The evaluation of bromotrifluoropropene as a halon 1211 replacement

J Grigg and A Chattaway

Kidde Research

Presentation contents

- Introduction

  - What is the AAWG?

  - What are it's aims?

- Tropodegradable molecules

- Agent shortlist

- Selection of a leading candidate

- Small scale class A & B testing

- Full scale testing

- Summary & conclusions

The Advanced Agent Working Group

- Research consortium looking for a drop-in replacement for halon 1301

- Members include US North Slope Oil Producers, US DoD, NMERI, UK MoD, QinetiQ (formerly DERA) and Kidde

- Approach
  - select likely candidate agents
  - conduct initial toxicity screening on paper
  - procure agents
  - test for toxicity & fire suppression effectiveness

- Tropodegradable bromocarbons

Tropodegradable bromocarbons

- Need bromine for catalytic radical removal mechanisms of fire suppression
  - But this presents ODP issues
  - Therefore need molecular degradation at low altitudes (tropospheric degradation or tropodegradable)

- Mechanisms available
  - Reaction with hydroxyl radical (OH$^\bullet$)
  - Photolysis
  - Physical removal (rainout)
  - Reaction with tropospheric ozone

- In practice only the first two are important

Molecular functions that impart tropospheric degradation

- Alkenes (C=C)

- Alcohols (C-OH)

- Ethers (C-O-C)

- Amines (C-N)

- Carbonyls (C=O)
  - aldehydes, ketones, esters

- Aromatics

Physical properties of BTP

Name	Halon 1301	Halon 1211	BTP
Chemical Formula	CF_3Br	CF_2BrCl	CH_2CBrCF_3
ODP	10	3	0.0037
Atmospheric Lifetime (years)	65	11	0.011
Molecular Weight	148.90	165.36	174.95
Boiling Point (°C)	-57.8	-4	34
Vapour Pressure (bar(a) at 25°C)	16.0	2.8	0.74
Liquid Density (g.cm^{-3} at 25°C)	1.54	1.8	1.65

Cardiotoxicity testing of BTP

- Carried out by Huntingdon Life Sciences, Cambridge, UK

- NoAEL = 0.5 vol%

- LoAEL = 1.0 vol%

- Cup burner is 4.6 vol%, so this agent cannot be used for total flooding in occupied spaces

- BUT these NoAEL/LoAEL values are identical with halon 1211

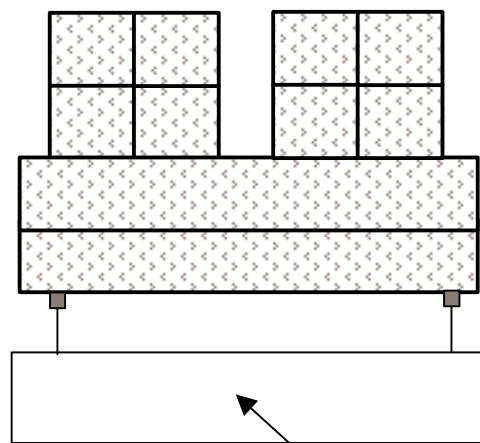- ***Is BTP a viable halon 1211 replacement?***

Cup burner testing

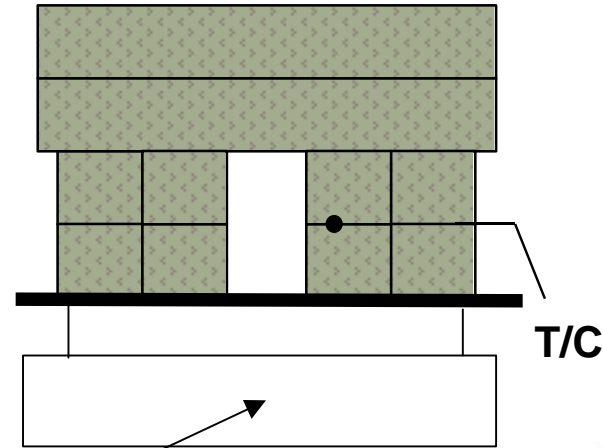| Agent	Fuel Temperature (°C)	Extinguishing Concentration (Vol%)
Halon 1301	57	3.6 ± 0.1
Halon 1011	50	4.1 ± 0.2
Bromotrifluoropropene	55	4.6 ± 0.1
HFC-227ea	50	6.8 ± 0.1

All values obtained with an airflow of 30 L/min.

Small scale testing (class A fires)

- Kidde Research mini-crib
- 16 wood members, 65x10x12mm, wire-wrapped in bundles of 4
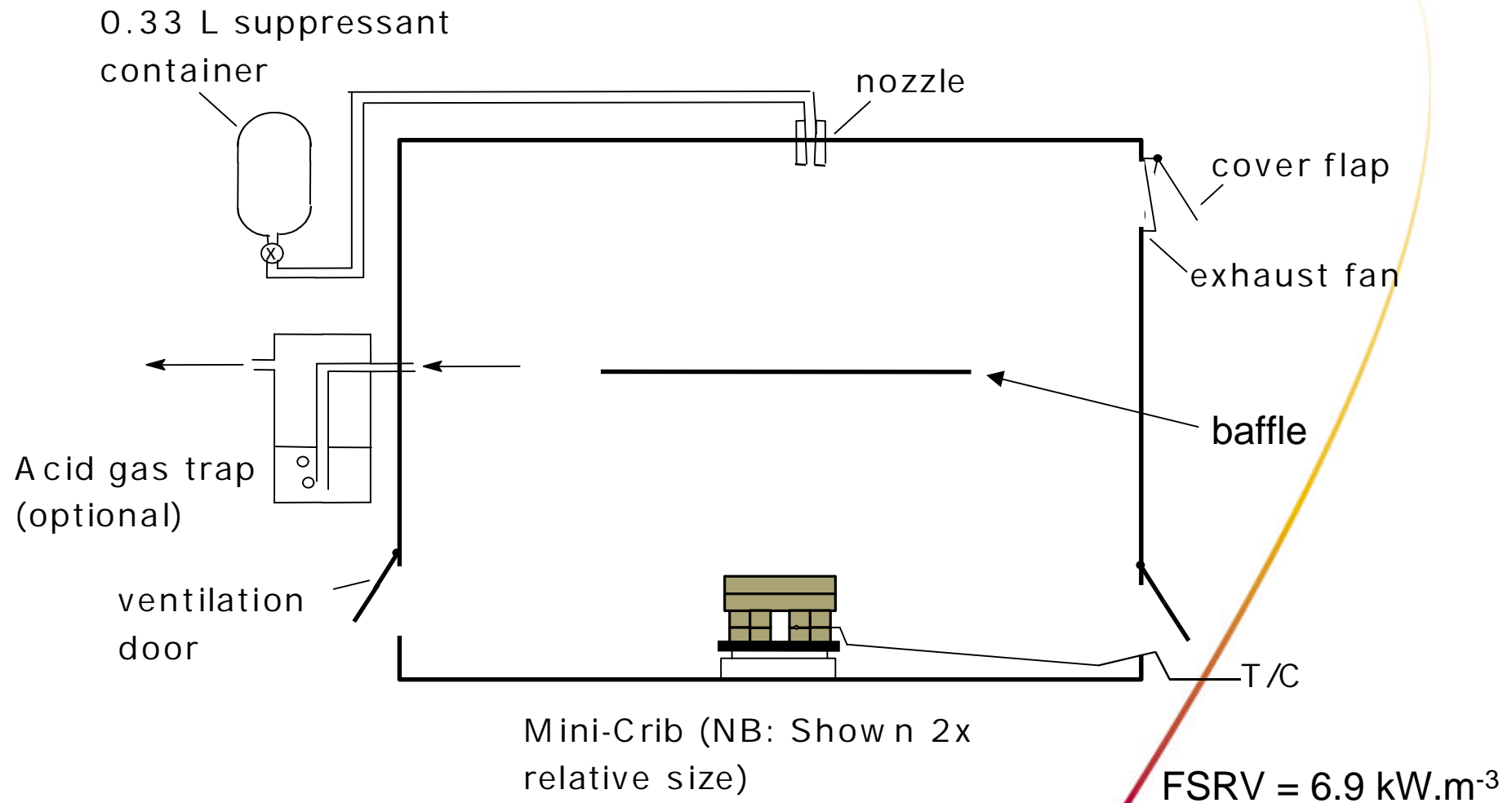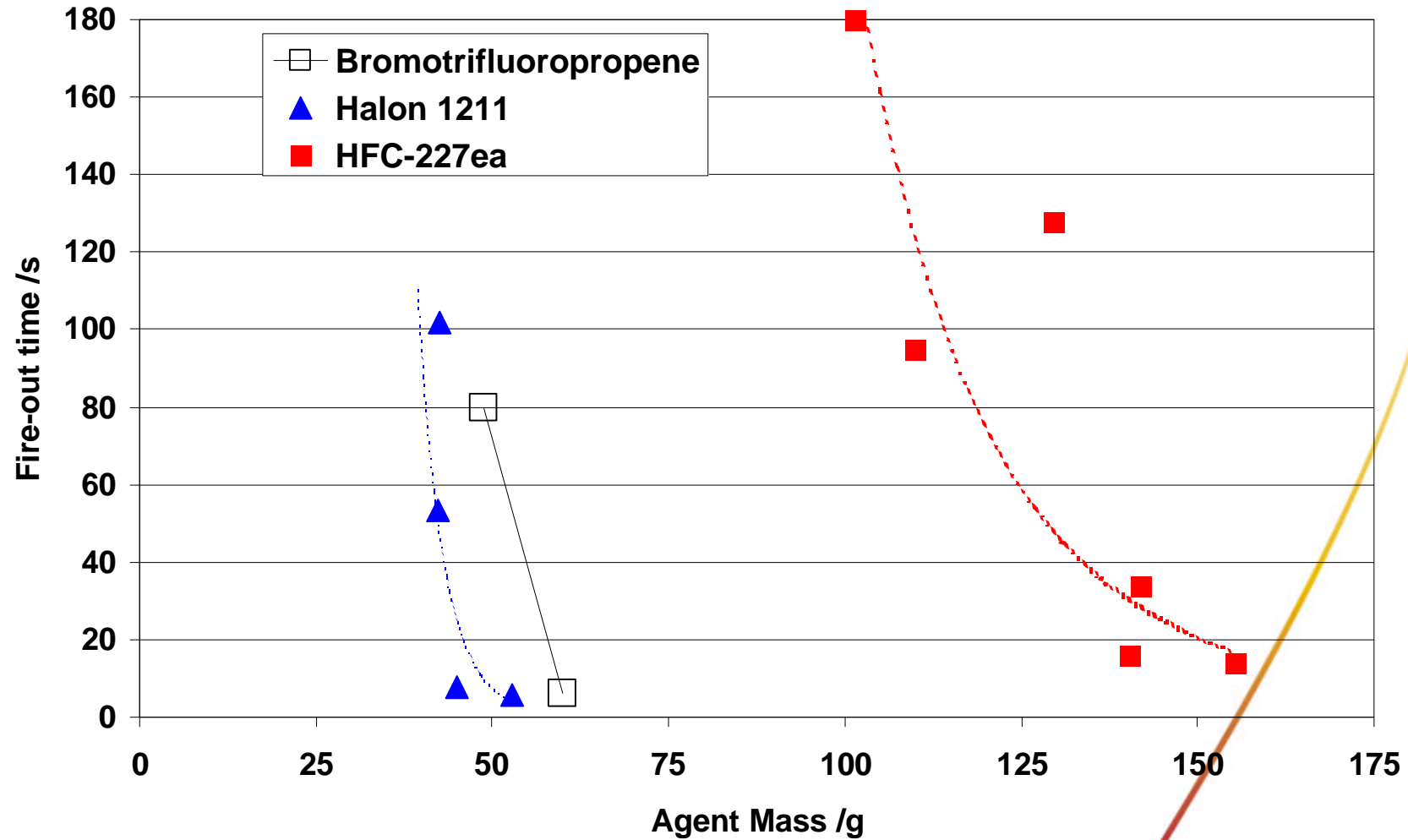- K-Type thermocouple (T/C) monitors core crib temperature

Side

Front

T/C

n-heptane ignition tray: 56 x 51 x 24 mm deep contains 10 mL fuel
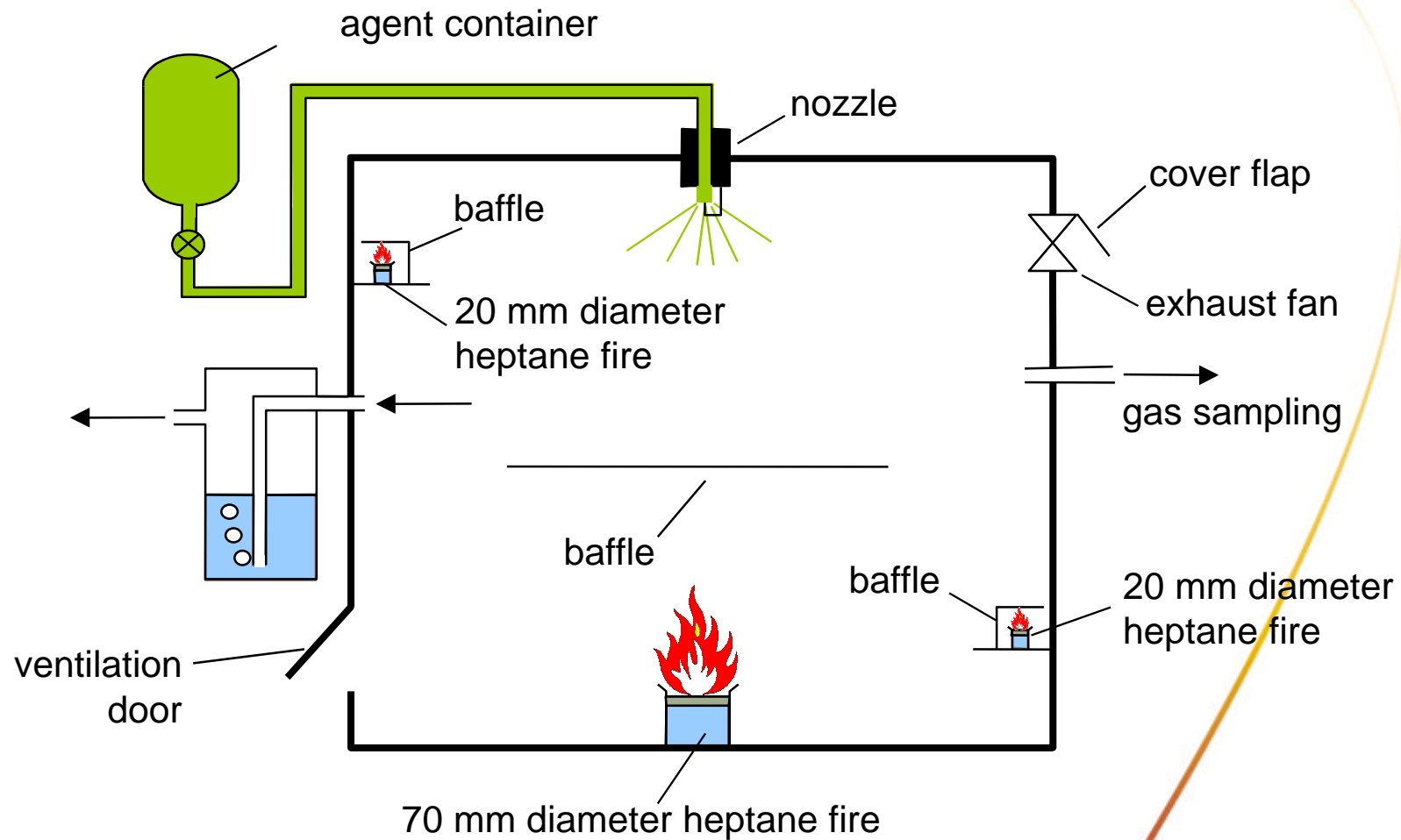
287 L Class A test chamber

0.33 L suppressant
container

nozzle

cover flap

exhaust fan

baffle

Acid gas trap
(optional)

ventilation
door

Mini-Crib (NB: Shown 2x
relative size)

T/C

FSRV = 6.9 kW.m^{-3}

200 L fire test chamber

agent container

nozzle

cover flap

baffle

exhaust fan

20 mm diameter
heptane fire

gas sampling

baffle

baffle

20 mm diameter
heptane fire

ventilation
door

70 mm diameter heptane fire

Fire size to room volume (FSRV) = 7.3 W m^{-3}
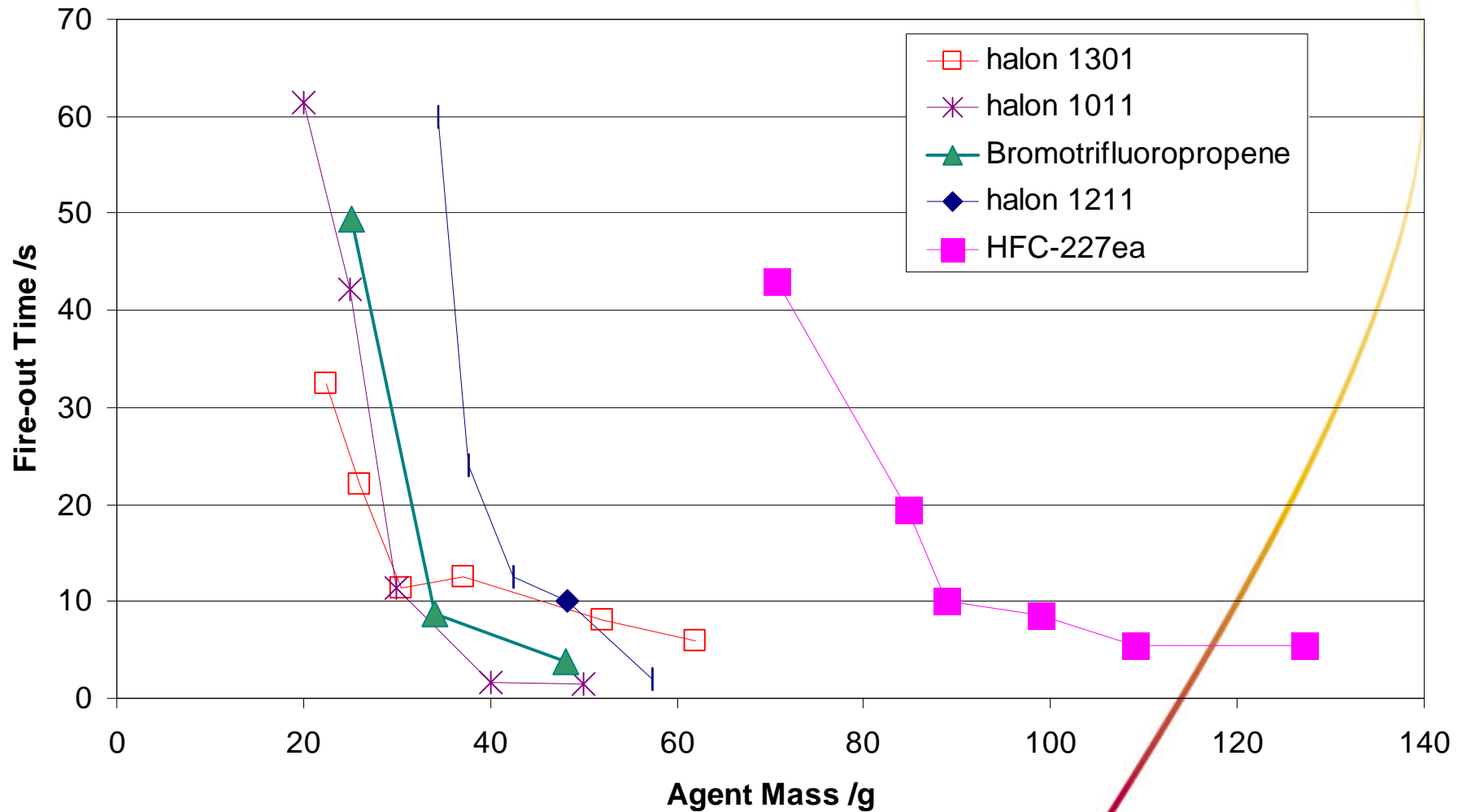
Decomposition products

- Comparison using results from class A testing

- Fire size to room volume: 6.9 kW.m^{-3}

Agent	Good Suppression			Poor Suppression		
	Agent Conc. (volume%	Fire-out time (s)	Peak Acid Gas (ppm)	Agent Conc. (volume%	Fire-out time (s)	Peak Acid Gas (ppm)
FM-200	6.4	16	6000	5.1	95	12000
BTP	2.8	6	650	2.3	80	1900
Halon 1301	2.4	18	125	2.2	41	560

Full scale hand extinguisher testing

- Performed at UL Canada

- Standard Kidde 2.5 pound halon 1211 extinguisher used
  - nozzle orifice sized to give correct discharge time

- Target rating: UL 5B

- Cylinder charged with 3.5 pounds agent extinguished 5B fire
  - extinguishment time 5.2 s
  - actual mass discharged < 2.5 pounds

- Therefore BTP is a drop-in halon 1211 replacement agent

Toxicity testing

- Completed
  - AMES
  - Human lymphocyte (chromosomal aberration)
  - Preliminary limit test: 5 vol% for 30 minutes (rats)
  - Cardiotoxicity

- Outstanding
  - Tests relating to worker exposure, including sub-chronic toxicity tests

Summary and conclusions

- Small scale laboratory testing and full scale hand extinguisher testing confirms that BTP is a drop-in replacement for halon 1211

- Both agents share a similar toxicological profile

- Therefore there is an effective and environmentally acceptable alternative to halon 1211

- If the agent can be manufactured commercially, then halon 1211 can be phased out from aviation and military usage