

Full-Scale Fire Testing of HFC-227ea and HCFC Blend A

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ABSTRACT

Fire-suppression performances of HFC-227ea and HCFC Blend A were evaluated using full-scale fire tests conducted in a 121 m³ compartment which simulates a space on Canadian Navy frigates. At the design concentration of 12%, HCFC Blend A was effective in suppressing test fires in the test compartment. HFC-227ea also extinguished all test fires at the design concentration of 7.6%. Primary acid-gas products generated during the tests were: hydrogen fluoride (HF) and hydrogen chloride (HCl) for HCFC Blend A, and HF for HFC-227ea. The quantities of the acid gases were dependent upon agent concentration, agent discharge time and fire size. In this paper, an overview of the test program and the results are provided.

INTRODUCTION

The Department of National Defence Canada (DND) has been actively searching for suitable replacements and alternatives to replace ozone-depleting Halon 1301 which is currently used to protect many DND facilities. To meet DND's needs in the post-halon era, the National Research Council of Canada (NRCC) and DND jointly set up a research program, Halon Alternatives Performance Evaluation (HAPE), to evaluate the fire-suppression performance of available Halon replacements and alternatives.

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The initial efforts of the HAPE project were directed at finding suitable replacements for the Canadian Navy. HCFC Blend A and HFC-227ea were identified as potential replacements for Halon-1301.

The first series of full-scale tests for HCFC Blend A and HFC-227ea were conducted in a compartment mock-up of a radar room on the Navy's Halifax Class frigates, using a Halon-1301 piping as installed on the ships. This piping system was designed to provide a Halon-1301 concentration of 7.5%. The objectives were to assess the fire-suppression effectiveness of the agents and to determine whether the agents could be delivered effectively through the existing piping with minor system modification.

In the second series of full-scale tests, an optimum piping system was designed specifically for each agent (HCFC Blend A and HFC-227ea). The agents were tested using the optimum piping systems. This paper provides an overview of the test program and the results obtained.

FACILITY AND EXPERIMENTS

Test Room

A 121 m³ compartment shown in Figure 1, similar to Radar Room No. 2 on the Navy's Halifax Class frigates, was constructed inside the Bum Hall of the National Fire Laboratory. The test room had a steel access door on the North wall and three viewing windows. On the South wall, a pressure relief vent was located near the floor. Fan-pressurization tests of the room indicated that the equivalent leakage area of the room was 0.014 m² for a 50 Pa pressure difference.

Piping Systems

The existing Halon 1301 piping on the ships, designed for 7.5% Halon concentration, was duplicated in the test room (see Figure 1). The Ginge-Kerr* (GK) cylinder system, currently used on the ships, was used in the HCFC Blend A tests. Two types of nozzles were used in **the** first series of HCFC Blend A tests: Type-A nozzle (manufactured by **SES** Cease Fire), which produced a 360°, horizontal spray, and Type-B nozzle (provided by Safety Hi-Tech), which produced a cone-shaped downward spray. In the HFC-227ea tests, Chemetron cylinder and two cylindrical Chemetron nozzles, designed for use with HFC-227ea, were used.

The optimal HCFC Blend A piping system with two Type-A nozzles was designed to deliver 12% agent into the room in 10 s. The optimal HFC-227ea piping system with two cylindrical Chemetron nozzles was designed to deliver 7.6% HFC-227ea in 10 s. The piping arrangements are shown in Figures 2 and 3.

Instrumentation

Pressure transducers and thermocouples were installed along the pipe of each system to monitor the state of the agents inside the pipes during discharge. A broad-band sound meter was installed in the test room to monitor the sound **level**. The mass loss rate of the agents in the cylinders was measured using a weigh scale with a digital readout and a video camera with a timer in some tests. The discharge times of the agents were determined by these three measurements.

Three thermocouple trees were set up to measure the temperatures in the compartment (see Figure 1). To measure the pressures in the room, nine pressure taps were installed on the west wall at three elevations.

*Certain commercial products are identified in this paper in order to adequately specify the experimental procedure. In no case does such identification imply recommendations or endorsement by the National Research Council, nor does it imply that the product or material identified is the best available for the purpose.

Thermocouples were placed at each fire location to determine the fire-extinguishment time. A tygon sampling port was placed in the middle of the West wall to sample fire gases for CO₂, CO and O₂. In the second test series, another tygon port was added to the sampling line, about 1.4 m above the original port on the West wall. The sample line connected to a CO₂/CO analyzer and a O₂ analyzer. A Fourier Transform Infrared (FTIR) spectrometer was used to measure the concentrations of the agent and acid gases generated in the room during the tests. Three FTIR Gas-Sampling Ports with quartz tubing were placed near the Southwest corner at 1.5 m above the floor, near the centre at 0.6 m above the floor and near the Northwest corner at 2.8 m above the floor, respectively (see Figure 1). Video cameras were set up at the three windows to obtain visual records of the agent discharge and the behaviour of the fires under suppression.

Fire Scenarios

Test fires were of different types and sizes, including a 400 kW round-pan (RP, 0.7 m diameter) fire, three 50 kW square-pan (SP, 0.3 m x 0.3 m) fires, simulated fires in electronic cabinets (ECs), wood-crib (WC) fires and tell-tale (TT) fires. Heptane was used as the fuel for the TT, SP and RP fires.

Scenario-1 (200 kW). TT fires with 50 kW total heat output were placed strategically throughout the room. Three SPs were placed in the Southeast corner and the Northwest corner a few centimetres above the floor and in the Southwest corner approximately midway up the wall, all with their edges 50 mm from each wall.

Scenario-2 (600 kW). TT fires with 50 kW total heat output were placed strategically throughout the room. Three SPs were placed in the Northeast corner and the Northwest corner a few centimetres above the floor and in the Southwest corner approximately midway up the wall. The large round pan was placed near the Southeast corner of the room.

Scenario-3. Two mock-up cabinets (each with 5% opening, 0.81 m by 0.81 m and 1 m high) were placed approximately 1 m away from the **SE** comer, one on top of the other. Another mock-up cabinet with 2% opening was located near the North wall. Tell-tales were placed in the centre of each mock-up cabinet. An electronic switching-gear cabinet was placed against the East wall, near the door. A short cable bundle with diesel-soaked hemp rope as an ignitor was placed in the upper portion of the electronic switching-gear cabinet, and against a side wall and one tell-tale was placed on the bottom of the cabinet. A wood crib, made of 40 mm by 40 mm pine sticks in 6 layers, was placed in the **SW** comer. Two different sizes of wood crib were used, one measured approximately 0.3 m by 0.3 m and 0.24 m high (Scenario-3A, 100kW) and another 0.6 m by 0.6 m and 0.24 m high (Scenario-3B, 400 kW).

Scenario4 (400 kW). This fire scenario was similar to Scenario-3, except that a shielded-heptane-pool (0.7 m diameter) fire was used instead of the wood-crib fire. The round pan was placed in the **SE** comer and was covered with a box made of perforated sheet steel with 33% opening on the sides and 6% opening on the top.

Experimental Procedure

Test data from the instrumentation were collected by a data acquisition system. Test fires were allowed at least a 30 s pre-bum. During the pre-bum period, the door was kept open. Agent discharge was activated manually (usually at $t = 60$ s). The pressure relief vent and the access door were deliberately held closed during each test. The tests were terminated at 10min. The pressure relief vent was opened and a fan connected through an exhaust duct was activated to ventilate the room.

RESULTS

Since the access door was opened to allow fresh air entering the room during the pre-bum period, oxygen reduction was minimized. The upper portion of the room was not

ventilated, however, and a shallow hot layer did develop at ceiling level before the agent discharge.

Extinguishment

In the first series of tests, the Halon-1301 piping system effectively delivered both agents into the room within 10s. HCFC Blend A, at the design concentrations of less than 10%, had difficulty in suppressing some fires in each test. The SPs at floor level in the comers were not extinguished at all and only the elevated SP was extinguished in several cases.

In the second series of tests, HCFC Blend A was tested at the design concentration of 12% using the optimal piping system. Scenario-1 fires were successfully extinguished on the completion of the discharge in the first trial. More challenging and realistic fires were pursued in the subsequent tests. Test results showed that, at the design concentration of 12%, HCFC Blend A gave effective total-flooding fire-extinguishing performance for the test scenarios in this compartment. Most test fires were extinguished before the completion of the agent discharge. The fires inside the three mock-up cabinets and the wood-crib fire, however, took more time (11 to 30 s) to be extinguished.

HFC-227ea was tested at the design concentrations of 7.6% using the Halon-1301 piping system and at 7.6% and 8.8% using the optimal system. In both series of tests, HFC-227ea extinguished all the test fires, most of them within the discharge time. Fire extinguishment of the three mock-up cabinets and the wood crib took more time (15 to 30 s).

Acid-Gas Production

Because the FTIR Gas-Sampling Port 1 was placed right beside the fire in the SW comer, the measurement gave the maximum acid-gas concentrations at that fire location. For the tests at 12% concentration, HCFC Blend A produced the temporal-peak concentrations of 1,200 to 14,000 ppm hydrogen fluoride (HF) and 1,900 to 6,000 ppm hydrogen chloride

(HCl) at the fire location. The temporal-peak HF produced by HFC-227ea was in the range of 1,200 to 20,000 ppm at the fire location. The acid-gas concentrations were lower at the locations away from the fires or at a later time.

The quantities of the acid gases generated during the fire suppression were dependent upon agent concentration, agent discharge time, fire type and size as well as extinguishment time. The optimal HFC-227ea piping system appeared to give lower acid-gas production during suppression than the Halon-1301 piping system.

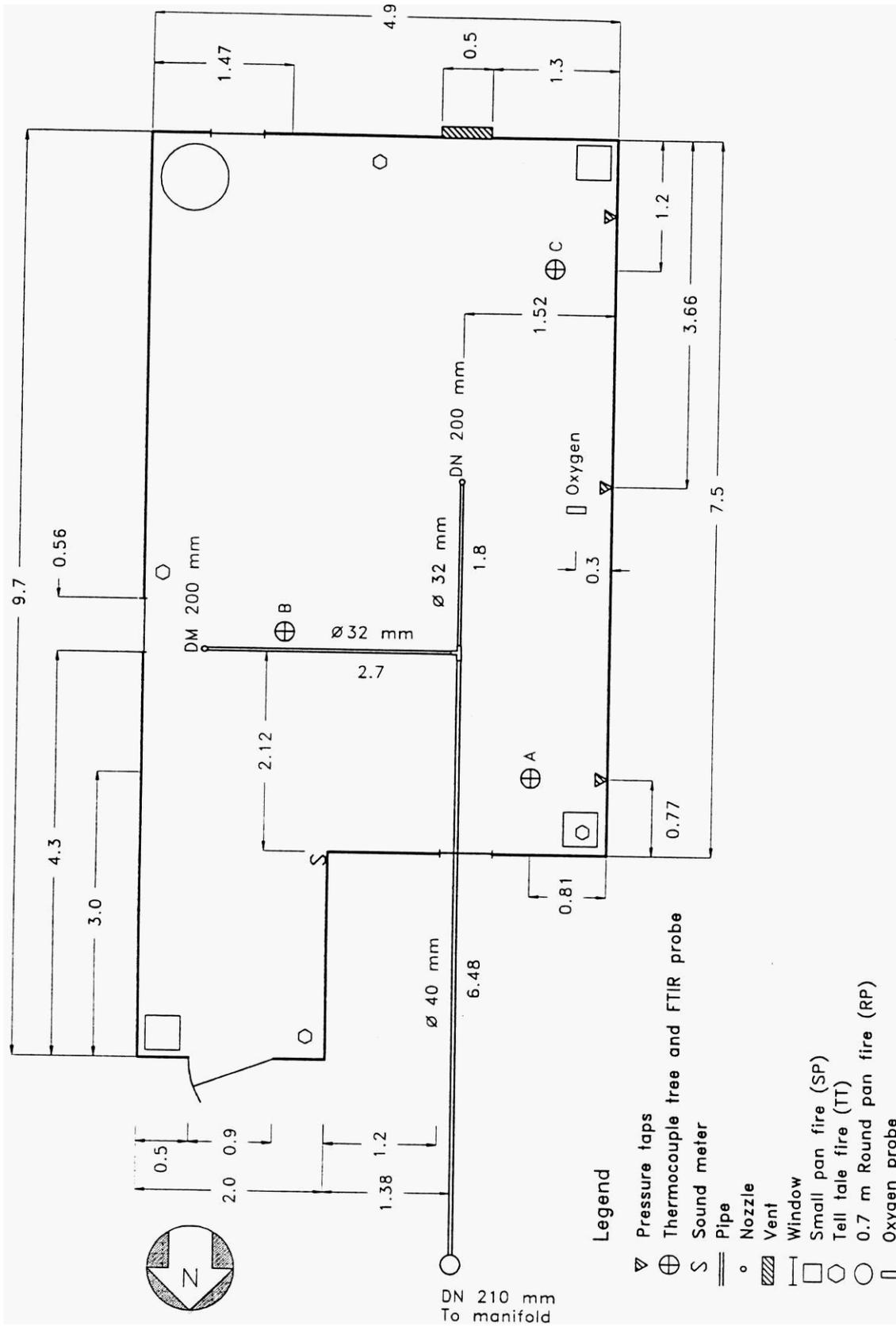
CONCLUSIONS

Both HCFC Blend A, at the design concentration of 12%, and HFC-227ea, at the design concentration of 7.6%, gave effective total-flooding fire-extinguishing performance for the test scenarios in the test compartment. The quantities of the acid gases generated during fire suppression can be related to agent concentration, agent discharge time, fire type and size as well as extinguishment time.

Both agents could be delivered through the Halon piping system (designed for 7.5% Halon-1301 concentration) installed on the Halifax Class frigates. The agents achieved the effective fire-suppression concentrations in the test compartment. It was necessary to change cylinders (for HFC-227ea) and nozzles (for both).

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(All dimensions in metres)
Unless otherwise indicated

Figure 1 Room dimensions and piping arrangement (Halon piping)

DND #A4223

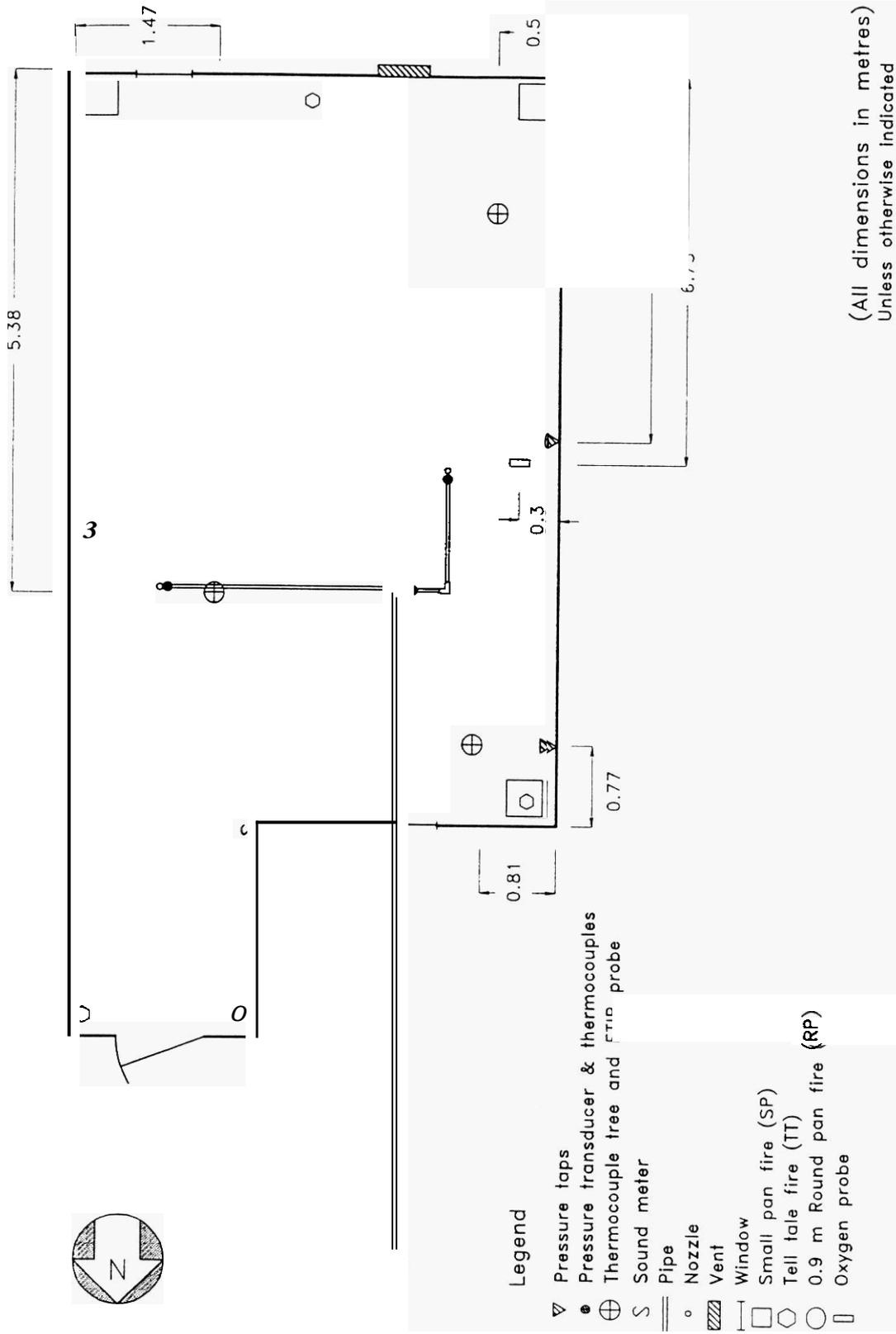


Figure 2. Plan view of instrumentations and fire locations for HFC-227ea NND #A4273

