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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE

Toulouse Aeronautical Test Centre (CEAT)

« Fire Safety Department »

FIRE BEHAVIOUR OF MAGNESIUM ALLOYS

DGA

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Synthesis of works performed at CEAT for aircraft suppliers

- EADS / Innovation Works
- Grupo Antolin
- MERIDIAN
- Sicma Aero Seat
- …

The tests were performed on :

➔ 8 alloys (with or without protection layer)

The specimens were exposed to 1 or several of the following fire sources :

- **Bunsen burner flame :**
  - **843 °C during 15 / 30 / 60s (45°, horizontal and vertical test conditions)**
- **Radiant furnaces with or without flame :**
  - **2.5 w/cm² / 4 mn (smoke & toxicity test conditions (NBS))**
  - **3.5 w/cm² / 5 mn (heat release test (OSU))**
- **Oil burner :**
  - **11.9 w/cm² / 3 or 5mn (seat cushion test conditions with an extended test duration)**
    - **small test samples & real seat with Mg structural parts**

EADS-IW

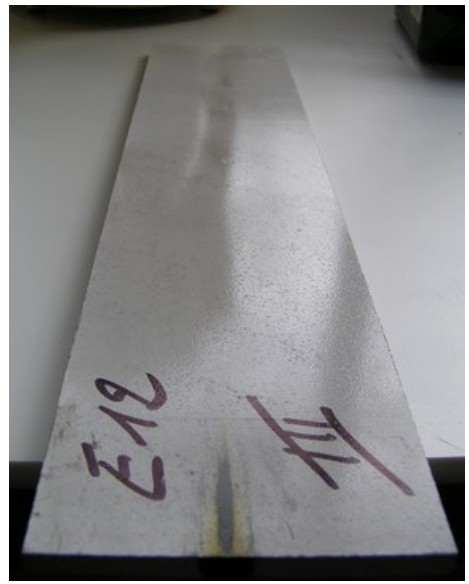
Bunsen burner test results :
Test on WE43 & Elektron 21T6

Test conditions :
- **843 °C during 15 / 30 / 60s**
- **(45°, horizontal and vertical test conditions)**

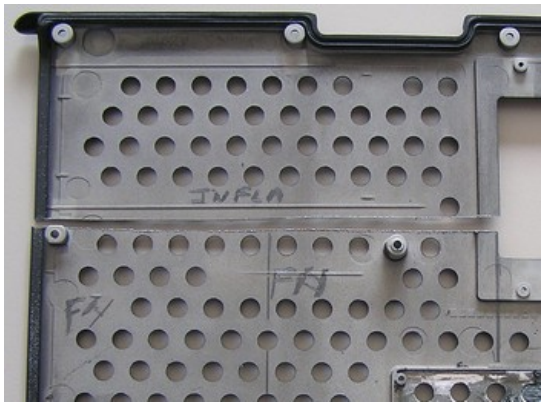
- with surface protection
- without any protection

2 thicknesses have been tested :
- **2 mm**
- **6 mm**

All test conditions :
- No ignition
- small burn length on protection layer



Bunsen burner test results : Test on laptop specimens

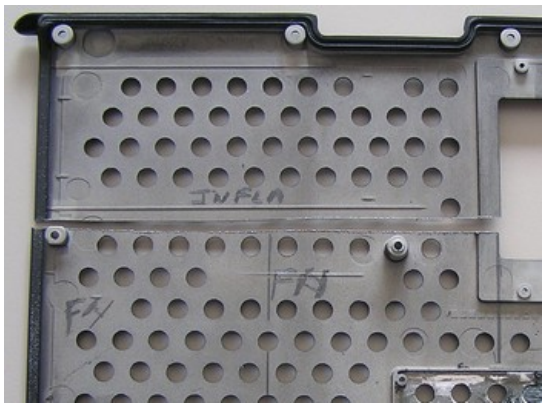


Test conditions :
- o **843 °C during 60s (vertical test conditions)**

various thicknesses :
- o **1.2 mm to 3.8 mm**

No ignition

Smoke Test Chamber (NBS) : Test on laptop specimens



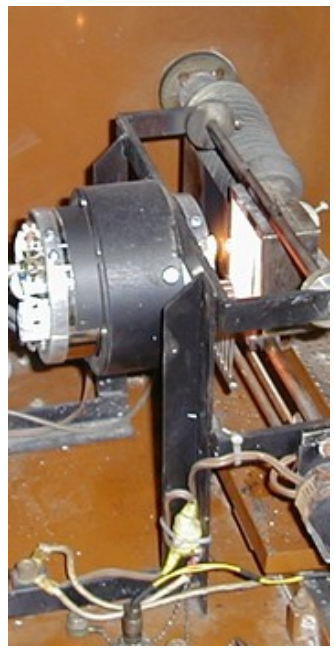
Test conditions :

- **Radiant heat flux : 2.5 w/cm² / 4 mn**
- **flaming / non flaming mode**

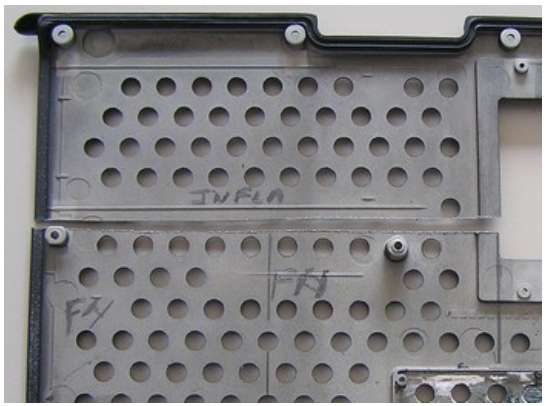
various thicknesses :

- **1.2 mm to 3.8 mm**

No ignition



Heat Release Test Chamber (OSU) : Test on laptop specimens



Test conditions :

- **radiant heat flux : 3.5 w/cm² / 5 mn**

various thicknesses :

- **1.2 mm to 3.8 mm**

No ignition

Grupo Antolin

Heat Release Test Chamber (OSU) : Test on AZ91 Test samples (with black paint)

Test conditions :

- **radiant heat flux : 3.5 w/cm² / 5 mn**

various thicknesses :

- **0.9 mm**
- **2 mm**
- **2.9 mm**

- No ignition on 2 mm and 2.9 mm test samples
- **IGNITION on 0.9 mm test sample**

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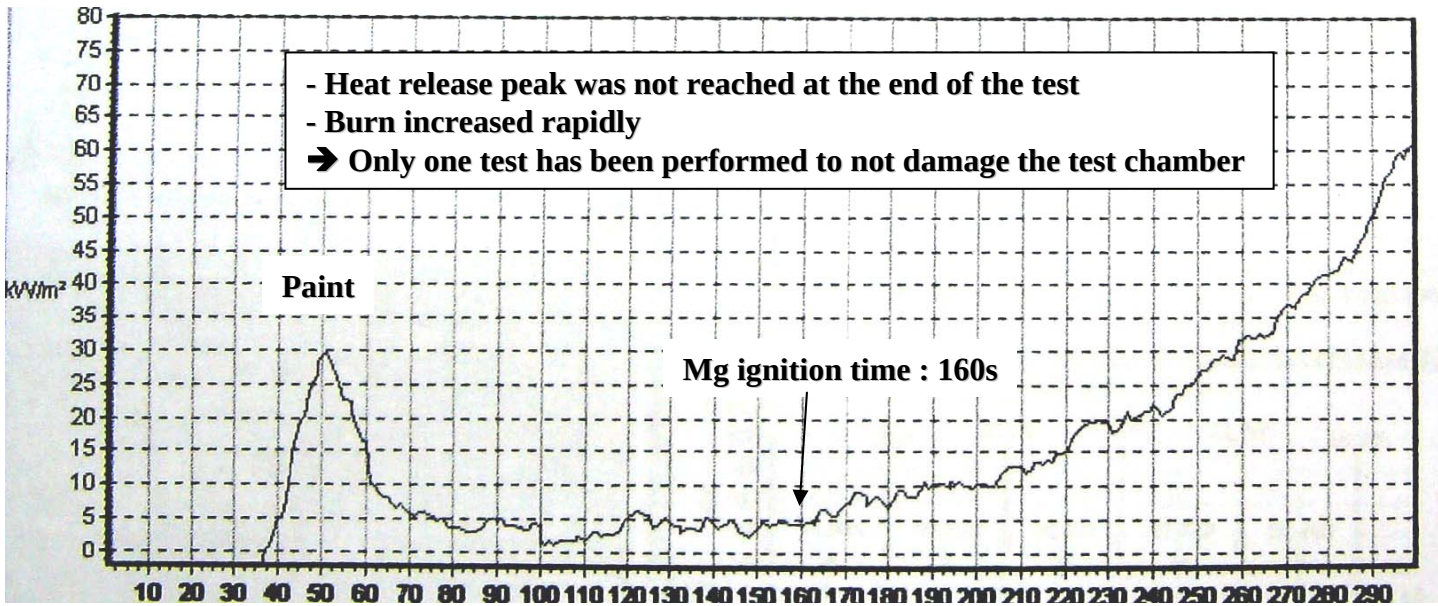
Heat Release Test Chamber (OSU) : Test on AZ91 Test samples (with black paint)

Heat Release Rate

- **thickness : 0.9 mm**



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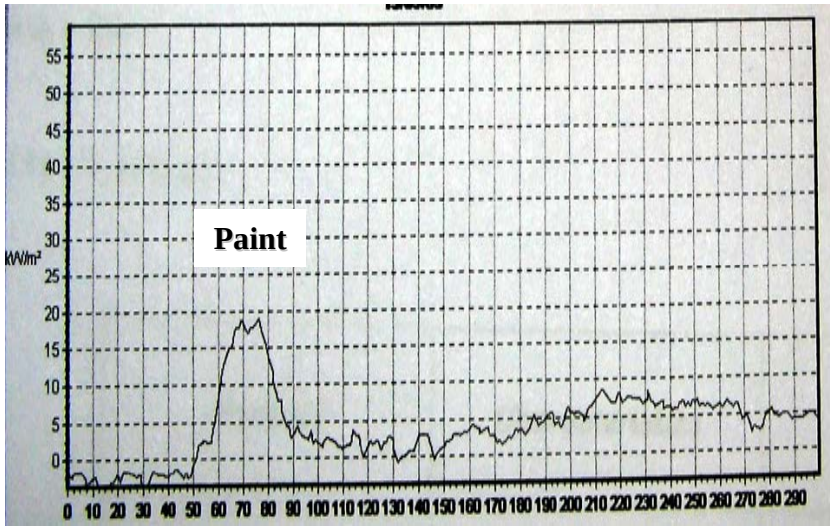
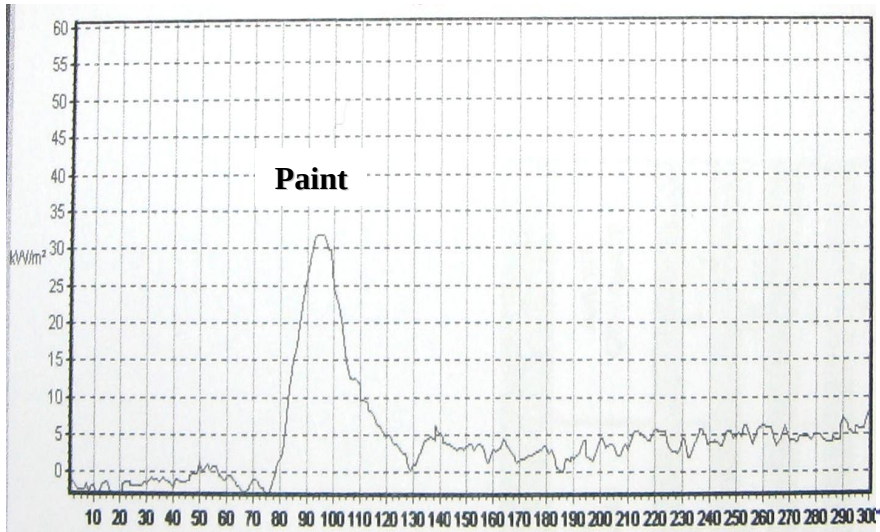
Heat Release Test Chamber (OSU) : Test on AZ91 Test samples (with black paint)



Heat Release Rate

- **thicknesses : 2 mm and 2.9 mm**



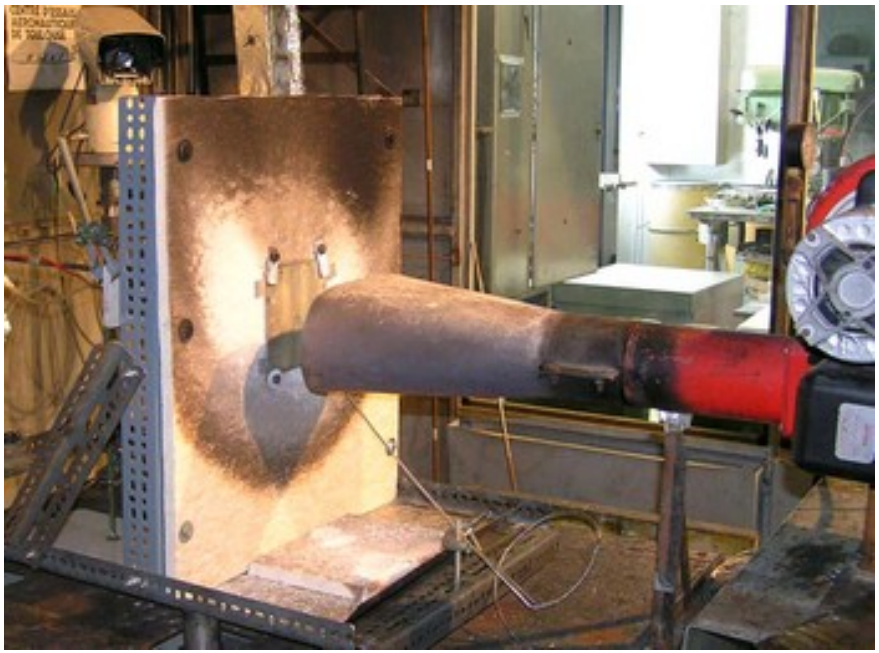
- **Peak of Heat Release (paint)**
- **no ignition of Mg**

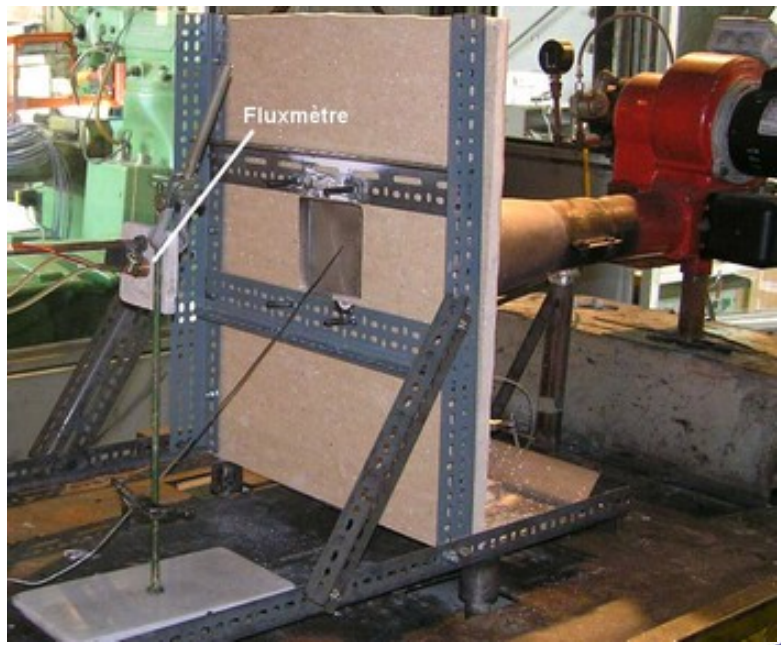
Sicma Aero Seat / EADS-IW / MERIDIAN

Oil Burner Tests

Small scale tests

- Test specimens : 150 mm x 150 mm
- 11.9 w/cm² / 5mn (intentionally extended flame time to assess the behaviour of the test sample over the exposure flame time of the seat cushion test (2mn)





- Heat Flux was recorded on the rear side
- T° on the front and rear sides

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Oil Burner Tests

Small scale test

- size of the test samples : 150 x 150 mm
- 3 different alloys
- with / without intumescent paint
- thicknesses : 3 and 6 mm

TEST RESULTS

		Thickness	1rst ignition spots	Melting time
Mg alloy 1	/	3 mm	110 s	120 s
Mg alloy 2	/	3 mm	140 s	145 s
Mg alloy 2	Intumescent paint	3 mm	140 s	140 s
Mg alloy 2	Intumescent paint	6 mm	180 s	200 s
Mg alloy 3	/	3 mm	125 s	130 s
Mg alloy 3	Intumescent paint	3 mm	100 s	150 s

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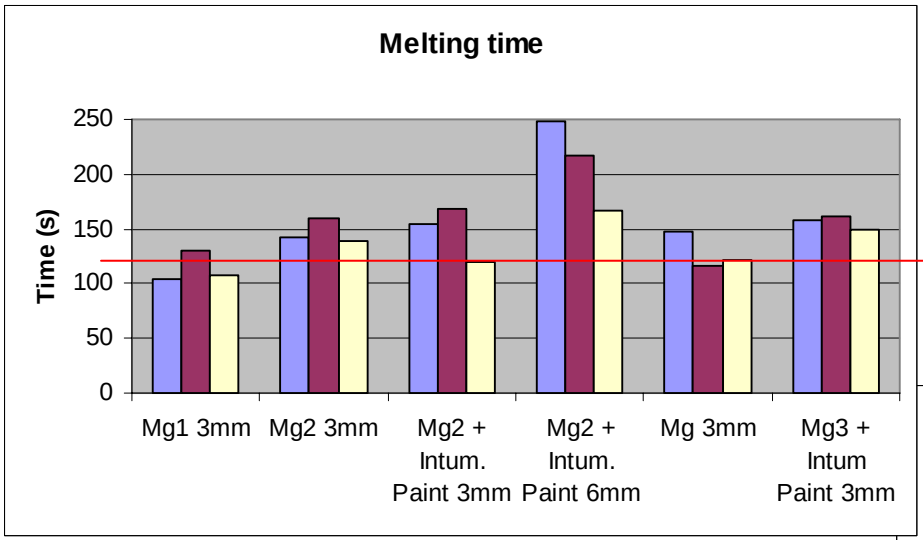
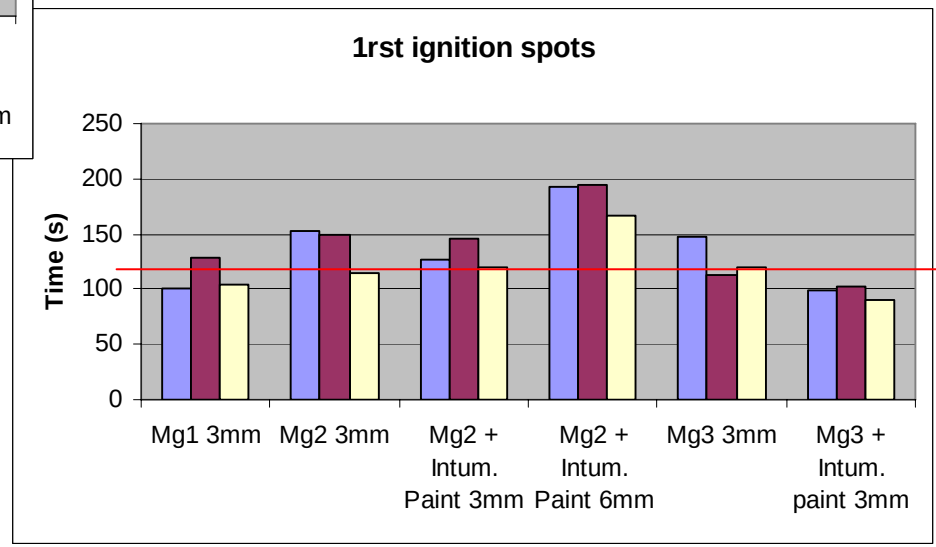


Seat cushion test flame time



- **First ignition spots are close to the flame time of the seat cushion test (2 mn)**
- **No significant effect of the intumescent paint**
- **Effect of the thickness**

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Oil Burner Tests

Small scale test

- All alloys (with or without intumescent paint) have shown a similar behaviour with an intense fire and showing sometimes sparking out

Video

Video paint

- In most cases, after a flame exposure of 5 mn, the sample burn completely until there is nothing left to burn.
- Generally, after the burner is turned off, the burn rapidly increase to an intense fire due to the O_2 contribution

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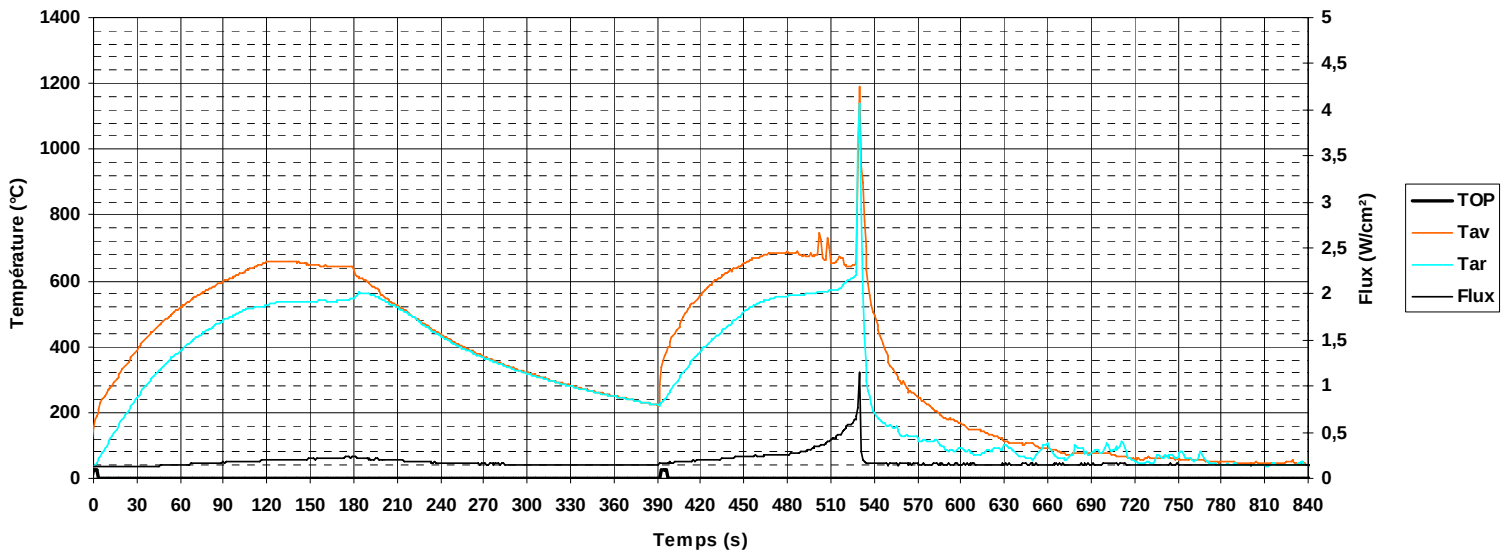
Oil Burner Tests

Small scale test

Some tests were interrupted 30s after the first ignition spots to evaluate the evolution of the burn after these first ignitions :

- **Generally in that case, the fire do not progress**
- **When the ignition spots are well ignited, after the burner is turned off, the fire rapidly growth due to O2 contribution, the fire is intense and self-sustaining**



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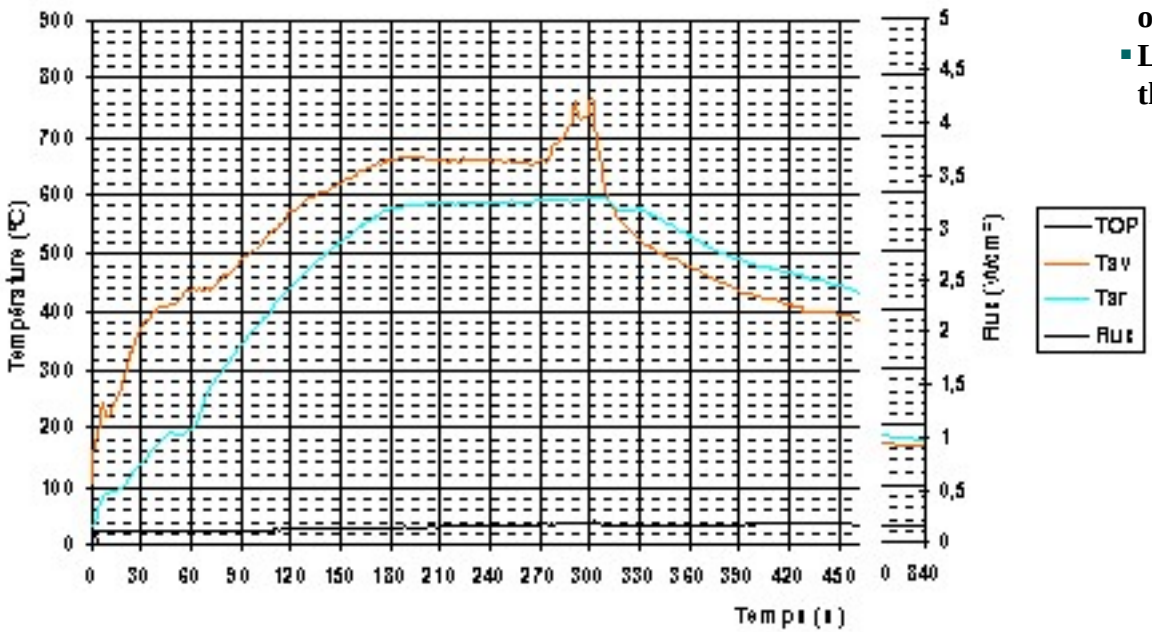
Oil Burner Tests

Small scale test

HEAT FLUX & T° MEASUREMENTS

- **No sign of ignition neither on T° recordings nor on Heat Flux recording**
- **Low level of Heat Flux on the rear side (less than 0,2 W/cm²**



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Oil Burner Tests

Small scale test

LOW LEVEL OF HEAT RELEASE

The low level of heat release has been confirmed by measuring the heat flux of the melted magnesium, burning at the bottom of the test apparatus.

- **Maximum Heat Flux at 30 cm : 0.85 W/cm2**

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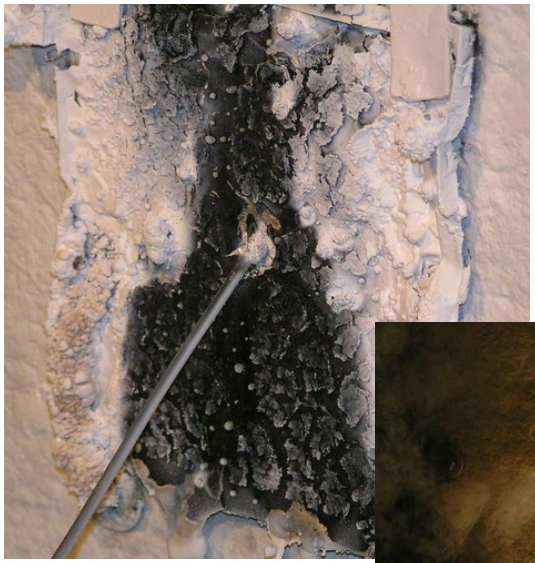
Oil Burner Tests

Small scale test



INTUMESCENT PAINTS

- **Ignition time : no significant effect of the intumescent paint**
- **The Mg melts, slips out of the intumescent paint and burns at the bottom of the test apparatus**

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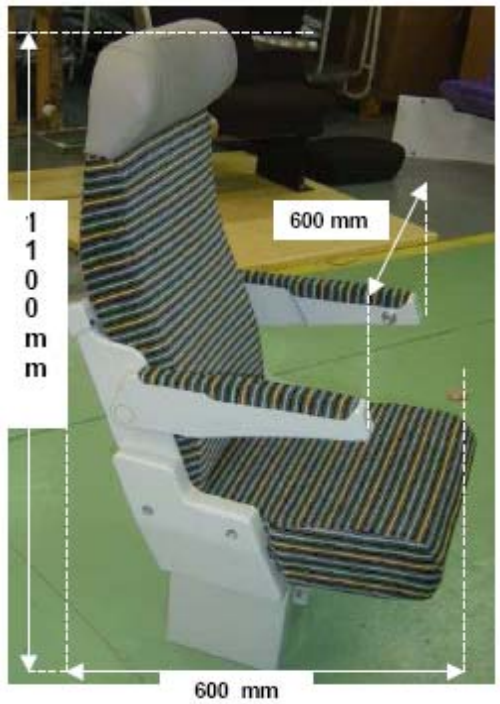
Oil Burner Tests

Real scale seat test

TGV seat
(French High Speed Train)

- **Test configuration : Aircraft Seat Cushion Test**
- **11.9 w/cm² / 3 mn (intentionally extended flame time to assess the behaviour of the seat beyond the requirement for the seat cushion test (2mn)**



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Oil Burner Tests

Real scale seat test

- Almost all visible metallic parts were in Mg alloys

Composition of the test specimen

- AZ91 Mg alloy + EPOXY paint 80 µm
- Foam : HEAD PU + Soly't inclusions
- Fireblocking layer : Duflet MLZ 1282 C
- Dress cover : LANTAL wool 90% / PA 10%

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TEST RESULTS

- No visible particular event within the regulatory flame time (2mn)
- 2 mn 42 s : Ignition & melt of Mg
  (➔ same time on small scale tests ➔)
- 3 mn : End of flame exposure
- Combustion of Mg
- 4 mn : Extinction by fireman (ABC powder)

Video

Grupo Antolin

Oil Burner Tests

Real scale seat test

SEAT AFTER TEST

- **No fire propagation on Mg outside of the flame impingement**

Conclusions

Magnesium Flammability

- **IGNITION under the Seat Cushion Test conditions (with an extended flame time) (11.9 w/cm²)**
- **IGNITION** (thickness < 0.9 mm) **under the Heat Release Test conditions (OSU) (3.5 w/cm² // 5 mn)**
  (no ignition for thicknesses > 1.2mm)
- **No Ignition** (thicknesses > 1.2mm) **under the Smoke Test conditions (NBS) (2.5 w/cm² // 4 mn)**
- **No Ignition** (thicknesses > 1.2mm) **under Bunsen Burner Test conditions**

Conclusions

Magnesium alloys = Factor of risk ?

- The ignition of Mg alloys occurs when the T° of the test sample is close to the melting point (600°C)
- Magnesium is a good conductor of heat
- And following the test conditions which led to ignition *(see previous slide)*

➢ Except for thin parts (thickness to be determined), it is probably necessary that the whole part must be brought to the melting T° before the ignition will occur and will become self sustaining.

➢ **In-flight fire : except in case of Hidden Fire, the usage of magnesium alloys inside cabin is probably not a factor of risk**

➢ **Post-crash fire : a massive usage of magnesium alloys could be a factor of risk for passengers (ignition time is close to the flame time of the seat cushion test)**

Conclusions

- **These test results are the result of separated studies or tests. The materials, thicknesses, surface protections and test programs were different and non-connected.**

  ➔ These conclusions only shows a tendency. The results must be confirmed.

  ➔ Full scale test should be necessary to assess the behaviour of Mg alloys under real fire conditions in case of massive usage inside cabin (effect of the surrounding temperature)

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