Performance of Novec1230 in Electronic Facility Fire Protection

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INTRODUCTION

Many halocarbon products have been introduced in the market place to fill the gap in the fire suppression area left by halons. Novec1230, which has zero ozone depletion potential, a very short atmospheric-life-time and a global warming potential of one, is one of those halocarbon products.

Halocarbons agents, upon exposure to open flame and high temperatures, can decompose and produce thermal decomposition products (TDP). Previous testing of halocarbon agents containing fluorine atoms demonstrates that hydrogen fluoride (HF) and carbonyl fluoride (COF_2) are common decomposition byproducts, with HF being the primary byproduct by a factor of three to four over COF_2. The amount of toxic decomposition products generated is influenced by a number of factors.

Information related to the thermal decomposition of Novec1230 generally states that the maximum HF concentrations generated are consistent with those of other halocarbon agents. Based on the composition, Novec1230 contains 3.6 times more fluorine than Halon 1301. Therefore, it can be reasonably expected to produce at least this much more HF than Halon 1301. This is in line with the findings of a previous study by NRC.

Without proper protection, these corrosive thermal decomposition products (HF) may cause corrosion damage to electronic facilities. The degree of corrosion damage is dependent on HF concentration, exposure time, temperature and relative humidity of the enclosure and the properties of the equipment exposed.

To determine the fire suppression effectiveness and to address the potential problem of corrosion damage on electronic equipments from the use of Novec1230 in electronic facilities, a project was carried out by NRC. In order to evaluate the effect of HF corrosion on electronic equipments, it was necessary to conduct full-scale fire tests and determine the amount of HF produced during fire extinguishment by Novec1230 for typical fire scenarios in a large compartment.

The project involved fire suppression performance of Novec1230 and HF measurement in a compartment containing simulated electronic cabinets. This paper describes the work carried out in the project, including the test facility, test protocol, and the results of the tests. The fire suppression effectiveness and concentrations of thermal decomposition products of Novec1230 during fire suppression in various parts of the test compartment are also discussed.

DESCRIPTION OF TESTS

Test Room

Full-scale tests were conducted in a 58 m^3 compartment (23.7 m^2 floor area, 2.44 m height). The test compartment simulated an electronic facility with various types of electronic cabinets. The compartment was equipped with a piping system for the delivery of Novec1230 as well as corresponding instruments that monitored and recorded the agent discharge, fire extinguishment processes and gas compositions in the compartment.

A total of six cabinets (two each of three types) were placed in the test room to simulate an electronic facility. The three types of cabinets used in the tests were "Closed cabinet" with no ventilation openings, "Ventilated cabinet" with ventilation openings (2% of surface area) and "Open cabinet" with unlimited ventilation. All cabinets measured 1.8 m high by 1m wide and 0.46 m deep.

Novec1230 was used in the full-scale fire tests at 6.5% design concentration. The agent distribution and HF production during fire suppression was measured using Fourier Transform Infrared (FTIR) Spectrometer. HF concentrations at various locations, including the open area of the compartment and inside cabinets, for different fire scenarios was measured during fire extinguishment period and for the duration of 10 min after the fire extinguishment.

Fire Scenarios

In the test series, Class A and B fires (wood crib and liquid fuel pool fires) and small cable bundle fires were used to evaluate the fire suppression performance of the agent and to measure the production of thermal decomposition products. Liquid fuel and wood crib fires were placed in the open area of the compartment, whereas the cable bundle fires were located inside the cabinets.

A round pan (RP), 0.7 m in diameter and 0.385 m^2 in area, was placed near the Southwest corner of the room. The pan contained 2 L of heptane fuel on a 4 L water base, and the lip height of the pan above the fuel level was approximately 20 mm. The amount of fuel in the pan provided approximately 720 s of burning time and the heat release rate of the RP with heptane fuel was approximately 500 kW. During the tests, the round pan was unshielded from the direct spray of the agent discharge.

A small wood crib, measuring 0.6 m by 0.6 m and 0.45 m high and weighing approximately 35 kg, was placed near the Southwest corner of the room, similar to the heptane pool fire case. The wood crib was ignited by five 9 inch aluminum pans, containing 200 ml of methyl hydrate, that were placed at the quarter points and centre under the wood crib. This ignition at five-point instead of one point ignition, promoted more even fire development of the wood crib. The wood crib fire was allowed to fully develop before the suppression system was activated.

Possible overheating of the cables and ignition into a cable fire in the cabinets was simulated by a small cable bundle fire placed inside the test cabinets. The cable bundle fire was produced by a bundle of cable wires wrapped with a Nichrome wire. The cable bundle consisted of 7 insulation skins of 200 mm long Belden Cable 4, 18 gauge conductor cables wrapped around with 14 gauge Nichrome wire. The Nicrome wire was connected to a 30 amps DC power source and within 20 s, the cable bundle ignited, producing a 3 kW fire. The cable bundles were placed in the middle of each type of cabinet used in the tests.

Test Procedure

Cabinet C-1 was the fire cabinet where the cable fire was placed. Three different ventilation conditions were used for Cabinet C-1. In Scenario 1, the door of Cabinet C-1 was wide open. In Scenario 2, the door of Cabinet C-1 was closed and the only ventilation to the cabinet was through leakage around the door. In Scenario 3, Cabinet C-1 had ventilation openings (about 2% of the total surface area of the cabinet) and its door was closed. In the large fire tests, the 0.7 m diameter heptane pool and wood crib fires were located in the open area of the test room.

For each scenario, a suppression test with Novec1230 was conducted. In the cable fire tests, fifty seconds after the electric power to the Nichrome-wire ignitor was turned on, the room door was closed and Novec1230 was discharged into the test room. Free burning test was conducted for Scenario 3 where the cable bundle was left to burn out without suppression. In the heptane pool fire tests, a 30 s pre-burn was allowed for the heptane pool fire to fully develop before the agent was discharged. In the wood crib fire test, pre-burn of 7 min 30 s was allowed for the wood crib fire to fully develop and to have a deep-seated fire.

RESULTS AND DISCUSSION

A total of 6 tests were conducted. One test was conducted allowing cable bundle in a ventilated cabinet to burn out without suppression. Three suppression tests with cable bundle fires in cabinets with three different ventilation conditions and heptane pool fire and wood crib fire tests were conducted.

Cable Burn without Suppression

In the free burning test, a cable bundle (weight of 33 g) was ignited using electrically-heated Nichrome wire. The cable bundle started to burn 18 s after the ignition power was turned on and was left to burn out without suppression. The heat release rate was 3-4 kW.

The cable bundle burned out in 240 s with less than 7 grams of residue left. The time for the cable bundle fire to trigger the North smoke detector near the Cabinet C-1 was 49 s, and the time to trigger the South smoke detector was 109 s. As a result of the cable combustion, CO, CO_2 and HCl were produced in the fire cabinet. The peak concentrations were 2250 ppm CO, 1.04% CO_2 and 500 ppm HCl in the ventilated fire cabinet. The concentrations of combustion products in the open area of the room were very low.

Suppression of In-Cabinet Cable Fire

In the cable fire suppression tests, Novec1230 was discharged into the test room in 12 - 14 s. Due to the cooling effect of the agent expansion and vaporization, the room temperature dropped by as much as 35^{o}C; the room pressure went down to as low as -475 Pa then went up to +52 Pa. The Novec1230 concentration in the test room reached a maximum concentration of 6.93% at the end of the discharge.

In the first suppression test (Test 1), the cable fire was in the open cabinet C-1. The cable fire was extinguished in 20 s. The concentration of HF generated from agent-flame interaction was below 100 ppm in the fire cabinet. The minimum O_2 concentration in the fire cabinet was 18.7% as a result of displacement by the agent and consumption by the combustion.

In the second fire test, the cable bundle fire was in the closed cabinet. Since the fire cabinet was totally closed and had no ventilation openings, the Novec1230 concentration in the fire cabinet took a long time to reach its plateau of 5.66%. The cable fire inside the cabinet was extinguished in 72 s, which was before the agent concentration reached the plateau. The maximum concentrations of combustion products in the fire cabinet were 5460 ppm CO, 1.63% CO_2 and 1170 ppm HCl, more than 20 times higher than those in Test 1. The HF generated from agent-flame interaction reached a peak concentration of 880 ppm in the fire cabinet, and then decayed slowly. The minimum O_2 concentration in the fire cabinet was 19%.

In the third test, a ventilated cabinet was used. The cable bundle fire in the cabinet was extinguished in 30 s. The maximum concentrations of combustion products in the fire cabinet were 1700 ppm CO, 0.82% CO_2 and 410 ppm HCl. The concentration of HF generated from agent-flame interaction was 120 ppm in the fire cabinet. The minimum O_2 concentration in the fire cabinet was 18.8%.

The tests showed that the ventilation condition of the cabinet affected the time taken for Novec1230 to reach the required concentration in the cabinets, and also affected the extinguishment time of the in-cabinet cable fire. The extinguishment time of the cable bundle fire determined the quantities of the acid gas products generated in the fire cabinet. In the closed fire cabinet, more HF was generated due to the longer time for agent-flame interaction than in the ventilated or open fire cabinet. The maximum HF concentration was 880 ppm in the closed fire cabinet, which decayed to below 100 ppm in 10 minutes. In the open or ventilated fire cabinet, the maximum HF concentration was 120 ppm.

In the non-fire cabinets C-3 and C-4, the FTIR gas measurement showed neither HF absorption signals nor other by-product absorption signals. The HF concentration in the non-fire cabinets was too low to be detected. This indicates that migration of gaseous by-products from the fire cabinet to the adjacent non-fire cabinets was minimal.

The HF concentrations in the test room were much lower than 100 ppm during all in-cabinet cable fire tests.

Suppression of Large Fires

In order to see the impact of large fires on electronic equipment, suppression tests of a heptane pool and wood crib fires were also conducted. In the large heptanes fire test, the maximum HF concentration in the room reached 2950 ppm, whereas measurement in the ventilated and closed cabinets showed a peak HF concentrations of 1150 ppm and 500 ppm, respectively. In the wood crib fire test, the maximum HF concentration in the room reached 2150 ppm. Measurements in the ventilated and closed cabinets showed a peak HF concentrations of 920 ppm and 75 ppm, respectively. When there is a large fire in the room, generation of HF from the fire suppression by Novec1230 was significant, and a large amount of HF migrated to the non-fire cabinets in the room, indicating potential corrosion problem on the electronic equipments inside the cabinets in the room even when a fire is not located inside the cabinet.

CONCLUSIONS

The extinguishment time of the cable bundle fire was affected by the ventilation condition of the cabinet, which in turn determined the quantities of acid gas products generated in the fire cabinet. The maximum HF concentration was 880 ppm in the closed fire cabinet but was below 100 ppm in the open fire cabinet since it took a longer time to extinguish the fire in the closed fire cabinet than in the open fire cabinet. In the ventilated fire cabinet, the maximum HF reached 120 ppm.

Very little HF moved into the non-fire cabinets (C-3 and C-4) and migration of gaseous by-products from the fire cabinet to the adjacent non-fire cabinets was minimal. During the in-cabinet cable fire tests, the HF concentration in the test room was much lower than 100 ppm.

When the test fire was large, however, the HF concentration in the test room was at dangerous levels (maximum of 2950 ppm). Considerable quantities of HF were transported into the non-fire cabinets. Potential corrosion damage by the acid gas to equipment in an electronic environment and exposure risk for people trapped inside would be a safety concern when suppressing a large fire using Novec1230. In view of human and property safety, early fire detection must be emphasized so that a small fire can be extinguished before it develops into a large fire.

Table 1 – Tests and Results

Test Fire			Cable Bundle (Test A)	Cable Bundle (Test 1)	Cable Bundle (Test 2)	Cable Bundle (Test 3)	Heptane Pan Fire (Test 4)	Wood Crib Fire (Test 5)
Fire Location			Ventilated Cabinet C-1	Open Cabinet C-1	Closed Cabinet C-1	Ventilated Cabinet C-1	Room C-1 Closed	Room C-1 Closed
Room T (^oC)			+30	-5.4;+29.4	-9.4; +25.6	-4; +29	+4.9; +125	+4.3; +181
Room P (in Pa)			0	-400;+52	-475; +50	-350; +50	-1800;+1000	-350; +55
Discharge Time (s)			-	12-14	12-14	12-14	12-14	12-14
Ext. Time (s) [a]			240	20	72	30	6	7
First Alarm (s) [c]			49	45	During discharge	During discharge	6	14
Second Alarm (s) [c]			109	During discharge	During discharge	During discharge	14	23
Maximum Concentrations in Cabinets and Room	C-1	Agent (%)	0	6.22	5.66	5.90	5.18	4.29
		HF (ppm)	0	4.5	880	120	600	75
		HCl (ppm)	500	55	1170	410	50	<50
		CO (ppm)	2250	300	5460	1700	2620	640
		CO_2 (%)	1.04	0.14	1.63	0.82	1.3	2.3
		O_2 (%)	19.4	18.7	19.0	18.8	18.1	17.8
	C-4	Agent (%)	0	6.93	6.87	6.99	6.81	7.44
		HF (ppm)	0	0	0	0	1150	920
	C-3	Agent (%)	0	5.85	6.18	5.97	5.39	5.18
		HF (ppm)	0	0	0	0	500	75
	Room	Agent (%)	0	6.92	6.93	6.83	7.79	7.78
		HF (ppm)	0	0	0	0	2950	2150
		CO (ppm)	0	112	370	160	6930	1270
		CO_2 (%)	.04	0.13	0.22	0.15	2.5	2.6
		O_2 (%)	20.9	18.9	18.8	18.8	17.3	16.6
Remark							Pre-burn 30 s	Pre-burn 7 min 30 s

Note: C-4 is target ventilated cabinet, C-3 is target closed cabinet