EXPOSURE SIMULATION DURING CF3I STREAMING FIRE TESTS

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INTRODUCTION

Trifluoroiodomethane (CF_3I) is an environmentally acceptable streaming fire suppression agent for non-residential applications. Determination of the potential level of human exposure to CF_3I and its thermal decomposition products (TDP) during fire suppression is important for health and safety assessments. Streaming fire suppression tests were conducted using handheld CF_3I extinguishers. Operator's exposure to fire gases was simulated during the tests by measuring gas samples in the operator's breathing zone. This paper presents the results and findings of these tests.

EXPERIMENT

CF_3I extinguishers charged with 1- and 2-kg CF_3I at 690 and 1345 kPa, respectively, were used in the fire tests. Test fires were heptane pool fires, including a 300 kW fire (0.372-m' square pan. 80% of the UL 2B pan size) and a 900 kW fire (0.836-m^2 square pan, 72% of the UL 5B pan size). The 2-kg CF_3I extinguishers were used to suppress the 900 kW pool fire in a 21,000-m^3 burn hall. The 1 kg CF_3I extinguishers were used to suppress the 300-kW pool fire in a 120-m^3 compartment and in a 45-m^3 compartment. The 45-m' compartment, with an equivalent leakage area of 0.090 m^2, was connected to a corridor area. Tests proceeded with background data collection, ignition. 20-s preburn, suppression and post-suppression observation.

Figure 1 shows a common test set-up used. **A** thermocouple tree was placed over the square pan to measure flame temperatures, with 6 thermocouples vertically distributed at 2.84, 2.28, 1.72, 1.17, 0.60, and 0.20 m. **A** cross-averaging tube (with 20 holes, 1.1-mm diameter) was placed beside the pan as a gas sampling probe, which was used to sample fire gases at the fire source.

The extinguisher operator stood at 2.4 m from the fire in the burn hall tests and 2.9 m from the fire in the compartment tests. To prevent exposure to excessive heat and gas byproducts, the operator wore an aluminum heat protective suit with self-contained breathing apparatus during all tests. **A** heat flux meter (air-cooled, 20 kW/m^2 range) was placed beside the operator at 1.2 m height to measure operator heat exposure.

An FTIR spectrometer was dedicated to measure the concentrations of the agent and its TDPs in the operator breathing zone. **A** gas sampling probe was positioned close to where the operator stood during firefighting. This probe was positioned at 1.5 m height. approximately the operator's nose height. and was connected to the FTIR spectrometer through a gas sampling line.

A second FTIR spectrometer was also used to measure the agent and its TDP during the tests. In the burn hall tests, the spectrometer was connected to the cross-averaging tube (beside the pan), through a heated gas sampling line, to monitor the agent and its TDP at the fire location. During the tests conducted in the 120-m' compartment, the FTIR spectrometer was used for in-situ

Figure 1. Common test set-up.

measurement in one corner of the compartment. During the tests conducted in the 45-m^3 compartment, the spectrometer was used to measure gas samples drawn from the corridor area through three heated gas sampling lines.

RESULTS AND DISCUSSION

The 2-kg CF_3I extinguishers were fully discharged in the burn hall tests. In the 120 and 45 m^3 compartments, the 1-kg CF_3I extinguishers quickly extinguished the fires (3-5 s) with 0.6 kg CF_3I discharged. Figure 2 is an FTIR spectrum of the gas samples taken through the gas sampling probe beside the fire pan in the test conducted in the burn hall. It shows the “finger prints” of CF_3I, fuel vapour, CO_2, CO, HF, and COF_2 at the fire source. HF and COF_2 were produced due to the interaction of the agent with flames. Figure 3 shows a spectrum from the in situ FTIR measurement in the corner of the 120-m^3 compartment. Discussions of this paper, however, emphasize the results of the gas measurement in the operator breathing zone.

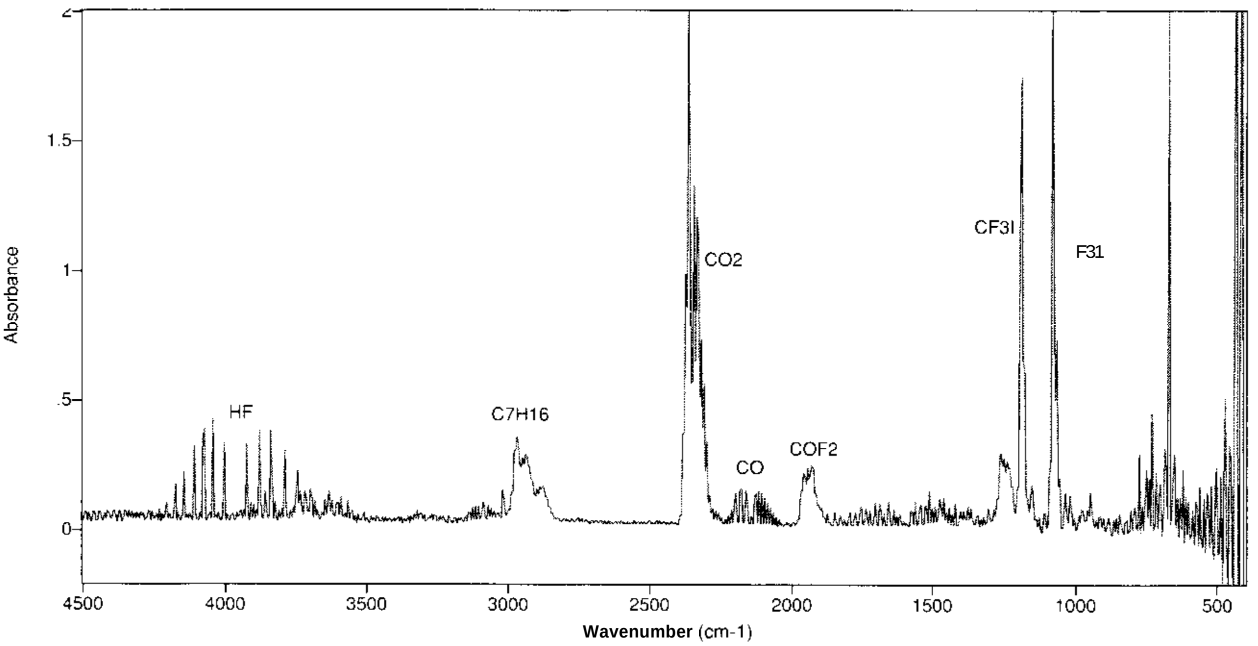

Figure 2. FTIR spectrum of fire gases at fire location in burn hall test

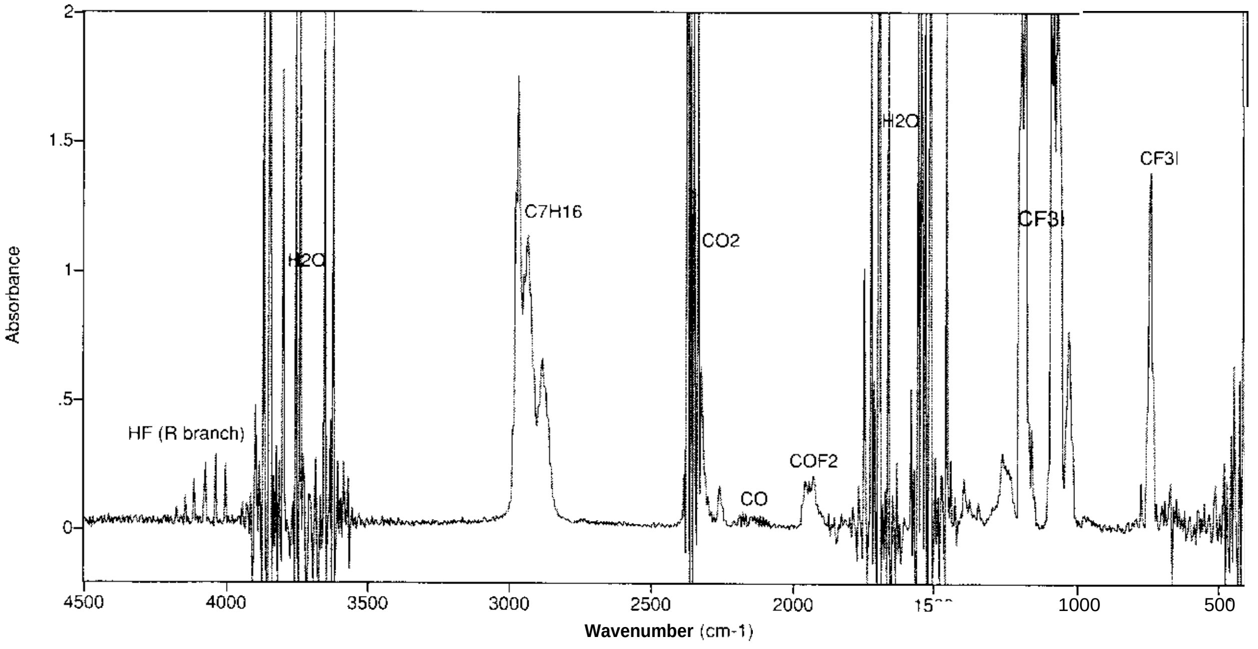

Figure 3. Spectrum of in-situ FTIR measurement.

AGENT EXPOSURE

The FTIR spectrometer was calibrated using gas standards of 0.4, 3.0, and 5.0% CF_3I before the fire tests. During the 21,000-m^3 burn hall tests, CF_3I was not detected in the gas samples taken from the operator breathing zone, indicating little agent exposure risk in this fairly opened space. The maximum CF_3I concentrations in the operator breathing zone were in the range of 0.14–0.16% during the 120-m^3 compartment tests and 0.06–0.18% during the 45-m^3 compartment tests. The agent concentrations in the corridor were much lower.

The NOAEL (no observed adverse effect level) for cardiac sensitization for CF_3I is 0.2%, and the LOAEL (lowest observed adverse effect level) for cardiac sensitization for CF_3I is 0.4%. The recommended OEL (occupational exposure limit) for CF_3I is 0.2% for firefighting [1, 2]. In the three test scenarios, the maximum concentrations of the agent in the operator breathing zone were below the NOAEL and OEL values. Therefore, potential exposure by the operator to the agent was tolerable in the test scenarios.

HF EXPOSURE

The ERPG-3 (Emergency Response Planning Guideline-3) for HF exposure is relevant for the firefighting emergency situations. The recommended 10-min ERPG-3 value for HF is 170 ppm, which is the maximum non-lethal concentration for a healthy individual [3]. At a 200-ppm HF concentration, a 5-min exposure may result in irreversible damage to health [3].

The FTIR spectrometer was calibrated using gas standards of 200, 1000, and 2000 ppm HF. In the burn hall tests, spectra of the gas samples taken from the operator breathing zone showed no obvious sign of the presence of HF or COF_2, indicating little exposure risk in this open space. The only gases outstanding in the spectra were water vapour and CO_2. In the 120-m^3 compartment tests, the peak HF concentrations in the operator breathing zone were 100–200 ppm, but these peak concentrations only lasted for a few seconds. The peak HF concentrations increased when the test compartment was smaller. In the tests conducted in the 45-m^3 compartment, the HF concentrations in the operator breathing zone were up to 1200 ppm, presenting a severe life hazard if inhaled. A self-contained breathing apparatus must be used to protect the operator during firefighting in small confined spaces.

In the corridor area, the peak HF concentration occurred near the door of the fire compartment during firefighting, when the door was open. During the tests, the peak HF concentrations in the corridor were below 100 ppm, which was tolerable. Closing the door after discharging the extinguishers prevented excess smoke and toxic gases moving from the fire compartment to the corridor area; thus, the corridor conditions remained tenable (temperatures below 40 °C, CO_2 concentrations below 0.14%, and CO concentrations below 50 ppm in the corridor).

HEAT EXPOSURE

During the preburn, the heat flux near the operator was 3.5 kW/m^2 for the 0.836 m^2-pan and 1.3 kW/m^2 for the 0.372-m^2 pan. In each test, when the operator initiated spray, a fireball was produced before fire extinguishment and the heat flux at least tripled the preburn value. Heat exposure was a severe hazard to the operator when fighting the pool fires. This heat exposure hazard was more severe in the confined space than in the open space. The operator must wear heat-protective clothing.

CONCLUSIONS

The 2-kg CF_3I extinguishers were used to suppress a 900 kW heptane pool fire in the 21,000-m^3 burn hall. The I-kg CF_3I extinguishers were used to suppress a 300-kW heptane pool fire in the 120-m’ compartment and in the 45-m^3 compartment. Gas samples from the operator breathing zone were measured using the FTIR spectrometer. Potential exposure to CF_3I was tolerable and the agent itself did not pose life or health risk to the operator in the test scenarios. Potential exposure to HF was tolerable in the burn hall and in the 120-m’ compartment. In the 45-m^3 compartment, however, the HF concentration was at a dangerous level during the tests; a self-contained breathing apparatus must he used to protect the operator during firefighting. After firefighting. closing the door prevented excess heat and toxic gases moving from the fire compartment to the corridor area; the corridor conditions remained tenable for evacuation purposes. Heat exposure was a severe hazard to the operator in the pool fire scenarios.

ACKNOWLEDGMENTS

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HANDHELD FIRE EXTINGUISHER DEVELOPMENT

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The work reported herein was performed under TACOM Contract # DAAE07-98-L043: Project title – "Development of Hydrophilic Anti-Caking Dry Agent Coatings for Combined Dry Chemical Agent Water Mist Systems."

INTRODUCTION

This project compared the relative performance of a series of fire suppressants being considered for use in MetalCraft 2¾-lb. halon handheld fire extinguishers as replacements for the current Halon 1301. This study resulted in a recommended agent (50% potassium acetate) for continued consideration for use in **US** Army portable fire extinguishers in combat vehicles. Additional testing of this agent is currently underway.

Project extinguisher performance, and environmental and toxicity goals are listed below.

Project extinguisher performance goals

- Extinguish 2B jet fuel (JP8) fire
- Employ existing MetalCraft 2% Ib. halon extinguisher
- Operation range –40 to + 140 °F
- Storage – 60 to + 160°F
- Following discharge No re-suspension of powders from surfaces
- No or low visual obscuration following discharge

Environmental and toxicity goals

- Minimize HF
- Low to no toxicity (Equivalence to Halon 1211)
- ODP < 0.02, No Class I or II ODC's
- Low Atmospheric Lifetime
- Low or no Global Warming Potential

DISCUSSION

To date, FM-200 (HFC-227ea) has been considered a leading candidate for replacing Halon 1301 in US Army portable extinguishers. However, high levels (–4000 ppm) of hydrogen fluoride (HF) produced during fire suppression events present a very significant inhalation hazard. Suppressants based on blends of bicarbonate salts and FM-200 were evaluated for their post extinguishment HF levels and effects on visual obscuration. The sodium and potassium bicarbonates employed were expected to trap the acidic HF gases.

The detailed results of this HF reduction testing will be part of a comprehensive presentation on this subject scheduled during the *HOTWC* 2000 conference. Although these tests demonstrated

HF levels were substantially below those employing only FM-200, the HF levels were still judged unacceptable.

Addition of bicarbonate salts did, however, dramatically improve the fire suppression performance of FM-200 without creating a significant degree of visual obscuration. The advantages and disadvantages of the bicarbonate salt/FM-200 blends are itemized below.

FM-200 with $KHCO_3$ or $NaHCO_3$: Observed Advantages

- Enhances fire suppression performance of all HFCs tested
- HF production is reduced by approximately a factor of 10
- Visibility not seriously affected
- Relatively clean
- Adequate performance in existing hardware

FM-200 with $KHCO_3$ or $NaHCO_3$: Disadvantages

- 3-min [HF] at levels aprox. 400–600 ppm
- GWP (FE-36, FM-200) a problem eventually
- Potential corrosion ($K^+ > Na^+$)
- Slight residue requiring minimal cleanup
- Other as yet unidentified problems may exist for specific applications

Also tested as part of this study were solutions of 50 and 60% KOAc by weight in water. Potassium acetate produces no HF, presents minimal environmental and toxicity concerns, and is a very effective extinguishing compound. It does, however, leave a wet residue upon discharge. Although the residue was observed to dry rapidly to an adherent white surface, it was easily removed with water. The authors are aware of at least one commercial potassium acetate extinguisher on the market that has a UL C-rating, which suggests that this modified MetalCraft extinguisher *may* also achieve a C-rating. Further testing and evaluation are underway.

Testing has demonstrated that the modified MetalCraft extinguisher charged with 1.8 lbs of 50% KOAc is capable of extinguishing four 2B pan fires in succession. The average time to extinguishment of each 2B fire was approximately ***2.6*** sec in this testing. This extinguisher/agent combination is also capable of extinguishing a 5B Jet-A fire.

The identified advantages and disadvantages of the KOAc extinguishant are listed below.

H_2O / Potassium Acetate (50%): Observed Advantages

- When misted, excellent fire suppressant (5B and 2B jet fuel fire extinguishment)
- No environmental impact
- Low toxicological impact if any
- Clean-up similar to HFC/K or Na bicarbonate
- Residue will not re-suspend
- Electrical "C" rating in KOAc extinguishers
- NO HF or other fluorinated decomposition byproducts generated
- Modified MetalCraft extinguisher, 1.8 lb KOAc, 450 psi pressurization is capable of extinguishing four 2B Jet-A fires with agent to spare

H_2O /Potassium Acetate (50%): Disadvantages

- Post-extinguishment residue. (Note: KOAc is very water soluble)
- Potential corrosion (K^+)
- Other as yet unidentified problems may exist for specific applications

The test fixture employed in the visual obscuration and HF testing is presented below in Figure 1.

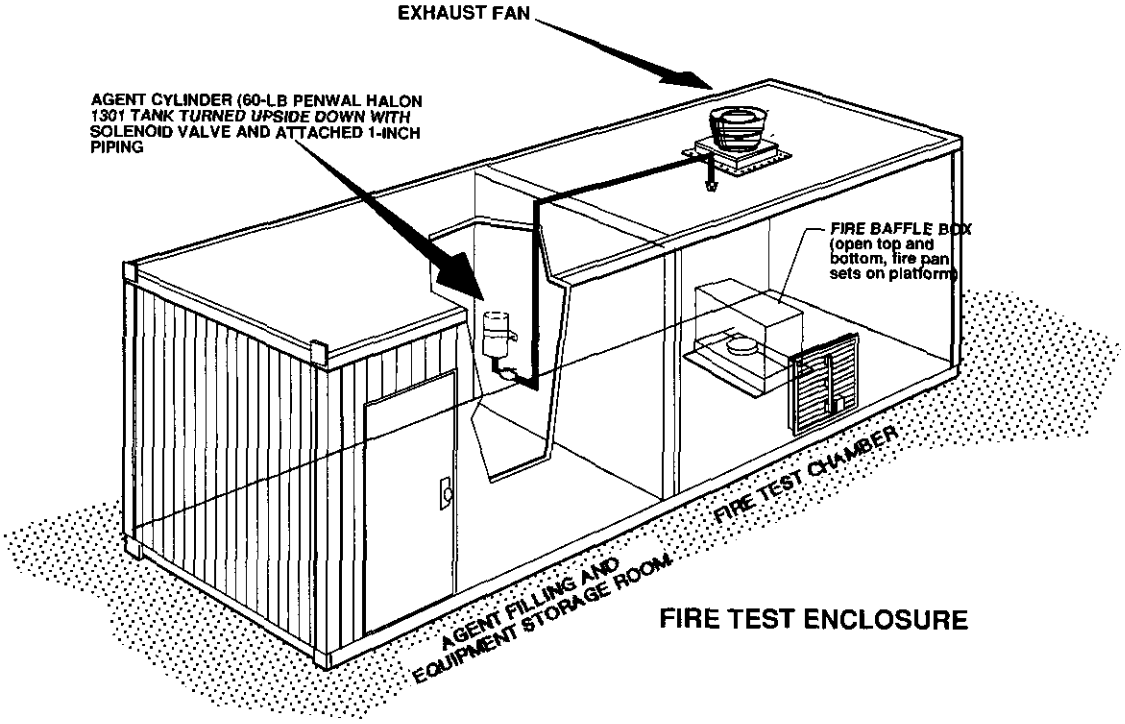

Figure 1. HF and visual obscuration test and evaluation equipment.