FIRE SUPPRESSION TESTING OF HFC-125, CF_3I, AND IG-541 FOR FIRE PROTECTION IN ENGINE COMPARTMENTS OF ARMOURED VEHICLES

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1.0 INTRODUCTION

The National Research Council of Canada (NRC) has undertaken an experimental study for the Department of National Defence (DND) to evaluate HFC-125, CF_3I, and IG-541 for potential fire protection applications in the engine compartments of land vehicles. This evaluation was conducted for Leopard tanks and Cougar armoured vehicles.

2.0 FIRE TEST AND FACILITY

A series of real-scale fire suppression tests were conducted in two test compartments that simulated the engine compartments of Leopard and Cougar, respectively. HFC-125 and IG-541 were tested in both compartments. CF_3I was tested only in the Leopard test compartment.

Mock-Up Leopard Engine Compartment

The Leopard test compartment was a rectangular enclosure with dimensions of 2.62 m in length, 2.01 m in width, and 1.22 m in height. Two simulated fuel tanks and one simulated engine mock-up were inside the Compartment. The engine mock-up occupied most of the space. The net free space inside the mock-up compartment was 2.47 m^3. (When the engine mock-up was removed from the compartment, the empty compartment was 4.9 m^3 in volume.) The test compartment had a lid with *two* 0.84 m x 0.18 m vent openings. The hood vent openings were covered by perforated sheet metal. To simulate forced ventilation for engine cooling in the compartment, a fan was used to blow fresh air into the compartment at a flow rate of 0.1 m^3/s (220 cfm).

A piping system simulating the existing fire extinguisher system in the Leopard tank was used in the tests. (A high-pressure manifold was used in the IG-541 tests. This manifold was able to reduce its downstream pressure to an allowable working pressure for the existing piping.) The system had pipes with uniform outside diameter of 19.0 mm (inside diameter of 12.7 mm) and five discharge outlets (or orifices). The agent quantity used in each Leopard test was 2.1 - 2.2 kg for HC-125, 1.4 - 1.8 kg for CF_3I, and 3 kg for IG-541. Figures 1 and 2 show the test compartment and the piping system that simulated those in the Leopard tank.

Mock-Up Cougar Engine Compartment

The Cougar test compartment was an irregularly shaped enclosure with dimensions of 2.9 m in length, 1.3 m in width, and 1.4 m in depth. With an engine mock-up installed in the test compartment, the net free space was 2.1 m^3. (When the engine mock-up was removed from the

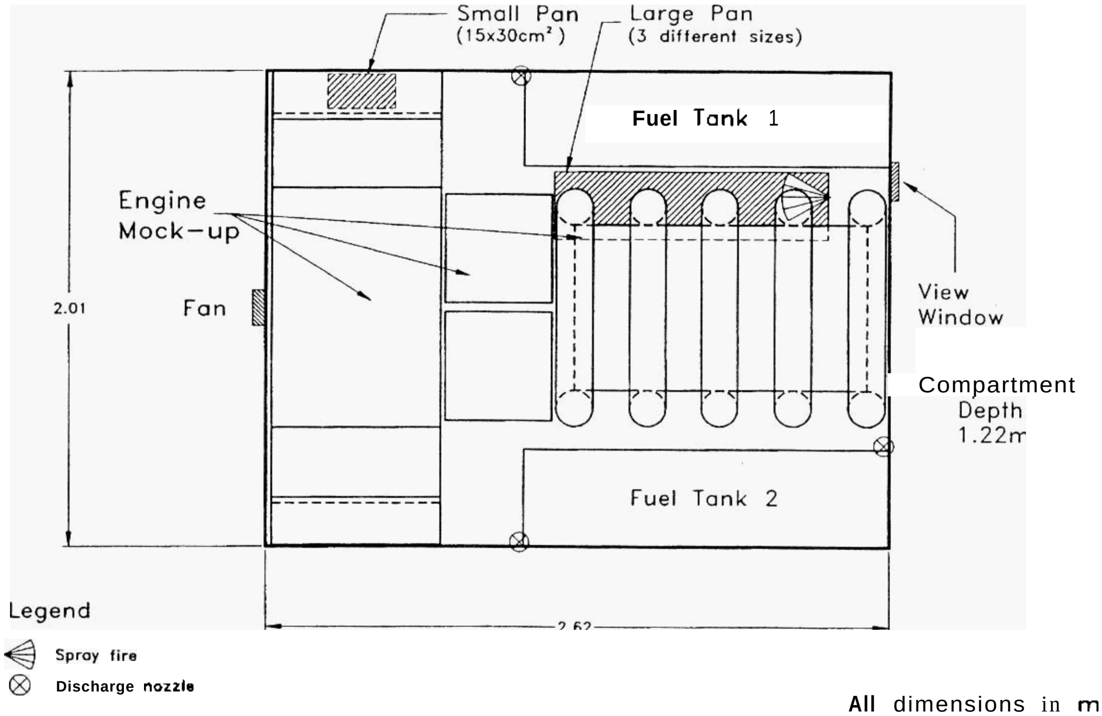

Figure 1 **Mockup** Leopard engine compartment

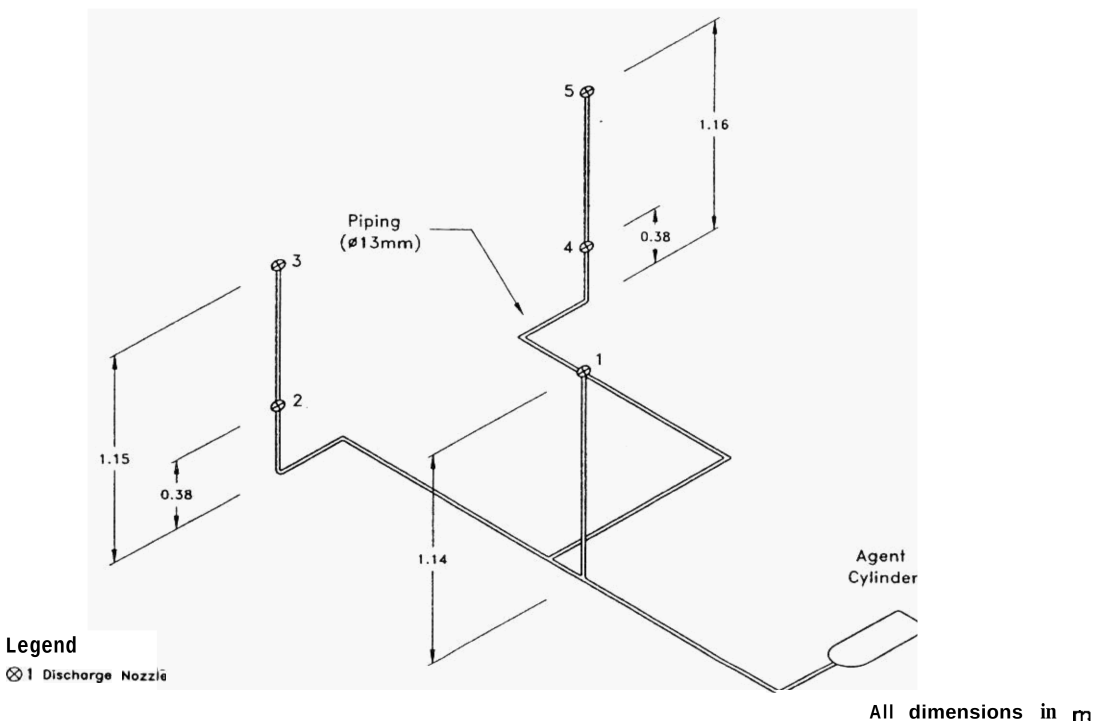

Figure 2 Simulated piping system for Leopard tank

compartment, the empty compartment was 2.9 m^3 in volume.) The test compartment was covered by perforated sheet metal.

To simulate forced ventilation in the engine compartment, a fan was used to bring fresh air through the perforated hood into the compartment at a flow rate of 0.19 m^3/s (405 cfm).

Figure 3 shows the Cougar test compartment and the piping layout. For the HFC-125 tests, the discharge pipe had an outside diameter of 9.5 mm (inside diameter of **6** mm). Each **of** the three discharge nozzles had a discharge orifice of 1.7 mm in diameter. For the IG-541 tests, the same piping layout and nozzle locations were kept while three special nozzles (2.53 - 2.64 mm diameter orifice; eight side holes) and a high-pressure manifold were used. In some IG-541 tests, the inside diameter of the pipe started with 12.7 mm and reduced to 9.5 mm and then 6.35 mm. The agent quantities used in the Cougar tests were 1.5 - 2.9 kg of HC-125 and 1.5 - 3 kg of IG-541.

Fire Scenarios

Potential fire scenarios in the engine compartment of an armoured vehicle include fuel leaking from cracked fuel tanks, from broken fuel lines or from hydraulic fluid lines, which becomes ignited by hot metal surfaces in the exhaust, brake or transmission assemblies. To simulate potential fires, pool fires and a spray fire were used in the tests. Heptane was used as the fuel for these tests.

Pool fires. Rectangular pans of four different sizes (15 x 30 cm, 30 x 30 cm, 30 x **60** cm, and 30 x 120 cm) were used to create pool fires. The heat release rates from these pan fires were approximately 25, 50, 100, and 200 kW, respectively. One pan was used for each test. The locations of the pool fires were chosen to represent the most challenging position for fire extinguishment.

Spray fire. Heptane fuel was sprayed at a rate of 0.35 l/min though a nozzle. The heat release rate of the spray fire was 190 kW. In the mock-up Leopard engine compartment, the fuel spray nozzle was placed between fuel tank 1 and the engine block with a downward angle of 45 deg. In the mock-up Cougar engine compartment, the fuel spray nozzle was placed on the top of the engine mock-up with a downward angle of 20 deg.

Re-ignition attempts. Attempts were made to re-ignite the pan fire using an electric ignitor after the initial fire extinguishment. The ignitor temperature reached a maximum of 750 °C.

Instrumentation

Test data from a wide array of instrumentation (pressure transducers/taps, thermocouples, gas analyzers and an FTIR spectrometer) were collected by a data acquisition system. Instruments were used to monitor the temperatures and pressures in the compartments and the piping systems, to determine the agent discharge time and fire extinguishment time, and to measure the fire gas composition.

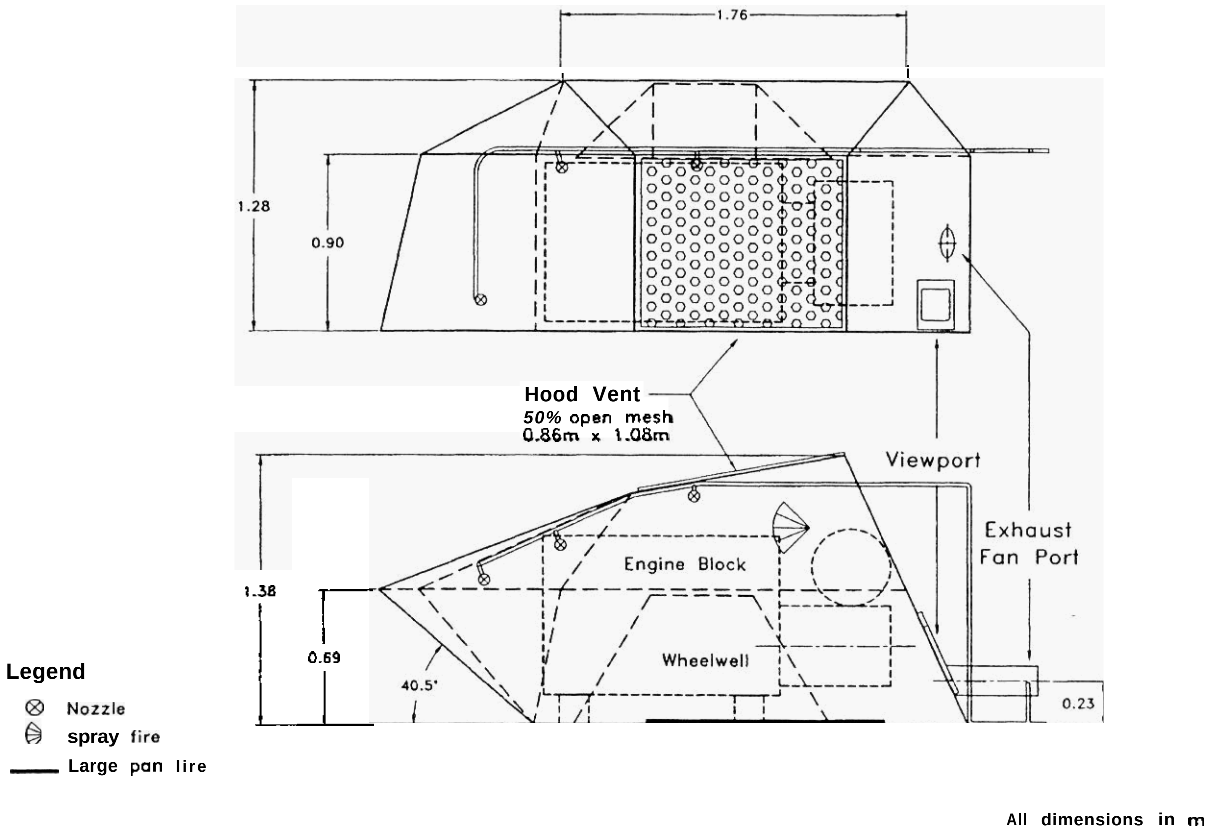

Figure 3 Mockup Cougar engine compartment and piping layout

3.0 RESULTS AND DISCUSSIONS

The results of the real-scale fire tests showed that fire suppression performance of HFC-125, CF_3I, and IG-541 depended on many factors. Agent type, fire scenario, ventilation condition, and discharge performance all played a role in the fire suppression performance of the agent.

For all three agents, **a** large fire, such as the combined pool and spray fire, was very challenging to extinguish. For IG-541, **a** small fire was more challenging to extinguish than **a** large fire in some cases.

Fire extinguishment and re-ignition prevention were more difficult under forced ventilation conditions. Shutting down the forced ventilation in the early stage of the discharge helped to extinguish the fire and prevent re-ignition.

Agent discharge time is crucial for fire extinguishment. It determines whether or not, and in how much time, the fire can be extinguished. When the fires were extinguished, the extinguishment always happened before the completion of agent discharge. A fast and dynamic discharge can reduce the effect of the buoyancy force and forced ventilation and can improve the fire suppression effectiveness of the agent. No pressure build up was noted in the compartments during the discharge.

The agent concentration achieved in the test compartment is a function of agent quantity, discharge time, and ventilation (rate and duration). For a given quantity, the agent reaches a higher peak concentration and stays longer inside the compartment under a natural ventilation condition. **A** fast agent discharge can overcome forced ventilation and provide a higher agent concentration in the compartment, compared to a slow discharge for the same quantity of agent.

In the real-scale tests, 2.2 kg of HFC-125, 1.4 kg of CF_3I, and **3** kg of IG-541 were able to suppress all test fires as long **as** agent discharge was fast. Test results showed a distinctive ability of CF_3I to prevent re-ignition. CF_3I was able to prevent the fuel from re-ignition even at a very low concentration (less than 1%).

HF was produced in the HFC-125 and CF_3I tests. The concentration of HF produced in the HFC-125 tests was in the range of 100 - 5000 ppm. The HF concentration measured in the CF_3I tests was less than 100 ppm. In the Leopard tank, the engine compartment is completely separated from the crew compartment and the risk of fire gas exposure to the crew is low. In the Cougar, however, the potential of fire gases leaking from the engine compartment to the crew compartment exists.

4.0 CONCLUSIONS

The minimum quantities of agents required to provide adequate protection for the engine compartments are the functions of agent type, agent discharge time, and compartment ventilation rate, With fast discharge, 2.2 kg of HFC-125, 1.4kg of CF_3I, and **3** kg of IG-541 suppressed all test fires under the test conditions. If the ventilation rate is higher, the quantity of the agent required may be larger.

The tests have shown that shutting down the forced ventilation in the early stage of the discharge can help to suppress the fire and prevent re-ignition. In real fire situations, it is recommended, when possible, to shut down the ventilation as soon as fire is detected.

The tests have indicated that, with minor changes in the system, IG-541 can provide effective fire protection for the Leopard tank and the Cougar vehicle. Designing inert gas systems for combat vehicles requires careful considerations to the severe conditions and special fire protection requirements since the space constraint does not allow having backup cylinders.

HFC-125 and CF_3I can be used for fire protection in the engine compartment of the Leopard tank. Caution must be taken when deciding whether to use HFC-125 and CF_3I for fire protection **in** the engine compartment of the Cougar vehicles because fire gases might leak from the engine compartment to the crew compartment.

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