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FIRE DETECTION SYSTEM PERFORMANCE IN USAF AIRCRAFT

Charles L. Delaney

Air Force Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

August 1972

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TECHNICAL REPORT AFAPL-TR-72-49

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AIR FORCE AERO PROPULSION LABORATORY
AIR FORCE SYSTEMS COMMAND
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13. ABSTRACT

This report is concerned with the determination of the performance of fire detection systems in USAF aircraft. Data on false fire warnings and aircraft engine nacelle fires was taken from Air Force accident/incident reports obtained from Headquarters Air Force Inspection and Safety Center, Norton Air Force Base, California. This data included the time period 1965 through 1970 and is restricted to noncombat related accidents/incidents.

Analysis of the data showed that false fire warnings are a major problem in the majority of USAF aircraft (83% of all reported alarms are false). These false fire warnings resulted in damage or destruction to aircraft as well as crew injuries/fatalities. In addition, it was found that in approximately 50% of the engine nacelle fires, where the performance of the detection system could be determined, the system did not provide an alarm.

It was also found that the fire detection system in a number of aircraft had been partially or totally removed to reduce or eliminate the false fire warning problem. As a consequence the majority of the fires which occurred in these aircraft were not detected.

The information contained in this report is for use solely for safety purposes and accident prevention and is not to be used for any other purpose.

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FOREWORD

This report was prepared for the Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio under Project 3048, "Fuels, Lubrication, and Fire Protection" and Task 304807, "Aerospace Vehicle Fire Protection".

The work was accomplished from March 1971 through September 1971.

The author of this report is Mr. Charles L. Delaney, AFAPL/SFH. Mr. Robert Shanks of the Headquarters Air Force Inspection and Safety Center (SESM), Norton Air Force Base, California, provided the USAF aircraft accident and incident information used in the report.

This report was submitted by the author June 1972.

This technical report has been reviewed and is approved.

BENITO P. BOTTERI
Chief, Fire Protection Branch
Fuels and Lubrication Division
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SECTION I

INTRODUCTION

The Air Force Aero Propulsion Laboratory (AFAPL) has been involved in research and development of hazard detection equipment for Air Force aircraft for approximately seven years. During this period the AFAPL emphasis has been placed on developing hazard detection equipment with greater reliability and improved capability applications. As a consequence such items as the Integrated Fire and Overheat Detection System, Time Domain Reflectometry and Self-Generating Overheat Systems, 1000°F fiber optic bundles, silicon carbide ultraviolet detector, 750°F infrared detector, 1000°F ultraviolet detector, 550°F ultraviolet detector, and a smoke detector have or are being developed for aircraft use. In the near future several of these developments will be ready for application to operational aircraft or to aircraft under development.

In addition, it appeared from contact with personnel from the Air Force System Command's Aeronautical Systems Division and the USAF operating commands that numerous deficiencies continue to exist with the detection systems used in Air Force operational aircraft. Therefore, the AFAPL decided to conduct an investigation to determine the performance of the fire and overheat systems in these operational aircraft as a means of further verifying the need for the advanced detection equipment being developed.

Virtually all Air Force aircraft utilize some form of temperature sensing for detecting fire and overheat conditions. Table I shows the

TABLE I - USAF AIRCRAFT FIRE DETECTION SYSTEM

AIRCRAFT	DETECTION SYSTEM	REMARKS
UH1F	EDISON CONTINUOUS	
CH3	FENWAL CONTINUOUS	
H16	EDISON CONTINUOUS	DISCONTINUED
H43	FENWAL CONTINUOUS	
H53	PYROTECTOR OPTICAL	
O2	FENWAL UNIT	
OV10	KIDDE CONTINUOUS	
A1	EDISON UNIT	
B47	FENWAL UNIT	DISCONTINUED
B52	FENWAL UNIT	
B57	KIDDE CONTINUOUS	
B58	KIDDE CONTINUOUS	DISCONTINUED
B66	KIDDE CONTINUOUS	DISCONTINUED
C5	KIDDE CONTINUOUS	DISCRIMINATOR - PERFORATED TUBE
C7	KIDDE CONTINUOUS	
C54	EDISON UNIT	
C97	EDISON UNIT	THERMOCOUPLE

TABLE I - USAF AIRCRAFT FIRE DETECTION SYSTEM (Continued)

AIRCRAFT	DETECTION SYSTEM	REMARKS
C118	EDISON UNIT	THERMOCOUPLE
C119	EDISON UNIT	THERMOCOUPLE
C121	FENWAL UNIT	TWO TERMINAL
C123	EDISON UNIT	THERMOCOUPLE
C124	EDISON UNIT, THERMOCOUPLE	
C130	FENWAL UNIT, KIDDE CONTINUOUS PYROTECTOR OPTICAL	
C131	EDISON UNIT, CONTINUOUS	
C133	EDISON CONTINUOUS	
C135	FENWAL UNIT	
C141	KIDDE CONTINUOUS	ISOLATED DISCRIMINATOR
F4	FENWAL CONTINUOUS	
F5	EDISON CONTINUOUS	
F84	FENWAL UNIT	
F86	EDISON UNIT, THERMOCOUPLE	
F89	FENWAL UNIT	
F100	FENWAL UNIT	SOME ARE TWO TERMINAL
F101	KIDDE CONTINUOUS	

TABLE I - USAF AIRCRAFT FIRE DETECTION SYSTEM (CONCLUDED)

AIRCRAFT	DETECTION SYSTEM	REMARKS
F102	EDISON CONTINUOUS	
F104	FENWAL UNIT	
F105	FENWAL UNIT	
F106	EDISON CONTINUOUS	
F111	KIDDE CONTINUOUS	ISOLATED DISCRIMINATOR
T28	FENWAL UNIT	
T33	FENWAL UNIT	
T37	EDISON CONTINUOUS	
T38	EDISON CONTINUOUS	
T39	EDISON CONTINUOUS	

type of detection system used on various Air Force aircraft. These systems have limited capability in that total detection coverage of an area or volume is not possible because the sensor may not receive heat from the fire or overheat source depending upon its location with respect to the hazard condition. In addition, because the temperature sensing device has a finite mass, a minimum of several seconds is required to heat it to the alarm temperature. Therefore, considerable damage could occur before an alarm is provided.

In order to properly assess the performance of present day fire and overheat detection systems, the AFAPL chose to investigate the accidents/incidents in Air Force aircraft involving engine nacelle fires or false fire warnings from 1965 through 1970. Headquarters, Air Force Inspection and Safety Center (SESM), Norton Air Force Base, California was requested to provide this information. Computer listings containing information from accident/incident reports describing engine nacelle fires and false fire warnings were graciously provided by SESM. Without their support, this report would not have been possible.

SECTION II

DISCUSSION

The Inspection and Safety Center indexes and automates USAF aircraft accident and incident information. The most important categories of information needed for analysis of aircraft mishaps are transferred from the accident/incident reports to an automated data retrieval system.

In response to the Air Force Aero Propulsion Laboratory, SESM provided information on false fire warnings and fires in USAF aircraft. The information received showed 532 accidents/incidents involving fires in the aircraft engine nacelle under non-combat conditions. A review of the information resulted in the role of the detection system being determined in 427 cases. The following is a discussion of the information received on false fire warnings and engine nacelle fires.

1. FALSE FIRE WARNINGS

The accident/incident reports for the period 1965 through 1970 contained 1250 cases wherein the aircraft fire detection system provided an alarm. One thousand and thirty six or 83% of these cases were false fire warnings. Table II depicts these reported false fire warnings by aircraft by year. A review of the data revealed the following:

a. Reported false fire warnings for the B-52 and C-135 aircraft appear to be at an acceptable level. However, in reviewing the history of the fire detection systems for these aircraft it was found that some of the unit detectors in the engine nacelle of these aircraft had been removed to reduce false fire warnings. Thus, these aircraft presently have a minimal fire detection system capability.

TABLE II - REPORTED FALSE FIRE WARNINGS IN AIR FORCE AIRCRAFT

AIRCRAFT	1965	1966	1967	1968	1969	1970	TOTAL
UH1F	6	2		2	2		12
CH3				1		2	3
O2				2	4	15	21
A26		1					1
B52	1	1	3	1	6	7	19
B57	5	10	5	5	3	7	35
F4	45	37	40	37	24	46	229
F5	4						4
F84	1		1				2
F89	4	1	1				6
F100	15	2		1		2	20
F101	44	22	9	18	12	14	119
F102	1	4	2	1			8
F104	1	1					2
F105	7	8	1	1		1	18
F111				2		4	6

TABLE II - REPORTED FALSE FIRE WARNINGS IN AIR FORCE AIRCRAFT (Concluded)

AIRCRAFT	1965	1966	1967	1968	1969	1970	TOTAL
T33	2	1	2	3	2		10
T37	36	58	32	36	56	46	264
T38	54	21	17	11	22	37	162
T39	11	3	5	4	8	8	39
C7			5			1	6
C47				2			2
C118	1						1
C119					1	1	2
C123						1	1
C130	8	1	2	1	1	1	14
C131	2	2	1	1	1	3	10
C133	4	1					5
C135	1	4	1		1		7
C141			1		2	5	8
TOTAL	253	180	128	129	145	201	1036

b. The T-37, T-38, F-4 and the F-101 aircraft have reported high numbers of false fire warnings. In addition, the number per year has been fairly constant over the time period investigated. Apparently these aircraft have had detection system problems for several years which have never been resolved.

c. In addition to the excessive number of aborted missions, added maintenance, and the general nuisance factor, false fire warnings in Air Force aircraft have some very serious consequences in terms of damaged or destroyed aircraft and crew member fatalities. As can be seen from Table III, during this time period false fire warnings resulted in three crew members being killed, four aircraft being destroyed and another receiving major damage.

2. ENGINE NACELLE FIRES

The computer printout contained 532 accidents/incidents during the time period 1965 through 1970 involving a fire or overheat condition in the engine nacelles of USAF aircraft. Table IV presents these by aircraft by year. A review of the data resulted in the role of the detection system being determined in 427 accidents/incidents. The remaining 105 accidents/incidents included in the computer printout either involved fire in aircraft which did not have a detection system, or did not contain sufficient information in the report such that the role of the detection system could be determined. However, the 427 cases in which the detection system role was determined was a sufficiently large sample (75%) so as to be adequately representative of all the cases. In 213, or approximately 50% of the 427 accidents/incidents the detection system did not provide an alarm as indicated in Table IV.

TABLE III - CONSEQUENCES OF FALSE FIRE WARNINGS

YEAR	AIRCRAFT	DAMAGE	INJURY
1966	RB-57	DESTROYED	FATAL
1968	F-101	DESTROYED	NONE
1969	T-33	DESTROYED	NONE
1970	F-4	DESTROYED	FATAL
1970	O2-A	MAJOR	NONE

ESTIMATED DAMAGE - $12,000,000

THREE (3) KILLED

TABLE IV - USAF AIRCRAFT ENGINE NACELLE FIRES

AIRCRAFT	ENGINE NACELLE FIRES							TRUE FIRE WARNINGS							FIRE WITHOUT WARNINGS						
	65	66	67	68	69	70	TOTAL	65	66	67	68	69	70	TOTAL	65	66	67	68	69	70	TOTAL
UF1F	1		1		1	1	4					1		1	1						1
CH3	1		1			1	3	1						1			1				1
H16	2	1			1		4														
H21				1			1				1			1							
H43	3	2			2		7								3						3
H53				1			1											1			1
U2			1				1										1				1
OV10					1	2	3													2	2
A1	2				1		3								2				1		3
A26	1		1				2										1				1
B47	1		2				3														
B52	15	11	11	17	11	11	76	8	9	5	2	5	4	33	3	2	5	15	6	7	38
B57	3	1	1	1	1		7	2			1	1		4	1						1
B58	2		1				3	1						1			1				1
B66	2				3		5														
F4	1	7	8	4	14	11	45	1	4	6	2	11	4	28		1	2	1	2	7	13

TABLE IV -- USAF AIRCRAFT ENGINE NACELLE FIRES (Continued)

AIRCRAFT	ENGINE NACELLE FIRES 65	66	67	68	69	70	TOTAL	TRUE FIRE WARNINGS 65	66	67	68	69	70	TOTAL	FIRE WITHOUT WARNINGS 65	66	67	68	69	70	TOTAL
F5					1		1												1		1
F84	1	1	2	1	3		8			1				1		1	1	1	3		6
F86	3	1					4	2						2		1					1
F89	6	1					7	4						4	2	1					3
F100	8	9	5	4	16	3	41	4	5	1	2	6	2	20	3	4	3	2	5	1	18
F101	9	8	3	3	3	2	28	4	3	2	2	1	2	14	4	4	1		1		10
F102	4	3	2	3	2		14	3	1	1	1	1		7		1	1				2
F104	2	1	1		2		6			1		1		2	1				1		2
F105	13	11	7	4	1	2	38	3	3	1	1			8	7	7	5	2			21
F106		1		1		1	3		1		1			2						1	1
F111		2		3	2	1	8														
T28		1		2	1	1	5														
T33	4	1		3		2	10	2	1		1		2	6	1						1
T37	3	2	1	2	3	2	13					2	1	3	2	1		2	1		6
T38	4	1	1		2	3	11	2	1	1		2	1	7	2					2	4
T39	1					1	2						1	1							

TABLE IV - USAF AIRCRAFT ENGINE NACELLE FIRES (Concluded)

AIRCRAFT	ENGINE NACELLE FIRES							TRUE FIRE WARNINGS							FIRE WITHOUT WARNINGS						
	65	66	67	68	69	70	TOTAL	65	66	67	68	69	70	TOTAL	65	66	67	68	69	70	TOTAL
C7				1	2	1	4					1	1	2							
C47		7			5	1	13		2			2		4		3			3		6
C54	3		1	1			5	2		1				3	1			1			2
C97	4	3		1	2		10	2			1	1		4	2	3			1		6
C117	1						1														
C118	2	1					3	1						1	1						1
C119	7	4			3	5	19	2				2	3	7	5	1			1	2	9
C121	2		3	1		1	7	1		2	1			4			1				1
C123	1	4	2		4	3	14					2	1	3	1	4	2		2		9
C124	3		3		1	1	8			2				2	2		1		1		4
C130	2	1	3	2	3	4	15	1		1	2		3	7	1	1			2	1	5
C131		2		1	2	1	6					1		1				1	1	1	3
C133	1			2			3	1						1				1			1
C135	6	6	7	9	10	17	55	4	5	4	2	2	11	28	2		1	6	8	6	23
C141					1	1	2						1	1					1		1
TOTAL	124	94	67	68	100	79	532	51	35	29	20	42	37	214	47	35	27	33	41	30	213

Of the 427 accidents/incidents, 307 or 72% of these cases involved fire only; that is, no structural damage or explosion preceding the fire. In 137 or 45% of the 307 cases the fire detection system did not provide an alarm.

For the vast majority of these accidents/incidents, it was impossible to determine from the report the damage resulting from the detection system not providing an alarm, or to quantitatively assess the value of a faster alarm by the detection system. However, Table V shows three accidents wherein it appears that aircraft were either destroyed or received major damage as a result of the detection system not providing an alarm.

As can be seen on Table IV the B-52 and C-135 aircraft experience a high percentage of undetected fires in the engine nacelle. This is partly due to the removal of a portion of the detection system because of false fire warning problems as has previously been mentioned. It was further noted that a large percentage of these fires involved burner-can or fuel manifold failures which initially result in fairly localized, intense, high velocity flames. Consequently, the probability of detection by a unit or continuous overheat device within a reasonable time after combustion initiation, if at all, is extremely low particularly for a burner-can failure. Radiation sensors would be much more suitable for detecting this type of fire because of their volume coverage capability. In addition, the radiation sensor would provide early detection of the fire thus, potentially, greatly reducing the ensuing damage to the engine nacelle. Table VI summarizes the USAF aircraft fire and overheat warning experience from 1965 through 1970.

TABLE V - CONSEQUENCE OF MISSED FIRES

YEAR	AIRCRAFT	DAMAGE	INJURY	REMARKS
1965	F-4	DESTROYED	MAJOR	WARNING RECEIVED TOO LATE
1966	C-47	DESTROYED	MAJOR	
1969	KC-135	MAJOR	NONE	ENGINE DROPPED OFF

TABLE VI - USAF AIRCRAFT FIRE AND OVERHEAT WARNING EXPERIENCE

Total Number of Incidents - 1608

		FIRE ?	
		YES	NO
WARNING LIGHT ON ?	YES	214	1036
	NO	213	NO INCIDENT
	UNKNOWN	105	NO INCIDENT

SECTION III

CONCLUSIONS

The review of the accidents/incidents involving fire, overheat, and false fire warnings in Air Force aircraft engine nacelles disclosed the following:

a. Approximately 83% of the reported fire alarms in USAF aircraft are false (1036 out of 1250 cases).

b. False fire warnings are a major problem in Air Force aircraft not only because of their frequency but because of the resulting cost (funding and injuries/fatalities).

c. False alarm problems should never be resolved by reducing or eliminating the detection system capability as has been done in certain aircraft in the past because of the resuling increase in the number of missed fires. This in turn could result in additional damage/destruction to aircraft as well as potential injury/fatalities to crew members.

d. Present day detection systems do not provide adequate detection capability as evidenced by their failure to alarm in approximately 50% of the fire accidents/incidents in Air Force aircraft. Radiation sensors should be used in lieu of overheat sensors for the detection of fires to correct this deficiency.

e. Several aircraft have had detection system problems such as false fire warnings and missed fires which have never been resolved.

f. Assessment of detection system capability on USAF aircraft in a combat environment was not possible from the data available. Information on the effect of missed fires and the criticality of detection time would be particularly valuable. Potential data to make these determinations can be obtained from the Combat Damage Information Center (CDIC) at Wright-Patterson AFB, Ohio.

g. The deficiencies (false fire warnings and missed fires) of present day fire detection systems in operational USAF aircraft can be resolved by the use of advanced fire detection systems developed by the AFAPL. False fire warnings can virtually be eliminated by using either the Self Generating Overheat Detection System or the Dual Loop Continuous Overheat System. The Dual Loop System is a derivative of the Integrated System and is currently being used with great success in many commercial aircraft. Both false fire warnings and missed fires potentially can be eliminated by use of the Integrated System which utilizes redundant radiation sensors for fire detection and redundant (dual loop) continuous sensors for overheat detection resulting in a high degree of system reliability.