EXTENDED DISCHARGE TESTING WITH HFC-125

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ABSTRACT

HFC-125 (pentafluoroethane, CF_3CF_2H), is a zero ODP replacement for Halon 1301 in total flooding applications. We report here the results of our investigation into the use of extended discharge times with HFC-125, including the impact of extended discharge times on the suppression of Class A combustibles and on the thermal decomposition of HFC-125.

Fourier Transform Infrared (FTIR) spectroscopy was employed to quantify the production of HF during the extinguishment of fires typical of those expected to be encountered in electronic data processing (EDP) and telecommunications applications. Full-scale fire tests included magnetic tape, PC board, cable and wastepaper fires. Both standard (10 second discharge time) and extended (discharge time > 10 seconds) discharge systems were shown to provide efficient suppression, and also produced levels of HF well below the mammalian LC_{50} and human DTL. Details of the test program and the results are presented, along with a discussion of the implications of the results with respect to suppression system design.

INTRODUCTION

HFC-125

HFC-125 (pentafluoroethane, CF_3CF_2H), is a zero ODP replacement for Halon 1301 in total flooding applications; fire suppression systems utilizing HFC-125 are marketed by Fike Corporation under the tradename ECARO -25™. Physical properties of HFC-125 are shown in Table 1.

HFC-125 is currently employed worldwide for the protection of both Class A (cellulosic fuel) and Class B (liquid and gaseous fuel) hazards. As is the case for the class of clean agents in general, the protection of Class A assets represents approximately 95% of all commercial fire protection scenarios for HFC-125. Typical Class A hazards include those found in electronic data processing (EDP) and telecommunication facilities.

HFC-125, like all fluorine-containing fire suppression agents, is known to produce hydrogen fluoride (HF) during the extinguishment process due to thermal decomposition of the agent when exposed to the high temperatures of the flame. Previous studies [1,2] have shown the generation of thermal decomposition products associated with the use of the hydrofluorocarbon (HFC) suppression agents to be a strong function of both the fire size to room volume ratio (expressed in units of kW/m^3) and the discharge time: for a given concentration of fluorine-containing agent, an increase in either the fire size to room volume ratio or the discharge time results in increased production of HF.

The objective of this study was to quantify the amount of HF formed during the extinguishment with HFC-125 of fires typical of those expected to be encountered in electronic data processing (EDP) and telecommunications applications. A further objective of the study was to assess the impact of an extended (> 10 second) discharge time on the suppression and on the thermal decomposition of HFC-125.

Table 1. Physical Properties of HFC-125 [3]

Property	
Chemical Name	Pentafluoroethane
Chemical Formula	CF_3CF_2H
CAS Number	354-33-6
Molecular Weight	120.02
Boiling Point, ^oC (^oF)	-48.14 (-54.7)
Freezing Point, ^oC (^oF)	-103 (-153)
Critical Temperature, ^oC (^oF)	66.25 (151.25)
Critical Pressure, kPa (psia)	3631 (526.6)
Critical Density, kg/m^3 (lb/ft^3)	4.983 (0.3111)
Vapor Pressure, 25 ^oC (77 ^oF), kPa (psia)	1381.5 (200.4)
Heat of Vaporization at bp, kJ/kg (BTU/lb)	164.4 (70.7)
Relative dielectric strength (N_2=1)	1.007
Ozone Depletion Potential	0
Global Warming Potential (100 year ITH) [4]	3400
NOAEL, % [1]	7.5
LOAEL, % [1]	10
Safe 5 Minute Human Exposure Limit, % [1]	11.5
Wood Crib Extinguishing Conc., % [5]	6.7
n-Heptane Cup Burner Extinguishing Conc, % [4]	9.3

EXPERIMENTAL PROCEDURE

TEST ENCLOSURE

A test enclosure was constructed with internal dimensions of 13.3 ft x 21.3 ft x 11.9 ft, providing 3,371 ft^3 of floodable volume. The enclosure was constructed of 0.5 inch gypsum board over 2 x 4 wood framing, and included two 2 ft x 3 ft polycarbonate and one 1 ft x 1 ft polycarbonate windows to allow for observation of the tests. Access to the test enclosure is gained through a steel door.

SUPPRESSION SYSTEM

System design was accomplished with the HAI HFC-125 Flow Calculation Program, version FIK 3.00K, developed by Hughes Associates, Inc. HFC-125 was discharged from a Fike 215 pound upright system cylinder (part no. 70-087) which was equipped with a quarter-turn valve. The standard discharge system was designed to afford a 10 second discharge of 8.7% v/v HFC-125, and the extended discharge system was designed to afford a 20 second discharge of 9.25% v/v HFC-125. The agent flowed through a pipe network constructed of 1.25 inch NPT Schedule 40 pipe terminating at a 1.25 inch Fike 360^o nozzle with either a 0.5161 in^2 (standard discharge system) or a 0.2354 in^2 (extended discharge system) nozzle area.

INSTRUMENTATION

<u>Temperature</u>. Enclosure temperatures were monitored employing fiberglass-braided type K thermocouples located on two vertical trees. Cylinder and nozzle temperatures were also monitored employing type K thermocouples.

<u>Pressure.</u> Cylinder and nozzle pressures were monitored with Omega Engineering Model PX613-5V pressure transducers with a range of 0 - 500 psig (0 - 3.45 Mpag). Enclosure pressures were monitored with an Omega Engineering Model PX653-05BD5V pressure transducer with a range of -0.18 to +0.18 psig (-1.2 to +1.2 kPag).

<u>Smoke.</u> Smoke production was measured with an optical density meter with a pathlength of 5.00 ft (1.52 m). The light source employed was a 12 Vdc lamp, and the receiver was a photoelectric diode.

<u>Agent and HF Concentration</u>. Agent and HF concentrations were monitored in situ employing a KVB/Analect Diamond 20 Fourier Transform Infrared (FTIR) spectrometer, equipped with a light pipe system utilizing calcium fluoride windows. Oxygen was monitored with a Servomex 540A paramagnetic oxygen analyzer.

DETECTION SYSTEM

A Fike Shark® detection system equipped with photoelectric and ionization detectors was employed. The detectors were located 14 feet from the fire location, corresponding to a worse case 20 foot on-center detector spacing. Industry standard alarm thresholds were employed: 1.4

percent obscuration per foot for the ionization detectors and 2.15% obscuration per foot for the photoelectric detectors.

TEST FIRES

The test fires employed in this study were essentially identical to those employed in a previous study of the thermal decomposition products of HFC-227ea [6], and involved four types of fuel configurations:

- Wastebaskets containing paper
- Printed circuit boards
- Electrical cables
- Magnetic tapes

The wastepaper basket fires consisted of 200 g of newsprint shred into approximately 2 mm x 2 mm pieces loosely packed into a soft polyethylene wastebasket (Rubbermaid 2955). The paper was ignited with a match through a 1 inch hole centered on the side at the base of the basket. The average heat release rate for these fires was estimated to be 19 kW, based upon visual observation and consideration of the heat of combustion.

The printed circuit board fires consisted of two blank circuit boards vertically mounted onto frames one inch apart and heated to ignition by a Glo-coil heating element (Eagle 4125-120). The average heat release rate of these fires was estimated to be approximately 11 kW, based upon visual observation and consideration of the heat of combustion.

The electrical cable fires consisted of 100 pair, PVC insulated/PVC jacketed telephone cable ignited by 30 mL of heptane burning in a 2 in x 2 in square pan centered below the cables. The average heat release rate of these fires was estimated to be approximately 4 kW, based upon visual observation and consideration of the heat of combustion.

The magnetic tape fires utilized 10.5 inch (26.7 cm) round reel tapes arranged on a double sided 120 tape library rack with four tapes per row and three rows high. Tapes were hung in adjacent slots on the rack. The average heat release rate of these fires was estimated to be approximately 23 kW, based upon visual observation and consideration of the heat of combustion.

PROCEDURE

Data collection was commenced approximately 15 seconds prior to ignition of the fuel by match or Glo-coil, and the fire allowed to burn until a 30 second delay period had elapsed after either the photoelectric or ionization detector alarmed. During this period, the enclosure door was shut, and the inlet and outlet vents were open with the blower off. At 15 seconds after alarm the vents were closed and at 30 seconds after alarm the agent was discharged. Ignition and extinguishment times were recorded by tripping instrumentation flags. Ten minutes after the end of discharge, the enclosure was opened and purged.

RESULTS

The results of the test series are summarized in Table 2.

PVC CABLE FIRES

Two configurations were employed for the electrical cable tests. In the first, the cables were extended to (touched) the lip of the ignition pan; in the second configuration a space of approximately 0.5 inch was employed between the top of the ignition pan and the wires. In the case of the wires touching the ignition pan, smoldering combustion dominated over flaming combustion, whereas in the case of the raised cable, increased flaming combustion was observed. Rapid extinguishment was achieved with both the standard and extended discharge systems in all cases. For the configuration with the wires touching the ignition pan, extinguishment times and HF levels were higher in the case of the standard discharge system. In the configuration with raised cables, the extinguishment times tended to be shorter for the extended discharge system, and the range of HF levels observed were similar, i.e., 67 to 169 ppm HF for the standard system compared to 0 to 150 ppm HF in the case of the extended discharge.

PAPER FIRES

The standard and extended discharge HFC-125 systems both afforded rapid suppression of flaming combustion, and following the 10 minute soak period smoldering combustion had ceased. Extinguishment times, measured from the end of agent discharge, varied from 7 to 26 seconds for the standard system, and from 8 to 68 seconds for the extended discharge system. Peak HF values ranged from 76 to 121 ppm HF for the standard system, and from 240 to 336 ppm HF for the extended discharge system.

MAGNETIC TAPE FIRES

The magnetic tape fires were rapidly extinguished by both the standard and extended discharge systems, the extended discharge system affording more rapid extinguishment in general. HF levels varied only slightly with the system, ranging from 69 to 92 ppm HF for the standard system, and from 102 to 105 ppm HF for the extended discharge system.

PRINTED CIRCUIT BOARD FIRES

The printed circuit boards fires were rapidly extinguished by both the standard and extended discharge systems. Extinguishment times for the standard system ranged from 6 to 17 seconds from the end of discharge. In the case of the extended discharge system, extinguishment was more rapid, occurring during the agent discharge. HF was below detection levels (approximately 5 ppm) in all cases.

Table 2. Summary of Thermal Decomposition Test Results with HFC-125

Test	Fuel	System	Detection Time, s	Extinguishing Time[a], s	HF Max., ppm	HF 10 min Ave, ppm
FE09	PVC cable	Standard	370	26	245	148
FE02	PVC cable	Extended	220	-1	122	43
FE04	PVC cable	Extended	269	4	136	89
FE05	PVC cable[b]	Standard	145	0	67	38
FE21	PVC cable[b]	Standard	234	16	169	108
FE17	PVC cable[b]	Extended	168	2	150	87
FE18	PVC cable[b]	Extended	239	-13	0	0
FE08	Paper	Standard	252	26	121	61
FE12	Paper	Standard	387	7	76	37
FE15	Paper	Extended	275	8	336	163
FE03	Paper	Extended	275	68	240	124
FE10	Magnetic tapes	Standard	168	56	92	42
FE13	Magnetic tape	Standard	181	16	69	26
FE14	Magnetic tape	Extended	188	25	105	48
FE06	Magnetic tapes	Extended	166	15	102	33
FE11	PC board	Standard	212	17	0	0
FE20	PC board	Standard	244	6	0	0
FE16	PC board	Extended	216	-8	0	0
FE19	PC board	Extended	261	-10	0	0

[a] From end of discharge
[b] Raised cables

DISCUSSION OF EXPERIMENTAL RESULTS

THERMAL DECOMPOSITION OF HFC-125

As discussed above, HFC-125, like all fluorine-containing fire suppression agents, is known to produce hydrogen fluoride (HF) during the extinguishment process due to thermal decomposition of the agent when exposed to the high temperatures of the flame. Previous studies [1,2] have shown the generation of thermal decomposition products associated with the use of the hydrofluorocarbon (HFC) suppression agents to be a strong function of both the fire size to room volume ratio (expressed in units of kW/m^3) and the discharge time: for a given concentration of fluorine-containing agent, an increase in either the fire size to room volume ratio or the discharge time results in increased production of HF.

It has also been observed that as the agent concentration is increased, the production of HF is reduced [1]. Given the known relationships between HF production, agent concentration, and discharge time, it should be possible to maintain similar levels of HF by increasing both the discharge time and the agent concentration relative to the original system, i.e., the expected increase in HF production due to the use of a longer discharge time could be offset by employing a higher agent concentration. In this study, a comparison was made between a standard, 10 second discharge system employing 8.7% HFC-125, and an extended, 20 second discharge system employing 9.25% HFC-125.

Figure 1 shows the HF concentrations resulting from the extinguishment of the test fires for those tests which produced the highest peak values of HF; this corresponds to the extended discharge system in the case of the paper (test FE15) and magnetic tape fires (test FE14), and the standard system in the case of the PVC cable fires (test FE07); HF was not detected in any of the printed circuit board tests. Figure 1 also shows the mammalian LC_{50}, derived from Sax [7], and the human dangerous toxic load (DTL) derived by Meldrum [8]. The DTL was derived by Meldrum based upon an evaluation of HF exposure data for mice, which show the greatest sensitivity to HF exposure of all mammals tested, and corresponds to exposure levels at which severe distress would be expected for all exposed personnel. As seen in Figure 1 the highest HF levels produced from the extinguishment of typical Class A fuels under realistic conditions were well below both the estimated mammalian LC_{50} and human DTL, for both standard and extended discharge systems.

The threat to electronic and other equipment from exposure to the halogen acids is a function of several variables, including the decomposition product concentration, the exposure time to the halogen acids, the deposition rate of acids on the equipment surface, the relative humidity and temperature, the sensitivity of the equipment and combined effects with smoke. Pedley [9] at NASA reported the results of exposure of a variety of electronic equipment to HF and HBr. Tests included the measurement of corrosion rates for metals exposed to HF and HBr, the effects of HF and HBr on nonmetallic parts, and the effects of HF and HBr on unpowered and powered electronic equipment, printed circuit boards and conformal coatings. For atmospheres of 500 ppm HF and 200 ppm HBr, no damage to powered electronic equipment occurred and no damage to the various conformal coatings was observed. The NFPA 2001 Technical Committee, following their review of the available data concluded that short term damage to electronic equipment was not likely for exposures of 500 ppm HF for up to 30 minutes [1]. As seen from Figure 1, HF levels produced upon extinguishment of typical Class A fires under real world conditions are significantly below the levels examined by Pedley and the damage threshold estimated by the NFPA 2001 Technical Committee, for both the standard and extended discharge systems.

It should also be noted that the HF levels observed for both the standard and extended discharge HFC-125 suppression systems are comparable to HF levels observed for suppression of identical fires by a standard (10 second discharge) HFC-227ea suppression system [6].

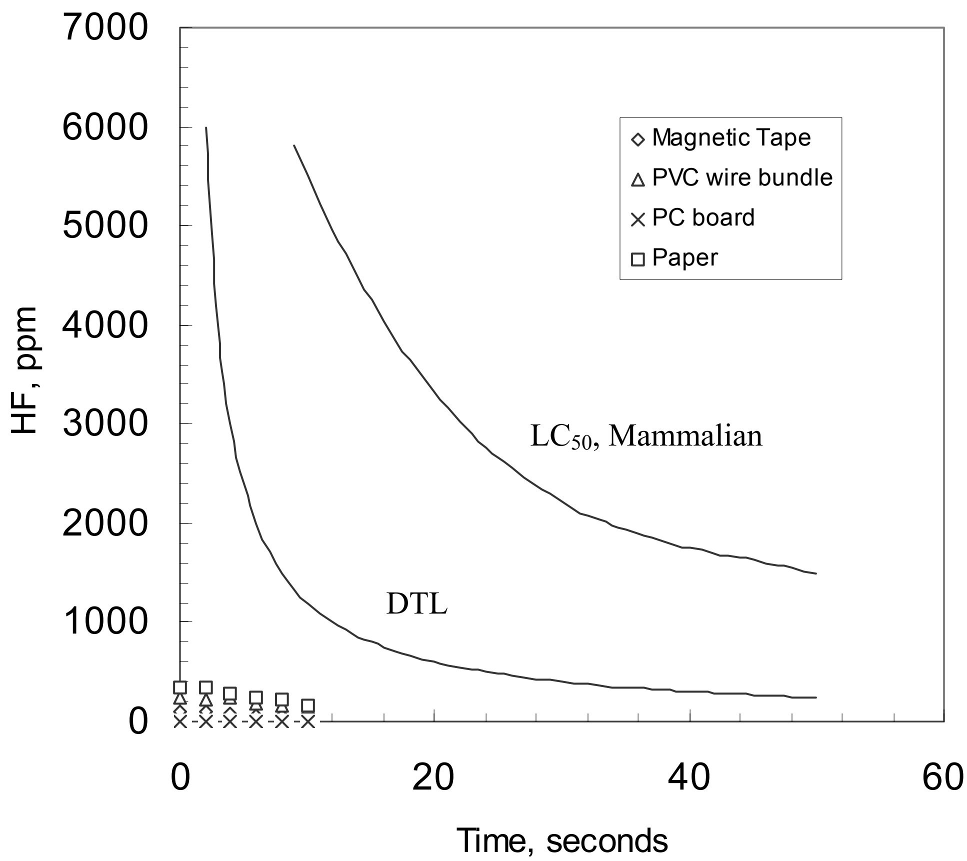

Figure 1. Hazard Assessment of HF Concentrations: HFC-125

CLASS A FIRES: FIRE SIZE AND DETECTION

The vast majority of fire suppression applications of HFC-125 involve the protection of Class A hazards, for example those found in electronic data processing (EDP) and telecommunication facilities. Fire hazards in such facilities are characterized by low fuel loads, and include wire insulation, PC boards, electronic components, transformers, insulating materials and plastic housings. As indicated by Meacham [10] fires in such facilities are of low energy output, often less than 5 to 10 kW.

Detection capabilities in EDP and telecommunication facilities are such that fires are detected in their incipient stages, and there exists an industry wide desire to detect fires at as small a size as possible. Some telecommunication companies desire to detect at a fire size of 1 kW, whereas other have indicated that detection at a fire size of 0.1 kW is desirable for sensitive equipment [11]. Meacham [10] has categorized the type of detection required based upon the level of damage tolerable, and in his evaluation considers fires larger than 10 kW to result in a major loss (see Table 2).

It should be noted that, with the exception of the PVC electrical cable fires, the test fires in this study exceeded 10 kW in fire size.

Table 2. Classification of Loss as a Function of Fire Size

Acceptable Loss	Fire Size
Major loss	> 10 kW
Large loss	5 - 10 kW
Moderate loss	2 - 5 kW
Small loss	< 2 kW

CONCLUSIONS

The thermal decomposition products associated with the use of HFC-125 were measured for a series of fires involving typical materials protected by gaseous total flooding systems. It was shown that a standard (10 second) discharge system employing 8.7% v/v HFC-125 provided rapid extinguishment of all test fires, and produced HF levels well below the mammalian LC_{50} [7] and human DTL [8]. It was also shown that an extended (20 second) discharge system employing 9.25% v/v HFC-125 provided efficient suppression, and again produced levels of HF well below the mammalian LC_{50} and human DTL. The HF levels observed with both the standard and extended discharge systems are also significantly below the damage threshold to electronic equipment estimated by the NFPA 2001 Technical Committee [1]. The HF levels observed in this study for both the standard and extended discharge HFC-125 systems are comparable to those observed in the extinguishment of identical Class A fires with a standard discharge (10 seconds) HFC-227ea system, as reported in a previous study [6].

The results of this study indicate that equivalent protection of Class A hazards, i.e., rapid extinguishment, is possible employing a properly designed detection system and a combination of increased agent concentration and longer discharge time relative to a reference HFC-125 fire suppression system.

The results of this study also indicate that for the suppression of Class A fires, equivalent levels of the thermal decomposition product HF can result for HFC-125 suppression systems employing a properly designed detection system and both a higher agent concentration and a longer discharge time compared to a reference HFC-125 fire suppression system.

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