Toulouse Aeronautical Test Center (CEAT)

« Fire Safety Department »

AC 20-135 / ISO 2685

Fire tests on components used in fire zones.
Comparison of gas burner to oil burner.

Serge LE NEVE
E-mail : Serge.le-neve@dga.defense.gouv.fr
Various test methods, standards or guides are used to assess the fire behaviour of various components used in fire zones

✓ Aircraft Material Fire Test Handbook:

  Chapter 12 is used to determine the capability of components & constructions to control the passage of fire or its effects in powerplant compartments,

✓ AC 20.135:

  Guidance to demonstrate the compliance with the powerplant fire protection requirements of the FAR (materials & components used in engines & APU installations and in areas adjacent to fire zones).

✓ ISO 2685:

  Test procedure for airborne equipments to assess the fire resistance of components, equipments & structures located in “fire zones”.

➢ The ISO standard is often asked / used by airplane suppliers to show the compliance with the FAR / CS requirements
Various methods of Heat Flux calibration are specified to set the burners

- **Aircraft Material Fire Test Handbook Chapters 11 & 12 :**
  - requirement : > 10.6 W/cm² (9.3 Btu/ft².s) OR > 4500 Btu/hr
  - Heat Flux density is measured by a water-cooled calorimeter
  - Power is measured by the heat transfer device

- **AC 20.135 : requirement :** > 10.6 W/cm² (9.3 Btu/ft².s) OR > 4500 Btu/hr
  - Parameters are measured by the heat transfer device or calorimeter. AC 20.135 does not clearly specify if the heat flux density must be measured from a water-cooled calorimeter or if it can be calculated from the power measured by the heat transfer device.

- **ISO 2685 : requirement :** 11.6 W/cm² (+/- 1 W/cm²)
  - The Heat Flux density is calculated from the heat transfer device (the total heat recorded by the heat transfer device is supposed to come from the surface of the tube in front of the burner exit).

- **Requirements :** The choice is open (power or heat flux density)
- **Heat Flux density :** The choice is open for the device to use (water-cooled calorimeter or heat transfer device)
Various burners are described and/or approved

- **Aircraft Material Fire Test Handbook:**
  - Oil burner (such as Park PDL 3400) is described,
  - Gas burner (SAE AS401B Propane Burner) is also acceptable (chapt 12).

- **AC 20.135:**
  - Oil burner is described,
  - Gas burner is also acceptable.

- **ISO 2685:**
  - Oil burner or gas burner
    Can be used depending of the size of the critical part to be tested.
Various test configurations
(depending of the standard and the type of burner)

<table>
<thead>
<tr>
<th></th>
<th>Oil Burner</th>
<th>Gas Burner</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAR / CS (Handbook / AC 20-135)</td>
<td>4” (101,6 mm)</td>
<td>2” (50,8 mm)</td>
</tr>
<tr>
<td>ISO 2685</td>
<td>Env 100 mm (4”)</td>
<td>Env 75 mm (3”)</td>
</tr>
</tbody>
</table>
SUMMARY OF THE SITUATION

To test the same kind of components used in the same area (fire zones):

- Several standards or guidance providing:
  - 2 different methods of heat flux calibration,
  - 2 different burners,
  - Various test configuration (positions of the burner)

- But same acceptance criteria:
  - Fire resistant: 5 mn
  - Fireproof: 15 mn
Experiences with the Park burner has shown the difficulty to obtain the same test results using only one type of burner.

What about the test results with 2 so different burners used in accordance with various standards?

- **AS401B gas burner**
- **Park oil burner**
Some recent tests performed on real components according to ISO 2685:

- failed when performed with oil burners,
- passed when performed with gas burner.

CEAT ran a short preliminary study on simple test specimens to compare these various test configurations.
Test Program

Tested configurations (position of the burner):

- Oil Burner / d = 4 inches (ISO, FAA: Handbook, AC)
- Gas burner / d = 3 inches (ISO)
- Gas burner / d = 2 inches (FAA: Handbook, AC)

Tested samples

- Simulating critical areas to be tested
- Sizes of the samples / critical areas were in accordance with all test methods (< 2xS_burner)
**Flame calibrations**

- **T° Gas Burner**
  - ISO requirement: 1100°C +/- 80°C
  - *Gas Burner*: av. flame T° = 1065°C
  - *Oil Burner*: av. flame T° = 1038°C
  - dist. Burner = 3 inches

- **T° Oil Burner**
  - *Gas Burner*: av. flame T° = 1065°C
  - dist. Burner = 4 inches

**Comparison of gas burner to oil burner**

AC 20-135 / ISO 2685
- **Heat Flux – Gas Burner**

  ![Flame calibrations](image)

  **Calculated heat flux density**
  
  \[
  \text{Flux (W/cm}^2\text{)} = \frac{\text{dist. Burner = 3 inches}}{\text{Temps (s)}}
  \]

  **Recorded power**: 2284 Btu/h

  - **Gas Burner**: av. heat flux = 11.65 W/cm²
  - **Oil Burner**: av. heat flux = 12.43 W/cm²

- **Heat Flux – Oil Burner**

  ![Flame calibrations](image)

  **Calculated heat flux density**
  
  \[
  \text{Flux (W/cm}^2\text{)} = \frac{\text{dist. Burner = 4 inches}}{\text{Temps (s)}}
  \]

  **Recorded power**: 4478 Btu/h

ISO requirement: 11.6 W/cm² +/- 1 W/cm²
### Tests on small 2024 aluminium plate

A 1.2mm aluminium plate is fitted behind a 3mm steel plate, simulating a critical area to be tested.

#### Dist. Burner = 3 inches

**Gas Burner**

- Melting (s): 290
- Burnthrough (s): > 600

**Oil Burner**

- Melting (s): 290
- Burnthrough (s): > 600

#### Dist. Burner = 4 inches

**Gas Burner**

- Melting (s): 309
- Burnthrough (s): > 600

**Oil Burner**

- Melting (s): 315
- Burnthrough (s): > 600

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<table>
<thead>
<tr>
<th></th>
<th>Oil Burner</th>
<th>Gas Burner</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test 1</td>
<td>Test 2</td>
</tr>
<tr>
<td>Fire resistant (5mm)</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Burnthrough</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>Fire resistant (5mm)</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>Fusion</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Behaviour at 10mm</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>Burnthrough</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

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**Comparison of gas burner to oil burner**

- Melting (s): 281
- Burnthrough (s): 281

- Melting (s): 275
- Burnthrough (s): 436

- Melting (s): 246
- Burnthrough (s): 246
Tests on small 2024 aluminium plate

### Melting time (s)

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Gas Burner</th>
<th>Oil Burner</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>100 - 150</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>150 - 200</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>200 - 250</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>250 - 300</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>300 - 350</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>350 - 400</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>400 - 450</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>450 - 500</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>500 - 550</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

### Av. burnthrough time (s)

<table>
<thead>
<tr>
<th>Burner</th>
<th>Time (s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>&gt; 308</td>
<td>Pass : 3 samples</td>
</tr>
<tr>
<td>Oil</td>
<td>&gt; +280s</td>
<td>Fail : 2 samples</td>
</tr>
</tbody>
</table>

**Melted areas**

- **Gas Burner**
- **Oil Burner**
Tests on aluminium tube – ISO 2685 standard

- Dist. Burner = 3 inches
- Nut & bolt simulating a critical part
- L = 30 cm / Ø = 10 cm / th. = 1.2 mm
- Failure time: burnthrough / fall of the bolt

- Dist. Burner = 4 inches
- Failure time:
  - 1mn 42 s (+45%)
  - 1mn 10 s

AC 20-135 / ISO 2685
Comparison of gas burner to oil burner

CEAT / Fire Safety Department
International Aircraft Materials Fire Test WG - Atlantic City - Oct 08

MINISTÈRE DE LA DÉFENSE
DGA
Tests on 2024 aluminium former – ISO 2685 standard

Failure time: > 15 mn

Fire resistant (5mn): Pass

Fire proof (15mn): Pass

Nut & bolt simulating a critical part

Thickness = 5 mm

Failure time: fall of the bolt

Failure time:

4 mn 45 s

Fire resistant (5mn): Fail

Fire proof (15mn): Fail
Comparison of failure times

In all cases, the gas burner is less severe.
Comparison of the ISO gas burner flame
To
FAA Handbook / AC 20.135 requirements

Heat flux Mapping (gas burner)
(horizontal centre line)

- Maximum Heat-Flux: 10.76 W/cm²
  Handbook/AC requirements: ≥ 10.6 W/cm²

- Power: 2698 Btu/h (+20%)
  ISO calculated heat flux: 13.76 W/cm²

The gas burner is in accordance with the AC /
Handbook requirement
But the heat flux peak is thin

Burner setting according to the ISO specification

Flame measurement according to AC 20.135
(d = 2 inches)
Comparison of the ISO gas burner flame
To
FAA Handbook / AC 20.135 requirements

ISO 2685 standard configuration

ISO flame settings + AC 20.135 test configuration (d = 2 inches)

- **Failure Time:** > 15 mn
  - Fire resistant (5mn): Pass
  - Fireproof (15mn): Pass

ISO & AC 20.135 configuration (Oil Burner)

- **Failure Time:** 4 mn 45 s
  - Fire resistant (5mn): Fail
  - Fireproof (15mn): Fail
Comparison of gas burner to oil burner

Comparison of failure times

Comparison of Failure Times

- ISO gas burner at d = 3 inches
- ISO gas burner at d = 2 inches

If used at d = 2 inches from the test sample
- ISO gas burner is in accordance with AC/Handbook requirements
- Gas burner & Oil burner test results are very close
Comparison of the ISO gas burner flame
To
FAA Handbook / AC 20.135 requirements

(ISO 2685 is often used by suppliers to demonstrate the compliance with the FAA / EASA requirements)

Heat flux Mapping
(center line (vertical impact position))

Handbook/AC requirements : \( \geq 10.6 \, \text{W/cm}^2 \)
(using a Heat Flux Transducer)

- Maximum Heat-Flux (gas burner) : 10.3 W/cm²

When the heat flux density is measured with a water cooled calorimeter :
- The gas burner is close to the AC / Handbook requirement
- But the heat flux peak is very thin
Comparison of the oil burner flame (set according to ISO 2685)  
To  
FAA Handbook / AC 20.135 requirements

Heat flux Mapping  

Handbook/AC requirements : ≥ 10.6 W/cm²  
(using a Heat Flux Meter)

• Maximum Heat-Flux : 9.8 W/cm²

When the Park Burner is set according to ISO 2685 specifications :

➔ The heat flux density is not in accordance with the Handbook / AC requirements.
T° (steel plate - 3mm 500x500 mm)

➢ Gas Burner

S : ≈ 28 inch²
(>5“x5“)

➢ Oil Burner
Comparison of gas burner to oil burner

IR mapping (steel plate - 3mm 500x500 mm)

- Oil Burner 1 mn
- Gas Burner 1 mn
- Oil Burner 3 mn
- Gas Burner 3 mn
- Oil Burner 5 mn
- Gas Burner 5 mn

- Estimated area >520°C:
  - Oil Burner: 189 cm² (~14cm x 14cm)
  - Gas Burner: 49 cm² (~7cm x 7cm)
Conclusion 1

These tests show that:

- Within the ISO 2685 standard, the gas burner flame is always less severe than the oil burner flame,
- Heat flux methods of measurement are not equivalent and the values of heat flux calibrations must not be compared,
- When the gas burner and oil burner are calibrated according to the ISO standard, their flames are not in accordance with the Handbook / AC 20-135 requirements,
Conclusion 2

Gas burner and oil burner are not equivalent

Gas burner:
- Could be used within the Handbook/AC on small items.
- Practical aspect: Should not be used on medium size items under the Handbook test configuration (d=2 inches) (too close to the burner => possible burner damages (heat concentration – radiation from the sample)
- When this burner is used, as specified in the various standards it should be used only on small critical parts
- Because of thermal diffusion effect, it should be allowed only on small items (gas burner should not be allowed to test large items with a small critical part, even if the critical part is at the centre line of the burner)
Conclusion 3

As the ISO standard is often used in substitution with the FAA guidances and as the gas burner can be less severe than the oil burner:

➤ The ISO 2685 standard and (or) the Handbook / AC should be revised to fix all these «anomalies»

➤ As the ISO 2685 is currently under discussion within the TC20 ISO committee, the French mirror committee will probably ask for a complete review
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