Status of Research & Testing to Replace Halon Extinguishing Agents in Civil Aviation

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International Aircraft Systems Fire Protection Working Group
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Current Usage of Halon 1301/1211

Cargo Compartments

Engine Nacelles

Hand Held Extinguishers

Lavatory Trash Receptacles
Halon Replacement in Civil Aviation

- Halon Fire Extinguisher Used in Civil Aviation for Over 45 Years
- Montreal Protocol Banned Halon Production (*Not Use*) on January 1, 1994
- Example of Relative Agent Weights (B777): Lavs (1.5 to 3.0 lbs), Hand-Held (10 to 17.5 lbs), Engine/APU (58 lbs), Cargo (377 lbs)
- FAA Established International Halon Replacement Working Group (Now Called International Systems Fire Protection Working Group) to Develop Minimum Performance Standards (MPS) for Each Application
- Purpose of Each MPS is to Define Full-Scale Fire Tests to Demonstrate Equivalency
- Tests Developed at FAA Technical Center
## Agents Tested

<table>
<thead>
<tr>
<th>Agent</th>
<th>Chemical Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halon 1301</td>
<td>CBrF$_3$</td>
<td></td>
</tr>
<tr>
<td>Halon 1211</td>
<td>CBrClF$_2$</td>
<td></td>
</tr>
<tr>
<td>HFC-227ea</td>
<td>CF$_3$CHFCF$_3$</td>
<td>FM-200</td>
</tr>
<tr>
<td>HFC-125</td>
<td>CHF$_2$CF$_3$</td>
<td>FE-25</td>
</tr>
<tr>
<td>FIC-13I1</td>
<td>CF$_3$I</td>
<td>Triodide</td>
</tr>
<tr>
<td>2-BTP</td>
<td>CH$_2$CBrCF$_3$</td>
<td></td>
</tr>
<tr>
<td>HCFC Blend B</td>
<td>CF$_4$/CHCl$_2$CF$_3$</td>
<td>Halotron I</td>
</tr>
<tr>
<td>HFC-236fa</td>
<td>CF$_3$CH$_2$CF$_3$</td>
<td>FE-36</td>
</tr>
<tr>
<td>FK-5-1-12</td>
<td>CF$_3$CF$_3$COCF(CF$_3$)$_2$</td>
<td>Novec 1230</td>
</tr>
<tr>
<td>Water Mist</td>
<td>H$_2$O</td>
<td></td>
</tr>
<tr>
<td>Water Mist/Nitrogen</td>
<td>H$_2$O/N$_2$</td>
<td></td>
</tr>
</tbody>
</table>
Lavatory Trash Receptacle Summary

- FM-200 and FE-36 Passed MPS Test
- Airbus and Boeing Offer Lavatory Extinguishers
- MPS Report: DOT/FAA/AR-96/122
Lavatory Trash Receptacle Extinguishers
Hand-Held Extinguishers Summary

- Two Fire Tests Required in MPS
- Hidden Fire Test Standard (Effectiveness)
  - Developed by IASFPWG
  - U.L. Offers Test Approval
- Seat Fire Extinguishing Test (Toxicity)
  - Full-Scale Tests at Tech Center
  - Measure Agent Decomposition Products
- Draft AC 20-42D: “Hand Fire Extinguishers for Use in Aircraft”
  - Safe Agent Discharge for Wide Range Aircraft/Compartment Volumes
- Know Agents Listed by U.L. (Hidden Fire Test)
  - HCFC Blend B (Halotron 1)
  - HFC-227ea (FM-200)
  - HFC-236fa (FE-26)
- MPS Report: DOT/FAA/AR-01/37
Hidden Fire Test Apparatus
Seat Fire Extinguishing Test (Toxicity)
FAA Advisory Circular AC 20-42D

- Guidance for New Installations of Required Hand-Held Extinguishers
- Lists FAA-Approved Replacement Agents
  - HCFC Blend B
  - HFC-227ea
  - HFC-236fa
- Would replace AC 20-42C
- Developed with Experts in IASFPWG
- Publish in Federal Register in 2008 for Public Comment
### Appendix

**MINIMUM SAFE COMPARTMENT VOLUME**

**NO VENTILATION**

For the following 5 B:C extinguishers, released at 70°F: (21.1°C)

<table>
<thead>
<tr>
<th>Agent</th>
<th>Agent Weight</th>
<th>Minimum Safe Volume (ft³)</th>
<th>Sea Level (For info only)</th>
<th>8,000 ft P Altitude (Pressurized Cabin)</th>
<th>14,000 ft P Altitude</th>
<th>18,000 ft P Altitude Nasal Cannula Oxygen Supply</th>
<th>25,000 P Altitude Diluter-Demand Oxygen Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCFC Blend B</td>
<td>5.2</td>
<td>1337</td>
<td>1799</td>
<td>2276</td>
<td>2678</td>
<td>3586</td>
<td></td>
</tr>
<tr>
<td>HFC-227ea</td>
<td>5.5</td>
<td>99</td>
<td>135</td>
<td>170</td>
<td>200</td>
<td>269</td>
<td></td>
</tr>
<tr>
<td>HFC-236fa</td>
<td>4.75</td>
<td>80</td>
<td>107</td>
<td>128</td>
<td>159</td>
<td>214</td>
<td></td>
</tr>
<tr>
<td>Halon 1211</td>
<td>2.5</td>
<td>556</td>
<td>749</td>
<td>947</td>
<td>1111</td>
<td>1497</td>
<td></td>
</tr>
<tr>
<td>Halon 1301</td>
<td>5.0</td>
<td>192</td>
<td>259</td>
<td>327</td>
<td>385</td>
<td>517</td>
<td></td>
</tr>
</tbody>
</table>

1. The agent weight for a 5 B:C extinguisher is extinguisher dependent.
2. Use this table if air change time is unknown or exceeds 6 minutes
3. Multiply this number by the number of extinguishers in the aircraft
4. If nasal cannula oxygen on-board

[Image of nasal cannula]
**AGENT TOXICITY: NO. OF 5BC BOTTLES ALLOWED**  
*(NO VENTILATION, 8000 FT ALTITUDE, 70°F)*

<table>
<thead>
<tr>
<th>Aircraft/ Helicopter</th>
<th>Vol (ft³)</th>
<th>Max No. Seats</th>
<th>AC20-42C &amp; UL1093</th>
<th>AC40-22D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Halon 1211</td>
<td>Halon 1211</td>
</tr>
<tr>
<td>Cessna 152</td>
<td>77</td>
<td>2</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Cessna 210C</td>
<td>140</td>
<td>6</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Cessna C421B</td>
<td>217</td>
<td>10</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Sikorsky S76</td>
<td>204</td>
<td>14</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>B727-100</td>
<td>5,333</td>
<td>131</td>
<td>17</td>
<td>7.1</td>
</tr>
<tr>
<td>B767-200</td>
<td>11,265</td>
<td>255</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>B 747</td>
<td>27,899</td>
<td>500</td>
<td>90</td>
<td>37</td>
</tr>
</tbody>
</table>

*Less than one 5 B:C extinguisher allowed*
MODELING ARTERIAL BLOOD CONCENTRATIONS OF HALOCARBONS USING 1st ORDER KINETICS

\[ \frac{dB}{dt} = k_1 C(t) - k_2 B(t) \]

Blood \[ B(t) \]
Waste

\[ \tau = \text{Air Change Time} \]

where: \[ C(t) = C_0 \cdot \exp(-t/\tau) \]

Solution:

\[
\frac{\bullet \cdot \tau ( - \tau - - )}{( \bullet \cdot \tau ) -}
\]
KINETIC MODELING OF ARTERIAL HALON 1211 BLOOD CONCENTRATION IN VENTILATED AIRCRAFT

The peak arterial concentrations are used to develop the selector curves.
KINETIC MODELING OF ARTERIAL HFC236fa BLOOD CONCENTRATION IN VENTILATED AIRCRAFT

The peak arterial concentrations are used to develop the selector curves

Arterial Blood Concentration (mg/L) for Exposure to 15% HFC236fa at Various Air Change Times

C/Co = \exp(-t/\tau)

k_1 = 27.73

k_2 = 3.924

\tau = \text{Air Change Time}

\tau = 0.5 \text{ min}

\tau = 1 \text{ min}

\tau = 2 \text{ min}

\tau = 3 \text{ min}

\tau = 4 \text{ min}

\tau = 5 \text{ min}

\tau = 6 \text{ min}

\tau = 100000 \text{ min}

Safe Human Exposure

Measured B No Ventilation

\tau = 1 \text{ minute}

\tau = 6 \text{ minutes}
Federal Aviation Administration

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HFC-236fa SELECTOR FOR PRESSURIZED VENTILATED COMPARTMENTS

Pressurized aircraft (at 8,000 ft. P altitude):
Maximum safe weight HFC-236fa for 100 ft³ aircraft at Tau = 0.5 min
= 100 ft³ × 0.1053 lbs/ft³ = 10.53 lb. HFC-236fa

Perfect mixing assumed

8,000 ft pressure altitude
Engine Nacelle/APU Summary

- Full-Scale Engine Nacelle Fire Simulator Only Exists at Tech Center
- Spray and Residual (Pan) Fires/Jet Fuel, Hydraulic Fluid, Engine Oil
- Two Mass Flow Rates/Two Temperatures
- Equivalency Determinations (Halon 1301 = 6%)
  - HCF-125 = 17.6%
  - CF$_3$I = 7.1%
  - FK-5-1-12 = 6.1%
- FAA/Airbus Tests in ENFS
  - Proprietary Agent Equivalency/Certification Criteria Determined
  - Agent/System Will be Made Available for Production Airplanes
- FAA/Walter Kidde/Boeing Began Testing New Agent in ENFS in 2007
- MPS Report: Draft (Available)
Federal Aviation Administration

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IMAGERY - TEST FIXTURE

- exhaust duct (difficult to see)
- fire extinguisher
- test section (difficult to see)
- housing for the electrical resistance heaters
- supply blower
- inlet duct supplying the blower
- approach duct
Status of Research & Testing to Replace Halon Extinguishing Agents in Civil Aviation
Effect of Mass of HFC-125 on Reignition Time Delay

![Graph showing the effect of mass of HFC-125 on reignition time delay. The x-axis represents the reignition time delay in seconds, ranging from 0.0 to 3.0, and the y-axis represents the mass of HFC-125 in kilograms, ranging from 0.0 to 6.0. The graph plots several data points, indicating an increase in reignition time delay with increasing mass of HFC-125.]
Three Year Variation of Ignition Time Delays

- HiVent JP8 spray
- HiVent OIL spray
- LoVent JP8 spray
- LoVent OIL spray
- HiVent JP8 pool
- LoVent JP8 pool
- Standard deviation

Test Identification

Status of Research & Testing to Replace Halon Extinguishing Agents in Civil Aviation
Equivalent Concentration of HFC-125, CF3I, and FK-5-1-12 at Different Fire Scenarios

Legend:
- △ HFC-125
- ○ CF3I
- ◆ FK-5-1-12

High Ventilation Flow:
- JP8 spray: 17.6%
- JP8 pool: 16.9%
- OIL spray: 12.2%

Low Ventilation Flow:
- JP8 spray: 7.7%
- JP8 pool: 7.4%
- OIL spray: 4.8%
Comparison of Maximum Equivalent Concentrations of CF3I HFC-125, and FK-5-1-12 with NFPA 2001 Inerting and Cup Burner Data

![Graph showing comparison of maximum equivalent concentrations.](image-url)
Cargo Compartment Summary

• **Full-Scale 2000 ft³ Test Article Specified in MPS**
• **Four Fire Scenarios**
  – Bulk-Loaded Cargo
  – Containerized Cargo
  – Surface Burning Fire
  – Exploding Aerosol Can
• **Much Activity but Each Approach has Shortcomings**
  – HFC-125/FM-200: High Weight Penalty, High HF Concentrations, Ignition of Smoke Layer
  – CF₃I: Toxicity Concerns
  – 2-BTP/Novec 1230: Overpressures at Below Inerting Concentrations During Aerosol Can Scenario
• **Water Mist/Nitrogen System Concept**
  – Promising but Requires Significant Development and Acceptance
• **MPS Report: DOT/FAA/AR-TN05/20**
Cargo Compartment MPS
Bulk-Load Configuration

178 Cardboard Boxes

Ignited Box
Status Summary on Halon Replacement in Civil Aviation

- **Lavatory**: Replacement Agents (2) identified and are being installed in newly manufactured aircraft.
- **Hand-Held Extinguishers**: Replacement agents/extinguishers (3) identified but are not being installed by manufacturers because of increased weight and volume.
- **Engines**:
  - Significant and promising activity last several years.
  - One manufacturer has selected a replacement agent for a new aircraft design and possibly current manufactured aircraft.
  - Another manufacturer having new agent tested at FAA.
- **Cargo Compartment**:
  - No substantive activity in recent years.
  - Previous agents tested unsuitable or require significant development.
  - Most challenging and most important (largest Halon usage) application.
  - FAA will conduct tests in cooperation with the aircraft manufacturers.