Navy Halon Replacement Efforts for MH-60 Helicopters

October 30, 2007

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H60 ENGINE FIREX SYSTEM 101

Traditional Configuration

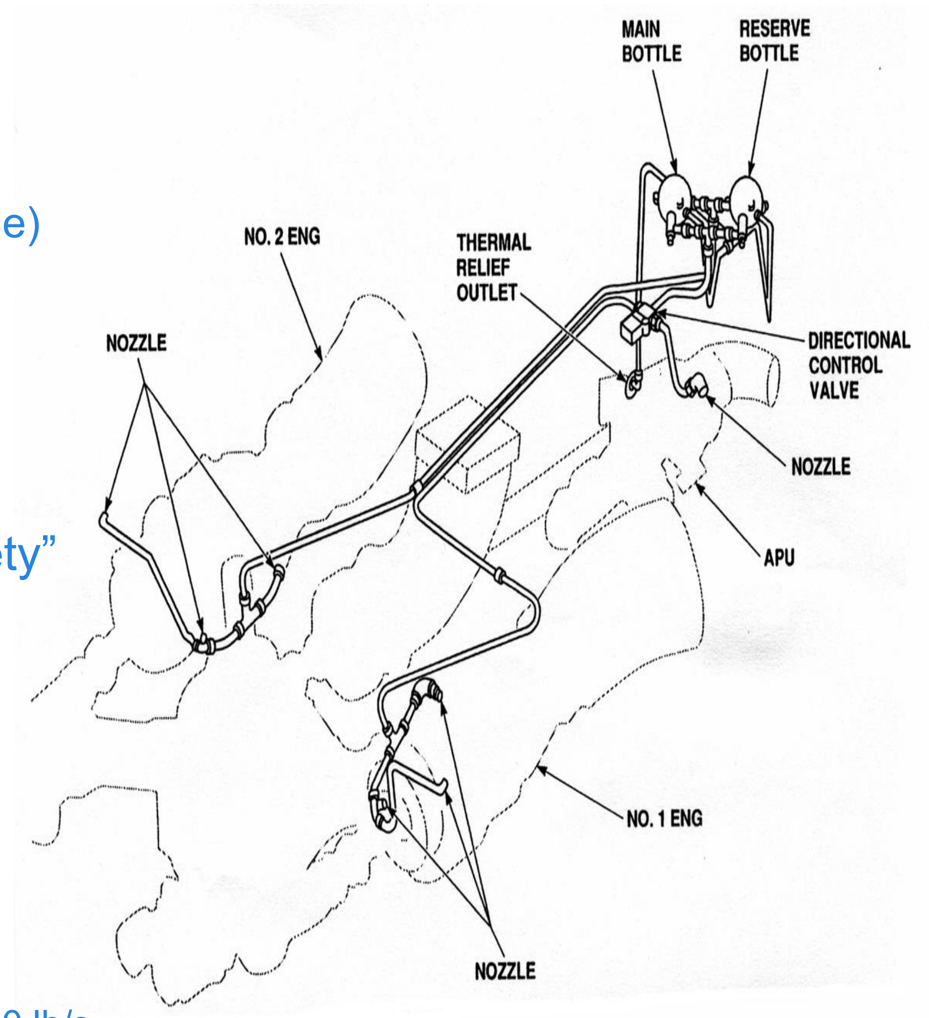
- Two 86 in^3 bottles
  - Main Bottle to No. 1 Engine
  - Reserve Bottle to No. 2 Engine
  - Total agent weight - 5.0 lbs (2.5 lbs/bottle)
- 2nd Shot Capability - Cross Plumbing
  - 1st shot does not extinguish fire
  - Reserve Bottle to No. 1 Engine
  - Main Bottle to No. 2 Engine

Function

- Designed & qualified to extinguish “safety” fires
  - not fires from battle damage or engine failures
- No MIL-Spec for a 2-shot system

H60 System Qualification

- In-flight testing
  - 6% agent for 0.5 seconds
  - Hover, 80 & 120kts, forward level flight
    - 120 kts nacelle airflow estimated to be 2.0 lb/s
  - air samples drawn from engine/APU compartment after bottle discharge



Phase I Analytical Study Conclusions

- Agent Down Select
  - HFC 125 chosen as best alternative available
- Single vs. Redundant Shot System Analysis
  - <u>Redundant Shot System</u>
    - Traditional H60 system: Main and Reserve Bottles, 1 bottle discharged
    - Reserve Bottle for 2nd shot capability
    - Determined 3.53 lb needed to meet DoD design equation
    - Existing qualified H53 bottle can hold up to 3.7 lb of agent
  - <u>Single Shot System</u>
    - BOTH Main and Reserve bottles discharge into nacelle
    - Lose 2nd shot capability
    - Utilizes qualified H60 bottles holding 2.5 lb of agent each for a total of 5 lb
    - Convert H-60 2-Shot Halon System to a 1-Shot Non-Halon System - least impact to system; only minor wiring changes, system “tweaking”
      - Cursory review of aircraft fire history & engine compartment fire analysis indicates loss of reserve shot is acceptable

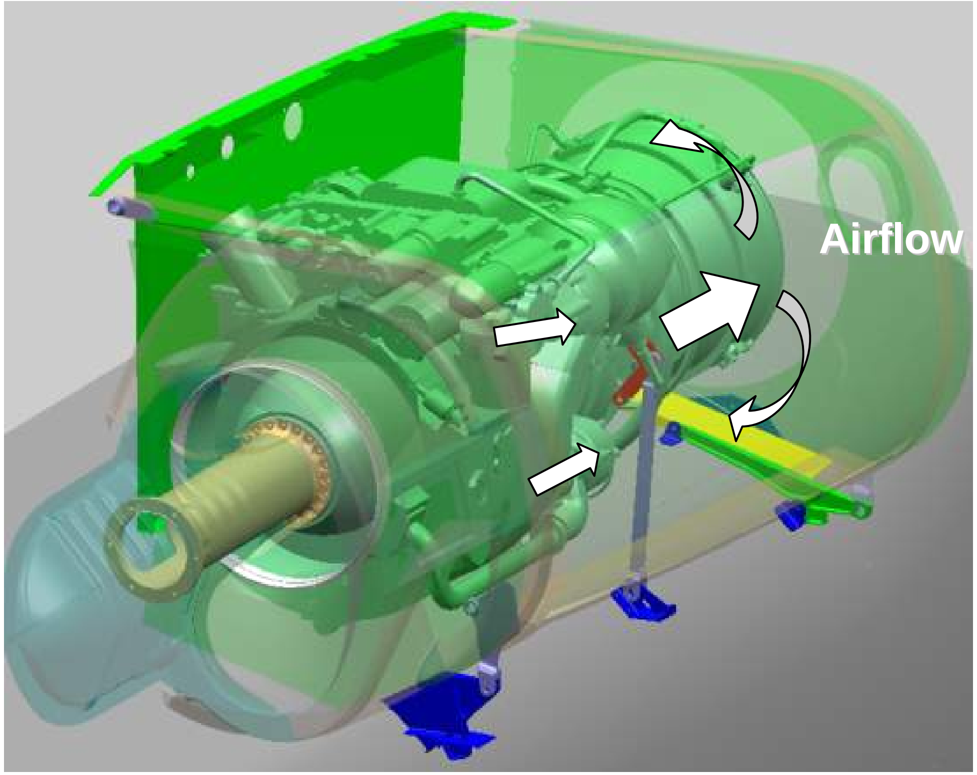
Accepted Recommendation: Redundant HFC125 System

Phase II System Development Risk Mitigation Test Objectives

- Build H60 engine nacelle simulator
- Verify simulator through Halon 1301 concentration testing
  - "Match" original system qualification data
- Baseline Halon 1301 system effectiveness through fire testing
- Evaluate HFC 125 Redundant Shot performance using H53 sized bottles against Halon 1301 baseline (assess Single Shot as necessary)
- Measure HFC 125 concentrations at fire locations and establish qualification criteria
- No distribution tube changes to ease impact of retrofit (retain common system)

Phase II System Development
Establishing Test Airflow

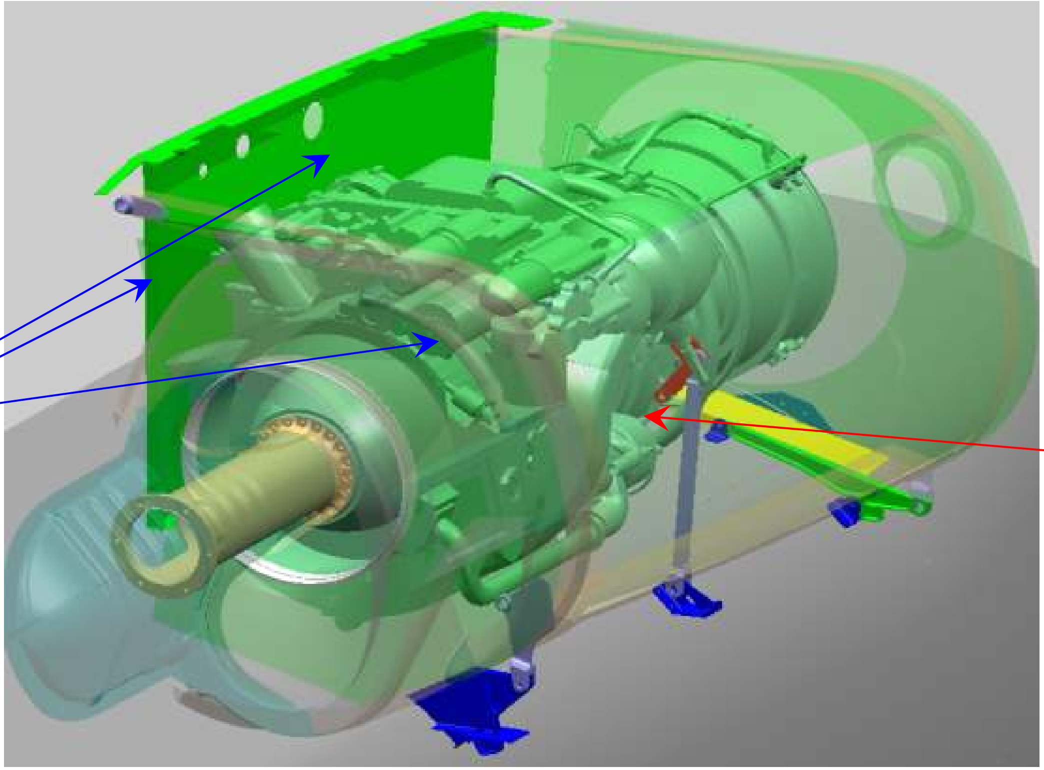
- Airflow
  - Chaotic airflow path through nacelle
  - Two exhaust configurations
    - MH-60R - Standard (Straight) exhaust
    - MH-60S - Hover Infrared Suppression System (HIRSS) exhaust
  - Tested at three mass flow rates
    - 1.5 lb/s – represents lowest safe single engine air speed (80 kts)
    - 2.0 lb/s – matches estimated Qual airspeed (120 kts)
    - 2.25 lb/s – provides margin to system design



Phase II System Development Establishing Fire Location(s)

- Only one workable fire location due to simulator interference and system discharge points
- Fire location in the leanest concentration area of the nacelle

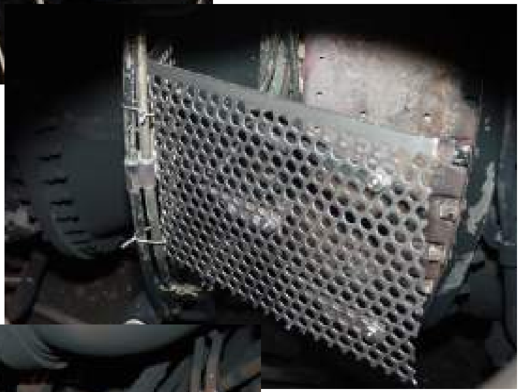
Agent Discharge Ports



Fire Location

Phase II System Development
Establishing Test Repeatability

- Relight Surfaces/Fuel Nozzle positions
- Attempted to use actual engine clutter
  - Not practical due to use of actual engine
  - Surfaces not replaceable
- Introduced “artificial” surfaces
  - F18 tube assembly
    - Unsuccessful
  - Used thin perforated sheet metal bolted together
    - Not durable/repeatable
  - Settled on ¼” thick perforated stainless steel plates
    - Needed a surface to last many fire tests due to sensitivity of data repeatability



Phase II System Development
Establishing Test Methodology/Halon Equivalence

- F18 Method
  - Establish Halon temperature threshold
    - Find temperature at which Halon will extinguish the fire and not relight
    - Ensure a temperature 50F -100F hotter will sustain relight
  - Ensure HFC 125 performs at the same temperature threshold
- H60 Method (similar to FAA methods)
  - Measure relight times at 3 different surface temperatures
  - 5 Halon discharges vs 5 HFC 125 discharges for any given condition
    - The average of 5 HFC 125 discharges must be equal to or greater than the average of 5 baseline Halon discharges

      Avg HFC 125 ≥ Avg Halon
    - **AND** the average minus one standard deviation of 5 HFC 125 discharges must be equal to or greater than the average minus one standard deviation of 5 baseline Halon discharges

      [Avg – Std Dev] HFC 125 ≥ [Avg – Std Dev] Halon

Phase II System Development
Fire Test Results: HFC-125 Equivalent Systems

- MH-60R (Standard exhaust)
  - Redundant Shot with H53 sized bottles (total 3.5 lb of HFC 125)
  - Single Shot with two H53 sized bottles (total 7.4 lb of HFC 125)
- MH-60S (HIRSS exhaust)
  - Single Shot with two H53 sized bottles (total 7.4 lb of HFC 125)

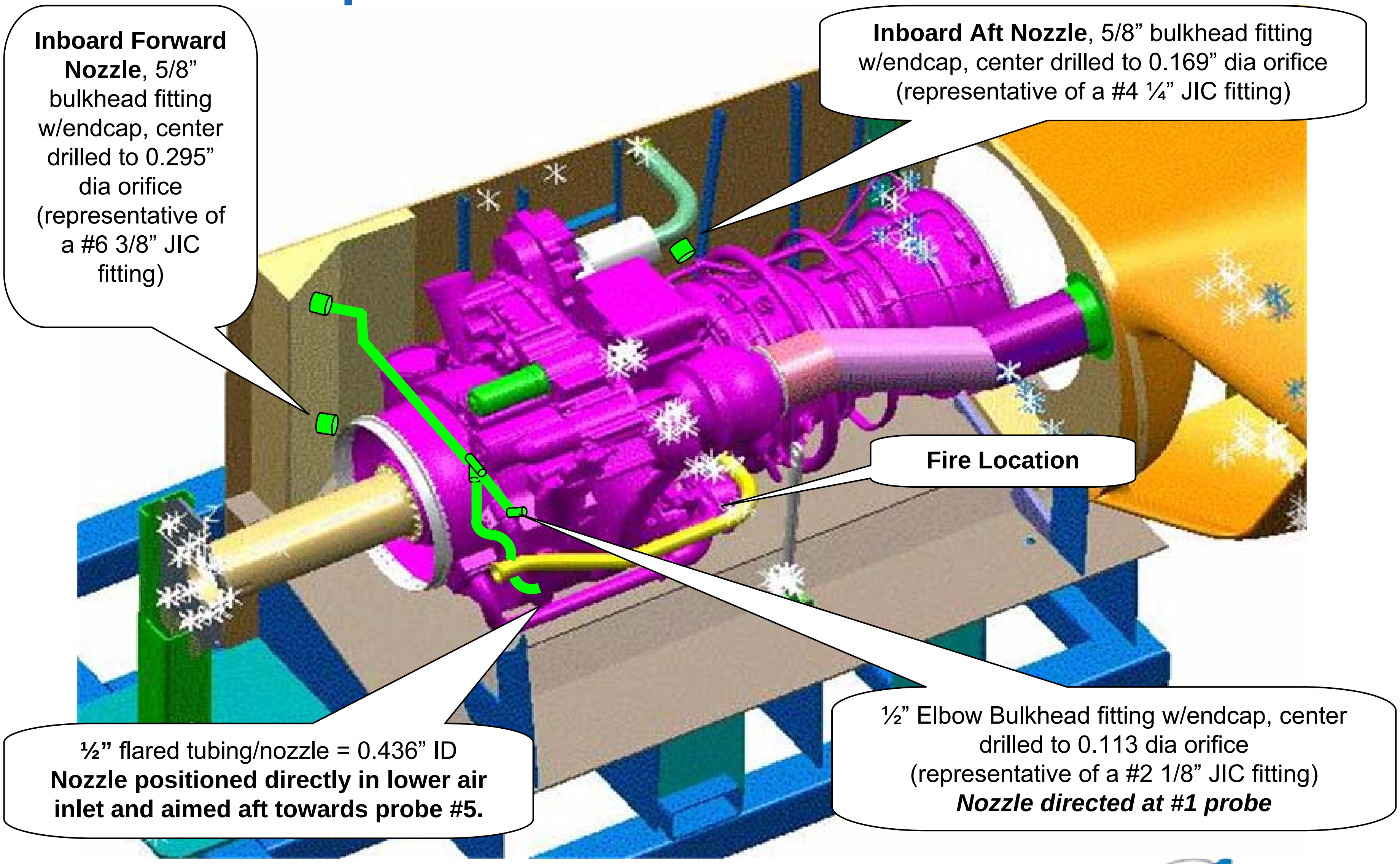
Commonality Preferred:
Selected Single Shot System with two H53 sized bottles based on fire testing results (concentration test still necessary)

Phase II System Development
Establishing Concentration Qualification Criteria

- Fire Location concentration measurements
  - Measured concentrations at the fire location would provide a qualification concentration only for that localized area
  - All other concentration probes not in that vicinity must meet the HFC 125 DoD Design Equation concentration (2.25 lb/s = 19.1%, 2.0 lb/s = 19.9%, 1.5 lb/s = 21.5%)
- Single Shot with two H53 sized bottles (total 7.4 lb of HFC 125)
  - Lowest concentrations in the fire location were roughly 15%
  - Three other probes in the nacelle failed to meet both the DoD Design Equation and the 15% fire location level

Conclusion: Optimization of the distribution system is required due to failure of concentration probes outside the fire location

Phase II System Development
Optimized Distribution Solution



Phase II System Development Conclusions

	Current System	Proposed System
Agent	Halon 1301	HFC 125
Logic	Redundant	Single Shot
Reserve Shot	Yes	No
Total Agent Weight	5 lb	5 lb
Number of Distribution points	3	4
Outboard Line Size	0.375"	0.5"
Outboard High Nozzle Size	0.305"	0.113"
Outboard Low Nozzle Size	None	0.436"
Inboard Forward Nozzle Size	0.484"	0.295"
Inboard Aft Nozzle Size	0.484"	0.169"

- Utilize existing H60 fire bottles in a Single Shot system
- Optimized Single Shot system met HFC 125 DoD Design Equation concentrations with total of 4.5 lb of agent
  - Bottles can accommodate an additional 0.5 lbs, for margin
  - All concentration probes met the DoD Design Equation for the same 0.5 second interval at all airflows & exhaust configurations

Through system optimization, obtained better overall system performance with less agent!

Phase III System Qualification and Implementation Plan Forward

- Build production representative prototype system and install into aircraft
- Concentration test the prototype system in flight and qualify to the DoD design equation
- Sikorsky Aircraft Corporation (SAC) issues ECP to implement new system into the production line

Summary

- Phase I
  - Down selected to HFC 125
  - Proved valid use of a Single Shot system as a weight savings opportunity
- Phase II
  - Through a systems engineering approach proved, in the laboratory environment, an H60 HFC 125 firex system equivalent to the current Halon 1301 firex system
    - Successfully optimized the distribution system to meet the DoD HFC 125 Design Equation
    - Effectively increased agent performance while decreasing agent weight
    - Minimized impact to overall aircraft weight
- Phase III
  - Planning final in flight qualification

System optimization key to finding a non-Halon alternative!

Back Up Slides

Safety Center Data Summary

H60 Navy Safety Center Fire Data					
Date	Location	Flight Status	Aircraft Lost	Method Extinguished	Notes
6/7/1983	APU	Ground	No	Hand Held	Primary and Reserve Engine Bottles Used First
2/17/1988	APU	Ground	No	Primary Engine Bottle	
11/13/1988	Wiring	In Flight	No	Self Extinguished	
9/14/1989	No. 1 Engiine	In Flight	No	Self Extinguished	
2/22/1991	No. 2 Engine	In Flight	Yes	No Attempt	
9/11/1992	APU	Ground	No	Primary Engine Bottle	
4/6/1995	APU	Ground	No	Primary Engine Bottle	
12/27/1996	Wiring	Ground	No	Self Extinguished	
9/17/1998	APU	Ground	No	Ground Efforts	Primary and Reserve Engine Bottles Used First
3/18/1999	???	Ground	No	Ground Efforts	
3/9/2000	APU	Ground	No	Primary Engine Bottle	

H60 Army Safety Center Fire Data					
Date	Location	Flight Status	Aircraft Lost	Method Extinguished	Notes
2/8/1982	Flight Control Cowling	Landed	No	Self Extinguished	
3/30/1982	APU	In Flight	No	Primary Engine Bottle	
7/24/1982	APU	Ground	No	Primary Engine Bottle	
7/20/1995	No. 2 Engine	Ground	No	Ground Efforts	Primary Engine Bottle Used First
5/14/1997	No. 2 Engine	Landed	No	Hand Held	Primary and Reserve Engine Bottles Used First
1/26/1998	Wiring	Ground	No	Hand Held	
8/8/2000	No. 2 Engine	Landed	No	Primary and Reserve Engine Bottles in Succession	
3/24/2002	No Data	No Data	No	No Data	
10/21/2002	No. 2 Engine	Landed	No	Primary Engine Bottle	
12/8/2005	Engine/APU	In Flight	No	Self Extinguished	

Note Safety Center mishap reports open to interpretation

HFC 125 DoD Design Equation Review

•Concentration Equation

$C=21.1+0.0185(T)-3.124(W)+5.17(K)+0.0023(T)(K)+1.597(K)(K)$

- •C = Required HFC-125 Concentration by Volume (%)
- •T=Maximum Air Temperature in the Nacelle or APU Compartment (F), 100(F) minimum, 275 (F) maximum
- •W=Airflow in Nacelle or APU Compartment (lbm/sec), 0.9 lbm/sec minimum, 2.7 lbm/sec maximum
- •K= Fuel Constant, use 0.3586 for JP fuel

•Mass Formula

MASS (lb.) = 0.003166XeV+4.138(Xe/(100-Xe))*Wactual

- •Xe=(from formula above) C - %
- •V = free volume of nacelle or APU - FT3
- •Wactual = actual maximum air mass flow rate - lb/sec

Background

Legal Drivers

- 1988 Montreal Protocol
  - Halon Class I Ozone Depleting Substance (ODS)
- 1990 Clean Air Act Amendments
  - Banned Halon Production in U.S. After Jan 94
- Defense Authorization Act FY93
  - Prohibits the use of ODS in new contracts

Navy Responsible Use Policy

- Halon Stockpile
- Minimize Use & Release
  - Recycle & Reclaim
- Halon Alternative R&D
  - DoD Efforts - TDP; NGP
  - Navy Efforts - Gas Generator Technology; Water Mist Technology

Non-Halon Agent Considerations

Agent	Pros	Cons
HFC125	• Selected As The Only Halon Alternative By The DOD TDP • Offers Lower Technical Risk & R&D Costs • Currently Fielded And Supported By Several Navy And Air Force Aircraft - F/A-18 E/F, V22, H1 And F22 • “Equivalent-Level-Of-Safety” Is Known • Very “Halon-Like” - No Impact To Existing Maintenance/Logistics/Supply Systems	• 2-3x Growth Predicted With UNOPTIMIZED Systems • F/A-18 E/F Experienced Showed Potential For Less W/Optimized System • Global Warmer
FM200	• Similar Chemical Characteristics As HFC125 • Comparable Volume Requirements as Halon	• Requires Slightly Higher Weight for Comparable Halon Performance • Poor Low Temperature Performance • Global Warmer
Gas Generators	• Potential Weight/Space Savings • No Toxicity Concerns (Generates Inert Gases Only) • Currently Fielded & Supported By The Navy	• Inconsistent System Performance (E/F Experience) For Engine Nacelle Applications • Thermal, Insensitive Munitions And Distribution Issues • Requires Special Handling/Storage Procedures • Classified As A 1.3 Explosive
CF3I	• Excellent Fire Extinguishing Performance • Comparable Volume Requirements As Halon	• Unresolved Environ., Health & Toxicity Issues • Poor Low Temperature Performance • Long Term Storage Issues • Material Compatibility • Limited Availability – High Cost

HFC125 Offers the Best Overall Halon Replacement Characteristics