Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

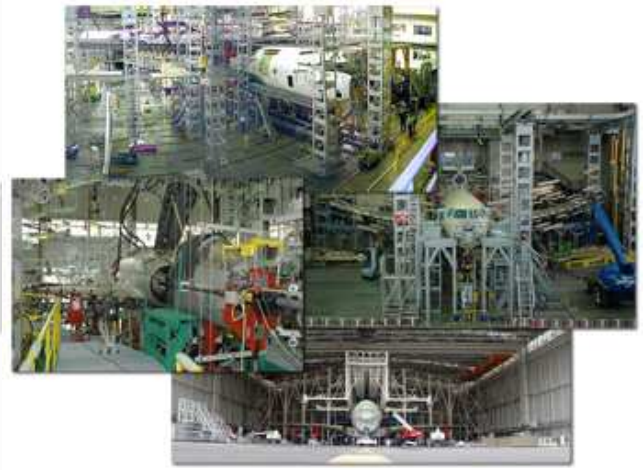
MINISTÈRE DE LA DÉFENSE

DGA Aeronautical Systems

(ex. CEAT)

« Fire Safety Department »

Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire Source



DGA

Serge LE NEVE
E-mail : Serge.le-neve@dga.defense.gouv.fr

- **Objectives of the works**
- **Propane Hidden Fire Source**
  - **First test results & next works**
- **Radiant Heat Source**
  - **First test results & next works**
- **Underload Fire Behaviour**
  - **4-point-bending test method**

➔ Study's Aim

➔ To check the ability of structural composite materials to keep their integrity when they are submitted to a hidden fire source

AC 20-107 (Composite Aircraft Structure) :
- § 11.b : « …The exposure of composite structures to high temperatures needs to extend beyond the direct flammability and fire protection issues to other thermal issues … »

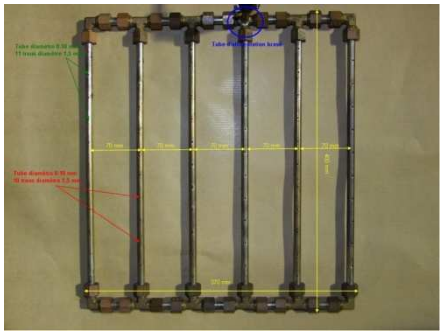
➔ 3 different damaging sources will be used :

- **Propane fire source**
- **Radiant heat source**
- **Electric Arc source** ***(test method to be define)***

Note : The main goal of the study is more to assess the mechanical behaviour of the structural composite materials than to assess their flammability behaviour.

Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

PROPANE FIRE SOURCE



A propane fire source has been designed on the basis of the FAA foam block fire source characteristics, assuming that these characteristics are representative of a declared hidden fire :

- **The Heat Flux Density & T° are similar to the flame characteristics produced by the FAA foam block**
- **The Flame size is wider to produce an homogeneous damaged area compatible with the mechanical test specimens to be removed (area ~ 150 mm X 300 mm)**

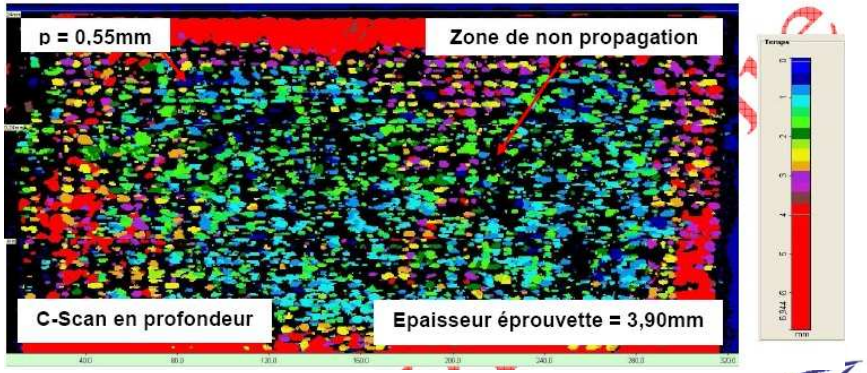
Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

PROPANE FIRE SOURCE

Foam Block Fire :
- **Time of exposure : complete burning (but the major part of the damages are produced during the 1st stage of fire (1mn)**
- **Distance burner / test sample : 3 inches**

- **Very good homogeneity**
- **Very good agreement of the damages**

Equivalent Scenario :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**



NDI of the damages

PROPANE FIRE SOURCE

FIRE TESTS

BASELINE TEST (representative of the foam block fire scenario) :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**

Test on :

T300 / 914 Carbon / Epoxy	**16 plies / 2,4 mm**
T800H / DA508 Carbon / Epoxy	**16 plies / 2,4 mm**
T800H / 5245 Carbon / Epoxy-Cyanate-Bismaleimid	**16 plies / 3 mm**
Aluminium 2024	**1,6 mm**

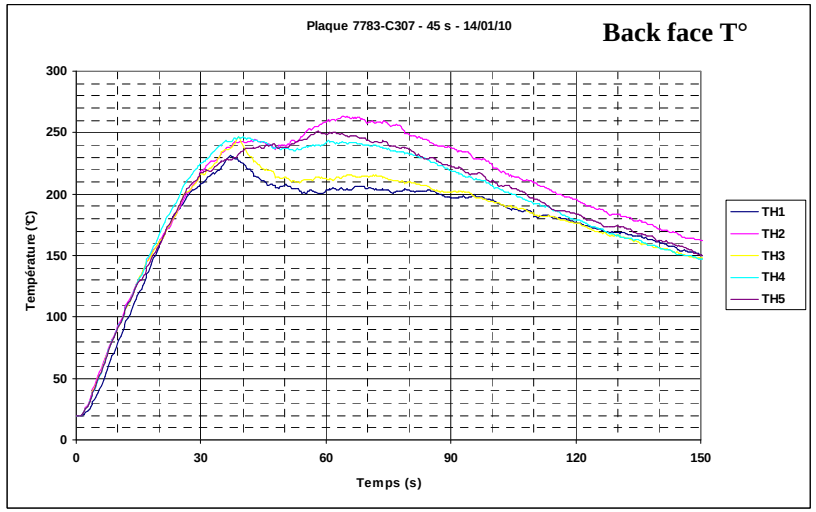
Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

PROPANE FIRE SOURCE

FIRE TESTS

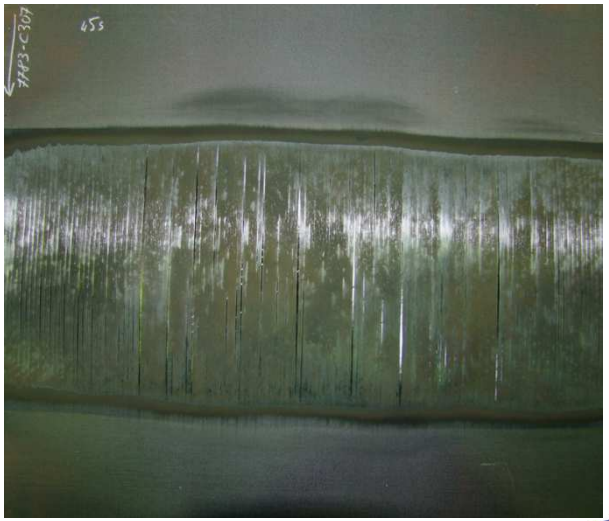
BASELINE TEST (representative of the foam block fire scenario) :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**

- **T300 / 914 Carbon / Epoxy 16 plies / 2.4 mm**



2.4 mm Totally delaminated

➔ ***No mechanical test***

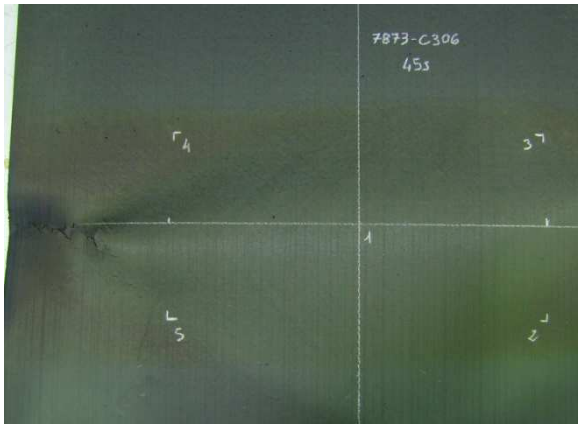


PROPANE FIRE SOURCE

FIRE TESTS

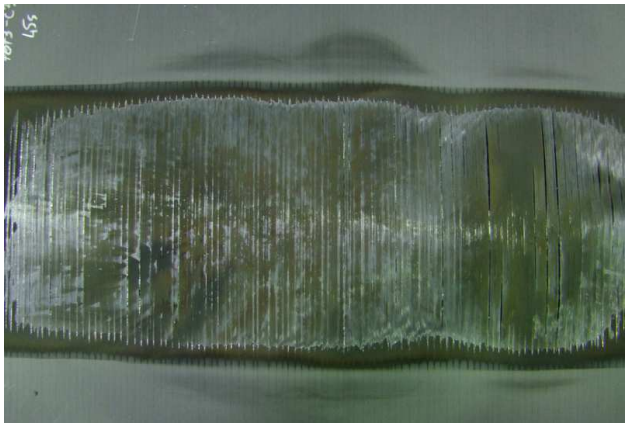
BASELINE TEST (representative of the foam block fire scenario) :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**

- **T800H / DA508 Carbon / Epoxy 16 plies / 2.4 mm**



2.4mm Totally delaminated

➔ *No mechanical test*



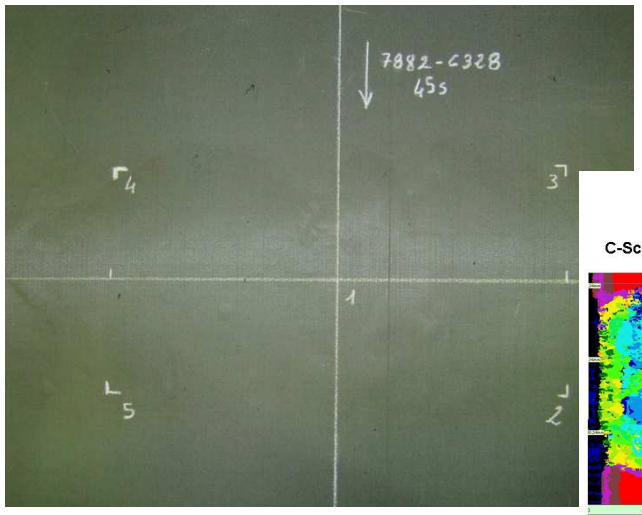
Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

PROPANE FIRE SOURCE

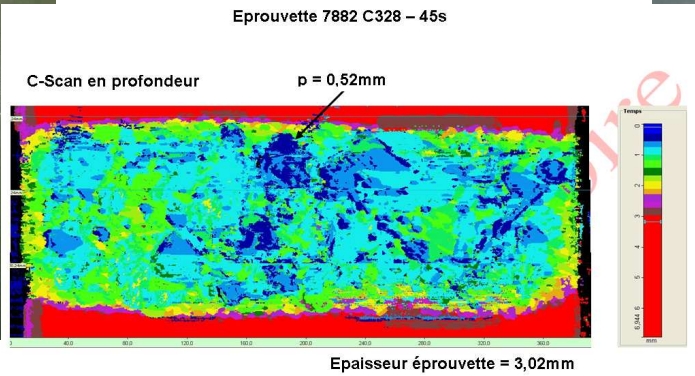
FIRE TESTS

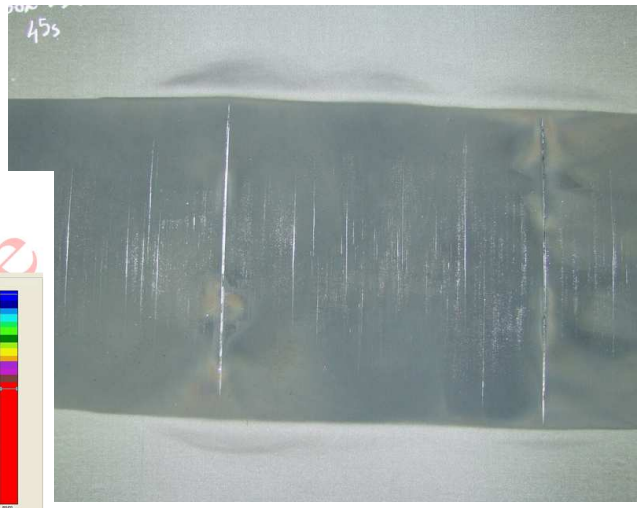
BASELINE TEST (representative of the foam block fire scenario) :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**

- **T800H / 5245 Carbon / Epoxy-Cyanate-Bismaleimid 16 plies / 3 mm**



80% delaminated
Better but Thicker





PROPANE FIRE SOURCE

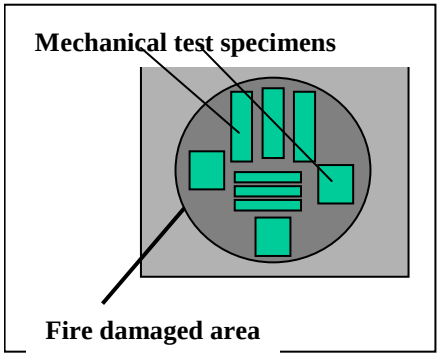
FIRST TEST RESULTS

BASELINE TEST (representative of the foam block fire scenario) :
- **Time of exposure : 45 s**
- **Distance burner / test sample : 6 inches**

➢ **The mechanical test results shown that :**

Under the baseline test conditions (representative of the foam block fire scenario used for the ignition time on the intermediate scale hidden fire test):

✓ **A 16 plies composite material representative to a fuselage skin is at least 80% delaminated**



T300 / 914 Carbon / Epoxy	2.4 mm (16 plies)	Totally delaminated
T800H / DA508 Carbon / Epoxy	2.4 mm (16 plies)	Totally delaminated
T800H / 5245 Epoxy-Cyanate-Bismaleimid	3 mm (16 plies)	80% delaminated

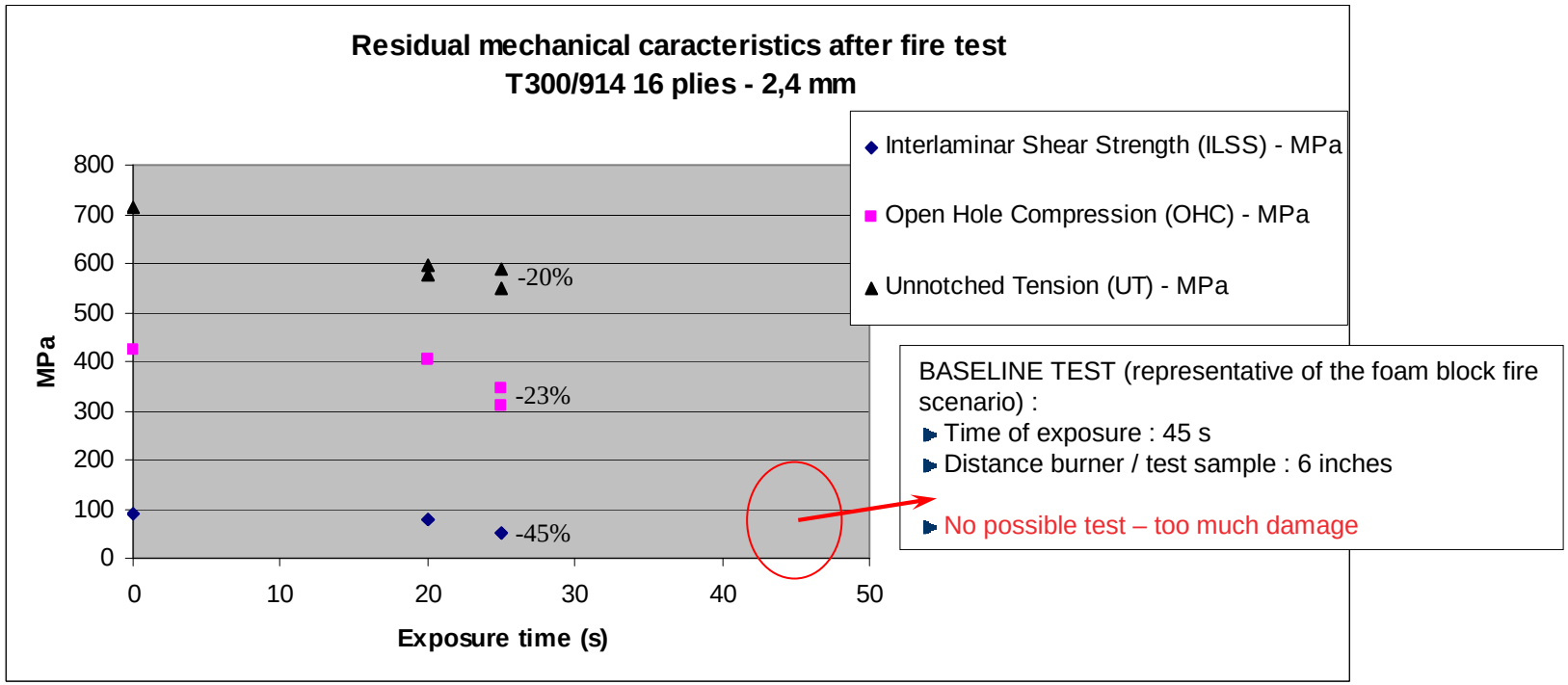
➔ **These test conditions are too severe to make a study on the mechanical behaviour of the composite materials used for fuselage applications**

Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

PROPANE FIRE SOURCE

2 other scenarios were tested with a reduced time of exposure

FIRST TEST RESULTS



BASELINE TEST (representative of the foam block fire scenario) :
- Time of exposure : 45 s
- Distance burner / test sample : 6 inches

- No possible test – too much damage

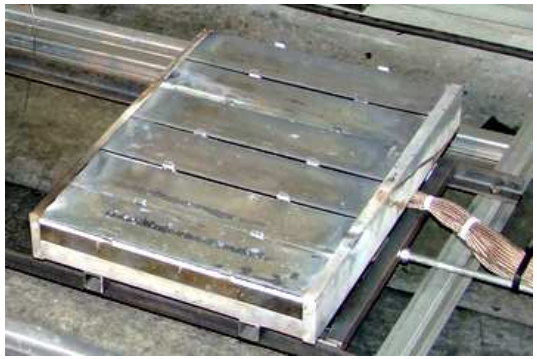
PROPANE FIRE SOURCE

- **The next step will be to determine less severe scenarios which will be able to discriminate and classify the composite materials :**

  - ✓ **By reducing the gas flow-rate**

  - ✓ **without reducing the baseline time of exposure which is already very short (45s)**

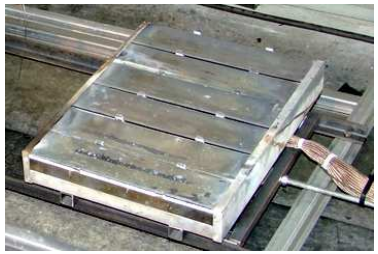
RADIANT HEAT SOURCE



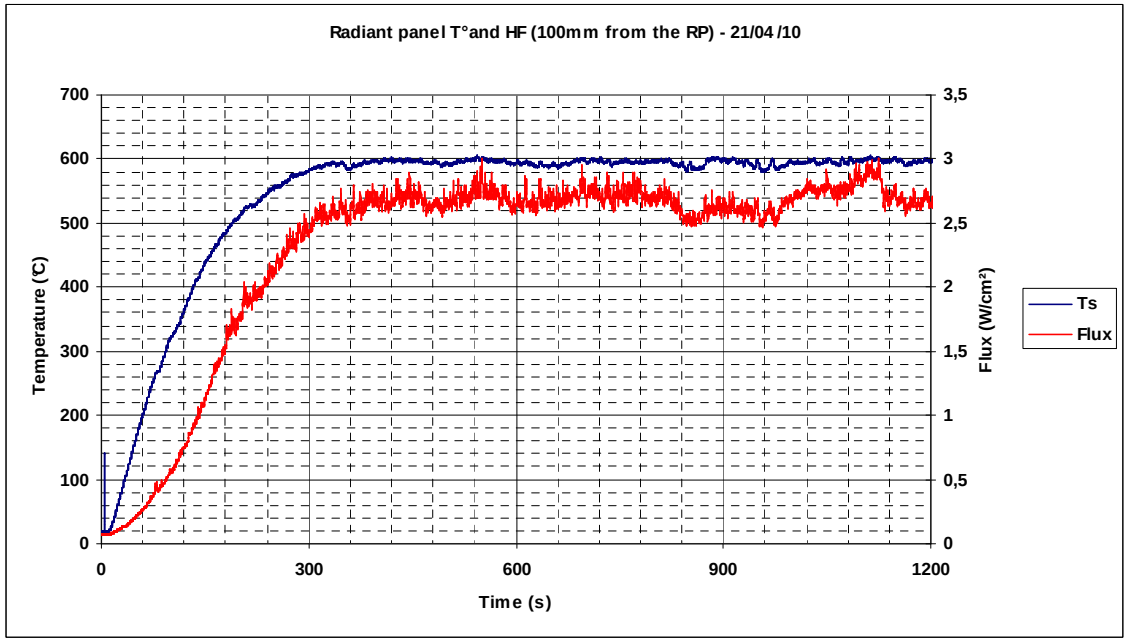
We have designed a damaging test rig using a radiant panel :

- **The composite test sample is 10 cm above the horizontal radiant panel**

RADIANT HEAT SOURCE

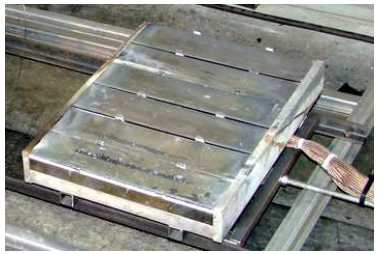


Characterisation of the radiant heat source (d = 10 cm)

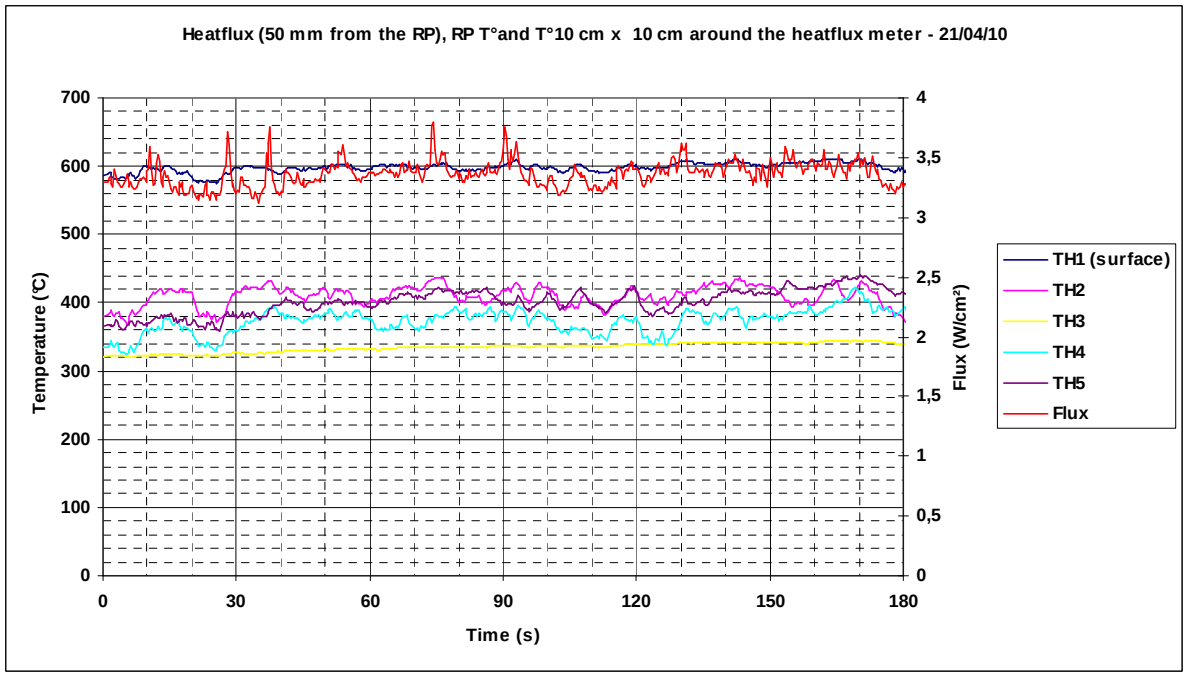


- Radiant Panel setting T°: 600°C
- Heat Flux : 2.7 W/cm²

RADIANT HEAT SOURCE



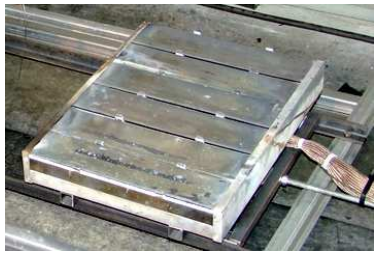
Characterisation of the radiant heat source (d = 5 cm)



- Radiant Panel setting T°: 600°C
- Heat Flux : 3.5 W/cm²

Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

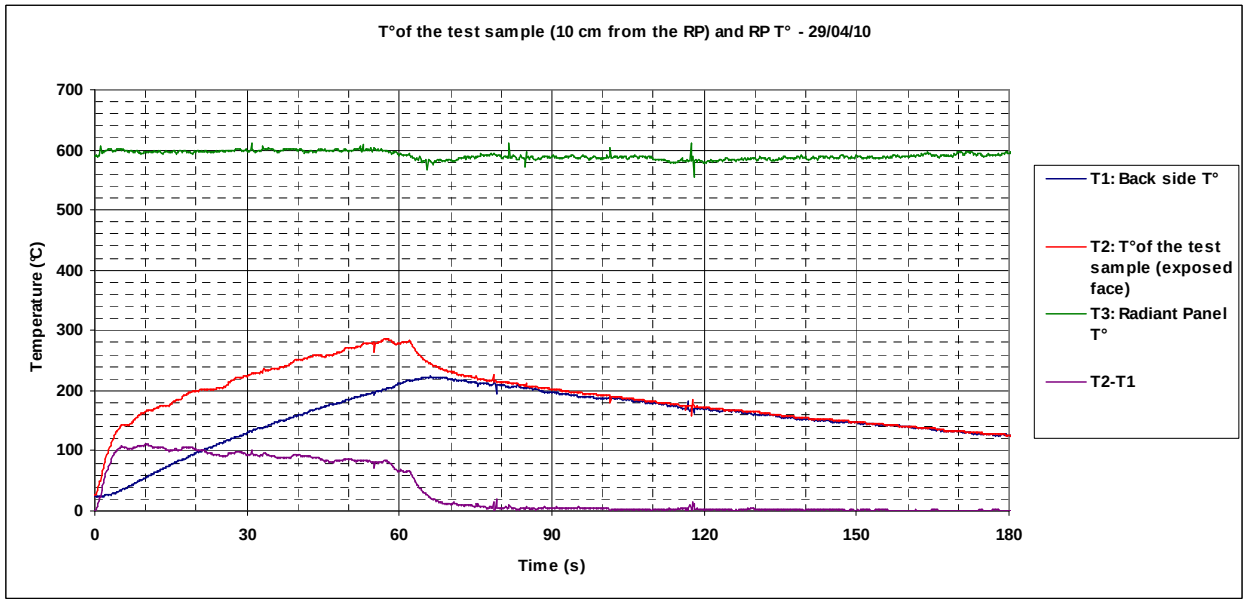
RADIANT HEAT SOURCE

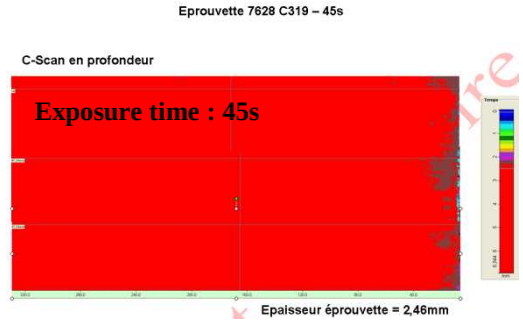


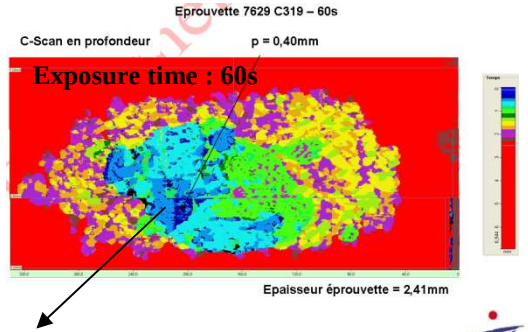
FIRST TEST RESULTS

- **T300 / 914 Carbon / Epoxy 16 plies / 2.4 mm**

The test sample is 10 cm above the Radiant Panel







A maximum of 80% of the thickness is delaminated after 1 mn of exposure

RADIANT HEAT SOURCE

FIRST TEST RESULTS

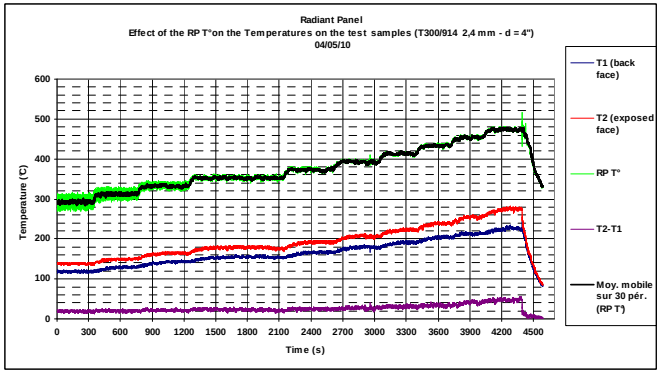
- **The first test results show that :**

Under exposure conditions (1mn under 2.7 W/cm²) **less severe than the conditions used for the Radiant Panel Test for electrical wiring** (1mn under ~3 W/cm²)**:**

✓ **A 16 plies composite material representative of a fuselage skin is 80% delaminated**

➔ **These test conditions are too severe to make a study on the mechanical behaviour of the composite materials used for fuselage applications**

RADIANT HEAT SOURCE



- **The next step was to find the setting T° of the radi ant panel which generates surface temperatures of the composite material close to the resin glass transition T° (190 / 200°C):**

We found that:

✓ **380°C / 3mn generates a T° of ~_ 200°C on the exposed face (170°C on the opposite face)**

(no visible damages by NDI)

✓ **460°C / 2mn generates a T° of ~_ 255°C on the exposed face (200°C on the opposite face)**

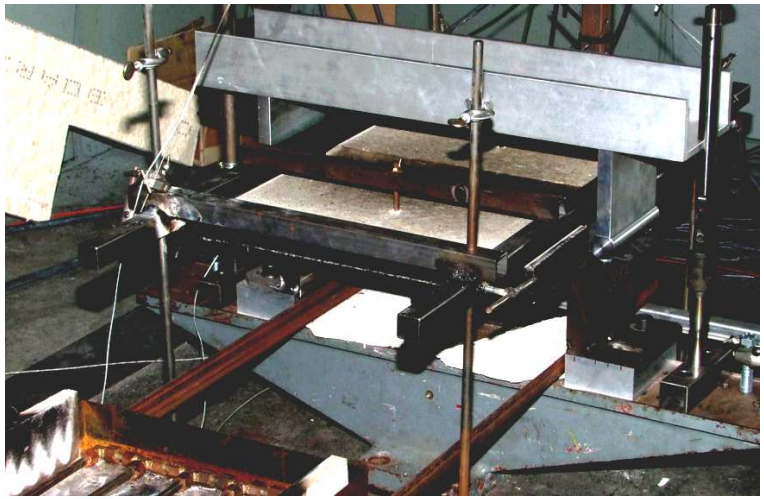
(beginning of the damages visible by NDI)

➔ **We have now to determine the best scenarios of exposure around these settings to compare the residual mechanical properties of various composite materials**

UNDERLOAD FIRE BEHAVIOUR

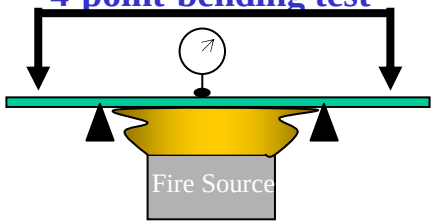
To assess the mechanical behaviour of composite materials during the exposition to a hidden fire :
- We designed a 4-point-bending test rig
- Using the gas fire source or the radiant source
- The load (100 MPa) is representative of the fuselage in-flight stress
- The test sample is 6 inches above the heat source

- Continuous recording of the bending displacement measured at the centre of the test sample



Underload mechanical behaviour

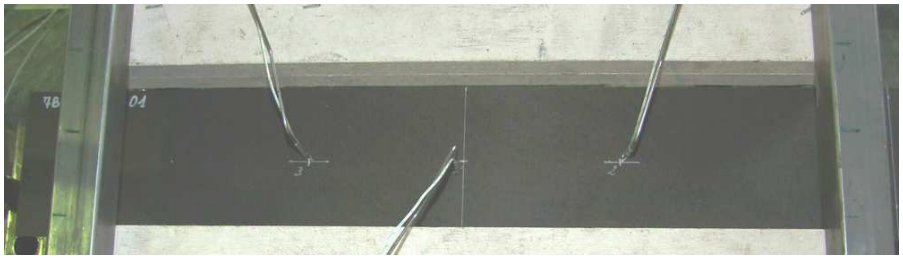
4-point-bending test



Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire

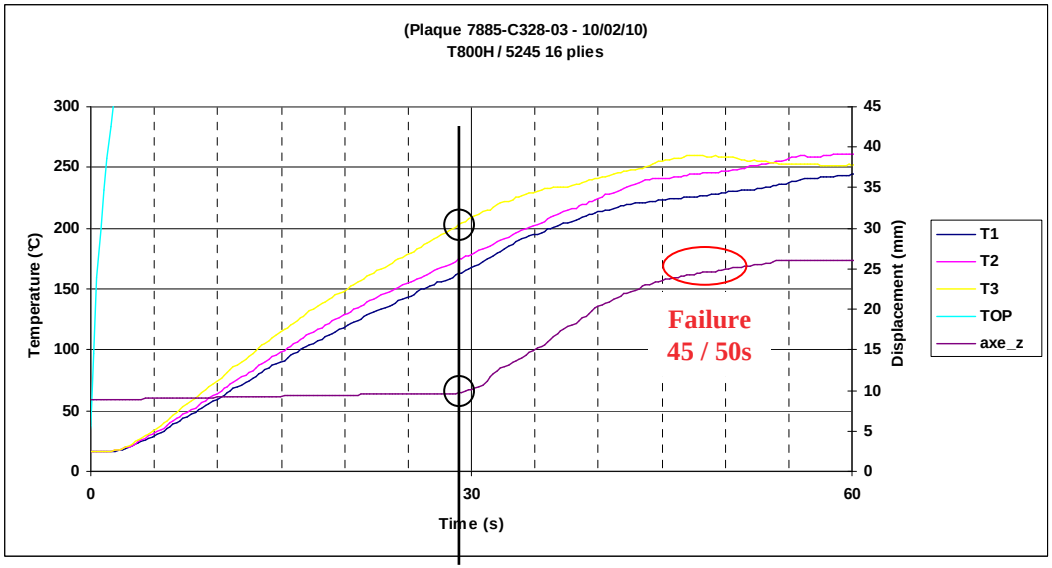
UNDERLOAD FIRE BEHAVIOUR

FIRST TEST RESULTS



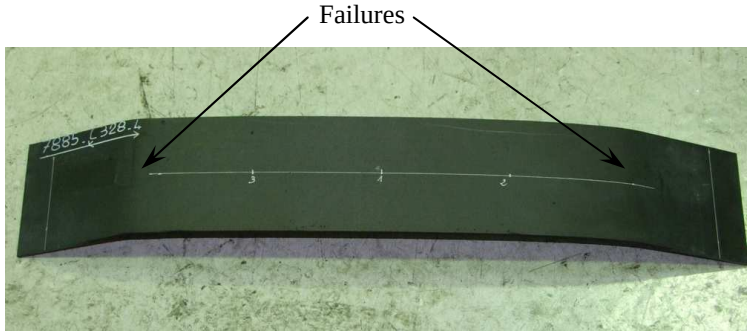
Thermocouples on the back side

- **T300 / 914 Carbon / Epoxy 16 plies / 2.4 mm**



The test sample began to bend after
29s at 200°C max (close to the Glass Transition T°)

Fire source :
Gas fire source (BASELINE setting (representative of the foam block fire scenario)) :
- **Distance burner / test sample : 6 inches**



Test sample after test

CONCLUSIONS

We have designed

- **a propane fire source representative of the FAA foam block fire source used for the ignition of the intermediate scale fire test**

- **a radiant heat source to assess the behaviour of materials submitted to a heat source without flame**

- **a 4-point-bending test rig to assess the underload behaviour of materials submitted to a thermal threat with or without flame**

CONCLUSIONS

- **We thought that the hidden fire source or the heat source used to test the cabin materials would have been a good source for the assessment of the fire and mechanical behaviour of composite materials for fuselage.**
- **We are surprised that these fire sources are too severe, leading to a delamination of (at least) 80% of the thickness (16 plies of carbon-epoxy, 2.4mm, representative of a fuselage skin).**
- **If a fire would propagate with the same characteristics, all the exposed parts of the composite fuselage would lose most of their mechanical properties within less than 1 minute?**
- **Are they realistic scenarios for the assessment of the flammability behaviour (propagation) but not realistic for the assessment of the mechanical behaviour?**
- **Or are they only intended to be representative of a local ignition source but not intended to be representative of a realistic larger in-flight fire?**

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

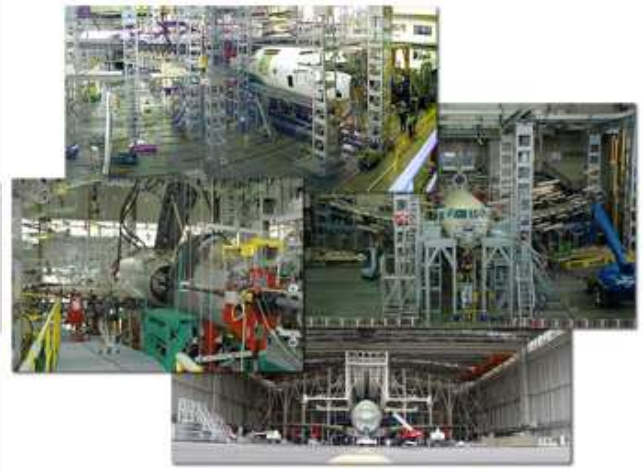
MINISTÈRE DE LA DÉFENSE

DGA Aeronautical Systems

(ex. CEAT)

« Fire Safety Department »

Fire Behaviour of Structural Composite Materials Submitted to a Hidden Fire Source



DGA

Serge LE NEVE

E-mail : Serge.le-neve@dga.defense.gouv.fr