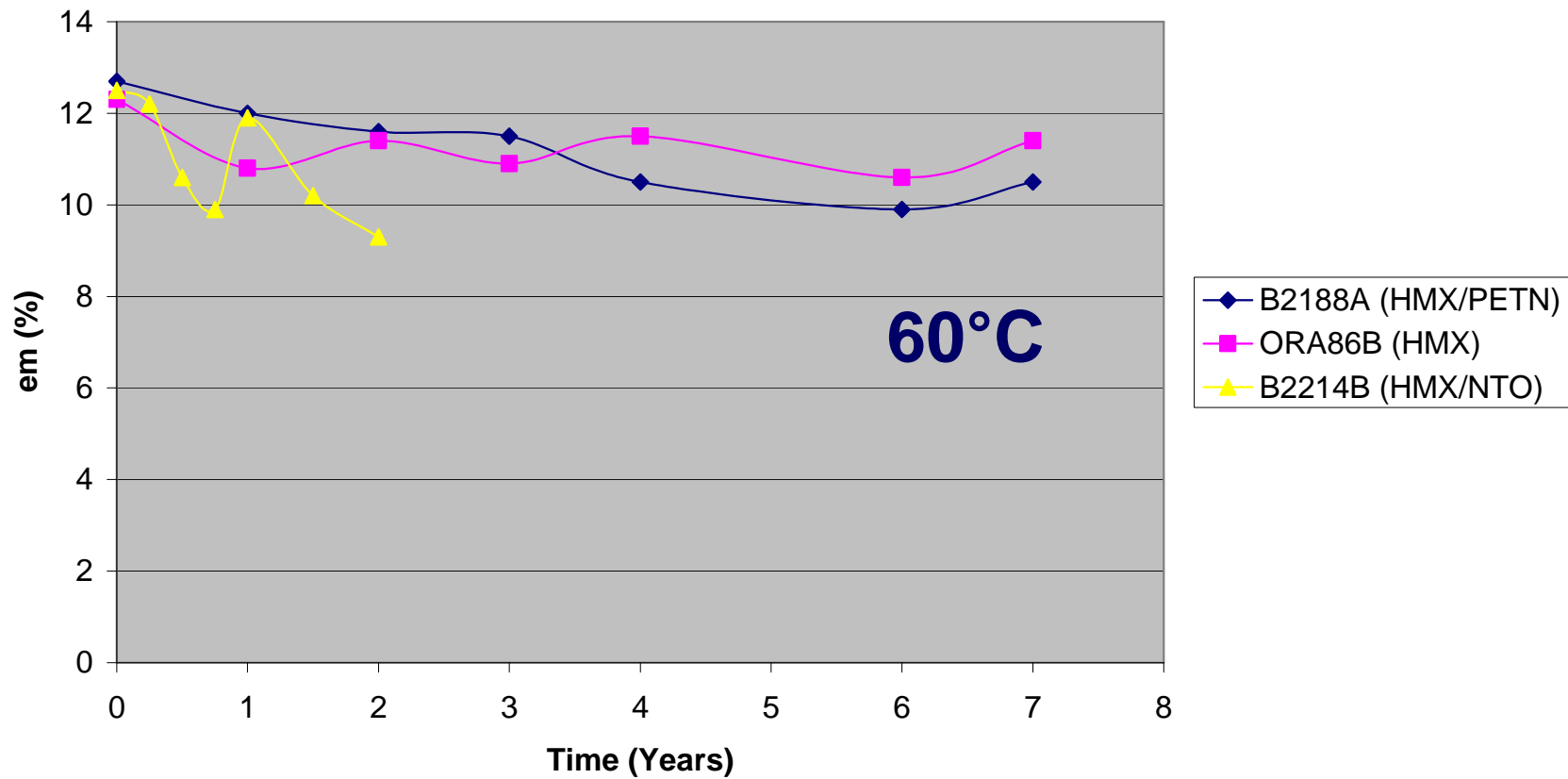
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>9</sub>

## MECHANICAL PROPERTIES: COMPRESSION TEST Maximum stress versus time



# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>10</sub>

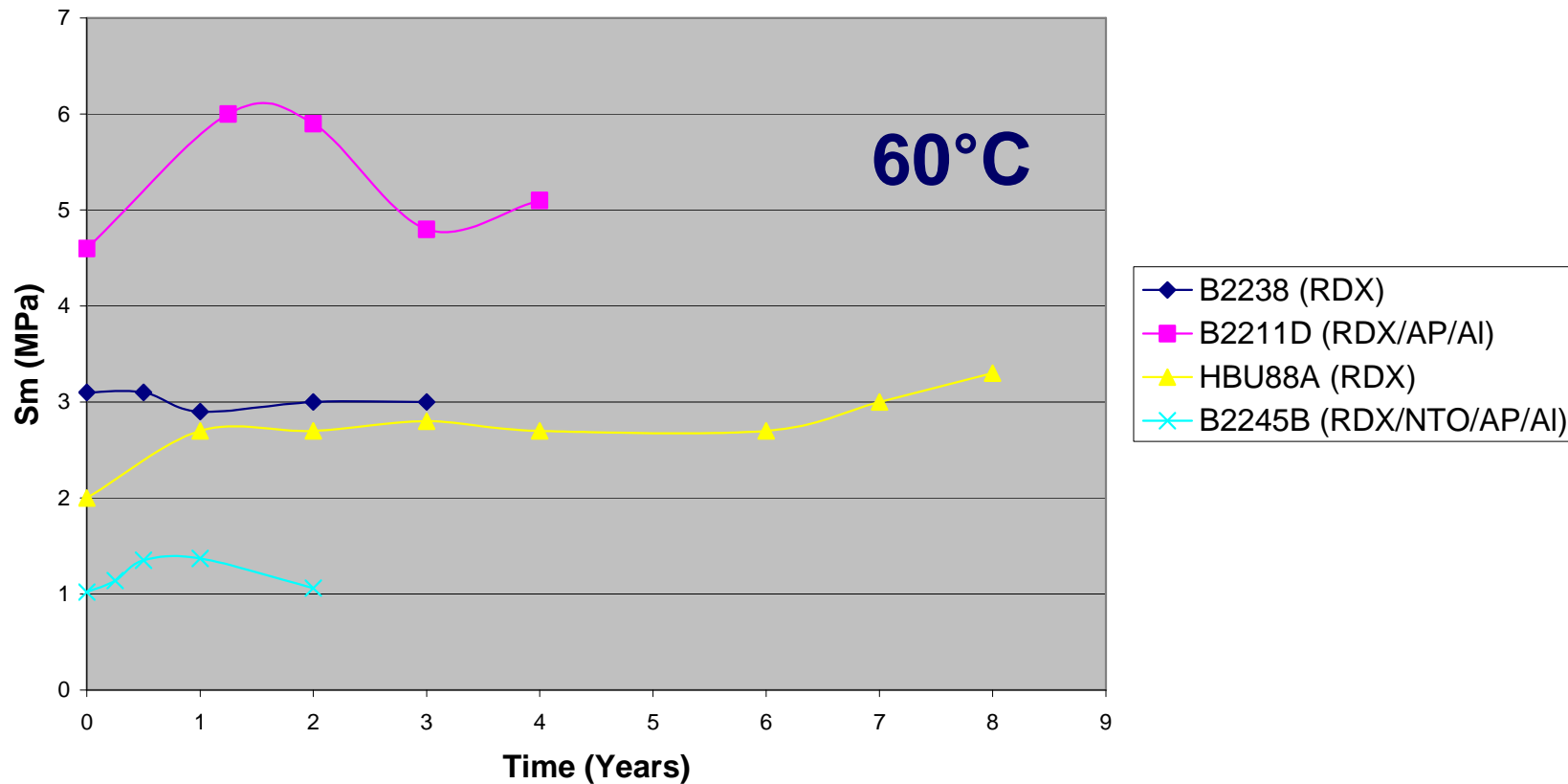
## MECHANICAL PROPERTIES: COMPRESSION TEST Deformation versus time





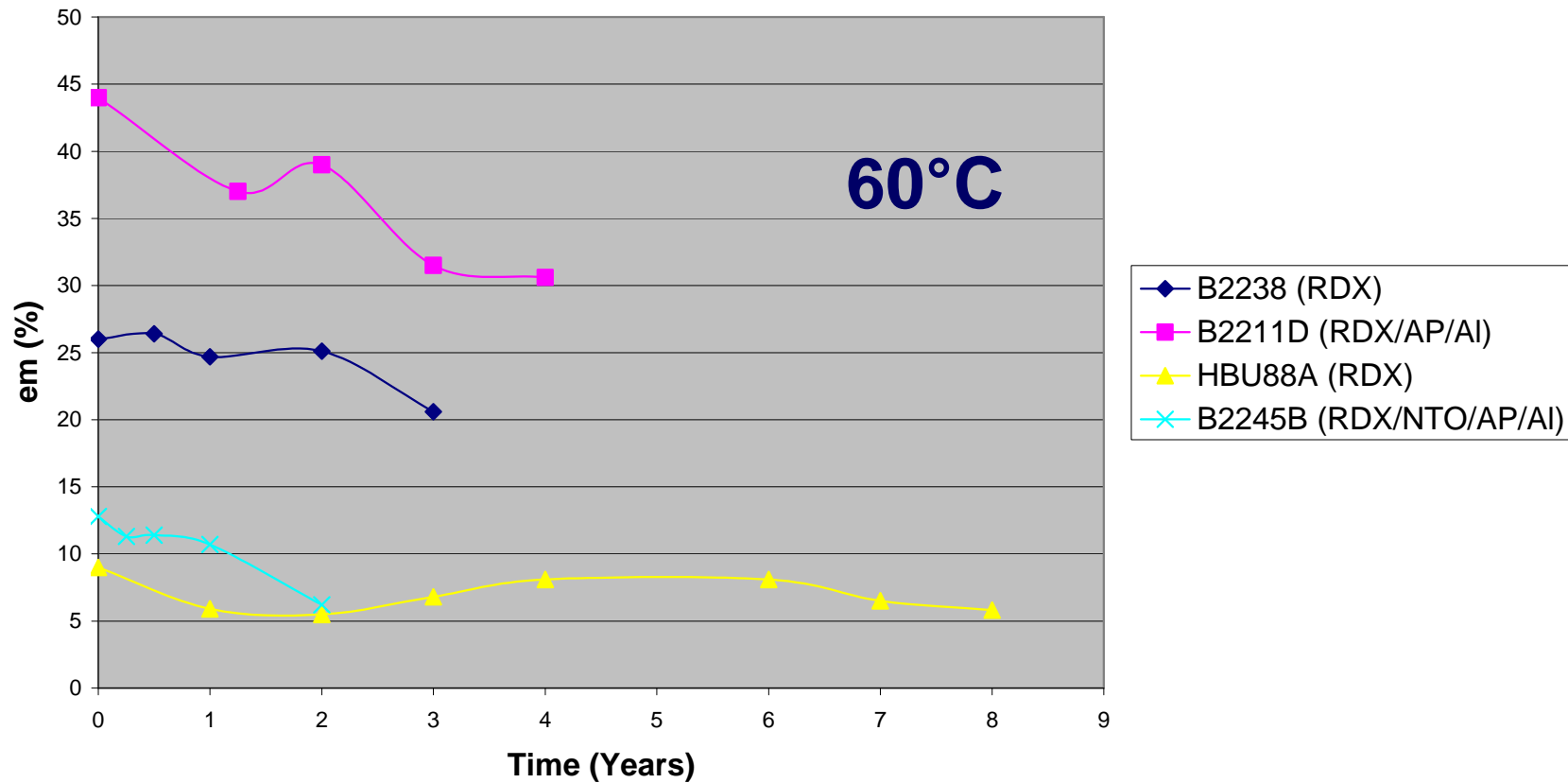
# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>11</sub>

## MECHANICAL PROPERTIES: COMPRESSION TEST Maximum stress versus time



# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>12</sub>

## MECHANICAL PROPERTIES: COMPRESSION TEST Deformation versus time



# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>13</sub>

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## Safety and vulnerability tests:

- Impact sensitivity (BAM) according to STANAG 4489C.
- Friction sensitivity (BAM) according to STANAG 4487A.
- Shock sensitivity (Intermediate Scale Gap Test) according to STANAG 4488B.
- Friability test according to AOP 7 (201.08.004) or UN 7c)ii).
- Combustion under high pressure: this test allows determining the pressure frontier between the layer by layer combustion propagation and cracking combustion which can outcome any deflagration-to-detonation transition. This frontier is called Break Pressure. It is performed in a closed vessel with a static resistance to rupture of 1000 MPa.
- 12.7 mm bullet impact in vehicle according to AOP 7 (201.05.002).

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>14</sub>

## Safety and vulnerability tests:

| Duration (years)<br>at 20°C | Friability<br>(dP/dt)max | Combustion under<br>high pressure | Bullet impact<br>(V = 850 m/s) |
|-----------------------------|--------------------------|-----------------------------------|--------------------------------|
| 0                           | 5                        | No pressure break                 | Pneumatic explosion            |
| 1                           | 6.5                      | No pressure break                 | Pneumatic explosion            |
| 5                           | 7.3                      | No pressure break                 | Pneumatic explosion            |
| 11                          | 7.3                      | No pressure break                 | Pneumatic explosion            |

***ORA 86 B : Effects on the friability, combustion and bullet impact tests***

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>15</sub>

## Safety and vulnerability tests:

| Time (years)   |             | 0   | 0.5 | 1    | 2   | 3   | 6    | 11   |
|--|-------------|-----|-----|------|-----|-----|------|------|
| <b>HBu88A</b>  | <b>20°C</b> | 17  |     | 30   |     | 23  | 25.3 | 33.5 |
| <b>B2188A</b>  |             | 18  |     | 22.5 |     | 22  | 23.1 | 20.0 |
| <b>B2211D</b>  |             | 3.8 |     | 4.0  |     |     | 4.2  |      |
| <b>B2238</b>   |             | 2.5 |     | 3.2  |     | 3.8 | 3.6  |      |
| <b>B2245</b>   |             | 3.6 |     |      |     |     | 2.1  |      |
| <b>B2245</b>   | <b>60°C</b> | 3.6 | 4.0 |      | 3.7 |     |      |      |
| <b>Effects on friability test: <math>dP/dt_{max}</math> (MPa/ms)</b> |             |     |     |      |     |     |      |      |

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>16</sub>

## Safety and vulnerability tests:

| Time (years)                         |             | 0                   | 1                   | 2                   | 6                    | 11                  |
|--------------------------------------|-------------|---------------------|---------------------|---------------------|----------------------|---------------------|
| <b>HBu88A</b>                        | <b>20°C</b> | Pneumatic explosion | Pneumatic explosion |                     | Pneumatic explosion  |                     |
| <b>B2188A</b>                        |             | No reaction         | Pneumatic explosion |                     | Deflagration         | Pneumatic explosion |
| <b>B2211D</b>                        |             | Pneumatic explosion | Pneumatic explosion |                     | Pneumatic explosion. |                     |
| <b>B2238</b>                         |             | Pneumatic explosion | Pneumatic explosion |                     | Pneumatic explosion  |                     |
| <b>B2245</b>                         | <b>60°C</b> | Pneumatic explosion |                     | Pneumatic explosion |                      |                     |
| <b>Effects on bullet impact test</b> |             |                     |                     |                     |                      |                     |

# PROPERTIES STUDIES OF AGEING CAST CURED PBX<sub>17</sub>

## Experimental Characterizations:

| Time (years)   |             | 0        | 1        | 2        | 6        | 11       |
|--|-------------|----------|----------|----------|----------|----------|
| <b>HBu88B</b>  | <b>20°C</b> | No break | No break |          | No break | No break |
| <b>B2188A</b>  |             | 420      | 405      |          | 320      | 460      |
| <b>B2211D</b>  |             | No break | No break |          | No break |          |
| <b>B2238</b>   |             | No break | No break |          | No break |          |
| <b>B2245</b>   | <b>60°C</b> | No break |          | No break |          |          |
| <b>Effects on combustion under high pressure (MPa)</b> |             |          |          |          |          |          |

# CONCLUSIONS

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- This paper presents many experimental results concerning the industrial Cast Cured PBX compositions.
- The compositions filled with RDX, HMX, HMX/NTO and HMX/PETN do not show significant variations of their mechanical properties during the ageing.
- The compositions filled with RDX/AP/Al and RDX/NTO/AP/Al present slight variations of mechanical properties, hardening or softening, which induce no evolution of the safety and Bullet Impact test results.
- This family of explosive compositions is particularly stable in the time and in temperature.
- Moreover, this paper presents methodologies allowing to predict munitions responses to each vulnerability trial taking into account the life cycles.