

# INERGEN FIRE SUPPRESSION TESTING

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## INTRODUCTION

Most commercial halon replacements (i.e., halocarbon agents) contribute to global warming and may be subject to regulation in future developments of the Kyoto Protocol. The use of environmentally safe ingredients for fire suppression is a preferred option in applications where total flooding of an area is required. The National Research Council of Canada (NRC) conducted a series of full-scale tests to evaluate the performance of Inergen (52% N<sub>2</sub> + 40% Ar + 8% CO<sub>2</sub> by volume) for fire suppression applications. Test results are provided in this paper.

## FIRE SUPPRESSION TESTS

### Test Compartment

Full-scale suppression tests were conducted in a 121 m<sup>3</sup> compartment, which simulated Radar Room No. 2 on the Canadian Navy Halifax Class frigates, as shown in Figure 1. The test compartment was relatively airtight. Fan pressurization tests indicated that the compartment had an equivalent leakage area of 0.014 m<sup>2</sup>.

Inergen was tested at a design concentration of 40%. Since a rapid injection of a large quantity of the agent into the compartment could cause sudden over-pressurization, a pressure relief vent (0.5 by 0.5 m) was used to prevent damage to the enclosure during the discharge of the agent. During the initial 10 sec of the discharge, the louvres of the pressure relief vent were kept open.

Three thermocouple (TC) trees were placed in the compartment to monitor the compartment temperature during the tests. Each TC tree was 2.8 m high and contained six thermocouples. Nine pressure taps were installed on the west wall at three elevations (0.29, 1.47, and 2.67 m) and were connected to pressure gauges to monitor the compartment pressure during the tests.

CO<sub>2</sub>/CO and O<sub>2</sub> analyzers were used to measure the concentrations of CO, CO<sub>2</sub>, and O<sub>2</sub> in the test compartment during the fire tests. The analyzers were connected to two sampling ports mounted on the west wall. The discharge sound level in the compartment was measured using a broadband sound meter.

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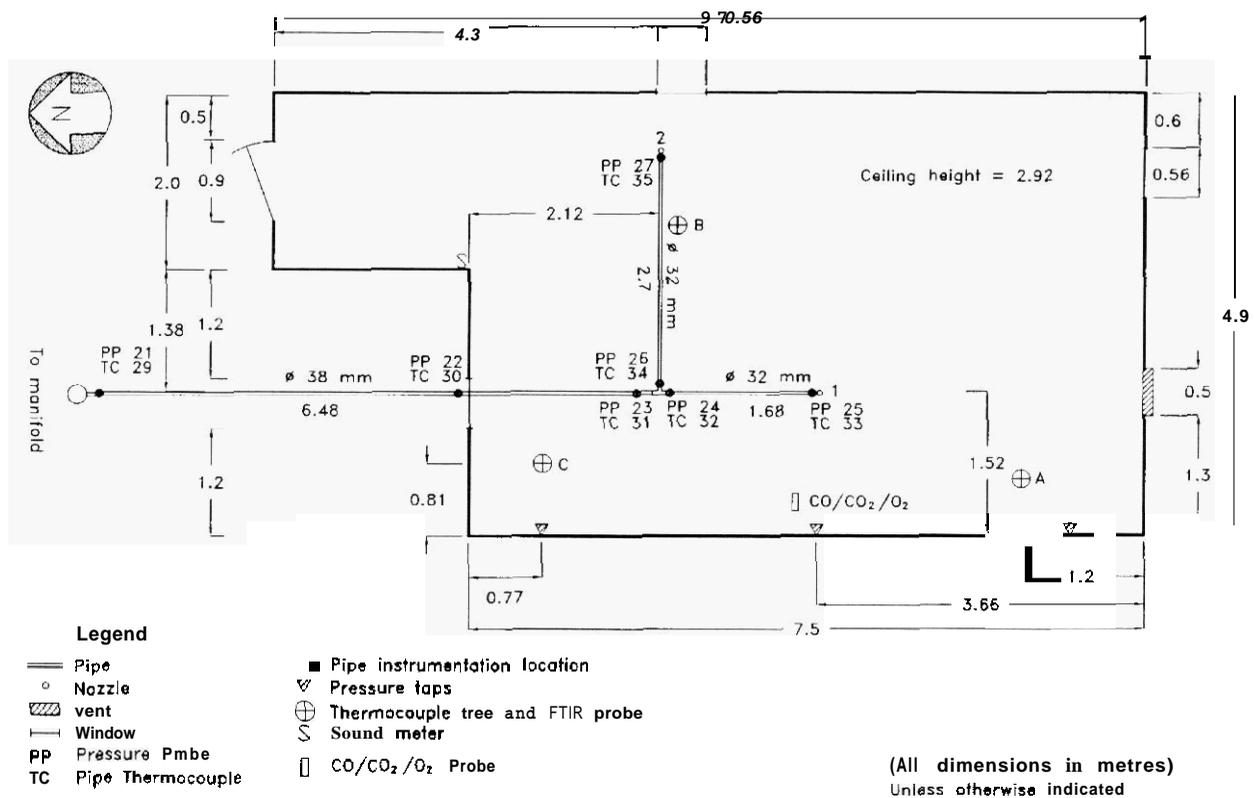


Figure 1. Plan view of test compartment, piping system, and instrumentation.

## Piping System

The Navy frigate room had a two-nozzle Halon 1301 piping system. The existing Schedule 80 distribution pipes of the Halon 1301 system were kept and used in the Inergen tests. Figure 1 shows the pipe arrangement.

Discharge nozzles, agent cylinders, and a manifold connecting cylinders to the distribution pipes were provided by the Inergen manufacturer. The nozzles were cylindrical with 3 rows of 8 holes around the nozzle axis. The discharge orifices were 15.5 mm in diameter for the south nozzle and 14.7 mm in diameter for the east nozzle. Five cylinders (0.28 m in diameter and 1.57 m in height) were used in each test. Inergen was pressurized in the cylinders at a pressure of 150 bar. The discharge valve for the cylinders was activated manually. Pressure transducers and thermocouples were installed along the pipe to monitor the agent flow inside the pipe during discharge.

## Fire Scenarios

Figure 2 shows four fire scenarios created using simulated electronic-cabinet fires, wood-crib fires, heptane pool fires, and heptane spray fires.

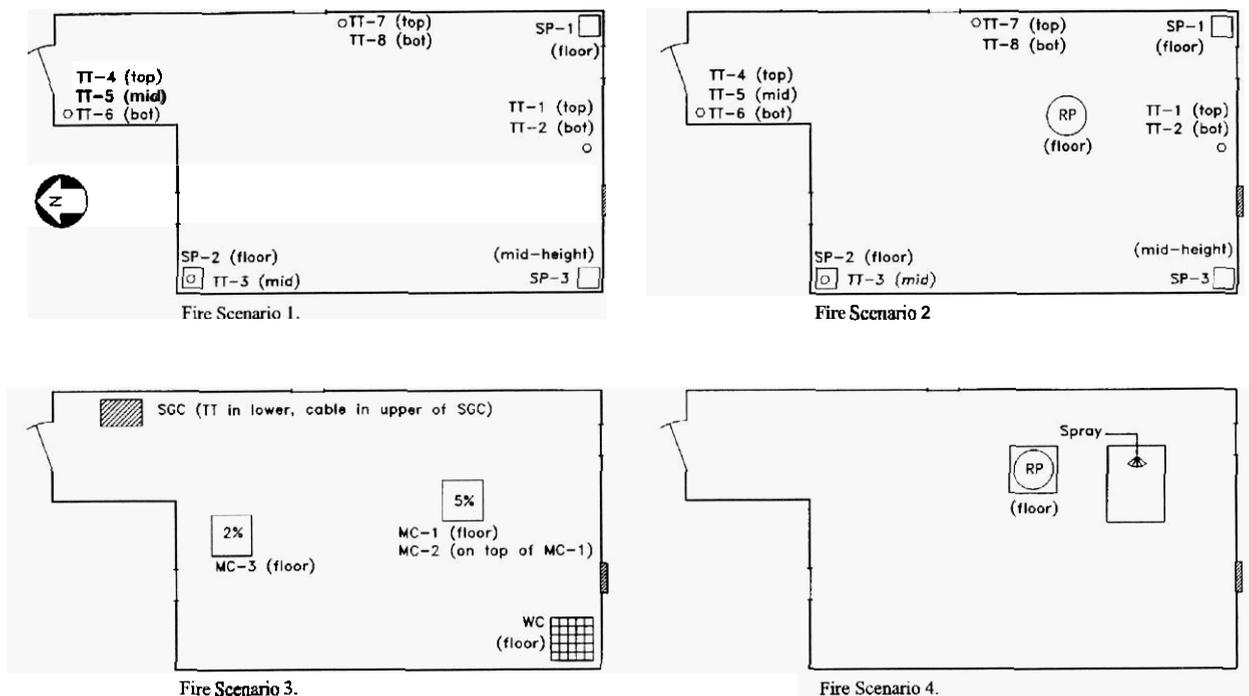


Figure 2. Four fire scenarios.

Fire Scenario 1 included telltale (TT) fires and square-pan (SP) fires. Each TT used a 75 mm diameter can containing 20 mL of heptane fuel. Each SP (0.3 x 0.3 m) contained 425 mL of heptane fuel. Two SPs were placed on the floor in the southeast and northwest corners. Another SP was placed midway **up** the wall in the southwest corner. (Each SP was placed 50 mm away from the walls.) Ignition of the test fires took place 30 sec before discharge. The TT and SP fires were ignited sequentially using torches. The total heat release rate was estimated to be 200 kW.

Fire Scenario 2 included TT fires, SP fires and a large round-pan (RP) fire. The RP (0.7 m in diameter) contained 2 L of heptane fuel and was placed on the floor. The TTs and SPs were placed at the same locations as in Scenario 1. Ignition of the test fires occurred 30 sec before discharge. The fires were ignited sequentially using torches: first the TT fires were ignited, then the SP fires and, finally, the RP fire. The total heat release rate was estimated to be 600 kW.

Fire Scenario 3 included simulated electronic-cabinet fires and Class A wood-crib (WC) fires. An electronic switching gear cabinet (SGC, 0.75 by 0.61 by 2.1 m) was placed against the east wall near the door. This metal cabinet had ventilation grills on the sides. A telltale can was placed at the bottom of the metal cabinet. A 0.4 m long cable bundle in a PVC slotted cable ladder was mounted vertically in the upper portion of the metal cabinet. Three other mock-up cabinets (MC, 0.81 by 0.81 by 1.0 m) were made of polycarbonate plastic sheets, each with two small grill openings. MC-1 and MC-2 had an opening ratio of 5% (ratio of the opening area over the total surface area of the cabinet) and were placed one on top of the other. MC-3, with an opening ratio of 2%, was placed on the floor. Each mock-up cabinet had a telltale can inside. The wood crib (0.6 by 0.6 by 0.24 m) was made of pine sticks (40 by 40 by 600 mm) arranged in 6 layers, and was placed in the southwest corner on the floor. The wood crib was ignited 120 sec

before discharge in order to have a fully developed fire. Ignition of the in-cabinet fires took place 30 sec before discharge. The total heat release rate was estimated to be 400 kW.

Fire Scenario 4 included an RP fire and a spray fire. Both fires were shielded. The circular RP was covered with a box made of perforated sheet steel. The meshed metal sheet had an opening ratio of 33% for the sides of the box and an opening ratio of 6% for the top of the box. The heptane fuel was sprayed from a fuel nozzle at an operating pressure of 5.8 bar. A metal table (1 m wide by 1.36 m long by 0.61 m high) was used to cover the fuel nozzles and shield the spray fire. Ignition took place 20 sec before discharge. The RP fire was ignited first, and then the spray fire was ignited. The total heat release rate was estimated to be 1 MW.

Thermocouples were placed at each fire location to monitor fire extinguishment times. To minimize oxygen consumption by the fires, the compartment door was kept open during the preburn. The door was closed when discharge began. After extinguishment had been achieved, reignition of the fuel pans and/or spray was attempted using electrical heating ignitors.

## RESULTS AND DISCUSSION

Figure 3 shows the discharge characteristics during the discharge test. The peak pipe pressure was 52 bar. The pipe temperature dropped by 30 to 40 °C, depending on position, as a result of agent expansion. The maximum sound level measured inside the compartment was 128 dB. (In previous halocarbon tests, conducted by NRC in the same compartment, the maximum sound level was 122 dB). When the agent was discharged into the compartment, the compartment temperature generally decreased and the compartment pressure had a positive pulse.

The magnitude of the temperature and pressure changes in the compartment depended on the agent quantity and compartment conditions. In the fire tests, the cooling effect of the agent decreased and the positive pressure pulse in the compartment increased when the fire size increased. The largest pressure pulse in the compartment during the fire tests was 540 Pa, which is bearable for most building structures.

Based on the measured oxygen concentration during the discharge test, the Inergen concentration in the compartment achieved the designed 40% value. This is 1.4 times the cup-burner value (29%) for the heptane fuel [1,2]. The discharge time to release 90% of the agent from the cylinders was 45 sec, which was determined using the time profiles of pipe pressure and temperature, and compartment sound level. During the discharge, visibility in the compartment remained adequate for evacuation purposes.

All the fires were extinguished well before discharge was completed. Table 1 shows fire extinguishment times. The unshielded telltale fires were extinguished within 5-25 sec of the start of the agent discharge; the in-cabinet fires were extinguished within 15-30 sec. The extinguishment of the SP-3 fire in Fire Scenario 1 took 46 sec, the longest extinguishment time among all tests. The larger fires were extinguished more quickly than the SP-3 fire as larger fires consume more oxygen, which accelerates fire extinguishment. The large round-pan fire was extinguished in 35 sec in the test with no shielding and 40 sec in the test with shielding. The shielded spray fire was extinguished in 23 sec, and the wood crib fire was extinguished in 27 sec. CO<sub>2</sub> and CO are the major products generated during fire tests. Table 1 shows stabilized concentrations of CO<sub>2</sub>

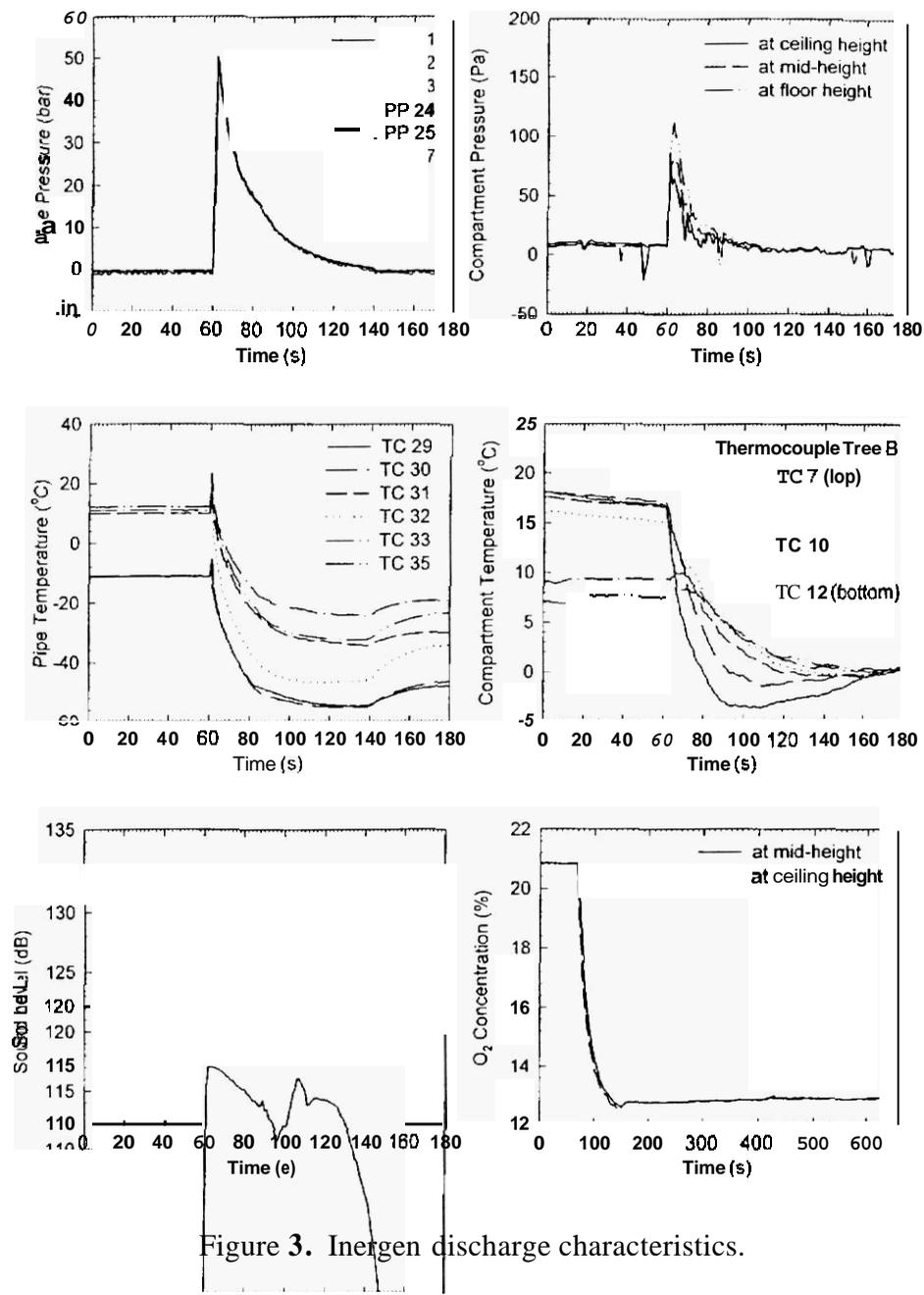


Figure 3. Inergen discharge characteristics.

and CO after discharge and extinguishment. Combustion accounts for less than 2% CO<sub>2</sub> concentration in the fire tests, since 3.1% CO<sub>2</sub> concentration comes from the agent itself.

Inergen extinguishes fires by reducing the oxygen concentration in an enclosure to a level that no longer supports combustion. That O<sub>2</sub> level, however, must be able to support life in the normally occupied spaces. When there was no fire or when the fire size was small, oxygen concentration in the test compartment after the discharge of the agent was above 12%. However, when a large fire was used, the oxygen concentration in the compartment fell to below 10% in some tests. Low oxygen concentrations can cause asphyxiation for people trapped in a confined space during a fire. The implication is that a fire must be extinguished before it becomes large.

TABLE I. RESULTS OF FIRE SUPPRESSION TESTS"

		Discharge	Telltale only	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Fire</b>	8 TT		5 to 25	5 to 15	5 to 10		
	3 SP			15 to 46	10 to 37		
<b>Extinguishment Time (s)</b>	RP				35		40
	WC					27	
	Cabinets					15 to 30	
	Spray						23
<b>Concentration</b>	O <sub>2</sub> (%)	12.6	12.3	11.0	10.2	9.7	9.5
<b>after Discharge/</b>	CO <sub>2</sub> (%)	3.1	3.6	4.1	4.5	5.0	4.9
<b>Extinguishment</b>	CO (ppm)	4	10	50	90	230	160

\*45 sec needed to release 90% of the agent from the cylinders

Note: Shaded areas indicate that the fires were not used.

After initial fire extinguishment, several reignition attempts were made and it was determined that, in the absence of ventilation, the agent was effective in preventing reignition. The measured O<sub>2</sub> concentration, as shown in Figure 3, indicates that the Inergen concentration was maintained and uniformly distributed in the compartment for an extended period of time.

## CONCLUSIONS

Using a pressure relief vent, the positive pressure pulse generated in the test compartment during the discharge was in the range of 100 to 540 Pa, depending on fire size. These pressures are bearable for most building structures. The agent concentration in the test compartment was maintained uniformly for an extended period of time in the absence of ventilation.

Inergen extinguished the test fires by reducing the oxygen concentration in the compartment. The total volume of the cylinders used in the Inergen tests is 3 times larger than that used in previous NRC halocarbon tests. All the test fires were extinguished well before discharge was completed. In general, extinguishment times were shorter for the unshielded fires than for the shielded fires. With the inert gas agent, small fires were challenging to extinguish while large fires were easier to extinguish. When the fire size became large, however, in some tests, the oxygen concentration in the compartment fell to below 10%, which can cause asphyxiation for individuals trapped in the confined space during a fire. Therefore, an early fire detection system must be an integral part of the inert gas fire suppression system in order to extinguish a fire before it becomes large. Otherwise, sufficient time should be allowed for evacuation. It is worth noting that, during the discharge, visibility in the compartment remained adequate for evacuation purposes.

## ACKNOWLEDGMENTS

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