MARINE APPLICATIONS OF CLEAN AGENTS: HALOCARBON AGENTS FOR THE PROTECTION OF PLEASURE CRAFT ENGINE COMPARTMENTS

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ABSTRACT

Because of its unique combination of properties, Halon 1301 has served as a near-ideal fire suppression agent in numerous applications, for example for the protection of engine spaces in both small and large watercraft. Halon 1301 is characterized by high fire suppression efficiency, low toxicity, low residue formation following extinguishment, low electrical conductivity, and long-term storage stability. However, due to its implication in the destruction of stratospheric ozone, Halon 1301 production was halted on January 1, 1994. As a result, clean fire suppression agents with minimal environmental impact, such as HFC-227ea, have been developed to replace Halon 1301.

This paper will discuss the use of clean fire suppression agents for the protection of engine spaces in commercial pleasure craft. These applications present a number of challenges to the fire suppression system design engineer, including addressing the intake of large amounts of air during suppression, requirements for full throttle stops and concerns over the effects of the suppression agent on engine startup. We also present discharge test results of a marine heptafluoropropane (HFC-227ea; trade name FM-200®) suppression system in the engine compartment of a typical marine pleasure craft.

INTRODUCTION

With the demise of Halon 1301, the clean agents have found extensive use as replacements for Halon 1301 in applications demanding clean extinguishment and minimal damage to valuable assets. Clean agents are currently employed worldwide for the protection of both Class A (cellulosic fuel) and Class B (liquid and gaseous fuel) hazards. As was the case for Halon 1301, the vast majority (> 95%) of fire suppression applications of the clean agents involve the protection of Class A hazards, for example those found in electronic data processing (EDP) and telecommunication facilities. For example, HFC-227ea, marketed under the tradename FM-200®

by Great Lakes Chemical Corporation, is currently employed in an estimated 100,000 installations, in more than 70 countries worldwide.

While Class A hazard protection represents the vast majority of the applications of the clean agents, these agents are also employed for the protection of facilities containing Class B hazards. For example, FM-200® clean agent fire suppression systems are employed in numerous marine applications, including the protection of paint storage lockers and engine compartments of military, commercial and pleasure craft. Current Class B hazard applications protected by FM-200® suppression systems include the following:

- US Navy: LPD-17 San Antonio Class Amphibious Assault Ships
- US Navy aircraft carrier USS Harry Truman (CVN-75)
- US Navy aircraft carrier USS Ronald Reagan (CVN-76)
- Military Sealift Command's T-AKE Lewis & Clark Class 41,000 ton ammo/cargo vessel
- Alaska Marine Highway System high-speed catamaran ferries
- Turkish coastal patrol boats
- Inland waterway barges - Netherlands
- LA Fireboat #2 - largest fireboat in the US, radical design, includes water tractor propulsion system
- Recreational boats: Sealine, Hatteras, Sunseeker, Broom Boats, Lissen Yachts
- Halon Retrofits:
    - T.S. Enterprise - commercial training vessel of Mass. Maritime Academy
    - Numerous US Army watercraft

FIRE PROTECTION REQUIREMENTS FOR MARINE VESSELS

INTERNATIONAL

International marine vessel requirements are described in the SOLAS 74 International Convention for the Safety of Life at Sea. Fire-related requirements for marine vessels are described in SOLAS Chapter II-2.

VESSELS WITHIN U.S. WATERS

For marine vessels operating within U.S. waters, Title 46 of the Code of Federal Regulations (46 CFR) describes vessel requirements. Vessels are divided into seven classes as follows:

- Class C: Uninspected Vessels
- Class D: Tank Vessels
- Class H: Passenger Vessels
- Class I: Cargo and Miscellaneous Vessels
- Class K: Small Passenger Vessels Carrying > 150 Passengers
- Class T: Small Passenger Vessels (under 100 gross tons)
- Class U: Oceanic Research Vessels

Table 1 indicates the sections of 46 CFR detailing the fire suppression requirements of the seven classes of vessels.

Table 1. Fire Protection Requirements Under 46 CFR

Vessel Class	Subchapter	Parts	Fire Protection Requirements
Uninspected	C	46 CFR 24-28	46 CFR 25
Tank	D	46 CFR 30-39	46 CFR 34
Passenger	H	46 CFR 70-89	46 CFR 76
Cargo & Miscellaneous	I	46 CFR 90-105	46 CFR 95
Small Passenger, >150 passengers	K	46 CFR 114-124	46 CFR 118
Small Passenger, < 100 gross ton	T	46 CFR 175-187	46 CFR 181
Oceanographic	U	46 CFR 188-196	46 CFR 193

RECREATIONAL BOATS

U.S. requirements for recreational boats may be found in the pamphlet "Federal Requirements and Safety Tips for Recreational Boats," available on the USCG website. USCG approved fire extinguishers are required on boats when a fire hazard could be expected from the motors or the fuel system. Extinguishers are classified by a letter and number system, the letter indicating the

type of fire the unit is designed to extinguish, and the number indicates the relative size of the extinguisher. USCG approved extinguishers for boats are hand portable units with either a B-I or B-II classification, and require specific marine type mounting brackets. Table 2 shows the properties of USCG approved B-I and B-II extinguishers.

Table 2. USCG Approved B-I and B-II Extinguishers

Classes	Foam (gallons)	CO_2 (lb)	Dry Chemical (lb)	Halon (lb)
B-I	1.25	4	2	2.5
B-II	2.5	15	10	10

Fire extinguishers are required on boats when any of the following conditions exist:

- Inboard engines are installed
- Closed compartments and compartments present under seats where portable fuel tanks may be stored
- Double bottoms not sealed to the hull or which are not completely filled with flotation materials
- Closed living spaces
- Closed stowage compartments in which combustible materials are stored
- Permanently installed fuel tanks

The number of fire extinguishers required on a recreational boat is based upon the overall length of the boat, as shown in Table 3. In the case where a USCG approved fire extinguishing system is installed for the protection of the engine compartment, the required number of units may be reduced in accordance with Table 3.

Table 3. Minimum Number of Handheld Portable Fire Extinguishers Required on Recreational Boats

Vessel length	No Fixed system	With approved fixed system
< 26 ft	1 BI	0
26 to 39 ft	2 B-I or 1 B-II	1 B-I
40 to 65 ft	3 B-I or 1 B-II plus 1 B-I	2 B-I or 1 B-II

ENGINE COMPARTMENT PROTECTION WITH CLEAN AGENTS

Two clean agents are currently employed for the protection of engine room compartments on recreational boats/pleasure craft: HFC-227ea (CF_3CHFCF_3) and HCFC-124 (CF_3CHFCl). Table 4 provides a comparison of the properties of HFC-227ea and HCFC-124. Note that since HCFC-124 is a hydrochlorofluorocarbon (HCFC), it is slated for eventual phaseout, due to its contribution to the destruction of stratospheric ozone (ozone depletion potential, ODP, nonzero). Also note that the use of HCFC-124 is restricted to unoccupied spaces, due to its design concentration (8.5%) exceeding its LOAEL (lowest observed adverse effect level) for cardiac sensitization (2.5%). HFC-227ea is approved for use in both unoccupied and occupied machinery spaces.

Table 4. Comparison of HFC-227ea and HCFC-124

	HFC-227ea	HCFC-124
Chemical Formula	CF_3CHFCF_3	CF_3CHFCl
Chemical Class	HFC	HCFC
Boiling point, ^oF	2.4	10.3
Design Conc., %	8.7	8.5
ODP	0	0.022
LC_{50}, 4 h, %	>80	23-29
NOAEL, %	9.0	1.0
LOAEL, %	> 10.5	2.5

Pre-engineered HFC-227ea systems are available the protection of engine compartments ranging in size from 25 to 1500 ft^3, for both diesel and gasoline powered vessels. These systems employ a design concentration of 8.7% v/v HFC-227ea. Systems are available as automatic only units, and also as combination manual/automatic systems, equipped with an optional manual pull cable. Automatic systems are heat actuated, discharging at 175 ^oF (79 ^oC). Similar systems are available which employ HCFC-124 at a design concentration of 8.5% v/v HCFC-124.

Engineered HFC-227ea systems, capable of protecting volumes in excess of 1500 ft^3 are also available.

As part of the investigation of the use of clean agents in pleasure craft engine compartments, Hatteras Yachts and Great Lakes Chemical Corporation performed a series of discharge tests aboard a typical pleasure craft. Of concern in this instance was whether the design concentration of HFC-227ea could be maintained for a sufficient length of time, due to the intake of large amounts of air into the engine compartment during agent discharge. The engine compartment characteristics for the craft are shown in Table 5. The engine compartment was equipped with twin CAT diesel engines protected by a SeaFire FD800M FM-200® fire suppression unit charged with 32.5 lb of HFC-227ea, corresponding to a design concentration of 8.7%.

Table 5. Engine Compartment Characteristics

Engine	Twin CAT diesel
Engine Space volume	760 ft^3
Air intake	2500 cfm
Air exhaust	6000 cfm
Extinguishing unit	SeaFire FD800M 32.5 lb HFC-227ea 8.7% HFC-227ea (gross volume) Vertical mount
Agent sample point	0.5H
Stop conditions	Full throttle stop

The vessel was operated at a normal cruising speed, and at the desired time a full throttle stop was initiated, and the suppression system manually activated. Agent concentration was monitored via a calibrated thermal conductivity meter. Table 6 shows the results of the tests for several operating conditions.

Table 6. Test Results

Test Conditions	Hold time at or above extinguishing concentration, s
Full throttle stop Engine room hatches closed	60
Full throttle stop Engine room top hatch open	45
Full throttle stop Engine room top and side hatches open Exhaust blower left on	35

The results of Table 6 indicate that a sufficient hold time of the agent was obtained, even for the case where the engine room hatches were left open and the exhaust blower left on. Proper operational procedure would call for the engine room hatches to be closed during normal vessel operation, and ideally any exhaust would be discontinued at the time of system actuation. No problems were observed due to ingestion of agent into the engines; in all cases the engines started immediately following the completion of the tests.

CONCLUSION

Although employed primarily for the protection of Class A hazards, clean agents such as HFC-227ea have found numerous applications for the protection of Class B hazards, for example the protection of engine compartments aboard pleasure craft. The successful use of clean agents in these applications further demonstrates their ability to reduce industry dependence on ozone depleting substances.