METHODOLOGY FOR REPLACEMENT OF FLOODING HALON

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This halon alternatives workshop paper will present the initial work that was performed for the Aeronautical Systems Division at Wright-Patterson Air Force Base and that was an investigation to find halon replacements.

The popular halons destroy the Earth's ozone layer. The international Montreal Protocol under the Vienna Convention initially limited the consumption of halon at their 1986 levels. The 1990 Amendments to the Montreal Protocol further reduced consumption to 50% by 1995 and to 100% by the year 2000. The 1990 Amendments to the United States Clean Air Act had the same 50% and 100% phaseout dates as the Protocol but reduced consumption at an increased rate, starting with 15% reduction in 1991. Additionally, the Omnibus Reconciliation Act imposes a tax on halon that is now 25¢ per pound and escalating in 1994 to $26.50 per pound of Halon 1301.

Based on additional data, the Chief of the United States Environmental Protection Agency announced that the Earth's ozone layer in thinning twice as fast as previously believed. Recently the President of the United Stated ordered a halt of production of ozone layer depleting substances (OLDS) by 1995, thereby furthering the elimination the unavailability of OLDS. And very recently, the United States Air Force (USAF) banned the purchase of OLDS and of equipment that uses them, effective July 1, 1992.

A goal for finding halon replacements is to minimize emission of OLDS. The USAF has a great many locations where halons have been used so the logistics associated with a replacement agent must be considered. Considering the escalating phaseout of halons then a replacement should be found soon, and a goal of not using a transitional substance would provide for cost effectiveness.

Agents that could be used similarly to Halon 1301 and Halon 1211 for general applications would be desirable. Most applications in the USAF are similar to those in industry and range from large and small total flooding to local flooding and handheld extinguishers. There are differences between fire suppression and explosion suppression, it being known for Halon 1301 that about a 5% concentration may do the job whereas greater than 10% concentration may be required for explosion suppression.

There are several important characteristics for a new fire suppression system using a new halon replacement. Weight is a very important factor for aircraft applications[2] since the agent suppression system must be carried aboard. The agent should have minimum toxicity and toxicogenicity, since the agent must be stored and transported even for unoccupied space applications.[1] Volume effectiveness is especially important for retrofitting. The term cost effectiveness is a comprehensive term that incorporates not only agent and system cost but also extinguishment effectiveness, toxicity and lifetime.

Most all of the characteristics of Halon 1301 are desirable for a replacement except that the environmental impact should be very low or zero. It would be desirable to have a replacement agent that could provide these good characteristics and that could perform the wide range of protection for the varied applications.

There are several common applications of halons in aircraft. Engine nacelles are now commonly protected by Halon 1301 total flood fire protection systems. The fire threat is usually a liquid jet fuel ignited by a hot surface. High airflow is characteristic of engine nacelles. Auxiliary Power Units (APU) or Jet Fuel Starters fire threats are similar to engine nacelles but at a reduced scale.

Wet bays or fuel tanks can be multiply located in an aircraft. The ullage vapor volume above the liquid fuel could be ignited by electrical or projectile threats. Fuels on aircraft have included volatile JP-4 with the conversion to the less volatile JP-8 fuel. Other liquid fuels include hydraulic fluids and transmission oils.

Dry bays are volumes that may have flammable fluid lines and potential ignition sources. Class A fires are also considered for cargo aircraft. The threat to combat zone aircraft may include projectiles which can lead to explosive events with resultant high ventilation.2 Avionics, crew and bomb bays usually do not have a liquid fuel fire threat and are usually protected by handheld fire extinguishers. Agent cleanliness and conductivity are important around avionics type of equipments, and breathing oxygen may become involved to produce an oxygen enriched atmosphere.3

There are many factors[4] to be considered when evaluating a halon replacement for aircraft applications. In addition to the characteristics of high effectiveness and low toxicity for general application, a halon replacement for aircraft applications should be clean and should provide high weight effectiveness for fire suppression. The boiling point and freezing point of the agent should be suited to provide performance throughout the environmental conditions. One major change from the commonly used halons is that a replacement must have acceptable ozone depletion potential (ODP) and should be acceptable from a global warming potential (GWP) viewpoint. A replacement agent would of course need to have acceptable toxicity and byproducts, so that the bottom line for selecting a replacement would involve weight effectiveness, volume effectiveness and system effective cost.

There is concern that a single agent may not be found to replace, say, Halon 1301. Multiple agents to protect that range of applications now protected by the single agent Halon 1301 are less desirable because of the cost associated with multiple equipments and the logistics of multiple agents. It may be hypothesized that different agents may need to be used for occupied and unoccupied areas since a higher toxicity agent may provide better weight or volume effectiveness. However, toxicity is always of prime concern since any agent has to be stored, transported and maintained.

Halon 1301 is used for total flooding in a great many applications and minimizes the cost and time associated with developing a fire suppression system. However, the more liquid Halons 1202,1211 and 2402 have been used for applications that now utilize Halon 1301. The use of more liquid halons can provide a faster rate of suppression and better extinguishment5 A total flooding halon may only appear to be the solution when a detailed understanding of the fire problem is not obtained.

Multiple agents might be needed to provide good fire protection for the wide range of applications that would have been protected by the ozone depleting halons. The physically and chemically active natures of potential replacements may provide noticeable differences for fire suppression as compared to inerting an atmosphere against potential fire. A higher cost agent with good weight effectiveness for aircraft application may not be as desirable as a low cost agent with high volume effectiveness and low toxicity. It is the overall system cost and application performance that must be evaluated over the range of applications and environments.

Other factors can influence agent selection. New rulings about GWP may result from the upcoming international meeting in Brazil. Multiple suppliers for a new agent are desirable for security. Since the agent may be widely deployed, worldwide acceptability can be a factor. Due to the continuing escalation of OLDS phaseout it appears that time is of the essence for implementing a halon replacement agent. A competitive marketplace for *the* agent provides security for availability and ***cost.*** Although **an** agent is being sought that has halon-type characteristics except that it should be environmentally acceptable, other alternate agents such as compatible *dry* chemicals and water sprays are also undergoing evaluations.

The new agent(s) should be readily identifiable because of the escalation **of** phaseout, cost and unavailability. Effectiveness and toxicity information about a potential replacement agent should be available since a long-term research and development **program** does not provide a needed near-term solution. **For** example, although the cost **to** perform **an** LC_{50} is relatively rapid and inexpensive it does not come near the effort necessary to adequately consider the toxicity **of** an agent. Additional criteria for governmental applications result from the range of subscale and large-scale evaluations and the developments for a suppression system based on a new replacement agent, these providing the information necessary to accurately procure an agent and the associated systems.

Boiling point, energy capacity and heat of vaporization increase with increasing molecular weight for the alkane series of perfluorocarbons. Although it appears that the heavier molecules possess better physical firefighting capacity, this kind of consideration helps judge how big the molecule can get before the boiling point becomes inappropriate for the application.

The effect of a hydrogen substitution into the alkane perfluorocarbons was examined, hydrogen substitution promoting destruction in the troposphere. It was found that indeed the cup burner extinguishing concentration is reduced as the molecular weight increases. However, the vapor pressure decreases and the boiling point increases rapidly from C_1 to C3 HFCs, these being less desirable for a flooding agent.

Data was gathered to allow comparison of the LC_{50} for the perfluorocarbons and the single hydrogen substituted **HFCs.** The effect **of** hydrogen substitution to increase reactivity in the troposphere also increases the toxic reactivity.

The effect of a single hydrogen substitution into the C_1 to C_3 saturated perfluorocarbons is to increase the boiling point. Another hydrogen substitution further increases the boiling point. And the third hydrogen substitution results in an unacceptably high reactivity. The same trend due to hydrogen substitution also **occurs** for the C_1 ***to*** C3 saturated perfluorocarbons that had undergone a single chlorine substitution. Finally, if two chlorine substitutions have been done then the boiling point is already high and hydrogen substitution only further increases the boiling point.

A saturated fluorocarbon containing chlorine and/or bromine presents an undesirably high ODP. When iodine is used as the halogen for firefighting effectiveness and a single hydrogen substitution is performed the resultant product has a high boiling point of +72 0F. The effect of using heavier halogen elements results in higher boiling points as the molecular weight increases.

The previous data about boiling point, toxicity and reactivity is being used to identify potential halon replacements, primarily a total flooding agent for fire suppression, inerting and explosion suppression. Weight effectiveness and volume effectiveness are used along with cost and availability to provide an overall evaluation for selecting agents to test at other than laboratory conditions. Because of the high effectiveness of bromine compounds and the associated high ODP, mixtures of bromine containing compounds with non-bromine containing compounds can be used to obtain a nonlinear effect of relatively high chemical reactivity at reduced concentration in the mixture while achieving an acceptable ODP. Azeoptropes such as HFC-32/HFC-125 can also provide uniform property behavior with generally improved physical and chemical characteristics. Finally, in addition to nitrogen, compounds with low boiling points and high vapor pressures, such as HFC-23 can be used for blending to achieve storage pressure and adjust mixture properties while themselves providing enhancement of firefighting capability.

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