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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE

Toulouse Aeronautical Test Centre (CEAT)

« Fire Safety Department »

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

DGA

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FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

DGAC
CEAT
AIRBUS

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➔ **Background**

➔ **Test program / Laboratory tests**

➔ **New test methods**

- ✓Electric arc effect
- ✓Hidden fire test :
  - Fire source
  - Scenarios
  - Mechanical tests
  - Under load fire test
- ✓Burnthrough test
  - Smoke box
  - Test procedure
  - Gas analysis

➔ **Conclusions**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

Increase in the use of composite materials in new aircraft programs (structural applications and fuselages)

- The use of composite structures has been increased because of the advantages composites offer over metal

- Boeing 787 or Airbus 350 will have about 50 % of the structural weight including wings and fuselage

- Currently, there is no fire requirement on composite materials used outside the cabin or cargo compartment

➔**The aircraft manufacturer will be required to demonstrate that polymer structural composites provide an equivalent safety level to the current material (aluminium alloy)**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

- **MANY TESTS HAVE BEEN DEVELOPPED FOR FIRE SAFETY REQUIREMENTS**

CABINE LAYOUT
HIDDEN AREA
CARGO COMPARTMENTS
FIRE AREAS or POWERPLANT INSTALLATIONS

- **works will allow to determine if the current aeronautical fire tests are sufficient to assess the fire behaviour of structural composite materials**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

TEST PROGRAM

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

In-flight thermal damaging

- Hidden fire damaging
- Electric arc effects
- Check the residual mechanical properties

Post-crash fire effects

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

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

FIRE TEST MEANS (available or to be developed)

Available laboratory test means

- Bunsen burner test,
- OSU test chamber (Heat Release)
- NBS test chamber (Smoke / Toxicity),
- Radiant Panel test (Flame Propagation / self-extinguishability)
- Burnthrough test
- Cone calorimeter
- Gas burner for ISO 2685 Fire Test (Fire resistance test)

Various specific test means & procedures to be defined or adapted

- Hidden Fire source (to be defined)
- Burnthrough box test (available test mean to be adapted),
- Under load fire test (to be defined)
- Electric arc effects (method to be defined)

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

WORKING PROGRAM

- **To define the materials to be tested,**
- **To define or adapt the new test methods,**
- **To carry out each fire test on every materials**
- **To carry out mechanical tests on samples submitted to hidden fire source**
- **To compare and analyse test results from current regulatory (or manufacturer) test requirement and new test methods**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

MATERIALS

➢ **18 composite materials from various structural applications**

- **AIRBUS France will supply the CEAT with 11 materials**
- **7 materials are manufactured at the CEAT**

- **Some materials are used on helicopter or military applications**
- **Each material will be submitted to all fire tests**

➢ **Tests on aluminium alloys (hidden fire tests) (reference)**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

LABORATORY TEST METHODS

- **Bunsen burner test (FAR 25.853)**
- **OSU test chamber (Heat Release) (FAR 25.853)**
- **NBS test chamber (Smoke / Toxicity) (FAR 25.853 / ABD0031)**
- **Cone calorimeter (7,5 & 10 W/cm²)**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

NEW TEST METHODS

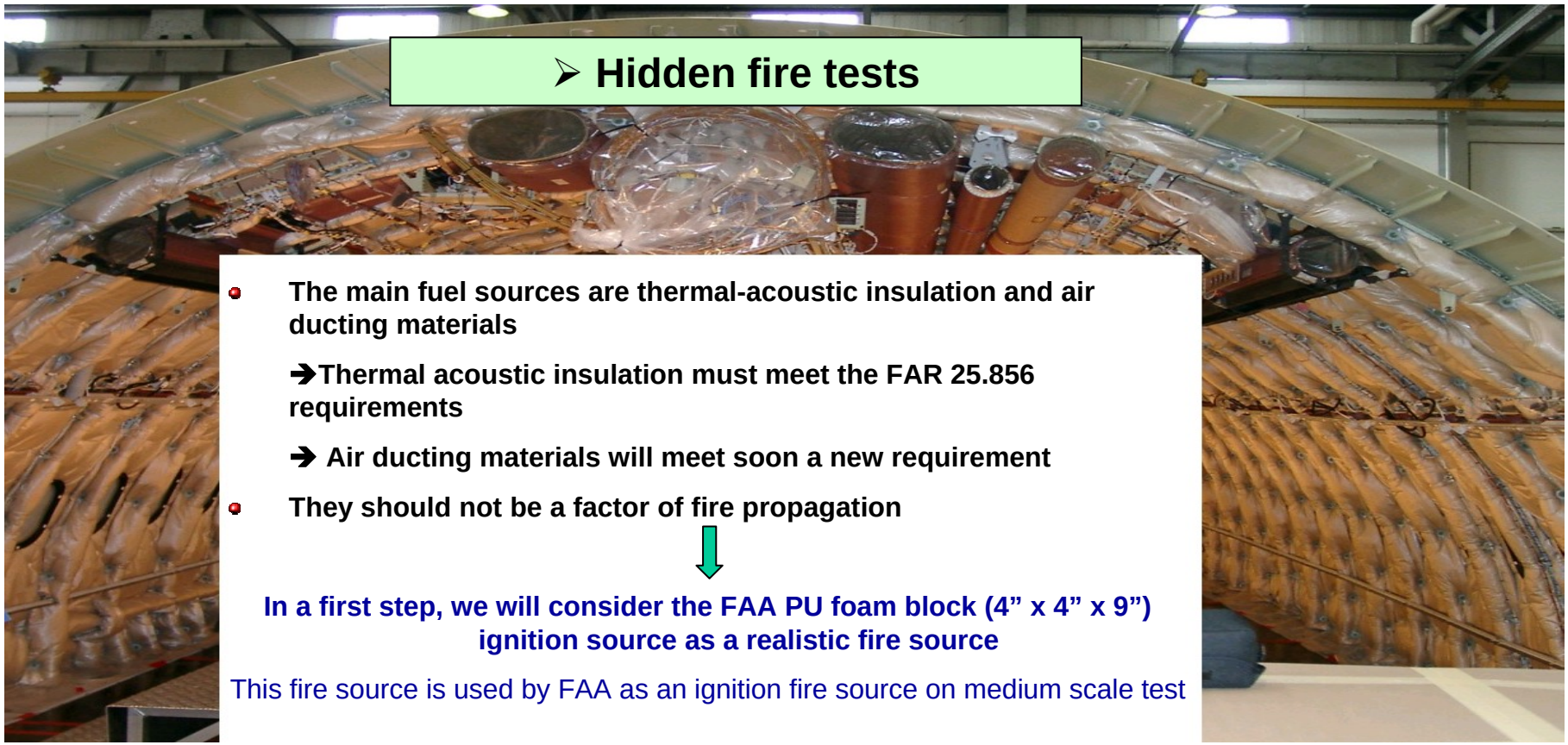
➢ Electric arc effects

(task not detailed in this presentation)

- **To identify the currents which are carried in hidden areas (Airbus support)**
- **To define or develop the test method**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

NEW TEST METHODS



➢ Hidden fire tests

- **The main fuel sources are thermal-acoustic insulation and air ducting materials**

  ➔Thermal acoustic insulation must meet the FAR 25.856 requirements

  ➔ Air ducting materials will meet soon a new requirement

- **They should not be a factor of fire propagation**

In a first step, we will consider the FAA PU foam block (4” x 4” x 9”) ignition source as a realistic fire source

This fire source is used by FAA as an ignition fire source on medium scale test

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Hidden fire tests

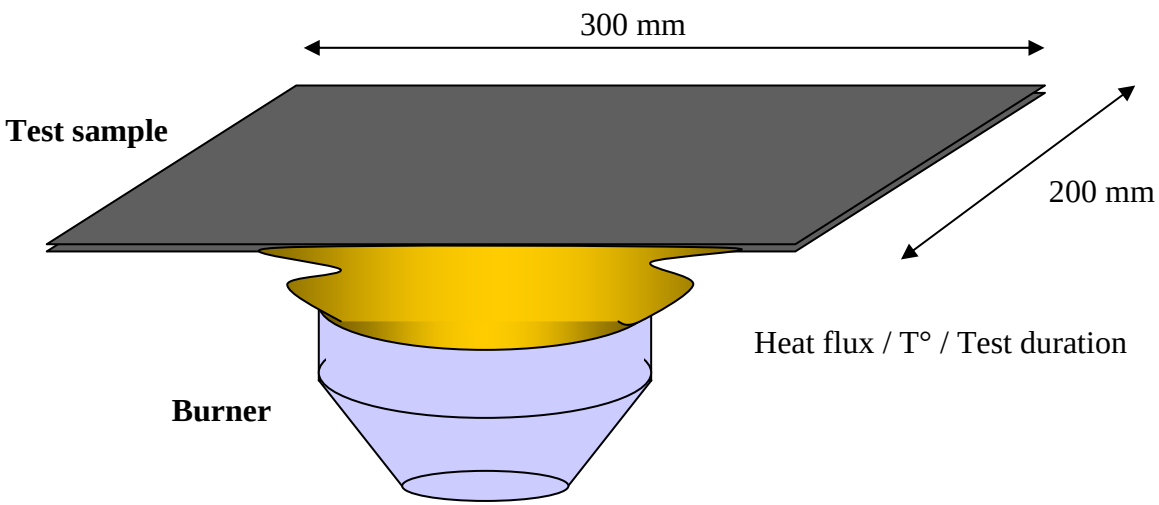
STUDY / DEVELOPMENT OF A REPEATABLE FIRE SOURCE

- To characterize the foam block fire source (heat flux / T°)
- To adapt or develop a repeatable fire source
- The new fire source could be based on the gas burner used for Fire Resistance Test (ISO 2685) with modified flame calibration

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Hidden fire scenario

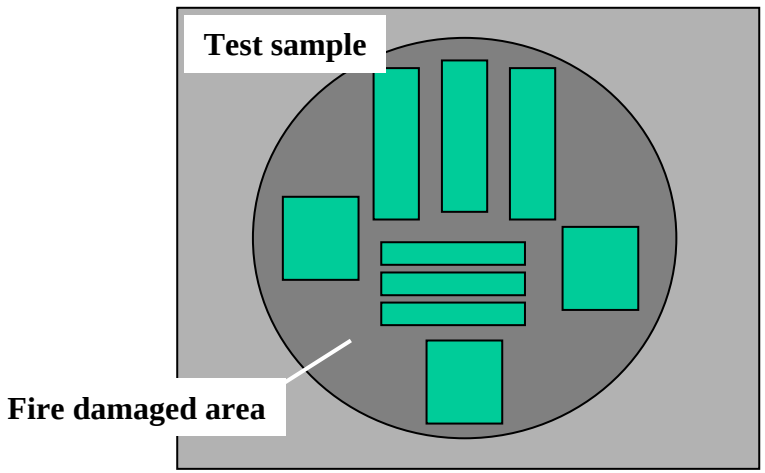
- **To define several realistic scenarios (heat flux / test durations)**
- **➔ Aluminium alloys will be systematically tested as a reference solution**



FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Mechanical tests

- Test specimens removed from the fire damaged area
- Mechanical tests to be performed :
  - Interlaminar Shear Strength (ILSS)
  - Open Hole Compression (OHC)
  - Unnotched Tension (UT)
  - Unnotched Compression (UC)

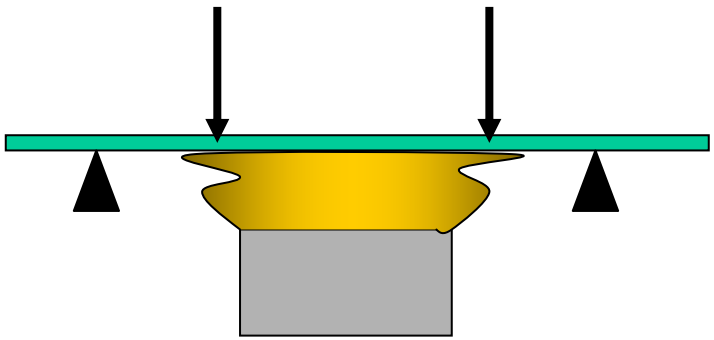


FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

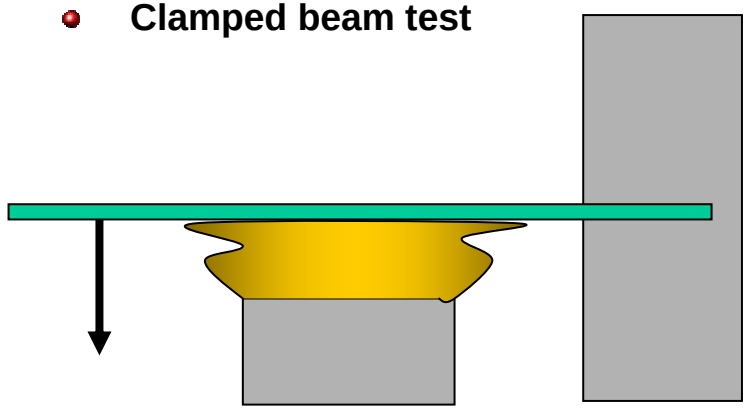
NEW TEST METHODS

➢ Under load fire tests (to be defined)

- 4-point-bending test



- Clamped beam test



➔ Fire source has to be defined (PU foam block / ISO 2685 gas burner / …)

➔ 2024 Aluminium alloy will be tested as a reference solution

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NEW TEST METHODS

➢ Burnthrough tests

- A small scale test has already been developed by the CEAT since 1998 to be used as screening device for evaluating thermal insulation blankets
- The test apparatus consists in a smoke box (1m^3), a specimen holder and a Park burner as a fire source
- Many tests were carried out on insulation blankets which gave a good repeatability on burnthough time, smoke density and toxicity
- However this design remained unsuccessfully as regulatory burnthrough test mean (probably because smoke and toxicity were not a requirement until today)

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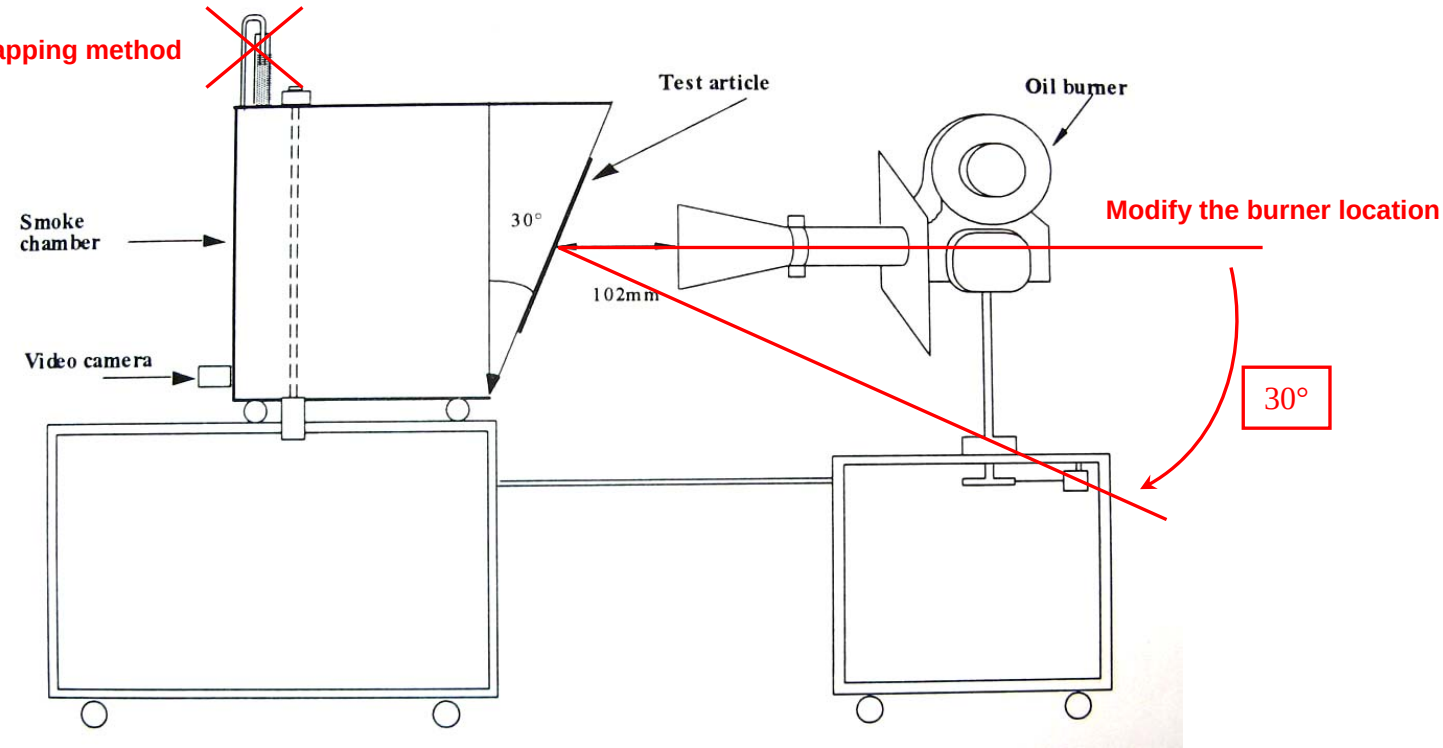
➢ Modifications of Burnthrough Test

Modify the gas trapping method



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➢ Smoke box

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➢ Test procedure

- **Calibration and application of the flame will be in accordance with the rule (burnthrough test procedure)**
- **Smoke density will be recorded all along the test duration**
- **Gas analysis will be performed by FTIR when possible (continuous gas analysis)**
- **Test duration : 5 mn**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ **Materials to be tested**

➢ **18 materials will be tested**

- ➔ **Various resins, fibbers, thicknesses, with & without Nida**
- ➔ **Some tests will be carried out on assembly “composite / insulation blanket / wall panel”**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Gas analysis

➔ **Species to be analysed : at least ABD 0031, maxi : STANAG 4602 under review (NATO Standard for Naval Ship)**

➔ **Gas analysis : to develop a continuous analysis by FTIR**

➔ **Preliminary toxicity tests will be performed with NBS smoke chamber to determine the species to be analysed**

➔ **Smoke release : optical density measurement**

➔ **First step :**

- **To adapt / develop a gas taking system & an analysis procedure**
- **The test results will allow a comparative analysis of rate release of gas & smoke**

➔**Second step :**

- **To try to determine acceptance criteria : compared with the NBS test results ? Full scale test results ?**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Toxicity requirements (Airbus)

GAS COMPONENT	*LIMIT OF CONCENTRATION*
Hydrogen Fluoride	HF → 100 ppm
Hydrogen Chloride	HCl → 150 ppm
Hydrogen Cyanide	HCN → 150 ppm
Sulfur Dioxide	SO_2 → 100 ppm[26]
Nitrous Gases	NO/NO_2 → 100 ppm
Carbon Monoxide	CO → 1000 ppm

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Toxicity requirements (NATO STANAG 4602)

AIRBUS REQUIREMENT

~~Probably to be REMOVED from the NATO REQUIREMENT~~

To be quantify because of their incidence on the toxicity index

Except Acrolein, the other species have a moderate impact on the toxicity index

Gas[1]	
Carbon dioxide	CO_2
Carbon monoxide	CO
Oxides of nitrogen	NOx (NO + NO_2)
Sulphur dioxide	SO_2
Hydrogen fluoride	HF
Hydrogen bromide	HBr
Hydrogen chloride	HCl
Hydrogen cyanide	HCN
Acrylonitrile (Propenonitrile)	CH_2CHCN
Ammonia	NH_3

Gas[1]	
Formaldehyde (Methanal)	HCHO
Phenol	C_6H_5OH
~~Benzene~~	~~C_6H_6~~
~~Styrene (Phenylethene)~~	~~$C_6H_5CHCH_2$~~
~~Toluene (Methyl benzene)~~	~~$C_6H_5CH_3$~~
Hydrogen sulphide	H_2S
Formic acid	HCOOH
~~Carbon disulphide~~	~~CS_2~~
Acrolein (2-Propenal)	CH_2CHCHO
~~Acetaldehyde (Ethanal)~~	~~CH_3CHO~~

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

➢ Gas to be analysed

Gas Component	
Carbone monoxyde	**CO**
Oxides of nitrogen	**NOx (NO + NO_2)**
Sulphur dioxide	**SO_2**
Hydrogen fluoride	**HF**
Hydrogen bromide	**HBr**
Hydrogen chloride	**HCl**
Hydrogen cyanide	**HCN**
Hydrogen sulphide	**H_2S**

FIRE BEHAVIOUR OF STRUCTURAL COMPOSITE MATERIALS

Conclusions

- **In-flight fire damaging and post-crash fire effect on structural composite materials will be studied**
- **The hidden fire tests and mechanical tests will allow to evaluate the effect on flight safety**
- **The test results from the burnthrough test apparatus on toxic gas production and smoke release will allow to compare different types of composite materials and contribute to evaluate the effect of a composite fuselage on post-crash survivability**

<u>All these test results will contribute to determine</u> :

- ✓ **if a large usage of composite materials has an effect on the fire safety level**
- ✓ **if the current aeronautical fire tests are sufficient to assess the fire behaviour of structural composite materials**

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