Status/Update of New Agent Development

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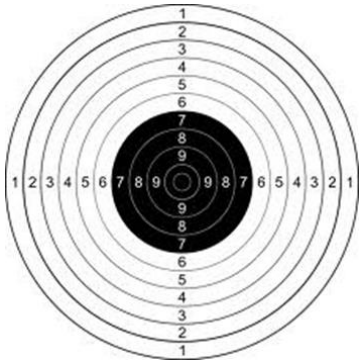
Total Flooding Agents



- High mass efficiency
- Chemically inert
  - *No reaction with water, common solvents*
  - *No reaction in humans*
  - *Long term storage stability*
- High volatility
  - *bp -70 to + 40 ^{o}C*
- Electrically non-conducting
- Low toxicity
- Cost effective

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Fire Suppression Properties of Total Flooding Agents for Occupied Areas

Property	Halon 1301	FM-200®	Novec™ 1230	TF- 1
Class A MDC, % v/v	5.0	6.7	4.5	5.6
Class B MDC, % v/v [a]	5.0	8.7	5.9	6.9
Class C MDC, % v/v	5.0	7.0	4.7	6.3
Relative mass efficiency, heptane hazard	0.48	1.00	1.26	1.00
Relative mass efficiency, Class C Hazard	0.60	1.00	1.25	1.00

Based on laboratory-scale Testing

Mass Efficiency:

Flooding Candidate 1 ~ HFC-227ea > Novec 1230

Higher mass required

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Toxicological Properties of Total Flooding Agents for Occupied Areas

Property	Halon 1301	FM-200®	Novec™ 1230	TF-1
4h LC_{50} , ppm	>800,000	>800,000	>100,000	>231,000
CS NOAEL, % v/v	5.0	9.0	10.0	10.0
CS LOAEL, % v/v	7.5	10.5	> 10.0	12.5

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TF-1: Total Flooding Candidate 1

Suitable for the protection of normally occupied areas containing Class A, Class B, and Class C hazards

- *4h LC_{50} > 23.1%*
- *CS NOAEL = 10%*
- *CS LOAEL = 12.5%*
- *MDC Class A = 5.6%*
- *MDC Class B = 6.9%*
- *MDC Class C = 6.3 %* ⟸ **95% Clean Agent Applications**

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Physical & Chemical Properties of Total Flooding Agents for Occupied Areas

Property	Halon 1301	FM-200®	Novec™ 1230	TF-1
Chemical Formula	CF_3Br	CF_3CHFCF_3	$CF_3CF_2CF(CO)$-$CF(CF_3)_2$	Proprietary
Boiling point (°C)	-58	-17	49	31
Liquid density (g/cm^3 @ 25 °C)	1.54	1.38	1.72	1.3
Chemical Reactivity	Low	Low	High	Low

Volatility : Halon 1301 > FM-200 > TF-1 > Novec 1230

Increasing Ease of Evaporation ←

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TF-1: Atmospheric Lifetime & GWP

$k(272\ K) = 3.2 \times 10^{-13}\ cm^3\ molecule^{-1}\ s^{-1}$
$[OH] \sim 1 \times 10^6\ molecule\ cm^{-3}$

Lifetime = ~36 days

Including other loss terms would lead to a shorter lifetime

Global Warming Potential (GWP)

Chemical Transport Model (CTM) calculation
to determine corrected RE (Hodnebrog et al., 2013)

GWP(100 year time-horizon) = 2

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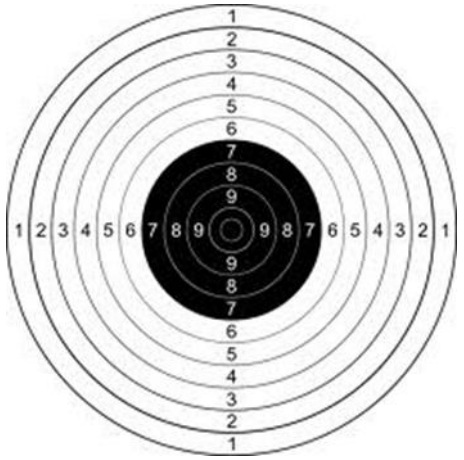
Clean Agent Development

Streaming Agents



- High mass efficiency
- Chemically inert
  - *No reaction with water, common solvents*
  - *Long term storage stability*
- Liquid or high bp gas
  - *bp -10 to + 40 ^{o}C*
- Electrically non-conducting
- Toxicity
  - *Equal to or better than Halon 1211 or HCFC-123*
- Cost effective

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Physical & Chemical Properties of Streaming or Non-Occupied Area Agents

Property	Halon 1211	2-BTP	Streaming/ Non-occupied Area Candidate 1 (SC1)	Streaming/ Non-occupied Area Candidate 2 (SC2)
Chemical Formula	CF_2BrCl	$CF_3CBr{=}CH_2$	Proprietary	Proprietary
ODP	3	0.0028	0	0
Atmospheric lifetime (y)	16	0.02	TBD	0.07
GWP (100 year ITH)	1890	0.26	< 10 est.	5
Boiling point (^oC)	-4	34	31	18
Liquid density (g/cm^3 @ 25 ^oC)	1.8	1.65	1.38	1.3
Chemical Reactivity	Low	Low	Low	Low

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Fire Suppression Properties of Streaming or Non-Occupied Area Agents

Property	Halon 1211	2-BTP	Streaming/ Non-occupied Area Candidate 1 (SC1)	Streaming/ Non-occupied Area Candidate 2 (SC2)
Class A MDC, % v/v	5.0	?	5.6	4.8
Class B MDC, % v/v	5.0	6.1	7.3	6.2
Class C MDC, % v/v	5.0	?	6.3	5.0
Relative mass efficiency, heptane	1.0	1.3	2.0	1.0
Relative mass efficiency, Class A	1.3	?	1.9	1.0

Candidate 2 exhibits a mass efficiency equal to or superior to that of Halon 1211 and a mass efficiency superior to that of 2-BTP

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Toxicological Properties of Streaming or Non-Occupied Area Agents

Property	Halon 1211	2-BTP	Streaming/ Non-occupied Area Candidate 1 (SC1)	Streaming/ Non-occupied Area Candidate 2 (SC2)
4h LC_{50} , ppm	31,300 to 100,000	> 20,000	> 102,900	120,000
CS NOAEL, % v/v	0.5	0.5	1.25	2.50
CS LOAEL, % v/v	1.0	1.0	2.50	> 2.50

Candidate 2 exhibits toxicity profile superior to that of Halon 1211 and 2-BTP

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Development of Zero ODP, Low GWP Clean Agents

- **Total Flooding Candidate Developed**
  - ODP = 0
  - GWP = 2
  - Low chemical reactivity
  - bp = 31 ^{o}C
  - Suitable for normally occupied areas
  - Completed small scale fire tests, tox tests, physical properties

- **Two Streaming/Non-Occupied Total Flooding Candidates Developed**
  - ODP = 0
  - GWP = 5 (SC2) ; GWP <10 (SC1)
  - Low chemical reactivity
  - bp (SC1) = 31 ^{o}C bp (SC2) = 18 ^{o}C
  - Candidate #2 mass efficiency = Halon 1211; superior tox to Halon 1211, 2-BTP
  - Completed small scale fire tests, tox tests, physical properties

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