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EVALUATION OF A HALON 1301 SYSTEM FOR AIRCRAFT INTERNAL PROTECTION FROM A POSTCRASH EXTERNAL FUEL FIRE

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16. Abstract

The use of a Halon 1301 fire-suppression system was evaluated in regard to increasing occupant escape time during a ground crash situation with an external fire adjacent to a cabin opening. Tests were conducted in a DC7 fuselage, varying the exit configurations and external wind conditions. Tests were also conducted using a curtain to compartmentize the cabin, with the Halon 1301 concentration and location of discharge being varied. Smoke, temperature, carbon monoxide, oxygen, and Halon 1301 levels were continuously monitored during the tests at various locations throughout the cabin. Hydrogen fluoride (HF) and hydrogen bromide (HBr) concentrations were obtained by analyzing samples taken from the cabin at various times. The results indicated that the length of protection from flame penetration through an opening was dependent upon external wind conditions. Flame penetration was controlled for up to 3.5 minutes with zero wind, but with a wind of as little as 2 miles per hour (mi/h), the time was reduced to less than 15 seconds. High HF levels were rapidly reached inside the cabin, with concentrations ranging from 60 parts per million (p/m), with no wind, to well over 300 p/m with 2-mi/h wind conditions. Test results also indicated that the use of a curtain to compartmentize the cabin could slow the spread of HF (15 to 20 seconds), but it does not lower the levels reached.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

PURPOSE.

The purpose of this program is to determine the ability of Halon 1301, discharged in an aircraft passenger compartment, to increase escape time in the presence of a penetrating external fuel fire.

BACKGROUND.

This report covers the second of a two-phase effort involving Halon 1301 fire-suppression/extinguishment in aircraft passenger compartments. The first phase dealt with internal cabin fire and was reported on in reference 1. Prior work in the development and testing of the modular dispensing system used in this program was reported on in reference 2.

The greatest hazard during an aircraft crash situation (other than impact itself) is the fuel fire. In most cases, this fire is at first restricted to outside the passenger cabin area. The fire usually enters the cabin through a rupture, an opened exit, or burns its way through the aircraft skin. The entrance of the fire into the cabin greatly reduces escape time.

HALON 1301 CHARACTERISTICS AND HAZARDS.

Halon 1301 is a colorless, odorless gas which is easily liquified under pressure. The vapor pressure at 70° Fahrenheit (F) is 200 pounds per square inch gauge (psig), with the critical temperature and pressure being 152.6° F and 575 psig, respectively. Chemically, Halon 1301 is bromotrifluoromethane ($CBrF_3$) and has a molecular weight of 148.93 (reference 3).

The National Fire Protection Association (NFPA) guidelines (reference 4) state that Halon 1301 can be safely used in occupied areas in concentrations up to 7 percent, but further recommend that occupant exposures to Halon 1301 concentration of 7 percent or less not exceed 5 minutes. The agent concentration in the majority of tests in this program was 5 percent by volume. Since a postcrash evacuation should require less than 5 minutes, the 5-percent concentration was well within the NFPA's guidelines.

At elevated temperatures (approximately 900° F), Halon 1301 breaks down into decomposition products including hydrogen fluoride (HF), hydrogen bromide (HBr), free bromine, and carbonyl halides. The decomposition products of Halon 1301 can pose much more of a threat to human habitation than does the agent itself. The reported approximate lethal concentration (ALC) using white rats for decomposed Halon 1301 ranges from 2,300 p/m (reference 5) to 14,000 p/m (reference 6). From previous data, it was determined that the major decomposition product of Halon 1301 was HF (reference 5) and that the ALC for decomposed Halon 1301 and for HF were close enough to assume that the toxicity of the decomposed Halon 1301 was due to the HF concentration (reference 5). Therefore, the majority of analysis of the Halon 1301 decomposition products in this test was aimed at HF, although samples containing large quantities of decomposed agent were also analyzed for HBr (refer to the appendix of reference 1 and reference 7 for details of the analysis).

In low concentrations, HF is an irritant, but in larger amounts, HF can lead to serious injury or death. Table 1 (reference 8) shows some of the effects of various concentration of HF on humans.

TABLE 1. EFFECT OF HYDROGEN FLUORIDE ON HUMANS

Hydrogen Fluoride Concentrations (p/m)	Symptoms
3-5	Redness of skin, irritation of nose and eyes after 1-week's exposure.
32	Irritation of eyes and nose.
60	Itching of skin, irritation of breathing tracks from exposure of 1 minute.
120	Conjunctival and respiratory irritation, just tolerable for 1 minute.
50-100	Dangerous to life after a few minutes.

DESCRIPTION OF TEST EQUIPMENT

TEST ARTICLE.

Two series of tests were run during this program using two different DC7 fuselages as test articles. A preliminary series of tests used a DC7 fuselage out of doors, while the primary test phase was conducted using a DC7 fuselage inside of a building.

Figure 1 is an illustration of the test article used in the preliminary tests, showing the cabin air sampling stations, thermocouples, etc. Figure 2 shows the same for the primary tests. Three main differences existed between the preliminary and primary tests:

1. The primary tests used a fixed modular Halon 1301 dispensing system (as tested in references 1 and 2); whereas, the preliminary tests used movable bottles with solenoid-operated valves inside the fuselage.

2. The primary tests were conducted inside a fire test building, thus reducing ambient effects and providing better control of the airflow through the fuselage.

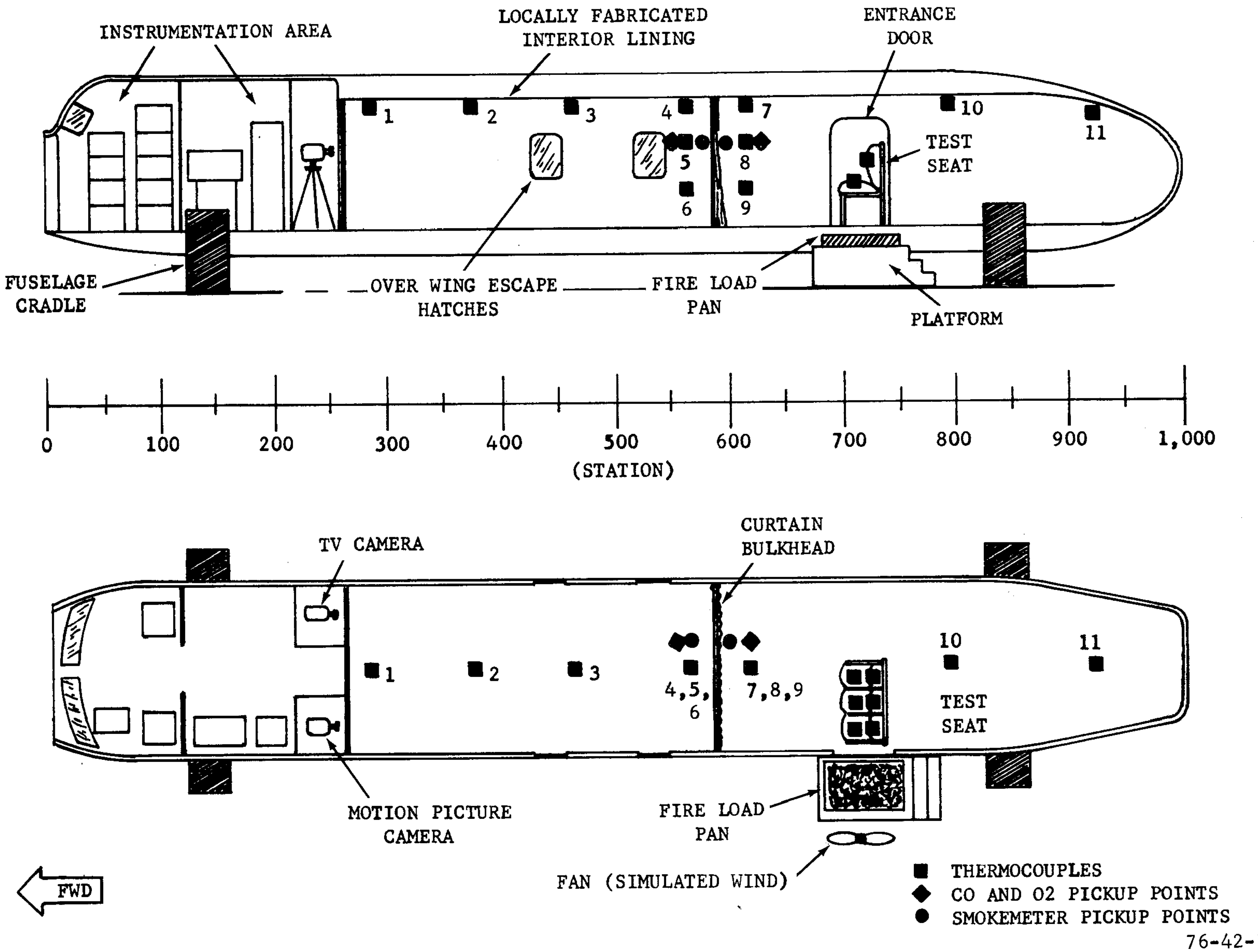


FIGURE 1. PRELIMINARY TEST ARTICLE CONFIGURATION

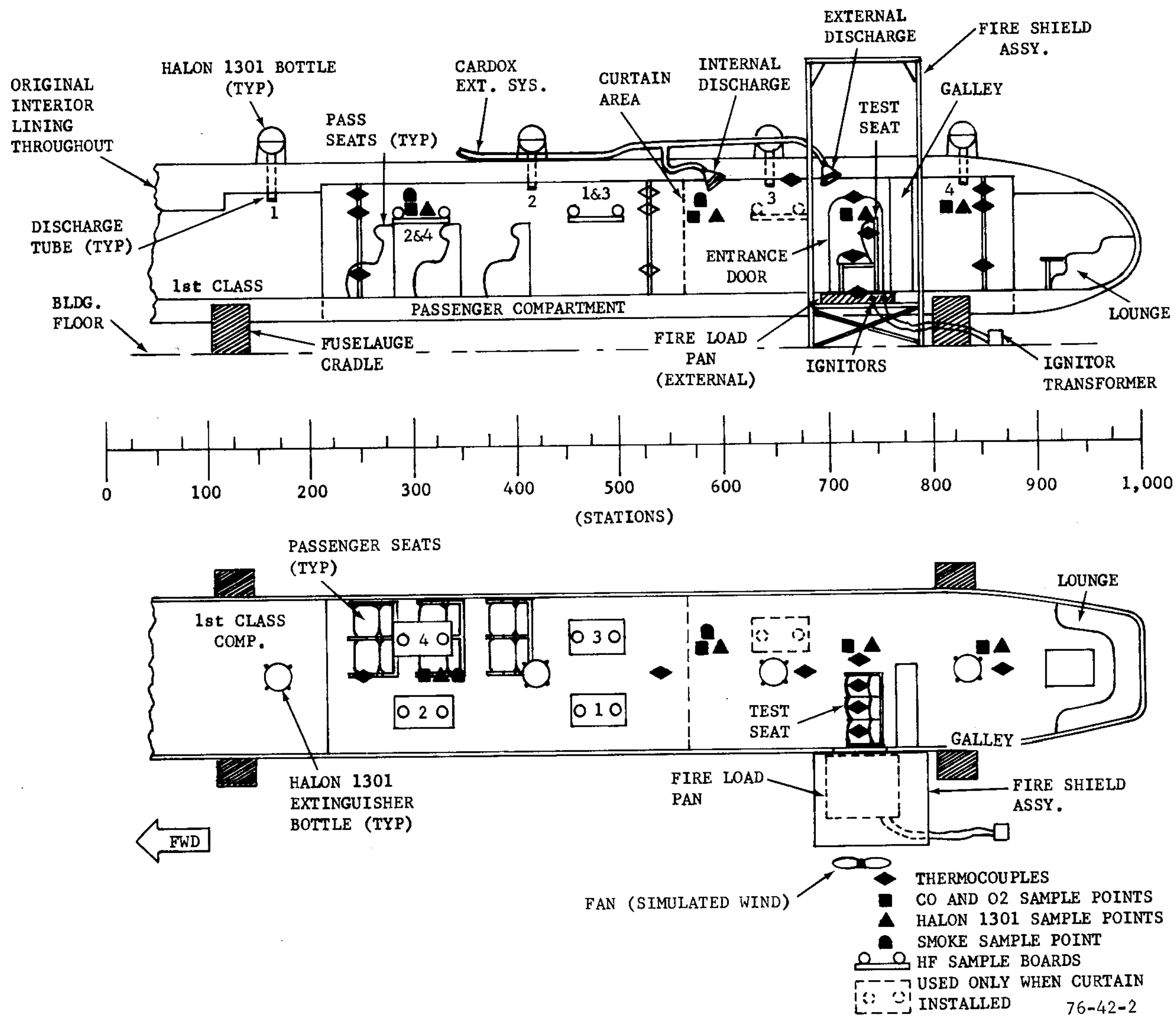


FIGURE 2. PRIMARY TEST ARTICLE CONFIGURATION

3. A separate sampling system was installed, and the decomposition products of the Halon 1301 were analyzed for the primary tests. For further information regarding this sampling system, refer to the appendix of reference 1.

The fire load for both series of tests consisted of a 30-inch by 36-inch pan containing 3 gallons of JP-4 jet fuel. The pan was located directly adjacent to the aft passenger doorway. During the preliminary tests, the door was opened and tied back, and during the primary test, the door was removed. In both cases, the doorway was insulated from the fire in order to avoid any enlargement of the opening during the test program. The doorway measured 36 by 72 inches. Four over-wing emergency exits were used during some of the tests. Each exit was 21 inches by 25 inches.

For several of the tests a Kynol® curtain was installed in the fuselage to serve as a barrier against the spread of heat, smoke, and gases throughout the cabin.

A seat constructed of steel angle and non-fire-retardant urethane foam (Staford Chemical Co. number 2037) was placed adjacent to the rear exit and was instrumented with six thermocouples. This seat was used in determining burn-in time and also rate of flame propagation in the cabin.

INSTRUMENTATION.

The parameters monitored and the instrumentation used for monitoring and recording them were as follows:

1. Oxygen: Beckman model 715 process oxygen monitor.

2. Carbon monoxide: Beckman model 864 infrared analyzer.

3. Halon 1301: Mine Safety Appliance Company infrared analyzer, model 300.

4. Hydrogen fluoride: fluoride-specific ion electrode (Orion range 10^{-1} to 10^{-6} moles/liter fluoride (F) ion). Ion analyzer (Orion Research model 801/ digital-PH).

5. Temperature: Chromel-Alumel thermocouple wire, 22 gauge. Thermo Electric Chromel-Alumel Ceramo, 32 gauge.

6. Smoke: Weston model 856 photocell and PR3 light bulb, monitoring light transmission over a distance of 1 foot. (The smoke meter was located external to the fuselage, with a sample continuously drawn through a 3/4-inch sample line to the meter).

7. Video: Sony model AV-3400 Videorover®. Sony model CVM-192U Monitor.

8. Recorders: Esterline Angus model D2020 digital chart recorder (for oxygen (O_2), carbon monoxide (CO), Halon 1301 and temperature). Esterline Angus model L11025 strip chart recorders (for smoke and temperature).

9. Film coverage--16mm.

All instrumentation was calibrated prior to each test, and all lag times for the sampling systems were incorporated when reducing the data. (Lag times for all the sampling systems were less than 5 seconds.)

TEST DESCRIPTION

PRELIMINARY TESTS.

Six preliminary tests (101 to 106) were conducted using a DC7 fuselage out of doors (refer to table 2). The pan fire adjacent to the rear exit was lit using a spark ignitor, and the initial discharge of Halon 1301 was accomplished manually when thermocouples in the urethane seat indicated that the seat had ignited. During all of the preliminary tests, the over-wing exits were open. Tests 101 and 102 were background tests using no extinguishing agent. The difference between the two tests was the use of a curtain at fuselage station 596 during test 102 in order to compartmentize the cabin.

A fan was used to force the flames against the fuselage. The average airflow through the cabin, created by this fan, was 2,028 cubic feet per minute (ft^3/min), with a noncompartmented cabin and 1,683 ft^3/min when the cabin was compartmented (measured prior to test). The external wind conditions caused a vast fluctuation in the airflow and in the flame pattern outside the fuselage, thus requiring the move inside for the primary tests.

Four Halon 1301 tests (103 to 106) were conducted during the preliminary phase of this project. Test 103 was conducted using a 5-percent-by-volume concentration to inhibit the fire. Two discharge bottles were positioned and used as shown in figure 3A. Bottle locations for test 104 are shown in figure 3B. Only half the agent was discharged initially, with the remainder being discharged after the re-ignition of the foam seat.

The Kynol® curtain was installed for the final two preliminary tests (dividing the cabin into roughly two equal volumes). All agent was discharged aft (fireside) of the curtain for these tests (figure 3C and D). Test 105 used two discharges (same as test 104), whereas in test 106, all 62 pounds of agent were discharged at seat ignition. Thus, assuming little initial flow of agent through the curtain, the agent concentration in the aft section for test 105 was ≈5 percent after the first discharge, and ≈5 percent more was added at the time of seat re-ignition. The initial concentration for test 106 was ≈10 percent. At the completion of all preliminary fire tests, the pan fire was extinguished by the NAFEC fire department.

TABLE 2. TEST MATRIX

Test No.	Pounds of Halon 1301 Used	Exit Configuration	Cabin Compartmented	Location of Agent Discharge	Airflow (ft^3/min)	Remarks
101[1]	-	open	No	-	2,028	-
102[1]	-	open	Yes	-	1,683	-
103[1]	62=5%	open	No	Normal[2]	2,028	-
104[1]	62=5%	open	No	All agent in aft section	2,028	31 lb. discharged at 7 seconds Another 31 lb. at 37 seconds
105[1]	62=5%	open	Yes	All agent in aft section	1,683	31 lb. at 5 seconds. Another 31 lb. at 67 seconds.
106[1]	62=5%	open	Yes	All agent in aft section	1,683	62 lb. discharged at 6 seconds.
107[3]	80=5%	close	No	Normal	-	-
108[3]	80=5%	open	No	Normal	-	-
109[3]	80=5%	open	No	Normal	4,686	-
110[3]	-	open	No	-	4,686	Background for 109
111[3]	-	open	No	-	-	Background for 108
112[3]	-	close	No	-	-	Background for 107
113[3]	80=5%	open	No	Normal	2,728	-
114[3]	80=5%	open	No	Normal	3,057	-
115[3]	80=5%	close open	No	Normal	3,057	-
116[3]	40=5% in aft	open	Yes	All agent in aft section	3,057	-
117[3]	-	open	Yes	-	3,057	Background for 116
118[3]	60=9.5% in aft	open	Yes	All agent in aft section	3,057	-
119[3]	-	open	No	-	3,057	Background for 114
120[3]	-	open	No	-	2,728	Background for 113

—=None

1. Preliminary tests using outside DC7 fuselage.
2. Normal distribution was when agent was distributed "evenly" thoughout the cabin.
3. Primary tests using inside DC7 fuselage.
4. Exits closed during discharge opened after discharge.

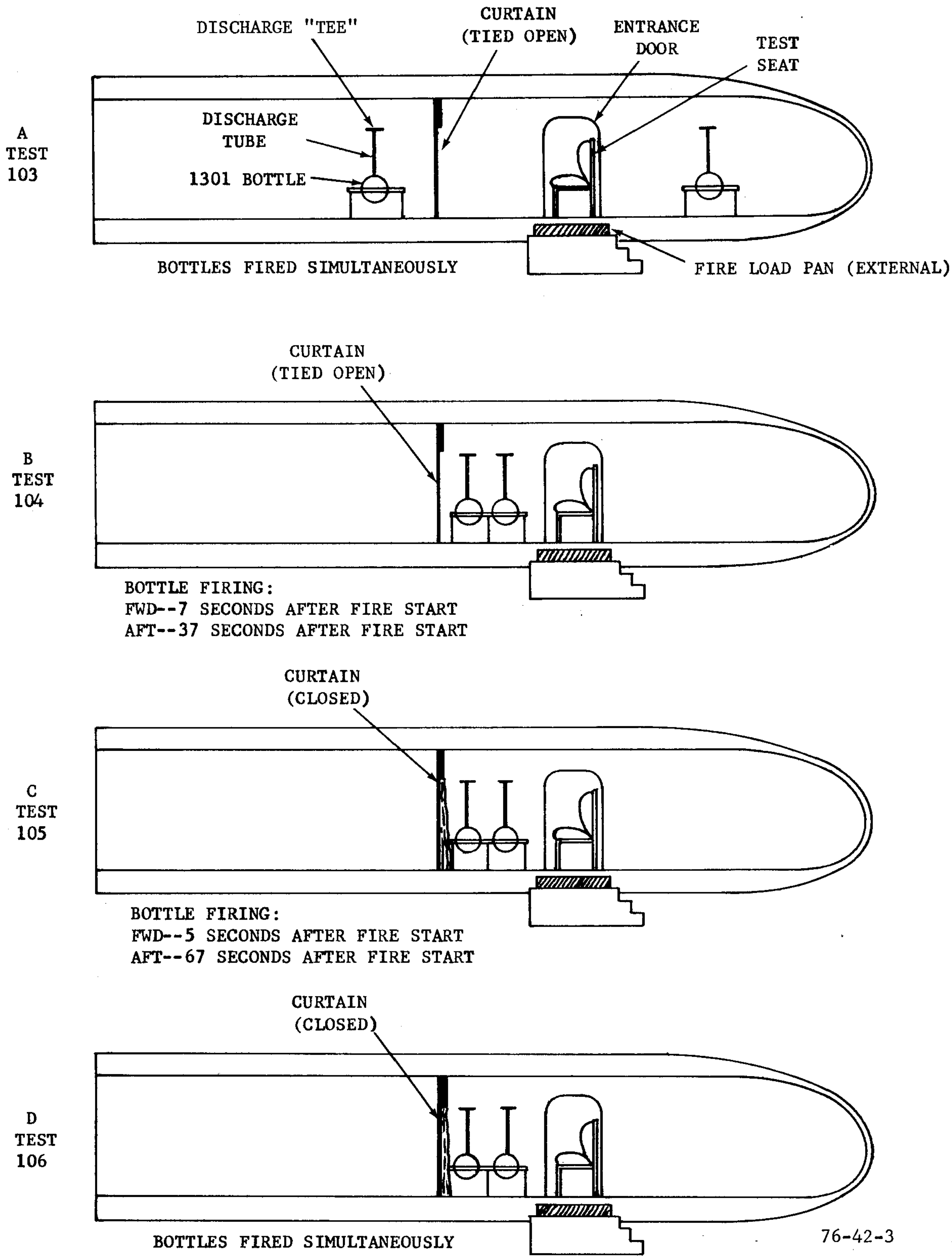


FIGURE 3. PRELIMINARY TEST HALON 1301 DISCHARGE LOCATIONS

PRIMARY TESTS.

Fourteen primary tests (107 to 120) were conducted utilizing a DC7 fuselage located inside a fire test building. Eight of the tests involved the use of Halon 1301, and the other six were background tests using no extinguishment (table 2). During all primary tests using Halon 1301 except test 115, the agent was discharged when a thermocouple located at the ceiling 1 foot from the rear exit door reached 165° F (a standard setting for thermal detectors). For test 115, agent was discharged prior to the opening of the exits. Airflow across the pan fire and through the fuselage was varied by the use of variable-speed fan. The exact configurations for all the primary tests are listed in table 2.

All tests conducted without the use of compartmentation used a 5-percent-by-volume concentration of Halon 1301 and varied the exit configurations and the airflow over the fire and through the fuselage. When a curtain was used to compartmentize the cabin, the exits were kept open, the airflow remained constant, and the amount of agent used was varied. At the completion of all tests, the fires were extinguished using a CO_2 total flood system.

TEST RESULTS

PRELIMINARY TESTS.

The main objective of the preliminary tests was to isolate any problems that might arise before testing began inside of a building using the greater instrumented DC7 fuselage. Because of the lack of instrumentation and uncontrolled environmental conditions, the only data available were general in nature and related to the burn-in rate and flame spread in the cabin for various configurations at discharge.

A comparison of the burn-in time (that is the length of time from ignition of the pan fire until the ignition of the foam seat in the aircraft) is shown in figure 4. The burn time was calculated using both the thermocouples in the seat and film coverage.

For tests 104 and 105, both having multiple discharges, the burn-in time represents the ignition of the seat after the final agent discharge. For test 104, the seat ignited at 37 seconds, and agent was discharged. The agent did not extinguish the seat, so burn-in time was 37 seconds. For test 105, a discharge at 67 seconds temporarily extinguished the seat, but ignition again occurred at 77 seconds, thus burn-in time was 77 seconds.

The following general results can be seen by comparing the preliminary test data:

1. The use of compartmentation increased the time for the flame to enter the cabin by reducing the draft through the cabin. This is shown by the comparison of tests 101 and 102 (figure 4), where burn-in time increased

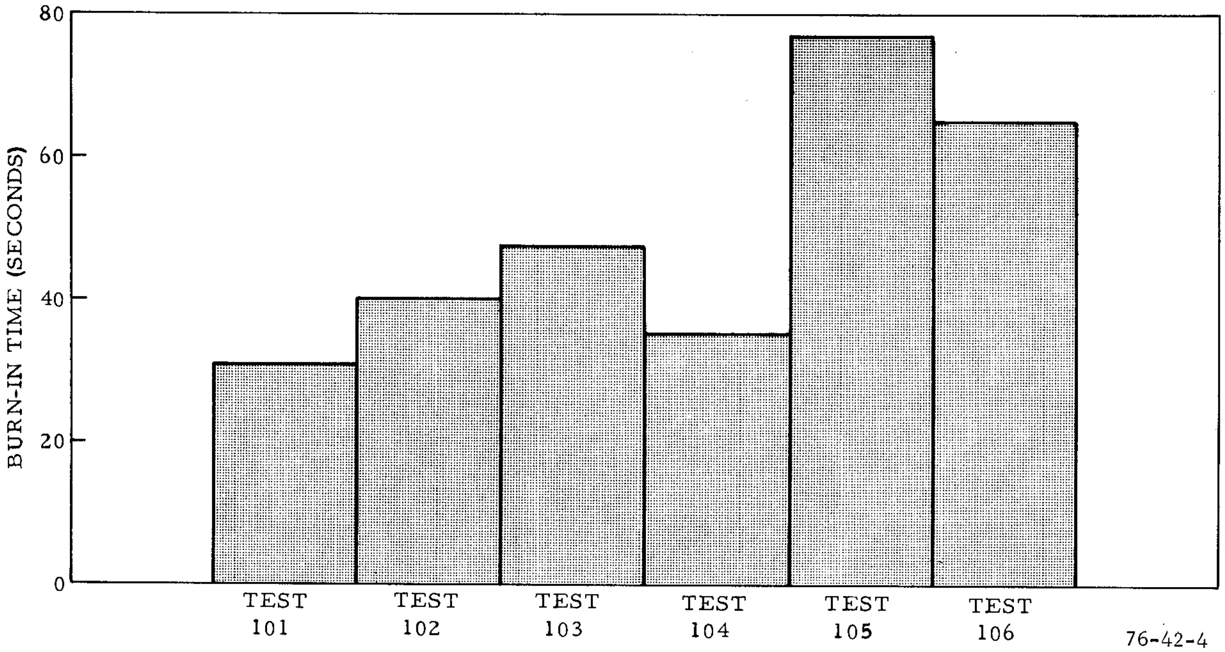


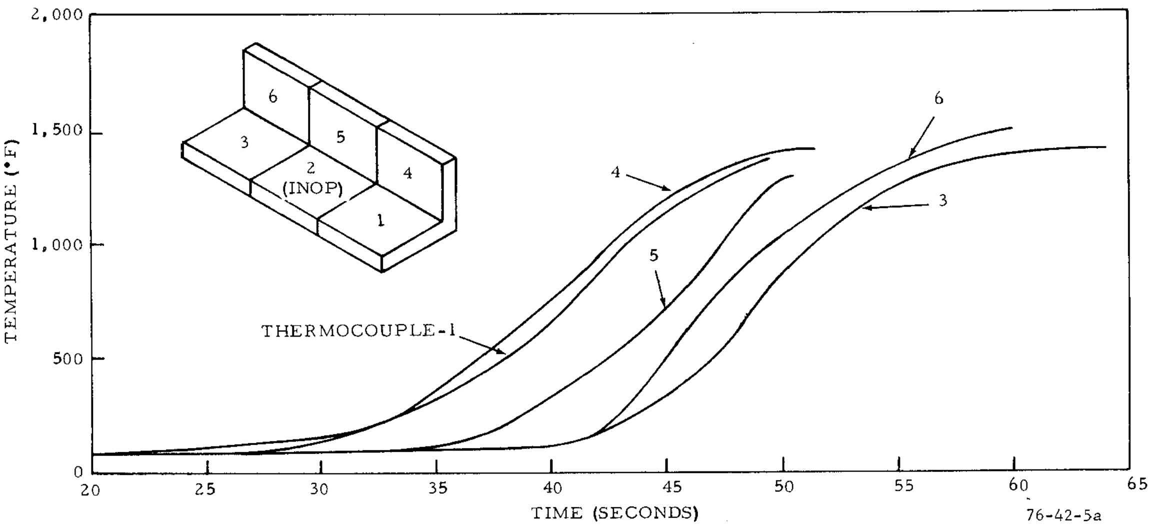
FIGURE 4. BURN-IN TIME FOR PRELIMINARY TESTS

from 30 to 40 seconds when the cabin was compartmented. A check of the airflow out the over-wing exits showed that with no curtain used for compartmenting the cabin, the airflow through the cabin was 2,028 ft^3/min, and when the curtain was used, the airflow dropped to 1,683 ft^3/min.

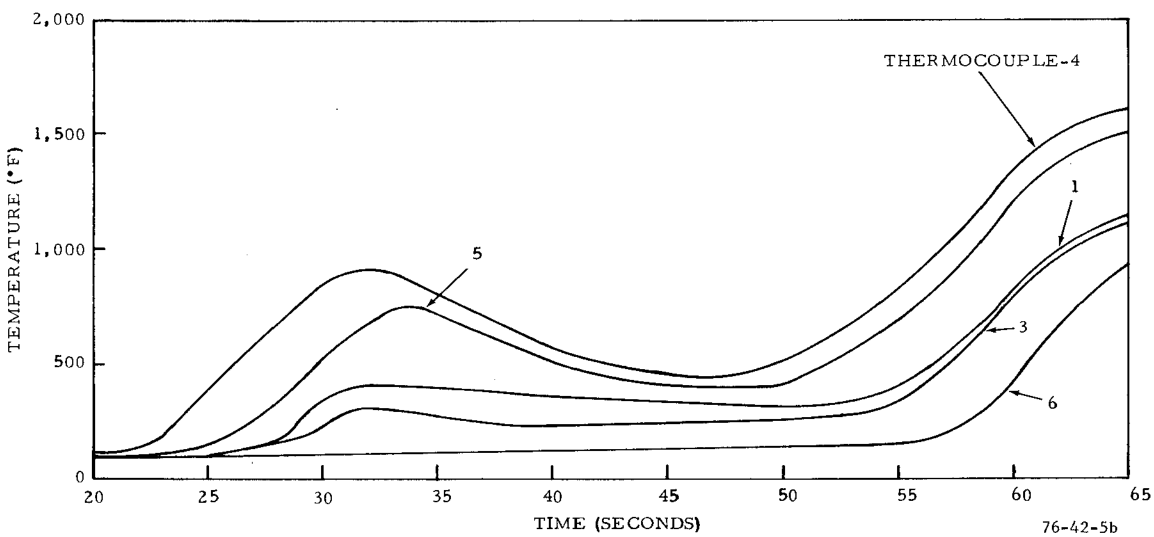
2. The use of a 5 percent by volume concentration of Halon 1301 throughout the cabin increased burn-in time from 30 seconds to 47 seconds (figure 4). Although burn-in time was increased by the use of Halon 1301, the rate at which the flame spread on the seat after burn-in was not decreased. Figure 5 represents the time-temperature profile of the seat surface at five different locations (thermocouples 1 and 3 being on the seat cushion and 4, 5, and 6 on the seat back). The time from ignition of the seat until the entire seat was engulfed in flame was approximately 10 seconds for both tests.

3. When a concentration of less than 5 percent by volume of Halon 1301 in the cabin was used locally with no means of restricting its spread throughout the cabin, very little increase in burn-in time was recorded (figure 4, test 101 versus 104).

4. Burn-in time was significantly increased when compartmentation was used in conjunction with Halon 1301 (figure 4, test 105 and 106). Test 105 used two discharges of Halon 1301; each discharge was 5 percent by volume of the aft compartment (not the entire cabin). Although test 105 produced the longest time to burn-in (12 seconds longer than test 106, in which a single discharge of 10 percent by volume of the aft compartment was used), the seat



A. NO AGENT USED



B. HALON 1301 USED

FIGURE 5. FLAME PROPAGATION ON SEAT WITH AND WITHOUT THE USE OF HALON 1301 IN THE CABIN

did ignite twice during the test, both times being extinguished by the agent, prior to final burn-in. The burning of the seat in test 105 caused a higher internal cabin temperature than was recorded during test 106.

Another indication of the amount of thermal protection provided by each configuration is shown in figure 6. The temperature shown was measured using thermocouple 2 (figure 1) located near the ceiling, half way in the forward section of the cabin. Figure 6A shows the three tests not using compartmentation. The worst condition was not when no agent was used, but when the amount of agent used was not enough to extinguish the fire. The use of 5 percent by volume of agent increased the thermal protection equal to the increase in time to burn-in.

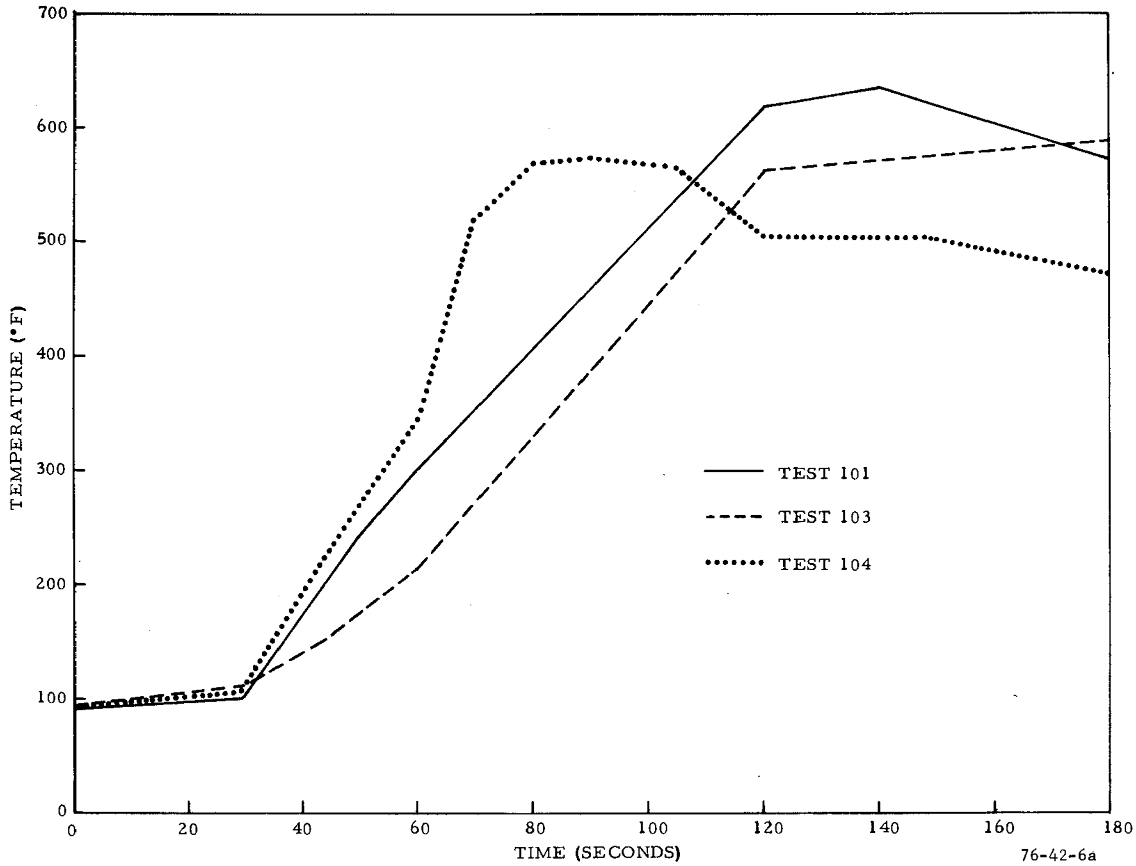
When Halon 1301 was used in conjunction with compartmenting the cabin (figure 6B), added thermal protection was gained. Although the longest time to burn-in was recorded in test 105, test 106 provided the most thermal protection--the reason being, as stated before, no internal burning occurred between the initial discharge of agent and burn-in time during test 106; whereas, the seat did re-ignite and was again extinguished during test 105.

A comparison between figures 6A and B shows the vast thermal improvement when the Halon 1301 is used in conjunction with a compartmented cabin rather than an open cabin.

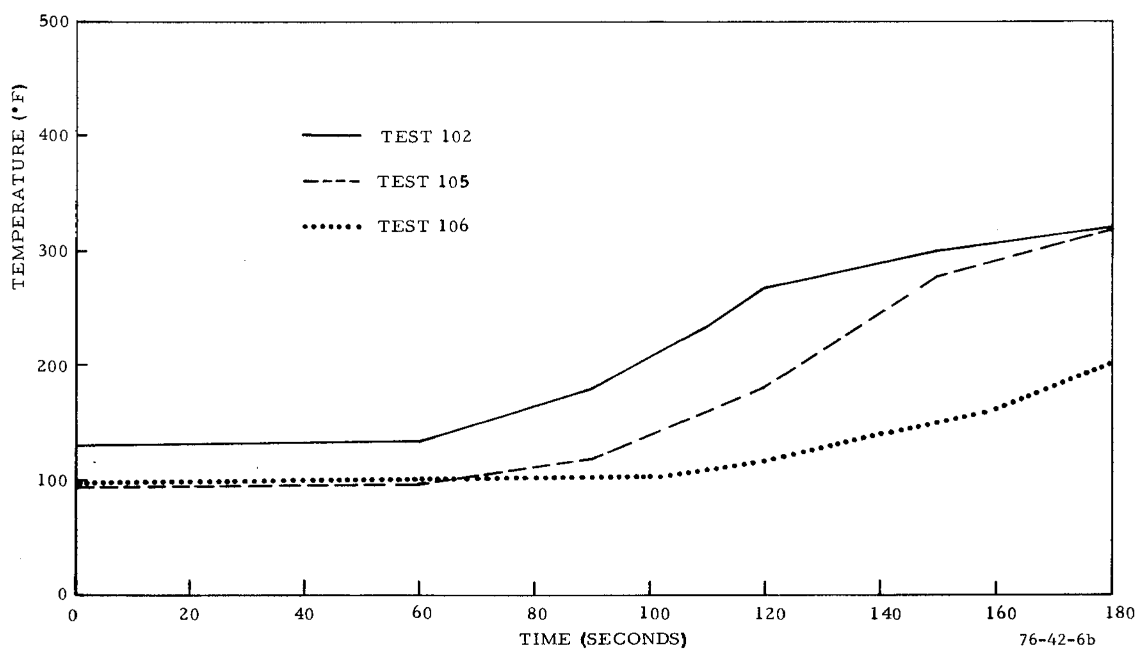
PRIMARY TESTS.

Since the primary tests were conducted in an enclosed area, the ambient conditions around and through the fuselage could be controlled. One of the most important variables studied was the effect of wind conditions on the use of a Halon 1301 system. Figure 7 shows the time to burn-in for four different airflow conditions. Each time was calculated using two tests, a Halon 1301 test and a background test using no agent.

Since the discharge of agent was triggered by a 165° F temperature near the ceiling directly in front of the exit where the fuel fire would enter, and not by the ignition of the seat, the time for an initial burn-in not using Halon 1301 could not be obtained during the extinguishing tests. Therefore, a separate background test for determining the initial burn-in time was conducted for each test configuration. A burn-in time was obtained for both tests with the difference in times equating to the added protection of the Halon 1301. The time plotted in figure 7 is the difference between the burn-in time with and without the use of Halon 1301 (the added protection from the use of Halon 1301). There was a great dependence of burn-in time on airflow; burn-in time with zero airflow was 3 1/2 minutes, and an airflow of 4,686 ft^3/min (which equates to a 3-mi/h wind through the rear exit) only providing an additional 10 seconds of protection from burn-in. The dependence of burn-in time on airflow was caused by (1) the bending of the exterior flame towards the interior of the aircraft, and (2) the concentration of Halon 1301 being forced away from the doorway by the airflow through the rear exit.



A. NO COMPARTMENTATION USED



B. COMPARTMENTATION USED

FIGURE 6. FORWARD THERMAL LEVEL DURING PRELIMINARY TESTS

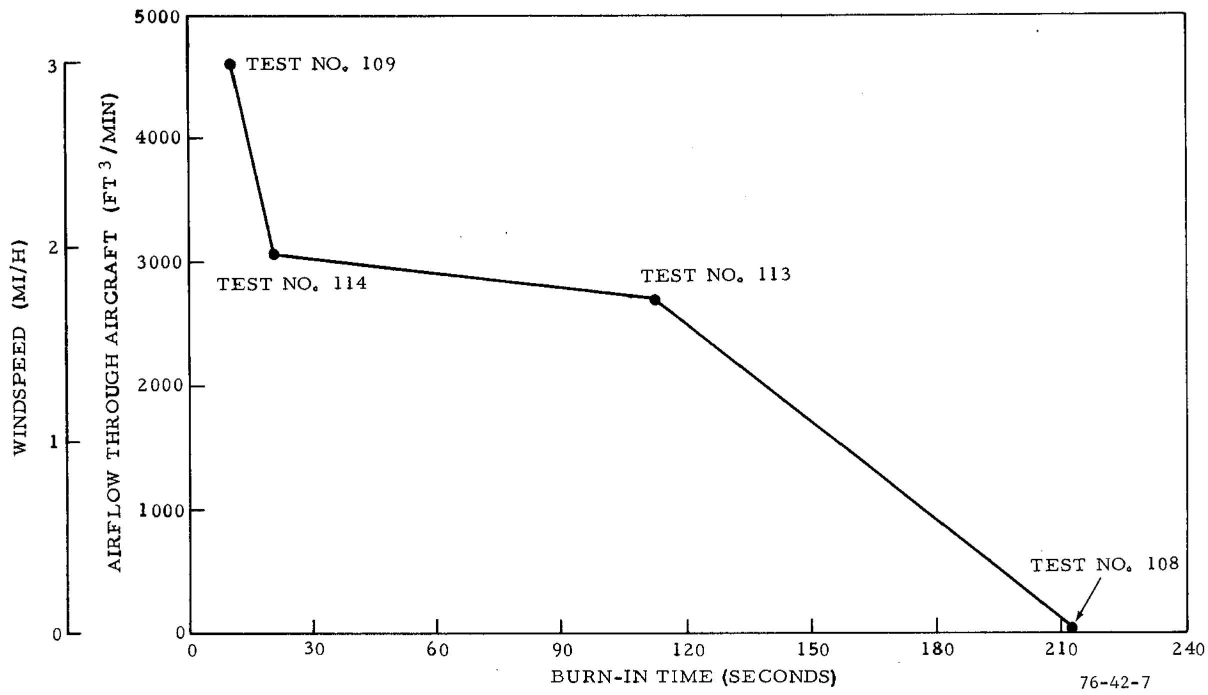


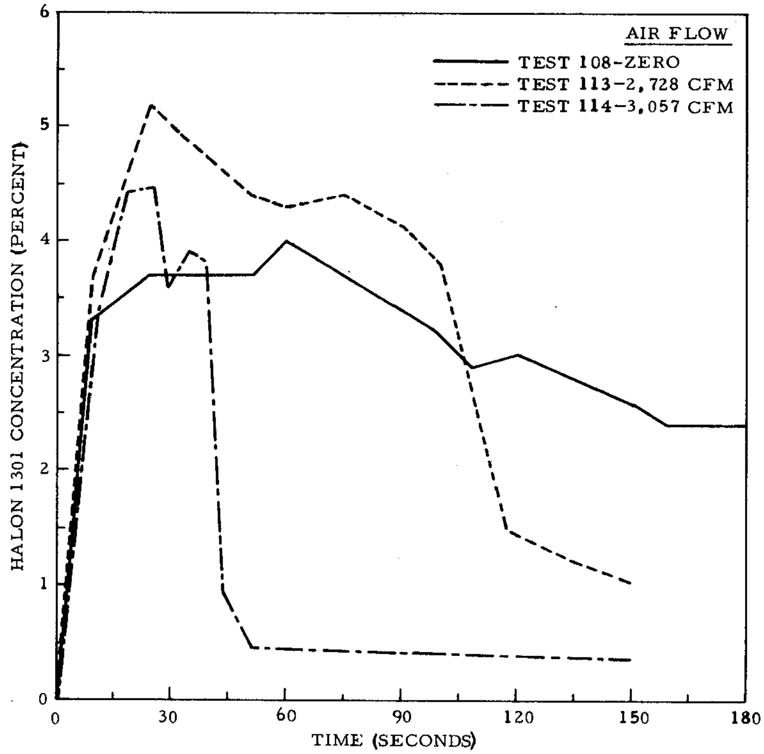
FIGURE 7. DEPENDENCE OF BURN-IN TIME ON WIND CONDITIONS

Figure 8 illustrates the ability of airflow to lower the Halon 1301 concentration in the fuselage and, in particular, near the rear exit. Figure 8A shows that the airflow through the opening kept the agent from flowing out of that opening, thus the higher initial concentrations with airflow. But the airflow caused a quicker drop in agent concentration, with the rate of decreasing agent concentration near the opening depending on the amount of airflow through the opening. Further forward in the cabin, at station 610, the initial concentrations were more comparable (figure 8B), with the no airflow case being slightly higher than the tests with airflow. The rate of agent depletion increased as the amount of airflow increased.

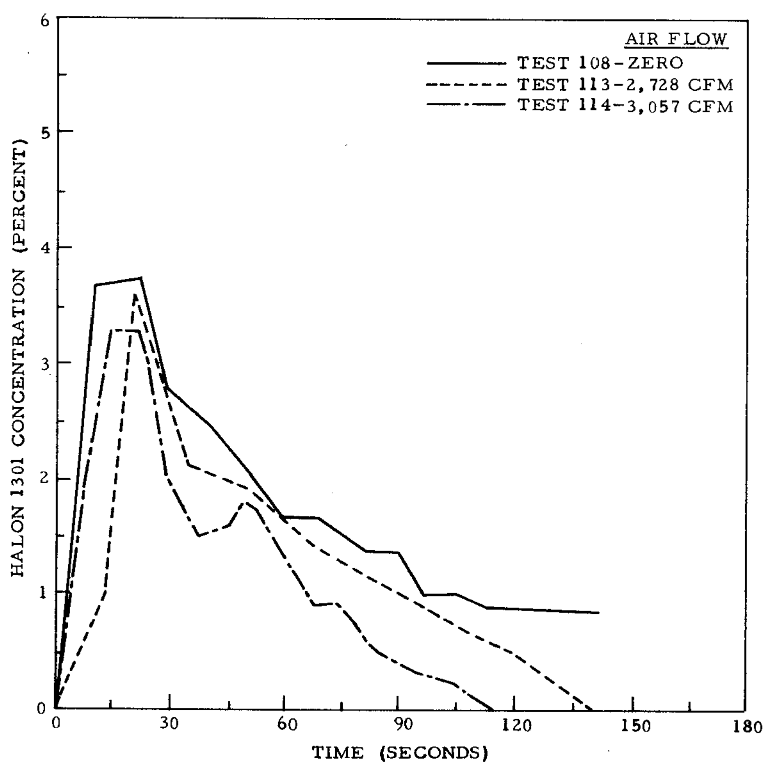
The most important parameter measured during this test program was the decomposition of the Halon 1301. Since it had been determined from previous test work that the largest portion of the decomposing agent would be hydrogen fluoride (reference 5), most of the emphasis was placed on HF analysis. However, HBr analysis was performed on samples from tests 113 and 114.

Figure 9 shows the HF concentrations for the four tests not using a compartmented cabin. When any amount of airflow was used, the decomposing Halon 1301 was rapidly transported throughout the cabin, causing high (400 p/m) HF concentrations. When no ambient airflow was present, HF concentrations in the cabin reached about 60 p/m in less than 60 seconds.

Figure 10 shows the HBr concentrations measured during tests 113 and 114. The HBr levels were approximately 70 percent of the HF levels measured. This HBr



A. SAMPLE AT SEAT CUSHION STATION 740



B. SAMPLE AT EYE LEVEL (5 FEET 6 INCHES FROM FLOOR) AT STATION 610

FIGURE 8. THE EFFECT OF AIRFLOW ON HALON 1301 DEPLETION IN THE CABIN

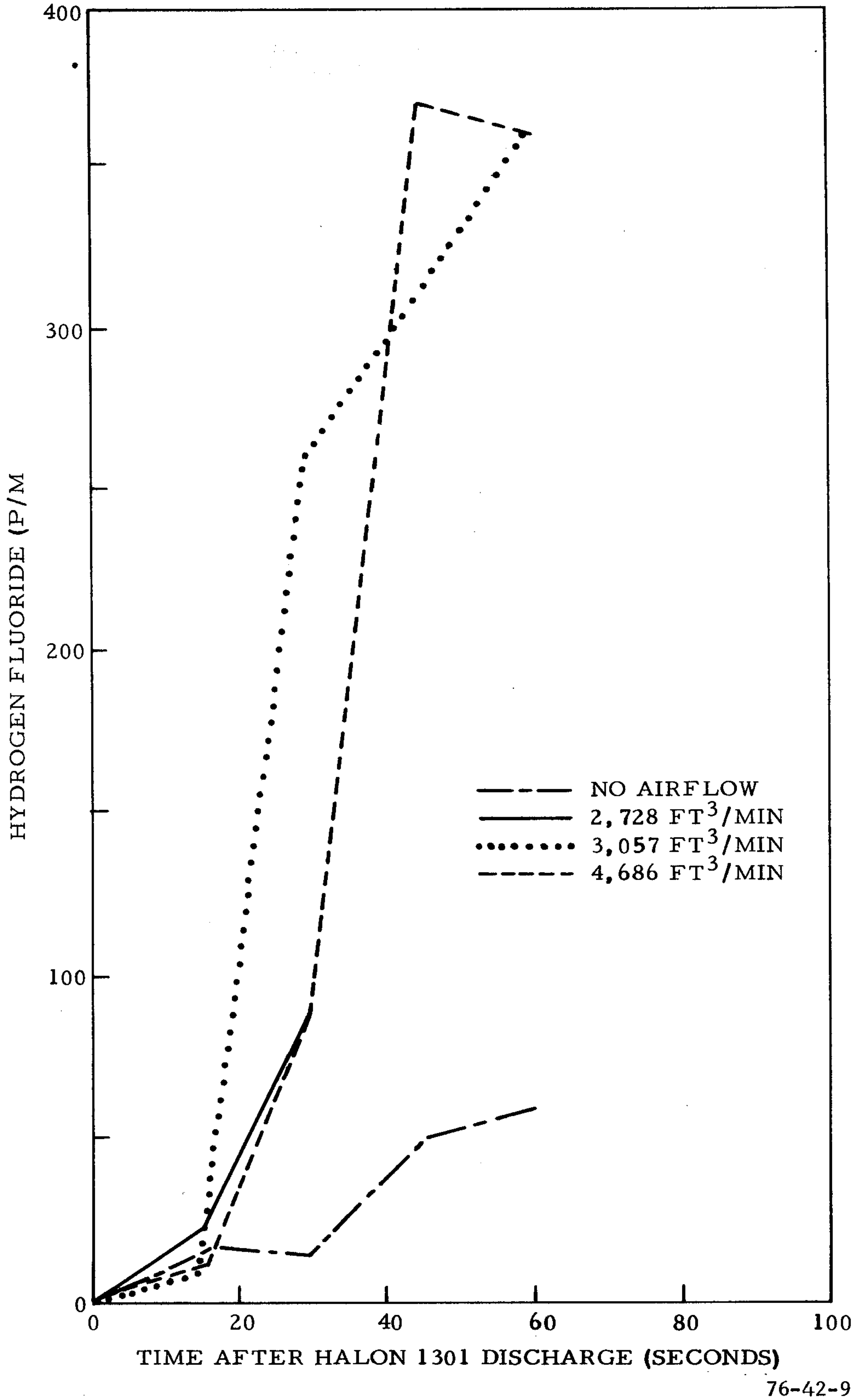


FIGURE 9. AIRFLOW EFFECT ON THE DECOMPOSITION OF HALON 1301 IN THE CABIN

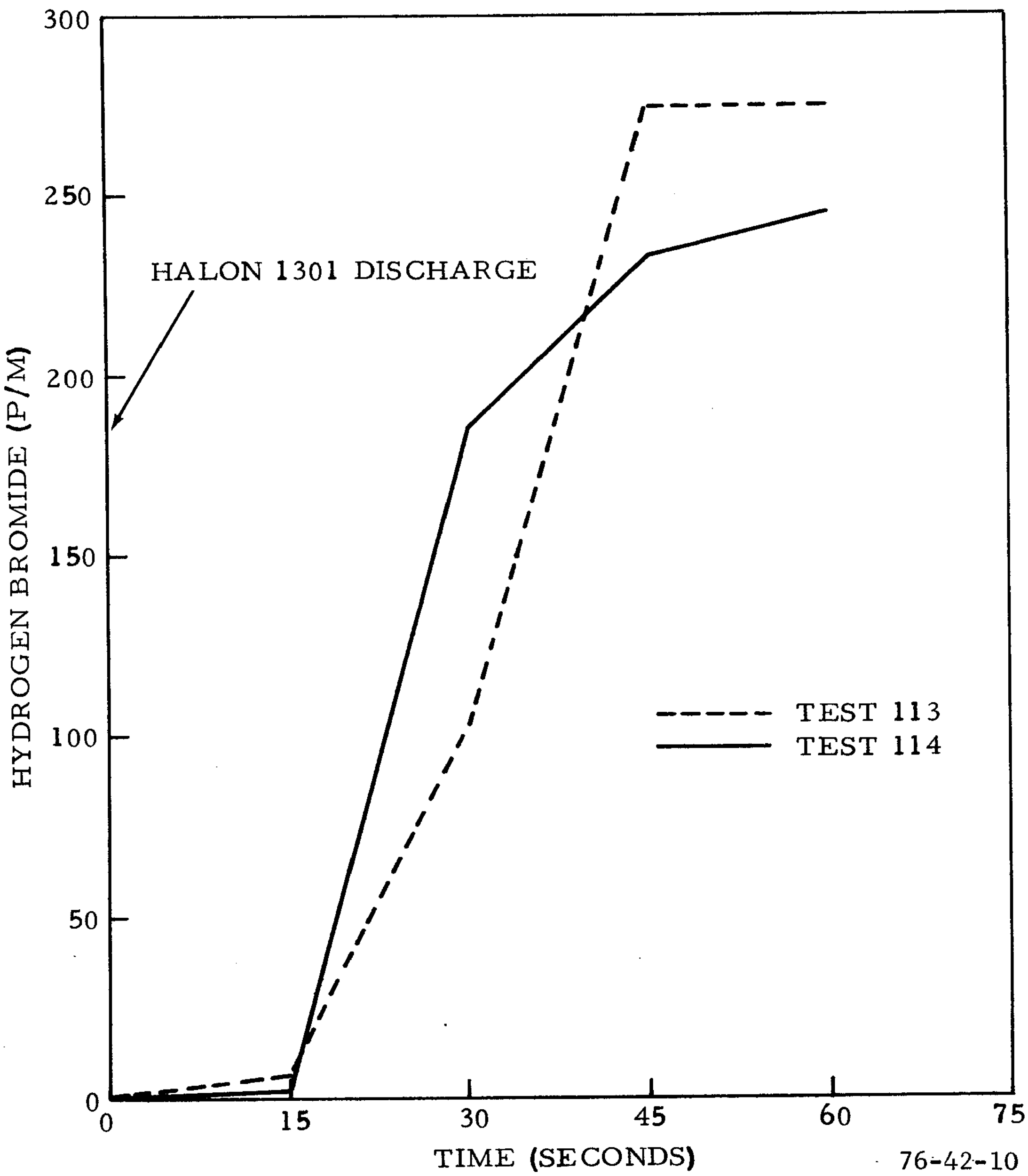


FIGURE 10. HYDROGEN BROMIDE CONCENTRATIONS FROM 5-PERCENT HALON 1301 DECOMPOSING FROM AN EXTERNAL CABIN FIRE

level was much greater than anticipated and leads to the assumption that HBr plays as important a role under this type of fire and environment as does HF, from the standpoint of toxicity of decomposing Halon 1301. Four samples were analyzed for each of the tests, with the HBr level ranging from 66 percent to 76 percent of the HF level. Therefore, it is assumed that the HBr level for all tests in this program are approximately 70 percent of the HF.

Since the use of Halon 1301 was designed to increase escape time, a comparison of parameters that could preclude occupant escape for tests with and without the use of Halon is shown in figure 11. The test condition picked for this analysis was zero airflow, since that condition produced the greatest increase in burn-in protection and the lowest concentrations of HF. The starting time on both figure 11A and B was when the temperature at the ceiling, just in the exit adjacent to the fire, reached 165° F. In test 108 (figure 11B), 5 percent of Halon 1301 was discharged at that time. During test 111 (figure 11A), no extinguishing was used. All measurements were taken in the area of station 300. At 60 seconds after detection (165° F at ceiling), when no agent was used, the light transmission was still greater than 90 percent, and temperature was less than 200° F. When Halon 1301 was used, the temperatures and light transmission remained near normal. (The exterior fire was nearly extinquished during the 60 seconds after discharge.) However, at 60 seconds after agent discharge, HF concentration was over 60 p/m, with an estimated HBr level of 40 p/m.

The use of a curtain to compartmentize the cabin was tested in tests 116, 117, and 118. In test 116, 40 pounds of agent were discharged into the fire compartment, thus theoretically providing a 5-percent Halon 1301 concentration. The actual measured Halon concentrations in the forward and aft sections are shown in figure 12. The agent quickly flowed from the aft section past the curtain to the forward section.

The use of a curtain did slow the spread of HF from the aft section to the protected forward zone. Figure 13 shows the HF levels on both sides of the curtain for both tests 116 and 118. Test 118 used a 7.5 percent by volume of agent in the fire zone. The amount of HF produced seemed to be proportional to the Halon 1301 concentration used (i.e., 400 p/m for a 5-percent Halon concentration and 700 p/m for a 7.5-percent concentration). In both cases, an approximate 20- to 30-second delay in the spread of HF from the aft to the forward sections was recorded. Although the use of a curtain delayed the spread of HF, the peak concentrations remained the same.

The discharge of the agent prior to the opening of cabin exits was analyzed in test 115. No difference in results was obtain than from the exits open at discharge configuration.

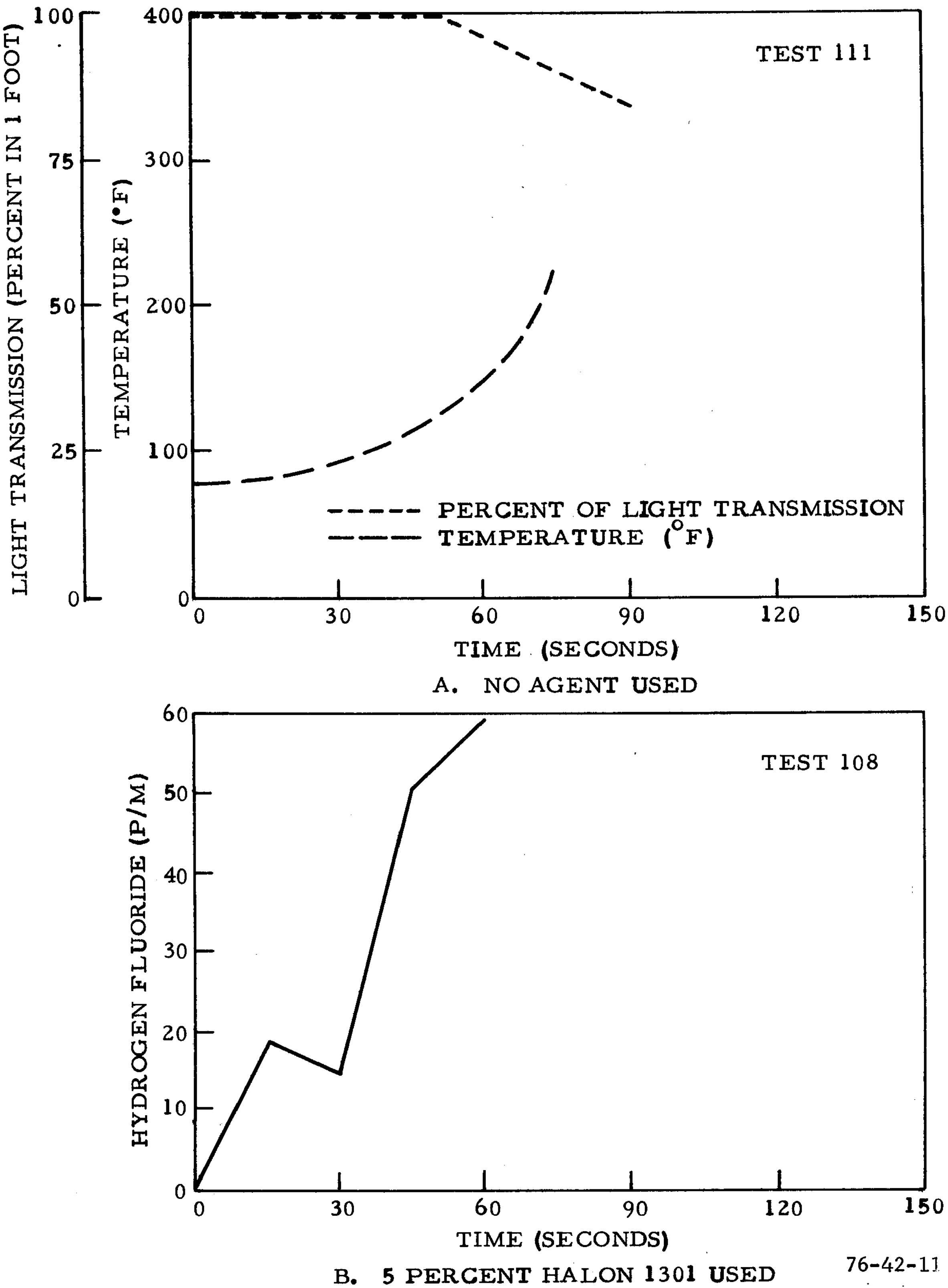


FIGURE 11. A COMPARISON OF POSSIBLE SURVIVAL LIMITING FACTORS WITH AND WITHOUT THE USE OF HALON 1301

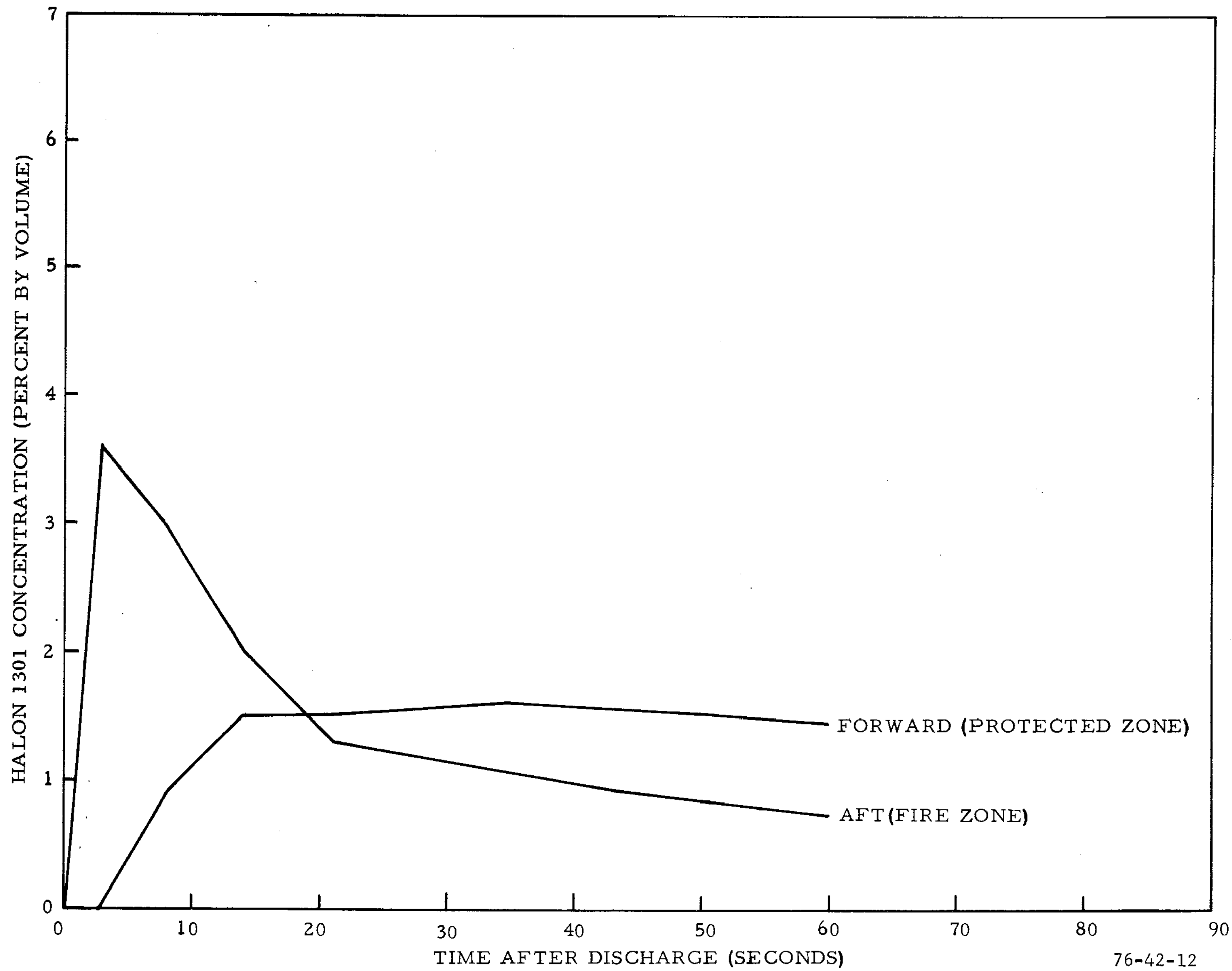


FIGURE 12. HALON 1301 CONCENTRATIONS FOR AGENT DISCHARGE IN COMPARTMENTIZED AREA (TEST 115)

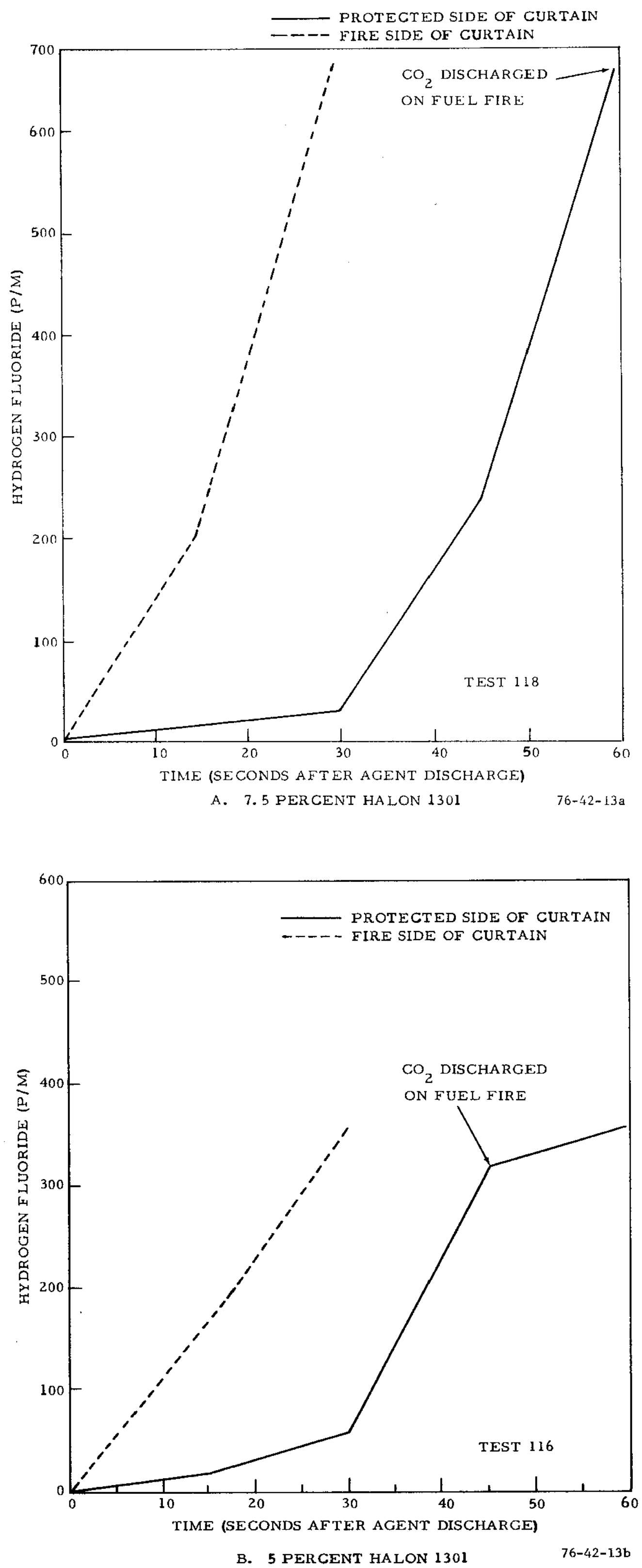


FIGURE 13. PROTECTION FROM DECOMPOSING HALON 1301 PROVIDED BY COMPARTMENTIZING WITH A CURTAIN

SUMMARY OF RESULTS

1. Airflow (wind) greatly affects burn-in time of an external fuel fire. An airflow of as little as 2 mi/h caused a large decrease in burn-in time.

2. The effectiveness of Halon 1301 on inhibiting the external fire from entering the cabin was dependent on airflow. Protection from burning ranged from 210 seconds, with no airflow, to only 10 seconds with an airflow of 4,686 ft^3/min (3 mi/h).

3. Concentrations of hydrogen fluoride ranging from 60 to 800 p/m were produced in the cabin in less than 60 seconds after agent discharge during the extinguishing tests.

4. The lowest concentration of HF (60 p/m) resulted when there was no airflow present.

5. Even the smallest airflow tested produced HF concentrations in the cabin in the 300 p/m range.

6. HBr concentrations measured were approximately 70 percent of the HF levels.

7. The use of curtains to compartmentize the cabin, and the exclusive discharge of agent into the fire compartment alone, proved ineffective in providing burn-in protection. The agent quickly flowed through the curtain (at openings around the curtain), thus lowering the agent concentration below the protection range.

8. The use of a curtain to compartmentize the cabin, however, did provide thermal and smoke protection in the forward area as well as slowing the speed at which HF was transported from the fire to other parts of the cabin. The peak concentrations of HF remained the same for tests with or without the curtain, but the time to reach that peak was delayed 15 to 20 seconds by use of a curtain.

9. No advantages were gained by discharging the agent prior to the opening of the aircraft exits.

CONCLUSIONS

From the results, it is concluded that:

1. The effectivity of a Halon 1301 system in controlling burn-in from a postcrash external fire is dependent on wind conditions. With windspeed over 2 mi/h, little protection is provided by the system used.

2. Intolerable concentrations of toxic gases (hydrogen fluoride and hydrogen bromide) are very rapidly produced inside the cabin when the Halon 1301 system is used to protect against an external fire.

3. Under some conditions, the use of Halon 1301 can cause intolerable conditions in the cabin before temperature and smoke would have become intolerable had no agent been used.

4. The use of a curtain to compartmentize the cabin provides thermal and smoke protection from the external fire and also causing a slight delay (20 to 25 seconds) in the spread of hydrogen fluoride.

5. The discharge of Halon 1301 in a compartment separated from the remainder of the cabin is impractical because of the rapid decline of agent in the compartment as it flows through the curtain area.

6. The decomposition of Halon 1301 during an external fuel fire entering an aircraft cabin produces a greater quantity of HBr than reported in other types of fire tests, the HBr level being approximately 70 percent that of the HF.

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