RETROFIT OPPORTUNITIES FOR HFC-125 IN AIRCRAFT ENGINE NACELLES

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The Naval Air Systems Team has conducted and participated in several varied test programs recently. each offering data that give rise to the opportunity of successfully applying HFC- I25 to the in-service fleet as an adequate alternative to halon. The particular on-board retrofit applications being promoted are the fixed Halon 1301 fire protection systems protecting the engine nacelles aboard aircraft.

The history of restrictions on ozone-depleting substances continues to grow, starting with elimination of chemical production and leading up to preclusion of use in future contracts. The ever-present threat of use restrictions on currently allowed applications remains a concern. Any policy of continued reliance on the halon we have access to today does have risks associated with it.

The Navy's response to the stacking legislation and internally instituted restrictions has been a clear definition of and strict adherence to our Responsible Use Policy, summarized as follows: (1) stockpile, (2) recycle, and (3) R&D alternatives. Proper compliance with each of the three tiers of the policy is critical to satisfying our environmental responsibilities while ensuring uninterrupted provisioning for the fleet's fire protection needs.

The application and use of halon was limited to those aircraft in service prior to 1993. After that date, all new or significantly modified aircraft were precluded from invoking the use of halon. Thus, relatively clear lines of authorized use of the fixed halon stockpile were drawn, based on the platform's positioning in the fleet in 1993.

Said another way, the fleet did not suffer an imperative need for a halon retrofit solution as long as the halon stockpile was maintained and viable. Further. and just as important. is the fact that no halon alternative chemical could satisfy all the extreme performance requirements as a retrofit. Thus, we did not have a retrofit solution. but we did not need one yet either. What is being presented. however, is the new opportunity that has only recently arisen to employ HFC-125. a chemical known to be less effective than halon. as an acceptable halon alternative for retrofit. Two recent test series, the Navy's F/A-18E/F and the Army's H-60. offer insight on engineering a fire protection system that optimizes the less effective HFC- I25 chemical. It has been proven that HFC-125 coupled with an enhanced bottling and discharging arrangement can. in fact, meet or exceed the currently flying halon system.

HFC-125 is not a new chemical io the Department of Defense or private industry. After extensive study during the joint Halon Alternative Technology Development Program, it was selected among all chemicals tested to be an acceptable chemical alternative to Halon 1301. Design equations for its use had been developed years ago, which defined its utility as a forward fit solution for new aircraft that could afford to grow by 200 – 300%. but just as strongly implied that the system growth prediction made it an unacceptable option for retrofit.

The Navy has joined with the Army in evaluation of data recently collected during an in-flight fire protection system discharge test. The dual shot halon system currently in use aboard all H-60 helicopters was modified to allow both fire bottles to discharge simultaneously when the system was activated from the cockpit during the test flight. The bottles were emptied of their halon and refilled with HFC-125. Effectively, system expansion of 200% was immediately achieved with this simple change in discharge logic. When discharged into the instrumented nacelle during a flight test, the concentrations of HFC-I25 delivered throughout the nacelle very nearly met the agent requirements defined by the design equation. Historically, when the agent distribution was this close to "passing" (only 1 of 12 instrumentation channels was slightly under the required concentration levels), a slight "tweaking" of the agent discharge nozzle was often all that was needed to redirect agent from an area of high agent concentration to the area in need of more agent. Another H-60 test series is planned to evaluate the success of such minimal modifications on agent distribution.

The promotability of turning the dual-shot halon system into a single-shot HFC-125 system may give reason for concern from the safety community. Thus, data from a naval study conducted in 1993 was reviewed to evaluate the effectiveness of these redundant halon systems. All aircraft fire events occurring aboard naval aircraft were reviewed to segregate those mishaps during which the second halon bottle was employed during the emergency. The results of the data review show that a significantly low success rate can be expected from the second bottle. When considered directly, it does make sense that a fire that could not be extinguished with the discharge of the first bottle, which continues to grow as a fuel-fed fire while the pilot struggles with his in-flight emergency and hopes that the first bottle's been successful, would likely not be extinguished when the pilot gets around to discharging the second bottle. Thus, there is a very convincing argument (one that has already been made successfully to several aircraft platforms) that eliminating the redundancy feature of their current halon system will effectively cost nothing by way of crew safety. The benefit, however, is significant, as testing shows the very real possibility of acceptably incorporating a halon retrofit chemical with minimal hardware changes to the aircraft and minimal system testing to qualify the new system.

The testing that originally caught the Navy's attention regarding retrofit was, oddly enough, a forward-fit halon alternative test program. The Navy's newest fighter attack aircraft, the F/A-18E/F, was evaluating halon alternatives but did not have the **luxury** of accepting any larger a system than the halon system currently aboard their earlier models. Thus, whatever the E/F program selected as an acceptable halon alternative would receive much attention as a potential retrofit for the F/A-18A through D models. Again, the utility of HFC-I25 was suspect due to the predicted amount of the chemical that would be needed, as specified by the design equation. Nonetheless, the Navy testing focused on nacelle airflow analyses and plumbing optimization, and proved that enhanced distribution of the **less** effective chemical could and did deliver an **HFC**-I25 system capable of meeting the performance of the halon system it was replacing.

The general characteristics of the enhanced E/F plumbing highlight the significance of plumbing modifications. Compared with the much simpler C/D plumbing scheme, which employs a single discharge nozzle. the E/F four nozzle system prepositions the HFC-I25 throughout the nacelle and in concert with the prevailing nacelles airflows, in such a way as to optimize agent presence at the fire, wherever it may be in the nacelle.

There is a significant difference between the "required" HFC-I 25 concentration to extinguish an F/A-18E/F nacelle fire, as predicted by the design equation, and the actual concentration recorded during successful fire testing of the HFC-125 system with the enhanced plumbing.

A review of the Navy's aircraft fleet shows interesting promise in the acceptability of HFC-I25 as a retrofit option. **All** naval helicopters, and several fixed wing platforms, havc redundant halon systems and thus are candidates for a relatively minimal test effort that could provide an acceptable HFC-125 system to be retrofitted. Also of interest **is** whether the commercial tlect has any platforms that have redundant halon systems tlying today. There is every opportunity to promote a similar assessment of retrofit potential.

Further. the remaining in-service fleet. those aircraft that do not have redundant systems, might also hold hope of designing an acceptable HFC-I 25 system. It would take particular attention to the nacelle airflow and dedicated full-scale high fidelity fire testing to prove the system's performance, hut exactly that was conducted on the F/A-18E/F with surprisingly good results. Recall that it is system equivalence that is required—not chemical equivalence.

For general planning purposes, an outline of basic tasking was constructed that offers the roadmap to successfully designing and qualifying an HFC-I 25 for retrofit purposes. As the critical parameters under evaluation (nacelle geometry, nacelle airflow. hot surfaces. etc.) are platform-specific, each program would have to develop its own details to fill in the overall test program direction, but it is felt that few aircraft, military or commercial, would find it technically infeasible to pursue an HFC-I25 retrofit test program.

It remains to be seen which, if any, aircraft programs will use the data presented here to conduct their own research and test effort in pursuit of a halon retrofit solution. It must be emphasized, however, that conducting the system optimization testing that is being promoted would also aid their existing halon-based system in use today. Any enhancements realized through HFC- I35 system optimization studies/tests would certainly also enhance the perfonnance of halon. Thus, program commitment to design and prove an acceptable HFC-125 system does not imply any less commitment to the existing halon stockpile. Specifically. a system proven to accept HFC-125 (complete with bottle discharge logic changes and/or plumbing modifications) could be installed in existing aircraft. hut with no change in chemical. The halon system will enjoy a boost in performance from the new plumbing and that platform is now positioned to accept HFC-I25 if and when it becomes appropriate to do so—either after the halon stockpile has "naturally" run out. or in response to a more immediate loss of the supporting chemical driven by potential future halon use restrictions. This promotion for retrofit testing is intended to offer an option to continued reliance on a fixed halon stockpile. an option never available before. Playing out this option and pre-positioning the fire protection system as one amenable to both halon and HFC-I25 significantly reduces program risk to an uncertain future.

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LEGAL HISTORY

- 1988 Montreal Protocol
  - Designated Halon as Class I Ozonc Depleting Substance (ODS)
  - Called for Limits on Global Production
- U.S. Clean Air Act Amendments of 1990
  - Prohihited Halon Production in U.S. After Jan **94**
  - hohihited Purposeful Venting
  - Required Training to Preclude Improper Emissions
- FY93 Defense Authorization Act
  - Prohibited **Use** of ODSs in New Contracts

NAVY RESPONSIBLE USE POLICY

- ODS Stockpile (Strategic Reserve)
  - Supports 1993 Fleet Until 2028 (If Necessary)
  - Nu Extended Conflicts. No FMS **Support**
- Minimize **Use**
  - Recycle During **Bottle** Maintenance
  - Address Inadvertent System **Discharges**
- Alternative R&D
  - Find *and Implement* Alternative(s)
  - TDP / NGP
  - Gas **Generators** / Water Mist

NAVAIR USE OF HALON

- New Aircraft Programs (Post - 1993)
  - **Non-Halon** System
  - **NO** Reliance on Stockpile
- In-Service Aircraft (Pre - 1993)
  - U.S. **DOD Halon** Stockpile
  - Intent to Implement Alternatives, If/When Available

RETROFIT OPPORTUNITY

- Old Retrofit Solution:
  - None Needed (None Available)
- New Retrofit Opportunity: HFC-125
  - **11-60** System Modification and Discharge Testing
  - Unexpected Forward Fit Solution for F/A-18E/F
- Drivers of Change
  - **Enhanced** (and Growing) Pressures on Stockpile
  - Commitment to Implement Alternatives When Identified
  - Eliminate Continued Reliance on ODS

High Potential for Retrofit Solution

HALON ALTERNATIVE TECHNOLOGY DEVELOPMENT PROGRAM

- 1992 Start, 4 Year Effort
- DOD Program w/ **FAA** Participation
- First "Corporate" Effort to Identify Chemical Alternative for Halon
  - Extinguishing Performance: Tonicity: Material Compatability; Agent Stability; Availability
- TDP Answer: HFC-125
  - Design Equation Specifies 3x Halon Concentration

Predictions of 200 - 300% System Growth Necessary

H-60 *DISCHARGE* TEST PROGRAM

- Army Testing with Navy Support
- Current Redundant Halon System Modified to Single Shot HFC-125
  - *Benefit*: Immediate 200% Growth
  - *Cost*: Loss of Back-up Bottle
    - H-60 Back-up System Used **Once** - Unsuccessful
- Agent Concentrations Approach Design Equation
  - Planned Retest with Slight Plumbing Modifications

Minimal System Modification Needed for Platforms with Redundant Systems (Helos)

REDUNDANT SYSTEMS NAVAIR FIRE HISTORY (1977- 93)

Helicopter	Fixed Wing
– 161 Fires	– 388 Fires
– 37 **Ext'g** Attempts	– 57 Ext'g Attempts
– 14 Second Bottle Used	– 7 Second Bottle Used
– 1 Success w/ 2nd Bottle (H-3)	– 3 Successes w/ **2nd** Bottle (All P-3)

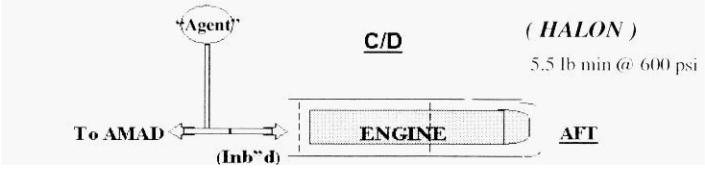
Redundant Systems Historically Ineffective

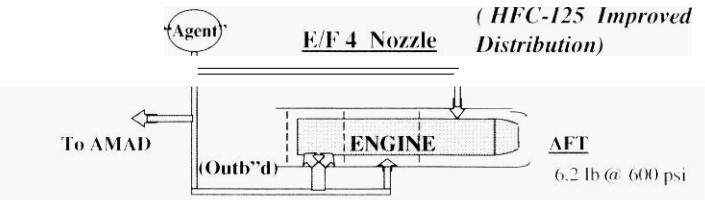
F/A-18E/F ***FIRE* TEST** PROGRAM

- Minimal Bottle Growth Allowance
  - Effectively, a Retrofit Challenge
- HFC-125 Successful with Similarly Sized Bottle
  - *Optimized Distribution*
  - 5.5 #Halon Being Replaced with 6.2# HFC-125
  - "Better Than **or** Equal" Performance Achieved
  - Actual Concentration Far **Less** Than Design Equation Prediction

Optimized Plumbing Can Significantly Enhance System Performance

Nozzle Placement(s)





HFC-125 CONCENTRATION COMPARISON

1998 F/A-18E/F ENGINE BAY FIRE TESTING

	Minimum Req'd Volumetric Concentration	Agent Mass (Pounds)
Design Equation Prediction (per TDP)	18.51 %	4.87
Fire Test Data	8 - 9%	5.6

GOOD NEWS

- Approximately Half of the **Navy's** In-Service Aircraft Fleet Could Accommodate **an** HFC-125 System Sized to Meet the Design Equation
  - Remove Redundancy Feature
    - Minimal Hardware Modifications
  - Some Platforms Could Accept Another Bottle
  - Minimal Test Effort to **Quality** New System
    - System Discharge Testing Only
  - DOD / Commercial Applications

BETTER NEWS

- Even If No System Growth Potential, Acceptable HFC-125 System Performance Could Still Be Achieved for the Remainder of the Fleet
  - By Addressing the Plumbing, HFC-125 Systems Can Be Made As Efficient as Halon 1301 Systems
  - More Extensive Hardware Modifications Necessary
  - Fire Testing Required

***System* Equivalence is the True Goal**

GENERIC RETROFIT PROPOSAL

- Phase I: Analytical Evaluation
  - Extensive Coordination with Airframer
  - Airflow Analyses / Fire History
  - Potential Hardware Enhancements
- Phase II: Nacelle Airflow and/or Fire Testing
  - Full Scale High Fidelity Test Article
  - System Discharge Studies
  - Agent Concentration / Nacelle Firc Testing
- Phase III: Qualification and Implementation
  - System Qualification Testing
  - Retrofit Kit Development

EFFECT ON STATUS QUO

- HFC-125 Study/Test Proposal Offers Alternate to Halon System - ***Does Not Mandate It***
  - Plumbing Optimization Studies/Testing
    - Enhances Halon Performance as Well as HFC-125
  - Continue to Use Halon Until It's Gone
    - "Normal" **Predicted** Usage Rate
    - No Destruction Costs
  - Hedge Against Unanticipated Halon **Use** Restrictions or Destruction Mandates

Conduct Necessary Evaluations Now, Introduce HFC-125 as Appropriate