AIRCRAFT FIRE PROTECTION: A CRITICAL HALON APPLICATION

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INTRODUCTION

Halon 1301 is the optimum fire extinguishing agent for the aircraft industry. Almost every aircraft produced in the last thirty years has used Halon 1301 for engine fire protection and in many cases cargo and dry bay protection as well. Every organization associated with aviation is searching for a substitute agent. In a few years, probably as few as two years, this search may well become urgent if not critical.

Halon 1301 Usage in the Aircraft Industry

After World War II, the Army initiated a program to find new fire suppressants similar to the previously used halogenated agents like carbon tetrachloride but with better properties, eg. clean, effective and safe to humans. These chemicals were called halons which is short for halogenated hydrocarbons. Halon 1301 was developed as the aircraft engine fire fighting agent as a result of the Army study (1). Its useful properties are detailed in Table 1.

Table 1

- high fire fighting efficiency
- low residue
- low electrical conductivity
- low metals corrosion
- high materials compatibility
- long-term stability
- low toxicity of the agent and its combustion products (although some of the combustion products are extremely toxic, they are created in very small quantities and have rarely been the cause of injury.)

It is interesting to note that the Army study included many of the agents that are now being proposed as alternate agents. When an aircraft flies at an altitude of 30,000 to 50,000 feet the temperatures outside the aircraft are as low as -74 °C (-100°F). Typical fire extinguisher bottles are placed in the wings or pylons near the engine nacelles in unheated, unpressurized spaces. If the threat of fire exists, these fire extinguishers must provide the fire suppressant agent in a gaseous form at very low temperatures (-65 °C) very quickly (typically in one second or less). With Halon 1301 this can be accomplished very well, and is one of the main reasons that Halon 1301 is nearly ideal for the aircraft engine fire suppression application.

Halon 1301 boils at -68 °C, therefore, it is distributed as a gas in an aircraft engine, even though the temperature would render most agents in the liquid state.

In addition, Halon 1301 can be super pressurized, this property permits the distribution into the engine nacelle in a matter of about a second. Not only does it possess these important physical properties, but it is a chemically active agent in fighting a fire. This means that it chemically disrupts the chemistry of the combustion reaction and is much more efficient at extinguishing a fire than an agent the acts in a physical way. A good comparison is with CO_2, carbon dioxide. Carbon dioxide is a physical agent that can only dilute, cool, and smother a fire by depriving the fire from its oxygen source. As such, it is required to be present in nearly 21% by volume to extinguish and at this concentration there is insufficient oxygen to sustain life. Halon 1301 on the other hand requires only a little over 3% by volume to extinguish a fire (typical designs require that the concentration reach 5% to 6%, in an aircraft engine application).

Halon 1301 is essentially inert in the presence of metals. Charged containers that have been in use for many years are still equally suitable for fire extinguishment as those that are freshly charged.

The FAA recently published a report on the feasibility of recycling Halon 1301 to extend the current supplies for the aircraft application (2). From this study the following picture emerges for the commercial aircraft industry. There are a total 5500 aircraft in which some 220,000 pounds of Halon 1301 are being carried. The annual usage from fire incidents and discharges due to false alarms is between 13,000 and 17,000 pounds.

The estimated annual commercial aircraft requirement for recycled (or new) Halon is about 100,000 pounds. There is probably at least an equal Halon requirement for the Military. The production of Halon 1301 peaked in 1988 and was in the neighborhood of 28 million pounds.

Assessment of the Availability of Halon 1301 in the Future

cientific Assessment: UNEP Panels

A synthesis of the reports of various technical panels, which are being prepared for consideration at the next meeting of the Parties of the Montreal Protocol was published in Nov. 1991 **(3).** This Synthesis represents the "judgment of several hundred experts of appropriate disciplines from developed and developing countries." The conclusions are as follows:

a) Additional **ozone** depletion is expected during the next decade.
b) Many adverse effects on humans, animals and plants **are** expected.
c) Significant Reductions in atmospheric chlorine and bromine levels **are** feasible.
d) Phaseout is feasible by **1995 - 1997,**
e) Phaseout costs are falling.
f) Developing countries can accelerate phaseout.

The White House Response

In Feb. **1992,** the President issued a press release that committed the U.S. to phase out production by Dec. **1995.** Further, the statement has asked US producers to reduce **1992** output to one half that of **1986** levels. The President further stated that the **US** will re-examine the phaseout schedule of HCFCs.

The Military Response

All branches of the US Armed Services have issued regulations, which have **resulted** in a major reduction in the use of Halons for training and testing. They have instituted serious studies to find replacements and have developed plans for banking current supplies of Halon for use in "mission critical" applications. The EPA has been encouraging all of the Military to issue a ban on the purchase of new Halon and to issue regulations that would require any new purchases to be restricted to recycled Halon.

The EPA Response

The EPA is charged with enforcing the Clean Air Act and will therefore, have the responsibility of controlling the production of Halon. There have been several meetings called by the EPA with the purpose of identifying a process to develop a "recycling bank."

Their concept is that recycling of Halon for essential use application is the environmentally responsible approach. If recycled Halon is used, there is no requirement for the industry to continue to produce "new" Halon.

The Montreal Protocol Response

There will be a meeting of the Montreal in Nov. 1992. At this meeting there will be several proposals discussed including an 85% cut by 1/1/94, and complete phaseout by either 1/1/94, 95, or 96. It is very probable that the phaseout by 1995 will be followed as requested by the President.

Conclusion

It is doubtful that the production of new Halon will survive the US tax which will cost over $24/pound in 1994. This tax does not affect the price of recycled Halon. It is our opinion that the supply of new Halon will be stopped in late 1993 or early 1994.

THE AIRCRAFT INDUSTRY: *AN* ESSENTIAL HALON APPLICATION

What is the Meaning of Essential Use?

The concept of an "essential use" for halon and other CFCs was developed to provide a rationale for a limited production of "new" agent. As stated in the previous section, there will in all likelihood be no new agent production beyond 1994. However, the identification of essential uses will hopefully stimulate the creation of a mechanism by which we can ensure a supply of recycled Halon 1301 for these essential uses.

The UNEP Halons Technical Options Committee has drafted a definition of Essential Use for possible adoption at the November Meeting of the Parties. Their draft statement follows (4): "A critical need must exist to minimize damage due to fire, explosions, or extinguishing agent

application, which would otherwise result in serious impairment of an essential public service, or pose an unacceptable threat to life, the environment, or national security, and all other appropriate fire protection measures have been taken."

The Aircraft Industry

Virtually all US Organizations including the Military, PA, and FAA have accepted the aircraft fire protection application as Essential Use. As far as is currently known, all counmes that are considered to be "head start" counmes at implementing the phase out of CFCs and Halons have made exceptions for the aircraft fire protection application. In general the Military have identified aircraft fire protection as "mission critical", which in their terminology is equivalent to "essential use."

The main reason for this is the lack of a "drop in" replacement, which possesses the necessary cold dismbution characteristics, can meet the time of dismbution specifications, can put out a fire with the same efficiency, and will not harm the Ozone Layer.

An aircraft retrofit program with an agent that is less efficient would require major redesign, structural modifications, and result in weight penalties and added costs. The world wide costs of such a retrofit program would be in the many Billions of dollars. Many aircraft simply have no space to put additional bottles or plumbing for dismbution systems. The aircraft currently in design such as the Boeing 777, the AF22, C17, MD12, and others are being designed using Halon 1301. The aircraft manufacturers are investigating the impact of using an alternate agent, but their baseline designs are with Halon.

ALTERNATE AGENTS FOR THE AIRCRAFT INDUSTRY

The DuPont Chemical Company, Great Lakes Chemical Company, North American Fire Guardian Technology Inc., the 3M Company, and a few others are offering agents as potential substitutes for Halon 1301.

Most of the alternate agents that have been proposed are of the FC, HFC, HCFC or HBFC chemical families. Of these only the agents belonging to the FC and HFC classes will have an Ozone Depletion Potential (ODP) of zero. The US Government Clean Air Act of 1990 will prohibit the production of any agent with an ODP of greater than 0.2 after the year 2000. The agents in the HCFC (and HBFC) class are supposedly protected by the Montreal Protocol until the

year 2020 and possibly the year 2040 (if their ODP is less than 0.2). However, it is probable that the Parties may change the year of protection when they meet in November.

The proposed alternate agents that have been identified to date are listed in Table II, along with their Halon number, chemical class, and the company that is proposing the agent.

A comparison of important data for these proposed substitute agents is given in Table III. Data for Halon 1301 is provided as a reference point. Critical properties for the aircraft industry are the boiling point and the efficiency as a fire fighting agent.

In Table III under the "efficiency" columns, a number larger than one indicates that more agent is required than if one were using Halon 1301. For example tetrafluoromethane, Halon Number 14 will require 2.9 times the weight of Halon 1301 and 3.3 times the volume of Halon 1301 to extinguish a fire.

Assessment of the Proposed Alternate Agents

None of the proposed alternate agents is ideal. It is clear that there may not be a "drop in" replacement for Halon 1301. The only agent that is stated by the manufacturer to be a pound for pound drop in is the NAF S-111 blend. This product was introduced last summer and has little testing data as yet. It contains an HCFC with a small ODP.

Most of the potential replacement agents are less stable than Halon 1301. The question must be asked as to how long they will be stable in their containers and are the decomposition products corrosive to the containers. It may be that the current replacement agents might have relatively short lifetimes, maybe as short as three to five years as compared to Halon 1301 which, has been demonstrated to last up to 20 years.

The ultimate conclusion that no substitute agent available today can be used as a drop-in replacement for Halon 1301 is inevitable.

Table II.

Proposed Halon Replacement Agents

Chemical Name	Chemical Formula	Halon Number*	Class	Company
Bromodifluoromethane	$CHBrF_2$	1201	HBFC	GT LAKES
Tetrafluoromethane (Perfluoromethane)	CF_4	14	FC	NMERI[1]
Trifluoromethan	CHF_3	13	HFC	NMERI[1]
Difluoromethane	$CH2F_2$	12	HFC	NMERI[1]
Chlorodifluoromethane	$CHC1F_2$	121	HCFC	NAFG[2]
Perfluoroethane	$CF3CF_3$	26	FC	
2,2-dichloro-1,1,1-2 Trifluoroethane	$CHCl_2CF_3$	232	HCFC	DuPont[2]
2-chloro-1,1,1,2-Tetrafluoroethane	$CHClFCF_3$	241	HCFC	2
Pentafluoroethane	HCF_2CF_3	25	HFC	DuPont
Perfluoropropane	$CF_3CF_2CF_3$	38	FC	
Heptafluoropropane	CF_3CHFCF_3	37	HFC	GT LAKES
Perfluorobutane	FC	4-10	2CF2CF3	3M3

1 These chemical agents have been tested and recommend for further study as replacements for Halon by the New Mexico Engineering Research Institute, NMERI, however, they have not been offered by any of the chemical manufacturing companies *(5)*.

2 These chemicals are part of a blend offered by North American Fire Guardian Technology Inc., called NAF-SIII.

3 The 3M Company has stated that they will offer peffluorohexane as well; however, it does not appear to be a suitable aircraft alternative because of its rather high boiling point.

Table III

Comparision Of Properties

Halon Number	Trade Name	ODP[1]	GWP[2]	BP (OC)	weight EFF.[3]	Volume EFF.[4]
1301	HALON*	16	2.0	-58	1.0	1.0
201	FM-100	1.4	N/A	-15.5	1.38	1.34
14	--	-0-	N/A	-128	2.90	3.30
13	--	-0-	N/A	-82	2.07	2.05
12	--	-0-	N/A	-52	1.09	1.79
121	NAF-SIII[5]	0.04	0.35	-25	2.42	3.10
26	--	-0-	N/A	-78	2.60	2.45
232	FE-232 NAF-SIII[5]	0.02	0.018	+28	2.36	.42
241	NAF-SIII[5]	0.02	0.25	-12	2.66	2.89
25	FE-25	-0-	0.58	-48	2.70	3.29
38	--	-0-	N/A	-36	2.75	2.57
37	FM-200	-0-	N/A	-16.4	N/A	1.93
4-10	3M	-0-	N/A	-2.2	(2)	1.45

*Reference Agent

1 The Ozone Depletion Potential is calculated from an atmospheric computer model.

2 The Global Warming Potential is also calculated from an atmospheric computer model.

3 The weight efficiency is based on an experimental extinguishment concentration, relative to Halon 1301, as determined at NMERI

4 The volume efficiency is based on an experimental extinguishment concentration, relative to Halon 1301, as determined at NMERI (5).

5 NAF-SIII is a blend of these agents plus an additive to decrease unwanted combustion by-products.

THE RECYCLE OPTION

In the "Report of the Halons Technical Options Committee," which has just been released, it has been estimated that the use of recycled Halons for the "essential use" requirements would provide sufficient 1301 supplies for several decades **(4).** This report goes on to encourage recycling as the only environmentally responsible solution to the Halon that has already been produced.

The **U.S.** Environmental Protection Agency has strongly encouraged the **U.S.** Military to formulate policies that would permit only the purchase of recycled Halons.

The **FAA** has studied the issue of using recycled Halon 1301 to extend its available for up to twenty years *or* until a suitable replacement has been found. A report has just been published on this issue **(2).**

The Halon Alternatives Research Corp., HARC, is in the process of supporting a project to identify the logistics of developing a "bank" for commercial/industrial "essential" uses. This study will be available in the very near future.

The **U.S.** Military - all branches - have developed strategies for banking excess Halon and recycling in each branch for use in "essential" or "mission critical" applications. In a recent meeting called by the EPA to discuss issues of Halon recycling, the modification of Military Standards was discussed to ensure acceptable quality for recycled Halon.

All parties at this meeting agreed on the importance of the environmentally responsible requirement for the development of a Halon banking system to enable the recycling option.

We feel that the best solution for the aircraft industry is to adopt the policy of using recycled halon. Future planes will undoubtedly be designed with an alternate agent, but the cost of retrofitting old aircraft with the alternate agent will be prohibitive.

REFERENCES

1. "Vaporizing Fire Extinguishing Agents," U.S. Army Project 8-76-04-003.1950. (Called the "Purdue Research Foundation Study.")

2. "Feasibility of Systematic Recycling of Aircraft Halon Extinguishing Agents, DOT/FAA/CT-91/21, 1991.

3. "Synthesis of the Reports of the Ozone Scientific Assessment Panel, the Environmental Effects Assessment Panel, and the Technology and Economic Assessment Panel" prepared for the Parties to the Montreal Protocol, Nov. 1991.

4. Report of the Halon Technical Options Committee prepared for the parties to the Montreal Protocol, 1992.