Halon Replacement for Airplane Portable Fire Extinguishers - Progress Report

International Aircraft Systems Fire Protection Working Group Conference
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Objective

Provide a progress report on development of BTP (2-bromo-3, 3, 3-trifluoropropene), a promising new environmentally safe Halon replacement fire extinguishing agent
Agenda

- Halon Replacement Dates
- Steps to Commercialization
- BTP Performance
- Agent Summary
- Fire Extinguisher Installation
- BTP Risks
- BTP Near-term Steps
- Summary
## Halon Replacement Dates

<table>
<thead>
<tr>
<th></th>
<th>Proposed Requirement</th>
<th>Lavatory</th>
<th>Handheld</th>
<th>Propulsion/ APU</th>
<th>Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New Design (New TC Application)</strong></td>
<td>EC Cutoff Date</td>
<td>2011</td>
<td>2014</td>
<td>2014</td>
<td>2018</td>
</tr>
<tr>
<td></td>
<td>ICAO</td>
<td>2011</td>
<td>2016</td>
<td>2014</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>UL Standard</td>
<td>NA</td>
<td>2014</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Current Production</strong></td>
<td>EC End Date (incl. retrofit)</td>
<td>2020</td>
<td>2025</td>
<td>2040</td>
<td>2040</td>
</tr>
<tr>
<td></td>
<td>ICAO</td>
<td>2011</td>
<td>2016</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>UL Standard</td>
<td>NA</td>
<td>2014</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Notes:**

EC dates were adopted in March 2010 and published August 18, 2010; to be effective December 31 of the stated year.

ICAO proposed halon replacement “resolution” adopted at ICAO General Assembly Meeting on October 6, 2010. Amendments to Annexes 6 & 8 in-work.

Underwriters’ Laboratory Standard 1093 to be withdrawn September 2014.
Steps to Commercialization

- Cup burner testing - 2002
- Initial toxicity tests (Ames, cardiotox…) - 2002
- 2D ODP, GWP and atmospheric lifetime - 2004
- Prototype extinguisher, near drop-in replacement for Boeing 1211 extinguisher - 2009
- UL 711 5B pan fire tests - 2009
- UL 711 cold temperature pan fire test - 2009
- FAA MPS AR-01/37 hidden fire tests - 2009
- 3D model analysis of ODP and GWP - 2010
- FAA MPS AR-01/37 seat fire toxicity tests - 2011
- ASTM flammability tests (per NFPA 704) - 2011
- Airplane material compatibility tests - 2011
- Synthesis of BTP for toxicology testing - 2011
- Publication of 3D ODP scientific paper
- Complete toxicology testing
- PBPK testing and modeling
- Provide PBPK data to FAA for inclusion in AC 20-42D and FAA/AR-08/3
- Additional BTP properties testing
- US EPA TSCA inventory listing
- US EPA SNAP approval
- EU REACH approval
- 3.25” diameter bottle
- UL 2129 fire extinguisher bottle tests and UL listing
- ASTM standard for BTP
# BTP Performance

## Initial BTP toxicity test results

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames (mutagenic test)</td>
<td>No effects noted</td>
</tr>
<tr>
<td>Human Lymphocyte (chromosomal aberration)</td>
<td>No effects noted</td>
</tr>
<tr>
<td>Cardiotoxic Dog Inhalation</td>
<td>NOAEL .5% LOAEL 1.0%</td>
</tr>
<tr>
<td>Preliminary Limit Test (5% for 30 minutes)</td>
<td>Some potential anesthetic effects noted</td>
</tr>
</tbody>
</table>

Data from J Grigg & A Chattaway, “The Evaluation of Bromotrifluoropropene as a Halon 1211 Replacement”, NIST SP 984, June 2002
http://www.fire.nist.gov/bfrlpubs/fire02/PDF/f02114.pdf
BTP Performance

Passed UL 711 5B and UL 2B cold temperature fire tests, December 2009
Passed FAA MPS AR-01/37 hidden fire tests at UL, December 2009
BTP Performance

Passed FAA MPS AR-01/37 seat fire toxicity tests, February 2011
BTP Performance

FAA MPS seat fire toxicity test results:

<table>
<thead>
<tr>
<th>Agent</th>
<th>Test Number</th>
<th>HF 1-Minute Average (200 ppm limit)</th>
<th>HF 4.5-Minute Average (100 ppm limit)</th>
<th>Agent Used (pounds)</th>
<th>Discharge Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTP</td>
<td>1</td>
<td>47.8</td>
<td>23.9</td>
<td>1.85</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>65.7</td>
<td>34.5</td>
<td>1.76</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>88.2</td>
<td>47.7</td>
<td>1.55</td>
<td>2.9</td>
</tr>
<tr>
<td>Halon 1211 2011 tests</td>
<td>1</td>
<td>20.5</td>
<td>11.7</td>
<td>.64</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>20.4</td>
<td>11.0</td>
<td>.64</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>25.8</td>
<td>14.6</td>
<td>.57</td>
<td>2.0</td>
</tr>
<tr>
<td>Halon 1211 1999 tests</td>
<td>1</td>
<td>9.28</td>
<td>6.01</td>
<td>1.2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>21.04</td>
<td>13.87</td>
<td>.8</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>19.83</td>
<td>12.92</td>
<td>.96</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Data from FAA test data sheets

BTP HF levels below the MPS requirements, and FE-36 and FM-200 levels
BTP Performance

Passed NFPA 704 required flammability tests, March 2011

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D92 Flash point (Cleveland open cup)</td>
<td>None, vapor extinguished flame</td>
</tr>
<tr>
<td>ASTM E659 Auto ignition Temperature</td>
<td>No ignition</td>
</tr>
<tr>
<td>ASTM E681 Upper and lower flammability limits</td>
<td>Non-flammable</td>
</tr>
<tr>
<td>ASTM D6668 Flammability rating</td>
<td>F=0</td>
</tr>
</tbody>
</table>

**NFPA 704 flammability rating of zero**
BTP Performance

Passed Boeing aircraft materials compatibility testing, March 2011

- Non-corrosive to standard aircraft metals
- No effect on standard aircraft plastics
- No effect on standard seals or sealants
- No effect on standard aircraft interior materials

BTP is compatible with typical aircraft materials
BTP Performance

3-D Modeling of BTP by Dr Wuebbles and Ken Patten of University of Illinois (UIUC) completed Dec 22, 2010

- Whole Atmosphere Community Climate Model (WACCM) version 3.5.48.
- Based on BTP emissions over land areas between 30N and 60N latitude:
  - Very short lived compound - 7 days.
  - Oxidizes in troposphere, where bromine is rained out.
  - 0.0028 ODP.
  - 0.005 GWP (100 year).

“BTP should be environmentally safer than other likely choices of agents” Dr. Wuebbles
## Agent Summary

<table>
<thead>
<tr>
<th>Agent</th>
<th>UL 711 Rating</th>
<th>Agent Weight (#)</th>
<th>Total Weight (#)</th>
<th>Dimensions (H x W x D)</th>
<th>ODP</th>
<th>GWP (100 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halon 1211</td>
<td>5 BC</td>
<td>2.5</td>
<td>3.93</td>
<td>17 x 4.8 x 3.25</td>
<td>7.9¹</td>
<td>1890 ¹</td>
</tr>
<tr>
<td>BTP</td>
<td>5 BC</td>
<td>3.75</td>
<td>5.6</td>
<td>15.75 x 5 x 3.5</td>
<td>0.0028²</td>
<td>0.005²</td>
</tr>
<tr>
<td>Halotron 1 (HCFC Blend B)³</td>
<td>5 BC</td>
<td>5.5</td>
<td>9.3</td>
<td>15 x 5 x 4.25</td>
<td>0.01¹</td>
<td>77 ¹</td>
</tr>
<tr>
<td>FE-36 (HFC-236fa)</td>
<td>5 BC</td>
<td>4.75</td>
<td>9.5</td>
<td>15.9 x 8 x 4.5</td>
<td>0</td>
<td>9820 ¹</td>
</tr>
<tr>
<td>FM-200 (HFC-227ea)</td>
<td>5 BC</td>
<td>5.75</td>
<td>9.8</td>
<td>16.6 x 6.5 x 4.4</td>
<td>0</td>
<td>3580 ¹</td>
</tr>
</tbody>
</table>


2. University of Illinois at Urbana-Champaign Report “2-Bromo-3,3,3-Trifluoropropylene Ozone Depletion Potentials and Global Warming Potentials” dated December 22, 2010, author Kenneth Patten and Donald Wuebbles. (Note that ODP/GWP values vary depending on the assumed geographical distribution of BTP release. The latitudes considered include the U.S. and EU).

3. HCFC -123 (primary constituent of Halotron 1) is subject to US production phase-out in 2015. Supply will be limited to recycling after 2015 unless HCFC-123 is removed from the Montreal Protocol, or the Clean Air Act is amended.
Global Warming Potential (GWP) of Agents

- Halon 1211: 1890
- BTP: 0.005
- Halotron 1: 77
- FE-36: 9820
- FM-200: 3580
Agent Summary

Seat Fire Toxicology Test Results
HF 1 Minute Average

- Halon 1211
- BTP
- Halotron
- FE-36
- FM-200

Test #1
Test #2
Test #3
Agent Summary

Seat Fire Toxicology Test Results
HF 4-1/2 Minute Average

<table>
<thead>
<tr>
<th>Agent</th>
<th>Test #1</th>
<th>Test #2</th>
<th>Test #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halon 1211</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BTP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halotron 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE-36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM-200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Agent Summary

LOAEL & NOAEL of Agents

<table>
<thead>
<tr>
<th>Agent</th>
<th>LOAEL (% V/V)</th>
<th>NOAEL (% V/V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halon 1211</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>BTP</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Halotron 1</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>FE-36</td>
<td>14.5</td>
<td>10</td>
</tr>
<tr>
<td>FM-200</td>
<td>14.5</td>
<td>10</td>
</tr>
</tbody>
</table>
Agent Summary

Size and Weight Comparison of Handheld Fire Extinguishers

<table>
<thead>
<tr>
<th>Agent</th>
<th>Size</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halon 1211</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>BTP</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Halotron 1</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>FE-36</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>FM-200</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Fire Extinguisher Installation

Validation fit-check of 3.5” diameter BTP fire extinguisher was conducted on Boeing production models

- Diameter of existing production bottle used for BTP prototype caused interference on 737 models

- Boeing is developing a 3.25” diameter bottle of the same volume
Fire Extinguisher Installation

Example of a 737 installation (bracket is removed)
Fire Extinguisher Installation

Example of a 737 installation
Fire Extinguisher Installation
Example of a 777 installation
BTP Near-term Steps

- Submit paper on 3D atmospheric modeling (ECD 3Q11)

- Toxicology testing (ECD 2Q13)
  - Primarily subchronic, reproductive toxicity, PBPK, irritation
BTP Risks

- Must pass all toxicity tests prior to SNAP/REACH approval.

- Low volume production cost of BTP is high compared to Halon and alternatives. Expanding BTP market beyond airplane use will lower cost.

Boeing considers the higher price acceptable for the following reasons:
- Allows retrofit of existing airplanes with minimal impact to airlines
- Allows production incorporation with minimal cost and impact
- Provides a long term industry solution that is safe for the environment
- It is airplane safety equipment
Per AC20-42D - Halon 1211, Halotron 1, and BTP are unsafe for use in Boeing airplane flight decks and other small volumes.

- AC 20-42D, Chapter 4.4b(3), (4) states that concentrations may be adjusted to account for stratification...a report will be published at the FAA Technical Center with method to adjust safe-use concentrations.

The report providing necessary guidance to show compliance has not been developed or released.

Need to reconvene the Handheld Working Group and develop guidance material based on stratification testing
Summary

- BTP does not have the environmental, size, or weight issues of existing FAA approved halon replacement fire extinguishers/agents.

- BTP is a promising, environmentally safe, drop-in replacement.
  - 3D model validated near zero ODP and GWP.
  - Passed UL 711 5B, 2B cold temperature, and FAA MPS tests.
  - Passed Boeing aircraft material compatibility tests.

- Boeing has funded toxicology testing and is working toward commercialization of BTP.

**Boeing’s goal is to replace Halon portable fire extinguishers just one time, and with an environmentally acceptable agent.**
Questions?

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