Fire Extinguishing Agents Tested Using the Aircraft Cargo Compartment MPS Standard

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Outline

• Background
• MPS Fire Test Methods
• Fire Extinguishing Agents Tested
• Fire Test Results
• Final Words
BACKGROUND

• FAA requires fire protection systems for Class C aircraft cargo compartments (FAR 25.851 – 857)
• Aircraft industry selected Halon 1301 systems to comply with the FARs
• Halon 1301 is an ozone depleting agent
• Montreal Protocol banned production of Halon 1301 in 1994
• FAA established the IHRWG in 1993
• IHRWG commissioned work to develop MPS tests
Background

BACKGROUND (CONT.)

• In 2000, the FAA published the aircraft cargo compartment MPS for gaseous extinguishing agents

• In 2003, the aircraft cargo compartment MPS was re-published to include non-gaseous extinguishing agents

• In 2005, the 2nd version of the MPS was re-published (Below inert condition)
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• MPS Fire Test Methods
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• Fire Test Results
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MPS Fire Test Methods

Bulk Load Fires

Containerized Fires

Flammable Liquid Fires

Aerosol Can Explosion Simulation
TEST CELL

- The fire tests are to be conducted inside a simulated below floor cargo compartment of a wide-body aircraft

- Cargo Compartment Volume = 2000 ft³

- Compartment Leak Rate = 50 CFM

- Instrumented with thermocouples, gas analyzers, and pressure transducers
MPS Fire Test Methods

TEST CELL

FORCED VENTILATION SYSTEM. PERFORATED 4" DIAMETER DUCT. DUCT OPENS TO OUTSIDE OF COMPARTMENT

FORWARD SECTION

UP

AFT

STARBOARD

Ceiling Thermocouples
Sidewall Thermocouple
Pressure Transducer
Gas Analyzer Probes

66.00" (1.67m)

164.00" (4.16m)

319.30" (8.11m)

AFT SECTION

Ceiling Thermocouples
Sidewall Thermocouple
Pressure Transducer
Gas Analyzer Probes

Fire Extinguishing Agents Tested Using the Aircraft Cargo Compartment MPS Standard

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MPS Fire Test Methods

Bulk-Load Fire Test Method

178 Cardboard Boxes

Ignited Box
Bulk-Load Fire Test Method

- **Fire Load** = 178 card board boxes (30% of Vol.) containing 2.5 lbs of shredded office paper (strips, not confetti) at standard room temp.

- **Boxes** nominal dimensions: 18’x18”x18”

- **Fire Ignition** = 7 ft of nichrome wire wrapped around four folded paper towels (Energized with 120 Vac) inside box (with 1” holes).

- **Fire Suppression System Activation** = 1 minute after one of the ceiling T/C reaches 200 °F

- **Test Duration** = Four tests @ 30 minutes each; fifth test shall for at least 180 minutes. Hybrid systems shall run for 180 min.
MPS Fire Test Methods

Containerized Fire Test Method

Cardboard boxes

End View

Top View

Ignited

Not to scale

Federal Aviation Administration

Fire Extinguishing Agents Tested Using the Aircraft Cargo Compartment MPS Standard
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Containerized Fire Test Method

- **Fire Load** = 33 cardboard boxes inside an LD3. 3 LD3 in Compartment

- **Two ventilation slots** in main LD3 container size 12” x 3” +/-1/4 (access panel, and lower right panel)

- The LD3 access panel is made out of 0.08” polycarbonate sheet

- **Fire Ignition** = 7 ft of nichrome wire wrapped around four folded paper towels (Energized with 120 Vac)

- **FSS Activation** = 1 min. after one of the ceiling T/C reaches 200 °F

- **Test Duration** = Four tests @ 30 minutes each; fifth test shall for at least 180 minutes. Hybrid systems shall run for 180 min.
MPS Fire Test Methods

Surface Burn Fire Test Method

Cargo Compartment

Fire Pan With Fuel

Not to scale
Surface Burn Fire Test Method

• **Fire Load** = 0.5 U.S. Gallon of Jet A fuel inside a 2 ft x 2 ft x 0.33 ft pan

• **Add 13 oz of gasoline** to make ignition easier; add 2.5 gallons of **water** to reduce pan warping.

• **Place pan in most difficult location (1 ft)**

• **Fire Ignition** = Arc created by two electrodes

• **FSS Activation** = 1 min. after one of the ceiling T/C reaches 200 °F

• **Test Duration** = 5 minutes after agent discharge
MPS Fire Test Methods

Aerosol Can Explosion Simulation Test Method

- Aerosol Can Simulator
- Electrodes
- 8.5" long x 2" diameter Galvanized Steel Pipe with a thermocouple
- Igniter Box
- 58 Cardboard Boxes
Aerosol Can Explosion Simulation Test Method

• **Fire Load:**
  
  - **Simulator** - 0.2 lb. Propane, 0.6 lb. of denatured alcohol, 0.2 lb of water
  - **Cargo Bay** - 59 cardboard boxes

• **Ignition Sources** = Nichrome wire/paper towel and electrodes (away from sim).

• **FSS Activation** = 1 min. after one of the ceiling T/C reaches 200 °F

• **Heat up simulator** to increase pressure in content chamber to 210 psig

• **Aerosol Can Simulator Activation** = 5 minutes after one of the TCs, attached to the pipes, reaches 400 degF.

• **Test Duration** = shall be conducted for at least 180 minutes or until the simulator is activated.
MPS Fire Test Methods

Aerosol Can Explosion Simulation Test Method (Short Version)

End View

Not to scale
MPS Fire Test Methods

Aerosol Can Explosion Simulation Test Method (Short Version)

- **Fire Load** = 0.2 lb. Propane, 0.6 lb. of Denatured Alcohol, 0.2 lb of water

- **Ignition** = Arc created by two electrodes (230 W) that are 2 ft from the floor and 3 ft away from the simulator

- **Test Initiation** = Discharge agent and allow 2 minutes for dispersion

- **Simulator Activation** = When the agent, at 2 feet from the floor, is at the minimum protection concentration (must be measured)

- **Test Duration** = After the simulator is activated and data saved.
Acceptance Criteria

For Bulk Load, Containerized, Surface Burn Tests Only

- $t_1 =$ time when temperature $\geq 200^\circ F$
- $t_2 = t_1 + 1$ minute. Suppression System Activation
- $t_3 = t_2 + 2$ minutes; Data use for analysis
- $t_4 = t_3 + 28$ minutes or $t_4 = t_1 +$ deviation time, End of test

Data range use for analysis
MPS Fire Test Methods

Acceptance Criteria

<table>
<thead>
<tr>
<th>FIRE SCENARIO</th>
<th>MAXIMUM TEMPERATURE °F (°C)</th>
<th>MAXIMUM TIME-TEMPERATURE AREA °F -MIN (°C-MIN)</th>
<th>PRESSURE PSIG (KPa)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Load</td>
<td>720 (382)</td>
<td>9940 (5504)</td>
<td>N/A</td>
<td>Use the data that is between 2 minutes and 28 minutes after suppression system activation. See figure.</td>
</tr>
<tr>
<td>Containerized Load</td>
<td>650 (343)</td>
<td>14040 (7782)</td>
<td>N/A</td>
<td>Use the data that is between 2 minutes and 28 minutes after suppression system activation. See figure.</td>
</tr>
<tr>
<td>Surface Burn</td>
<td>570 (299)</td>
<td>1230 (665)</td>
<td>N/A</td>
<td>Use the data that is between 3 minutes and 5 minutes after reaching 200 degF.</td>
</tr>
<tr>
<td>Aerosol Explosion</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
<td>There shall be no evidence of an explosion. No enhancement of explosion at below inert.</td>
</tr>
</tbody>
</table>
Outline

• Background
• MPS Fire Test Methods
  • Fire Extinguishing Agents Tested
• Fire Test Results
• Final Words
## Fire Extinguishing Agents Tested

<table>
<thead>
<tr>
<th>Compound</th>
<th>Atmospheric Lifetime (yrs)</th>
<th>ODP</th>
<th>GWP&lt;sub&gt;100&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-BTP ((\text{CH}_2\text{CBrCF}_3))</td>
<td>0.008</td>
<td>0</td>
<td>Not Available</td>
</tr>
<tr>
<td>FK-5-1-12 ((\text{CF}_3\text{CF}_2\text{C(O)CF(CF}_3_2))</td>
<td>0.014</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>FM-200 ((\text{CF}_3\text{CHFCF}_3))</td>
<td>36.5</td>
<td>0</td>
<td>3,800</td>
</tr>
<tr>
<td>Halon 1301 ((\text{CF}_3\text{Br})), Baseline</td>
<td>65</td>
<td>12</td>
<td>6,900</td>
</tr>
<tr>
<td>HFC-125 ((\text{CF}_3\text{CF}_2\text{H}))</td>
<td>29</td>
<td>0</td>
<td>3,400</td>
</tr>
<tr>
<td>Water Mist/N2</td>
<td>Not Applicable</td>
<td>0</td>
<td>Not Applicable</td>
</tr>
</tbody>
</table>
## Fire Extinguishing Agents Tested

<table>
<thead>
<tr>
<th>Compound</th>
<th>State</th>
<th>Use Concentration</th>
<th>NOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-BTP ((\text{CH}_2\text{CBrCF}_3))</td>
<td>Liquid</td>
<td>6% (6%)</td>
<td>0.5%</td>
</tr>
<tr>
<td>FK-5-1-12 ((\text{CF}_3\text{CF}_2\text{C}(\text{O})\text{CF(CF}_3)_2))</td>
<td>Liquid</td>
<td>&gt;4.2% (8.1%)</td>
<td>10%</td>
</tr>
<tr>
<td>FM-200 ((\text{CF}_3\text{CHFCF}_3))</td>
<td>Gas</td>
<td>&gt;8.5%</td>
<td>9%</td>
</tr>
<tr>
<td>Halon 1301 ((\text{CF}_3\text{Br}), \text{Baseline})</td>
<td>Gas</td>
<td>5% (6%)</td>
<td>5%</td>
</tr>
<tr>
<td>HFC-125 ((\text{CF}_3\text{CF}_2\text{H}))</td>
<td>Gas</td>
<td>&gt;11.3% (15.6%)</td>
<td>7.5%</td>
</tr>
<tr>
<td>Water Mist/N2</td>
<td>Liquid/Gas</td>
<td>66g/m3 (&lt;12% O2)</td>
<td>&lt;19.5% O2 OSHA</td>
</tr>
</tbody>
</table>
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Video Deleted

Bulk-Load Fire Test Movie
Fire Test Results

MPS BULK-LOAD FIRE TEST DATA RESULTS

Acceptance Criteria Analysis Data

Temperature (degF) vs. Time (min)

- FK-5-1-12
- FM-200
- Halon 1301
- HFC-125
- Water
- Water/N2

3 Min Threshold:
- $T < 720 \text{ degF}$
- $A < 9,940 \text{ degF-min}$

Pass/Fail Criteria:
- Pass
- Fail
Fire Extinguishing Agents Tested Using the Aircraft Cargo Compartment MPS Standard

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Fire Test Results

MPS CONTAINERIZED FIRE TEST DATA RESULTS

Acceptance Criteria Analysis Data

3 Min Threshold

Time (min)

Temp (degF)

Acceptance Criteria

FK-5-1-12

Halon 1301

Water

Water/N2

T < 650 degF

A < 14,040 degF-min
Fire Test Results

MPS SURFACE BURN FIRE TEST DATA RESULTS

Acceptance Criteria Analysis Data

T < 570 degF
A < 1,230 degF-min

Time (min)

Temp (degF)

Acceptance Criteria
FK-5-1-12
Halon 1301
Water
Water/N₂

Pass
Fail
Aerosol Can Explosion Simulation Pre-Test (Screening) Method
Fire Test Results

AEROSOL CAN SIMULATION EXPLOSION TESTS

COMPARISON OF OVERPRESSURE HISTORIES OF VARIOUS AGENTS

Fire Extinguishing Agents Tested Using the Aircraft Cargo Compartment MPS Standard
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Fire Test Results

Aerosol Can Explosion Test (Baseline: No XA)

Video Deleted
Fire Test Results

Video Deleted

Aerosol Can Explosion Test (Fuel Enhanced)
## Fire Test Results

<table>
<thead>
<tr>
<th>Ext. Agent</th>
<th>Bulk Load Fire Test</th>
<th>Containerized Fire Test</th>
<th>Surface Burn Fire Test</th>
<th>Aerosol Explosion Test</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-BTP</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Failed (Below Inert)</td>
<td>Agent became part of the fuel that caused significant re-ignition temperatures and explosion enhancement. To prevent these events, it must be at inert concentrations (6%). See report DOT/FAA/AR-TN04/4</td>
</tr>
<tr>
<td>FK-5-1-12</td>
<td>Failed</td>
<td>Passed</td>
<td>Passed</td>
<td>Failed (Below Inert)</td>
<td>Agent became part of the fuel that caused significant re-ignition temperatures and explosion enhancement. To prevent these events, it must be at inert concentrations (8.1%). High dielectric strength (+). Report not available at this time.</td>
</tr>
<tr>
<td>FM-200</td>
<td>Failed</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Expected to Fail (Below Inert)</td>
<td>Agent became part of the fuel that caused significant re-ignition temperatures and explosion enhancement. To prevent these events, it must be at inert concentrations (12%). See report DOT/FAA/AR-TN04/4</td>
</tr>
<tr>
<td>Halon 1301</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
<td>It is the baseline and the acceptance criteria is based on its performance. See report DOT/FAA/AR-TN05/20</td>
</tr>
<tr>
<td>HFC-125</td>
<td>Failed</td>
<td>Data Not Available</td>
<td>Data Not Available</td>
<td>Failed (Below Inert)</td>
<td>Agent became part of the fuel that caused significant re-ignition temperatures and explosion enhancement. To prevent these events, it must be at inert concentrations (15.6%). See report DOT/FAA/AR-TN04/4</td>
</tr>
<tr>
<td>Water Mist</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
<td>Failed</td>
<td>See report DOT/FAA/AR-01/121</td>
</tr>
<tr>
<td>Water Mist &amp; Nitrogen</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
<td>See report DOT/FAA/AR-01/121</td>
</tr>
</tbody>
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Final Words

In Summary,

• The FAA has a test protocol available to determine the fire suppression performance of new Halon 1301 replacement/alternative systems (for certification).

• Out of the seven agents/systems tested, only water mist combined with nitrogen is capable of meeting the MPS for aircraft cargo compartment.

• The FAA Fire Safety Team will continue evaluating agents/systems as they emerge and gain supports from industry.