HALON 1301 RETROFIT IMPLEMENTATION CONSIDERATIONS

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The US Navy is investigating fixed fire extinguishing systems for potential retrofit on current platforms. Implementation of replacement or alternative Halon **1301** systems on existing platforms poses a significantly larger design challenge than new construction. Shipboard space is typically already allocated. Furthermore, substitute system weight has to be evaluated for acceptability in weight critical ships.

There are a large number of different Navy uses of Halon **1301,** and a single Halon **1211** usage **on** surface ships. System design criteria and use protocols can vary from ship to ship based on the nature and geometry of the hazard.

This paper addresses the particulars of establishing an operating envelope for retrofitting halon substitute systems on Navy platforms. A framework is provided for analyzing a space currently protected by halon and establishing a retrofit suppression system performance envelope. Suppression system agent storage location, type of system (modular versus banked), and number of agent applications, or shots, are among the system design parameters that are being addressed. Suppression system performance requirements, together with a preliminary threat analysis, are also included.

Emphasis is given on generic and platform specific substitute suppression system attributes and performance requirements. Three ship classes are used to illustrate the proposed approach as they represent different continuing challenges for halon retrofit:

- DDG **51** (Arleigh Burke) Class: Aegis Guided Missile Destroyer (gas turbine engine propulsion).
- LHD 1 (WASP) / LHA 1 (Tarawa) Class: Amphibious Helo/Landing Craft Carriers (steam plant propulsion).
- LCAC: Landing Craft Air Cushion

The following framework is used to identify the generic and platform specific Halon **1301** suppression system attributes and performance/ implementation requirements:

1.0 Generic Halon **1301** Suppression System Attributes and Performance Requirements
1.1 Preliminary Threat Analysis/ Description of Fires on Which Halon Was Used
1.2 Platform Operating Envelope
- Operating temperature range
- Ventilation and compartment leakage

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1.3 Suppression System Design and Performance Requirements
1.3.1 Suppression System Design
- Agent design concentration envelope
- Discharge time: 10-sec maximum

1.3.2 Suppression System Performance Requirements
- Fire suppression
- Reignition protection
- Acceptance testing

1.4 Fire Suppression System Activation
- Activation mode
- Response time estimates

2.0 Platform Specific Halon Retrofit Implementation Particulars (also Sections 3.0 and 4.0)
2.1 Compartments Protected by Halon 1301
2.2 Platform Specific Suppression System Performance Requirements
2.3 Fire Protection Capability
2.4 Modification Possibility
- Increase agent storage capacity
- Agent distribution piping size/access
- Increase number of agent distribution nozzles

Although it is critical to identify the performance envelope of the existing system, it is equally important to reevaluate the entire fire protection approach in order to determine if a halon-like replacement agent is really the only acceptable fire suppression solution [1].

1.0 GENERIC HALON 1301 SUPPRESSION SYSTEM ATTRIBUTES AND PERFORMANCE REQUIREMENTS

1.1 Preliminary Threat Analysis/ Description of Fires on Which Halon was Used

Shipboard fires in Main Machinery Rooms (MMR), Auxiliary Machinery Rooms (AMR), Engine Enclosures, and Generator Rooms result from the ignition of a pressurized fuel leak (diesel/hydraulic or lubricating oil) or ignition of fuel soaked insulating material. Leaks onto hot surfaces result in three-dimensional spray fires with cascading liquid flow on complex surfaces and into flaming pools.

Fires in Flammable Liquid Storerooms (FLSR) and Paint *issue* rooms can be characterized as burning fuel cascading over highly obstructed fuel loaded shelves down into flaming pools on the deck.

1.2 Platform Operating Envelope

Operating temperature range: The Navy shipboard operating temperature range for total flooding fire protection systems is 10 °C (50 °F) to *66* °C (150 °F). This temperature range covers both the compartments to be protected and the storage of the agent. Temperature impacts concentration designs **as** delivered concentration depends on compartment temperature. Temperature, however, also impacts agent storage. For example, one consideration in selecting

HFC-227ea over HFC-23 was that while the same or less weight of HFC-23 was required, its higher vapor pressure at elevated temperatures necessitated employing reduced cylinder fill densities. More cylinders of HFC-23 would have been needed, thus significantly increasing system space and weight.

Ventilation and compartment leakage: Compartments protected by 1301 are equipped with ventilation interlocks. In the event of system activation, the ventilation fans are automatically turned off and ventilation dampers, when installed, are automatically shut.

1.3 Suppression System Design and Performance Requirements

1.3.I *Suppression System Design*

- ***Agent (Halon 1301) design concentration envelope:*** 5% at 10 "C (50 °F) to 7% at **66** °C (150 "F)
- ***Discharge time:*** 10-sec maximum (to promote agent mixing).

1.3.2 *Suppression System Performance Requirements*

- ***Fire suppression:*** Fire extinguishment within agent discharge (10 sec).
- ***Reignition protection;*** 15-min hold time (minimum time from agent discharge to compartment re-entry). Reflash in machinery spaces as well as other compartments is a serious consideration. During re-entry procedures agent concentration will decrease and additional oxygen will be available.
- ***Acceptance testing:*** In order for a system to he accepted, the average Halon 1301 concentration in the compartment must be between 5% and 7% by volume. Agent measurements are taken at 5 to 12 locations depending on compartment size (number of levels, total volume). The minimum measured value must he above **4%.**

1.4 Fire Suppression System Activation

Activation mode: All Halon 1301 shipboard systems are manually operated, both for occupied and unoccupied compartments. Fire detection by personnel or detector is followed by personnel assessment, evacuation, and system activation, as warranted (Table 1).

TABLE 1. SYSTEM ACTIVATION/ SEQUENCE OF EVENTS.

Event	Event Initiation and/ or Duration (min:sec)	
	Unmanned Compartment	Manned Compartment
Dampers are normally open/ fans are normally on		
Fire ignition	Variable (prolonged ignition will yield a larger fire, initially)	
“Detection”	High temperature and/or rate of rise detectors	Manned
Situation Assessment fire	Damage Control Central responds to detector signal by sending dispatcher to identify threat	On site personnel
Egress	-	0:30-1:00
System Activation		
Secure fan motors and close dampers (if present)	0:30 - 1:00 (system time delay for interlocked fan motors and dampers)	
Discharge Agent		

Response time estimates: Time from fire initiation to agent discharge can vary considerably between occupied and unoccupied spaces. For occupied spaces, system activation may occur rapidly, after situation assessment and compartment evacuation. The time to discharge can typically range from 1 to over **2** min. For unoccupied spaces, the Damage Control Central will respond to a detector alarm by sending an investigator to investigate the cause of the alarm. The elapsed time from the detector alarm initiation to discharge system activation will be a function of other ongoing activities in Damage Control Central, the availability of a dispatcher, and the proximity of the compartment to be investigated. The shortest times from detector response to suppression system activation are estimated at 1.5 to **2** min.

2.0 REPRESENTATIVE PLATFORMS FOR EVALUATING HALON REPLACEMENT RETROFIT IMPLEMENTATION

DDG 51 (Arleigh Burke) Class: Aegis Guided Missile Destroyer

The DDG 51 is representative **of** the newer ships where Halon 1301 was the suppression agent of choice during ship design. Therefore, there is enough space onboard to accommodate a two-shot Halon 1301 system for each MMR, AMR, and Generator Room.

2.1 Compartments Protected by Halon 1301

Main Machinery Rooms (Auxiliary Machinery Rooms (AMR), Flammable Liquid Storerooms (FLSR), Paint issue rooms, Pump Rooms, Generator Room

2.2 Platform Specific Suppression System Performance Requirements

See Section ***1.3.2 Suppression System Performance Requirements.*** System performance requirements that are compartment specific may be set by both platform owner and the Naval Sea Systems Command (NAVSEASYSCOM).

2.3 Fire Protection Capability

One- or two-shot system and agent storage location (Table **2).** All 1301 systems are "banked."

- MMR: two-shot halon system with the bottles in external manifold banks. LM2500 gas turbine enclosures have their own two-shot system.
- AMR: two-shot system, contains an engine enclosure and fuel delivery pipe. The enclosure is tight and halon protected. Enclosure protection is by a separate two-shot system.
- Generator Room: one-shot 1301 system, contains an engine enclosure that is protected by a two-shot system.
- Other spaces: typically protected by single-shot systems.

2.4 Modification Possibility

2.4.1 Increase agent storage capacity

MMR the bank compartments are crowded with perhaps 10% additional capacity. It may be possible to add 50% capacity in the MMR itself via modular units.

AMR: Retrofit space expansion of 100% may be feasible since suppression system can be down rated to a single shot.

Generator Room: some expansion space.

Several other small usage compartments exist and would need to be considered separately. These involve only one or two cylinders each.

2.4.2 Agent distribution piping size/ access

Varies from 1-in to over 6-in diameter Schedule 40 to Schedule 80 pipe depending on compartment size and bottle location. The larger systems have piping sized for the amount of agent to be discharged. There is probably not significant excess capacity. Smaller systems may employ standard pipe sizes that would allow significant additional fluid to be discharged within the time specifications. Piping is generally accessible.

2.4.3 Increase number of agent distribution nozzles

Additional nozzles could likely be added or nozzles changed particularly with a supplemental modular discharge system.

3.0 LHD 1 (WASP) / LHA 1 (TARAWA) CLASSES: AMPHIBIOUS HELO/LANDING CRAFT CARRIERS

The LHDs can be separated into LHD-I through LHD-4, and LHD-5 through LHD-7. While LHD-5 through LHD-7 compartments are likely to have dampers in the ventilation ducts, the other ships probably do not.

3.1 Compartments Protected by Halon 1301

Main Machinery Rooms (MMR), Auxiliary Machinery Rooms (AMR), Flammable Liquid Storerooms (FLSR), Paint issue rooms, Pump Rooms, Generator Room

3.2 Platform Specific Suppression System Performance Requirements

Reignition Protection: The LHD class has high pressure steam plants. The steam plants have high temperature piping that can provide possible ignition and reignition sources. Further, these pipes are slow to cool. While turbine and diesel propulsion plants have high temperature surfaces, these cool much faster. Unvented high pressure steam remains in the steam plant piping after boiler shut down.

3.3 Fire Protection Capability

One- or two-shot system and agent storage location (Table *2)*

- MMRs: LHD 1 to LHD 4 have the halon cylinders in the MMRs. LHD 7 has halon stored in dedicated compartments external to the MMRs. Additional space in the MMRs should he available onboard LHD 5-7. LHAs have single-shot systems with bottles inside the compartments.
- AMRs: early LHDs have two-shot that were later down rated as requiring only single-shot systems. LHD 1 - 4 have two-shot halon systems. LHD 5-7 have a single-shot system. The halon cylinders for all LHDs are stored inside the AMRs. LHAs have single-shot systems with bottles inside the compartments.
- Emergency Generator Room: LHDs and LHAs have a single shot. The agent is stored inside the compartment.
- Other spaces: typically protected by single-shot systems.

3.4 Modification Possibility

3.4.1 Increase agent storage capacity

- MMRs: LHD 1 - 4 will be the most difficult to retrofit because they have two-shot systems in the MMRs hence there is little additional space for more agent. LHD 5 - 7 have the agent stored outside the MMRs, therefore there will be space available for a

TABLE 2: NAVY DDG 51, LHD/LHA, AND LCAC HALON USAGE.

'latform	Space	Number of Enclosures in Compartment	Number of Shots (1301)	Location of Agent Cylinders	
				inside comp.	in adjacent comp.
'DG 51	MMR	2 or 3	2	-	Yes
	MMR Gas Turbine Enclosures	-	2	-	Yes
	AMR	1	2	Yes	-
	AMR Generator Enclosure	-	2	-	Yes
	Generator Room	1	1	Yes	-
	Generator Enclosure	-	2	-	Yes
	FLSRs, and other miscellaneous compartment	-	1	Yes	-
.HD 1-4	MMR	-	2	Yes	-
	AMR	-	2	Yes	-
	Emergency Generator Room	-	1	Yes	-
	Pump Room	-	1	Yes	-
	FLSRs, and other miscellaneous compartment	-	1	Yes	-
.HD 5-7	MMR	-	2	-	Yes
	AMR	-	1	Yes	-
	Emergency Generator Room	-	1	Yes	-
	Pump Room	-	1	Yes	-
	FLSRs, and other miscellaneous compartment	-	1	Yes	-
LHA	MMR	-	1	Yes	-
	AMR	-	1	Yes	-
	Emergency Generator Room	-	1	Yes	-
	Pump Room	-	1	Yes	-
	FLSR (CO_2)	-	1	Yes	-
LCAC	Engine Enclosure	-	2	-	Yes
	Auxiliary Power Unit	-	2	-	Yes
	Cargo Deck	150-lb Halon 1211 System		on Cargo Deck	
	Pump Room	-	2	Yes	-

modular agent system inside the MMRs where the agent used to previously be located (LHD 1 - 4). LHAs may be difficult to retrofit because they contain the one-shot suppression system in the MMRs.

- AMR: there is at least 100% space availability. For LHD 1-4 the second shot can be eliminated. Only a single shot protection is required, but space is available for the equivalent of a second shot.
- Generator Room: for all LHDs and LHAs limited space may be available.
- Several other small usage compartments exist and would need to be considered separately. These involve only one or two cylinders each.
- Flammable Liquid Cargo Hold: For all LHDs and LHAs space may be available if cargo capacity is reduced.

3.4.2 Agent distribution piping size/ access

Varies from 1" to over 6" diameter Schedule 40 to Schedule 80 pipe depending on compartment size and bottle location. The larger systems have piping sized for the amount of agent to be discharged. There is probably not significant excess capacity. Smaller systems may employ standard pipe sizes that would allow significant additional fluid to be discharged within the time specifications. Piping is generally accessible.

3.4.3 Increase number of agent distribution nozzles:

Additional nozzles could likely be added or nozzles changed particularly with a supplemental modular discharge system.

4.0 LCAC : LANDING CRAFT AIR CUSHION

The LCAC is an air cushion craft. There is currently no capability to obtain sea water for fire fighting **use.** In addition, the LCAC also travels over land (where there is no water source). It is very weight critical and carries Marine assault vehicles with their **fuels** and weapons. Another consideration in evaluating halon replacement retrofit is the service life of these craft. Although it might be extended, it is initially set at 20 yrs versus the 30+ service lives of ships.

4.1 Compartments Protected bv Halon 1301

The Cargo Bay is protected by an installed (fixed) Halon 1211 hand reel system. This is the only Navy instance of a fixed Halon 1211 system.

Halon 1301 is used to protect enclosed engine modules and pump rooms. **As** the engine modules are not very tight, Halon 1211 is required to he bled in (connecting hardware is installed) to assure continuing protection.

4.2 Description of Fires on Which Halon Was Used/ Has to Extinguish

A cargo deck fire obstructed by fueled vehicles carrying additional fuel on a rapidly moving vessel with 40 knots wind (for example) would be very difficult to extinguish. There is no test experience to gauge system effectiveness for this application. The Halon 1211 does satisfy the engine module requirement in conjunction with the installed Halon 1301 system.

4.3 Platform Specific Suppression System Performance Requirements

4.3.1 Engine Modules, Auxiliary Power Unit (APU), and Pump Rooms

Standard Halon 1301 system, see Section *1.3 Suppression System Design and Performance Requirements.*

4.3.2 *Cargo Bay*

The Cargo bay is protected by a hose connected to a 150-lb Halon 1211 tank.

4.4 Suppression System Performance Requirements

4.4.1 *Engine Modules*

Fire Suppression: within agent discharge (10 sec).

Reignition Protection: 15-min hold time. Halon 1301 is supplemented by the Cargo Bay 1211 to account for agent lost from the engine module due to leakage.

4.4.2 *APU Module*

Fire Suppression: within agent discharge (10 sec).

Reignition Protection: 15-min hold time

4.4.3 *Cargo Bay*

There is no test experience to gauge system effectiveness for this application.

4.5 Fire Protection Capability

One- or two-shot system and agent storage location: Table 2

Engine Enclosure: two-shot system with agent bottles located outside the enclosure.

APU: two-shot system with agent bottles located outside the enclosure.

4.6 Modification Possibilitv

Replacement will have to address both the engine modules and the cargo deck needs. While space should be available, this is an extremely weight-critical application without seawater being available.

5.0 OTHER SUPPRESSION SYSTEM IMPLEMENTATION ISSUES (ALL PLATFORMS)

Hardware must pass vibration/shock testing. Life cycle costs have to be addressed as part of the retrofit evaluation.

Agent inhomogeneities: Halon concentration uniformity is frequently not well characterized. Based on NRL testing aboard the ***ex-USS*** SHADWELL, variations of at least +/- 20% are to be expected; typical variation can be far broader. Agent distribution tests in a Cruiser (CG 47 - TICONDEROGA Class) Main Machinery Room (MMR) measured agent concentration variation as a whole number factor. This has significant implications for the fire protection provided by halon and more so on what would be required for an efficacious halon replacement system. Adding discharge nozzles to an existing system (in order to reduce inhomogeneities), while maintaining the proper agent nozzle discharge characteristics, may not be possible due to agent physical-flow constraints (see Agent Distribution Piping below).

In the cases of halon-like replacement agents, an In Compartment Modular Supplemental System ($ICMS^2$) is preferable to a complete redesign and installation of a new banked system. The $ICMS^2$ uses individual agent cylinders discharging through individual nozzles. When multiple $ICMS^2$ cylinders are used they are linked to a common activation system. The $ICMS^2$, when feasible, reduces retrofit costs and installation time by not having to remove the existing system and install a complete new system including an agent manifold and distribution system.

Agent distribution piping: Using the existing agent distribution network of a banked system *to* discharge the complete amount of replacement agent needed may not be feasible for larger systems. Larger systems have their piping already "optimized"(minimum size necessary) primarily due to weight constraints. Pipe diameter and distribution system length are, however, closely linked with limitations on the minimum and maximum pipe length and volume that a system can use and still discharge the agent with the desired throw characteristics at the nozzle(s). Smaller systems, due to the discreet number of bottle and pipe diameter **sizes** available, may have been designed with pipe diameters that provide some additional capacity that can be used by the replacement agent.

Table 2 summarizes the halon system specifics for the three platforms evaluated in this paper.

6.0 CONCLUSIONS / DISCUSSION

There are many **fire** scenarios in a variety of compartments aboard different ship classes. Space and weight requirements likewise vary. Some applications have already been evaluated as allowing retrofit via less efficient agents such as HFC-227ea. Other applications have a sliding scale of system 'expansion' factors. Some applications will need very close to 'drop-in' characteristics. Other compartments may accommodate an agent requiring more space and weight than a 'drop-in'. The fire protection needs and the efficacy of system-compartment design and requirements should be carefully evaluated.

7.0 REFERENCE

1. Alexander Maranghides, Ronald **S.** Sheinson, Tom Friderichs, Bruce H. Black, Michelle Peatross, and Walter D. Smith, "A Holistic Approach to Halon Replacement System Design: A **Case** Study," *1995 International CFC and Halon Alternatives Conference,* October ***23-25,*** 1995, Washington DC, pp. 578-593.