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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE



## Toulouse Aeronautical Test Centre (CEAT)

« Fire Safety Department »

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS



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# **FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS**

**Evaluation of materials located in inaccessible areas  
under Radiant Panel test conditions**

**DGAC  
CEAT  
AIRBUS**



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## → Background

## → Hidden areas

- ✓ Identification of materials
- ✓ Design of test samples

## → Test conditions

- ✓ Standard Radiant Panel Test
- ✓ Radiant Panel Test / Extended test conditions :
  - Pre-heating
  - Increased heat flux
  - Electrical sources of ignition

## → Test results

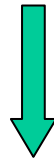
- ✓ Effect of test conditions
- ✓ Fire behaviour of materials

## → Conclusions

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## Background

- **Swissair MD11 accident (1998) : Insulation blanket involved**



- **New test requirement : The **Radiant Panel Test** has been developed to assess the behaviour of insulation blanket & other thermal insulation materials used in hidden areas.**

**What about the fire behaviour of the other materials installed in the same areas under the same conditions ?**

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## Background

- ▶ The DGAC has proposed a working program which involves CEAT, Airbus and material suppliers.

- ▶ To identify the materials and combinations of materials to be assessed.

- ▶ To conduct representative tests in order to check their possible contribution to fire propagation.

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

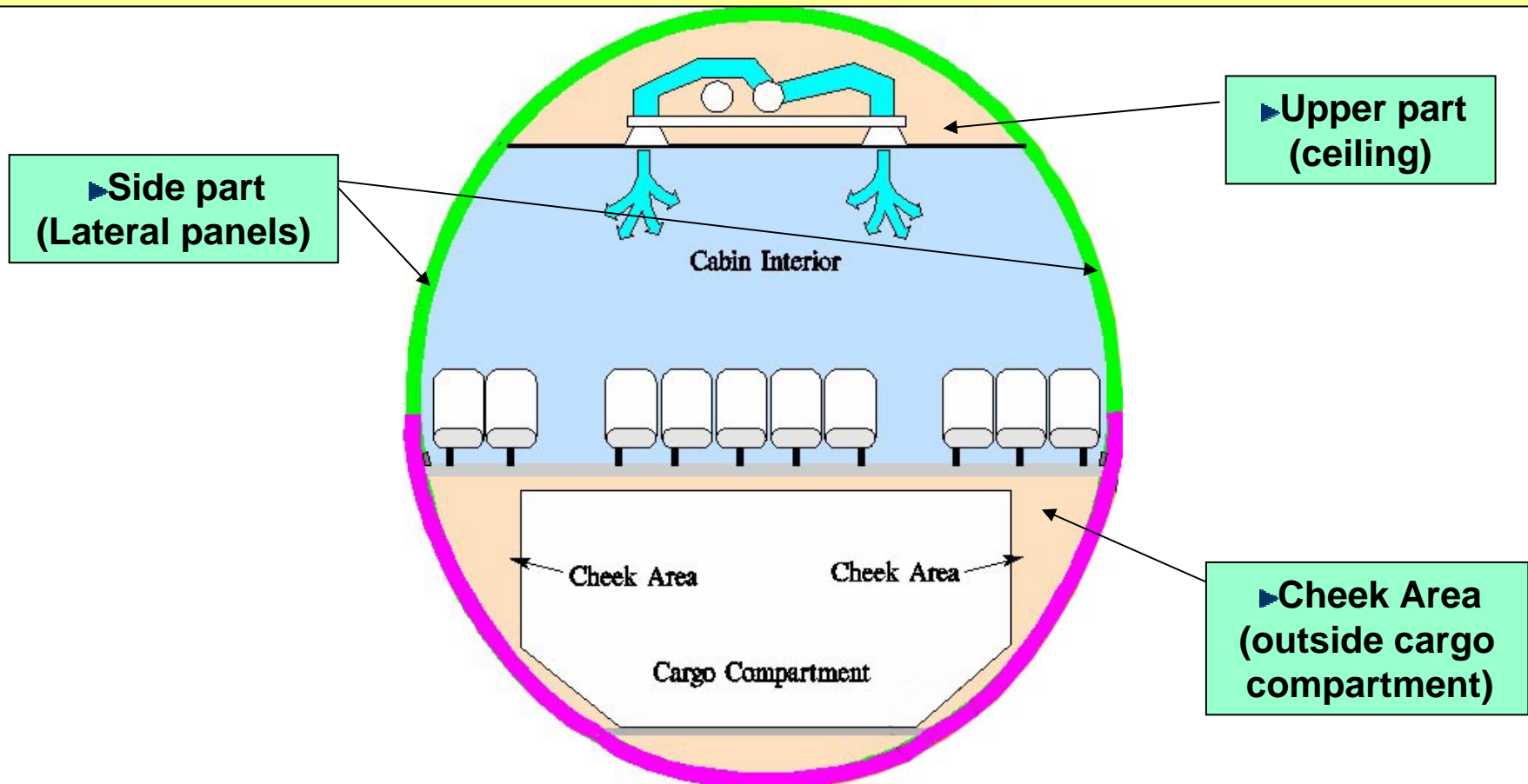
## ► Hidden Area



## ► Identification of materials installed in hidden area

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ►Hidden Area (Identification of materials)





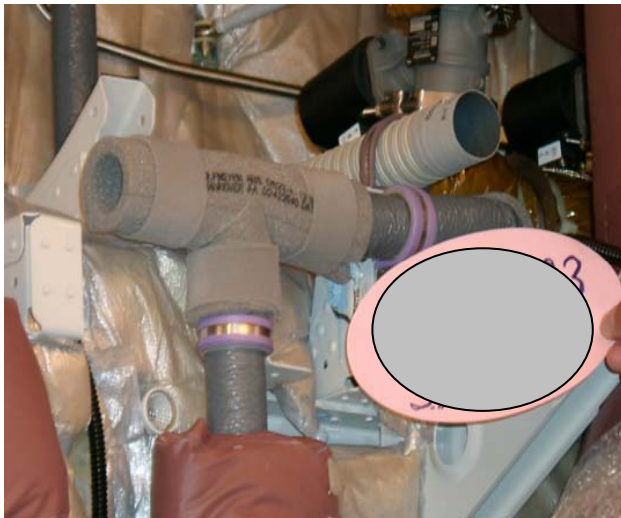
# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Hidden Area (Identification of materials)



- Insulation blankets
- Insulated Air Ducting
- Housing materials
- Electrical components (bundled wires etc..)
- Foams
- Cable ties / brackets





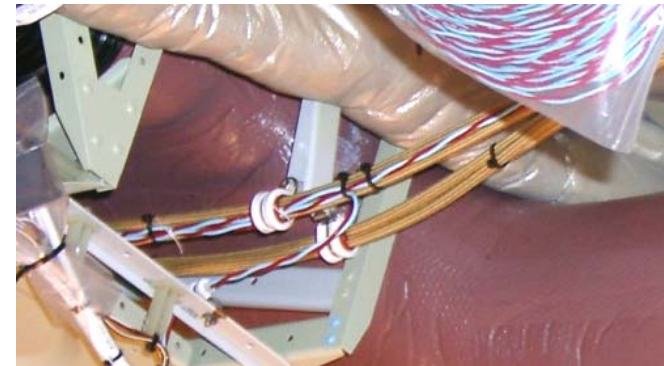
# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ►Hidden Area (Identification of materials)



### ►Details





# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Design of the test samples

### ► Materials

#### → Insulation blanket :

✓ TERUL 18

#### → Insulated Air Ducting :

✓ Glass phenolic composite or PEI

✓ Polyimide foam + Hypalon :

#### → Brackets / cable ties / wire holders

✓ PEEK, Polyamide, silicone

#### → Wires

✓ Various wires in usage on  
current airplane

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Design of the test samples



## ► Various Test samples



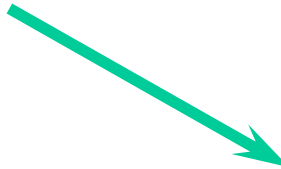


# **FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS**

## **►Test conditions**

### **Criteria used to define the test conditions**

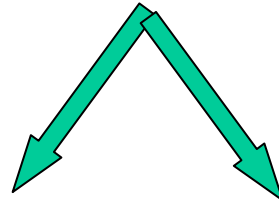
**►All materials installed in the same area  
are likely to be exposed to the same fire  
conditions**



**►the test conditions were defined to  
remain compatible with the behaviour  
of thermal-acoustic insulation materials**

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions



► Far 25.856

### Radiant Panel Test / Standard conditions :

- Flame time : 15s
- Heat Flux : 1.7 W/cm<sup>2</sup>

### Radiant Panel Test / Extended test conditions :

- Pre-heating
- Increased Heat Flux
- Electrical sources of ignition





# **FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS**

## **► Test conditions**

### **Extended test conditions Pre-heating**

- **To simulate the surrounding conditions in case of a declared hidden fire (increase of surrounding  $T^\circ$  and materials  $T^\circ$ ) before the arrival of the ignition source.**
- **To simulate the nominal  $T^\circ$  of electrical wires**



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

### Extended test conditions Pre-heating

#### Radiant Panel Pre-heating 600°C - 1.7w/cm<sup>2</sup>

- Preliminary tests have shown that the radiant panel was too severe on many insulation materials.  
(some materials burn or melt before the end of the pre-heating time (5mn))

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

**Extended test conditions**  
**Pre-heating**

### Thermal Chamber Pre-heating



- A pre-heating in a thermal chamber seems more representative of an actual heating condition in hidden area, confined, before the arrival of ignition source
- Various heating configurations have been tested : 50°C to 200°C / 5mn to 30mn
- Pre-heating conditions had to be sufficient to get T° stabilisation of the test samples but not too severe to keep their integrity.

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

**Extended test conditions**  
**Radiant Panel heat flux**



- To evaluate the effect of surrounding heat flux on the flame propagation
- Maximum heat flux possible with our Radiant Panel has been determined :  $2.2 \text{ W/cm}^2$ ,
- Tests have been conducted under 3 heat flux levels :
  - $1.7 \text{ W/cm}^2$  (standard condition),
  - $2 \text{ W/cm}^2$ ,
  - $2.2 \text{ W/cm}^2$  (standard + 30%).

# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test conditions

#### Pilot burner position

pilot burner position



pilot burner position



pilot burner position







# **FIRE BEHAVIOUR OF MATERIALS**

## **Installed in HIDDEN AREAS**

### **► Test conditions**

#### **Extended test conditions** **Electrical sources of ignition**

**► To evaluate the behaviour of materials and equipments with other ignition sources**

- A : 2 electrodes under 5 kV**
- B : 2 electrodes under 28 V with capacitor discharges**
- C : 1 electrode under 70V / 4 A**
- D : platinum filament under 4 A**

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

Extended test conditions  
Electrical sources of ignition



2 electrodes

- **A : 2 electrodes under 5 kV**
- **B : 2 electrodes under 28 V with capacitor discharges**
- **C : 1 electrode under 70V / 4 A**
- **D : platinum filament under 4 A**

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

Extended test conditions  
Electrical sources of ignition



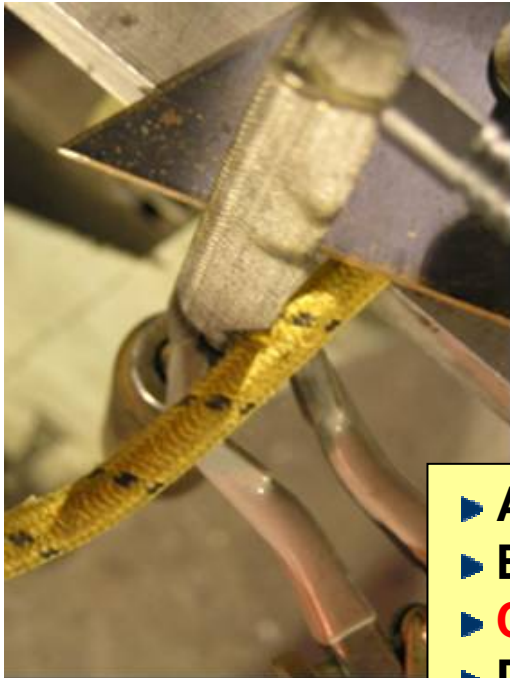
Arcing by rubbing

- A : 2 electrodes under 5 kV
- B : 2 electrodes under 28 V with capacitor discharges
- C : 1 electrode under 70V / 4 A
- D : platinum filament under 4 A

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test conditions

### Extended test conditions Electrical sources of ignition



Detail of the “file electrode”  
on vibrating table (70V / 4A)

- A : 2 electrodes under 5 kV
- B : 2 electrodes under 28 V with capacitor discharges
- **C : 1 electrode under 70V / 4 A**
- D : platinum filament under 4 A

# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test conditions

Extended test conditions  
Electrical sources of ignition



Detail of the platinum electrode

- A : 2 electrodes under 5 kV
- B : 2 electrodes under 28 V with capacitor discharges
- C : 1 electrode under 70V / 4 A
- D : platinum filament under 4 A



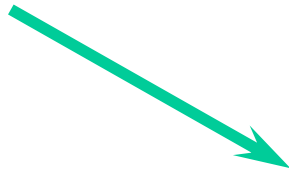


# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results





- 25 configurations
- 60 test samples

► No Flame propagation







► After flame up to 12mn



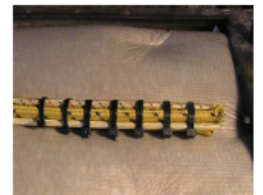

# Test samples

References	Compositions	
R17	Glass/Phenolic composite + polyimide foam + hypalon + insulation blanket	
R18 ; ET02 ; ET16 ; ET31 ; ET33 ; ET34 ; ET35	R17 + bundled wire (3 small power cables and 2 multi-conductors) + 3 cable ties separated by 1,5 cm	
R19	R18 with PEI (instead of Glass/Phenolic composite)	
R20 ; ET03 ; ET04 ; ET05 ; ET18	insulation blanket + cable crossing (3 small power cables + 2 multi-conductors / 6 small multi-conductors)	

R21 ; ET17 ; ET32 ; ET41	insulation blanket + 2 large power cables separated by holder and cable tie	
R22 ; ET19 ; ET30	insulation blanket + 6 power cables separated by a black holder (PEEK) and metallic cable tie	
R23 ; ET20 ; ET43 ; ET48 ; ET50	insulation blanket + Bundled wire (3 small power cables + 2 multi-conductors) maintained by a cable tie separated by 1,5 cm from the orange bracket (polyamide).	
R24	Idem R22	
R25	Idem R23 without the cable tie	
R26 ; ET08 ; ET09 ; ET10 ; ET15 ; ET21 ; ET22 ; ET46 ; ET49	PEI plate + polyimide foam + hypalon + Bundled wire (1 small power cable, 2 small and 1 large multi-conductors, 3 small and 2 large wires) + cable ties + large cable holder	

## Test samples

ET29	ET23 (30 cables) with 8 cable ties separated by 1 cm	
ET37	insulation blanket (ET28 without cable)	No picture
ET40	insulation blanket + Bundled wire (1 gros + 3 small power cables + 2 multi-conductors) maintained by an orange holder and 3 cable ties separated by 2cm	
ET39	insulation blanket + Bundled wire (1 large + 2 small power cables + 1 multi-conductors) + cable tie and holder.	
ET42.1 ; ET42.2	R18 + large cable holder	

ET 06	insulation blanket + large power cable + cable tie + large cable holder	No picture
ET 07	insulation blanket + large power cable + cable tie + small cable holder	No picture
ET11 ; ET12 ; ET13	(R26 with insulation blanket instead of foam) insulation blanket + Bundled wire (1 small power cable + 2 small and 2 large multi-conductors + 3 small et 2 large wires) + cable ties + large cable holder	Cf R26 (avec matelas d'isolation en remplacement de la mousse)
ET23 ; ET26 ; ET27	insulation blanket + Bundled wire of 30 small cable maintained by 6 cable ties separated by 2 cm	
ET24	insulation blanket + Bundled wire of 5 cables (2 small power cables + 2 large power cables) maintained by 3 colliers espacés de 2 cm	
ET25	ET24 (5 cables) with 7 cable ties separated by 1.5 cm	
ET28 ; ET38	ET23 (30 cables) with 7 cable ties separated by 1.5 cm	

# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test Matrix

	Radiant panel	Preheating			Thermal chamber - Duration (mn)			Irradiance (W/cm <sup>2</sup> )			Ignition source	
		Thermal chamber - T (°C)									Flame	Elect
		50	150	200	5	10	30	1.7	2	2.2		
R17								X			X	
R18 ; ET02 ; ET16 ; ET31 ; ET33 ; ET34 ; ET35	5		X				X	X			X	X
R19								X			X	
R20 ; ET03 ; ET04 ; ET05 ; ET18	5		X				X	X			X	
R21 ; ET17 ; ET32 ; ET41			X				X	X			X	X
R22 ; ET20 ; ET43 ; ET48			X				X	X			X	
R23 ; ET48 ; ET50			X				X	X		X	X	X
R24								X		X		
R25								X		X		
R26 ; ET08 ; ET09 ; ET10 ; ET15 ; ET21 ; ET22 ; ET46 ; ET49		X	X	X	X	X		X	X	X	X	
ET06											X	
ET07											X	
ET11 ; ET12 ; ET13			X	X	X			X			X	
ET23 ; ET26 ; ET27			X					X			X	
ET24			X					X			X	
ET25			X					X			X	
ET28 ; ET38			X					X			X	X
ET29			X					X			X	
ET37			X					X				X
ET40			X					X				X
ET39			X					X				X
ET42.1 ; ET42.2			X					X				X
ET43 ; ET44			X					X			X	X
ET47			X					X			X	
Polycarbonates											X	

Pre-heating conditions used for tests : 150°C / 30 mn (200°C / 5mn was too severe (melting of blankets) ;  
150°C / 10 mn was not estimated sufficient to stabilise the temperature of power wires.

# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test Results

Influence of test conditions  
(preheating, irradiance, type of ignition source)

### Standard conditions of the radiant panel test

Test samples	After flame time (secondes)	Comments
R17 ; R18 ; R19	0 ; 0 ; 0	
R20 ; R21 ; R23 ; R25	<b>144</b> ; <b>455</b> ; <b>153</b> ; <b>263</b>	Various configurations. Flame on cable ties and brackets
R22 ; R24	4 ; 6	Same configurations of test samples with <u>semi-metallic fasteners</u>
ET06	<b>460</b>	Flame on cable ties and brackets
ET07	<b>342</b>	Flame on cable ties and brackets

► No Flame propagation

► long after flame time on cable ties and brackets



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

**Influence of test conditions**  
(preheating, irradiance, type of ignition source)

### **Radiant Panel test + extended flame time (30s)**

Test samples	After flame time (secondes)
R21 (15s); ET14 (30s)	455 ; 453

► **No Flame propagation**

► **long after flame time on  
cable ties and brackets**



# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test Results

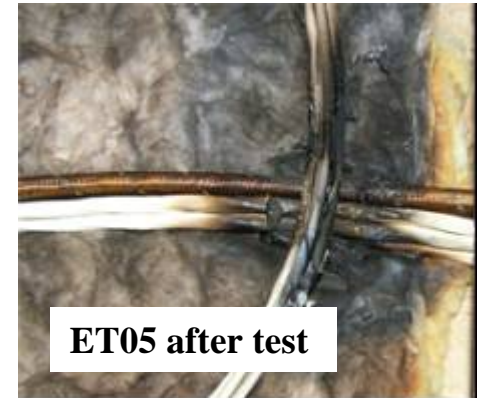
**Influence of test conditions**  
(preheating, irradiance, type of ignition source)

### Radiant Panel Pre-heating

Test samples	After flame time (secondes)	Comments
ET02	76 (blanket) 91 (cable ties)	- flame propagation on blanket (blanket not in conformity with the FAR/CS 25.856 - Flame on cable ties
ET03	36 (blanket) <b>164</b> (cable ties)	(same comments)
ET04	<b>177</b>	Flame on cable ties
ET05	<b>224</b>	Flame on cable ties

► No Flame propagation

► **long after flame time on**  
**cable ties and brackets**



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

Influence of test conditions  
(preheating, irradiance, type of ignition source)

### Thermal chamber Pre-heating (150°C / 30mn)

Test samples	After flame time (secondes)
ET16 ; ET24 ; ET25	32 ; <b>230</b> ; <b>137</b>
ET18 ; ET21 ; ET22	<b>229</b> ; <b>101</b> ; <b>356</b>
ET17 ; ET28 ; ET29	<b>296</b> ; <b>82</b> ; <b>103</b>
ET23 ; ET26 ; ET27	<b>117</b> ; <b>91</b> ; <b>97</b>



► No Flame propagation

► long after flame time on  
cable ties and brackets

# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test Results

**Influence of test conditions**  
(preheating, irradiance, type of ignition source)

### Thermal chamber Pre-heating (various conditions)

Test Samples	After flame time (s)	Comments
ET08	<b>711</b>	Thermal chamber preheating 200°C / 5mn
ET09	22	Thermal chamber preheating 150°C / 10mn
ET15	<b>410</b>	Thermal chamber preheating 200°C / 30mn
ET11 ; ET12 ; ET13	<b>469</b> ; <b>454</b> ; <b>553</b>	Same conditions with following preheatings : 200°C/5mn ; 150°C/30mn ; 150°C/30mn
ET10	<b>749</b>	Preheating 50°C (simulating working T° of a cable)

► No Flame propagation

► long after flame time on cable ties and brackets

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

Influence of test conditions  
(preheating, irradiance, type of ignition source)

### Effect of the Radiant Panel Heat Flux :

Test samples	After flame time (secondes)	Comments
ET22 ; ET46 ; ET49	<b>356</b> ; 9 ; 0	Same combinations tested under : 1.7 W/cm <sup>2</sup> ; 2W/cm <sup>2</sup> et 2.2W/cm <sup>2</sup>
ET20 ; ET45 ; ET48 et ET50	<b>388</b> ; <b>406</b> ; <b>397</b> et <b>238</b>	Same combinations tested under : 1.7 W/cm <sup>2</sup> ; 2W/cm <sup>2</sup> , 2.2W/cm <sup>2</sup> et 2.2 W/cm <sup>2</sup>
ET29 ; ET47	<b>103</b> ; <b>263</b>	Same combinations tested under : 1.7 W/cm <sup>2</sup> et 2 W/cm <sup>2</sup>

► No Flame propagation

► long after flame time on  
cable ties and brackets

→ These test results **don't show any effect of radiant panel heatflux.**

→ The increase of 30% of the heatflux seems to be without effect on fire behaviour of these materials

## ► Test Results

### Electrical ignition sources

► No Flame propagation

► long after flame time on  
cable ties and brackets

Test samples	After flame time (secondes)	Comments
ET31 ; ET32	<b>116 ; 523</b>	2 electrodes / U=5kV : Chamber preheating 150°C / 30mn Flame on cable ties and bracket at 22s
ET34 ; ET35 ; ET41	- ; -	1 electrode U=70V / I=4A : No flame
ET39	<b>490</b>	1 electrode U=70V / I=4A : Flame on cable and bracket
ET42.1 ; ET42.2	- ; <b>415</b>	1 electrode U=70V / I=4A : ET42.2 : small flames at 31s, 51s then the flame is well established at 155s (cable tie)
ET37 ; ET38 ; ET40	- ; <b>180 ; 520</b>	Platinum filament under 4A : ET37 : blanket ET38 = ET37 + cables and cable ties (flame on cable ties) ET40 : Flame on bracket
ET43.2 ; ET44	-	1 electrode U=70V / I=4A (electrode is a file to simulate a wear motion) : - no flame, but cable ties and bracket not use on these test samples
ET33		2 electrodes U=28V + capacitor discharges : Not relevant test : welding of the electrodes / melting of the cable ties.





# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

### Influence of test conditions

(preheating, irradiance, type of ignition source)

### Electrical ignition sources (remark)

- The electrical ignition sources (arc or filament) were applied until to set fire.
- The test repeatability was not good (manual control) and without sufficient information about the current (level and type) to be used, the test results may be not representative of an actual configuration.

➔ A specific study would be useful to assess the risk to set a fire with an electrical source.

➔ However, these tests has shown that it is possible to set a fire on cable ties and brackets with an electrical source.

# FIRE BEHAVIOUR OF MATERIALS

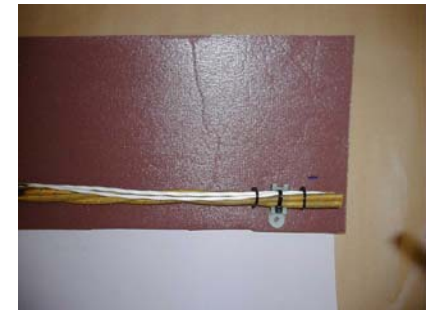
## Installed in HIDDEN AREAS

### ► Test Results

Influence of test conditions  
(preheating, irradiance, type of ignition source)

### Effect of Pre-heating :

Test samples (same configuration)	After flame time (secondes)	Comments
ET10	<b>749</b>	Thermal chamber preheating 50°C / 10mn
ET09 ; ET21 ; ET22	22 ; <b>101</b> ; <b>356</b>	Thermal chamber preheating 150°C / 10mn
ET08	<b>711</b>	Thermal chamber preheating 200°C / 5mn
ET15	<b>410</b>	Thermal chamber preheating 200°C / 30mn



► No Flame propagation

► long after flame time on cable ties and brackets

➔ No effect of pre-heating conditions.

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

### Fire behaviour of materials

#### Insulation blankets & foams :

Whatever the test configuration, the flame remained around the cable ties / brackets and did not propagate.

(blankets and foams used for test samples were in accordance with the FAR 25.856a requirements)

► No Flame propagation



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

### Fire behaviour of materials

#### Electrical wires :

► No Flame propagation

➔ Whatever the test configuration, there was no critical behaviour on any type of electrical wire



ET23



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

### Fire behaviour of materials

#### Cable ties & brackets :

→ **All types of wire fasteners** (except semi-metallic) have shown a weakness with the radiant panel test.

→ **Up to 12 minutes of after flame** has been noted (average of 3 to 4 minutes)



► **No Flame propagation**

► **Long after flame time**



# FIRE BEHAVIOUR OF MATERIALS

## Installed in HIDDEN AREAS

### ► Test Results

#### Fire behaviour of materials

### Cable ties & brackets :



ET17 test sample before,  
during and after test  
(after flame : 4mn56s)

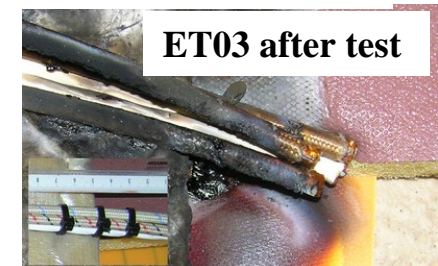
► **Complete combustion of  
cable tie & holder**



after flame : 3mn44s



after flame : 2mn44s



# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results

### Fire behaviour of materials

#### Cable ties pitch :



Various configurations of assemblies were evaluated (with various cable ties pitches ) in order to determine a critical distance leading to flame propagation.

➔ The tests did not show any propagation (minimum distance evaluated : 1 cm )



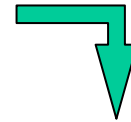
# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results Fire behaviour of materials

### Cable ties / Brackets / Holders :



### Critical behaviour



Complementary tests were carried out to evaluate the auto-extinguibility of these items (bunsen burner test).

P1 : Green cable holder (L 4 cm)
P2 : Green cable holder
P3 : Orange bracket (polyamide)
P4 : PEEK cable holder
P5 : Polyamide cable tie
P6 : silicone / metal cable tie

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

## ► Test Results Fire behaviour of materials

### Cable ties / Brackets / Holders :

	After flame time (s)	Glow time (s)	Drip extinguishing time (s)
P1 : Green cable holder (L 4 cm)	5	0	1
P2 : Green cable holder	3	0	0
P3 : Orange bracket (polyamide)	2	0	0
P4 : PEEK cable holder	4	0	1
P5 : Polyamide cable tie	4	0	1
P6 : silicone / metal cable tie	12	0	0
<b>Requirements</b>	<b>15</b>	<b>/</b>	<b>5</b>



➔ self –extinguishing  
when there are subjected  
to the bunsen burner test  
conditions

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS

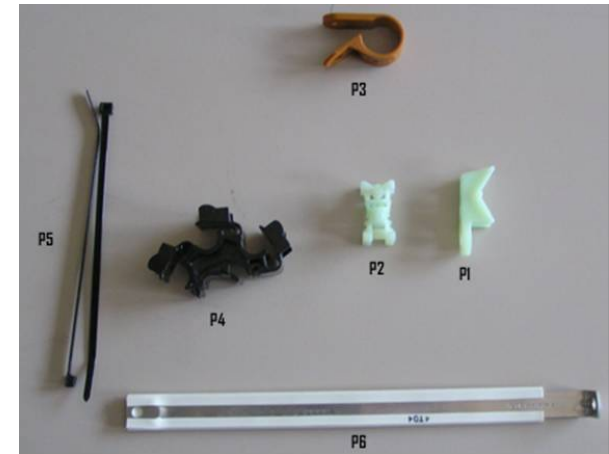
## ► Test Results Fire behaviour of materials

### Fasteners : Cable ties / Brackets / Holders

→ Most of these parts burn completely (after-flame up to 12 mn (3 to 4 mn on average))

→ Even if these parts are regarded as small parts, they contribute to increase the fire hazard.

→ They could, when exposed to an ignition source, become a fire source since they are not self-extinguishing according to the radiant panel test conditions.





# **FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS**

## **► CONCLUSIONS**

**→ All the series of tests carried out with the radiant panel show that the wires themselves fitted on airplanes contribute neither in after flame nor in flame propagation.**

**→ This study highlights a weakness in the fire behaviour of all the wire fasteners.**

**► important after flame time**

**► not self-extinguishing under the Radiant Panel test conditions**

**However, since the insulation blanket is in accordance with the FAR25.856, the flame remained locally around the fasteners and did not propagate.**



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MINISTÈRE DE LA DÉFENSE



## Toulouse Aeronautical Test Centre (CEAT)

« Fire Safety Department »

# FIRE BEHAVIOUR OF MATERIALS Installed in HIDDEN AREAS



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