Report No. RD-65-50

FINAL REPORT

Project No. 430-002-01X

POST-CRASH FIRE-FIGHTING STUDIES ON TRANSPORT CATEGORY AIRCRAFT

MAY 1965

FEDERAL AVIATION AGENCY
Systems Research & Development Service
Atlantic City, New Jersey

FINAL REPORT

POST-CRASH FIRE-FIGHTING STUDIES ON TRANSPORT CATEGORY AIRCRAFT

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Prepared by:

DON W. CONLEY

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ABSTRACT

Information was obtained on the effectiveness of helicopter downwash and ground foam equipment in extending the escape time for aircraft occupants in a post-crash fire environment by burning five C-97 aircraft under similar conditions. Additional tests, not involving C-97 aircraft, were conducted relative to rescue path studies.

Test data indicated that helicopter downwash extended the escape time when fire existed solely on the upwind side of a C-97 fuselage, but reduced the escape time when fire was on both sides or solely on the downwind side of the fuselage. It was also found that helicopter downwash provided a considerable reduction in the radiant heat and air temperature in a simulated rescue path.

For the standard fire condition used and the equipment employed, the ability of ground crews to extend the escape time was found to be dependent upon the preburn time and the fuselage integrity with respect to emergency doors open or closed. An escape time of 50 seconds was computed for a C-97 with emergency doors open as compared to 138 seconds for a C-97 with emergency doors closed. Test results amplify the need for a quick arrival of extinguishing equipment and a capability for a quick "knockdown" and control of the fire.

INTRODUCTION

Purpose

The fire test program reported herein was initiated by the Federal Aviation Agency and supported by the Department of Defense (DOD). The purpose of the tests was to provide information on the ability of helicopter downwash and ground fire fighting equipment to (a) assist occupants in their escape from a large transport aircraft in a post-crash fire situation and (b) establish rescue paths. The test program was conducted at the Fire Fighting Test Facility, National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey (Reference 1) from June 1, 1964 to October 7, 1964.

Background

The United States Air Force (USAF) has been the most extensive and organized user of the helicopter as a fire-fighting vehicle. The USAF considered this concept to be such a success with small aircraft that it was adopted by the Air Rescue Service (ARS) in 1956. As of October 1961, the USAF had credited the helicopter fire-fighting concept with saving 34 persons involved in actual crash-fire accidents (Reference 2).

The USAF concept of combating fires is accomplished by the use of helicopter rotor downwash combined with the help of foam from a portable fire-suppression kit which the helicopter airlifts together with the operators to the crash scene. There is considered to be enough foam in the fire-suppression kit to extinguish small fires completely or to establish a rescue path through large fires with the added assistance of the downwash from the helicopter rotors. The helicopter is believed to provide substantial cooling to the fire-fighting and rescue personnel (Reference 3).

The original development of the helicopter fire-fighting and rescue concept by the military was intended for use on tactical aircraft where relatively few persons are involved. In September 1961, however, an HH-43 was credited by the USAF with saving 12 persons involved in the crash of a C-123 aircraft which was split open from impact and subjected to a fuel fire environment (Reference 4). There were strong indications that the HH-43 extended the survival time of the injured and made conditions tolerable for rescue personnel by ventilating the passenger compartment with rotor downwash. Since a C-123 is capable of carrying 60 passengers, it is entirely possible that the same favorable results would have occurred had the above-mentioned C-123 been fully loaded.

DISCUSSION

Test Procedures

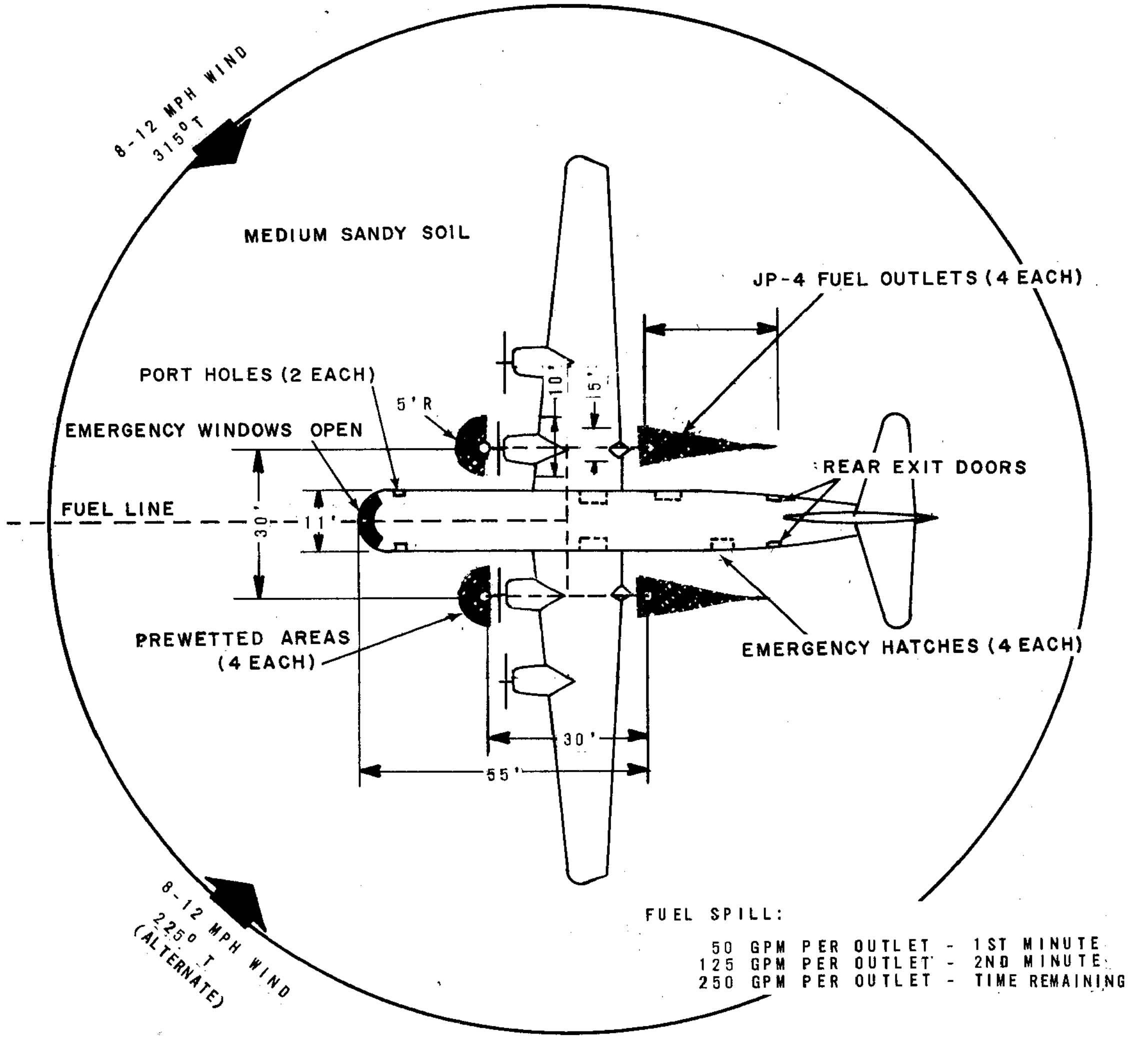
1. General

The test program consisted of two types of fire testing: (a) fires involving the burning of C-97 aircraft relative to helicopter downwash and ground fire-fighting studies, and (b) fires not involving C-97 aircraft in connection with rescue path studies.

Prior to the start of the tests, a set of conditions with respect to quantity of fuel, wind velocity, and other variables effecting the intensity of a fire were established and termed the "standard test conditions". To establish reference data on which to compare the effect of helicopter downwash and ground equipment, one C-97 aircraft was exposed to the fire resulting from the "standard test conditions", which is referred to subsequently as Test 1 or the standard test. No attempt was made to control this fire until the escape limits within the fuselage had been reached. The data collected from this fire became the reference data to which subsequent fire data were compared. A total of seven C-97 fire tests were conducted during the program including the standard test. Two of the C-97 aircraft were exposed to more than one fire. Three tests concerned ground fire fighting only, and three were primarily for helicopter downwash studies (ground trucks worked jointly on one of these tests).

The fuel spill and C-97 configuration used for the standard test conditions are illustrated in Fig. 1. (Note that fuel flowed on both sides of the C-97 and that open windows and simulated doors existed at the extreme ends of the fuselage.) This type of fuel-spill condition resulted in a fire which grew in size (wetted area) from a small fire at the instant of ignition to a large fire after a period of time.

Helicopter fire fighting Tests 2B and 4 (Fig. 2) deviated from the standard test conditions in that fire existed only on one side of the fuselage. The data obtained was still evaluated against that from the standard test and certain conclusions drawn.



STANDARD CONDITIONS AND NOTES

1. C-97 landing gear retracted and aircraft resting on its fuselage.
2. Upper deck and walls of passenger compartment insulated (5 inches thick).
3. Portholes at Fuselage Station 179 opened and 16- by 36-inch holes cut at Fuselage Station 1010 to simulate rear passenger exits. Pilot and copilot windows open. Emergency hatches (4 each) along fuselage closed.
4. C-97 fuel tanks purged with CO_2 and all aircraft hazardous components and systems removed or rectified to prevent explosions.
5. JP-4 fuel spilled at ground level from underground fuel system. Remote fuel tanks held 10,000 gallons.
6. Prewetted areas retained by 1-inch earthen dikes.
7. Fuel ignited at all four prewetted areas at same time by hand-carried torches.
8. Fuel was spilled at a total rate of 200 GPM for the first minute, 500 GPM for the second minute, and continued at 1000 GPM until either escape time was reached or the crash crew had the fire under control.

FIG. 1 STANDARD TEST CONDITIONS

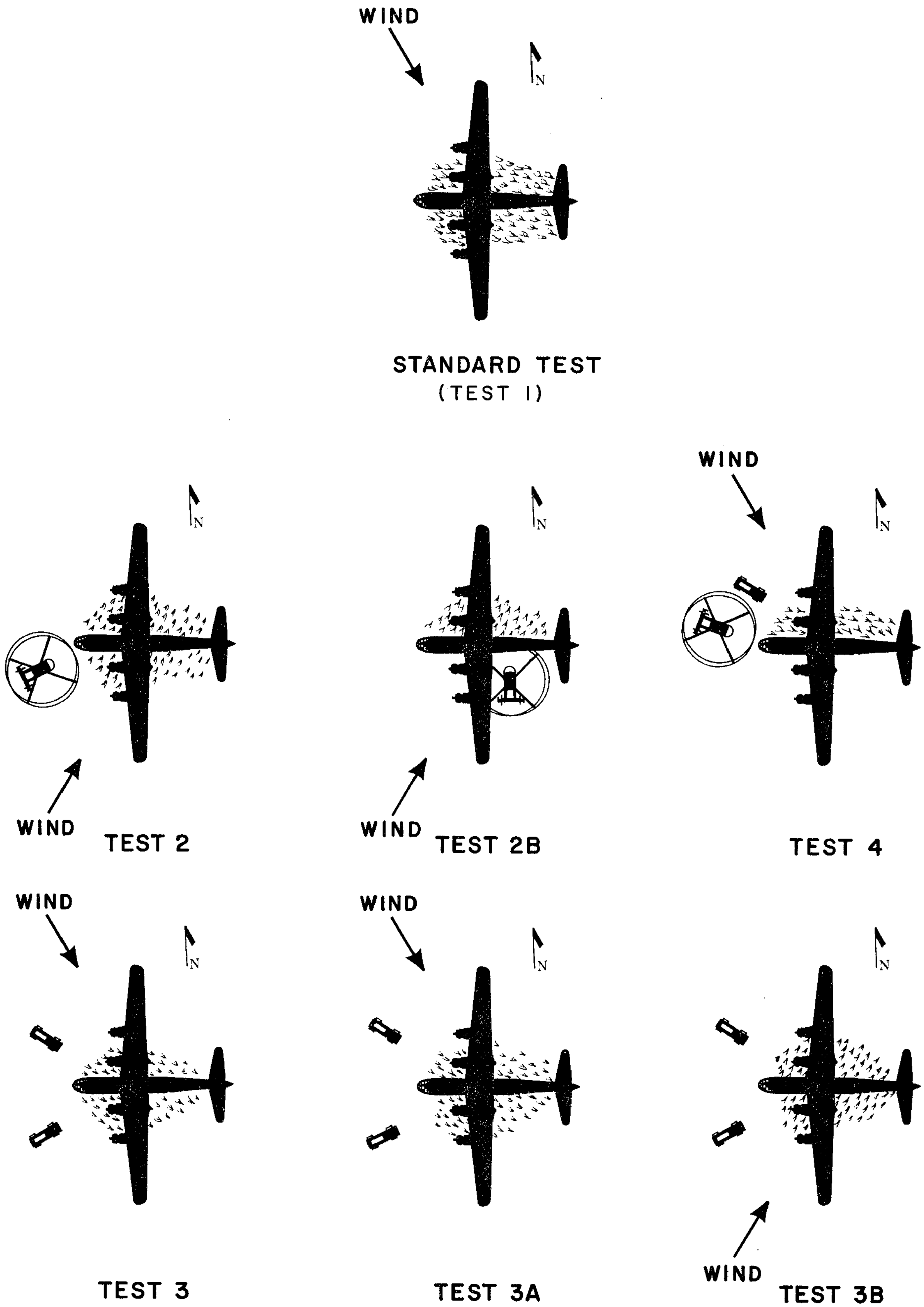


FIG. 2 GENERAL DESCRIPTIONS OF THE C-97 FIRE TESTS

The conclusions presented are based on the following assumptions: (a) The fire on the upwind side of the fuselage in the standard test was more severe than the fire on the downwind side and, therefore, was the controlling factor on the escape time obtained; (b) The external thermal environment of Test 4 would have been equal to that of the standard test for the upwind side had the helicopter not been used to influence the fire; (c) The external thermal environment of Test 2B would have been equal to that of the standard test for the downwind side had the helicopter not been used to influence the fire.

Ground fire-fighting Test 3B (Fig. 2) was conducted with a C-97 having its four emergency hatches open in addition to the other fuselage openings normally associated with the standard test conditions. The only comparison made for this test was the influence that the additional openings had on the escape time as compared to the standard test (Test 1).

Escape time was defined as the elapsed time from the instant of fuel ignition to that time when a human tolerance limit was reached which could prevent an aircraft occupant from escaping through his own efforts. These limits, discussed in Reference 5, are (a) unbearable pain due to radiant and convective heat exposures, (b) cabin air temperature of 390° F., and (c) collapse due to carbon monoxide exposures. Analytical techniques somewhat similar to those used in Reference 5 were used in computing the escape times relative to pain and carbon monoxide. During each C-97 test, measurements of the airplane's internal environment were recorded and used in determining escape time. The advantage or disadvantage of each fire-fighting technique was then expressed in extended or reduced escape time as compared to the standard test. Instruments used in the measurement of the internal and external environments were globe and disk calorimeters, radiometers, shielded thermocouples, infrared gas analyzers, and anemometers (Reference 6).

2. Helicopter Fire Fighting (C-97)

The primary helicopter used in the program was the USAF HH-43B operating with an average gross weight of approximately 7000 pounds. The HH-43B was used on all of the C-97 fire tests and most of the rescue path tests. During two of the rescue path tests, however, a United States Navy (USN) UH-2A (7000 pounds) was used. An FAA project pilot flew all test missions with the exception of the two tests which used the UH-2A.

Test procedures for the helicopter fire-suppression tests follow. Soon after the fuel had been ignited around a C-97, the helicopter pilot was notified to come in and start his suppression action. The time of arrival varied from 15 to 35 seconds after ignition. The position taken by the helicopter for those tests which involved fire on both sides (Test 2) and fire solely on the upwind side (Test 4) of the C-97 was a rotor height of 30 $\pm$ 10 feet and a ground position defined as an arc with a radius of 30 $\pm$ 10 feet (C-97 nose as a center) and running from 0^{o} relative to the C-97 heading to 30^{o} (upwind) relative to the C-97 heading. This position provided good airflow over most of the C-97 fuselage during preliminary testing. During these same preliminary tests, an effort was made to determine the optimum position for ventilating the C-97 cabin. Attempts at ventilating the cabin through the pilot/copilot windows were unsuccessful. The only noted success was when hovering on the upwind side of a C-97 with its emergency doors open and in a location defined as approximately 25 to 55 feet, rotor height, and located over the C-97 wingtip. Internal air velocities as high as 2.5 mph were recorded when hovering at these positions.

The ability of the helicopter to direct its downwash and remain stationary is a function of wind direction. It is necessary that the helicopter always be upwind from the fire area which limits the area where the downwash is effective. The helicopter hovering position taken for the single test involving the fire solely on the downwind side (Test 2B) of a C-97 was a rotor height of from 40 to 45 feet and a ground position defined as lying on the C-97 wing (upwind) and 20 feet from the fuselage centerline. Helicopter time-position data for the test program was obtained by the NAFEC Phototheodolite System (Reference 1).

After a fire test began, the helicopter normally continued its suppression action until notified by radio that a human tolerance limit had been reached inside the fuselage cabin. At this moment, the helicopter would pull away from the test site and the crash crew would start extinguishing the fire.

3. Ground Fire Fighting (C-97)

The ground fire fighting operations were performed by the NAFEC Crash Rescue Section using two 1500-gallon water/foam trucks, one 3000-gallon water tanker and a stationary 5000-gallon water tank. One 1000-pound dry chemical unit was used as a standby unit. The initial procedure for a test was to (a) position one water/foam truck on each side of the C-97 nose and (b) connect the trucks to the 5000-gallon stationary water tank through a 3000-gallon tanker truck.

Prior to the ignition of fuel, the crash crew was in an operational ready status.

For those tests which involved fire solely on one side of a C-97 fuselage, only one truck was used for the operation. The other 1500-gallon truck acted as standby, but on several occasions was called in to help control and extinguish the fire when it became apparent that it was needed.

The basic extinguishing procedure used by the crash crew was essentially the project experimental technique: (a) cool and protect the fuselage with foam, and (b) extinguish fire along fuselage and work out but guarantee rescue path integrity. Each foam truck discharged continuously at its maximum rate of 800 gpm until a fire was well under control. Handline and turret operators were directed by the Captain from each crew via hand signals and voice commands.

4. Rescue Path Study

The rescue path fire tests consisted of first measuring the thermal properties at the center of several simulated paths of various widths, all of which were exposed to similar fires. The thermal measurements were recorded with and without the influence of helicopter downwash. Tests were then conducted to determine the ability of helicopter downwash and/or ground equipment in establishing a rescue path. Thirty-foot long simulated paths were formed by separating two diked rectangular fuel areas (10 by 30 feet) at nominal distances of 10, 15, 20, 25, and 30 feet. Instruments used in the measurement of radiant heat and air temperature at the center of these paths were a disk calorimeter and a shielded thermocouple.

The test procedure for determining the ability and time required to establish a rescue path follows. JP-4 fuel was spilled (600 gallons) and ignited on the earthen test site forming a ground fire measuring about 400 to 500 square feet in wetted area. Attempts were then made at cutting a path using solely helicopter downwash, ground equipment, or helicopter downwash and ground equipment jointly.

Summary and Analysis of Results

Data from the helicopter fire tests indicated that the use of downwash can be an effective means of extending escape time when fire exists solely on the upwind side of a crashed transport. The escape time in Test 4, using downwash only, was 180 seconds at which time one water/foam truck assisted the helicopter downwash; together they extended the escape time another 154 seconds for a total of 334 seconds as compared to 138 seconds for the standard test (Fig. 3) which is an extension of 196 seconds in time available for occupants to escape. The helicopter, however, cannot be given full credit for this accomplishment since one 1500-gallon foam truck was called in to assist 180 seconds after ignition (Fig. 1, Appendix 1). The helicopter's ability to assist on upwind fires is a result of the reduction in radiant and convective heat transfer to the aircraft (Fig. 1 and 3, Appendix 3). The high velocity downwash bends the flames downward to the ground and away from the fuselage. A low radiant heat transfer absorption coefficient for the fuselage surface is achieved since this bending action prevents a deposit of combustion products on the fuselage (Fig. 1, Appendix 2).

Results from the tests conducted in which fire was on both sides of the C-97 and solely on the downwind side indicate that the use of downwash is a detriment. The escape time for Test 2 was computed as 127 seconds which is a reduction of 11 seconds in the escape time (Fig. 3). Test 2B resulted in an escape time of 123 seconds (Fig. 3) which is a reduction of 15 seconds in the time otherwise available for escape in a standard fire. This detrimental action is a result of the increased radiant and convective heating caused by the helicopter downwash (Figs. 2 and 4, Appendix 3). Test 2B provided unusual results in that the air temperature at Fuselage Station 550 (over the wing) was less than the standard test, but the air temperature at the extreme ends of the fuselage was higher than normal. This result was due to the hovering position taken by the helicopter (Fig. 2, Appendix 2).

The ability of the 1500-gallon foam trucks to extinguish the fire prior to attaining escape limits was found to be dependent on the preburn time and the C-97 fuselage integrity with respect to the fuselage emergency doors being open or closed for the given fire condition and extinguishing technique in use. A preburn time of 75 seconds was used for Test 3 (Fig. 2, Appendix 1) resulting in extinguishment of the fire and an infinite escape time (Fig. 4). Test 3A, which used the same C-97 aircraft as Test 3, was for a preburn time of 115 seconds

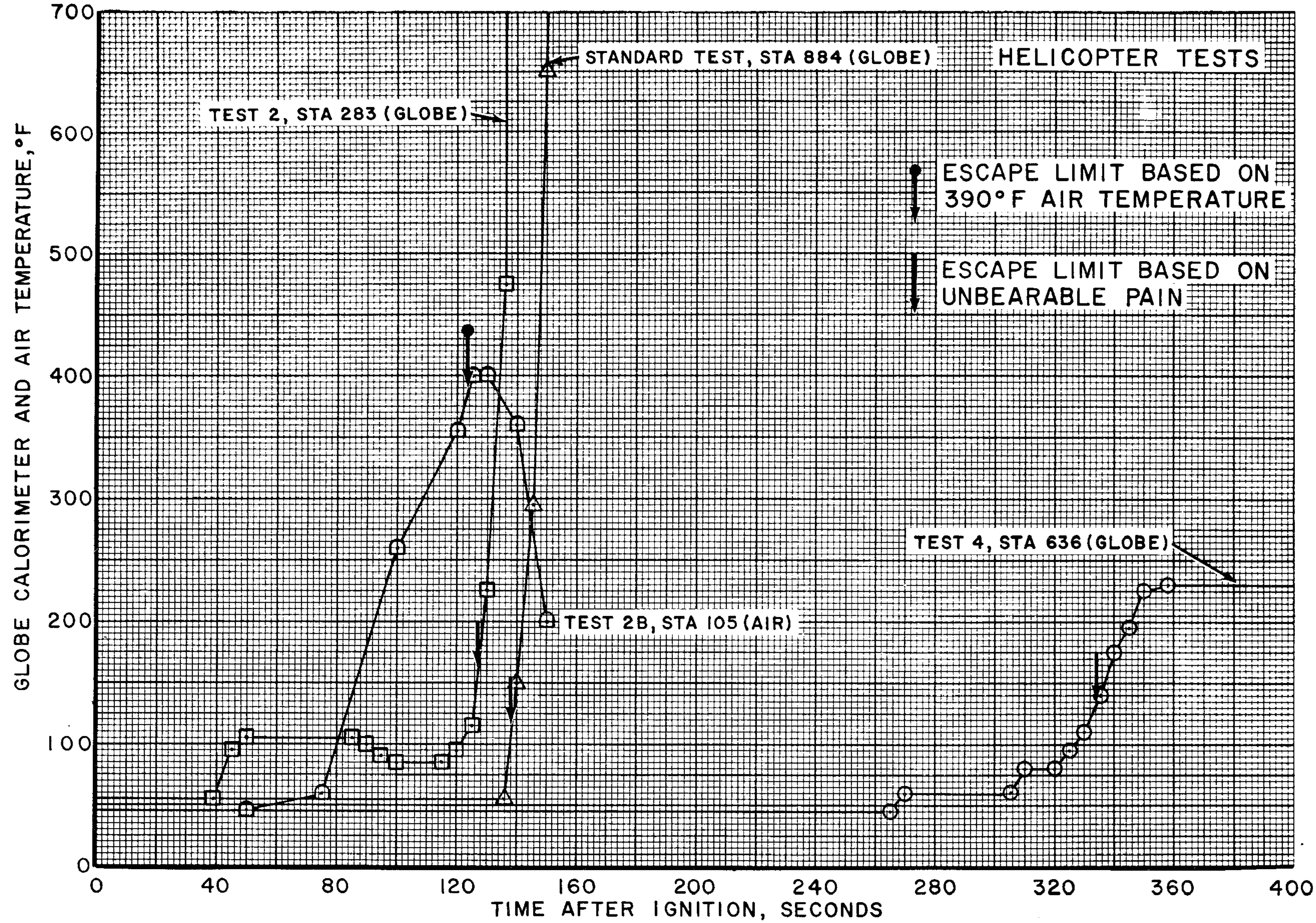


FIG. 3 C-97 CABIN THERMAL CONDITIONS AND ESCAPE TIMES FOR TESTS 1, 2, 2B AND 4

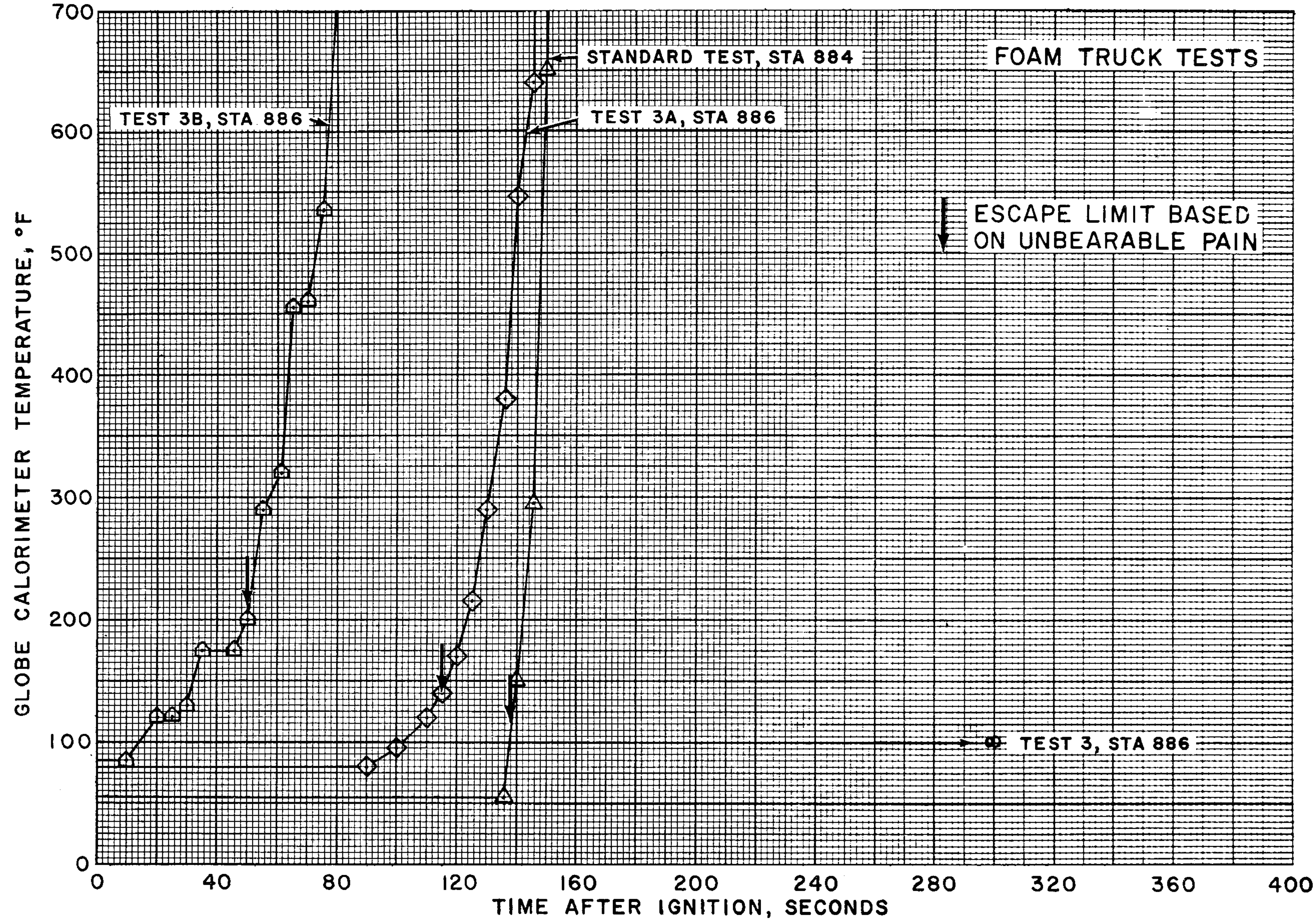


FIG. 4 C-97 CABIN THERMAL CONDITIONS AND ESCAPE TIMES FOR TESTS 1, 3, 3A AND 3B

(Fig. 3, Appendix 1). However, an escape time of 115 seconds (Fig. 4) was computed for this test indicating that the period of preburn time prior to starting the extinguishing operation was too long. Test 3A was considered more severe than the standard fire since (a) the C-97 had been exposed to a fire previously (increasing the radiant-heat absorption coefficient of the fuselage), and (b) the test site was still saturated with fuel and water from the previous day's tests causing a greater spread (area) of fuel for the standard spill rate. Test 3B, which used a C-97 with emergency doors open, resulted in an escape time of 50 seconds (Fig. 4). Crash trucks did not start the extinguishing action until 60 seconds after ignition, indicating again the prolonged preburn time before starting the extinguishing action (Fig. 4, Appendix 1).

It is of interest to compare the extinguishing techniques used for Test 3B and Test 3 since the conditions were similar except for the open emergency doors in Test 3B. Both fires were relatively small at the start of the operation; however, the critical zones next to the fuselage for Test 3 were under control in 70 seconds with a total water foam solution expenditure of 1700 gallons, while Test 3B required 150 seconds for control of the same zones and a foam expenditure of 3800 gallons (Figs. 2 and 4, Appendix 1). This big difference in the results was due to the extinguishing techniques. Foam was discharged against the fuselage for a long time period during Test 3B, but the foam discharged during Test 3 was directed alternately from ground to fuselage. The great amount of foam discharged against the fuselage during Test 3B had no retardant effect on the C-97's internal thermal rise (Fig. 4). This would suggest that concentrating the foam on the ground fire will be more beneficial than attempting to maintain a cool fuselage, especially if emergency hatches are open or if the fuselage is broken open due to impact damage. For a closed aircraft, foam discharged against the fuselage in sufficient quantities will give additional time for escape at the expense, however, of depleting the available foam supply and letting a fire increase in size (Fig. 4, Appendix 2). The discharging of foam against the ground fire for the closed aircraft will reduce the heating rate to the fuselage and will reduce the size of the fire but at the risk of the fuselage failing in some location and attainment of the escape limit resulting. The above analysis points out the need for individual judgment on the part of a crash crew regarding the approach to take upon arrival at a crash scene.

Post-fire examination of the C-97 used in Test 3B presented the following results. First, the fuselage skin was in very good condition, indicating an effective job of maintaining fuselage integrity by the crash crew. Upon entering the forward area of the passenger compartment, the first impression was that there had been no serious thermal environment inside the C-97. However, upon further and closer examination, it was observed that the vinyl covering of the fiberglas insulation had partially burned between Fuselage Stations 710 and 1166 (Fig. 4, Appendix 2). The more pronounced burning took place near the emergency hatches and simulated rear exit doors on both sides of the fuselage. Analysis of the globe calorimeter plots indicate that ignition of the vinyl was caused by radiant heat passing through the rear emergency hatch on the left side of the fuselage (The radiant heat intensity is directly proportional to the slope of the globe temperature plots). This suggests a need for more suitable interior materials for passenger cabins.

Test 3B results point out the consequence of opening emergency hatches, by airline personnel or occupants, earlier than necessary to effect escape. Such action may result in appreciably reducing the time otherwise available for occupants to escape. Test results also suggest that hatches be closed when not in use.

Of the three human tolerance parameters used in the determination of escape time, unbearable pain due to heat exposure proved to be the controlling parameter in all tests except Test 2B (air temperature of 390°F yielded the shortest time for 2B). Carbon monoxide was found not to be a principal factor in limiting escape on any test (Fig. 5, Appendix 3). No measurable carbon monoxide concentration was recorded during Tests 2B and 3, and the gas analyzer equipment was inoperative during Test 4.

Extinguishing data from the major tests show that, in most cases, 1500 gallons of water/foam solution (discharged at 800 GPM) is sufficient to gain control of at least one of the critical access zones and in some tests both zones on a single side were cleared with 1500-gallons of water/foam solution (Appendix 1). Also, data show that both forward and rear critical zones for one side of the aircraft were cleared with less than 3000 gallons of water/foam solution from one truck which is within the capacity of the vehicle when supported by a water tanker.

Of considerable importance, however, is the excessive time required to gain control of one or more of these critical access zones next to the fuselage. Data reflect a range of from 30 seconds for a small fire (Fig. 2E, Appendix 1) to more than 200 seconds for a large fire (Fig. 5A, Appendix 1), and an average of about 140 seonds for all seven tests. These data suggest a need for (a) higher foam discharge rates, and/or (b) different extinguishing agents and concepts. Ideally, what is needed is an agent and extinguishing technique which, when applied by a crash crew, will drastically reduce (not necessarily extinguish) the intensity of the overall fire in a matter of several seconds.

The joint use of ground foam trucks and a helicopter (Test 4) proved to be effective in extending the escape time. Some adverse observations were made, however, and are listed below.

a. Data reflect an extremely high consumption of foam for the joint operation. The 3000-gallon water tanker and 5000-gallon standby water tank were needed for joint operations (Fig. 1, Appendix 1).

b. Downwash can create a severe dust storm, and ground support personnel must wear goggles.

c. Downwash can lift the fire-fighters' hoods; therefore, these should be made secure for this type of operation.

d. Downwash can deflect the foam discharge stream down, and limit to some extent the effective distance and accuracy of the foam stream. Also, downwash can blow foam off fuel-wetted areas.

e. Some form of communication between pilot and ground appears to be necessary. Collision of a truck and helicopter is a hazardous possibility. Mirrors mounted on the helicopter might reduce this hazard.

Thermal values recorded at the center of the simulated rescue paths, without the effect of helicopter downwash, varied from less than 1 BTU/feet^2-second to 10 BTU/feet^2-second for radiant heat and from 300° F. to 1500° F. for air temperature, depending on the path width, wind direction, and wind velocity. These values were drastically reduced by the effect of HH-43B helicopter downwash (Fig. 5). The downwash effect is illustrated by the burn scenes of Fig. 3, Appendix 2.

Exposure to a radiant heat flux of 1 Btu/feet^2-second can produce unbearable pain in about 5 seconds and severe skin burns in about 20 seconds (Reference 7). This would suggest a path or an area in excess of 30 feet wide for safe rescue operations when aided by helicopter downwash.

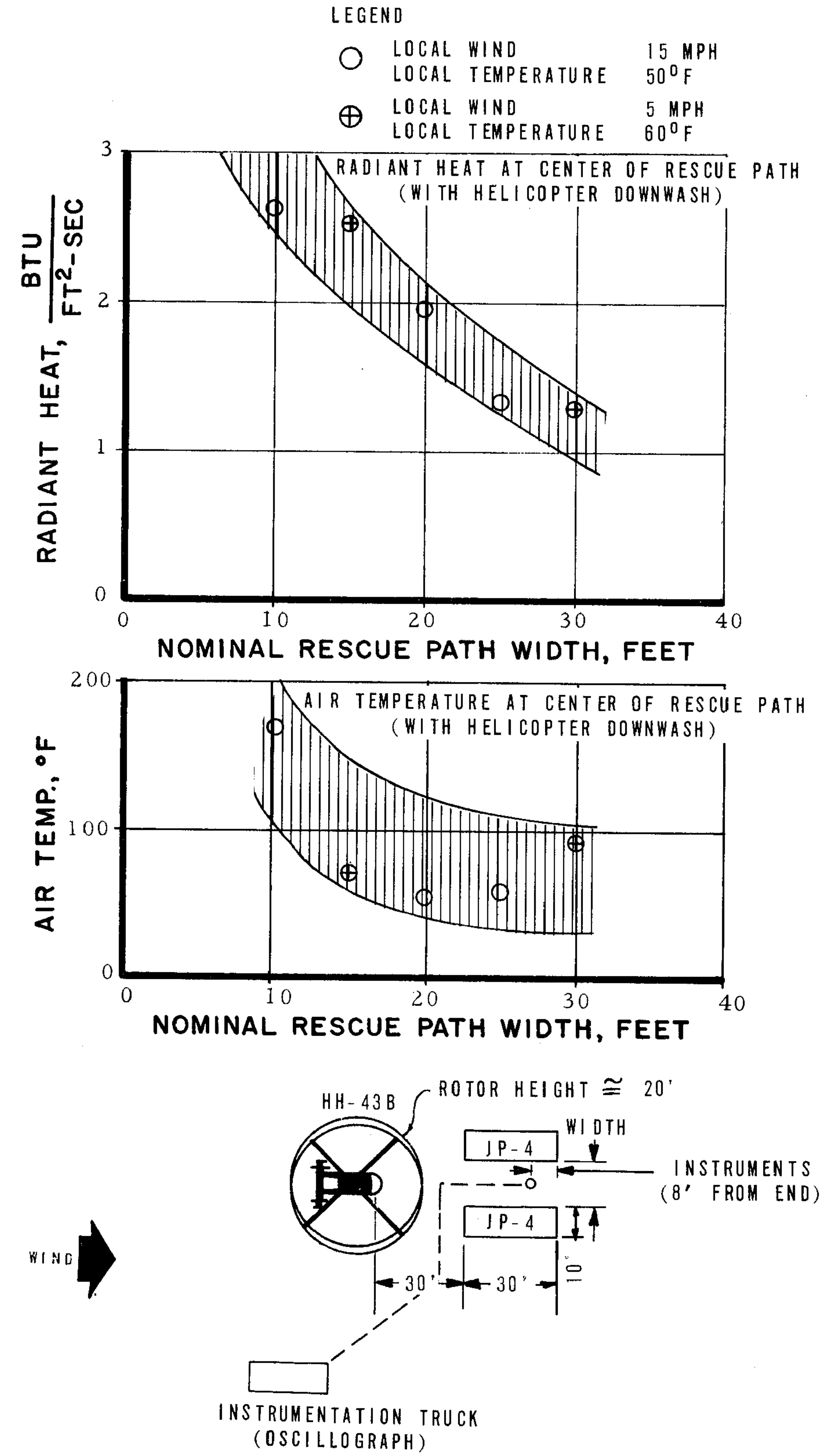


FIG. 5 TEST CONDITIONS AND THERMAL DATA FROM SIMULATED RESCUE PATH TESTS

The helicopter was unable to cut a rescue path through flames from a completely fuel-wetted area. Measurements taken on the upwind side of the fire area indicate that downwash increased the intensity of radiant heat (Fig. 6, Appendix 3).

Data from the several tests involving ground equipment alone and ground equipment working jointly with the helicopter in the cutting of rescue paths was erratic. Based on observation only, one conclusion which can be made is that technique and experience are required on the part of foam handline operators when working under the influence of helicopter downwash for the purpose of cutting a rescue path.

CONCLUSIONS

Based on the results of the fire tests reported herein, it is concluded that:

1. Helicopter downwash can be of assistance when a crashed transport is exposed to fire solely on its upwind side, however, it can be detrimental if fire exists on both its sides or on its downwind side only.

2. A helicopter and water/foam truck working jointly can extend escape time for a crashed transport exposed to fire solely on its upwind side, however, downwash can have adverse effects on the ground fire fighting operation.

3. The ability of ground crews to extend the escape time is primarily dependent upon the fuselage integrity and the preburn time for any given equipment and fire condition. The fuselage broken open from impact or with openings next to fire areas offers a much more hazardous condition than the relatively closed fuselage.

4. The extinguishing technique of discharging foam against the fuselage for the purpose of maintaining its integrity will produce less favorable results than when attacking the ground fire, when the aircraft under consideration is broken open from impact or has emergency hatches and doors open next to fire areas.

5. A quantity of 3000 gallons of water/foam solution can be adequate for controlling fires in the critical access areas next to a transport fuselage for severe fire conditions. However, control of the fires, when discharging water/foam solution at 800 GPM, can require in excess of 140 seconds which suggest a need for increased discharge rates, improved techniques, and/or new extinguishing agents and concepts.

6. The radiant heat intensity from a fuel fire located next to fuselage openings can be of sufficient strength to cause interior materials to ignite resulting in a flash fire within a passenger cabin. The selection and installation of the more suitable materials for window curtains, cabin trim and upholstery can substantially reduce the crash fire hazard.

7. The opening of emergency hatches by airline personnel or occupants while still in flight, such as in a declared emergency situation, or before the crashing aircraft slides to rest, can critically reduce the time otherwise available for occupants to escape since fire can develop adjacent to these hatches causing flash fires within the cabin.

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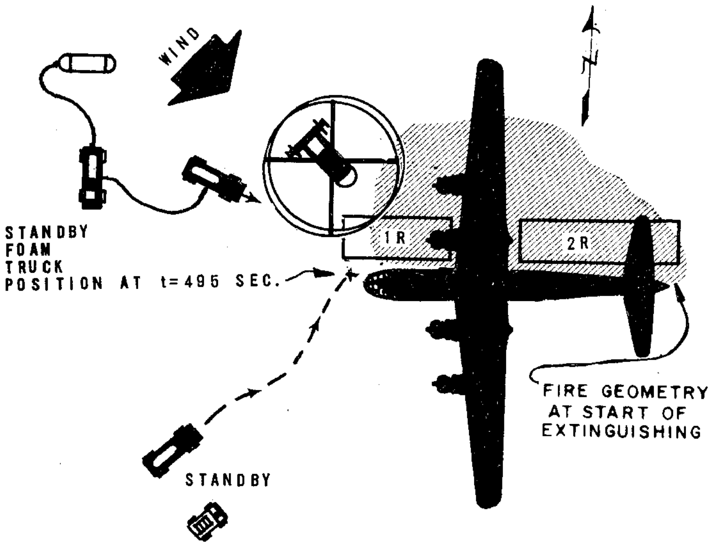
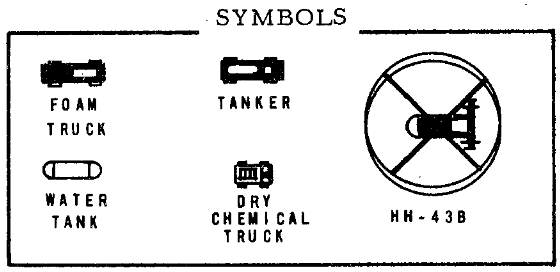
APPENDIX 1

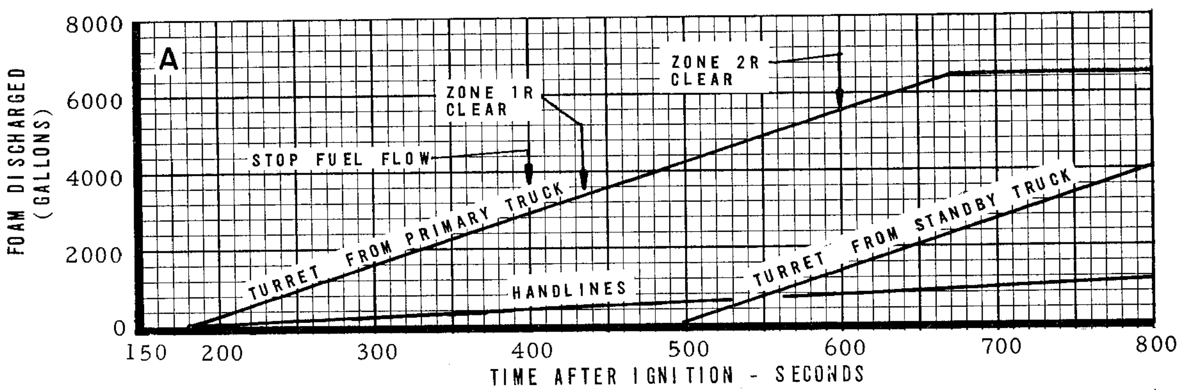
FOAM DISCHARGE DATA AND SPECIAL NOTES FOR THE C-97 FIRE TESTS

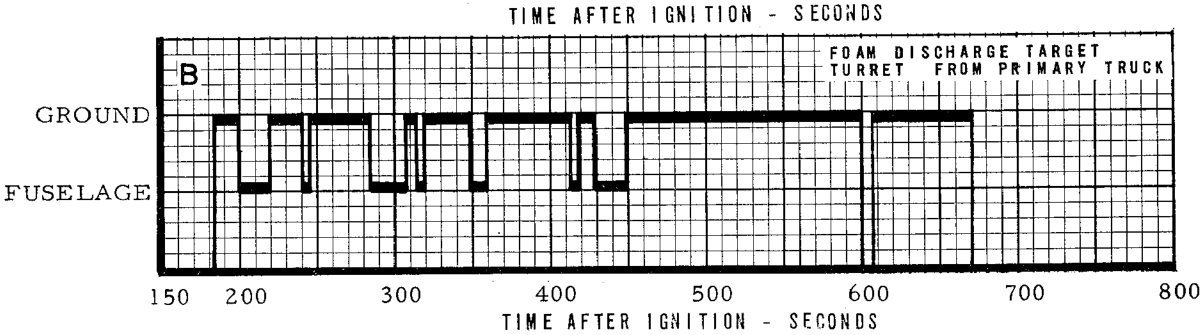




ZONE 1L & 1R = 15' x 35' LONG

ZONE 2L & 2R = 15' x 45' LONG





NOTES

1. Fuel stopped flowing 400 seconds after ignition.

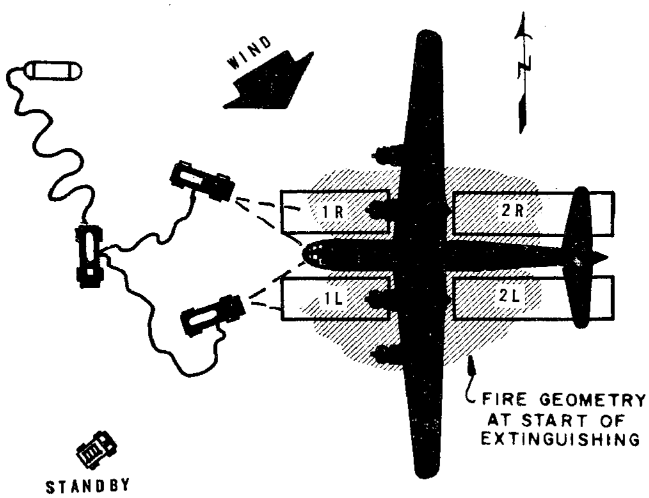
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text) except fuel was not spilled on downwind side of C-97.

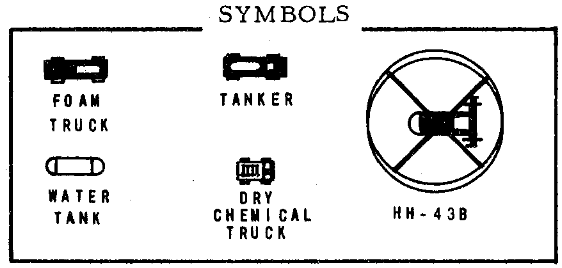
3. Average ambient wind condition was 6 mph at 315° True.

4. Helicopter arrived at crash scene 24 seconds after ignition and left crash scene 446 seconds after ignition.

5. Foam truck started extinguishing at 180 seconds after ignition (Fig. 1A above).

FIG. 1 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 4





ZONE 1L & 1R = 15' x 35' LONG

ZONE 2L & 2R = 15' x 45' LONG

NOTES

1. Fuel stopped flowing 420 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text).
3. Average ambient wind condition was 7 mph at 302° True.
4. Foam trucks started extinguishing at 80 seconds after ignition (Figs. 2A and 2C below).

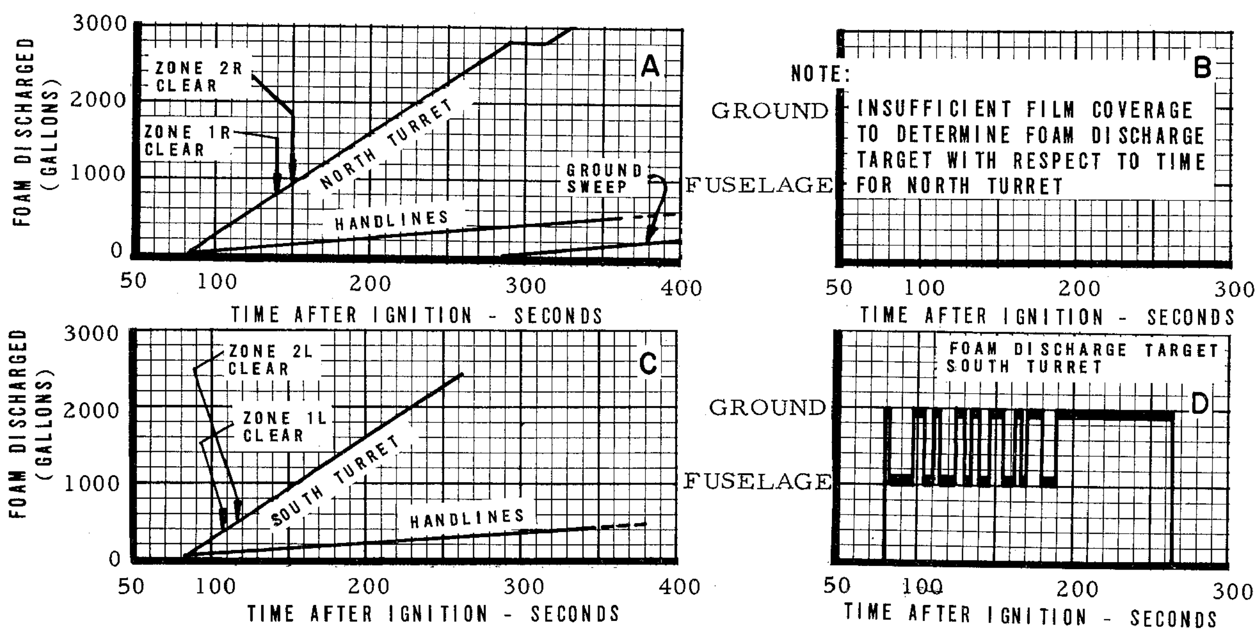
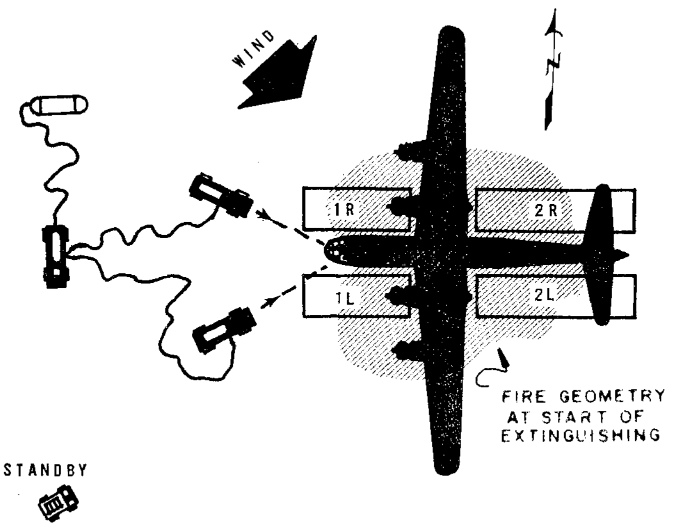
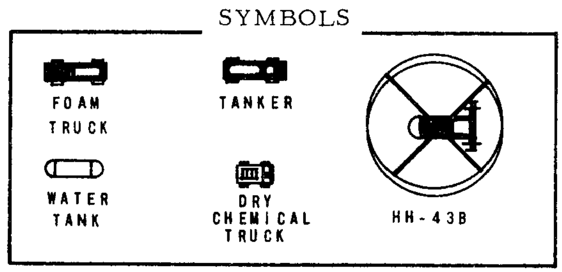


FIG. 2 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 3





ZONE 1L & 1R = 15' x 35' LONG

ZONE 2L & 2R = 15' x 45' LONG

NOTES

1. Fuel stopped flowing 390 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text) with the exception of (a) this C-97 was the same one used for Test 3, and (b) the surface condition of the site was saturated with fuel and water from the previous test; thus, this was a more severe condition than standard.
3. Average ambient wind condition was 6 mph at 315^{o} True.
4. Foam trucks started extinguishing at 115 seconds after ignition (Figs. 3A and 3C below).

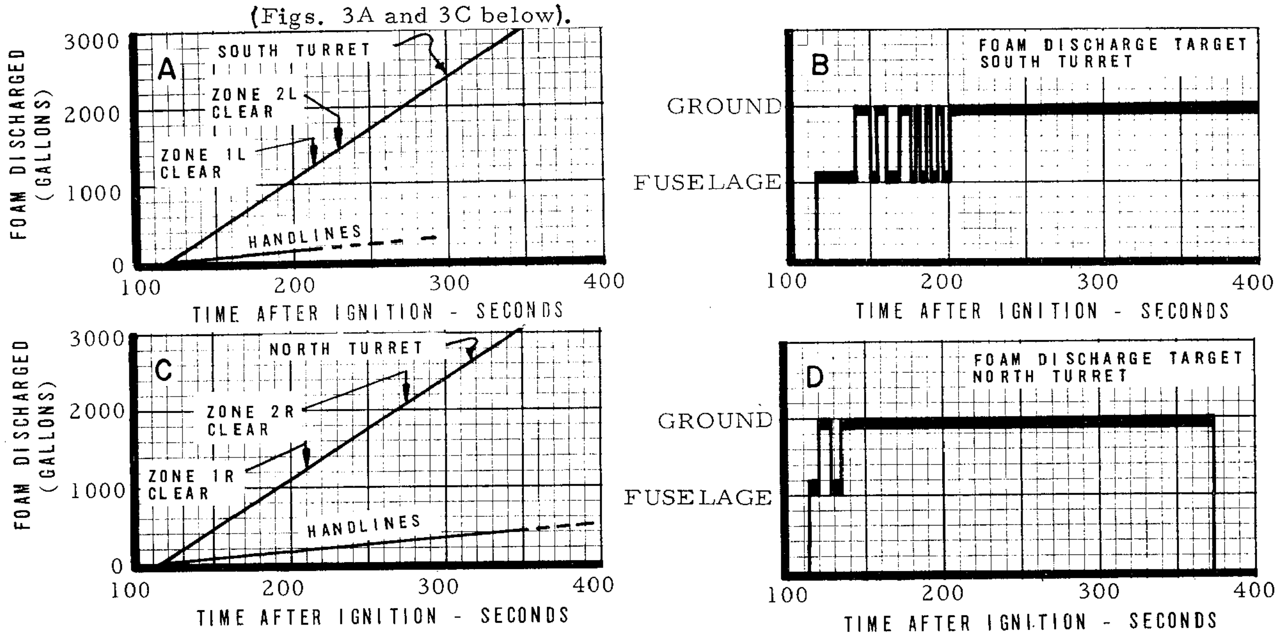
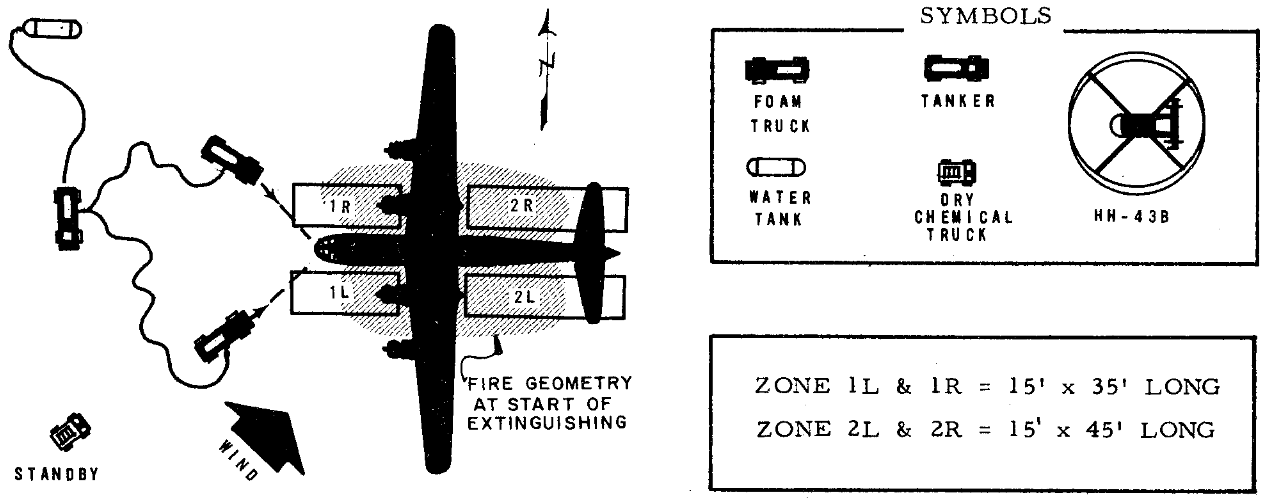


FIG. 3 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 3A



NOTES

1. Fuel stopped flowing 150 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text) with the exception that the fuselage emergency doors were open.
3. Average ambient wind condition was 9 mph at 202° True.
4. Foam trucks started extinguishing at 60 seconds after ignition (Figs. 4A and 4C below).

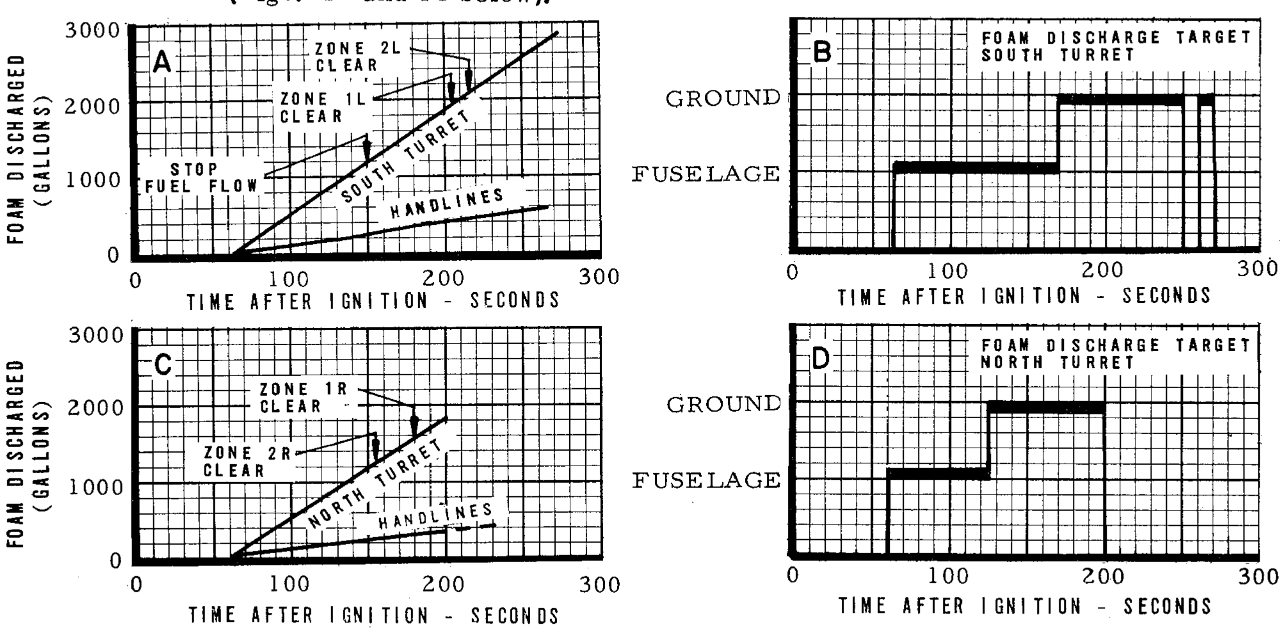
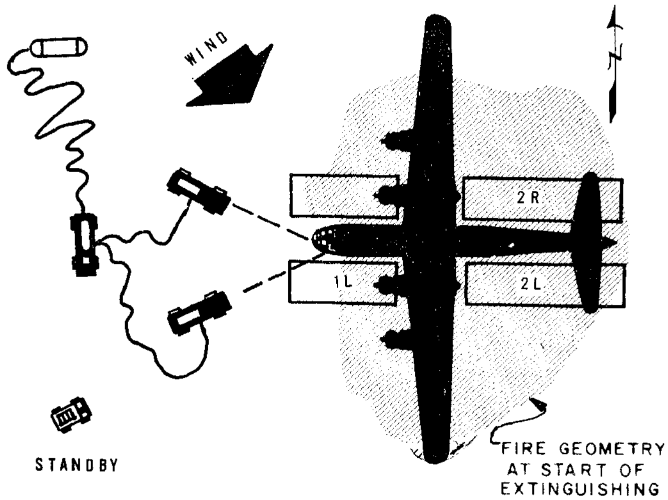
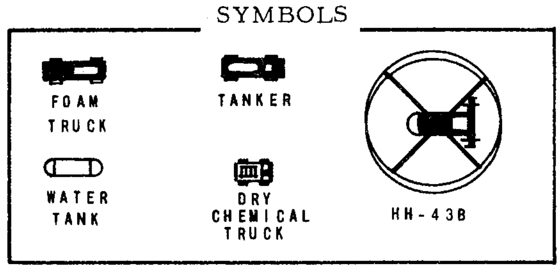


FIG. 4 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 3B





ZONE 1L & 1R = 15' x 35' LONG
ZONE 2L & 2R = 15' x 45' LONG

NOTES

1. Fuel stopped flowing 316 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text).
3. Average ambient wind condition was 8 mph at 315° True.
4. Foam trucks started extinguishing at 315 seconds after ignition (Figs. 5A and 5C below)

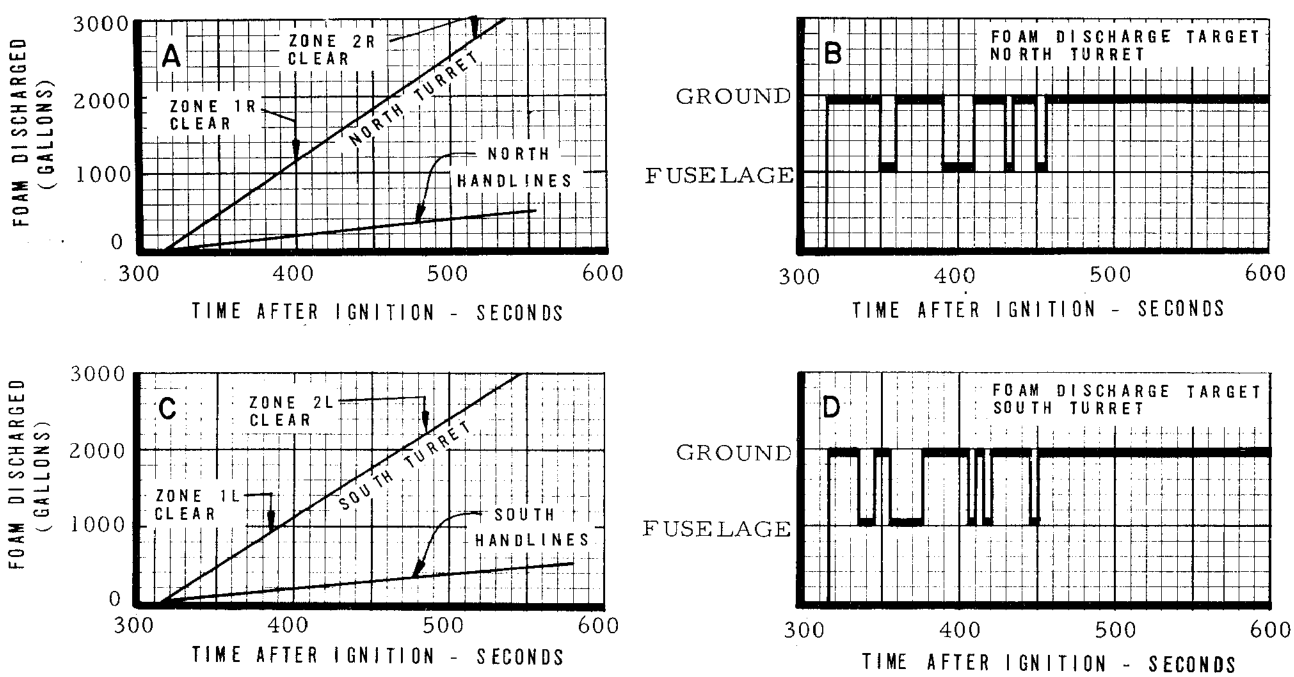
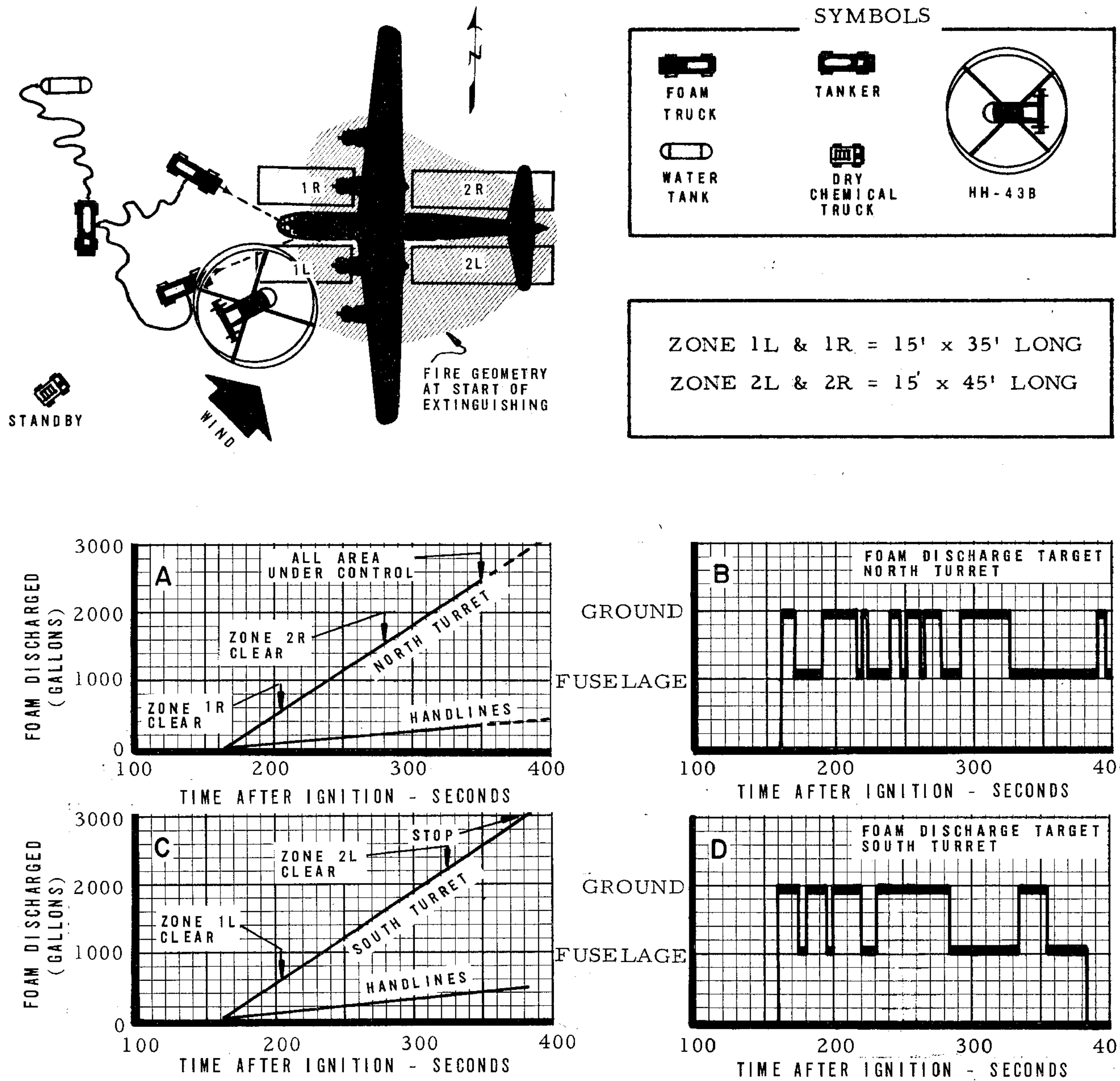


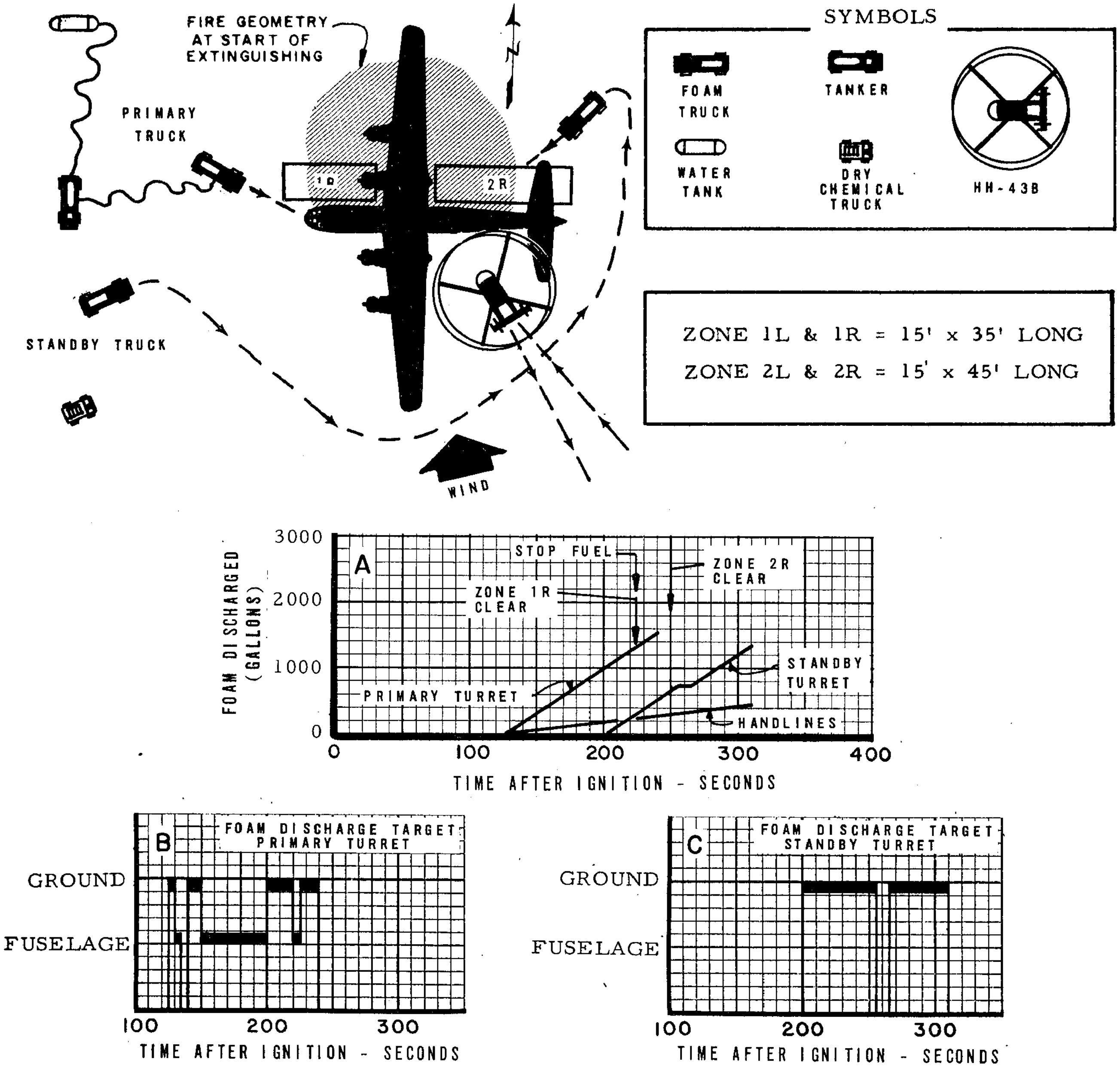
FIG. 5 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 1



NOTES

1. Fuel stopped flowing 157 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text).
3. Average ambient wind condition was 7 mph at 200° True.
4. Helicopter arrived about 20 seconds after ignition and left the crash scene about 225 seconds after ignition.
5. Foam trucks started extinguishing at 160 seconds after ignition (Figs. 6A and 6C).

FIG. 6 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 2



NOTES

1. Fuel stopped flowing 225 seconds after ignition.
2. Aircraft configuration and fuel spill were standard (Fig. 1 of text) except that this C-97 was the same aircraft used for Test 3B.
3. Average ambient wind condition was 6 mph at 158° True.
4. Helicopter arrived at crash scene 27 seconds after ignition and left 145 seconds after ignition.
5. Foam truck started extinguishing at 125 seconds after ignition (Fig. 7A).

FIG. 7 FOAM DISCHARGE DATA AND SPECIAL NOTES FOR TEST 2B

APPENDIX 2

BURN SCENES FROM THE C-97 FIRE TEST AND RESCUE PATH STUDY

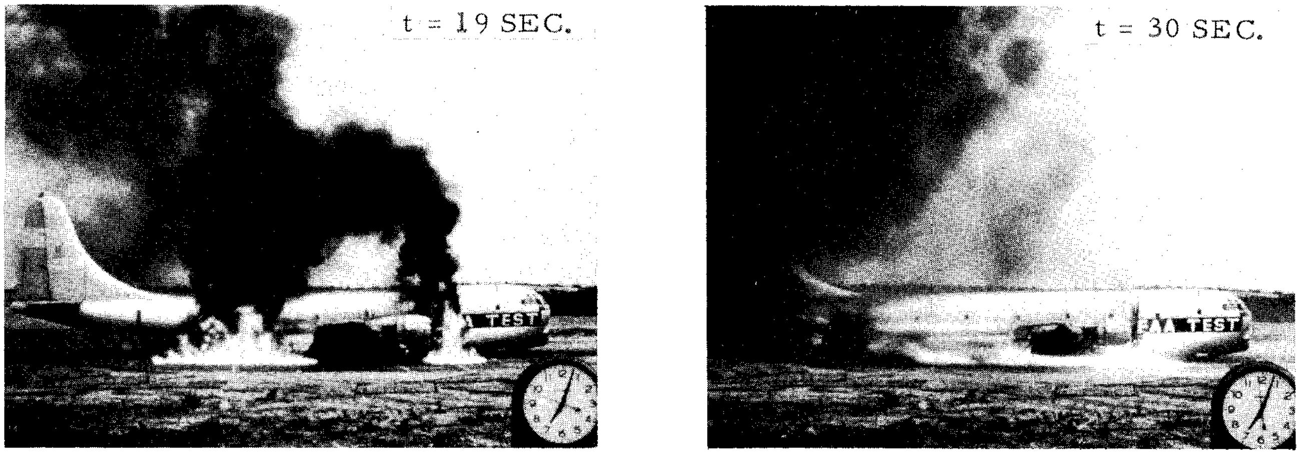


FIG. 1 BURN SCENES FROM TEST 4

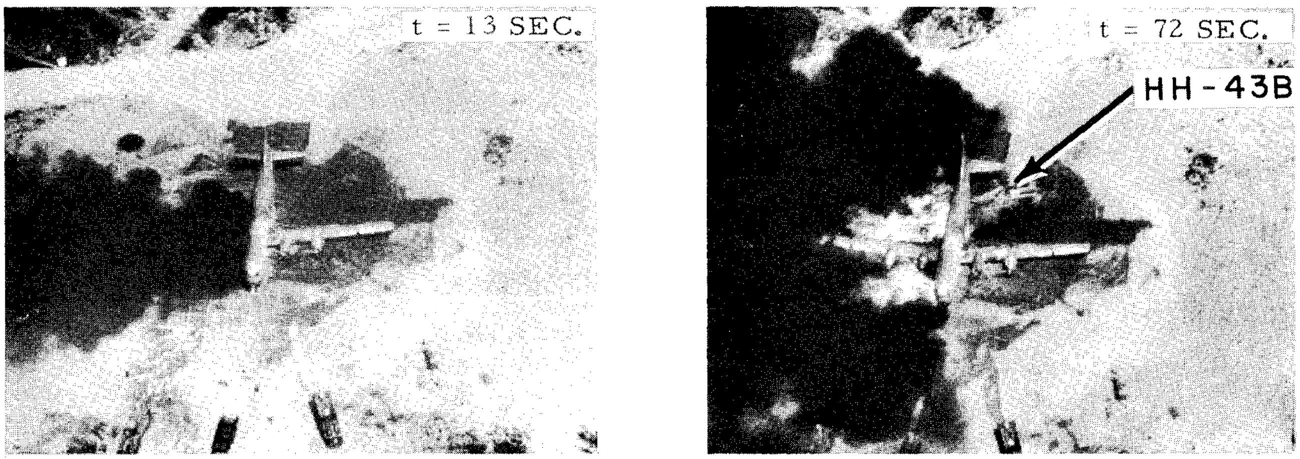
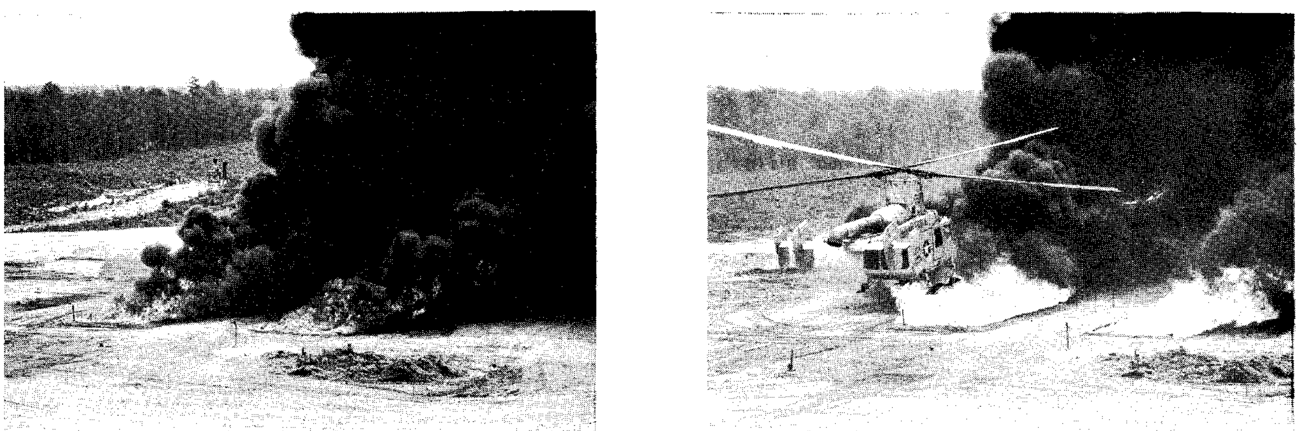


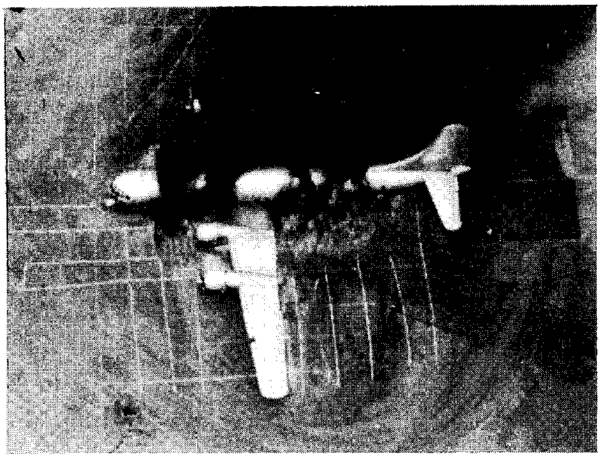
FIG. 2 BURN SCENES FROM TEST 2B



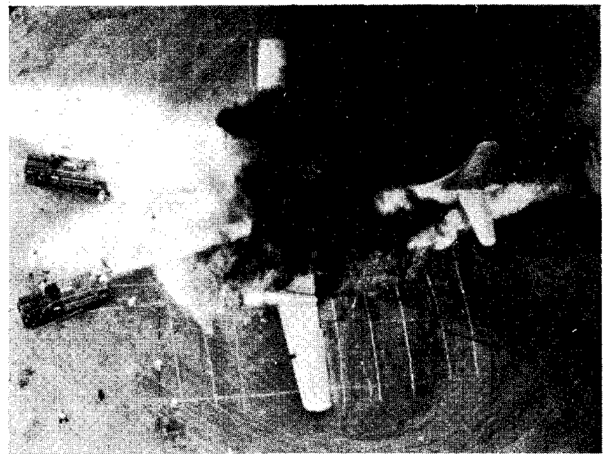
15 FT. PATH
(WITHOUT DOWNWASH)

15 FT. PATH

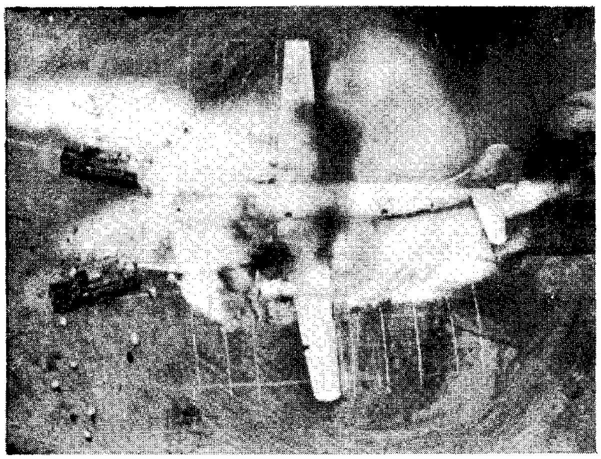
FIG. 3 BURN SCENES FROM RESCUE PATH STUDY



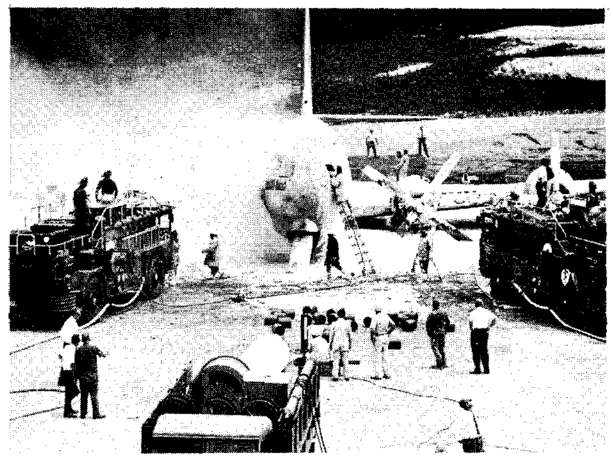
t = 58 SEC.



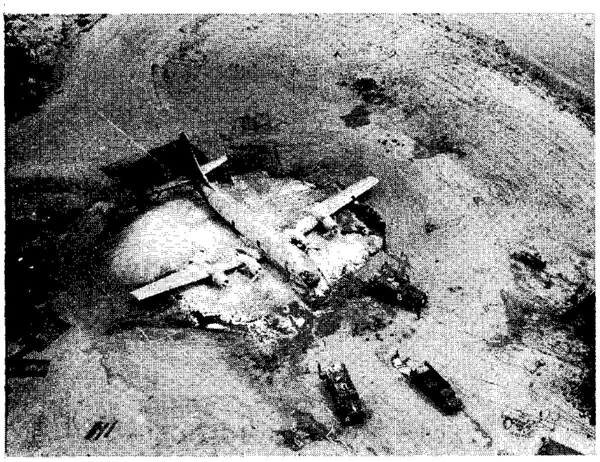
t = 150 SEC.



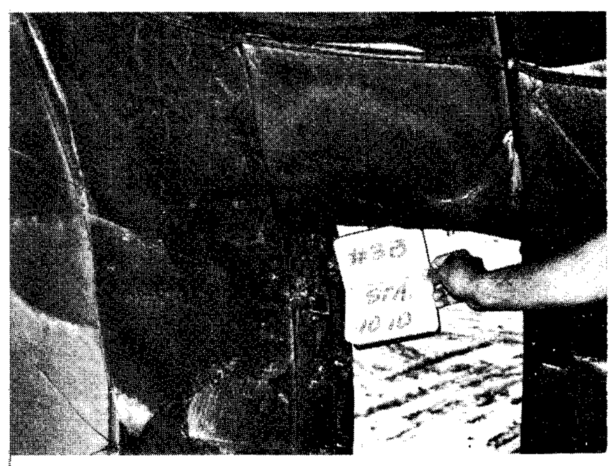
t = 200 SEC.



t = 565 SEC.



POST BURN SCENE



INTERIOR SCENE
STA. 1010

FIG. 4 BURN SCENES FROM TEST 3B

APPENDIX 3

THERMAL AND TOXIC GAS DATA FROM THE C-97 FIRE TESTS AND RESCUE PATH STUDY

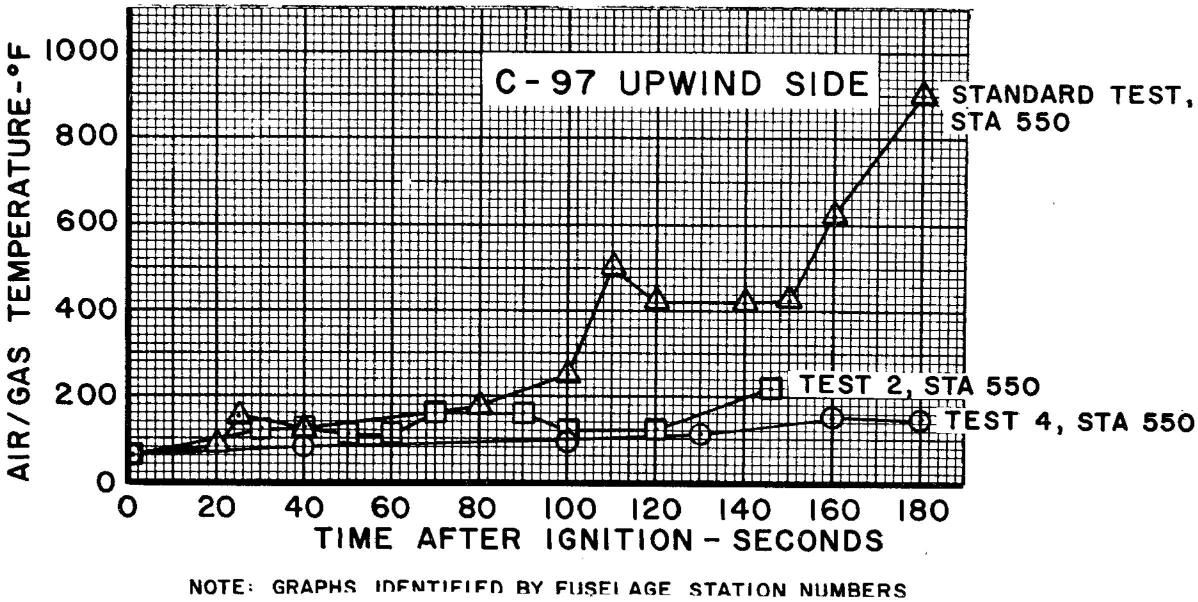


FIG. 1 EXTERNAL AIR/GAS TEMPERATURE ON THE UPWIND SIDE OF THE C-97; TESTS 1, 2 AND 4

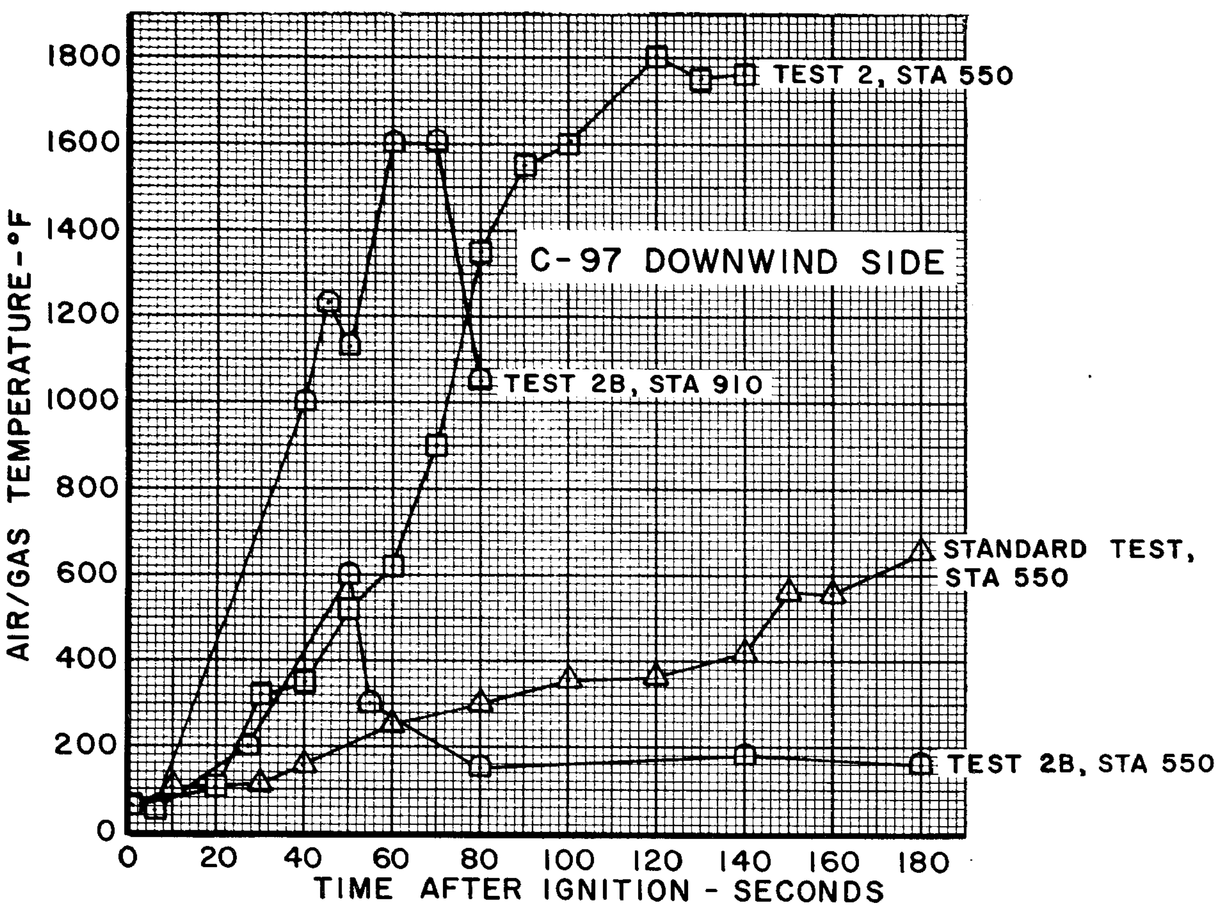


FIG. 2 EXTERNAL AIR/GAS TEMPERATURE ON THE DOWNWIND SIDE OF THE C-97; TESTS 1, 2 AND 2B

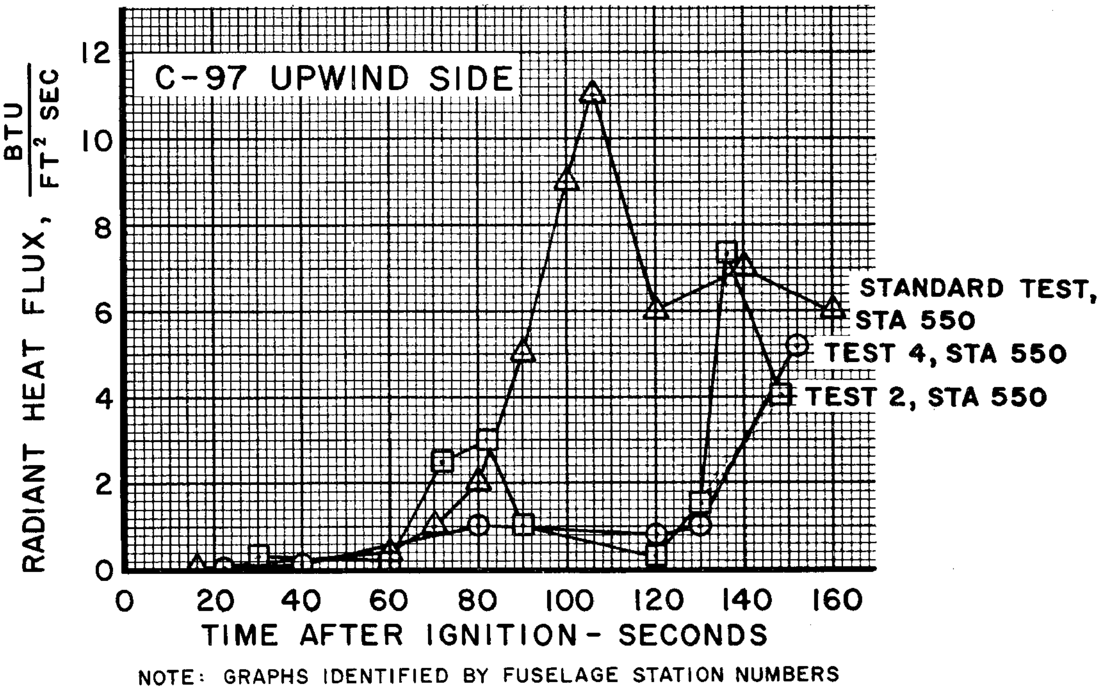


FIG. 3 RADIANT HEAT INCIDENT UPON UPWIND SIDE OF C-97 FUSELAGE; TESTS 1, 2 AND 4

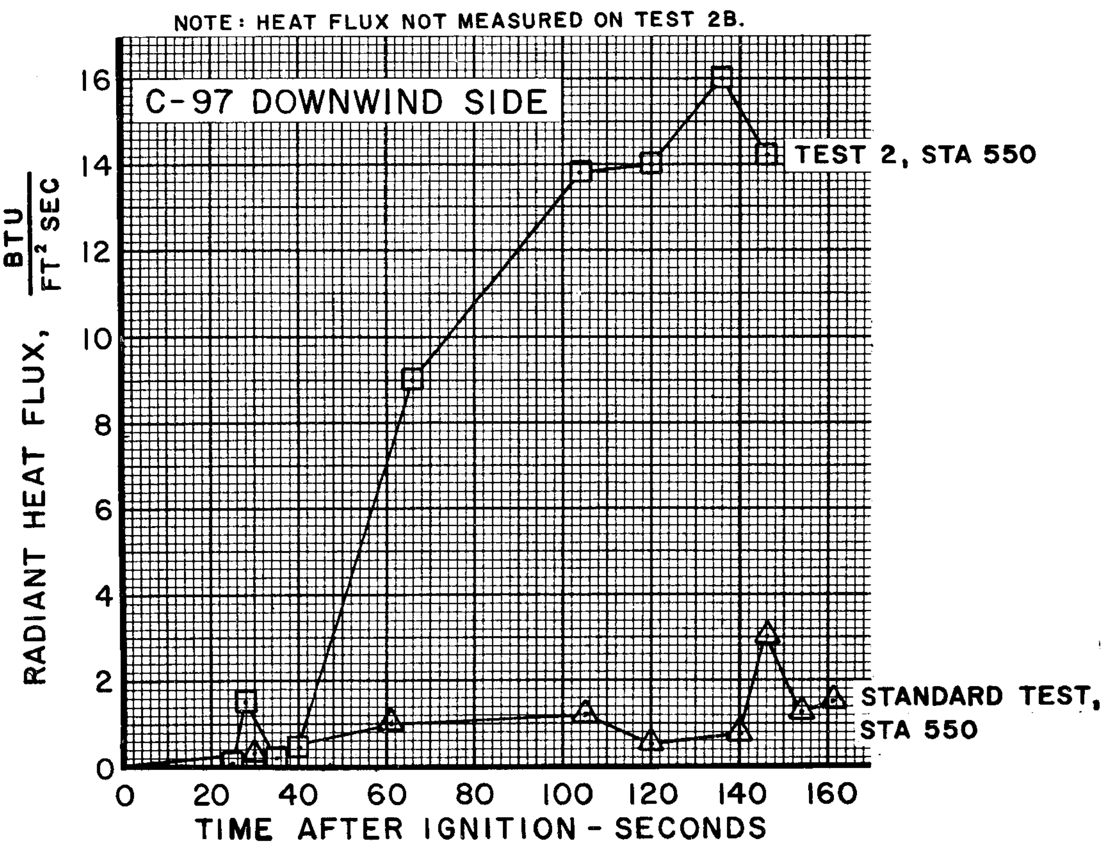


FIG. 4 RADIANT HEAT INCIDENT UPON DOWNWIND SIDE OF C-97 FUSELAGE; TESTS 1 AND 2

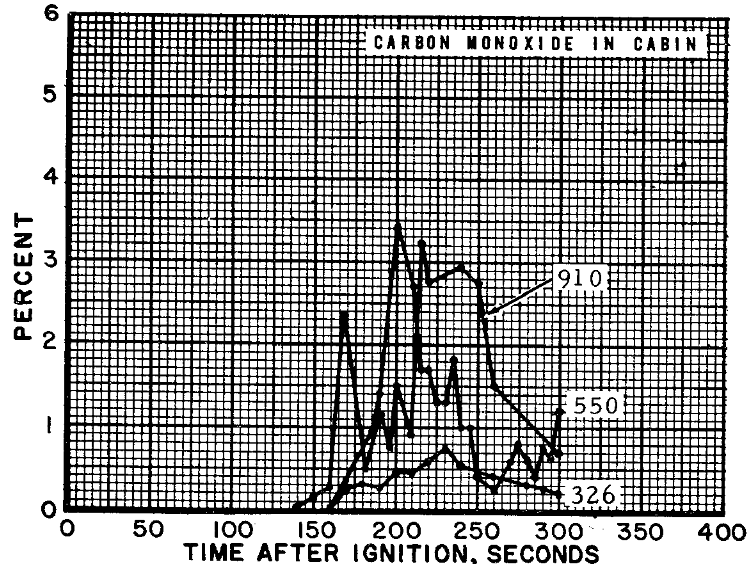


FIG. 5A TEST 1 DATA

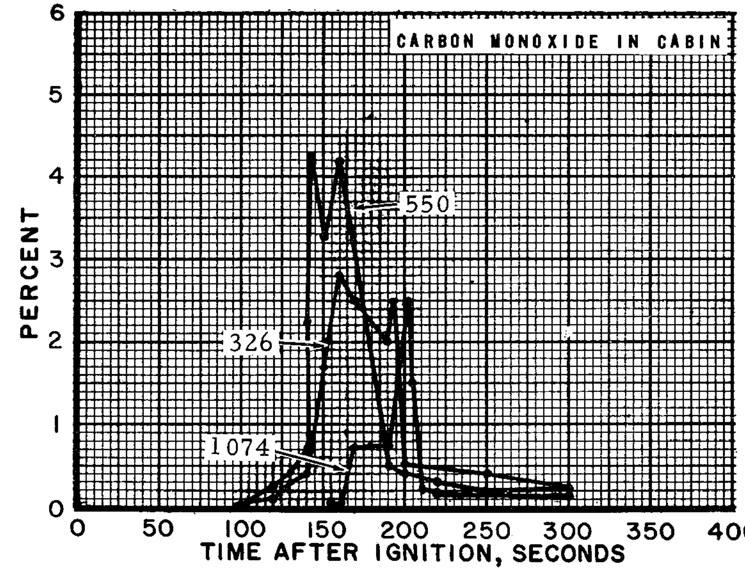
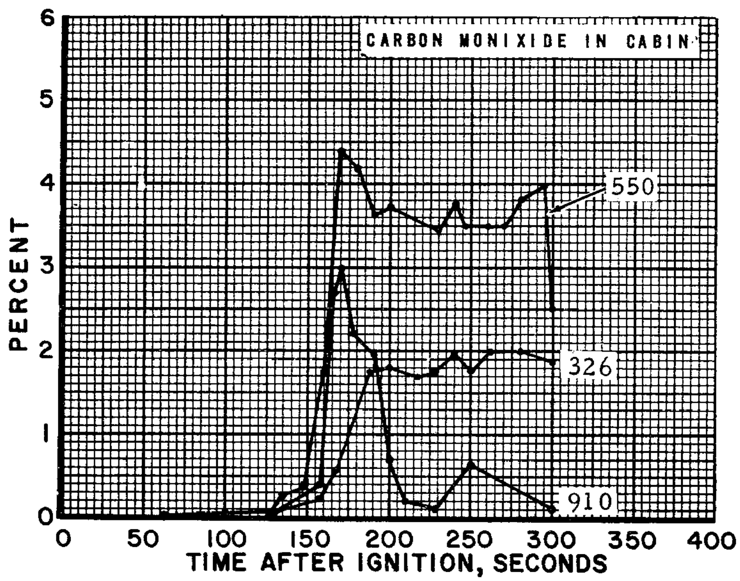


FIG. 5B TEST 2 DATA



FIG, 5C TEST 3A DATA

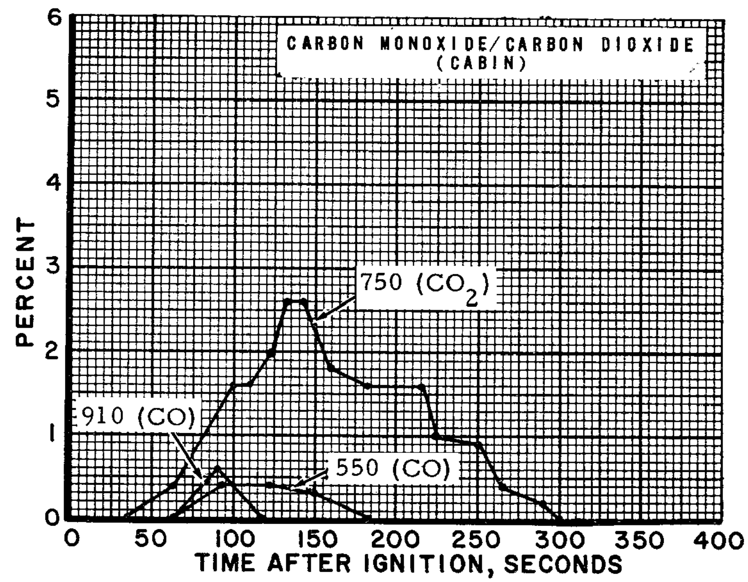
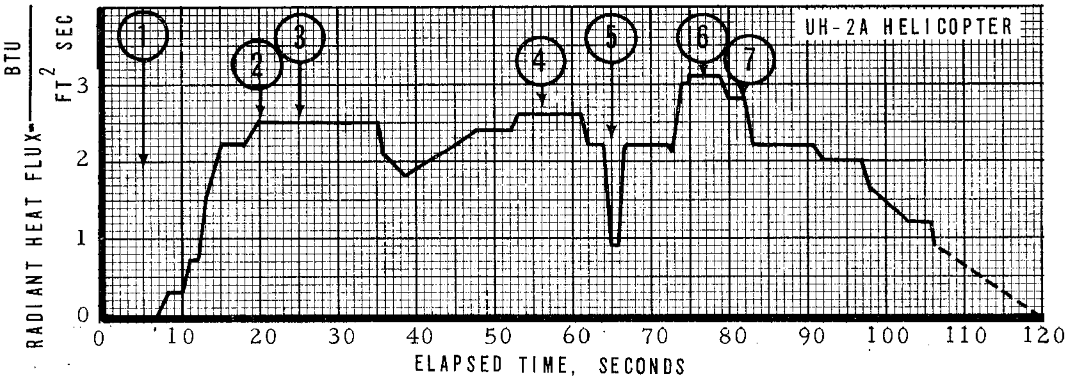


FIG. 5D TEST 3B DATA

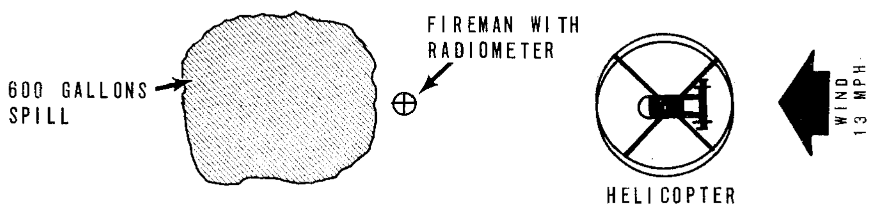
NOTE: GRAPHS IDENTIFIED BY FUSELAGE STATION NUMBERS

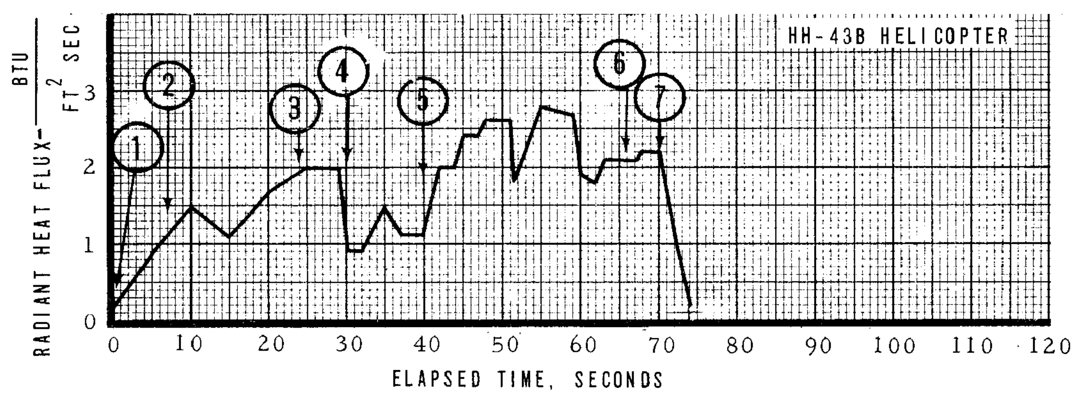
FIG. 5 CARBON MONOXIDE CONCENTRATIONS RECORDED IN THE C-97 FUSELAGE CABIN; TESTS 1, 2, 3A AND 3B



SEQUENCING

1. Fireman holding radiometer approaches fire at a distance of about 40 feet.
2. Fireman standing fixed next to fire at about 3-foot distance.
3. Helicopter approaching (200-yard distance).
4. Helicopter approaching (35-yard distance).
5. Fireman turns around.
6. Helicopter hovering at a distance of about 15 yards.
7. Fireman backs out away from fire.





SEQUENCING

1. Fireman holding radiometer approaches fire.
2. Fireman stops at about 6-foot distance from fire.
3. Owing to discomfort to hands, fireman backs up about 3 feet.
4. Owing to discomfort, fireman backs out away from fire to a distance of about 12 feet.
5. Helicopter arrives and hovers at a distance of about 10 yards from fire.
6. Fireman backing out away from fire.
7. Fireman turns away from fire.

FIG. 6 RADIANT HEAT INCIDENT UPON FIREMAN STANDING ON UPWIND SIDE OF A FIRE, WITH AND WITHOUT HELICOPTER DOWNWASH