US ARMY GROUND VEHICLE CREW COMPARTMENT HALON REPLACEMENT PROGRAM

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INTRODUCTION

Halon-based fire extinguishing systems are widely used throughout the world to protect military ground combat vehicles. The US Army has aggressively pursued environmentally and toxicologically acceptable alternatives to Halon 1301 for its three ground vehicle applications: crew compartment automatic 'explosion' suppression systems, engine compartment fire extinguishing systems, and portable extinguishers. To date, the 2.75-lb 1301 portable extinguishers have been replaced with 2.5-lb CO_2 units in most vehicles. Replacements have also been selected for vehicle engine compartments — dry powder will be used in vehicles with an automatic extinguishing system because of its superior performance and FM-200 will be used in vehicles that shut the engine off prior to agent discharge because of its ease of retrofit. The remaining research challenge is to identify an agent for crew compartments that can be retrofitted into current vehicles as well as address the needs of future vehicles.

With the exception of the former Soviet Bloc countries, Halon 1301 has been the agent of choice to protect vehicle crewmen against bums from ballistically initiated fuel or hydraulic fluid fires. The US Army currently has three fielded ground vehicles using Halon 1301 to protect their crew compartments: the M1 Abrams main battle tank, the M2/M3 Bradley Fighting Vehicle, and the M992 Field Artillery Ammunition Support Vehicle. The crew compartments of these vehicles range in volume from 250 to 700 ft^3 and employ from 7 lbs of agent in a single shot to 21 lbs in each of two shots.

The Army Surgeon General has established the guidelines shown in Table 1 as the minimum acceptable requirements of automatic fire extinguishing systems for crew compartments. These parameters have been established at levels that would not result in incapacitation of the crewmen from the fire and its extinguishment and would allow them to take corrective action.

The Army's crew compartment test program is divided into three phases. Phase I is a proof of concept and screening phase of multiple agents and technologies. Phase 11 will consist of further development testing of several of the most promising concepts from Phase I. If performance and system integration issues can be successfully addressed, a single concept will be selected for Phase III testing, using prototype extinguishing systems in the affected ground vehicles, starting in 2000. Testing is being conducted at the Army's Aberdeen Test Center in Aberdeen, Maryland.

TABLE 1. Crew Survivability Criteria

PARAMETER	REQUIREMENT
Fire Suppression	Extinguish all flames without re-flash
Skin Bums	Less than second degree (2400 "F-sec over 10 sec or heat flux < 3.9 cal/cm^2)
Overpressure	Less than 11.6psi
Agent concentration	Not to exceed NOAEL
Acid gasses	Less than 1000 ppm peak
Oxygen levels	Not below 16%

Several alternative concepts are currently under evaluation in Phase I. They can be divided into four categories: hydrofluorocarbons (HFC) with nitrogen overpressure, water spray with nitrogen overpressure, hybrid gas generators with HFCs, and hybrid gas generators with water. Various additives to inhibit freezing and enhance effectiveness of the water and to neutralize acid byproducts generated from the HFCs are also being investigated.

TEST SETUP

The crew test fixture has been constructed from a derelict hull and turret. The fixture has an interior volume of approximately 450 ft^3 empty. The cargo and turret hatches and ramp door were secured during each test while the driver's hatch was allowed to pop open to relieve internal pressure.

Instrumentation includes high-speed and standard video, 1-micron infrared detectors, heat flux gages, thermocouples, and pressure gages. Acid gas exposure levels are measured by four types of instrumentation: ion selective electrodes, sorbent tubes (NIOSH procedure 79031, midget impingers, and FTIR analyzers. The FT-IR is the only one of these methods that reports levels of the gases themselves, as opposed to fluorine or bromine ions. Gas species tested for include oxygen, hydrogen fluoride (HF), hydrogen bromide, and carbonyl fluoride. Nitrogen oxide and nitrogen dioxide levels are also monitored during gas generator tests.

Two test scenarios are being conducted in Phase **I:** fuel spray fires and ballistic penetrations. The spray fire is generated with approximately 0.3 gallons of JP-8 heated to 180-190 °F and pressurized to 1200 psi using a specially designed nozzle. **Fuel** flow continues for approximately 1.2 sec with the igniter energized for the duration of the spray to simulate the re-ignition sources present during a typical ballistic event. The spray fires are monitored with three one-micron infrared detectors. The extinguishing system is activated automatically after an 11-ms delay from the time the fire energy exceeds a predetermined threshold. Ballistic fires are generated by firing a 2.7-in shaped charge through an 18.7 gallon (2.25 ft^3) capacity aluminum fuel cell filled with 11 gallons of JP-8 heated to 165 "F. The fire extinguishing system is activated 25 ms after warhead initiation to eliminate the variability of the detection system.

OBSERVATIONS

Baseline tests have been conducted with Halon 1301 and FM-200 using standard Army extinguishers and nozzles. These tests indicate that a total agent weight of 10 Ihs of 1301 delivered by three extinguishers is required to successfully extinguish both the fuel spray and

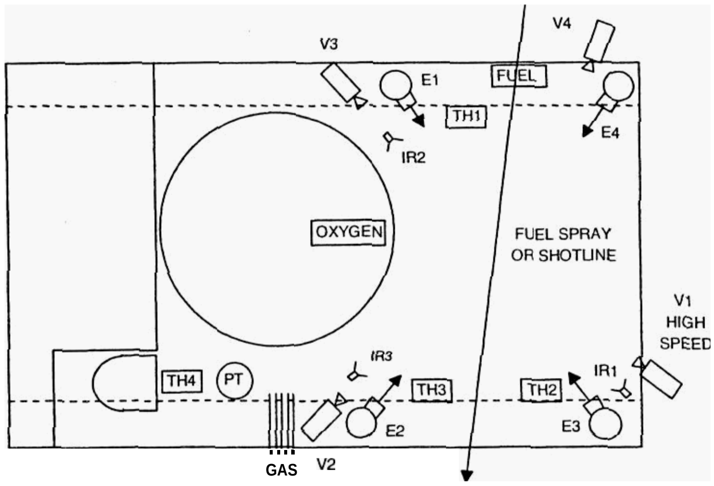

Figure 1. Test Scenarios.

ballistic fires. Lower agent weights lead to longer fire-out times, and the byproduct levels rise significantly. Fifteen pounds (15 Ibs) of FM-200 provided approximately equivalent performance relative to fire-out times and total byproduct levels. Temperature and heat flux data indicate that bum thresholds are not being approached under these scenarios.

Based on a relatively small number of trials of each system configuration and agent quantity, especially for the ballistic tests, the following trends were observed. Further testing is required to develop sufficient sample sizes to substantiate these findings and to fully define the system parameters for the most promising approaches.

(1) The spray fire scenario is a fairly reproducible event, and changes in configuration are relatively easy to assess. The fuel spray simulator is an inexpensive method for optimizing system performance prior to ballistic testing.
(2) Ballistic tests are much more variable than the spray tests. Multiple ballistic test firings are required per system configuration to get an accurate, overall assessment of system performance.
(3) After achieving a successful fire extinguishment concentration, adding additional HFC does not necessarily further reduce the fire-out time, but can lead to significant reductions in observed byproduct levels. This is shown best by the spray test fires.
(4) Discharging a small amount of an acid scavenger along with the HFC can significantly reduce the HF levels, sometimes by approximately 50%. The effect of the reduction is shown on the spray fire tests.
(5) Water sprays can suppress the initial fire event, but the fire typically reflashes within 1 sec.
(6) Select freeze point suppressants can be added to the water sprays that also successfully inhibit reflash of the fire.

FUTURE ACTIVITIES

A recommendation is required by September 1999 as to whether a replacement is ready for system testing in the affected vehicles or whether the Army must continue to rely on its halon reserve until additional agents become available. Critical activities necessary to meet that objective include the following:

- Down-selected approaches will be tested in the crew fixture in Phase II with realistic vehicle clutter and space claim using additional ballistic threats and shot lines. Design guidelines will be developed to assist system integration efforts required for Phase III.

- Freeze point suppressants, performance enhancement additives, acid byproduct scavengers, and agent misting techniques **will** be further evaluated to minimize the space claim and retrofit impact of the candidate systems.

- Toxicology studies have been initiated by the Walter Reed Army Institute of Research to further refine the criteria for HF exposures. It is necessary to know the maximum exposures and durations that crewmen can tolerate without significantly degrading their performance or forcing them to abandon the vehicle.

- A fire model is under development for the crew spray fire scenario. This is a joint effort between DoD and DOE Sandia to produce a verified design tool to predict the most probable outcome of a fire threat for any platform. An intermediate step should produce a model that includes crew compartment clutter that will be useful in the Phase II analyses.

SUMMARY

The Army is aggressively pursuing alternatives to halon in its last ground vehicle application— crew compartments of combat vehicles. By far, this application poses the largest technical challenges because of the stringent performance, toxicological, and retrofit requirements involved. This program is in its early stages and a significant amount of work remains to be completed before a decision can be made whether or not any of the current commercially available agents and technologies is suitable for this application. Test results to date have been encouraging; however, the most difficult testing with clutter and larger ballistic threats remains to be completed.