STATUS OF HALON REPLACEMENT AGENT EVALUATION IN COMMERCIAL AIRCRAFT AND AIRPORT APPLICATION

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ABSTRACT

Halon 1301 and Halon 1211 are used extensively in commercial aircraft fire extinguishment systems and airport firefighting equipment. The Federal Aviation Administration is currently testing and evaluating replacement/alternate extinguishing agents as part of a program to develop certification criteria for new agent approvals. Aircraft applications for halons include cargo compartments, engine nacelles, hand-held extinguishers and lavatories. Cargo compartment fires pose the most challenging threat - a deep-seated in-flight fire that must be suppressed for a long period of time, until the aircraft can be safely landed. The effectiveness of alternative concepts, including water spray and dry powder have been evaluated. In the airport fire fighting area, the effectiveness of a perfluorocarbon and an HCFC have been compared to Halon 1211 under a series of spilled jet fuel fire scenarios.

INTRODUCTION

Halon fire extinguishing agents, specifically Halon 1301 (CF_3Br) and Halon 1211 (CF_2BrCl), are used extensively in commercial aircraft and by airport firefighters. The selection of halons for aviation applications is based on a number of considerations, most notably extinguishment effectiveness per unit weight, effectiveness over a wide range of operational conditions, low toxicity, low corrosivity and virtually no cleanup. In commercial aircraft, Halon 1301 is used in total flooding systems in cargo compartments, powerplants and lavatory trash receptacles. Halon 1211 is required in portable extinguishers for use against passenger cabin fires. U.S. commercial fleet estimates for the installed quantities of Halon 1301 and Halon 1211 are 109 tons and 25 tons, respectively[1]. At airports Halon 1211 is an approved extinguishing agent for flight line extinguishers and crash fire rescue vehicles. A primary consideration in flight line extinguishers is the "clean" property of Halon 1211, as opposed to the corrosivity of dry powders. Minimal collateral damage from agent discharge itself is very important because the main application is against small or apparent fires in aircraft engines. Halon 1211 is used in crash fire rescue vehicles as an alternative to dry chemical. However, during an aircraft crash fire accident the "clean" property of Halon 1211 is not relevant.

The future availability of halon for aviation is uncertain. On January 1, 1994 the production of halon ceased in developed countries, including the United States, as specified by an international agreement called the Montreal Protocol, which was most recently amended in Copenhagen in 1992. The production of halon was banned because it is a chemical that depletes the stratospheric ozone layer. The policy of the Federal Aviation Administration (FAA) is to substantially reduce the discharge of halon in non-fire situations. FAA also believes it is necessary to continue using halon to maintain the current level of aircraft fire protection and airport firefighting capability. Recognizing the uncertain future availability of halon, FAA has programs underway to evaluate replacement and alternate agents/systems for aircraft and airport applications. For those agents/systems determined to be equivalent to halon in terms of extinguishment effectiveness and whose use is safe, environmentally acceptable and practical, the basis for FAA approval will also be developed.

PROGRAM

Aircraft Fire Safety. The FAA Aircraft Halon Replacement program is described in Public Notice 93-1[2] The main purpose of the program is to develop the certification basis for FAA approval of non-halon agents/systems in aircraft. It was stimulated by the "International Symposium on Halon Replacement in Aviation", held in Reston, Virginia on February 9-10, 1993, where it was concluded that FAA R&D was required to develop certification criteria for halon replacement fire suppression systems. Figure 1 shows the FAA program structure and the relationship of its elements. The key elements are the development of test articles and the establishment of an International Halon Replacement Working Group. Test articles are important because full-scale fire test results are mandatory for the development of certification criteria. The working group provides for industry participation in the program which is also very essential.

Airport Firefighting. The FAA Airport Halon Replacement Program consists of the evaluation of Halon 1211 replacement agents for airport firefighting under various fire scenarios. Two "clean" replacement agents were evaluated and compared with the performance of Halon 1211: perfluorohexane (3M) and Halotron I (American Pacific). The fire test scenarios employed to evaluate extinguishing agent effectiveness simulated moderate fires involving jet fuel spillage and/or aircraft components.

FIRE SCENARIOS AND TEST PARAMETERS

Aircraft Fire Safety. Halon 1301 total flooding systems protect aircraft cargo compartments, engine nacelles and lavatory trash receptacles. Of the three total flooding applications, the cargo compartment represents the most challenging fire problem and requires the largest quantity of agent. For example, the cargo compartments in a new Boeing 777 are protected by 294 pounds of Halon 1301[3]. A cargo compartment fire protection system must suppress and contain a deep-seated, inaccessible fire, involving a wide variety of cargo and baggage materials, until the airplane can be safely landed, which in some cases may be as long as 90 minutes. Depending on the discharge and extinguishing characteristics of the replacement agent, various test parameters must be employed to determine agent effectiveness across the full range of potential cargo fire conditions. Important test parameters include bulk versus containerized cargo, loading factor (cargo volume relative to compartment volume), location of ignition source and, of course, composition of cargo/baggage (including hazardous materials such as aerosol cans). For example, a containerized cargo fire in a highly loaded compartment represents a worst case fire scenario for a water spray system because of the presence of discharge obstructions and minimal opportunity for soaking of cargo materials. Cargo compartment Halon 1301 systems are designed to achieve a discharge concentration of 5% to extinguish open flaming, and maintain a concentrateion of no less than 3%, to prevent recurrence of open flames stemming from a deep-seated fire.

An engine nacelle fire extinguishing system is designed to discharge agent at a high mass flow rate in order to achieve extinguishing concentrations throughout the nacelle volume, which is purged by high speed air flow. Moreover, the required high discharge rate must be sustained over a wide range of operational temperatures, ranging from over 100°F to -65°F. The following are important test parameters: nacelle volume, air velocity, engine casing temperature, fuel source, presence of clutter shown in cross section in figure 2. In-flight ventilation conditions provide typical airflow rates and patterns. Ventilation air enters the cabin at the ceiling, exits the cabin through the baseboard air return grilles into the cheek area, flows around the cargo compartment and exhausts the aircraft through the outflow valve. The cabin ventilation rate is a typical 4 1/2 minutes per air change. It is important to create the proper air flow conditions surrounding the cargo compartment since the fire suppression system must prevent the passage of hazardous quantities of smoke and toxic gases into the occupied cabin. To this end, the cabin is instrumented with smoke meters (light transmissometers) and gas probes, including CO, CO_2, O_2, virgin agent, and agent decomposition products. The cargo compartment also contains smoke/gas instruments and numerous thermocouples, as shown in figure 2. The volume of the cargo compartment is 2357 cubic feet. The cargo compartment leakage rate, determined by CO_2 decay rate measurements, is 85 cubic feet per minute.

Cargo compartment fire tests have been conducted with two types of pyrotechnically generated aerosols. PGA dry powders offer a number of attractive marketing features, including efficient extinguishment (50 grams/cubic meter (g/m^3)), design simplicity, compactness, and absence of pressurized containers. In one test, 5 PGA generators were discharged at 15 second intervals after a ceiling thermocouple reached 250°F (figure 3). The fire load was shredded paper in cardboard boxes, 2.5 pounds per cubic feet, at a 30% loading factor. The initial discharge produced a concentration of 70 g/m^3. An additional 2 pound generator was discharged every 7 minutes after the initial discharge for the test duration (90 minutes) to counter agent concentration decay. The "total" concentration of agent was about 200 g/m^3. Each generator discharge is evidenced by a temperature spike and oxygen dip. Discounting the peaks the stabilized temperature is about 200°F higher than in a similar test employing Halon 1301. Also, there was significant smoke driven into the cabin, completely obscuring video cameras. Based on the initial testing completed on both types of PGA it has been concluded that the generators require cooling, and a better system is needed for discharging to the initial concentration and sustaining an inerting concentration. Of course, the airlines would have to be tolerant of clean up and possible corrosion and toxicity issues.

In recent years, the FAA has evaluated and developed an on-board cabin water spray system for postcrash fire protection[9]. A possible means of improving the cost/effectiveness of this system is to offset the weight penalty by utilizing the stored water for cargo compartment fire suppression. Tests have been conducted with dual fluid nozzles (water/air). provided by GEC/Marconi Avionics, mounted at the ceiling. The fire load was a worst case condition consisting of shredded paper/cardboard boxes inside a polycarbonate cargo container. The fire eventually burns out of the container, but the container is intended to minimize the soaking effect of the water. Additional cargo was placed adjacent to the container housing the ignition source in order to obstruct the water discharge. Manual operation of the system was dictated by ceiling temperature and spray duration. For example, in one test, discharge was activated at 250°F and deactivated at 150°F. A series of eight tests were conducted, varying the activation temperature (200-300°F), deactivation temperature (150-290°) and/or spray duration (6-10 seconds).

Typical cargo water spray results are shown in figure 4. Temperatures were maintained in the safe 200-300°F range and the oxygen concentration profile indicates that the fire was predominantly controlled by water spray (versus oxygen starvation). In general, the dual fluid nozzle system was effective in controlling the cargo fire, but the quantity of water was excessive, ranging from 80 to 110 gallons and showed little sensitivity to the discharge parameters studied. The water droplet size was also varied, by changing the fluid pressures, but was also found to have a minimal effect on water requirements. Two different water spray concepts will soon be evaluated to determine their impact on water usage: water fog, because of its potential total flooding characteristics, and water recycling, because of the observed water layer on the cargo compartment floor in the initial water spray tests.

The following is a brief summary of the activity in the remaining aircraft halon application areas. FAA is supporting the engine nacelle halon replacement program at Wright Patterson Air Force Base; B-737 engine parameters will be included in the test matrix. Under the auspices of the International Halon Working Group, Walter Kidde Aerospace has developed a lavatory trash receptacle mockup for replacement agent evaluation. This mockup will form the basis for a standard test procedure under preparation by the working group. Finally, the Joint Airworthiness Authority will request that research activities be undertaken in Europe related to hand-held extinguishers; viz., the development of a standard hidden fire extinguishment test and the evaluation of replacement agent cabin toxicity issues.

Airport Firefighting. Perfluorohexane and Halotron I have been evaluated against Halon 1211 for the previously described airport fire test protocols. Initially, an Amerex Model 600 extinguisher was employed to disperse all three agents. Subsequent tests with Halotron I included a booster cylinder filled with expander gas (1200 psi or 2000 psi) added to the Amerex extinguisher in order to obtain a steady stream of agent throughout the discharge duration. A pulsating flow had been experienced with the standard Amerex extinguisher.

The initial test results are shown in Table 1, which is a summary of data contained in reference 8. It is clear that when using the standard Amerex extinguisher neither perfluorohexane or Halotron I consistently extinguished the test fires as rapidly as Halon 1211. Only during the inclined plane test condition (figure 5) was a replacement agent, in this case Halotron I, superior to Halon 1211. Moreover, neither perfluorohexane or Halotron I was able to extinguish the engine nacelle running fuel fire with 24 gallons of fuel on the pad, or even with a reduced quantity of 15 gallons of fuel. Neither agent faired well as a "drop-in" replacement using existing Halon 1211 dispensing equipment.

Comparing the replacement agents, Halotron I was almost twice as effective as perfluorohexane in the inclines plane test and 33% more effective in the wheel well test. Conversely, perfluorohexane extinguished the pool fire about 20% faster than Halotron I.

It is stressed that the results presented are an initial evaluation of airport replacement agents. Although not quantified here the discharge characteristics of Halotron I was improved by optimizing the Amerex extinguisher with an expander gas booster cylinder. At the preparation of this paper, additional test protocol evaluations of Halotron I were underway using a twin agent unit (TAU) fire extinguisher. It is believed that the larger capacity TAU extinguisher may provide the additional agent needed for total fire extinguishment since in many of the initial tests the fire was nearly extinguished when the supply of agent was exhausted.

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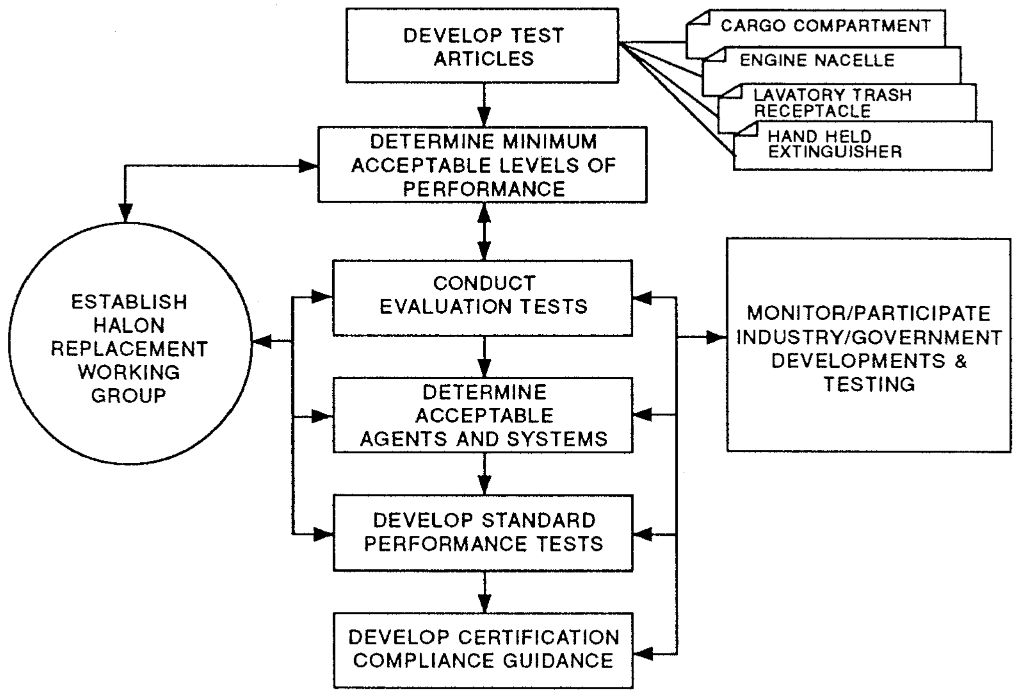

FIGURE 1. HALON REPLACEMENT PROGRAM FOR AIRCRAFT

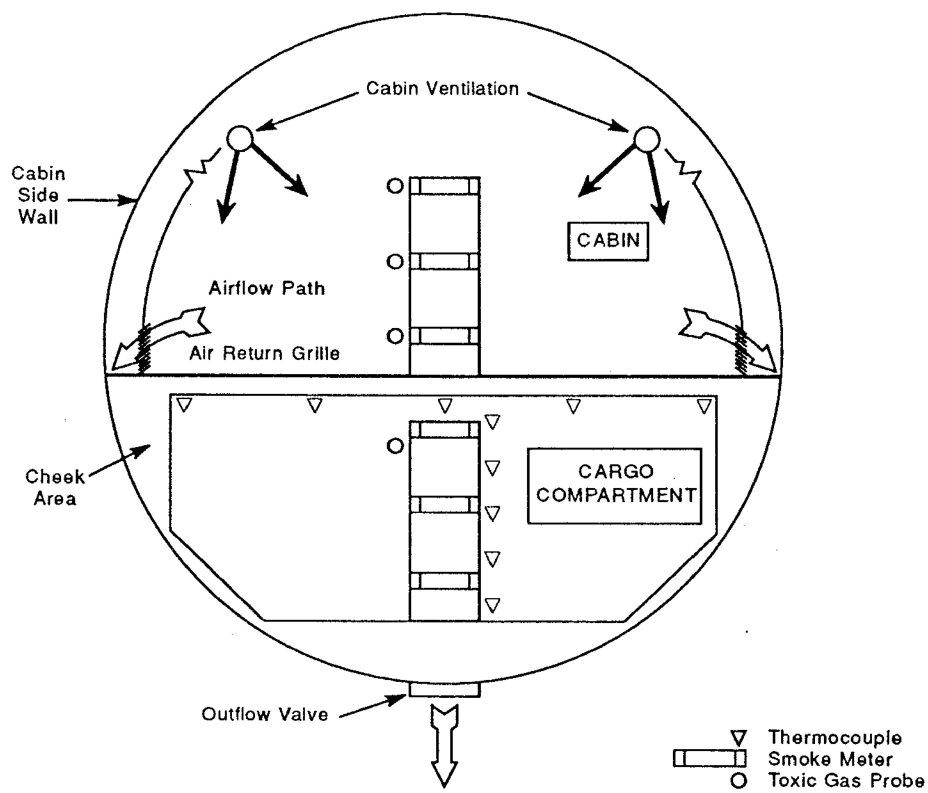

FIGURE 2. CARGO COMPARTMENT FIRE TEST SETUP

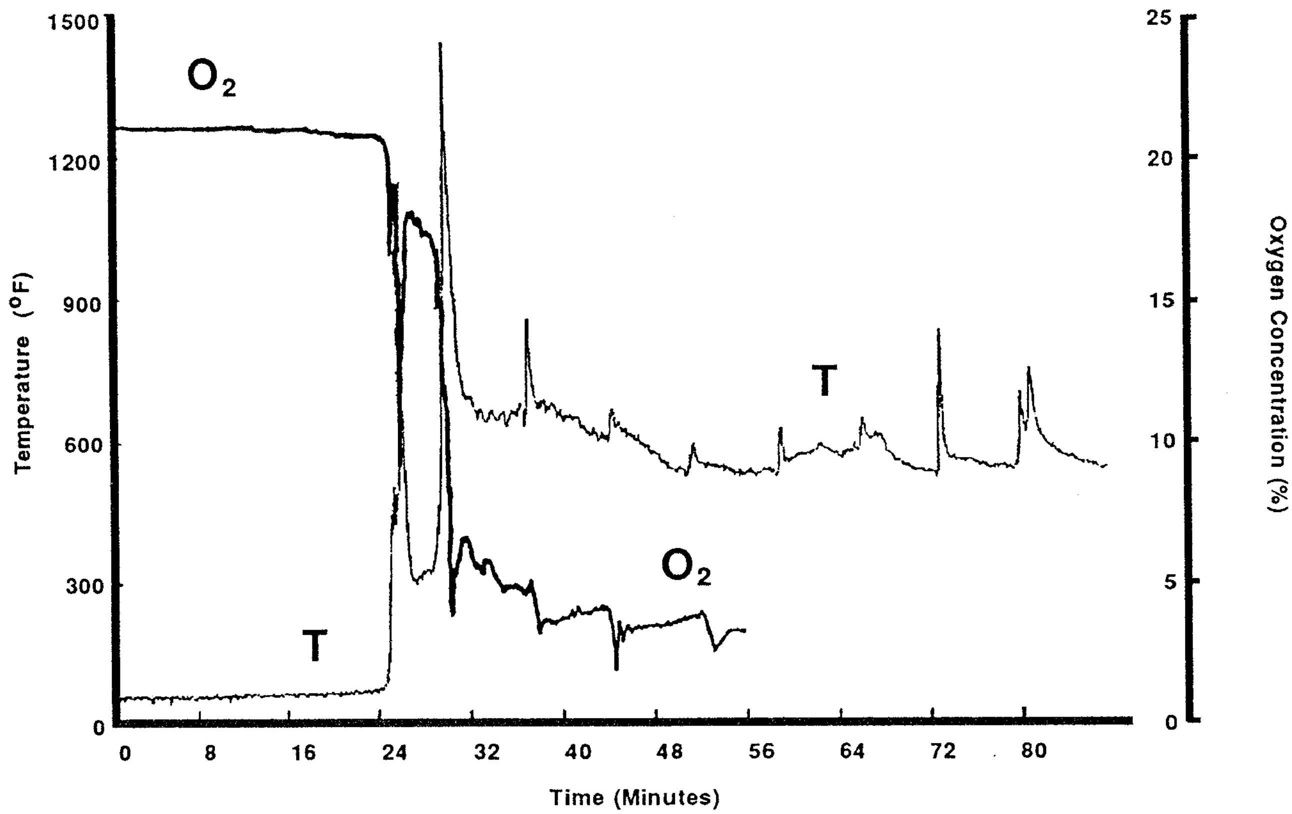

Figure 3. Pyrotechnically Generated Aerosol Test Results in Cargo Compartment

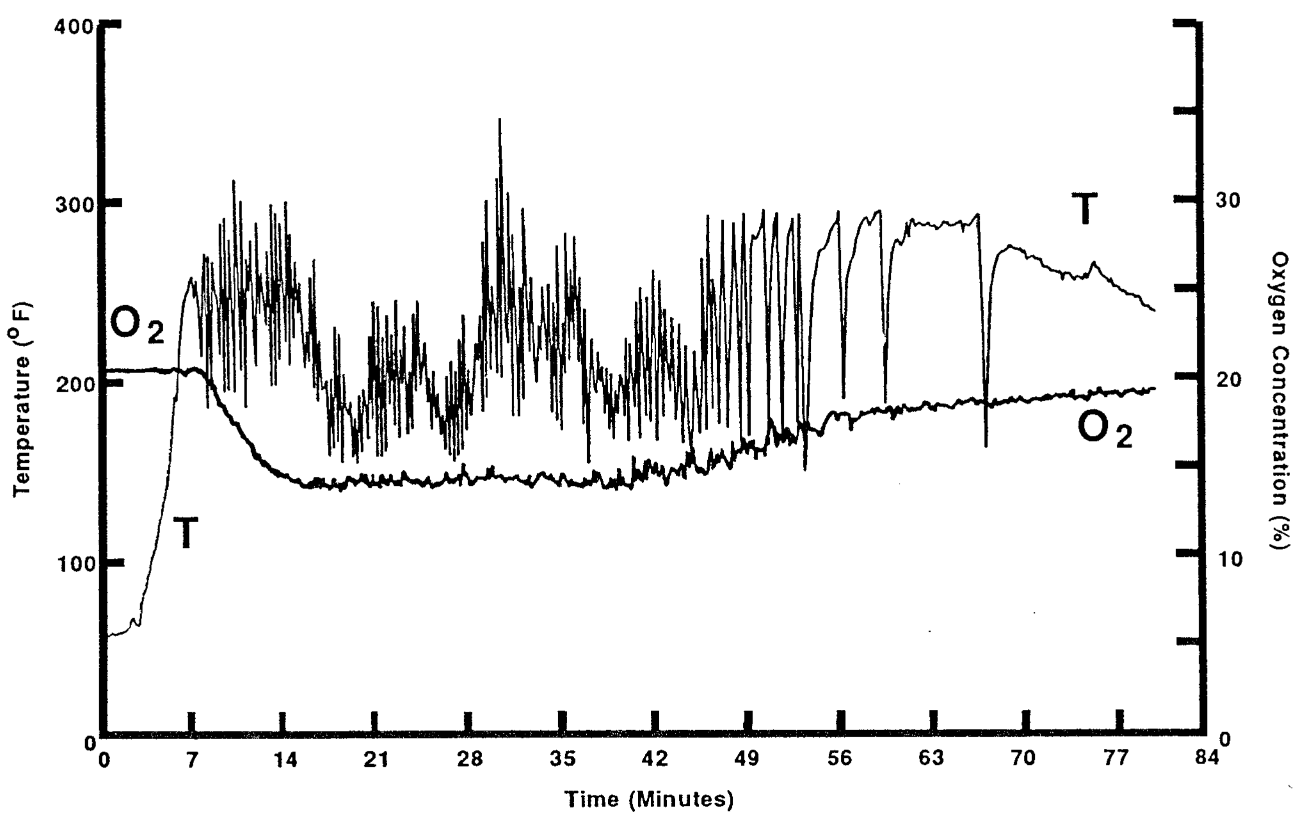

Figure 4. Water Spray Test Results in Cargo Compartment

Test Protocol \ Agent	Extinguishment Time (Sec)				
	Halon 1211	Perfluoro-hexane	Halotron I		
			std	std/1200	std/2000
Pool Fire 800 ft^2	13	18	22	—	—
Inclined Plane	23	35(1)	18(1)	(2)	—
Engine Nacelle 24 gal/pad	15	DNE	DNE	—	—
15 gal/pad	—	DNE	DNE	DNE	—
10 gal/pad	—	—	—	(3)	(4)
5 gal/pad	—	—	—	32(5)	27
Wheel Well	5	18	12	—	—

DNE Did not extinguish

(1) Average of 3 tests
(2) 4 test: DNE, DNE, 17, 28
(3) 3 tests: DNE, DNE, 26
(4) 3 tests: DNE, DNE, 29
(5) Average of 2 tests

Table 1. Initial Airport Firefighting Test Results

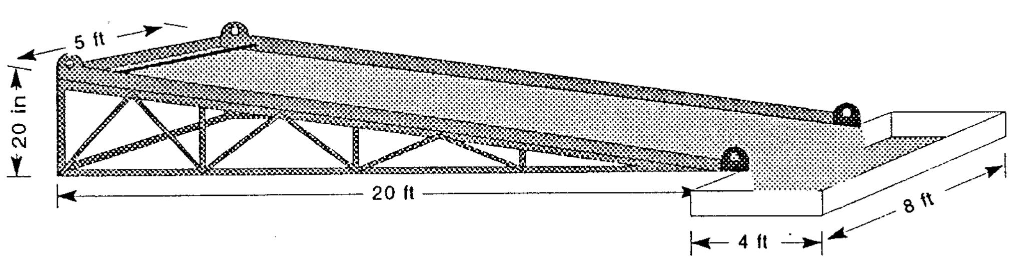

FIGURE 5. INCLINED-PLANE FUEL FIRE TEST SETUP