Determination of Means To Safeguard Rotary-Wing Aircraft From Powerplant Fires in Flight

Part 1

Fire-Detection and Fire-Resistance Studies of a Sikorsky H-5A Helicopter

By

Glenn S Laudig

Aircraft Division

TECHNICAL DEVELOPMENT REPORT NO. 351

FEDERAL AVIATION AGENCY
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

February 1959

FEDERAL AVIATION AGENCY
Elwood R. Quesada, Administrator
D M Stuart, Director, Technical Development Center

TABLE OF CONTENTS

DETERMINATION OF MEANS TO SAFEGUARD ROTARY-WING AIRCRAFT FROM POWERPLANT FIRES IN FLIGHT

PART I

FIRE-DETECTION AND FIRE-RESISTANCE STUDIES OF A SIKORSKY H-5A HELICOPTER*

FOREWORD

The investigation covered by this report was conducted at the FAA Technical Development Center, Indianapolis, Indiana, under U S Army Transportation Research and Engineering Command, Contract 21X2040 709-9062 P 5030-07 S 44-019, Subtask 701, Project 9-38-01-000, dated December 11, 1956

SUMMARY

The results of a series of simulated in-flight fire tests to determine means for the adequate fire protection of a Sikorsky H-5A helicopter are presented with the intention of applying some of the results to rotary-wing aircraft of present and future design The tests conducted on the H-5A installation represent the first in a series of simulated in-flight fire studies conducted on rotary-wing aircraft by the FAA Technical Development Center Results are presented in three parts as follows

Fire Detection.

Airflow and flame paths under simulated flight conditions were studied and optimum fire-detector locations for effective fire detection were determined Edison continuous-type, fire-detector elements were used during the tests for determining locations in the H-5A powerplant installation

Ignition Hazards.

Hydraulic fluid, lubricating oil, and aviation gasoline were sprayed on the engine hot-exhaust surfaces during simulated flight conditions and the exhaust surface temperatures at which these fluids ignited were determined Hydraulic fluid and lubricating oil ignited when the metal surface temperature of the exhaust manifold stacks exceeded 900° F. Gasoline did not ignite at 1,150° F , which was the maximum exhaust surface temperature attainable under the test conditions.

Fire Resistance

A severe (3 gallons per minute) 5-minute fire test was conducted under simulated autorotative descent conditions Results of this test showed that ambient temperatures in excess of 2,000° F could be expected in the powerplant during a severe in-flight fire. Surfaces subject to flame impingement, unless constructed of stainless steel or equivalent material, burned away rapidly and aggravated the fire

INTRODUCTION

In recent years, the transport-type helicopter has added to the already complex helicopter fire-protection problem This type of aircraft required additional power to meet its performance specifications of carrying a large payload with more passengers and fuel The over-all fire resistivity must be maintained for a longer time in order to allow the

---

*Reprinted for general distribution from a limited distribution report dated June 1958.

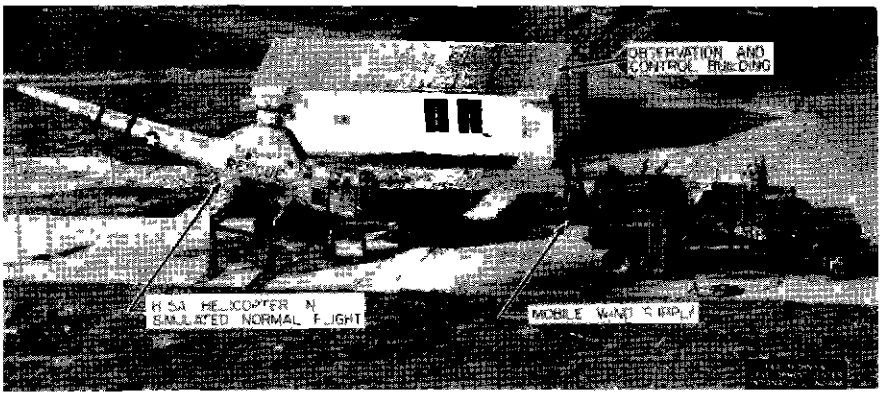

Fig. 1 Helicopter In-Flight Fire Test Facility - Normal Flight Attitude

aircraft to autorotate safely to the ground should fire occur at a high altitude. The development of means to safeguard rotary-wing aircraft from fires originating in the powerplant is a subject of vital interest to both civilian and military operators, and to the FAA

Information was needed to determine the ignition hazards and the fire-detection requirements necessary to provide fire safety in helicopters of present and future designs In line with these needs, and to obtain general information on the helicopter powerplant fire problem, a fire-test program was conducted at the Technical Development Center (TDC) under sponsorship of the Department of the Army. The evaluation of the results of this test program enables certain design criteria to be presented as a general guide for rotary-wing aircraft fire safety

TEST FACILITIES

The test facility shown in Figs 1 and 2 was constructed in order that fire problems could be examined under simulated normal and autorotative flight conditions. A mobile wind machine constructed on a truck bed and made up of an Allison 3420 engine driving two counterrotating propellers was used to supply air to simulate flight conditions Normal flight with a relative airspeed of 85 mph at an angle of 10° to 15° was simulated by lowering the nose of the helicopter Autorotative descent having a relative airspeed of 65 mph at an angle

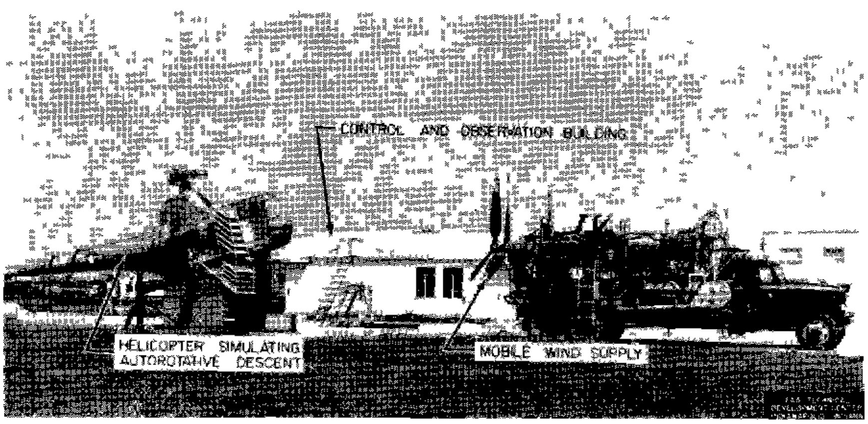

Fig 2 Helicopter In-Flight Fire Test Facility - Autorotative Attitude

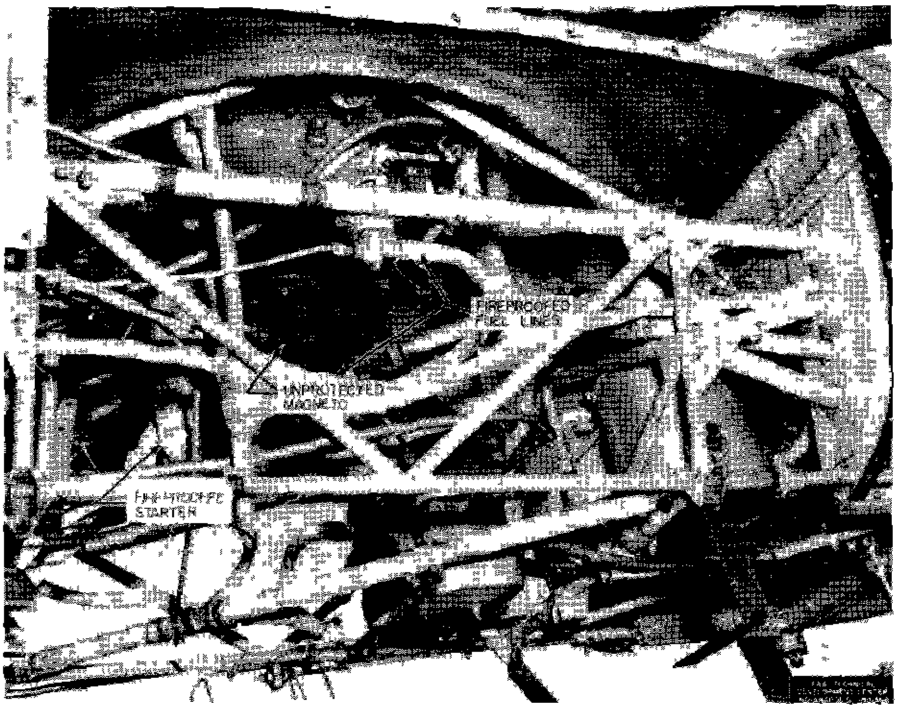

Fig 3 Left Side View of H-5A Engine Accessory Section

of 45° was simulated by raising the nose of the helicopter 15° and utilizing 30° angle air deflection vanes

Pitot static tubes were positioned at various locations within the powerplant, and air pressures were recorded during simulated flight The carbon monoxide contamination was measured in the passenger compartment during a severe fire by a Mine Safety Appliance Co Type B-1 carbon monoxide detector

Temperature measurements using chromel-alumel thermocouples were recorded by Brown self-balancing pyrometers The helicopter used for these tests was a Sikorsky YH-5A with three-bladed main and tail rotors These rotors were removed in the interests of personnel safety. The fuselage was constructed of welded steel tubing covered with aluminum and divided into three principal sections the cabin section, center or main section, and tail cone section The center section, which housed the powerplant, had steel firewalls fore and aft and was divided into an engine compartment and an accessory compartment, with a horizontal baffle between them

The helicopter was powered by a Pratt and Whitney Model 985AN5 nine-cylinder radial air-cooled engine mounted in an upright position and encircled by an aluminum ring cowling. A fan, spline-coupled to the transmission shaft, supplied cooling air when the engine was running The cooling air was forced down between the cylinders and out through the longitudinal opening on each side of the center section Cooling air also was forced through the exhaust collector ring shroud, the oil coolers, and into the carburetor air mixture chamber

Engine controls and accessories were located in the accessory compartment below the engine power section Many of the accessories, as well as the fuel and oil lines, were protected from flames during the tests by a covering of asbestos and water glass, as shown in Fig 3 Critical control surfaces, air ducts, bolted joints, tubular truss structure, cowling, firewalls, and oil coolers were left exposed to the fire

Air was supplied to the carburetor, mounted on the lowest part of the engine, through one filtered and one unfiltered air duct, the inlets to which are shown in Fig 4 The controls,

Fig 4 Right Side View of H-5A Helicopter Autorotative Attitude

operated by a series of push-pull rods and bell cranks, passed through forward firewall bushings of fire-resistant material which sealed the holes. Twin oil coolers of soldered aluminum construction were located in the accessory section in front of the lower rear firewall Air ducts from the engine cooling system directed air to each cooler Lubricating oil was carried to the engine through aluminum oil lines from the accessory section

Aluminum fuel tanks of welded construction normally were located fore and aft of the engine compartment and separated from it by firewalls One oil tank, located aft of the engine, remained installed for the fire tests, whereas the engine fuel tank was removed Fuel lines constructed of aluminum tubing and fittings passed through the accessory section

FIRE-DETECTION STUDIES

Fire-detection tests were conducted to determine the most effective fire-detector element locations within the H-5A helicopter powerplant These locations were determined by studying data obtained from airflow and flame path tests conducted under various simulated flight conditions Continuous-type fire detectors then were installed in the H-5A powerplant in these locations, and simulated in-flight fires were ignited to determine the fire-detector response

Airflow Tests.

Tests were conducted to measure the air velocity and direction in the H-5A powerplant during simulated flight conditions The data obtained from these tests are presented in Table I Five pitot tubes were used to obtain the measurements shown Airflow pitot tube position C described in this table remained stationary and was used as a reference point throughout the test series Other pickups were moved about to analyze the airflow pattern

Airflow measurements were taken during simulated autorotative descent under the following conditions

1 Engine operating with ventilating shutters closed
2 Engine operating with ventilating shutters open

TABLE I

MEASURED AIR VELOCITIES IN THE H-5A HELICOPTER ENGINE NACELLE UNDER SIMULATED AUTOROTATIVE DESCENT CONDITIONS

		Air Velocity in Miles Per Hour			
		Engine Running		Engine Not Running	
Pitot Tube	Location	Shutters Closed	Shutters Open	Shutters Closed	Shutters Open
A	Below left oil cooler and above rear port deflector pointing into 45° airflow	40	40	40	40
B	Above left front port of air deflector pointing into 45° airflow	59	61	61	59
C	On left side cowl of engine compartment pointing into 45° airflow	58	61	59	58
D	Above right front port of wind deflector pointing into 45° airflow	67	58	69	67
E	Below and between No 2 and No. 3 cylinders pointed up.	14	14	29	29
F	Near air intake pointed down.	13	0	20	15
G	At rear firewall above fan pointed down	0	0	25	20
H	Above fan blades pointed up	14	14	0	0
I	At front firewall above fan at shield pointed down	0	0	0	0
J	Under cylinder No 1, right front side pointed up inside shroud	32	40	25	14
K	Under cylinder No 1, in front pointed up	32	37	0	0
L	Under cylinder No 5, pointed up inside shroud.	0	17	0	0
M	Pointed up inside exhaust shroud.	0	29	25	14
N	Under cylinder No 3, pointed up inside shroud.	20	20	17	20
O	At rear of crankcase between fan and crank-case pointed up.	0	0	0	0
P	Above fins of No 1 cylinder pointed up at fan blades	0	0	0	0
Q	Near 12 o'clock position on crankcase pointed up between fan and crankcase	0	0	0	0
R	Above fins of No. 8 cylinder pointed up	0	0	0	0
S	In right oil cooler duct pointed up	20	20	0	15
T	Above forward air intake on right side pointed down.	0	10	0	10
U	Above forward air intake on left side pointed down	15	15	15	15
V	Left oil cooler pointed down	15	20	0	0
W	By carburetor pointed up	0	0	0	0

Pitot tubes A through D were outside engine compartment, all others were inside.

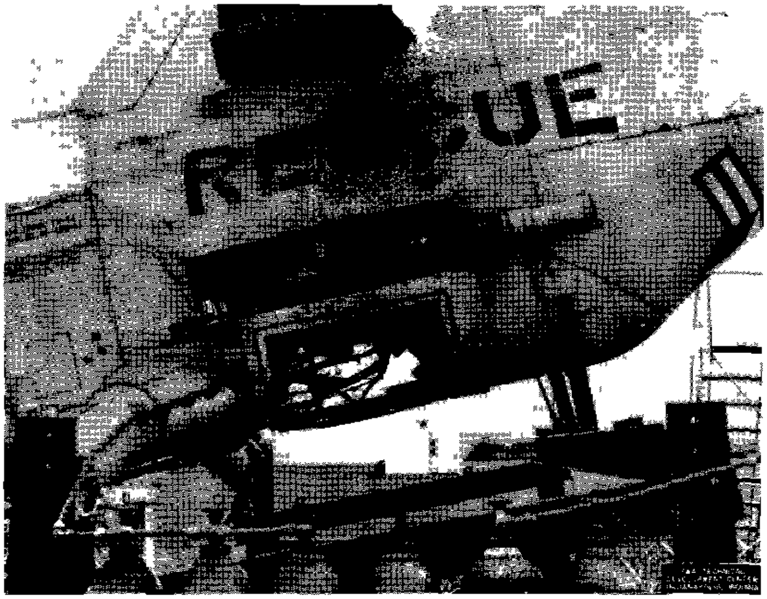

Fig 5 Engine Accessory Section - Flame Paths During Normal Flight

3 Engine not operating with ventilating shutters closed
4 Engine not operating with ventilating shutters open.

The results of the airflow studies conducted under simulated flight conditions showed that the secondary air velocities through the fire zones in the powerplant did not exceed 40 mph Aviation gasoline, lubricating oil, or hydraulic fluid could be ignited easily and combustion sustained at air velocities of 40 mph or less Minimum airflows occurred within the powerplant when the engine was not operating and with the ventilating shutters in a closed position

Flame Path Tests

In the engine compartment, two aluminum ducts direct air from the engine section to the oil cooler Test fires were ignited near the duct openings to determine if flames from the engine section actually passed through the ducts and endangered the oil cooler No evidence of flame impingement or excessive heating of the oil cooler was noted

In the accessory compartment, fire paths were observed visually through Plexiglas windows placed in the compartment cowling as shown in Fig 5 Flame paths observed during simulated normal flight conditions showed that a fire in the accessory section had flame paths moving in the aft-to-forward direction, whereas, in the autorotative descent condition, the flame paths traveled in the forward-to-aft direction

Detector System Tests

Edison continuous-type fire detectors were placed at different stations in the powerplant zones Sustained test fires of 5 to 10 seconds' duration were ignited at each location during simulated normal and autorotative flight conditions, and the response time of each variously located detector for each test fire was recorded. Power section compartment fire-detection elements were 10 feet long and were positioned as shown in Fig 6

An analysis of the detection results disclosed that, of 55 fires during simulated normal flight, detector C sensed all fires with an average response time of 4 6 seconds, B sensed 82 per cent with an average response time of 45 seconds, and A sensed 64 per cent with an average response time of 4 0 seconds See Table II Also, an analysis of the detection results disclosed that, of 71 fires during simulated autorotative flight, detector location C sensed 69 per cent of the fires with an average response time of

TABLE II

RESPONSE TIMES OF ENGINE SECTION DETECTORS IN THE H-5A HELICOPTER DURING SIMULATED NORMAL FORWARD FLIGHT

Locations of Fire Nozzle	Detector	Response Time Trials (seconds) 1	2	3	4
Above and between cylinders 7 and 8 on outer periphery directed across cylinder 8.	A	6.0	4.0	5 0	4 0
	B	4.0	4.0	4 0	3.0
	C	5.0	3 0	4 0	3 0
Between cylinders 1 and 2 on outer periphery *	A	2.5	2 5	3.0	2 5
	B	2.5	2 5	5 0	3 0
	C	2 5	2 5	2 0	2 0
Between cylinders 3 and 4 on outer periphery	A	N.T.	N T.	2 5	2.5
	B	N T.	N T	3 3	X
	C	N.T.	N T	1 5	2.0
Between cylinders 7 and 8 near crankcase directed to deflect fuel off crankcase.	A	X	X	3.5	5 0
	B	11.0	12 0	5.0	8 0
	C	5.5	5.0	8 0	7.0
Near crankcase between cylinders 1 and 2 *	A	X	X	N T	N T
	B	3.0	5 0	N T	N T
	C	8 0	4 0	N T	N T
Between cylinders 4 and 5 near crankcase directed across cylinder 4.	A	X	X	N T	N.T
	B	9 0	5.0	N.T	N.T
	C	4 0	4.0	N.T	N T
Between cylinders 6 and 7 directed across 7 to bounce fuel off crankcase.	A	5 0	5 0	N.T	N T
	B	6 0	4 0	N.T	N.T
	C	7.0	6 0	N T.	N T
Above cylinder 9 on outer periphery directed across 9 and 1	A	5.0	5 0	N T	N.T
	B	4.0	4.0	N T.	N T
	C	4.0	4.0	N T.	N T
Between cylinders 4 and 5 on outer periphery directed across 5	A	X	X	N.T	N.T.
	B	2 0	4 0	N T	N T
	C	3 0	4 0	N T	N T
Directed against crankcase to deflect onto cylinder 6.	A	4 0	X	N.T	N T
	B	3 0	3 0	N T.	N T
	C	5 0	5.0	N T	N T
Directed across cylinders 8 and 9.	A	4.0	X	N T.	N T.
	B	3 0	2 0	N T	N.T.
	C	4 0	3.0	N T.	N T.
Directed across cylinder 4	A	X	X	N T	N.T.
	B	3.0	2 0	N T	N T.
	C	4 0	3 0	N.T.	N T.
At outer periphery above cylinder 8 directed over crankcase	A	3 0	2 0	4 0	3 0
	B	2.0	2 0	3 0	2 0
	C	4 0	3 0	6 0	7 0

TABLE II (continued)

RESPONSE TIMES OF ENGINE SECTION DETECTORS IN THE H-5A HELICOPTER DURING SIMULATED NORMAL FORWARD FLIGHT

Locations of Fire Nozzle	Detector	Response Time Trials (seconds) 1	2	3	4
Above cylinder 5 near crankcase	A	5 0	6.0	5 0	4.0
	B	3.0	3.0	3 0	2 0
	C	5.0	5 0	3.0	3.0
At outer periphery above cylinder 3 directed over crankcase toward other side	A	10 0	12.0	N T	N.T
	B	3 0	2 0	N.T	N T
	C	9.0	13 0	N T	N T.
Under cylinder 3 directed toward base of cylinder 4 at crankcase	A	X	X	X	N.T
	B	X	X	6 0	N T
	C	6 0	6 0	4 0	N T
Between cylinders 7 and 8 directed to outside of cylinder 7	A	X	X	N T	N T
	B	X	X	N T.	N T
	C	4.0	2.0	N T	N T
Below cylinder 9 and directed across 1	A	X	X	N T	N T.
	B	X	X	N T	N T.
	C	3.0	3 0	N T	N T.
Below cylinder 5 and directed across base of 6 toward crankcase.	A	X	X	N T	N.T
	B	X	X	N T	N T.
	C	2 0	2 0	N.T.	N.T.
Between cylinders 7 and 8 directed to deflect fuel off the crankcase.	A	3 5	5.0	N.T.	N.T
	B	6 0	8 0	N.T.	N T
	C	8.0	7.0	N T	N T
Between cylinders 1 and 2 near crankcase *	A	6 0	8.0	N T	N T.
	B	6 0	8 0	N T.	N T
	C	6 0	8.0	N T	N.T
Between cylinders 4 and 5 near crankcase directed across cylinder 4	A	X	X	N T	N T
	B	X	X	N T.	N T
	C	4.0	4.0	N T	N T

Detector Locations
A - Loop was 4 inches below baffle on outer periphery of cylinders
B - Loop was near crankshaft above and concentric with engine wiring harness
C - Loop was around exhaust stacks 1 1/2 inches from stacks and 4 inches below cylinder baffle diaphragm, 1 inch outside exhaust stack

*Spherical nozzles, all others were tube nozzles   X - No detection. N T. - No test conducted

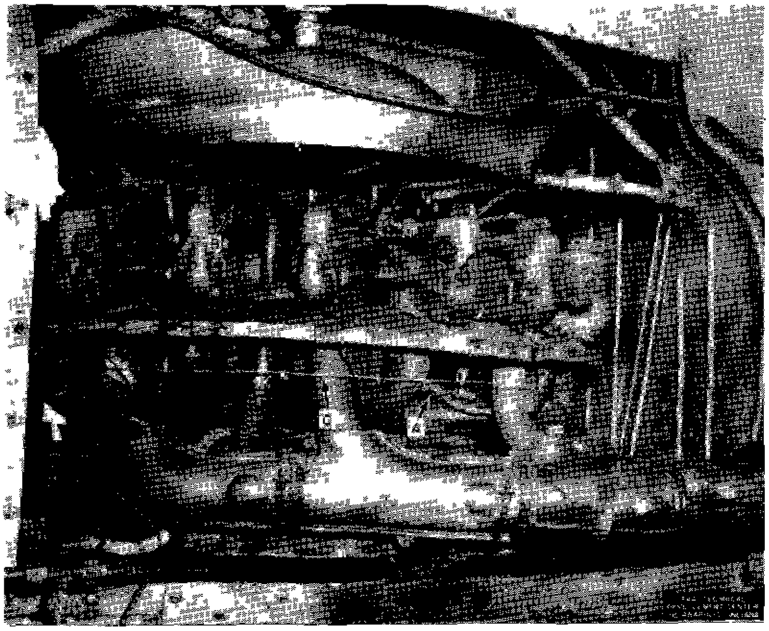

Fig 6 H-5A Helicopter Engine Power Section Showing Location of Fire Detector Elements A, B, and C

5 0 seconds, location A sensed 58 per cent with an average response time of 6 0 seconds, and B sensed 51 per cent with an average response time of 7 5 seconds See Table III

Accessory-section fire paths were observed visually through the transparent windows and were used in locating the accessory-section fire-detector elements Detectors D, E, F, and G, shown in Fig. 7, were located near the front bottom opening of the accessory section A series of test fires were ignited at various points in the accessory section to evaluate the detector locations during simulated normal flight An analysis of the data presented in Table IV indicated that detector location E was the most sensitive

Observation of fire paths in the accessory section during autorotative flight indicated that detectors placed across the rear opening will give results similar to those obtained when detectors are positioned across the front opening during simulated normal flight. Detector locations used for normal flight fire detection were not suitable for detecting fires in this section during autorotation because the airflow and flame paths reverse direction when the H-5A changes from normal flight to autorotative descent attitude

Ignition Hazard Tests

The elevated temperatures of exhaust disposal manifolds presented an ignition hazard Tests were conducted to determine the minimum temperatures at which the ignition of various flammable fluids will take place

Hydraulic fluid AAF 3850D and SAE 20 engine oil preheated to 175° F ignited during simulated autorotative descent conditions when the engine exhaust stack temperatures were above 900° F Gasoline did not ignite at 1,150° F , the maximum stack temperature attained at 2,400 rpm and 12 inches Hg manifold pressure

FIRE-RESISTANCE STUDIES OF THE POWER SECTION

A series of power-section fires were ignited to determine the ambient temperature pattern within the section and the temperatures reached by the surrounding structural

TABLE III

RESPONSE TIMES OF ENGINE SECTION DETECTORS IN THE H-5A HELICOPTER DURING SIMULATED AUTOROTATIVE FLIGHT

Fire Nozzle Locations	Detector	Response Time: Engine Operating, Shutter Closed (sec.)	Engine Operating, Shutter Open (sec.)	Engine Not Operating, Shutter Closed (sec.)	Engine Not Operating, Shutter Open (sec.)
Over No 6 cylinder 5 inches from crankcase directed across Nos. 6, 7, and 8 cylinders.	A	X	X	X	X
	B	X	X	X	X
	C	5.0	4.0	3.0	4.0
Between No. 2 and 3 cylinders 5 inches from crankcase directed across No. 2 cylinder.	A	6 0	6.0	X	6.0
	B	X	5.0	X	7.0
	C	4.0	4 0	4.0	4.0
Between No. 8 and 9 cylinders 5 inches from crankcase directed across No. 7 and 8 cylinders.	A	X	X	X	X
	B	X	X	X	X
	C	X	11.0	X	4.0
Above intake push rod housing of No. 5 cylinder 4 inches from crankcase directed at No. 6 cylinder.	A	7.0	5 0	X	X
	B	X	5.0	8.0	11.0
	C	3.0	3.0	4.0	4.0
Above intake push rod housing of No. 1 cylinder 4 inches from crankcase directed at No. 9 cylinder.	A	6 0	5.0	7.0	6.0
	B	X	6.0	7.0	5.0
	C	3.0	3.0	6.0	4.0
Above intake push rod housing of No. 1 cylinder 4 inches from crankcase directed at No. 2 cylinder.	A	X	X	X	X
	B	X	X	X	X
	C	3.0	5.0	X	4.0
Above intake push rod housing of No. 8 cylinder 3 inches from crankcase directed at No 9 cylinder intake rocker box	A	5.0	3 0	X	10.0
	B	9 0	6 0	X	X
	C	5 0	4 0	4 0	5.0
Above No 4 cylinder exhaust push rod housing 3 inches from crankcase toward No. 3 cylinder rocker box.	A	X	8 0	7.0	5.0
	B	X	9.0	6.0	6.0
	C	3.0	10 0	X	4.0
Above intake push rod housing of No. 3 cylinder 3 inches from crankcase pointing toward No. 4 intake rocker box	A	X	10 0	10 0	11 0
	B	X	X	X	X
	C	3.0	3.0	4.0	4 0
Above intake push rod housing No 7 cylinder pointing toward No. 8 cylinder	A	7 0	4 0	X	7 0
	B	7 0	5 0	10 0	7 0
	C	3 0	X	4.0	X
Above exhaust No 6 cylinder pointing toward No 7 cylinder	A	5.0	6.0	X	7 0
	B	8 0	8.0	X	10 0
	C	3.0	9.0	6.0	X
Above exhaust No. 2 cylinder pointing toward No 3 cylinder.	A	4 0	3.0	7.0	4 0
	B	5 0	5 0	X	7 0
	C	9 0	X	X	X
Above No 5 cylinder pointing toward No 4 cylinder 8 inches from crankcase	A	4 0	4 0	5 0	5.0
	B	5.0	7 0	X	X
	C	3 0	X	7 0	8.0

TABLE III (continued)

RESPONSE TIMES OF ENGINE SECTION DETECTORS IN THE H-5A HELICOPTER DURING SIMULATED AUTOROTATIVE FLIGHT

Fire Nozzle Locations	Detector	Response Time: Engine Operating: Shutter Closed (sec.)	Response Time: Engine Operating: Shutter Open (sec.)	Response Time: Engine Not Operating: Shutter Closed (sec.)	Response Time: Engine Not Operating: Shutter Open (sec.)
Above No. 3 cylinder pointing toward	A	4.0	*	5.0	9.0
No. 2 cylinder 8 inches from	B	4.0	*	9 0	11.0
crankcase.	C	X	•	X	13.0
Above No. 9 cylinder pointing toward	A	6.0	4.0	10.0	X
No. 1 cylinder 8 inches from	B	8 0	5.0	12.0	X
crankcase.	C	X	X	5.0	5.0
Above No 5 cylinder pointed in at base	A	X	18.0	8.0	7.0
of No. 4 cylinder 8 inches from	B	X	15.0	X	8.0
crankcase.	C	X	X	X	X
Above No. 3 cylinder pointed in at base	A	5.0	X	X	X
of No. 2 cylinder 8 inches from	B	4.0	5.0	13.0	X
crankcase	C	7.0	6.0	15.0	X
Above No. 8 cylinder pointed in at base	A	X	6.0	X	X
of No. 7 cylinder 8 inches from	B	X	5.0	X	X
crankcase.	C	X	4.0	22.0	X

Detector locations - same as normal flight.

Detector A - Loop was 8 inches below baffle and on outer periphery
Detector B - Loop was near crankcase above and concentric with engine wiring harness.
Detector C - Loop was around the exhaust and 4 inches below the cylinder baffle diaphragm

X - Designates no detection.

* - Designates no fire.

TABLE IV

RESPONSE TIMES OF ENGINE ACCESSORY SECTION FIRE DETECTORS IN THE H-5A HELICOPTER DURING SIMULATED NORMAL FORWARD FLIGHT

Fire Nozzle Locations	Detector	Response Time Trials (seconds) 1	2	3
Under left side of magneto.	D	7.0	8.0	6.5
	E	3.5	4.0	3.5
	F	X	X	X
	G	X	X	X
Right side aft and on left side of right-hand oil cooler.	D	5.0	5.0	X
	E	3.0	3.0	X
	F	4.0	4.0	X
	G	4.0	4.0	X
Right side aft and on right side of right-hand oil cooler	D	7.0	4.0	X
	E	5.0	3.0	4.0
	F	X	X	X
	G	X	X	X
Aft of oil coolers between and beneath them	D	4.0	4.0	X
	E	3.5	3.5	X
	F	4.0	3.5	X
	G	4.5	4.5	X
Aft of carburetor	D	5.5	5.5	X
	E	3.5	3.5	X
	F	X	X	X
	G	X	X	X
Forward of ring mount and 4 inches below and to the left	D	9.0	8.0	5.0
	E	4.5	4.0	X
	F	5.0	3.5	X
	G	6.0	4.5	X
Forward of ring mount and 4 inches below and to the right	D	X	X	X
	E	X	X	X
	F	3.5	3.5	3.0
	G	4.5	4.0	3.5
Four inches below engine ring mount and left side of accessory section	D	X	X	X
	E	X	X	X
	F	5.5	5.0	X
	G	5.0	5.0	X

Detector Locations

- D - Halfway between bottom cowl and horizontal tube nearly directly under horizontal tube
- E - Eight inches from firewall nearly in middle of opening
- F - Mounted on standoffs attached to horizontal tube element about 2 inches above and 3 inches fore of tube
- G - About 2 inches above bottom cowl panel and 3 inches to rear of bottom horizontal tube

X - Designates no trial.

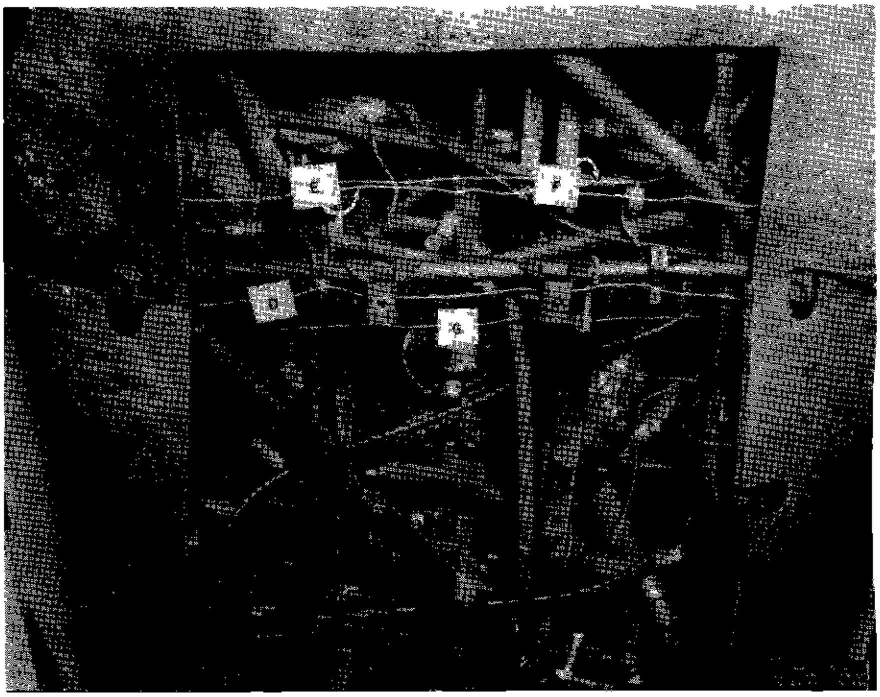

Fig 7 H-5A Helicopter Engine Accessory Section Showing Location of Fire Detector Elements D, E, F, and G

components during simulated in-flight conditions These tests served as a means of determining whether the helicopter structure could be expected to maintain its structural integrity during a severe fire The initial tests were conducted in such a way that the test article damage was limited and the fires would become progressively more intense and damaging

The 2 4-gallons-per-minute (gpm) gasoline fires were supplied 100/130 octane gasoline by an omnidirectional nozzle Temperatures were measured by chromel-alumel thermocouples located as shown in Fig 8

The first of this series of fires was supplied fuel with the nozzle placed 6 inches forward of the rear center firewall, 6 inches above the engine diaphragm, and 2 inches inboard of the nacelle skin Temperatures recorded during this test are shown graphically in Fig 9. Abnormally high temperatures were recorded in the rear fuel compartment Motion pictures taken during these tests disclosed that flames were forced by the engine cooling fan through leaky compartment seals that had burned through during previous fires

The second fire of this series was supplied fuel with the nozzle placed 12 inches forward of the rear center firewall, 6 inches above the engine shroud, and 6 inches inboard of the nacelle skin The temperatures during this test are shown graphically in Fig 10 These results showed that maximum temperatures occurred 18 seconds after the fire was ignited The engine cowl temperature was considerably lower with the engine operating, as the cooling fan forced the fire below the engine cowl

The third fire of this series was supplied fuel with the nozzle placed 18 inches forward of the rear center firewall, 6 inches above the engine shroud, and 2 inches inboard of the nacelle skin. The temperatures recorded during this test are shown graphically in Fig 11 These results indicated that temperatures of all instrumented surfaces were lower with the engine not operating The rear fuel-tank compartment had no appreciable rise in temperature when the engine was not operated Visual observation indicated that the flames were distributed entirely throughout the power section and were of greater intensity than in previous fires. These visual observations were corroborated by the measured temperatures within the engine section

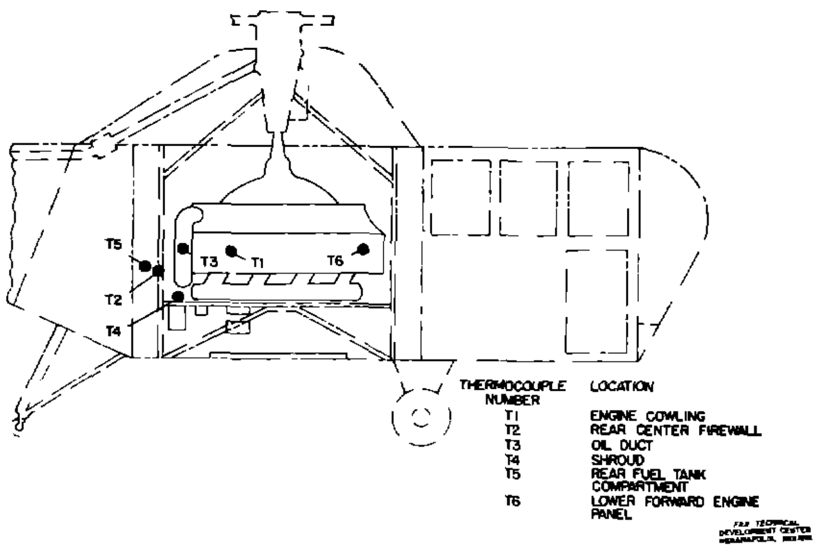

Fig. 8 Thermocouple Locations Used in 2.4-GPM Gasoline Fires

The 3 0-gpm gasoline fires were supplied 100/130 octane gasoline by the omnidirectional nozzle placed between the No. 7 and 8 cylinders, as shown in Fig 12. The 3 0-gpm flow rate was determined by breaking the main fuel supply line and measuring the rate of flow It then was assumed that this rate would produce the most severe fuel-fed fire that could be expected in the power section. Temperature measurements were recorded at the various locations shown in Fig. 13 and listed in Table V.

The first of these fires was ignited with the helicopter simulating autorotative flight and the engine not operating The temperatures recorded during this test are shown graphically in Fig 14, and damages are listed in Table VI These results indicated that the highest ambient temperatures were measured in the area surrounding the fuel nozzle.

Cabin air contamination was checked by analyzing a sample of cabin air immediately after the fuel to the fire was shut off This sample was analyzed by a Mine Safety Appliance Co carbon monoxide detector, Type B-1, which indicated a 0 02-per-cent concentration in

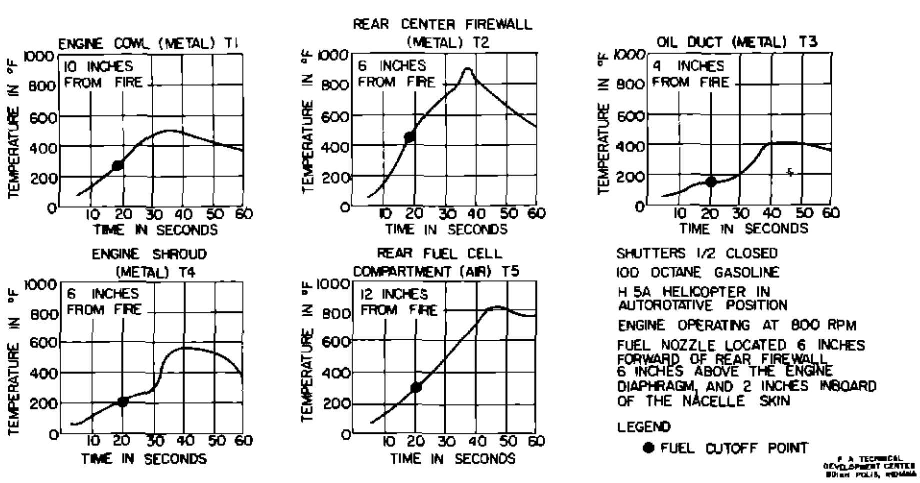

Fig 9 Temperatures Recorded During a 2.4-GPM Gasoline Fire

TABLE V

LOCATION OF THERMOCOUPLE PICKUPS IN H-5A HELICOPTER DURING 3.0-GPM GASOLINE FIRES

Thermocouple Number		Locations
T-1	(A)*	Carburetor air intake
T-2	(A)	Near main drive shaft universal joint
T-3	(A)	Near lower right rear transmission mount
T-4	(A)	Bottom center of left-hand engine panel.
T-5	(A)	Bottom center of right-hand engine panel
T-6	(A)	Midway between No 8 and 9 cylinders
T-7	(A)	Midway between No 2 and 3 cylinders
T-8	(A)	Near rubber intercylinder drain hose from No 6 cylinder
T-9	(A)	Rear fuel-tank compartment
T-10	(A)	Two inches forward and at center of rear firewall.
T-11	(A)	Two inches aft and at center of forward firewall
T-12	(A)	One inch from No 3 intake manifold
T-13	(A)	One inch from No 6 intake manifold
T-14	(A)	Midway between oil coolers
T-15	(A)	Midway between carburetor and magnetos.
T-16	(A)	Near main fuel pump
T-17	(A)	One inch from engine mounting structure
T-18	(A)	Forward lower part of accessory section
T-19	(M)**	Upper right center tubular support of main gear box and transmission mount
T-20	(M)	Upper right rear tubular support of main gear box and transmission mount
T-21	(M)	Upper left front tubular support of main gear box and transmission mount
T-22	(M)	Right rear center section of tubular structure

* (A) Ambient air temperature
** (M) Metal temperature

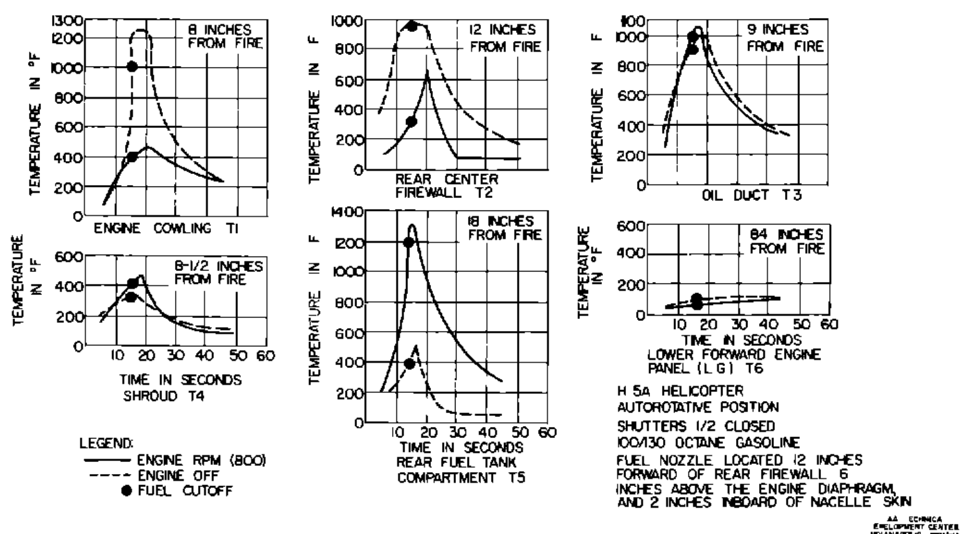

Fig. 10 Temperatures Recorded During a 2.4-GPM Gasoline Fire

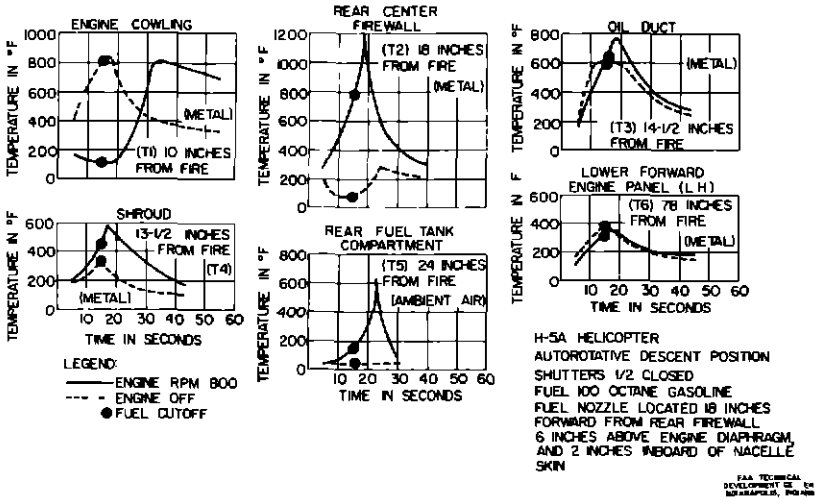

Fig 11 Temperatures Recorded During a 2 4-GPM Gasoline Fire

in the cabin area The detector chart indicated that this concentration would not affect personnel appreciably unless they are exposed to such concentrations for a period of at least 1 hour

The second of these fires was ignited with the helicopter simulating autorotative flight and the engine running for the first 42 seconds, at which time the engine was stopped The damaged areas are described in Table VII and are shown pictorially as the shaded areas in Fig 15 Temperatures measured during this test are shown graphically in Fig 16 These results showed the highest temperature of 2,200° F to have been measured in the vicinity of of the fuel nozzle

The third of these fires, of 5 minutes' duration, was conducted to determine the extent of damage that might be expected of a most severe fire The 5-minute period was calculated as the time necessary to make a controlled autorotative landing from 10,000 feet Thermocouples T-19 through T-22, listed in Table V, were added for this test to obtain additional metal surface temperatures of the main gear box and rotor supporting structure Aviation gasoline, 100/130 octane, was supplied at the rate of 3 0 gpm by the spherical nozzle located near the No 7 cylinder for a period of 5 minutes The helicopter engine was operated for the

Fig 12 Spherical Fuel Nozzle Located Near No 7 Cylinder Used to Supply Fuel for 5-Minute Fire

TABLE VI

DAMAGE INCURRED TO H-5A HELICOPTER
DURING A 3 0-GPM GASOLINE FIRE
WITH ENGINE NOT OPERATING
(See Fig 15 for Pictorial Presentation)

Area	Damaged Area (inches)	Aluminum Skin Thickness (inches)	Location of Damage
A	5 by 22	0 030	Oil duct
B	4 by 8	0 060	Spinner and spider section of engine cowling assembly
C	16 by 18	0 060	Skirt section of cowling assembly
D	6 by 7	0.040	Lower rear portion of forward fuel-tank panel (right-hand side).

first minute of the test fire and then shut down Fire damage is listed in Table VIII and a pictorial presentation of the damaged areas is shown in Fig 17 Temperatures recorded during this test are shown graphically in Fig 18 The helicopter, prior to this 5-minute fire, is shown in Fig 19 The damage incurred by the 5-minute fire is shown in Figs 20 and 21 Flame impingement past the stainless steel panels burned a hole through the aluminum skin of the fuel and oil compartments A section of the oil tank also was burned away The oil contained within the tank did not ignite, apparently, the main body of oil dissipated the heat

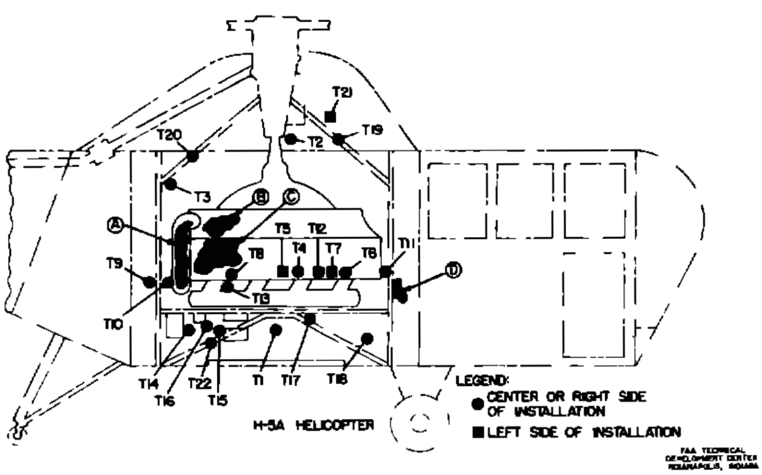

Fig 13 Thermocouple Locations Used for 3 0-GPM Gasoline Fires
Shaded Areas Show Damage Caused by First 3 0-GPM Fire.

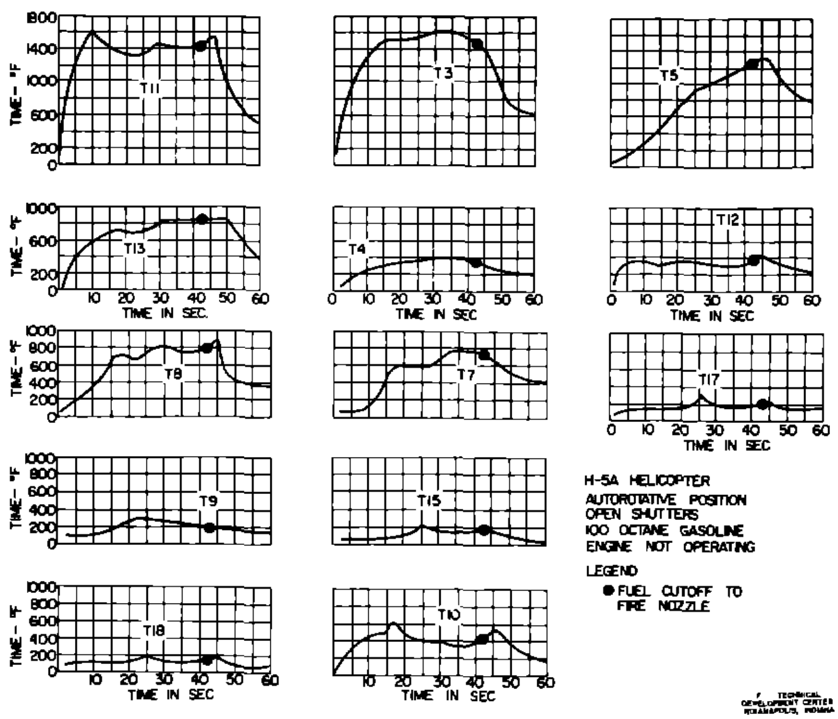

Fig 14 Temperatures Recorded During First 3 0-GPM Gasoline Fire

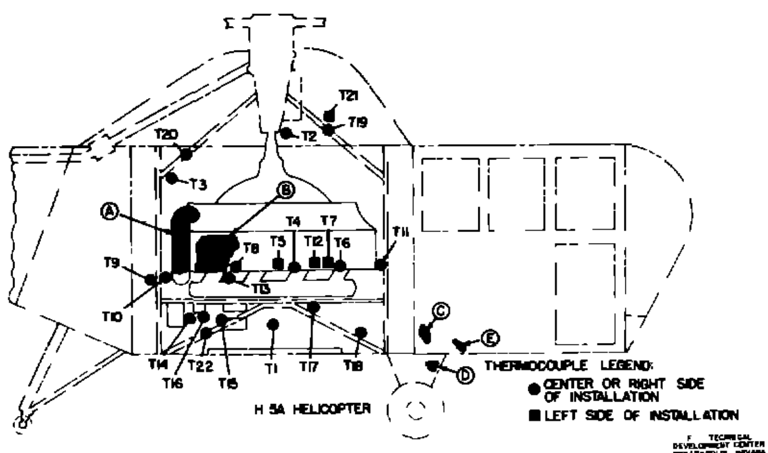

Fig. 15 Shaded Areas Showing Damages Caused by Second 3.0-GPM Gasoline Fire

TABLE VII

DAMAGE INCURRED TO H-5A HELICOPTER DURING A 3 0-GPM GASOLINE FIRE OF 1-MINUTE DURATION WITH ENGINE OPERATING (See Fig 13 for Pictorial Presentation)

Area	Damaged Area (inches)	Aluminum Skin Thickness (inches)	Location of Damage
A	5 by 22	0 030	Air cooler duct
B	12 by 18 1/2	0 060	Skirt section of cowling assembly
C	3 by 6	0 040	Batter and hydraulic pressure panel (right hand).
D	3 1/2 in dia	0 040	Alighting gear fairing (right hand)
E	1 by 4	0 040	Recognition lights panel (right hand).

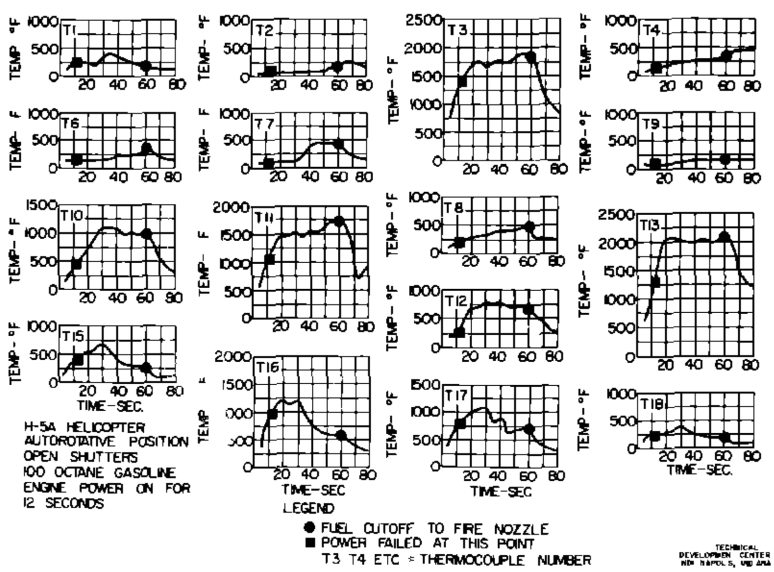

Fig 16 Temperatures Recorded During Second 3 0-GPM Gasoline Fire

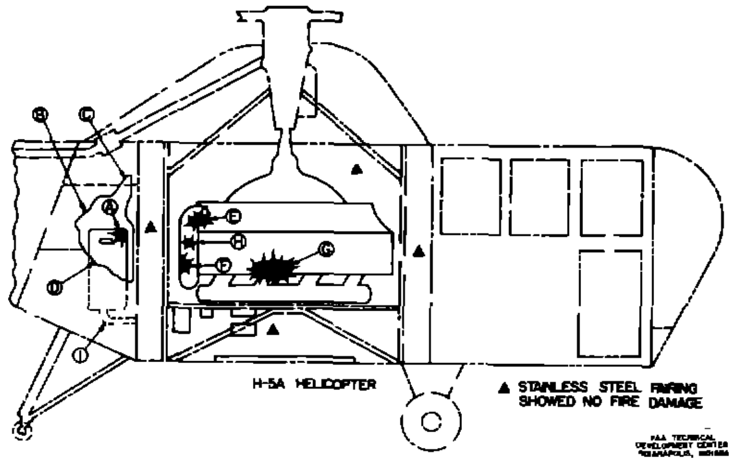

Fig 17 Shaded Areas Showing Damage Caused by 3.0-GPM Gasoline Fire of 5 Minutes' Duration

TABLE VIII

LOCATION OF DAMAGE INCURRED TO H-5A HELICOPTER DURING A 3.0-GPM GASOLINE FIRE OF 5 MINUTES' DURATION. ENGINE OPERATED DURING FIRST MINUTE OF FIRE

(See Fig 20 for Pictorial Presentation)

Area	Damaged Area (inches)	Aluminum Skin Thickness (inches)	Location of Damage
A	3 by 7	0 125	Oil tank
B	14 by 21	0.040	Right-hand supporting panel for center cone
C	3 by 4	0 040	Right-hand radio panel
D	9 by 13	0.040	Right-hand support panel for bottom cone
E	5 by 12	0 060	Spinner and spider section of engine cowling assembly
F	3 by 12	0 060	Right rear skirt of cowling assembly
G			Minor damage around fire nozzle
H	3 by 6	0.060	Upper left section of cowling assembly
I			Oil outlet hose. Hose burned through causing small leak.

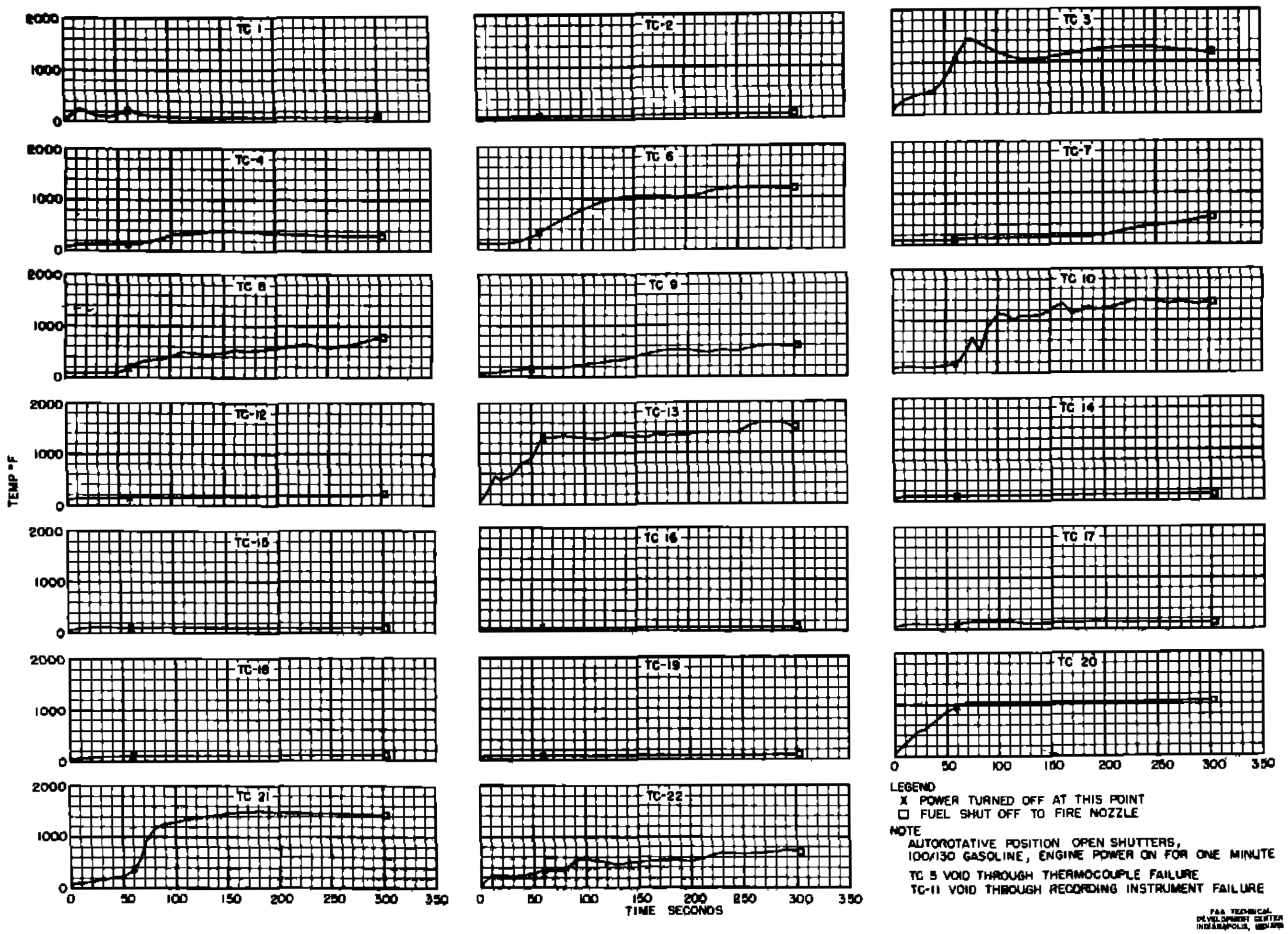

Fig. 18 Temperatures Recorded During 3 0-GPM Gasoline Fire of 5 Minutes' Duration

Fig 19 Stainless Steel Panels Used in 5-Minute Fire

FIRE-RESISTANCE STUDIES OF THE ACCESSORY SECTION

Fires were ignited in the accessory section to determine the effect of small fires upon engine operation and components The engine was operated during the initial moments of the test, however, the rubber material covering the junction of the carburetor air ducting was quickly burned away and the charred residue entered the carburetor intake causing engine failure

Critical engine controls such as bell-crank and push-rod mechanisms were not made inoperative Materials used to seal the forward firewall burned away rapidly at places where the controls pass through the openings into the space normally occupied by the forward fuel tank

Rubber insulation on wiring inside the top and bottom ignition harness manifold was melted, causing faulty ignition The flexible shield covering the wire was not damaged to any

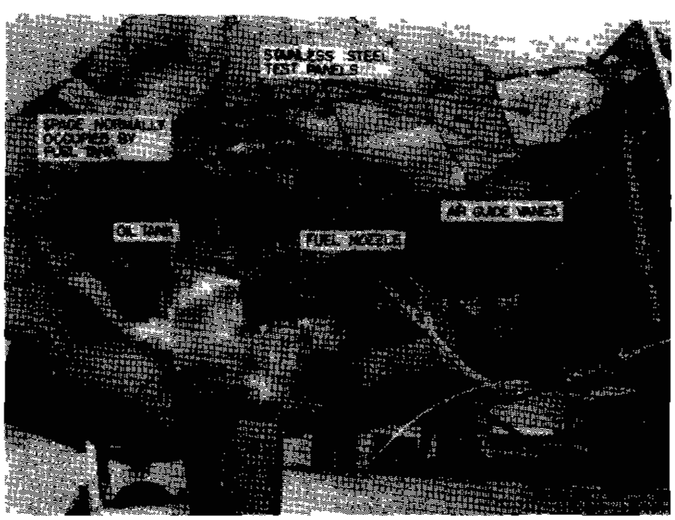

Fig 20 H-5A Helicopter - Damage Caused by 3 0-GPM
Gasoline Fire of 5 Minutes' Duration

Fig 21 H-5A Oil Tank Compartment Damage Caused by 3 0-GPM Gasoline Fire of 5 Minutes' Duration

great extent More than 60 fires of short duration had been ignited in the region of the wiring harnesses before the engine became inoperative due to their failure One fire of longer duration possibly could have caused an earlier engine failure

The engine starting motor and right magneto failed after several fires in the accessory section The starter motor failed, due either to overload caused by difficult starting, overheating caused by its fireproofing insulation, or by fire damage The magneto failed from fire damage Examination of the tubular structure supporting the motor disclosed no apparent major damage

CONCLUSIONS

1 The best location for a fire detector in the engine power section was found to be location C, shown in Fig 6 and described in Table II

2 The best location for a fire detector in the engine accessory section for normal flight was found to be location E, shown in Fig 7 and described in Table IV However, an additional fire detector must be added across the aft opening of this section if fire detection is desired during autorotation

3 Flames from an engine-compartment fire will endanger the rear fuel-tank and oil-tank compartments

4 Fuel lines, oil lines, and hydraulic lines constructed of aluminum or some less fire-resistant material are rapidly destroyed, allowing flammable fuels to be released for burning.

5 The limited fire resistance of engine accessories permits the engine to operate for only a short period following an accessory-section fire

6 The H-5A helicopter most likely will maintain structural integrity for 5 minutes if subjected to a gasoline-fed fire of 3 0 gpm

7 Carbon monoxide concentrations found in the cabin air should have no appreciable effect on personnel

USCOMM-DC-60460