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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE



Toulouse Aeronautical Test Centre (CEAT) « Fire Safety Department »

DEVELOPMENT
OF A REPEATABLE
HIDDEN FIRE SOURCE



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



→ Reminder of the full test program

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

→ Mechanical behaviour of composite materials submitted to a Hidden Fire Source

→ Burnthrough, Smoke & Toxicity of structural composite materials

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

► FULL TEST PROGRAM

► To assess the fire behaviour of structural composite materials faced with the following threats :



In-flight fire

- Hidden fire damaging
- Electric arc effects



Post-crash fire

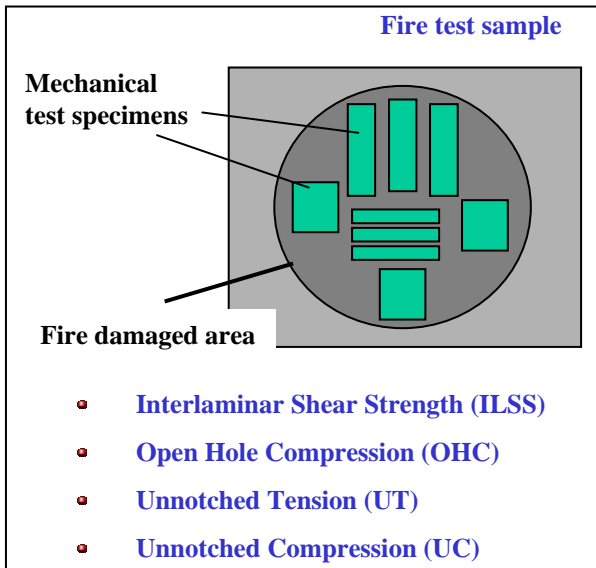
- Burnthrough behaviour
- Environmental effects on cabin side (smoke / toxicity / heat release)



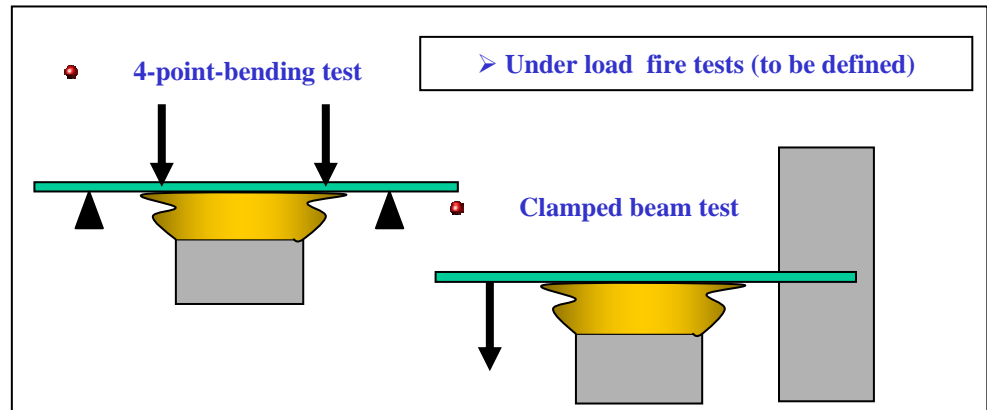
▶ HIDDEN FIRE DAMAGING

- ▶ Assessment of the mechanical behaviour of composite materials submitted to a hidden fire.

▶ Residual mechanical characteristics



▶ Underload mechanical behaviour

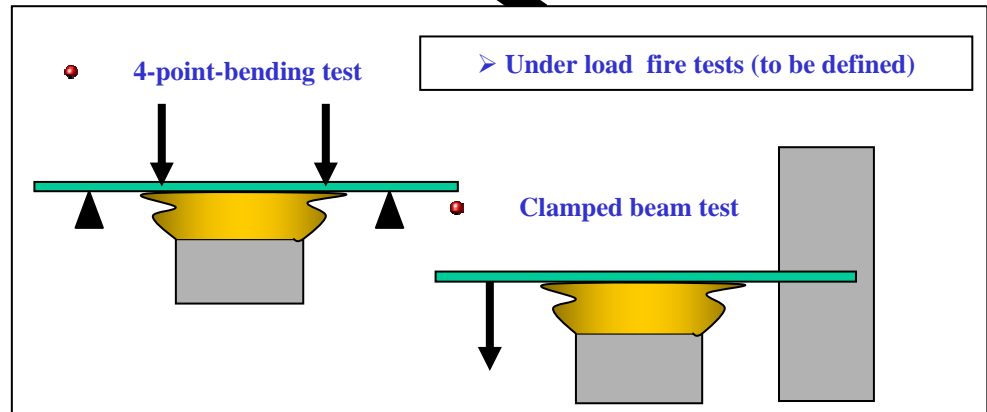
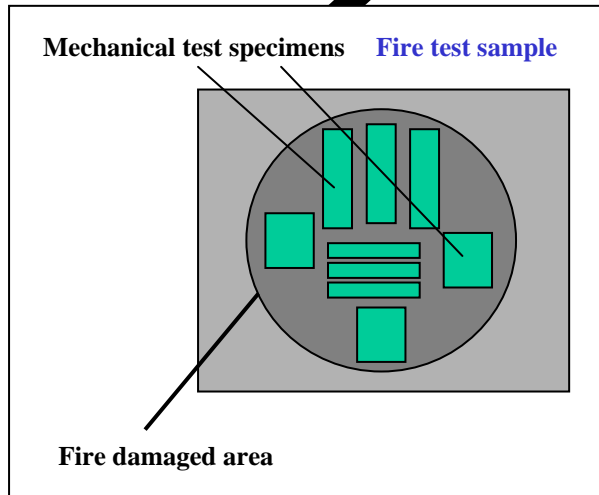




▶ HIDDEN FIRE DAMAGING

▶ We need a repeatable fire source

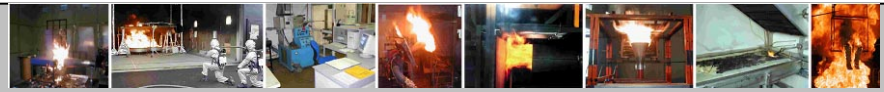
- ▶ To expose a **large surface** of the test samples
- ▶ To submit the materials to various scenarios (**various exposure times**)



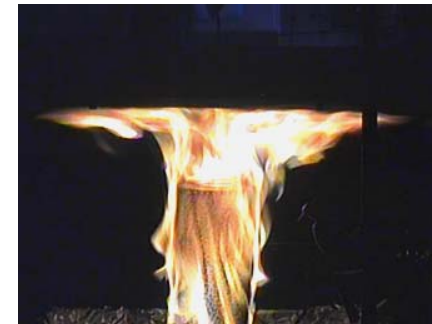
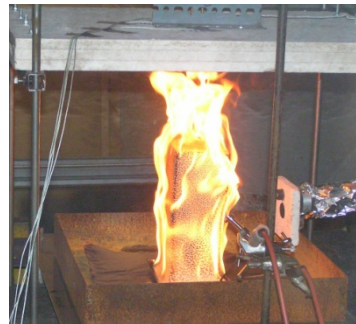


**DEVELOPMENT
OF A REPEATABLE
HIDDEN FIRE SOURCE**





► SPECIFICATIONS



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

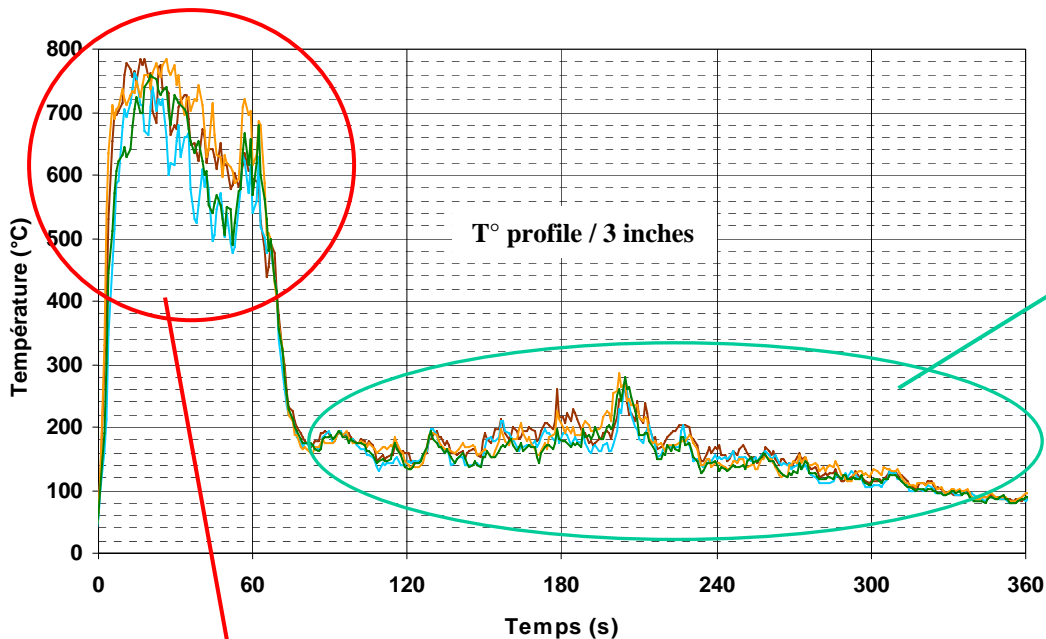
- Heat Flux Density / T° : The flame characteristics must be similar to the flame produced by the FAA foam block
- Flame size : The fire source to be designed must be capable to produce an homogeneous damaged area compatible with the mechanical test specimens to be removed (area $\approx 150 \text{ mm} \times 300 \text{ mm}$)



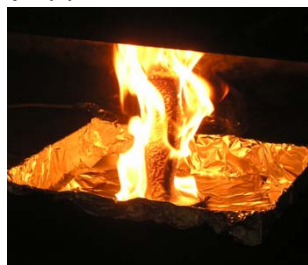
Hidden Fire Source

► Typical flame profile of the foam block fire

T° at 3 inches from the foam top

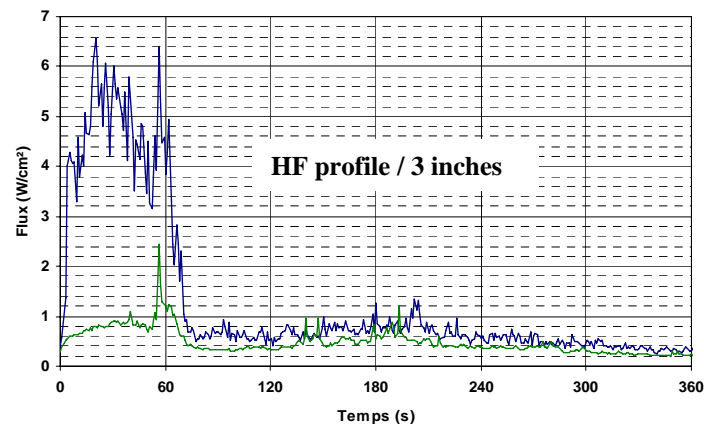


► Active burn time : $\approx 1mn$



- Secondary burn time :
 - the flames do not impinge the test sample
 - the HF is low ($< 1W/cm^2$)

Foam 16kg/m³ + Heptane 10ml - Foam top to HF meter : 3 inches
- 24/06/08

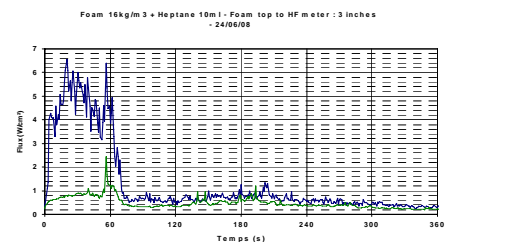
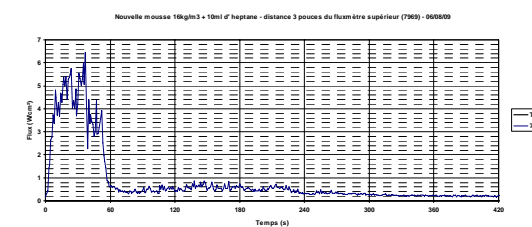
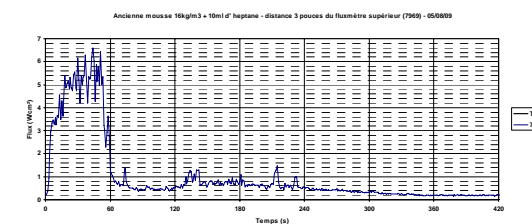
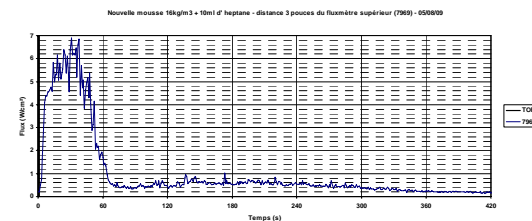
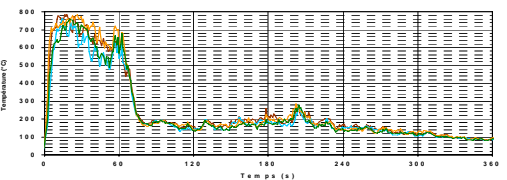
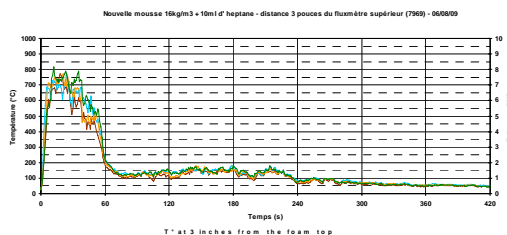
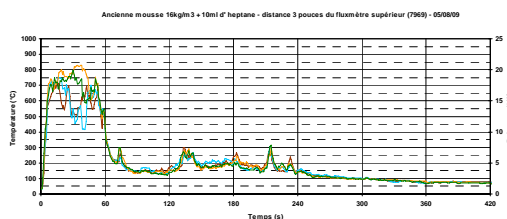
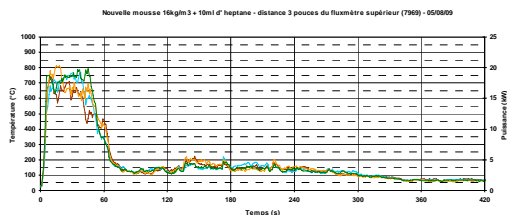




Hidden Fire Source

▶ Repeatability of the foam block fire source

Good repeatability



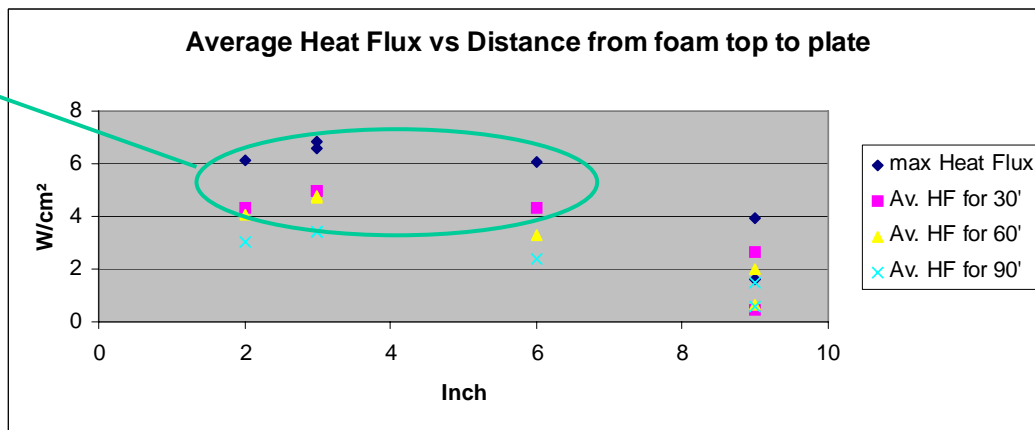
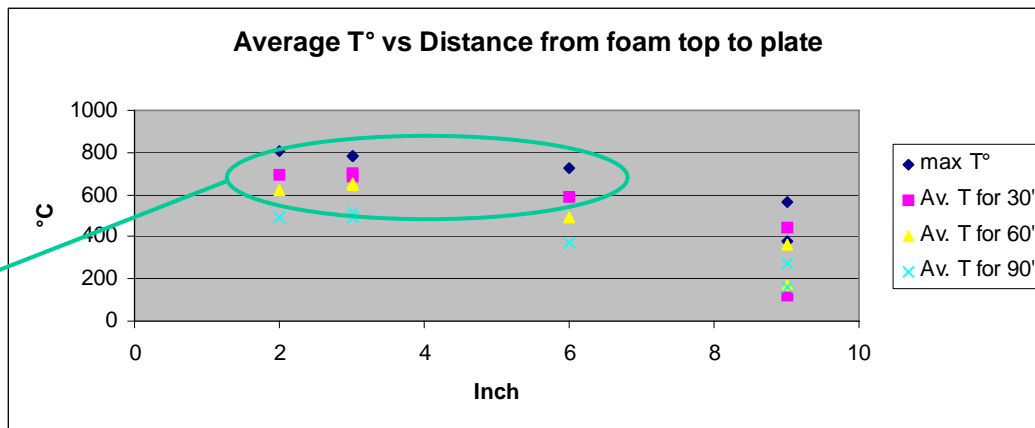


► Effect of the distance on the flame characteristics

Various distances from the foam top to the plate were tested :

- 9 inches
- 6 inches
- 3 inches
- 2 inches

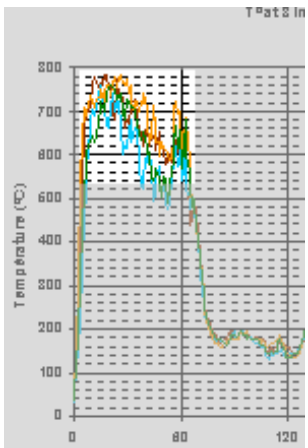
► The averages of T° and HF during the active burn time are relatively constant from 2 to 5/6 inches :





Hidden Fire Source

► Final specifications



► SPECIFICATIONS to be representative of the active fire stage at 2 / 3 inches :

Fire source specifications :

- $T^{\circ} \approx 650 \text{ to } 700 \text{ }^{\circ}\text{C}$
- Heat Flux Density $\approx 4 \text{ to } 5 \text{ W/cm}^2$

Av T°C	d = 2 inches	d = 3 inches	d = 6 inches	d = 9 inches
30"	697	700	588	447
60"	621	642	492	365
90"	494	495	375	278

Av HF (W/cm²)	d = 2 inches	d = 3 inches	d = 6 inches	d = 9 inches
30"	4,35	5	4,33	1,60 to 3,90
60"	4,05	4,75	3,32	0,65 to 2
90"	3,01	3,44	2,4	0,60 to 1,5

Max : 805°C 781°C

Max : 6,14 W/cm² 6,84 W/cm²



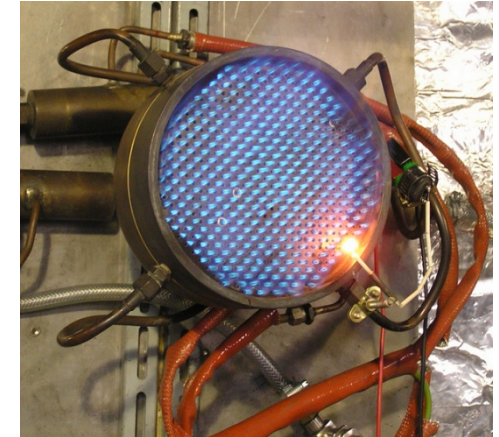
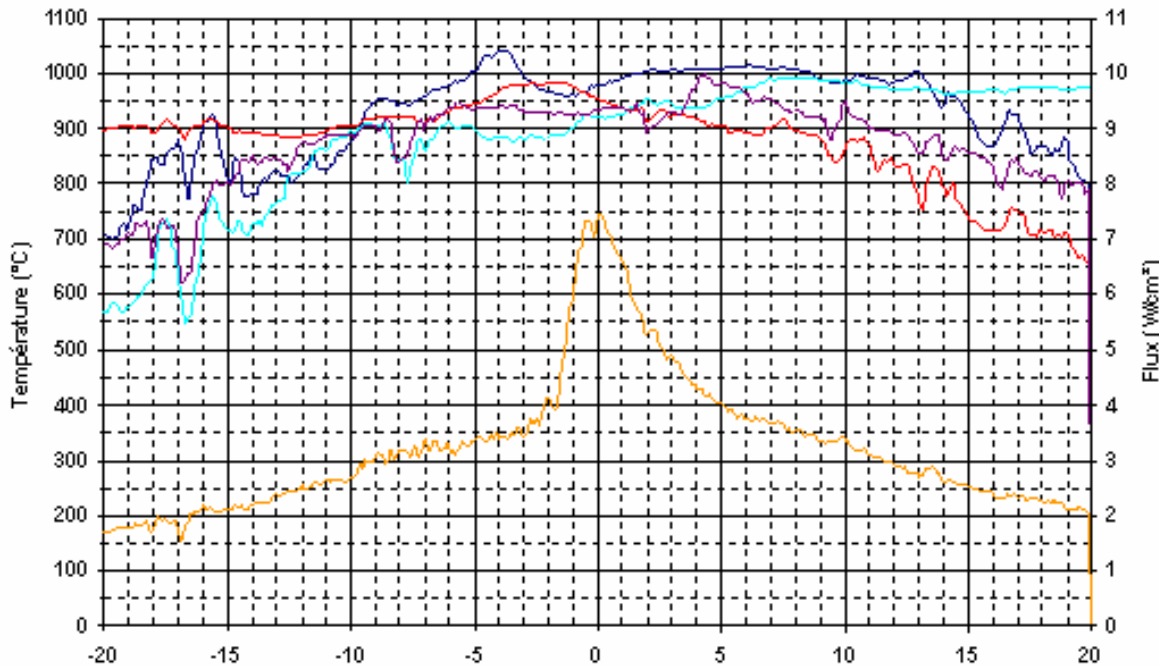


► ISO 2685 Gas Burner

Lowest energetic flame

► Several settings were tested, the lowest energetic flame was :

Heat flux Mapping (3 inches above the burner)

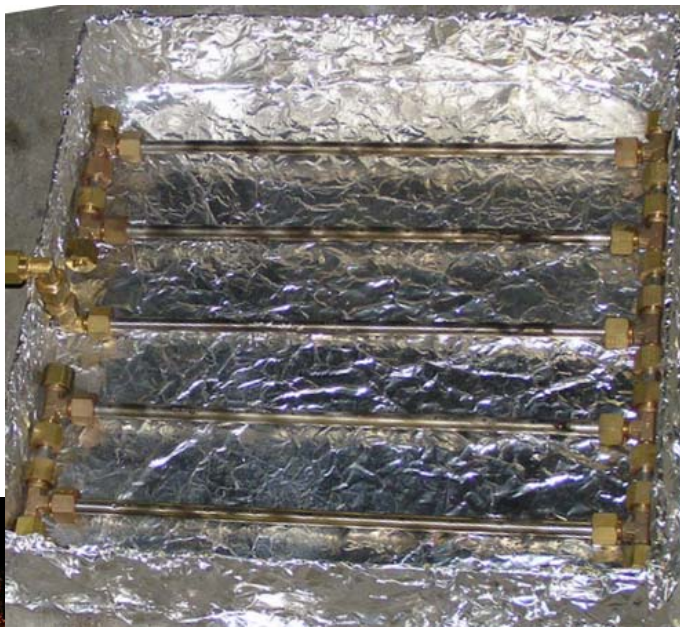


► Diameter = 152 mm

- The flame T° was too high (950 °C)
- The Heat Flux profile was not homogeneous, with a very thin peak of HF.



▶ CEAT Hidden Fire Source



**Experimental PROPANE burner made
with 5 drilled tubes**

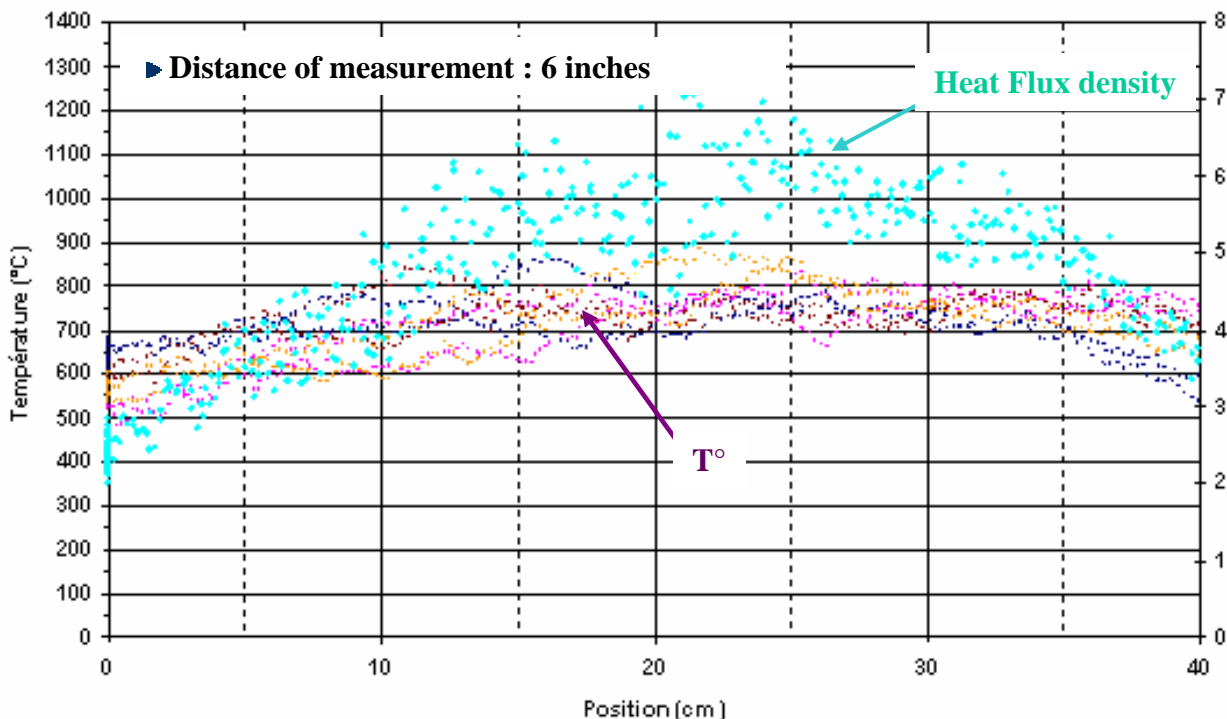
(1st design)





▶ CEAT Hidden Fire Source

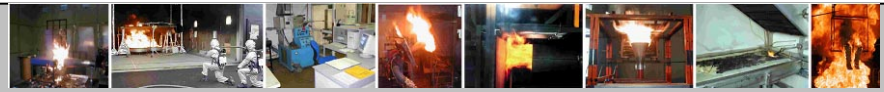
Characterisation of the CEAT gas burner's flame



The flame characteristics are homogeneous & close to the flame of the foam block

▶ Flame $T^{\circ} \approx 750^{\circ}\text{C}$

▶ Heat Flux $\approx 5,5\text{ W/cm}^2$



► Determination of the fire scenario equivalent to the foam block fire

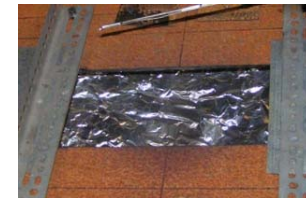
Several tests were performed to compare the profile of T° on the back side of the test samples

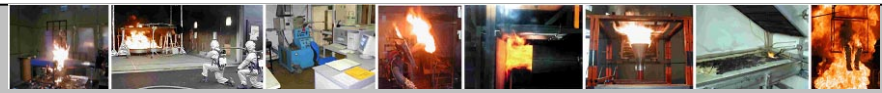
- T300 / 914 Carbon-Epoxy
- T300J or HTA / RTM6 Carbon-Epoxy



Surface exposed to the flame :

150 x 400 mm



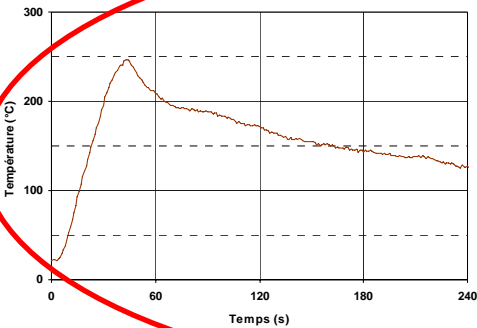


► Determination of an equivalent fire scenario

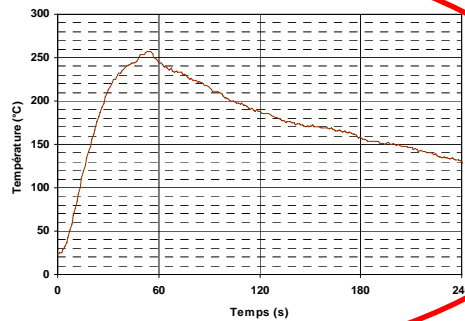
Comparison of the damage tests :
Foam block / Gas burner

► Foam block tests (exposure time : 7 mn (complete burning of the foam)) d = 3 inches

Back side T° - foam block test - T300/914 - 24/09/08



Back side T° - Foam block - T300/914 - 26/09/08



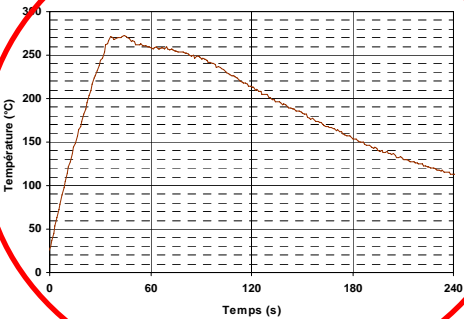
► The back side maximum T° are close
► 45 s gas burner test shows the more similar profile of T°

Equivalent scenario :

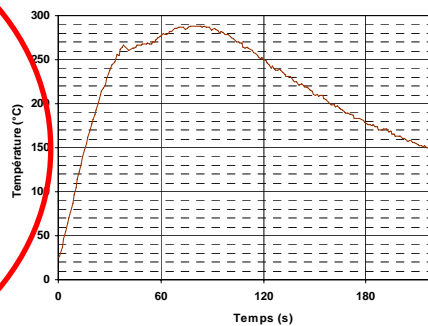
- Time of exposure : 45 s
- Distance burner / test sample : 6 inches

► Gas burner tests (exposure time : 45 s to 1 mn 30 s) d = 6 inches

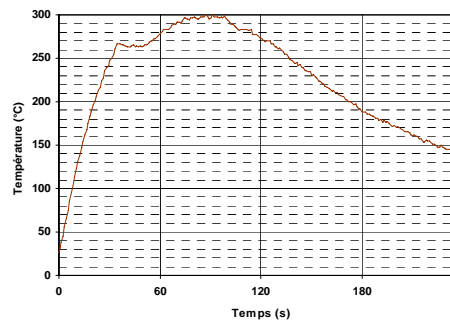
Back side T° - Gas burner test - 45 s - T300/914 - 26/09/08



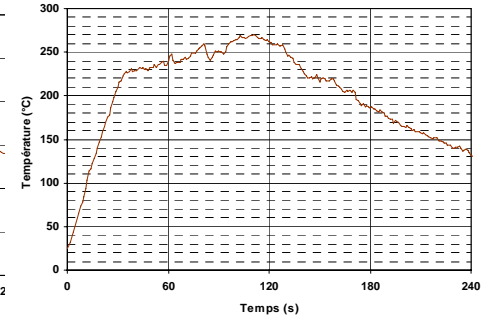
Back side T° - Gas burner test - 60 s - T300/914 - 26/09/08



Back side T° - Gas burner test - 1 mn 15 s - T300/914 - 26/09/08



Back side T° - Gas burner test - 1 mn 30s - T300/914 - 25/09/08





▶ Comparative damaging tests

Various materials and setting were investigated

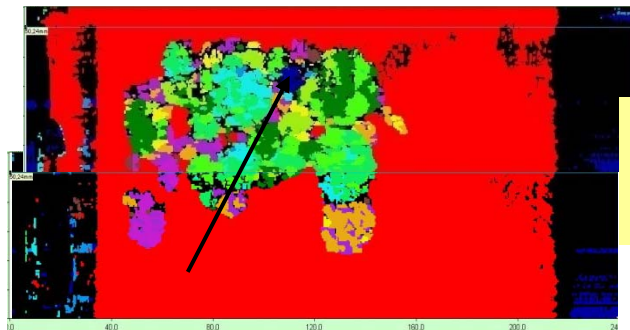
- T300 / 914 Carbon-Epoxy
- HTA / RTM6 Carbon-Epoxy
- T300J / RTM6 Carbon-Epoxy



Comparison of the damages :
Foam block / Gas burner

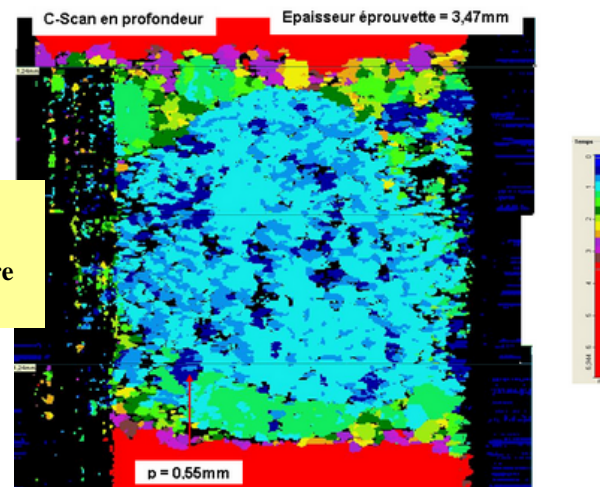
- ▶ Non Destructive Investigation
(Ultrasonic Phased Array Analysis)

Foam block test



- ▶ damages are homogeneous
- ▶ hidden fire source is a little bit more severe

Gas burner test





Hidden Fire Source

► Comparative damaging tests

Comparison of the back side T°

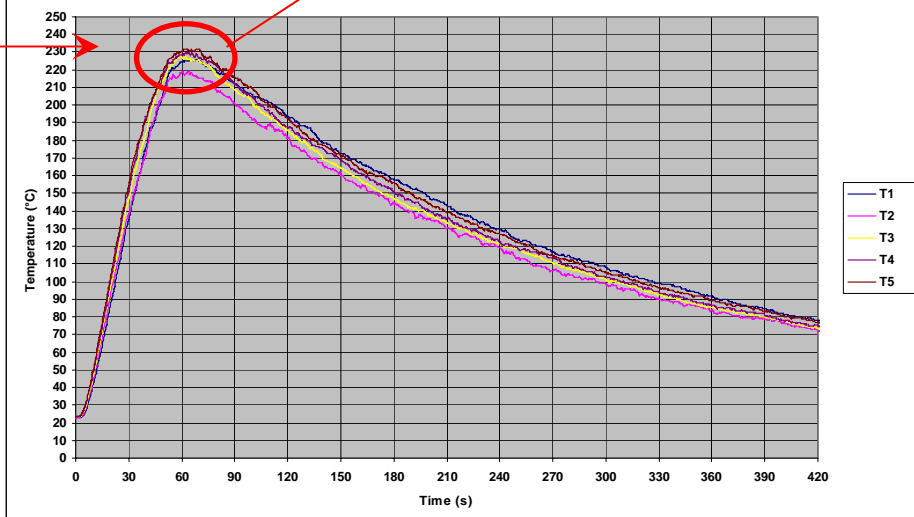
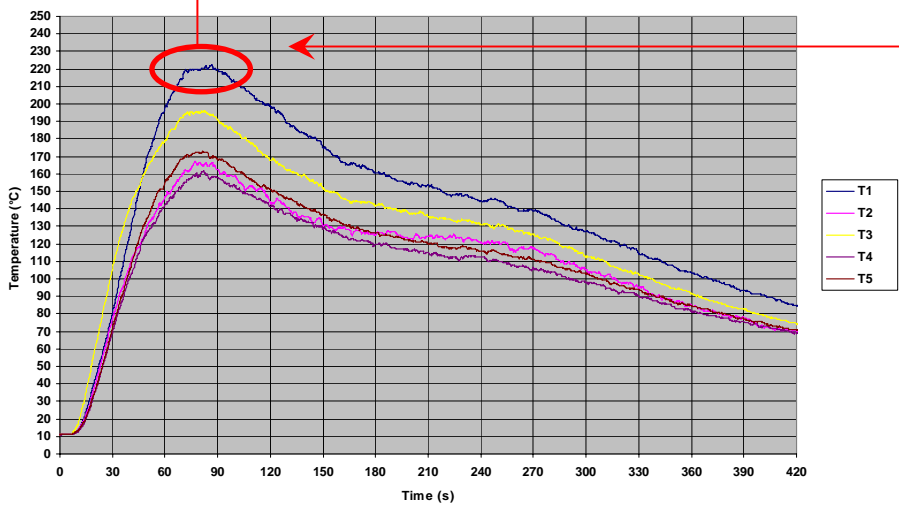
Good agreement of the maximum T°

Good homogeneity



5736-C259, 320*175 mm, Foam block at 3° - 07/04/09

5736-C259, 320*175 mm, 6 drilled tubes at 6°, 1070 In/h propane - 06/04/09



FOAM BLOCK

Hidden Fire Source



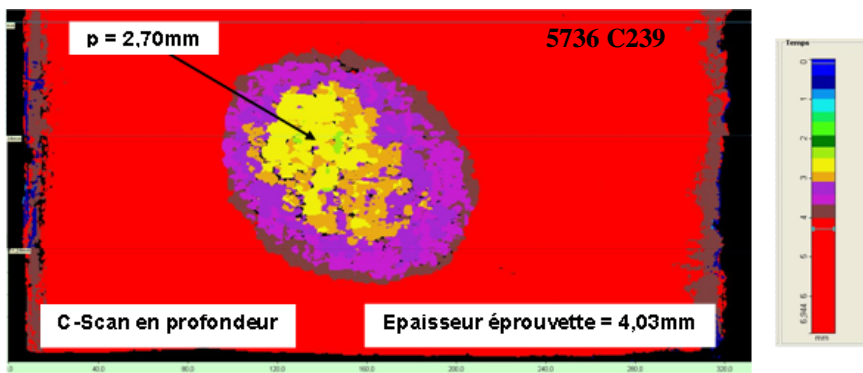


Hidden Fire Source

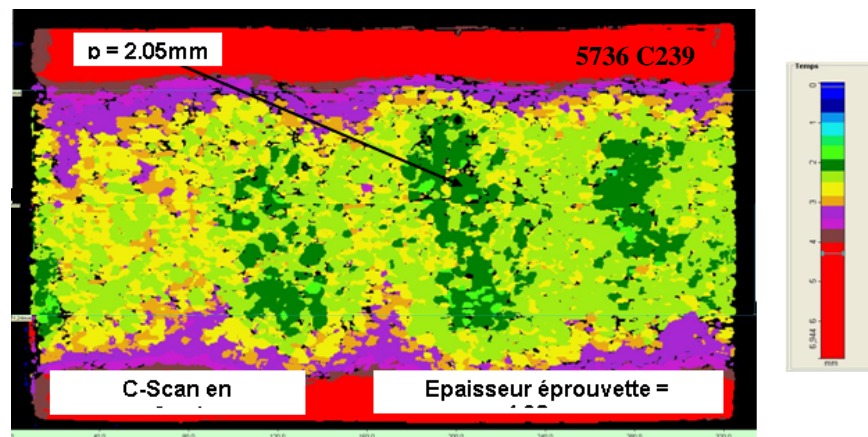
▶ Comparative damaging tests

NDI of the damages

FOAM BLOCK



Hidden Fire Source



- Quite good homogeneity
- Hidden fire source is a little bit more severe

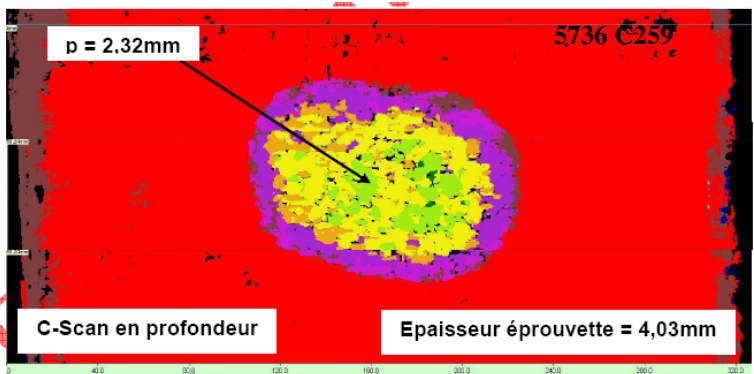


► Comparative damaging tests

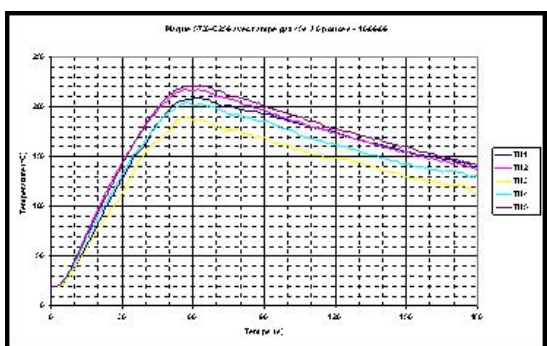
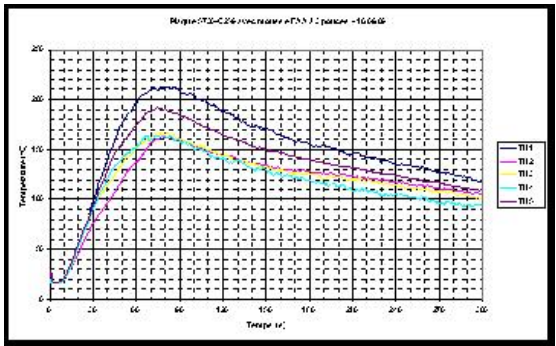
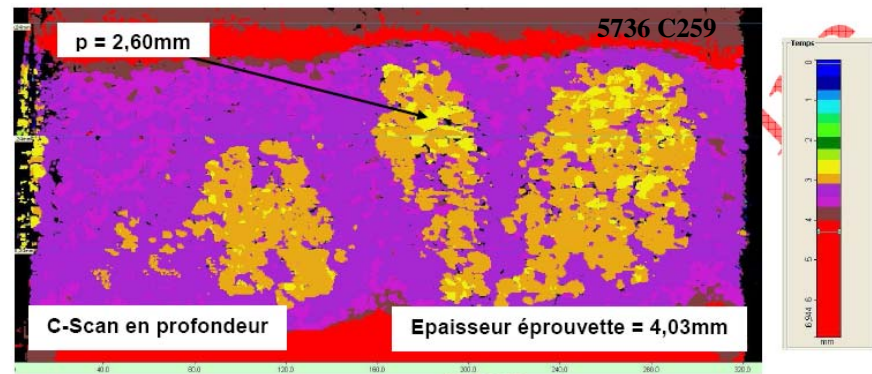
NDI of the damages

- Quite good homogeneity
- Hidden fire source is a little bit less severe

FOAM BLOCK



Hidden Fire Source





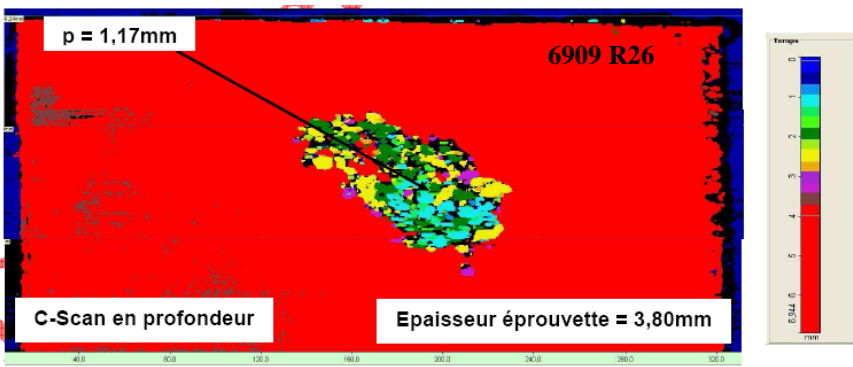
Hidden Fire Source

► Comparative damaging tests

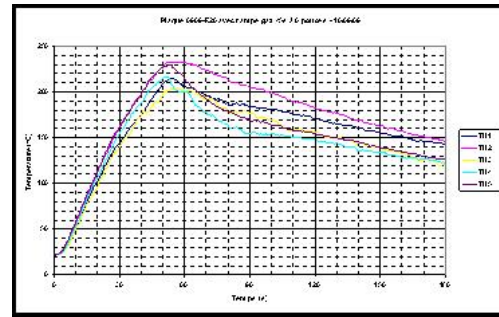
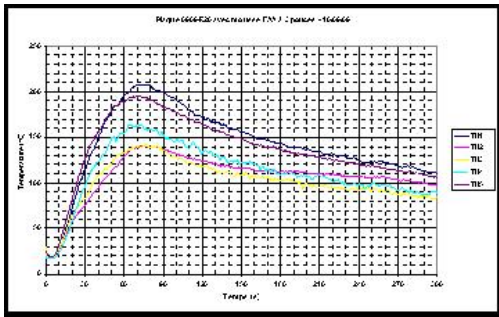
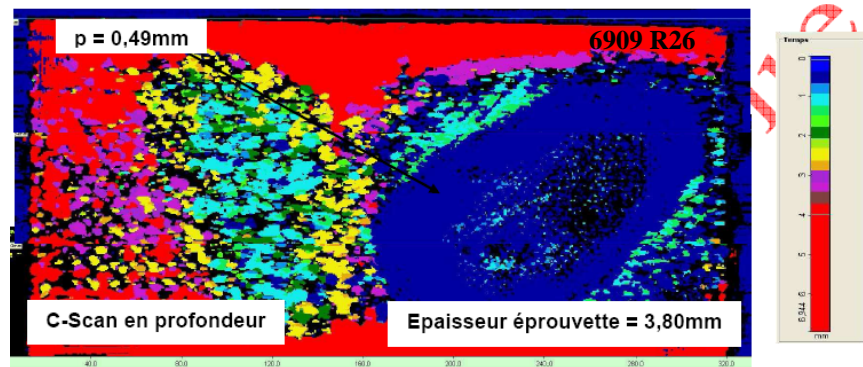
NDI of the damages

- Good homogeneity on the left side of the gas test sample
- the large delaminated area is probably due to a defect of the material

FOAM BLOCK



Hidden Fire Source



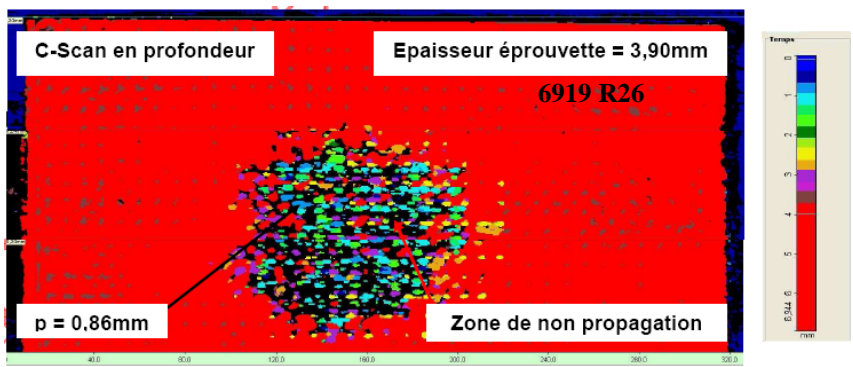


▶ Comparative damaging tests

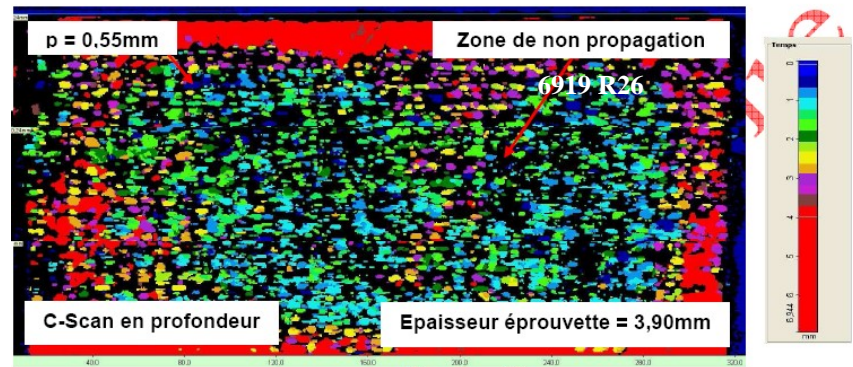
NDI of the damages

- Very good homogeneity
- Very good agreement of the damages

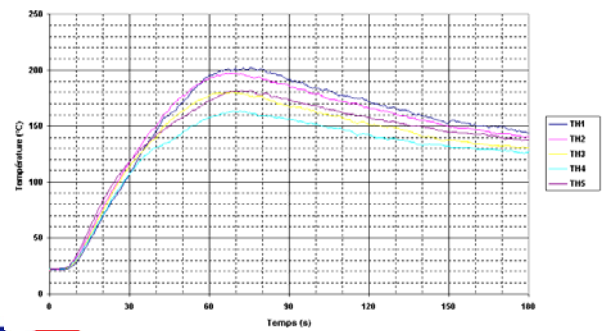
FOAM BLOCK



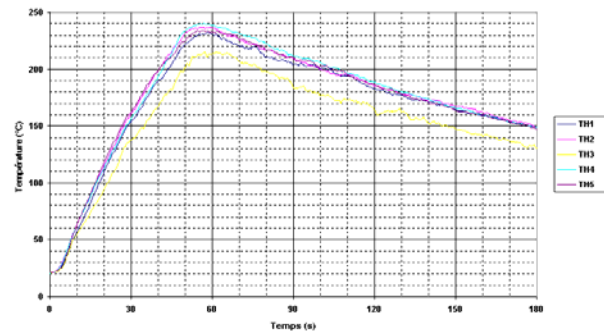
Hidden Fire Source



Plaque 6919-R26 avec mousse FAA à 3 pouces - 28/09/09



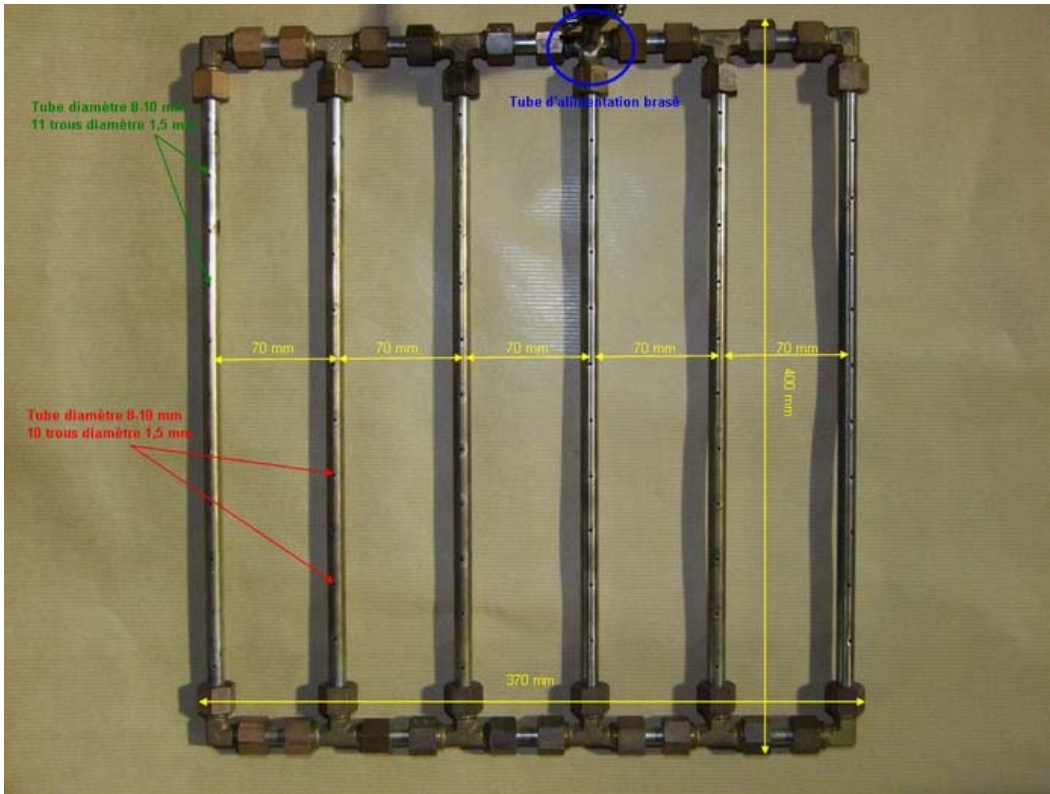
Plaque 6919-R26 avec rampe gaz 45e à 6 pouces après ajustage - 28/09/09



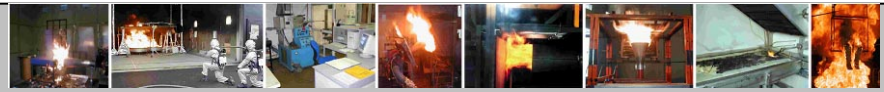


Hidden Fire Source

▶ Hidden Fire Source (Propane)



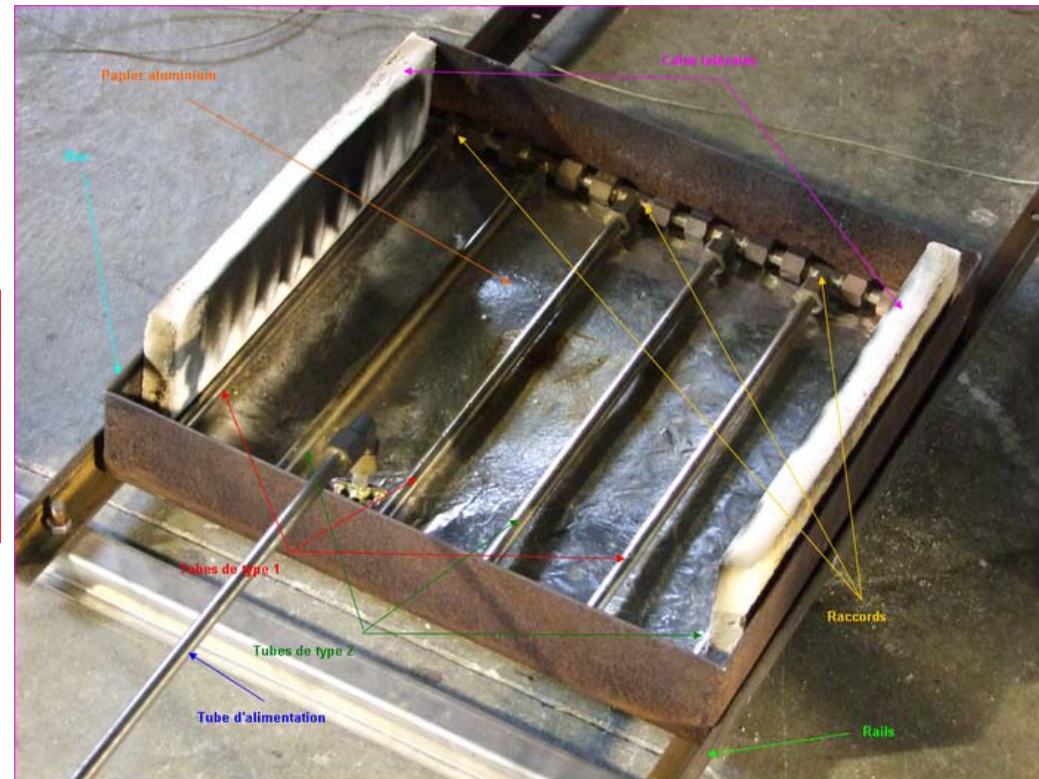
- Burner size : 400mm x 370mm
- 6 drilled tubes of 8mm (inner diam.)
- Diameter of the drillings : 1.5mm



Hidden Fire Source

▶ Hidden Fire Source (Propane)

- The burner is placed in a steel pan (404mm x 404mm)
- 2 ceramic plates on 2 sides to guide the flames from the lateral tubes





Hidden Fire Source

▶ Hidden Fire Source (Propane)

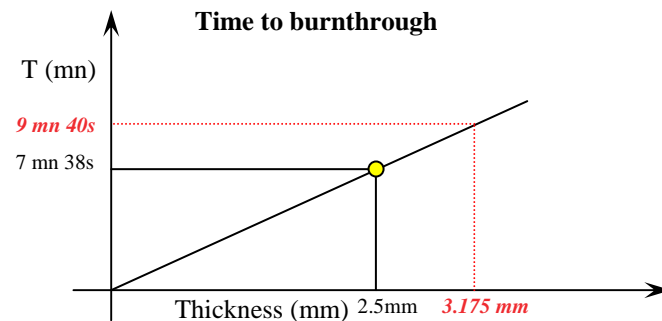
- Gas flow rate : 1000 ln/h (standard conditions)
- Flow rate control : Mass Flow Controller





► Damaging test on aluminium plate

► Aluminium plate – 2,5 mm



Burnthrough time :

7 mn 38 s

The fire source is very close to the FAA fire source used on wind tunnel test (under static conditions)

(FAA burnthrough time is : 9 to 10 mn (thickness 3.175 mm (1/4 inch)):

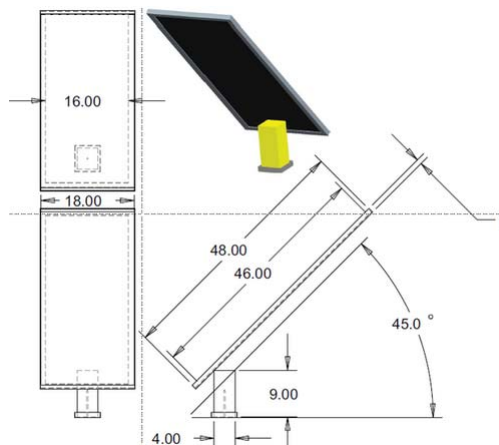
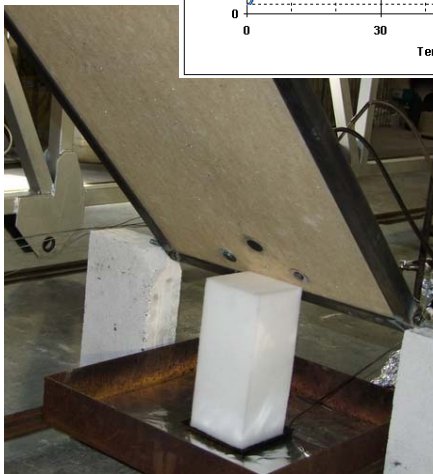
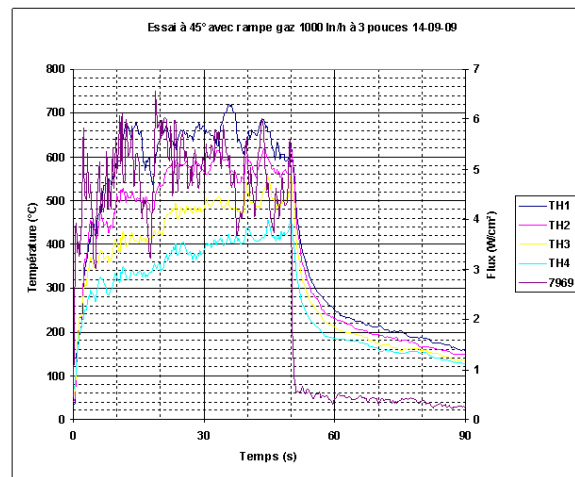
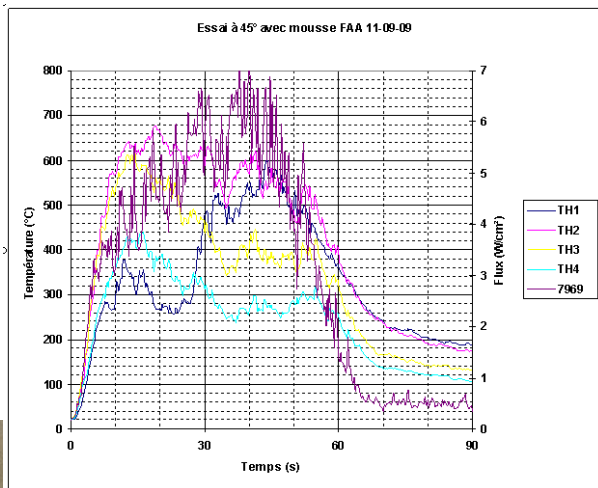
- an estimation of the burnthrough time using our fire source on an aluminum plate of 3.2 mm thickness is around 9 mn 40 s.



Hidden Fire Source

► 45° test

- Good agreement for the maximum T°
- HF is a little bit lower for the gas burner





Hidden Fire Source

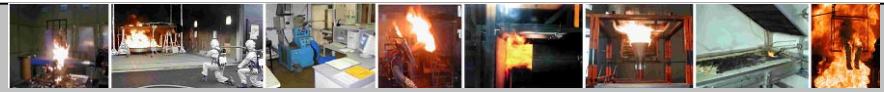
► 45° test

► Test on : Glass-Epoxy / Aramid Honeycomb



- Due to the size of the gas burner, the size of the damaged area is different
- The burn lengths are close





► CONCLUSIONS

- The gas fire source (at $d=6''$) generates the same flame characteristics (T° / Heat Flux) than the FAA foam block fire source (at $d=3''$)
- The repeatability of the flame characteristics and of the damages generated on composite materials has been verified
- The damages resulting from the gas fire source and from the FAA foam block are well correlated





▶ NEXT WORKS

- ✓ **To run the first fire tests and the mechanical characterisations after a fire exposure**
- ✓ **To define the other various scenarios of exposure**
(from 45s (ignition stage) to a duration to be determined simulating a declared hidden fire)
- ✓ **To define the test procedures for the under load fire test**
- ✓ **To run the fabrication of the various composite materials to be tested**





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Toulouse Aeronautical Test Centre (CEAT) « Fire Safety Department »

DEVELOPMENT
OF A REPEATABLE

HIDDEN FIRE SOURCE



Serge LE NEVE

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