ABSTRACT

Halon 1301 Surrogates for Engine Nacelle Fire Suppression System Certification[1]

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Until recently halon 1301 has been regularly discharged in Navy aircraft engine nacelles to certify that the fire suppression systems distribute the fire suppressant effectively. Halon 1301 can no longer be used in this manner because of its high ozone depletion potential. In order to continue to certify the fire suppression systems of Navy aircraft a surrogate for halon 1301 must be found. Ideally, this simulant will have the physical and dynamical properties that will allow it to mimic halon 1301 in discharge behavior in any aircraft fire suppression system. This work presents the significant parameters relevant to agent discharge in an engine nacelle, as well as a discussion of the procedure and preliminary results of our search for a halon 1301 simulant.

The discharge of halon 1301 during the aircraft certification process is a complex combination of many factors. It can be broken into four primary areas:

- N_2 pressurized bottle and storage
- Two-phase flow through the piping
- Spray discharge into the nacelle
- Statham analyzer detection of the agent

The physical characteristics of halon 1301 affect how it behaves in each of these areas. Some of its properties are more critical in a specific area than others. For example, the solubility of halon with N_2 will be of critical concern during the storage and pressurization stage. And as a consequence, it is important to take the solubility of any possible simulant into account. Similarly, during the discharge process the boiling point, heat of vaporization, and liquid heat capacity must be taken into account; these properties can be considered individually or in the composite value of the Jakob number. Below is a table summarizing some of the properties we have considered important and the areas they influence

	Storage	Pipe Flow	Discharge	Statham
Boiling Point		X	X	
Critical Temperature	X		X	
Molecular Weight	X	X		
Critical Pressure	X			
Liquid Density	X			
Liquid Viscosity		X		
Solubility w/N_2	X		X	
Surface Tension			X	
Melting Point			X	
Heat of Vaporization		X	X	
Liquid Heat Capacity		X	X	
Vapor Pressure	X			
Jakob Number		X	X	
Vapor Viscosity		X		X
Thermal Conductivity				X

[1] Sponsored by U.S. Naval Air Systems Team, Lakehurst, New Jersey

The first three properties listed above (boiling point, critical temperature, and molecular weight) were used for an initial review of a large number of chemicals. If a chemical was found to have a boiling point and a critical temperature in the range of plus or minus 25°C from that of halon 1301, then it was carried over to the next round of criteria. At the second level the qualifying chemicals were examined for suitability for the application. They could not be flammable, toxic, corrosive, unstable, or difficult to obtain. In addition, it was essential that their ozone depletion potential was below the cutoff value of 0.2, preferably zero. And though not a factor that eliminated any acceptable candidates, the atmospheric lifetime was used as an indicator of the global warming potential and, eventually was considered in the determination of the final selection of three candidates.

The five possible candidates, shown here alongside halon 1301, are:

	Halon 1301	HCFC-22	HFC-125	FC-216	FC-218	SF_6
Chemical Form	CF_3Br	$CHClF_2$	C_2HF_5	C_3F_6	C_3F_8	SF_6
Molecular Weight, kg/mol	148.91	86.47	120.03	150.00	188.03	146.06
Normal boiling point, °C	-57.83	-40.86	-48.57	-29.65	-36.75	-63.90
Critical temperature, °C	67.05	96.15	66.18	94.80	71.95	45.54
Melting point, °C	-168.10	-157.42	-103.00	-156.60	-147.69	-50.70
Vapor pressure, kPa at 22°C	1508	949.1	1174	602.7	814.6	2268
Jakob number, at 20°C	.51	.31	.52	.40	.58	.67*
Ozone Depletion Potential	16	0.05	0	0	0	0
Atmospheric lifetime, years	110	16	41	2800*	10,000	3200

A thorough analysis of these and other parameters was conducted to determine which of these chemicals had the highest potential to serve as good simulants of halon 1301. This analysis as well as review of experiments performed by NAVSEA on SF_6, HCFC-22, and halon 1301[2] led to the selection of three candidate simulants. The chemicals NIST has recommended to the Navy for testing are HFC-125, SF_6, and HCFC-22, in that order of preference. The strengths and drawbacks of each are summarized below:

	Strengths	Drawbacks
HFC-125	Excellent Jakob Number Very good overall comparison More conservative than SF_6 Zero ozone depletion potential Short atmospheric lifetime	Low liquid density Low vapor pressure
SF_6	Excellent molecular weight Very good overall comparison Zero Ozone Depletion Potential	Potentially too high Jakob number Long atmospheric lifetime High melting point
HCFC-22	Satisfactory overall comparison Very low ALT	Very low molecular weight Low Jakob number Low vapor pressure Non-zero Ozone Depletion Potential

NIST and Walter Kidde Aerospace are currently testing these three candidates for similarities with halon 1301 in flow, discharge, and wind tunnel tests.

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* Extrapolated value.

2 "Hydraulic Performance Test of Halon 1301 Test Gas Simulants," P.J. DiNenno, E.W. Forssell, M.D. Starchville, H.W. Carhart, J.T. Leonard, *Fire Technology,* May 1990, pp. 121-140.