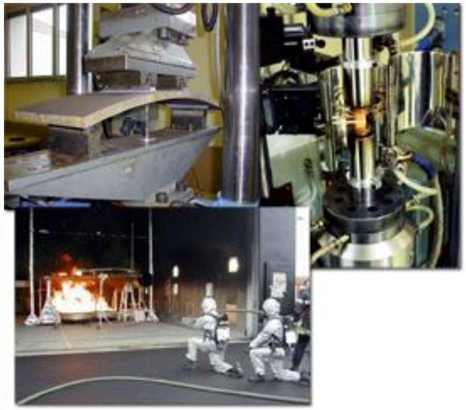

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RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE LA DÉFENSE

DGA Aeronautical Systems

« Fire Safety Department »

ALTERNATIVE JET FUELS
Effect of a fuel change on aircraft fire safety

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INERIS
maîtriser le risque
pour un développement durable

DGA

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→ Background

European projects

Some recent European programs have addressed the development of Alternative Jet Fuels (AJF) (fuels not derived from petroleum with properties similar to kerosene)

- SWAFEA (Sustainable Way for Alternative Fuels and Energy for Aviation) : Feasibility study based on available technologies, www.swafea.eu (completed in 2011)

- ALFA-BIRD (Alternative Fuels and Biofuels for Aircraft Development) : R&D project for the development of viable technical solutions compatible with current civil aircrafts. www.alfa-bird.eu-vri.eu (completed in 2012)

→ Background

Jet Fuel qualification process

- Petroleum-derived jet fuels and current alternative fuels have been qualified according to the ASTM D1655 specifications

- Future alternative fuel will be qualified according to the ASTM D4054 "Guideline for the Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives"

Currently, the qualification criteria are mainly based on fuel performances / engine compatibility.

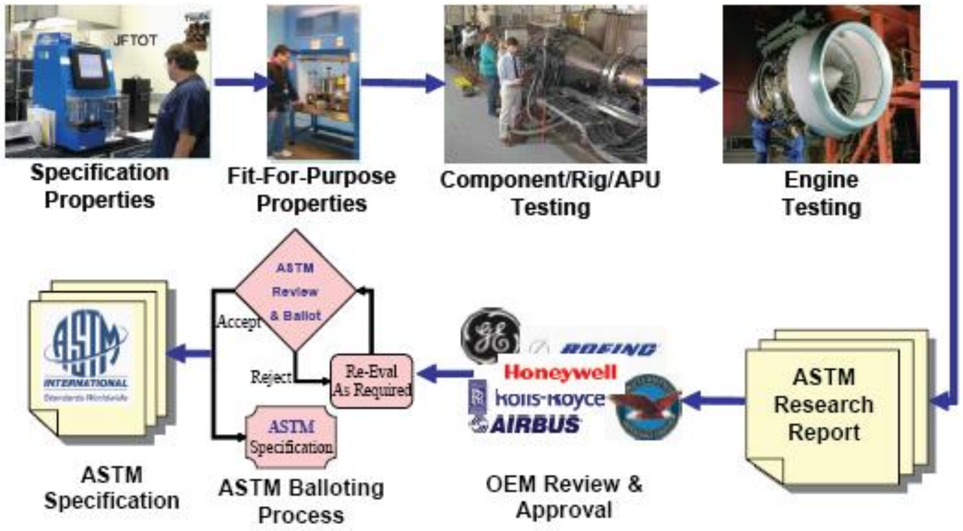


Figure 12: Industry aviation fuel qualification process.
(IATA 2009 – Report on alternative fuels)

→ Background

Cabin safety

Assessment of the fire safety risks in presence of a post-crash fire is essential to manage the cabin safety

- Fire resistant materials requirements were initially defined based on large scale tests using <u>kerosene fuel</u> and led to the <u>current standard tests</u> and to the <u>performance criteria</u> needed to reach the safety requirements

- Currently, <u>kerosene</u> is used to perform these tests to <u>assess the fire behavior of materials</u> against the post-crash fire threat and to <u>assess the aircraft equipment in fire zones</u>

Alternative Fuels and Biofuels for Aircraft Development

Alfa-Bird

Grant Agreement No. ACP7-GA-2008-213266

Framework of the study and objectives

These works were performed by DGA Aeronautical Systems with the support of INERIS (French Institute of Industrial Environment and Risks) in the framework of the alfa bird program to assess the effect of a fuel change on the fire safety, beyond the fire and explosion safety related questions already addressed in the initial program.

These works were performed with the following objectives :

- ✓ **Evaluate the effect of a fuel change on the characteristics of a post-crash fire**
- ✓ **Evaluate the impact on the fire resistance level of materials and aircraft equipment**

to be able to answer to the following questions :

- ✓ **Does a fuel change have an effect on the cabin and flight safety levels (post crash or engine fire)?**
- ✓ **And determine if actions are necessary to keep the current performance and safety level**

Alternative Fuels and Biofuels for Aircraft Development

Alfa-Bird

Grant Agreement No. ACP7-GA-2008-213266

Alternative Jet Fuels (AJF)

Four AFs were delivered to DGA Aeronautical Systems :

➔ **A high aromatic content AF (~10 % v/v of aromatics)** *Réf: 8040*

➔ **A middle aromatic content AF (~5% v/v of aromatics)** Réf: 8426

➔ **A low aromatic content AF (< 0.1 % v/v of aromatics)** *Réf : 8286*

➔ **A low aromatic content AF (< 0.1 % v/v of aromatics) blended with an oxygenated compound** *Réf: 8291*

Tests were also performed on Kerosene F34 (NATO ref. of US JP-8) and JET A1 for comparison

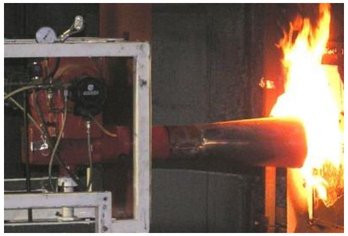
The following tests were carried out using the 4 selected alternative jet fuels in comparison with Kerosene

✓ **ISO 2685 (fire resistance test for materials and equipment in fire zones) : (Park Burner) (1100°C / 11.6 W/cm²)**
- 2024 aluminium plates of 2mm thickness

✓ **FAR/CS 25.856b AppF part VII (burnthrough test) : (NexGen Burner) (1038°C)** (≈ 18 W/cm²)
- Thermal insulation blankets
- 2024 aluminium plates of 3mm thickness

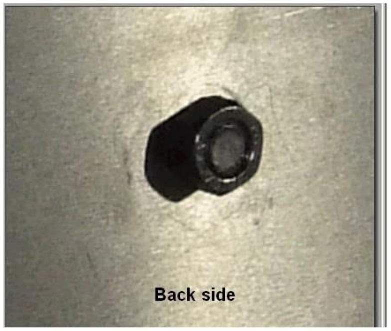
✓ **Characterisation of 2m² pan fires**

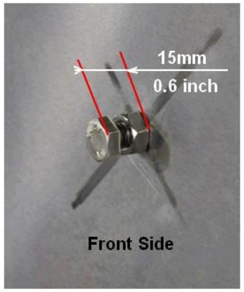
ISO 2685 tests
Park Burner



Test samples :

2024 aluminium plate 60 x 60 cm / 2mm thickness
(with a bolt fitted in the center of the plate to simulate the critical part to be tested and improve the repeatability of the tests)





Fuels :

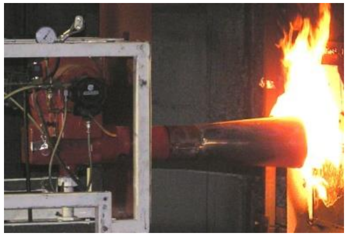
➔Reference : Kerosen F34 (NATO reference equivalent to US JP-8)
➔4 Alternative fuels : 8426 / 8040 / 8291 / 8286 (ALFA BIRD codes)

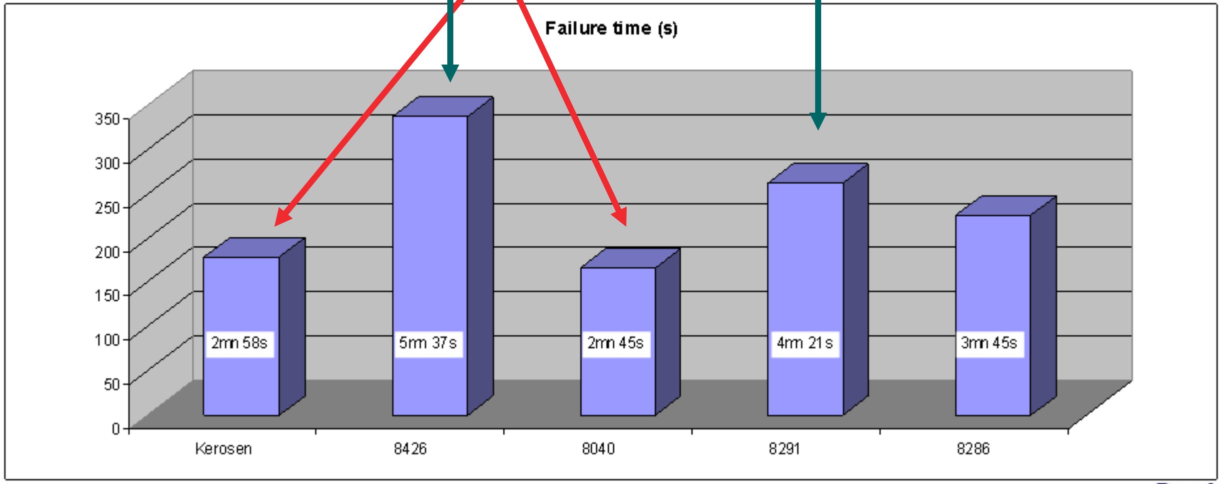
ISO 2685 tests results

Fuel	Flow rate (l/h)	Flame T° (°C)	Heat Flux Density (W/cm2)	Soot on the test sample	Burnthrough time (s)	Fall of the bolt (s)
Kerosen F34	8,4	1059	11,6	Very much	170	178
8426	8,5	1084	11,6	Not much	336	337
8040	8,6	1088	12,1	Much	156	165
8291	8,5	1042	11,4	Not much	235	261
8286	8,7	1093	12	Much	224	225

Oil flow rates are similar / Heat Flux Density and flame T° are in accordance with the calibration requirements

→ Failure times vary from 2mn 45s to 5mn 37s (> 100%)
→ Early failures with oils releasing smoke and soot (kerosene and 8040)
→ Best performances with alternative oils releasing few smoke





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Burnthrough tests
NexGen Burner

Test samples :

2024 aluminium plate 60 x 60 cm / 3mm thickness
(the fail criterion was the time of flame penetration)

Fuels :

➔Reference : Kerosene F34 (NATO reference equivalent to US JP-8)
➔4 Alternative fuels : 8426 / 8040 / 8291 / 8286 (ALFA BIRD codes)

Tests were also carried out on 2 kinds of insulation blankets but the test results are not usable. For all fuels :
- 1st material failed after less than 10s !!!
- 2nd material was not penetrated after 6mn of test

Setting of the NexGen Burner

➔ The NexGen burner was set according to the specifications of the burnthrough test methods for the Kerosene.

➔ The tests were performed using the Kerosene and the other fuels without any additional adjustments.

➔ Before each tests (for all fuels):

- Pressures & T° (Air / Fuel) were checked (and were in accordance with the specifications),
- The flame T° was noted.

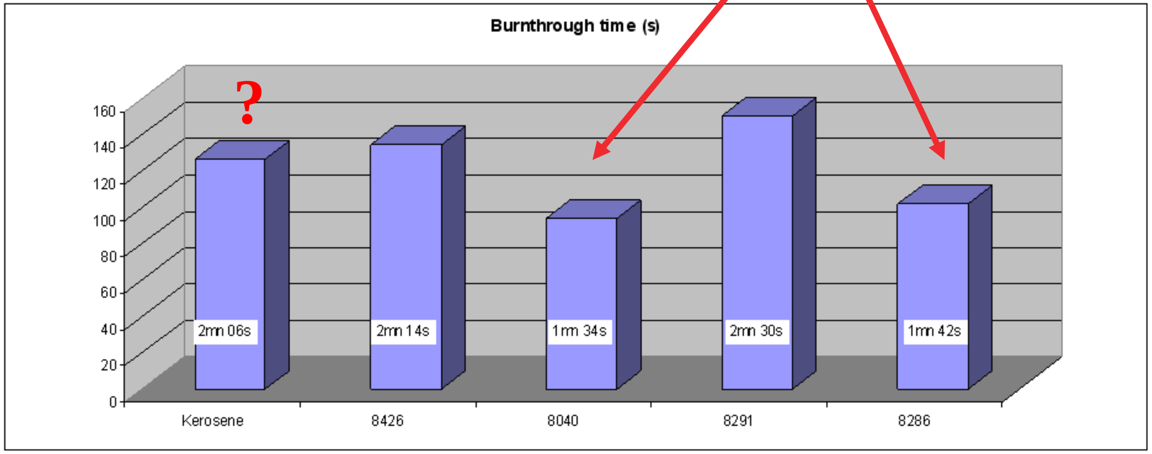
Burnthrough tests results

Fuel	Burnthrough Time (s)
Kérosène F34	126
8426	134
8040	94
8291	150
8286	102

→ Failure times vary from 1mn 34s to 2mn 30s

→ Again, alternative fuels releasing smoke and soot produce the more severe effect and show significant differences on the test results (up to 60%)

→ Additional series of tests have been performed to confirm the ranking (due to the "good" performance of the kerosene which releases as much smoke / soot than 8040 and 8286 fuels but shows a late penetration)



Burnthrough tests results (additional tests)

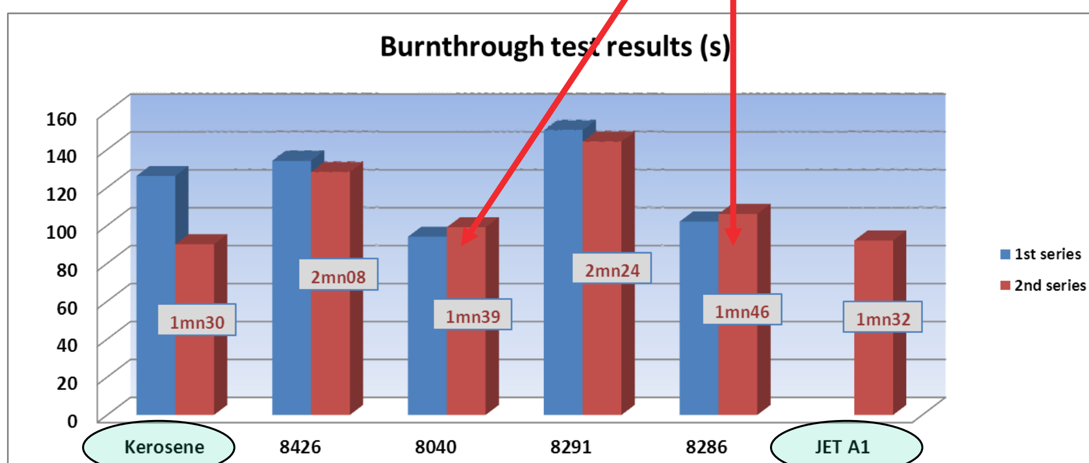
Essais complémentaires du 03/09/12			
	T moy	Burnthrough time (s)	
Kerosene	1031	90	1mn30
8426	1011	128	2mn08
8040	1026	99	1mn39
8291	1003	144	2mn24
8286	1023	106	1mn46
JET A1	1034	92	1mn32

→ **Failure times vary from 1mn 30s to 2mn 24s**

→ **The additional tests show a very good repeatability of the test results with alternative fuels**

→ **These tests show that Kerosene and Jet A1 are more severe than alternative fuels**

→ **The additional tests clearly show that fuels releasing smoke and soot produce the more severe effect (up to 60% on the burnthrough time)**

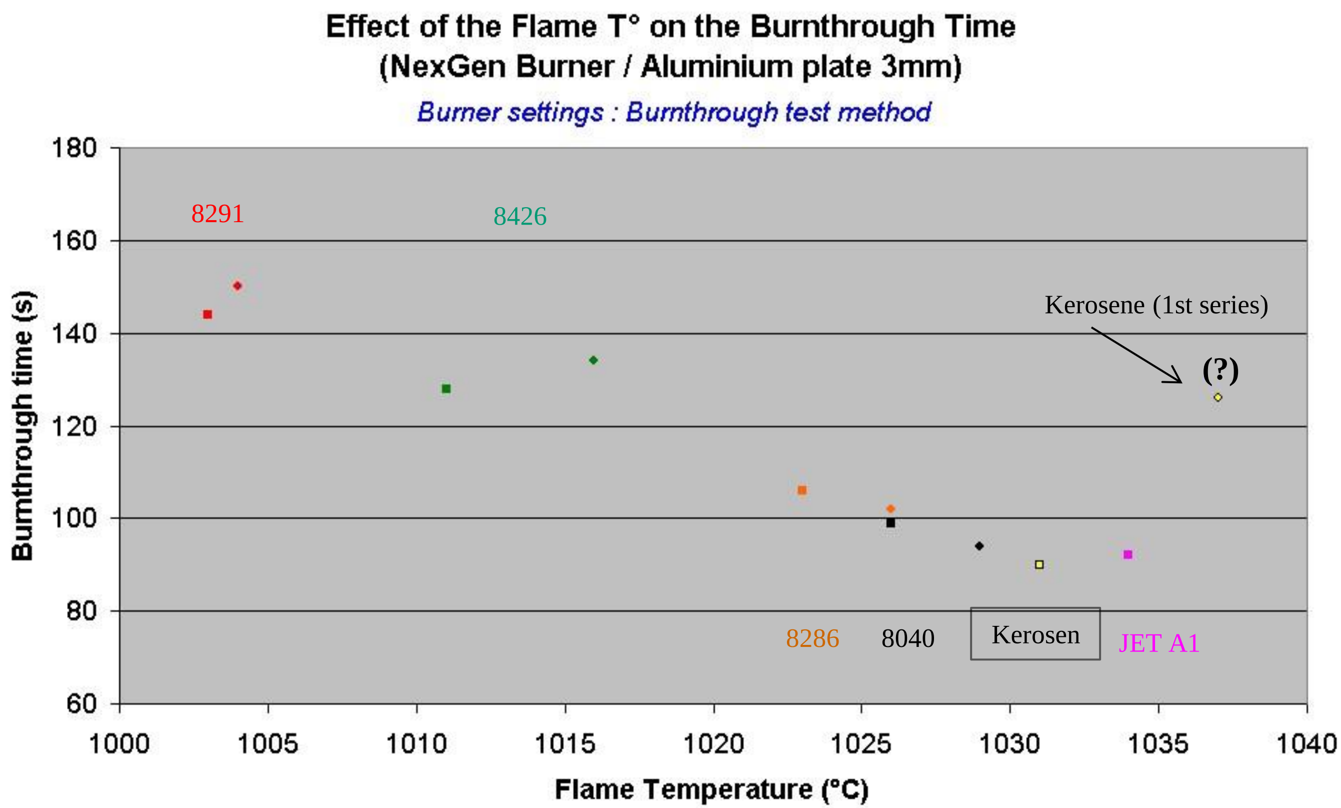


Burnthrough tests results

The whole of the test results clearly shows :

→ **The good repeatability of the test using the NexGen Burner**

→ **An effect of the T° on the burnthrough time (up to 65% for a gap of T° of less than 40°C)**



Comparative assessment of a pool fire (test method)

A 2m² pan with 6 litres of fuel on a layer of water were used for the characterisation of a pool fire representative of a post-crash fire.

This test configuration allows a stability of the flame of about 50s to measure the characteristics of the flame.

2 pan fire tests performed for each fuel to verify the repeatability of the test.

Fuels :

➔Reference : Kerosene F34 (NATO reference equivalent to US JP-8)
➔4 Alternative fuels : 8426 / 8040 / 8291 / 8286 (ALFA BIRD codes)

Comparative assessment of a pool fire
(test method)

Recorded parameters :

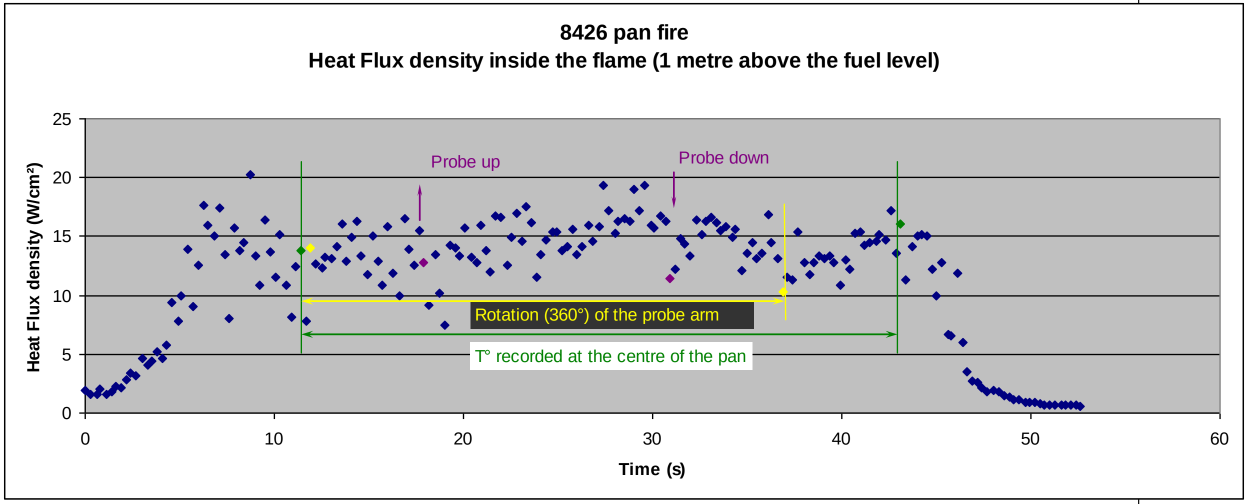
➔ Temperature and heat flux density inside the flame (1 metre over the fuel surface).

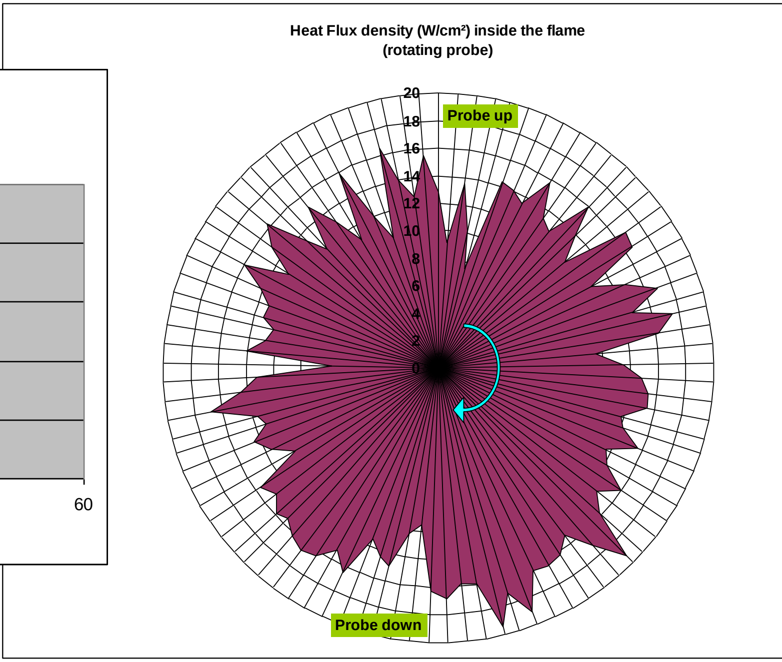
The temperature and heat flux probes are fitted on a rotating arm allowing to record these parameters from any direction,

➔ Heat radiation of the flame (1 metre from the edge of the pan / 1 metre over the fluel level).

Comparative assessment of a pool fire (test method)

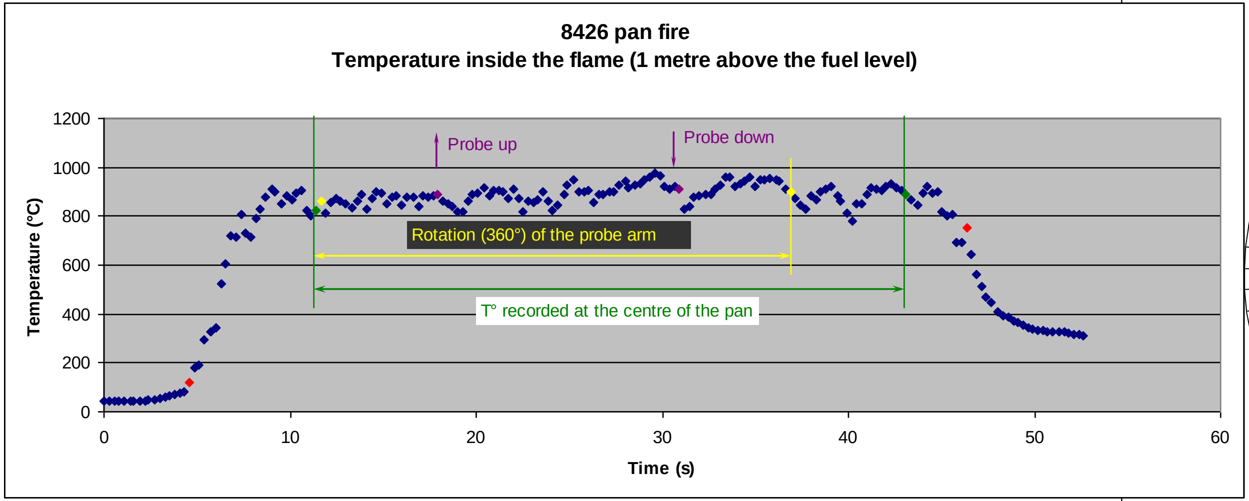
Heat Flux density measurement inside the flame :

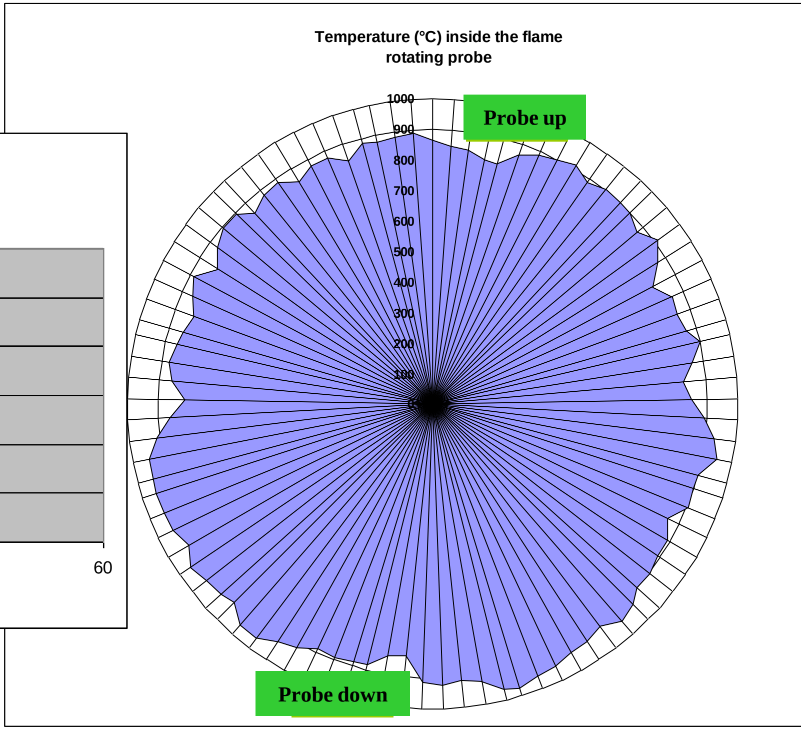




Comparative assessment of a pool fire
(test method)

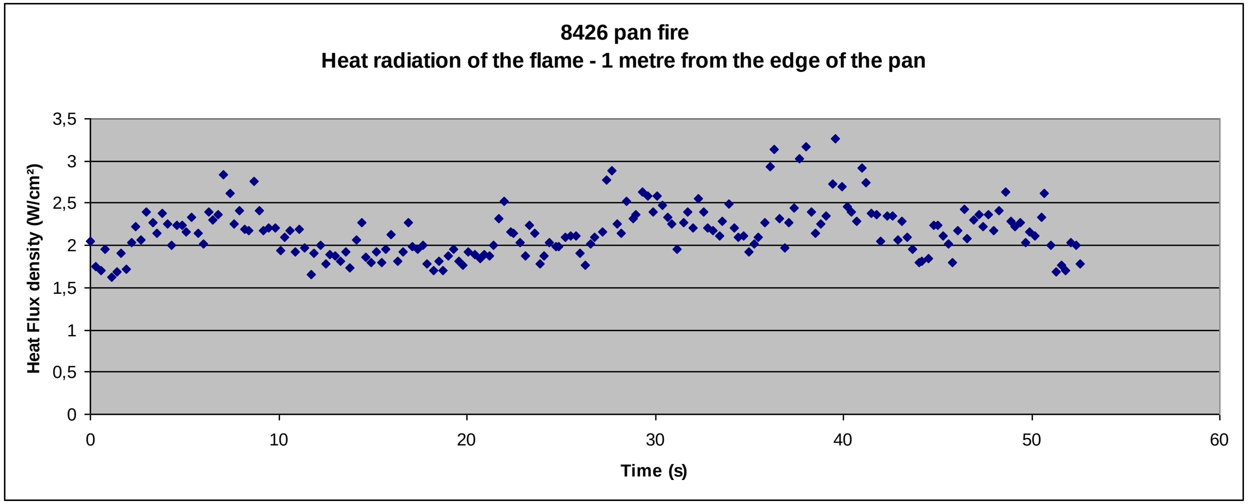
Temperature measurement inside the flame :





Comparative assessment of a pool fire (test method)

Heat radiation of the flame (1 meter from the edge of the pan) :



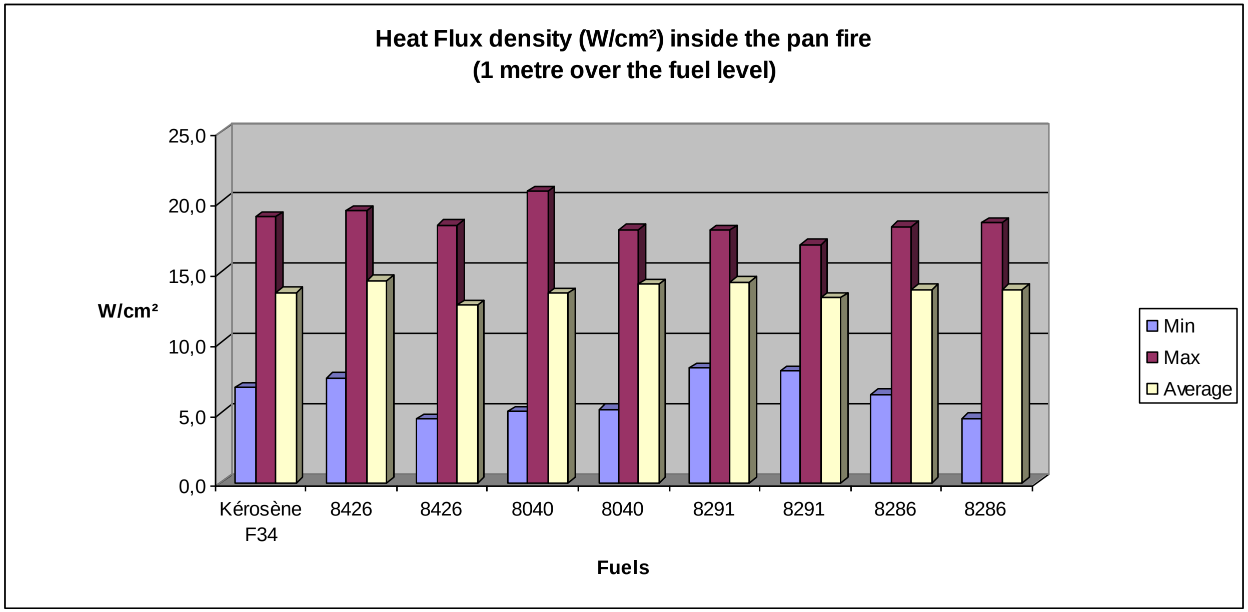
Comparative assessment of a pool fire

TEST RESULTS

Heat Flux density inside the flame :

➔ mini/max differences are due to the flame "pumping" phenomenon,

➔ values do not show significant differences among the various fuels

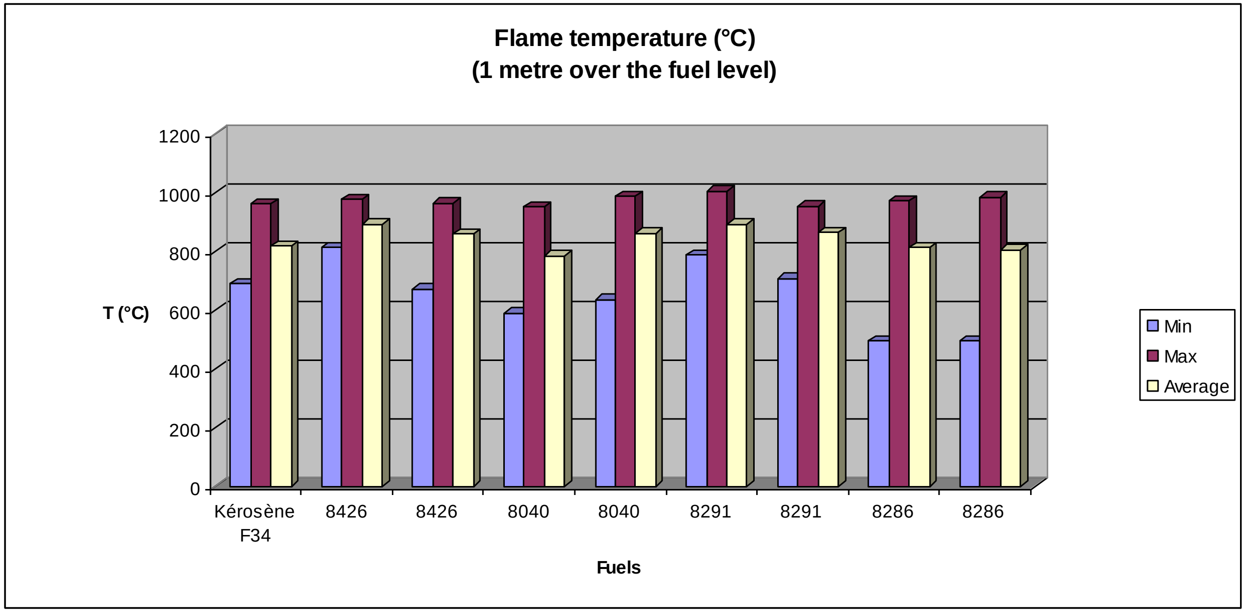


Comparative assessment of a pool fire

TEST RESULTS

Flame temperature :

➔values do not show significant differences among the various fuels

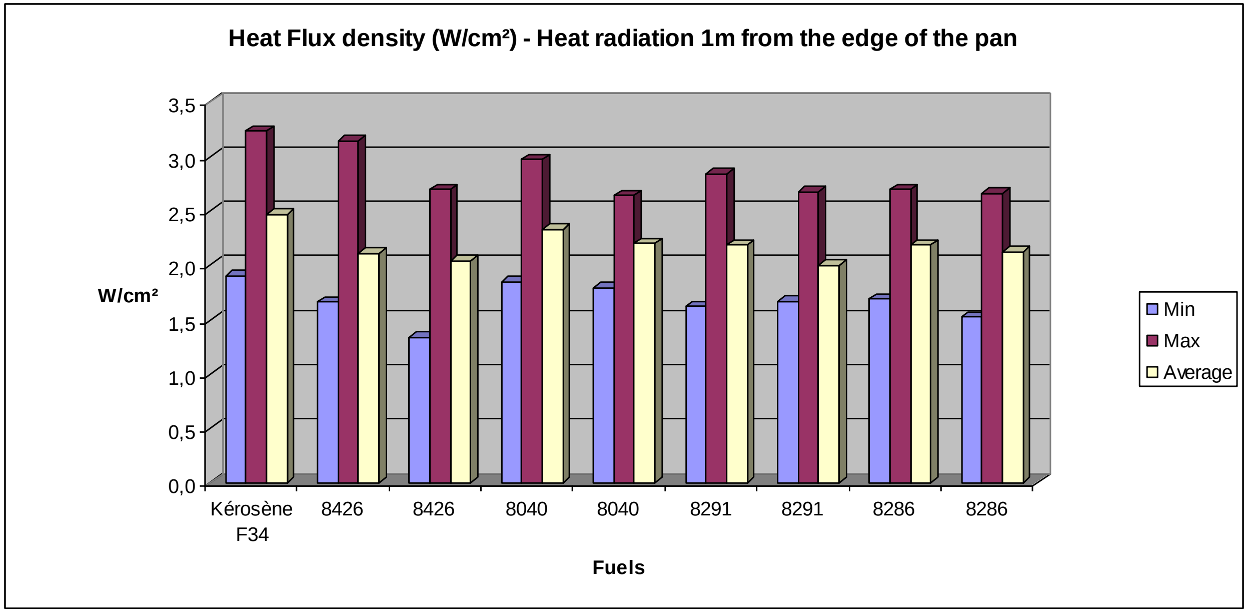


Comparative assessment of a pool fire

TEST RESULTS

<u>Heat radiation (1m from the edge of the pan)</u> :

➔Again, values do not show significant differences among the fuels



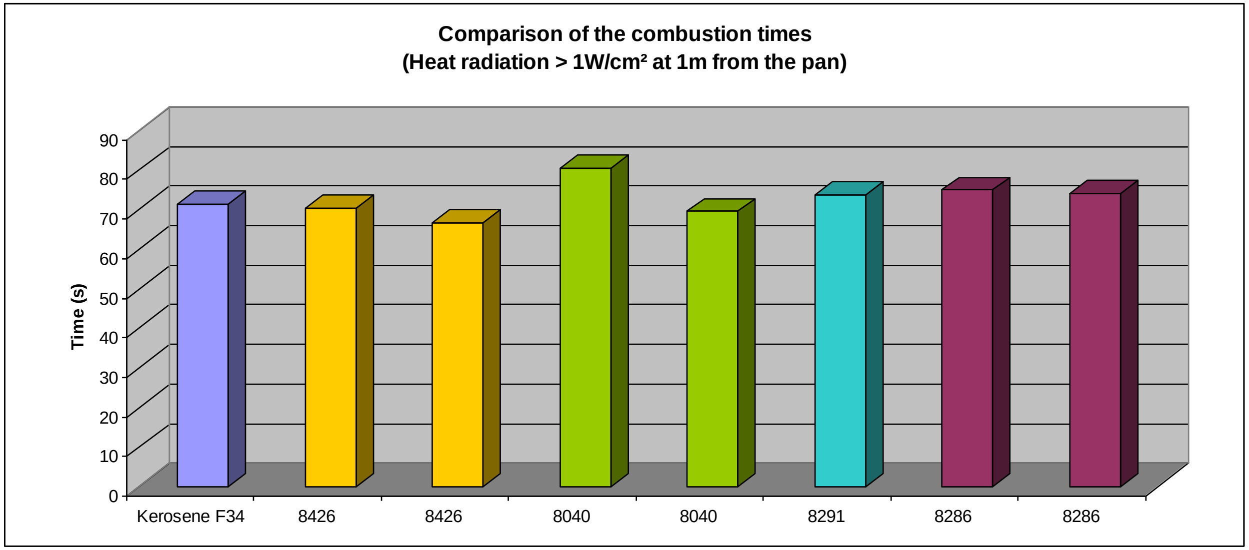
Comparative assessment of a pool fire

TEST RESULTS

<u>Comparison of the burning rate</u> :

Estimation of the burning rate of the various fuels can be made by comparing their combustion time

➔Again, does not show significant differences among the fuels



Conclusions

Effect of a fuel change on the characteristics of a post-crash fire

➔ All fuel fires have the same measured characteristics (burning rates / temperatures / heat radiation (inside and outside the fire))

➔ Differences were noticed on the amount of smoke released

Even if fuel fires have the same measured characteristics they may not have the same effect on the fire performance of equipment due to the soot left on during their exposure.

Impact on the fire resistance level of materials and equipment

➔ Significant differences depending on the fuel used to fuel the burner (up to 100% on the failure time (ISO 2685 tests) / up to 60% on the burnthrough time).

➔ Seems to confirm the significant effect of the released soot on the level of performance of the equipment to be tested.

Conclusions

Effect of alternative jet fuels on aircraft fire safety

Does a fuel change have an effect on the cabin and flight safety levels (post crash or engine fire)?
➔ Probably not for the tested fuels which release a low amount of smoke
(need to be confirmed for smoky fuels)

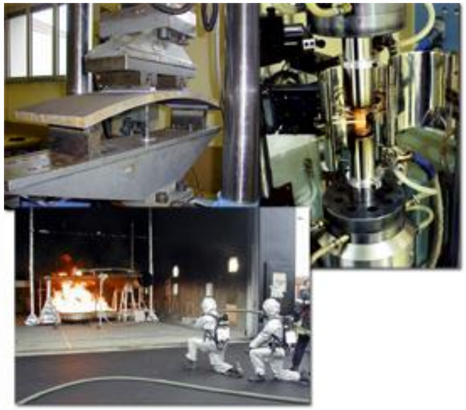
Are actions necessary to keep up the current performance and safety level ?
➔ Prioritize fuels with low amount of smoke
➔ Include a smoke specification in the qualification process of jet fuels (?)
➔ Could be useful to quantify the real effect of the smoke/soot of a fuel fire, on the fire performance of equipment

ALTERNATIVE JET FUELS

Effect of a fuel change on aircraft fire safety

ACKNOWLEDGEMENTS

This study was carried out with the financial support of the European Commission through the Seventh Framework program for Research and Technological Development ACP7-GA-2008-213266 contract "ALFA-BIRD", the French Ministry of Defense and the French Ministry of Environment. We also thank the ALFA-BIRD fuel suppliers who provided candidate fuels for the various tests.



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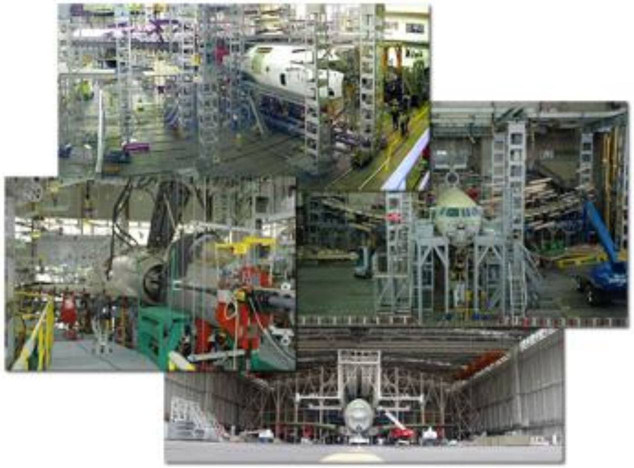

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