Fire Safety Assessment of Electrical Devices under regard of Airworthiness Authorities Requirements

Atlantic City, 25^{th}- 28^{th} October 2010
General – Cabin & Cargo Electrical Installations

Cockpit
- flight control units
- display units
- etc.

Cabin
- in flight entertainment
- Cabin inter-communication
- etc.

Cargo Areas
- door control units
- fire suppression system control units
- etc.

Topics
- Raising number of electrical devices
- Made from off-the-shelf products and components
- Great variety in design and installation location
- Devices are qualified according to DO160 using UL testing
- Raw materials are often not available for test samples
## General – Applicable Requirements Pressurized Area

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<th>Airbus Test Method*</th>
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<td>CS/FAR 25.853(a) &amp; App. F, Part I, §(a)(1)(i) to §(a)(1)(v) - Materials, Components</td>
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<td>AITM2-0003</td>
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<td>Toxicty</td>
<td>§4 - Materials, Components, Cables</td>
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* The referred Airbus test methods are derived from the airworthiness authorities test methods specified in CS/FAR§25 and FAA Fire Testing Handbook DOT/FAA/AR-00/12.
Fire Safety Assessment Process – Overview

1. Design Proposal
2. Device Analysis (I)
3. Test Selection (II)
4. Test Performance (III)
5. Test Results Evaluation (IV)

Safety analysis results are taken into account

Possibility of additional testing

Redesign

Fire Safety Interdiction

Fire Safety Clearance
Fire Safety Assessment Process – (I) Device Analysis

Fire Safety Concerns

Installation Zone

- Where is the device installation location?
  - pressurized section, hidden area, etc.
- How often is the device installed inside the aircraft?
- Are the installation locations accessible or permanent/non-permanent visible by crew or passengers?

Operating Parameter

- How are the operating parameters of the device?
  - power input, power output, etc.
- Is the device permanently on and working?
- How is the device secured against failure?
  - internal and/or external fuses, overheat protection, etc.

Housing Design

- How does the housing look?
  - dimensions, openings, etc.
- Which housing materials are used?
  - material specification, thicknesses, etc.
- How is the cooling of the device realized?
  - air cooling, heat-pipe method, etc.
- FST certificates are available for the used materials and parts?

# Fire Safety Assessment Process – (I) Fire Safety Categories

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<th>Recommended Criterions for</th>
<th>Fire Safety Accomplishment</th>
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<td>Installation Zone</td>
<td>Housing</td>
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<td>Fireworthiness Conformity *</td>
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<td></td>
<td>ABD0031 Conformity (Standard)</td>
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<td></td>
<td>Flame Spread Safe (equivalent or enhanced)</td>
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<tr>
<td></td>
<td>Fire Containment (equivalent or enhanced)</td>
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</tbody>
</table>

### Fireworthiness Conformity *
- accessible and permanently visible by crew or passenger
- overheated protection
- external and internal electrical fuse
- low power consumption (<20W)
- separate manual switch off
- material compliant with flammability (airworthiness standard)
- cooling by air venting or heat pipe
- fire stops when fire source vanishes
- smoke & toxicity gases can be released

### ABD0031 Conformity (Standard)
- accessible by crew or passengers during flight
- overheated protection
- external or internal electrical fuse
- moderate power consumption (<100W)
- material compliant with ABD0031
- cooling by air venting or heat pipe
- fire stops when fire source vanishes,
- smoke & toxicity gases are harmless and not released in significant quantities

### Flame Spread Safe (equivalent or enhanced)
- flight relevant systems nearby
- accessible by crew during flight (e.g. electronic compartments)
- secured by active fire safety means
- overheated protection
- external or internal electrical fuse
- shut down of forced venting
- nearly closed housing with small vent/decompression holes
- material compliant with ABD0031
- cooling by air venting or heat pipe
- fire kept inside housing
- no fire risk for materials or parts in surrounding
- smoke & toxicity gases can escape housing

### Fire Containment (equivalent or enhanced)
- flight relevant systems nearby
- inaccessible areas during flight (e.g. hidden area)
- no escaping smoke
- overheated protection
- external or internal electrical fuse
- completely closed
- material at least compliant with ABD0031
- cooling only by heat pipe principle
- fire & smoke kept inside housing

* Use of a devices inside Airbus commercial aircrafts that is certified only against airworthiness standards has to be allowed by exception permission from the responsible aircraft chief engineering department.
## Fire Safety Assessment Process – (II) Test Selection

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<tr>
<th>Fire Safety Level</th>
<th>Testing Methods (pp11 – 17)</th>
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<td>Flammability</td>
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<tr>
<td>Airworthiness Conformity</td>
<td>all materials &amp; parts*:</td>
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<tr>
<td></td>
<td>(1a), (1b), (3) &amp; (4)</td>
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<td>(1a), (1b), (3) &amp; (4)</td>
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<tr>
<td>Flame Spread Safe</td>
<td>only housing &amp; critical parts:</td>
</tr>
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<td>Fire Containment</td>
<td>only housing:</td>
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<td></td>
<td>(1a)</td>
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</table>

* Component parts inside a device can be regarded as „small parts“ that have not to fulfill flammability, smoke and toxicity requirements under certain circumstances. The way of handling is described in ABD0031, Issue G, chapter 2.2.5.1
Selection Criteria:

- made from non-metallic materials or contain flammable substances (e.g. thermoplastics, printed circuit boards, electrolyte containing condensers etc.)
- are larger in dimensions
- come in a larger quantity
- are placed at or nearby critical zones in the electrical device, (e.g. power supply, air venting holes)
- can contribute to flame propagation (e.g. cables, heat shrinkable tubing)
- carry larger amounts of energy (e.g. Li-Ion batteries)
Fire Safety Assessment Process – (III) Testing for Enhanced or Equivalent Fire Safety Demands

Critical Safety Analysis Factors

Need for enhanced or equivalent fire safety confidence

Critical Assessment Factors:

- hidden areas
- closeness to flight relevant systems or critical aircraft components
- critical operating parameters (e.g. high power consumption)
- Non-satisfactory fire safety compliances for used materials & parts

Enhanced Fire Safety Demands:

- fire shall stay inside housing
- smoke shall not be distributed inside aircraft
- possible malfunctions of switch-off routines shall be compensated
- relevant systems shall not be inflicted by incident
- missing fire certificates shall be compensated

Fire Containment Test

Flame Spread Test
Fire Safety Assessment Process – (IV) Test Evaluation

Safety Analysis Data
- Safety analysis data shall be comprehensible

Test Evaluation
- Tests shall be passed successfully
- No disaccords between tests results and risk analysis

Test Report Content
- purpose of testing
- designation, function and installation location of device
- unequivocal test specimen identification
- address of the fire test laboratory
- risk analysis derived requirements
- all test results

Test Report
- Completeness is guaranteed

Safety Analysis Data

Test Results

Fire Safety Clearance

Test Evaluation
- check if test results are correct and positive
- check if airworthiness requirements are fulfilled
- check if safety analysis requirements are fulfilled
Test Methods – (1a) Flammability  Testing Materials & Parts

Test Details

Materials & Boards without Components

Board with Components

- Flame applied to edge of tested component

Sample Layouts

Materials & Printed Circuit Boards

Condensers*

Connectors*

- 37,5mm
- 75mm
- 300mm
- burn length < 152mm
- after flame time < 15s
- after flame time drips < 3s

Testing in accordance to AITM2.0002B (12s vertical Bunsen burner testing)

* Condensers and Connectors have to be mounted in such a way that the complete row is filled

with protective coating as used in device

min 10mm

75mm
Test Methods – (1b) Flammability Testing Materials & Parts

Test Details

- Sample shall be tested in the same thickness as used in the device but not thicker than 3mm.

- Testing in accordance to AITM2.0003 (15s horizontal Bunsen burner testing)
  - Limits: Burn rate < 64mm/min

Sample Layouts

Generic test sample prepared for the test

- Sample shall be tested in the same thickness as used in the device but not thicker than 3mm.
Test Methods – (2) Smoke & Toxicity Testing Electrical Parts

Test Details

- Printed Circuit Boards
- Condensers*
- Connectors*

Sample Layouts

- 73mm
- 36,5mm

Testing in accordance with AITM2.0007 (smoke density) and AITM3.0005 (toxicity) in flaming & non-flaming mode.

Limits:
- Smoke density $D_m < 200$
- HF: 100 ppm
- HCl: 150 ppm
- HCN: 150 ppm
- $SO_2$: 100 ppm
- NO/NOx: 100 ppm
- CO: 1000 ppm

* Condensers and Connectors have to be mounted in such a way that they cover a surface area of app. 63mm x 63mm with no gaps in between.

At each edge 5mm have to be left free.
Test Methods – (3) Flammability, Smoke & Toxicity for Cables

Flammability

- Specimen setup
- specimen fixation
- 60° angle
- bunsen burner
- Weigh

Smoke & Toxicity

- Sample holder frame
- Radiant heat
- Pilot burners

Cables
- as installed in aircraft

Heat shrinkable tubing
- Shrinked on copper wire

Testing in accordance with AITM2.0005 (cables) or AITM2.0038 (heat shrinkable tubing)

Limits:
- Burn length < 76mm
- After flame time < 30s
- After flame time drips < 3s

Smoke & Toxicity

- Smoke density \( D_m < 20 \) within 16min
- or \( D_m < 200 \) within 4min
- HF: 100 ppm, HCl: 150 ppm, HCN: 150 ppm,
- \( SO_2 \): 100 ppm, NO/NO\(_x\): 100 ppm, CO: 1000 ppm

Cables wind up
- On wire holding frame and then wrapped with aluminum foil

Bending radius
- < 3.2mm
- > 3.2mm

Single cables placed on aluminum plate and wrapped with aluminum foil
Test Methods – (4) Battery Testing

Test Set-Up

1st Step: Distance Estimation (3min exposure)
- aluminium dummy with inside installed thermocouple
- fixation clamp
- d
- propane bunsen burner
- thermocouple

2nd Step: Sample Testing (10min exposure)
- test specimen
- vent hole position
- d
- fixation clamp
- test specimen
- fixation clamp
- thermocouple

Test Details

Test Procedure:
- aluminum dummy shall be up-heated above 200°C within 3 minutes by the burner
- flame temperature shall be measured
- distance between cell and burner is estimated
- replacement of dummy by test sample
- flame exposure of test sample for 10 minutes
- observation of behavior
- test is stopped
- damage on test specimen is documented and analyzed

Test conditions:
- room temperature of 20 ± 2°C
- test specimens shall be discharged below 75% of nominal capacity

Pass/fail criteria:
- all cases of the cell shall be intact
- no solid components shall be ejected
- hermetically sealed cells should only vent through the designated vent area
- non-hermetically sealed cells shall vent only at the seal area

Testing is done utilizing the test procedure described in British Standard BS 2G 239 (1992). The used burner shall be compliant with CS/FAR 25.853.
Test Methods – (5) Flame Spread Test Procedure

Test Set-Up

Test Details

Test Procedure:
- artificial fire source placed inside housing
- application of accelerant
- closing of housing
- starting of data acquisition and of video recording
- Activation of fan system (if necessary)
- ignition of the fire source
- test stop when fire source thermocouple shows again ambient temperatures
- opening of housing
- photo documentation of damage

Test conditions:
- room temperature of 20 ± 2°C
- relatively humidity of app. 50%.

Pass/fail criteria:
- no fire penetration of the housing,
- outside temperature of the housing has to be below 180°C,
- no significant flame propagation inside the housing
Test Methods –(6) Fire Containment Test Procedure

Test Set-Up

Test Details

Test Procedure:
- artificial fire source placed inside housing
- application of accelerant
- closing of housing
- starting of data acquisition and of video recording
- ignition of the fire source
- test stop when fire source thermocouple shows again ambient temperatures
- opening of housing
- photo documentation of damage

Test conditions:
- room temperature of 20 ± 2°C
- relatively humidity of app. 50%.

Pass/fail criteria:
- no fire penetration of the housing,
- outside temperature of the housing has to be below 180°C,
- no smoke outside the housing visible
Test Methods – Artificial Fire Source Layout

Fire Source Layout Criteria:
- type of test (fire containment or flame spread)
- detected critical fire load in device
- worst case assumption that these components are not flame retardant
- position inside housing
- accessibility at fire source position
- capability of igniting other components
- fire shall burn for an overall time of 200…300s

Fire Source Components:
- polyurethane foam without flame retardants (density ~30kg/m³)
- accelerant: heptane
- ignition source, e.g. heated filament
- thermocouple for fire source temperature measurement
Summary

- **Airworthiness flammability requirements (CS/FAR §25)**
- **Airbus fire safety requirements**

**Fire safety assessment & compliance testing procedure**

- Establishment of standardized way of compliance showing
- Complete coverage of all airworthiness and Airbus requirements
- Preparation of „easy-to-use“ test methods
- Comparability of results