AIRCRAFT FIRE DETECTION
Report of Conference

16–17 NOVEMBER 1970

by

ENGINEERING AND MANUFACTURING DIVISION
FLIGHT STANDARDS SERVICE

DEPARTMENT OF TRANSPORTATION
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FOREWORD

A symposium on aircraft fire detector systems was held in Washington, D. C. on 16 and 17 November 1970. The purpose of the symposium was to familiarize Federal Aviation Administration Regional personnel with the characteristics, capabilities, and limitations of the currently available detector systems. A number of presentations were made by representatives of leading fire detector, helicopter, and small airplane manufacturers, and by representatives of the military and the FAA National Aviation Facilities Experimental Center.

All aspects of aircraft fire detection were reviewed. The detector manufacturers described individual detector systems; airplane and helicopter manufacturers discussed system installations and experience; military representatives reviewed the more important system design and installation requirements applicable to military aircraft and discussed advanced techniques of fire and overheat detection. An FAA representative described the investigations in progress at NAFEC with respect to burn-through type fires.

Fire detector manufacturers were asked to follow an outline designed to bring out pertinent information about fire detectors, and to provide information on the manner in which the manufacturers go about meeting FAA standards. The outline suggested for airplane and helicopter manufacturers was of a slightly different nature, designed to convey information on installation practices and means of compliance with the rules. The two outlines follow. The papers including questions and answers, constitute the permanent record of the conference. A list of conference attendees may be found in Appendix A.

RECOMMENDED PRESENTATION OUTLINE
FIRE DETECTOR MANUFACTURERS

1. Principle of operation of the fire detector system
2. System Design
3. System Characteristics
4. Installation Recommendations
5. Methods of Showing Compliance with Fire Detector TSO -
    a. Paragraph 3.3.3 Altitude
    b. Paragraph 3.3.4 Vibration
    c. Paragraph 3.5 Magnetic Effect
    d. Paragraph 4.2 Reliability
    e. Paragraph 4.4.1 Adjustable Detector System
6. Suggestions for Improving TSO or Rules

RECOMMENDED PRESENTATION OUTLINE
FOR AIRPLANE & HELICOPTER MANUFACTURERS

1. Considerations Entering into Selection of a Fire Detector System
2. Installation Practices
3. Determination of System Location & Setting
4. Procedure for Showing Compliance with the Rules
5. Means of Demonstrating Adequacy of Installations
6. Suggestions for Improving Procedures
7. Suggestions for Improving TSO or Rules

INTRODUCTORY REMARKS

The conference was opened by Mr. Paul L. Clark, Assistant Chief of the Engineering and Manufacturing Division. Mr. Clark noted that there had not been a conference on aircraft fire detectors for many years but that great advances had been made in fire detector development. It was hoped that by this pooling of knowledge, everyone present would have the opportunity to become acquainted with the latest designs and the latest thinking in aircraft fire detector installation technology.

Mr. Stephen H. Rolle, Chief of the Propulsion Branch, acted as host and chairman of the conference. He stated that the purpose of the conference was to "up-date" everyone. He further explained that the papers presented at the conference would be bound as a single document together with any questions and answers that followed delivery of the papers. This document would then serve as a reference book for Federal Aviation Administration personnel who have responsibility for approving fire detector installations. Distribution would be made to all attendees.

OPERATION AND CHARACTERISTICS

OF THE

KIDDE CONTINUOUS FIRE DETECTOR

ROGER B. JONES

ASSOCIATE TECHNICAL DIRECTOR

WALTER KIDDE & CO., INC.

PRINCIPLES OF OPERATION

The Kidde Continuous Fire Detector is a thermal detector -- it monitors temperature or heat and responds with a signal whenever the temperature exceeds a pre-set limit. The sensing element is a thermistor device. It is a small diameter tube filled with a thermistor material in which is embedded a wire running the full length. The thermistor changes electrical resistance with temperature -- as the temperature goes up, the resistance goes down. The resistance is measured between the wire and the tube by means of an electrical connector at each end. Essentially, then, each unit of length of element is a thermistor resistance electrically in parallel with each other unit.

The thermistor has definite resistance-temperature characteristics, according to a published curve. (Figure 1). The slope of the curve is very steep, so that the thermistor has easily measured resistance values only within a temperature range of a couple hundred degrees. For that reason, we have available some 15 standard variations in the thermistor formulation to provide a curve at least every 100° between about 200 and 1400° F.

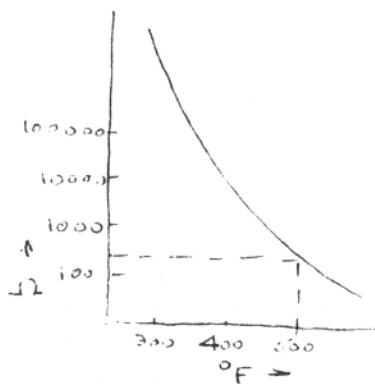
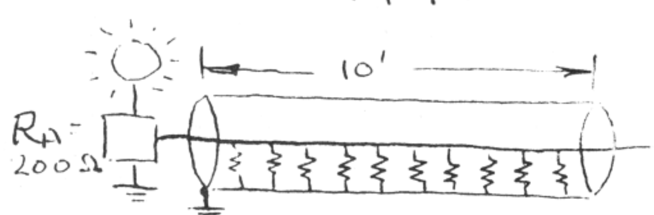


FIG. 1

Look at a representative system. (Figure 2). For this example, make the element 10 feet long. We can consider this as being 10 1-foot pieces in parallel. Our published curve gives the resistance of a 1-foot length at various temperatures, as shown in Figure 2. In this system we have chosen the alarm to be at 200 ohms. If only 1 foot is heated, the alarm will occur at 550° F. However, suppose all 10 feet are heated uniformly. When each



°F	R1'	R4'	R10'
RT	400K	100K	40K
250°	18K	2K	1.8K
310°		360	
375°	2K	220	200
425°	900		
530°	220		
550°	200		

FIG. 2

1-foot length is at 2000 ohms, the overall resistance will be 200 ohms (2000 divided by 10). This occurs at 375° F.

Suppose 9 feet of the element are at the maximum ambient -- for this example, 250°. The 9 feet will have a resistance of 2000 ohms (18000 divided by 9). If the remaining 1 foot is now heated, its resistance need only go down to 220 ohms for the alarm.

$$R_1 = \frac{R_2 \times R_T}{R_2 - R_T} \; ; \; R_{1'} = \frac{200 \times 2000}{2000 - 200} = 220\Omega$$

This corresponds to a temperature of 530°, showing that the ambient temperature had little effect.

Similarly, suppose the 1 foot section were close to a bleed air line, so that its ambient temperature is 425°. This, you will note, is higher than the alarm temperature of 375° established for the full length. However, the resistance of the 1 foot at 425 is 900 ohms. To alarm, the remaining 9 feet will have to be heated until its resistance drops to 360 ohms.

$$R_{9'} = \frac{900 \times 200}{900 - 200} = 360\Omega$$

This will occur at 370°, which is only slightly different from the uniformly-heated full length alarm temperature. This is the averaging effect, and you can see how such a sensing element can be routed through areas that may be hotter than the desired average alarm temperature without causing a nuisance alarm.

We normally connect the element string in a loop (Figure 3), monitoring the resistance from each end, so that if a break should occur, no loss of detection capability will result. A continuity test is part of the cockpit integrity test. One end of the loop is disconnected from the control unit and connected to ground (or a test circuit that

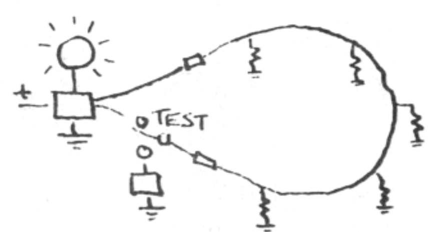


FIG. 3

simulates fire resistance). If the alarm light comes on, it indicates the loop is continuous, the control circuit is functioning, no shorts exist, the power is on, and the bulb is good. Thus, the system is in operating condition.

If a short should occur between the element wire and ground, the resistance will be lowered below the fire alarm point. Lighting the fire light (which would be a false warning, of course) is prevented by the short discriminator circuit. We use two monitoring circuits, set at different resistance trip levels, (Figure 4). If fire should occur, the element will be heated and the resistance will drop along a slope, since the element cannot be heated instaneously. As the resistance drops, it triggers the fire circuit and short discriminator circuit in sequence. The fire circuit, after a very short delay (milliseconds), lights the fire light, and at the same time disables the short discriminator so that it can have no effect.

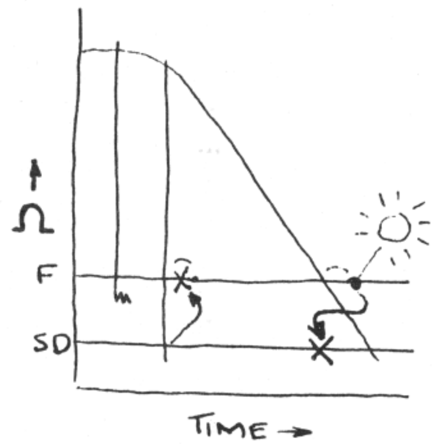


FIG. 4

But suppose a short had occurred instead of a fire. The resistance would have dropped instaneously, a characteristic of a short, and both circuits would be triggered simultaneously. However, the operation of the short discriminator circuit is virtually instantaneous (microseconds), and disables the fire circuit before it can operate. Thus, no fire signal is given. The short discriminator circuit can activate a fault signal, but timing is not a factor. When the short clears, the circuits reset instantaneously, so that the system is immediately ready again. The system will detect and signal fire right through repeated intermittent shorts. Obviously, if a short should occur that has a resistance value between the two circuit settings, and hold there for the delay period, a false warning will be given.

Another arrangement of the short discriminator reverses the sequence of the two circuits. (See Figure 5). Here, if a fire occurs, the short discriminator circuit is triggered, which now arms the signal portion of the fire circuit after a short delay. The fire circuit then activates the fire signal. If a short occurs, both circuits are triggered simultaneously, but the fire circuit disables the short discriminator circuit, which cannot now perform its arming function, and so no fire signal can be given. For a short to cause a false warning, it must drop to between the two settings, hold there for the delay period, and then drop below the fire setting. If it rises above the short setting, the system resets.

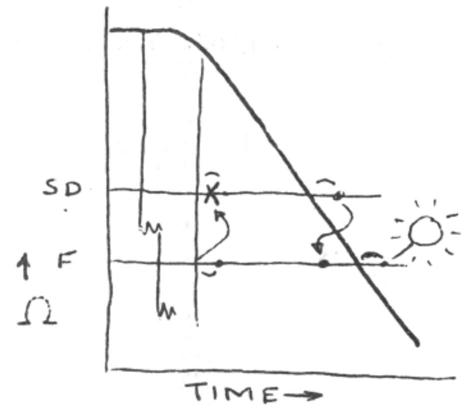


FIG. 5

Moisture in an element connector, or absorbed in a broken element, acts as a parallel resistance, particularly if it contains dissolved salts, and would thereby reduce the system resistance. If it reduced resistance low enough (below the fire trip point), it would cause a false warning. This is prevented by making use of a natural phenomenon. For water to conduct significantly, it must contain salts, which makes it an electrolyte. Electrolytes conduct by flow of ions between the electrodes, but the applied potential must overcome the ionization potential of the electrolyte. This occurs at about 1 volt, so we operate our measuring circuit in a manner that applies only about 1/2 volt DC to the sensing element. In this way, moisture does not conduct enough to form a low resistance shunt, (Figure 6).

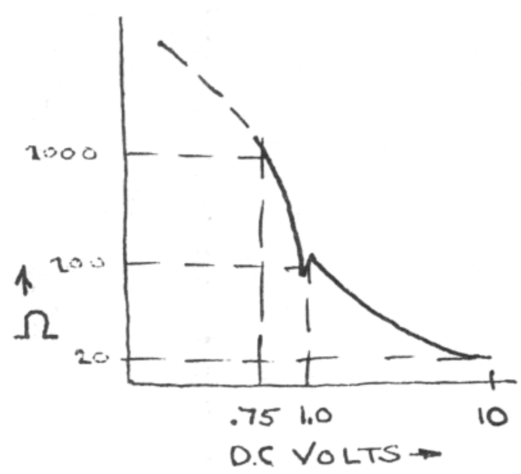


FIG. 6

In today's transport, we generally employ dual loop systems, (see Figure 7). This is, in effect, two complete detection systems. The redundancy gives added reliability, but the primary reason is for dispatchability. If one loop is discovered at preflight to be malfunctioning, it can be switched out, and the aircraft dispatched, since it still has a complete detection system fully meeting FAA standards. The words AND and OR that you hear nowadays, refer to the way the outputs of the two loops are connected. If in series, so that both loops must be triggered to activate the fire warning, it is said to be an AND system. If in parallel so that either can activate the fire warning, it is an OR system. Both have their adherents. However, an AND system should have some indication when only one loop is triggered, to protect against the possibility that a fire might occur when one loop has failed inoperative. With such a feature, the AND system actually becomes both AND and OR.

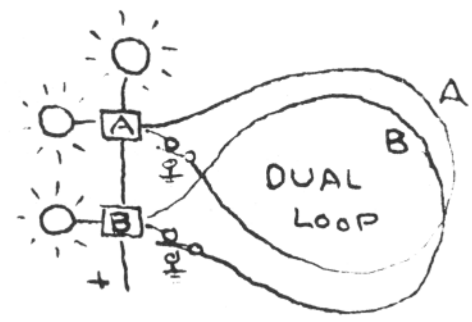


FIG. 7

The thermistor properties makes it possible to monitor the sensing element loop at two different resistance levels, (see Figure 8), corresponding to two different temperature levels. The alarm at the lower temperature level would indicate an excessive temperature rise and would permit corrective action short of shutting down the engine. The overheat warning could also be advance notice of a fire warning.

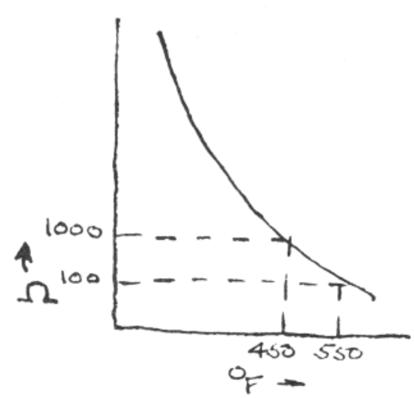


FIG. 8

An ohmmeter connected across the sensing element circuit can measure loop resistance under flight conditions, and thus establish whether the original nacelle temperature estimates were correct. On the basis of such a test, corrective action can be taken if necessary. Also, a meter can be permanently installed in the cockpit which, responding to element loop resistance, can be marked in temperature terms, and thus continuously indicate nacelle temperature.

It is also possible, monitoring the element loop from each end as we do, to tell where along the loop a low resistance has occurred. The low resistance can be due to overheat, fire or a short, and the location is determined with a special, but simple, circuit.

SYSTEM DESIGN

The system design starts with the identification of the fire hazards in the aircraft. Generally, for the engine, this is locating the fuel components and those areas where hot bleed air leaks can occur. Ambient temperatures must be determined and alarm temperatures established. Consideration must be given to the warning presentation. It should be established whether only a fire warning is required, whether separate zone indicators are desired, and whether or not a preliminary overheat warning is desired (for bleed air leaks, for example, where throttling or shutdown is accomplished w/o fire bottles). Then, reliability and dispatchability must be considered. For commercial transports, this generally means dual loop systems nowadays, although single loop systems provide adequate reliability for business aircraft where maintenance is different, and where dispatch delays can be tolerated.

These design considerations must be resolved by the aircraft manufacturer, perhaps with his customers, but we stand ready, of course, to assist. A mock-up comes next to establish the element coverage, determining the element length and routing, and, if armored or supported, the bend configurations. Considering the element lengths, we select the element thermistor type and alarm trip resistance to match the desired alarm temperature characteristics. If necessary, to achieve unusual effects, we will prepare a special thermistor mix to yield special effects. Based on the mock-up configuration, we will select an end connector arrangement to facilitate installation and replacement. We also design a control unit, selecting from our variety of control circuit features to achieve the end results desired -- we must consider the number and type of outputs desired, any automatic features, use of short discriminator circuits, fault or heat locator circuits, temperature indicator circuits, flasher circuits, and special test circuits to permit test of all functions.

We must, of course, consider the usual specification requirements. The TSO requirements are specified for civil aircraft, along with additional environmental requirements determined by the airplane manufacturer. Response time is an important requirement, and to meet it, we must consider the effect of the alarm temperature and select an element physical size accordingly.

Generally, such design requires a good deal of interplay between the aircraft manufacturer and ourselves, until his requirements and our capabilities are matched to our mutual satisfaction.

SYSTEM CHARACTERISTICS

1. The system responds to the lowering of resistance to a pre-set level.

2. The temperature of the element required to produce this lowered resistance is a function also of the length of element heated.

3. The resistance of the sensing elements can be measured under flight conditions to confirm estimated normal ambient temperatures. A meter can be permanently mounted in the aircraft to continuously indicate the temperature felt by the sensing elements and thus monitor nacelle temperature conditions.

4. A short circuit activates the short discriminator and blocks out the fire signal while the short exists. The system resets instantaneously when the short is removed, so that the system can detect fires even in the presence of continuous intermittent shorting. A separate indicator is provided to indicate when the short discriminator is activated. A patent has been granted on this feature.

5. Moisture, even salt solutions, in element connectors or entering broken elements, does not lower the resistance to the trip point. This is because of the low DC voltage applied by the measuring circuit which is insufficient to overcome the ionization potential of the salt solution. A patent has been granted on this concept.

6. AC voltages induced in sensing element connecting wires by adjacent power-carrying wires can suppress the operation of the detection system. This applies only to short discriminator systems where the suppression is

due to activation of the short discriminator by the AC pulses. It can be prevented, by suitable filtering at the control unit. Normally such interference is avoided by proper wire spacing practices.

7. Speed of response of the system to fire is a function of the alarm temperature -- the higher the temperature, the longer it takes. It is also a function of the mass of the element. Kidde elements are furnished in three sizes, 045, 065 and 085 diameter.

8. Reset time is a function of the air flow, the mass of the element, and the differential built in the control circuit between signal on and signal off. The TSO requires still air in the tests, and the element mass and the differential are part of the design selections to meet requirements.

9. The element can withstand ambient temperatures up to 1400° F., but the electrical connectors are normally rated for only 800° maximum. The materials will take higher temperatures, but we lose confidence in the ability of a spring contact to maintain good contact over long periods at high temperatures. This could be gotten around, perhaps, by breaking and remaking the connections periodically.

10. With the usual loop connection, a break in the element loop will not affect the functioning of the detector, since the resistance is monitored from each end of the loop. Interrupting the loop does not change its resistance, so it doesn't cause a false alarm. Of course, since the cockpit integrity test includes a continuity test of the element loop, it would indicate a failure.

11. The trip level of the short discriminator circuit is carefully maintained in relation to the fire trip setting so as to insure that no possible heating rate is fast enough to be interpreted as a short circuit.

12. The ability of the element to withstand abuse is amazing. It can be cut, twisted, bent sharply, all without failure or change in characteristics. It can be hammered flat, and continuity is still preserved thru the flattened section, it does not short, and the thermistor still functions. Obviously, such physical damage will weaken the element to fatigue failure, and so we recommend replacing the damaged element when the damage is noticed.

13. An element normally exhibits a high "insulation" resistance. This is really the thermistor resistance at low temperatures such as room temperature. A lower than normal resistance indicates that the element has been damaged, usually by absorption of water vapor through a break in the seal. Such low resistance is not necessarily harmful (particularly if due to moisture), but it does indicate an element that is not in first class condition, and is cause for replacement.

14. Many times, a corrective action for what is reported as a false warning is moving the element away from proximity to a hot surface. Since the element sheath is grounded anyway, there is no electrical effect. And because of the averaging effect, direct contact with a normally hot surface would not cause a warning.

INSTALLATION RECOMMENDATIONS

1. Element must be routed in the area where it will intercept air flow from the fire.

2. The element must be securely mounted so that it cannot chafe against engine parts or structure. Clamp spacing must be close enough to assure this.

3. We recommend the use of clamps with 2 mounting holes to insure against the clamp swiveling and thus allowing the element to be improperly aligned.

4. The element routing must avoid situations where maintenance damage would be likely. For example; do not route the element adjacent to or across a bolt that must be removed periodically. Damage from the wrench would be inevitable. If such areas cannot be avoided, then measures must be taken to prevent damage -- clamp the element out of the way, or install protective guards.

5. The element should not normally be clamped to support points having relative motion. Flexible cables should be used to make the transition.

6. Sensing element connecting wires should avoid wire bundles containing high power wires. If they cannot be avoided, then the induced voltages should be measured so that proper measures can be taken in the control circuit design.

7. Attention must be paid to the normal maximum ambient temperatures, to be sure they do not exceed the maximum capability of the elements or their connectors.

8. We recommend grommets of teflon-impregnated asbestos wherever temperatures (600° F max.) permit. These provide the best cushioning to avoid element vibration fatigue failures.

9. Control units should be located with regard to their temperature and vibration limitations. We suggest that the control units be readily accessible, since their connectors provide a ready access to the system for troubleshooting.

10. Installation of element loops on hinged cowl panels should be approached with the utmost caution. The problem is that even though the elements are installed initially so as to clear engine parts when the doors are closed, subsequent actions seem to pull the elements out of position so that they chafe against something when the doors are closed. And, of course, it is hard for the maintenance person to see beforehand that this will happen. The flexible cables crossing the hinge line are another source of trouble. They either break from being bent too sharply, pull apart from being too tight, chafe from being too loose, or get pinched in the hinge as the doors are closed.

11. Any installation requires great care in its design, and can be rewarded with a virtually trouble-free system.

The engine installation usually requires that the sensing element be routed between or adjacent to the fuel accessories. Generally there is very little clearance, so the installation must be designed with sufficient support points to insure that the element will not chafe against the engine parts. It must further be insured that when re-installed in the field, the clearances will be maintained. Enough support points must also be provided to avoid excessive spans and overhangs that might result in vibration failures.

As you might imagine, this could be quite difficult to do. And even if enough support points could be provided, the replacement of an element could be a difficult chore. These problems are solved on modern transports by providing a special support structure for the element. In some cases, we have encased the element in a pre-bent tube, perforated to let the heat in. Response time is maintained by using an element of much smaller mass. In other cases, we have attached the element externally to the support tube. Both of these methods have proven highly successful, and false warnings, which were primarily caused by element damage in the past, have virtually disappeared.

12. Virtually doesn't mean entirely, and our main problems now seem to be with connecting the sensing element to the aircraft wiring. Connectors are improperly assembled to the wire, the wires are bent too sharply where they enter the connector, and sometimes the connectors are not tightened to the element. Obviously, these are all maintenance problems, but the installation should be designed to make the maintenance easy, not difficult. The connectors should be visible, there should be room for the wire to make a gradual bend, and the wires should be properly supported near the connector.

METHODS OF SHOWING COMPLIANCE WITH THE TSO

We were requested to explain in this presentation the methods of showing compliance with the following fire detector TSO requirements (TSO-C11d):

a. Altitude, Paragraph 3.3.3

This is tested per Paragraph 7.10

7.10.1 The test system is placed in an altitude chamber, operating at standby. A test circuit is used to monitor the system output, while the chamber pressure is reduced to the specified altitude, and at the specified rate. The system is functionally tested before and after the test.

The system is then subjected to the flame response test. The sealed components are subjected to an under-water leak test, pulling the same vacuum as the altitude test. Bubbles are observed visually.

7.10.2 The above test is repeated for low altitude (-1000 feet).

7.10.3 A pressurization test is conducted on the control unit, in which the unit is subjected to 50 inches Hg for 15 minutes. At the end of this period, and with the control unit still under pressure, the elements are subjected to flame response test.

b. Vibration, Paragraph 3.3.4

This is tested per Paragraph 7.3

Control units and elements are tested separately because they have different requirements. The sensing elements are tested in a representative configuration, since the systems are too large to test in their entirety.

While testing the control unit, the elements are simulated with a variable resistor, and its functions checked periodically.

While testing the elements, they are connected to a control unit. The output is monitored, and the integrity test (for continuity) is performed periodically.

Another vibration is applied to the elements during the clearance time tests of Paragraph 7.12. This test is performed with the element in the flame and being vibrated by an eccentric at a constant frequency of 60 cps at the specified g level.

c. Magnetic Effect, Paragraph 3.5

There is no test given in TSO-C11 but there is one in C79.

The compass specified is a hand held model used by outdoorsmen. It is placed on a pedestal and the detector control unit is passed around in an East-West plane, coming closer with each pass until the needle deflects 5°. We can come to within 6 inches.

Sensing elements are not mounted near a compass in the aircraft, but in any event, they have virtually no current flowing, and their mass has virtually no magnetic effect.

d. Reliability, Paragraph 4.2

This is observed by our designs, and as confirmed by the performance of similar equipment in previous aircraft.

e. Adjustable Detector System, Paragraph 4.4.1

Previous adjustable systems were tested at the extremes of the adjustment. Present systems are not adjustable.

SUGGESTIONS FOR IMPROVING THE TSO

We want only to build equipment which will perform its intended function reliably in the face of the adverse conditions it will encounter. Obviously, we need specifications to tell us what these intended functions are, and what the adverse conditions will be.

These specifications should be completely objective. They should be complete, and there should be no unnecessary restrictions. Naturally, they should be realistic.

To be complete, the specification should provide a test for each important design function or environment. The test, too, should be realistic. Many times, no tests are given. Or tests are given which are too simple or unnecessarily difficult yet prove little. The test tells us what the design requirement really means.

Inspection of the TSO will show where it is deficient in these respects, and thus where it should be improved.

DISCUSSION FOLLOWING KIDDE PRESENTATION

Q. What tests are conducted to determine whether the amount of radio interference caused by a fire detector system is acceptable?

A. TSO C11d does not require Radio Magnetic Interference test. Kidde conducts a simple test with hand held compass within 6 inches of control box. We allow a maximum of 5^{o} deflection.

Q. What suggestions do you have for improving TSO-C11d?

A. Kidde has no suggestions for improving TSO C11d, but testing is the meat of the specification. The design requirements are not necessarily effective.

Q. For a detector having a particular temperature setting, what is the temperature tolerance?

A. The detector thermistor has a $\pm 25^{o}$ F. tolerance in each element length.

Q. What kind of feedback arrangements does Kidde have with the airlines or the airframe manufacturers?

A. Kidde has no formal arrangements for feedback of service experience. They have no problem in being informed of unsatisfactory service.

Q. What is the service experience with printed circuit cards?

A. Printed circuit cards used in control units, in response to military requirements for this type construction, cause no more problems than sealed control units.

Q. Frequently the mechanical reliability reports (MRRs) contain statements such as "no evidence of fire or overheat. Replaced fire control unit as precaution." What happens to the control unit?

A. It simply goes back to the service department where it is checked for servicability and returned to service. They are not returned to the detector manufacturer.

Q. Are the control units ever a cause of false fire warnings in such cases?

A. Possibly, but not very often.

Q. Are the detector manufacturers consulted regarding fire detector installations?

A. Yes, more so now than they used to be.

FENWAL FIRE DETECTION SYSTEMS

GEORGE J. GRABOWSKI

MANAGER - PROTECTION SYSTEMS DIV.

FENWAL INC.

Fenwal Incorporated manufactures Fire Detection components in the following catagories:

1. Unit or spot type detectors incorporating rate anticipation which provide an alarm signal when exposed to any rate of temperature changes above a pre-established level. This type of thermal sensing, while it has not been applied in the most recent fire detection systems, still has an application for certain unique applications.

2. Optical flame sensors which operate either in the infrared or ultra-violet regions. Fenwal continues to maintain Engineering effort in these areas. It is our opinion that, to date, the components available for the design and manufacture of optical sensors do not yet lend themselves to surviving in the environment associated with turbine engines.

3. Thermal sensors and associated electronics of the line or continuous sensing type are the most commonly installed on turbine powered aircraft. The remainder of the presentation will deal specifically with the design and application of this type system only.

The Fenwal Continuous Fire Detection System consists of a thermal sensing element with associated hardware for attaching to aircraft structure and a control unit. The thermal sensing element signals an overheat or fire condition by a change of state when the temperature within the area being monitored reaches a preselected temperature. The signal from the sensing element is then modified by the control unit to actuate auxiliary equipment provided by the airframe manufacturer to provide a visual or aural alarm to the aircraft pilot.

Sensing element temperatures available are - 255°, 310°, 400°, 575°, 765°, 900°, 1050° and 1200° F. The tolerance on these setpoints is ± 5%.

The sensing element consists of a solid nickel conductor insulated with porous aluminum oxide ceramic encased in Inconel tubing and hermetically sealed at both ends. The area surrounding the Inconel conductor and ceramic are saturated with a eutectic salt mixture. When the element is exposed to a fire or overheat condition, the resistance between the center conductor and the outer sheath drops sharply as the temperature reaches the eutectic point, or alarm temperature.

This design offers the prime advantage of discrete temperature sensing. This is inherent in the resistance-temperature characteristics of the eutectic salt used in the sensing elements. The resistance between the center conductor and the outer sheath drops from a very high level to a low level as the alarm temperature is reached. Because of the sharp drop in resistance at the alarm temperature, the alarm is signaled at the same temperature regardless of the length of element heated.

This is analogous to an infinite number of switches in parallel, only one of which has to close in order to signal an alarm condition.

Another advantage of the unique temperature characteristics is that elements of different alarm temperatures may be interconnected in series. Each of the elements in the series loop will alarm at its fixed temperature without regard to the environmental conditions effecting any of the other elements connected in the same loop. Therefore, if a large volume such as the typical turbine engine nacelle requires more than one temperature setting to provide proper protection, then this can be accepted in a Fenwal system by interconnecting the various temperature settings required in a single monitoring loop.

The control unit provided with the Fenwal systems has two basic functions:

1. To insure prior to flight that the fire detection system is in good working order. The test circuit determines that there is no break in the detecting element and associated wiring, the control unit is operating properly and the visual and aural alarms are operational. This is done by providing a switch which in its operate position opens the loop and grounds one end. The grounded end closes the circuit and will cause the control unit to actuate the alarm system.

2. To signal a fire or overheat condition in the operating position, the ground is provided by the low resistance path caused by the overheat or fire conditions between the inner conductor and outer sheath.

Control units can also be provided with added features beyond the basic function of signalling a fire or overheat condition. Additional electronics can be incorporated within the control unit to provide for short discrimination as a means of elimination of false fire warnings. A distance measuring capability can also be provided for extremely long lengths of sensing elements where it is desirable to determine the fault location causing the fire or overheat prior to opening up part of the aircraft structure, or engine nacelle. While these additional features, or functions, can be provided, they do not contribute to the basic requirements of a fire detection system and do nothing to enhance the reliability. It is inherent in any method of computing reliability that the addition of more electronic components, with their determined failure rates, must necessarily reduce the computed and experienced reliability on any such device.

For increased reliability, Fenwal Fire and Overheat Detection Systems can be provided in either a single or dual loop configuration. In the dual loop system, the sensing element network consists of two detector element loops in parallel within the area to be protected. The two element loops are connected to a single control unit so that both loops must detect a fire condition before the visual and/or aural alarm is energized. If only one element loop is energized for any reason, including a ground or short, no signal will be given. The dual loop system has the prime advantage by redundancy of being a fault tolerating system. While it is possible in a single loop system to distinguish between a fire and a short, the disadvantage of such a system is that when a short occurs, this loop no longer has a fire detection capability, and thus an information gap exists.

The dual loop system bridges this information gap as the odds are overwhelming against a fault occuring in both loops. The dual loop concept insures the integrity of one loop is maintained and, therefore, has the capability to detect any overheat or fire condition which may occur.

It is very difficult to provide specific installation instructions applicable to all turbine engine installations. It is significant to note that programs conducted over the past several years to evaluate the various types of fire detection systems currently available, two significant results of this investigation are:

1. Fires within the compressor and accessory compartments, in many cases, are too low for detection by long continuous type systems which respond only to the averaging temperature over the length of

sensing element.

2. Continuous type detector systems, which require heating of only, a short length of the element will provide an alarm signal not sensed by the averaging type of element.

Because the method of element installation, and the length of loop provided must be tailored to fit the particular area to be protected, Fenwal feels that the best installation can be accomplished by a change in the regulations covering responsibility of installing fire detection systems. This will be covered in greater detail later on in this presentation.

The present Fire Detection TSO, while it refers to the need for meeting certain environmental parameters, does not provide specific requirements for evaluation as to compliance with the referenced requirement. The requirements of Paragraph 3. 3. 4 having to do with Vibration can best be commented on by the airframe manufacturers. It has been our experience that in the past, while certain systems may pass the Vibration Test as presently defined, weaknesses do show up under actual operate conditions requiring corrective action. This, to us, is an indication that the environment defined is not necessarily that of the aircraft.

With regard to Paragraph 3. 3. 3 - Altitude - we do not feel that the requirements of Paragraph 7. 10. 2, Low Altitude, necessarily contribute to the performance or reliability of the fire detection system.

Paragraphs 3. 5 - Magnetic Effort and 4. 2 - Reliability. While they are requirements of the TSO, they provide no reference within Paragraph 7, Qualification Performance Tests Requirements, against which to evaluate this system. There are several specifications having to do with Magnetic Effect, and several others having to do with various Reliability requirements. It is suggested that these be reviewed and those applicable to transport aircraft be incorporated in either a new, or a revised, TSO.

FAR-25 presently requires that the airframe manufacturer assume responsibility for selection of and determining the airworthiness of the fire detection system to be installed on his airframe. With the increased complexity of turbine engines used on modern aircraft and the higher temperatures achieved, minimum response time is required in signaling a fire to the pilot if corrective action is to be taken. The engine manufacturer must, during development and design of a turbine engine for a given airframe, undergo many hundreds of hours of running time before the engine is ever installed for initial ground and flight tests as a integral part of the airframe. Fenwal would recommend that during this development and design phase for the engine that the fire detection system also be developed. Past experience obviously plays a great role in determining the initial sensor locations, but this valuable test time prior to the aircraft making its first test flight could be utilized to greater advantage in developing the fire detection system.

Fenwal, therefore, is specifically recommending that consideration be given to either delegating the responsibility for the fire detection system to the engine manufacturer together with the vendor of the detection system, or that it be made a joint responsibility of the engine and air-frame manufacturers.

DISCUSSION FOLLOWING FENWAL PRESENTATION

Q. Do you have any suggestions for improving the TSOs?

A. We suggest TSO C11 be completely revised or eliminated since it has not kept up with the requirements and changes in the aviation industry and is of no value whatever. Specifically the environmental conditions for vibration, altitude, magnetism, reliability and other parts are inadequate. Also we believe the airframe manufacturers should work closely with engine manufacturers.

Q. Have you tried to have engine manufacturers install detector systems during their development testing?

A. Engine manufacturers are not overly excited about doing it. We believe responsibility for detector installation should be delegated to the engine manufacturer, or jointly to the engine and aircraft manufacturer would help.

Detector manufacturers are being pushed to the wall by warranty and performance guarantees. We now refuse to accept a warranty unless the detector installation is approved by the detector manufacturer.

Q. What installation requirements are imposed in order to give the warranty?

A. Each installation must be designed on its individual merits and problems.

Q. What specific recommendations are suggested for rules changes.

A. Rules are all right, but specific recommendations cannot cover each and every installation.

THE LINDBERG MODEL 801DRS

FIRE AND OVERHEAT DETECTOR SYSTEM

JOHN S. WINTER

CHIEF ENGINEER

LINDBERG DIV., SYSTRON-DONNER CORP.

INTRODUCTION

The Model 801DRS fire and overheat detector design is the culmination of many years of aircraft fire and overheat detection service and design experience. The basic detector, like its predecessors, is pneumatically operated and incorporates the sensor and responder (pressure switch) components which have proven to be very reliable under severe turbo-prop and jet engine environmental conditions. The sensor and responder, which comprise the basic detector system, have had more than 50 million unit hours of flight service.

1. PRINCIPLE OF OPERATION

The detector is pneumatically operated by heating a small-diameter sensor tube which contains an inert gas and a gas-filled core material. The application of heat to the sensor causes an increase in gas pressure which operates a pressure diaphragm that closes an electrical contact to actuate the alarm circuit. The pressure diaphragm in the responder is the only moving part in the basic system and serves as one side of the electrical alarm contact.

The detector has a dual sensing function and can respond to an overall "average" temperature or a highly localized "discrete" temperature caused by impinging flame or hot gases.

Averaging Function

The sensor tube and responder serve as a fixed volume device and when filled with an inert gas, they operate as the overheat detector. The inert gas pressure increases in proportion to the absolute temperature and will operate the responder diaphragm at a predetermined "average" temperature. The average alarm temperature is set at the factory and cannot be changed in service.

Discrete Function

The sensor tube also contains a gas-filled core material which will outgas very large quantities of gas when a small portion of the sensor is exposed to the "discrete" temperature or higher. The core outgassing raises the internal pressure and actuates the responder diaphragm for alarm.

The average and discrete functions are reversible. When the sensor is cooled, the average gas pressure is lowered and the discrete gas returns to the core material.

The reduction of internal pressure allows the responder diaphragm to return to its normal position and open the electrical alarm circuit.

Please refer to Figure 1 for a graphic presentation of these functions.

Integrity Monitor

In addition to the basic pressure-actuated alarm responder there is a second responder in the system to monitor the averaging gas pressure at all temperatures down to -65°F. The diaphragm contacts are kept closed by gas pressure. Should the sensor develop a leak, the loss of gas pressure will allow the monitor contacts to open and signal a lack of detector integrity.

If the detector has been impaired, the system will not operate during integrity test. Figure 2 shows schematically how the alarm and integrity responder switches operate as a function of sensor tube pressure---or lack of pressure.

When desired, a fault indicating circuit can be furnished to monitor the integrity contacts at all times and automatically signal a fault when they open. Figure 5 shows a typical electrical circuit.

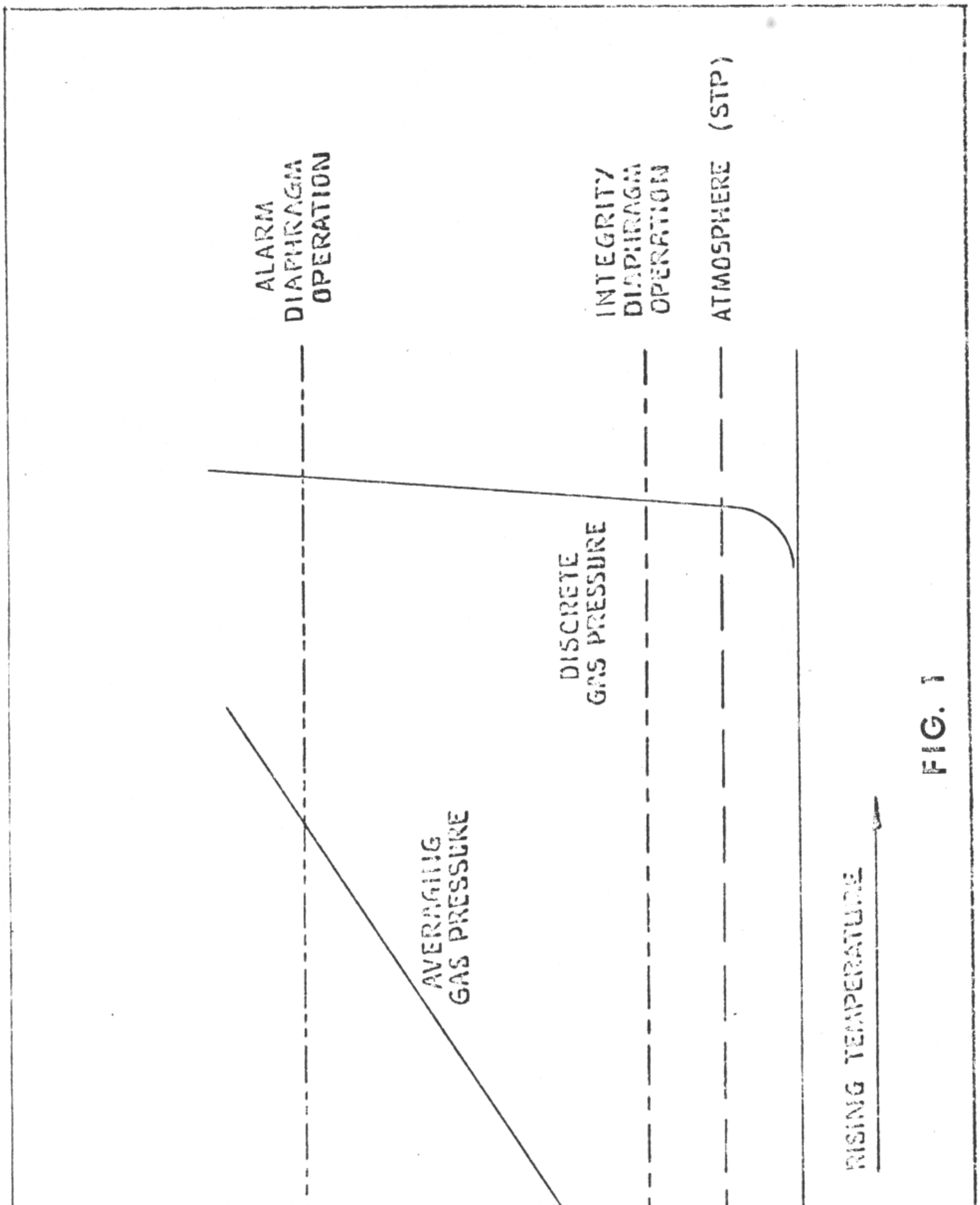
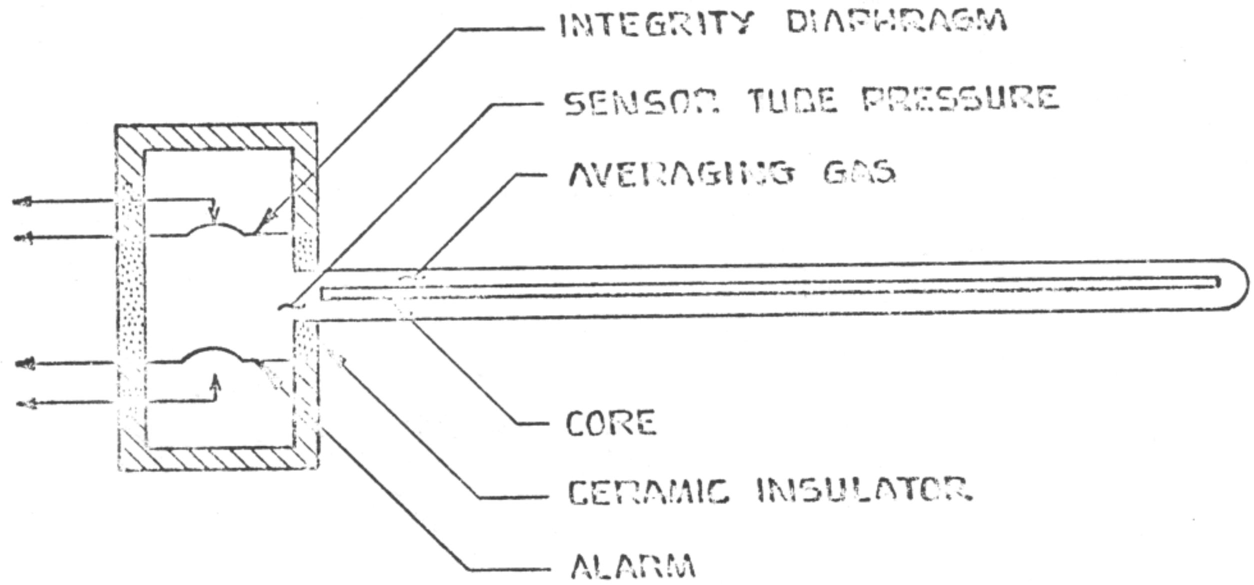

ALARM DIAPHRAGM OPERATION
INTEGRITY DIAPHRAGM OPERATION
ATMOSPHERE (STP)
DISCRETE GAS PRESSURE
AVERAGING GAS PRESSURE
RISING TEMPERATURE
RISING PRESSURE

FIG. 1

FUNCTIONAL DETECTOR ELEMENTS



NOTE : DIAPHRAGMS SHOWN IN NORMAL (NON-ALARM) POSITION

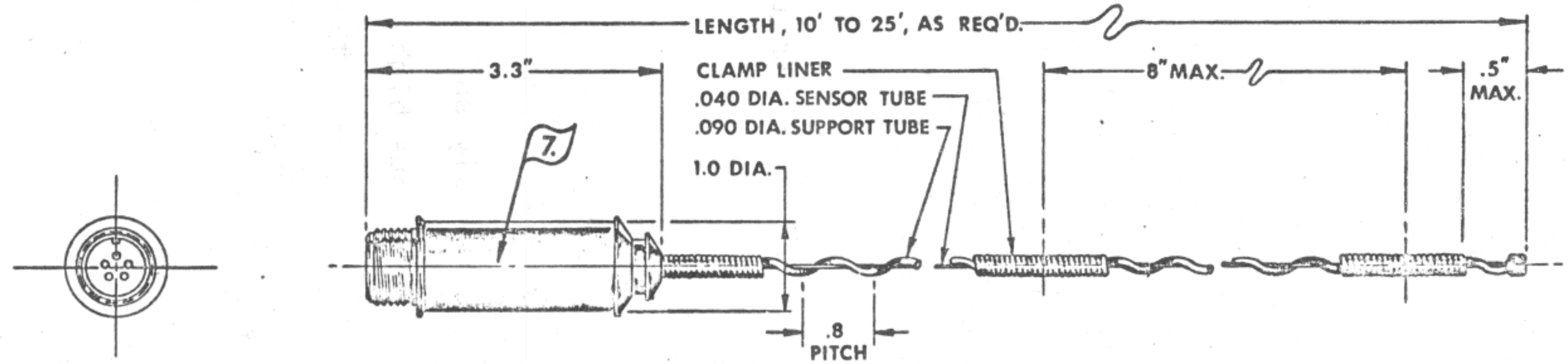
FIG. 2

2. DETECTOR DESIGN

The alarm and integrity responders are mounted in a hermetically sealed responder housing at one end of the sensor tube. The sensor tube is mounted through the central axis of a stainless steel helical support structure. Figure 3 shows the detector assembly including responder housing, spiral support structure, and integral metal clamp liners. A typical unit ten feet in length weighs 0.57 pounds.

The support structure provides support and protection for the sensor tube from vibration, abrasion, and impact.

The sensor and support structures have metal clamp liners to fit inside the quick-release mounting clamps. These clamp liners are a permanent part of the detector assembly and cannot be lost. The liners are designed for continuous high temperature operation and remain intact during a fire. The liners can be positioned during installation by a firm pull to one side or the other.



NOTES:

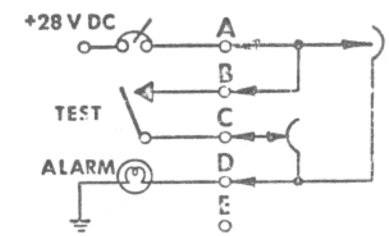
1. SUITABLE FOR CONTINUOUS OPERATION BETWEEN -65° AND +675° F
2. SUITABLE FROM SEA LEVEL TO AN ALTITUDE OF 70,000 FEET
3. MAT'L. & FINISH RESISTANT TO SKYDROL 500, LUB. OIL PER MIL-L-7808 & JET ENG FUELS
4. DETECTOR WEIGHT : .21 LBS. PLUS .036 LBS./FT. OF SUPPORTED SENSOR
5. ALL EXPOSED SURFACES ARE CORROSION-RESISTANT STEEL
6. DETECTOR IS HERMETICALLY SEALED
7. IDENTIFICATION, ELECTRO-ETCH AS FOLLOWS:

   LINDBERG SUBSIDIARY
   SYSTRON DONNER CORP.
   BERKELEY, CALIF.
   FIRE DETECTOR
   P/N 3801-XXX/XXX-XX
   S/N XXXXX

   XX — LENGTH - FEET
   XXX (second) — AVERAGE ALARM °F
   XXX (first) — DISCRETE ALARM TEMP. °F

8. CONTACT RATING : 0.4 AMP NON-INDUCTIVE 28 V DC

FIG. 3



SCHEMATIC DIAGRAM

QTY REQD	SYM	DESCRIPTION	CODE IDENT	PART NO.	SPECIFICATION	MATERIAL	ITEM NO

PARTS LIST

UNLESS OTHERWISE NOTED DIMENSIONS ARE IN INCHES
TOLERANCES: DECIMALS .X = ± .02, .XX = ± .01, .XXX = ± .005; ANGLES ± 1°

ORIGINAL DATE OF DRAWING 17 JUN 70
DRAFTSMAN CRITCHFIELD
CHECKER
ENGINEER
SUBMITTED

JOHN E. LINDBERG, INC.
SUBSIDIARY OF SYSTRON-DONNER CORP.
BERKELEY CALIFORNIA

FIRE DETECTOR
MODEL 801 DRS

MATERIAL:
NEXT ASSEMBLY:
CODE IDENT NO.
3801
SCALE 1/1

3. SYSTEM CHARACTERISTICS

The detector provides the following advantages:

- Simplicity of Design and Installation
- Rapid Response to Fire and Overheat Condition in the "As Installed" Configuration
- Freedom from False Warnings
- Integrity Monitoring
- Durability Under Severe Conditions
- Ease of Maintenance
- Self-Contained System - No Black Box Required

The pneumatic sensor is completely isolated electrically from the fire detection electrical circuit.

Mechanical damage to the sensor tube cannot result in a false alarm. The intrusion of conducting fluids into the electrical connector cannot cause a false alarm because of the action of a patented electrical shunt plate installed at the mating face of the responder connector.

4. INSTALLATION RECOMMENDATIONS

Experience has proven that airframe mounting of detectors provides greater reliability than direct engine mounting. This is primarily the case since the engines generally involve a higher degree of maintenance than the adjacent airframe structures and, thus, more potential damage to the fire detector installations. The sensor protection afforded by the support structure does assure maximum ruggedness for either engine or airframe mounting. Figure 4 shows typical detector mounting arrangements. The responder housing may be mounted through a firewall, which removes wiring from the firezone. If this is not practical, or if the detector is engine mounted, a quick release clamp can be used with high temperature connectors and firezone wire. The sensor is preferably mounted by quick release clamps. Maximum fastener spacing is normally eight inches. Bend radius of the sensor/support should not be less than $1\frac{1}{2}$ inches and preferably three inches. Clamp mountings should support radius curves of the sensor/support in such a way that there are no large sensor overhangs. Brackets should be sturdy enough to reduce detector/bracket resonances to a minimum.

Maintenance Considerations

The detector assembly has only one electrical connector and mounts with quick-release clamps. For this reason it can be removed and replaced quickly.

The support structure is flexible and can be formed to the required routing. The entire detector assembly can be coiled and will fit in a 20-inch square container. This allows the detector to be shipped and stored in a small package. Figure 6 shows a typical 801DRS detector assembly.

The integrity of the detector can be easily checked by testing for continuity through the integrity monitor pins C and D on the connector. This simple check can be performed on the bench or on the aircraft.

ALTERNATE MOUNTING METHODS

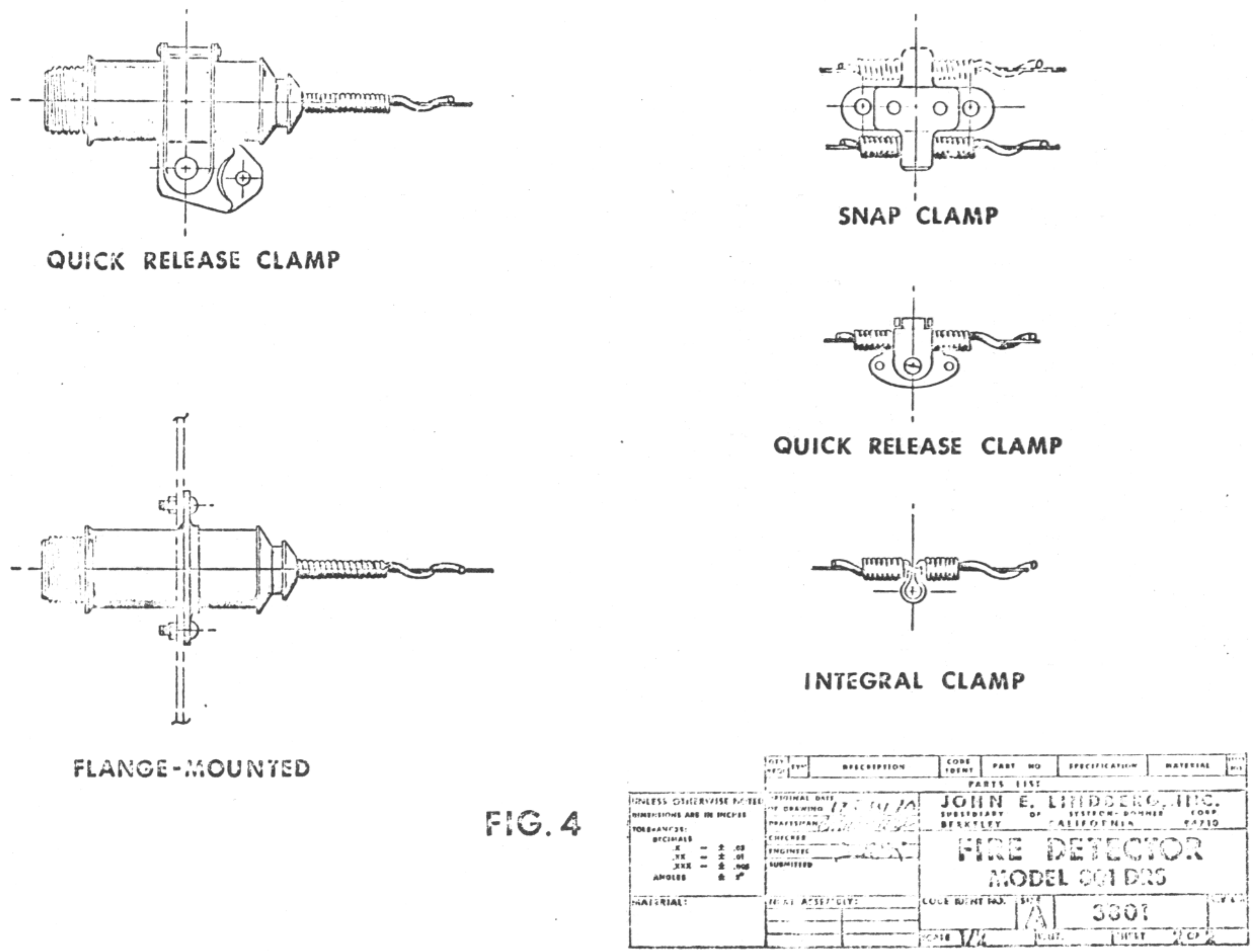


FIG. 4

Electrical Circuit

The electrical circuit, Figure 5, is simple and effective. The power for the alarm circuit goes into the responder through Pin A of the connector and comes out on Pin D when the alarm contacts close. The test circuit checks availability of power, the integrity monitor, and the alarm device, thereby assuring the crew that the detector is intact.

The sensor tube is electrically isolated from the system and is at ground potential at all times. Mechanical damage to the sensor will not affect the electrical system.

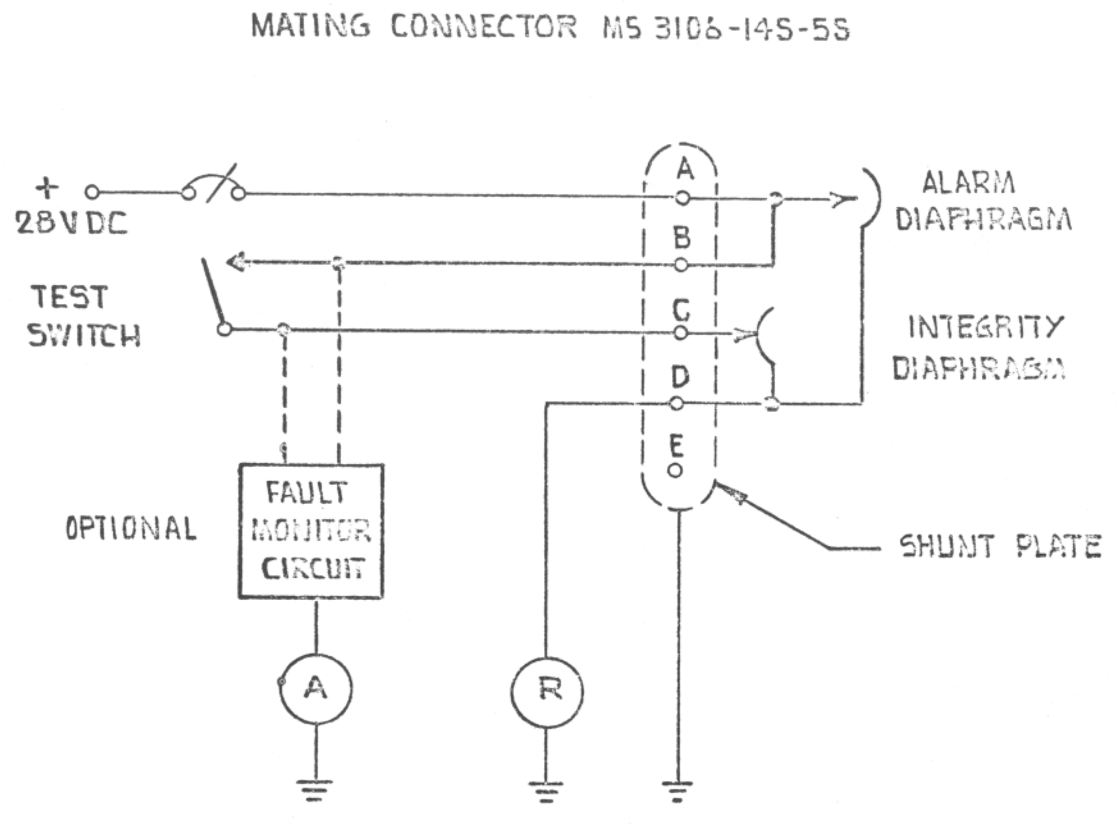


FIG. 5

TYPICAL ELECTRICAL CIRCUIT

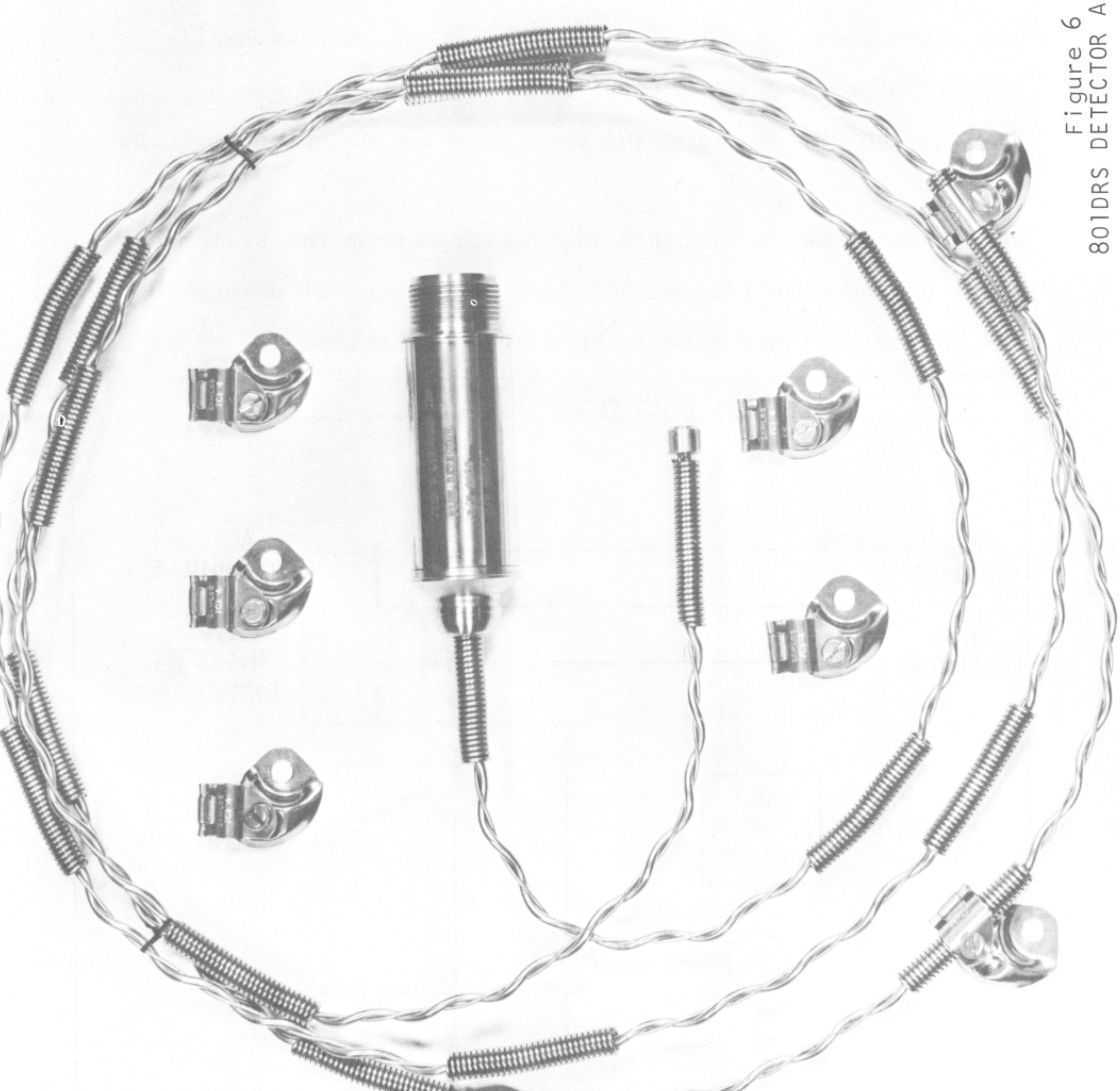


Figure 6
801DRS DETECTOR ASSEMBLY

5. METHODS OF SHOWING COMPLIANCE WITH TSO-C11D

(a) Paragraph 3.3.3 Altitude

The basic fire detector is a completely sealed unit including its responder (pressure switch) and is not subject to change in setting due to change in altitude. However, in the laboratory test units are subjected to altitude change by placing the coiled up detector under a bell jar and evacuating it to altitudes equivalent to = 100,000 feet. Discrete operation of the detector is obtained by leaving the tail portion of the sensor tube external to the bell jar (through a sealed port) and heating the exposed end to achieve operation.

When the detector system requires the use of control components, comparable simulated altitude tests are performed in a bell jar during which the control unit is operated. Altitudes far in excess of any normal usage are simulated.

(b) Paragraph 3.3.4 Vibration

Vibration tests are conducted in an outside laboratory facility to the requirements for "Powerplant Mounted" under Turbine Engines in paragraph 3.3.4. The frequency range is 5-1000 H_z.

Although practically all applications of detectors are on turbo-jet or turbo-fan powered aircraft, the more severe double amplitude and maximum acceleration requirements for piston engines are imposed; namely, .100 maximum double amplitude and 20g acceleration. Control components when used in the system are subjected to the requirements specified, depending upon where they are located in the aircraft. Generally, they fall into the category of 5-1000 H_z, .036 double amplitude and 2g acceleration. The control units are actuated during the vibration testing.

(c) Paragraph 3.5 Magnetic Effect

The only components of past systems which produce magnetic fields are small half-size crystal can relays in the control components. These are hermetically sealed units within ATR modules where additional shielding is afforded by the ATR case and cover. E and H field interference tests are run on the control circuit cards on which the relays are mounted. Virtually no signal is radiated from the control cards in free space.

(d) Paragraph 4.2 Reliability

Vibration tests are conducted in three axes. The integrity of the detector is monitored during the vibration testing. A special heating test apparatus is used for heating a six-inch segment of the sensor for response and clearance characteristics during the vibration testing. Thermal shock tests are conducted. They consist of plunging detectors into dry ice from an oven temperature comparable to the arithmetic average alarm temperature setting. Connector terminals are sized to preclude damage from manhandling. Shunt plates are used to eliminate false alarms due to contaminants in the connectors. The 801DRS detector is manufactured as a sealed unit with all external surface of stainless steel to minimize corrosion effects.

(e) Paragraph 4.4.1 Adjustable Detector System

All detector equipment is manufactured with alarm temperature settings accomplished as a part of the processing. Once factory set and sealed, there is no way to alter the settings in the field.

6. SUGGESTIONS FOR IMPROVING TSO OR RULES

We suggest that the proposed rules change to paragraph 25.1203 (b)(1) of FAR-25 be modified to include the following text:

(b) The fire detector system must be designed and installed so that:

(1) It will remain in an operable condition in the event it is severed at one point - unless as an alternate the detector system is provided with a means to monitor, in flight, the integrity of the system either by periodic checking or on a continuous basis: and

(2) There is a means provided to alert the pilot in the event a short circuit occurs in the detector system.

The addition of the suggested text, shown underlined, will not vitiate the intent of the proposed rule change and will permit the continued use of the successful pneumatic system.

DISCUSSION FOLLOWING LINDBERG PRESENTATION

Q. What happens to the fire detector capabilities after a mechanical abrasion or failure that allows escape of the pressurizing gas in the capillary tube?

A. In the event this occurs a switch operates to energize a circuit to an indicator that the system has faulted - but it will still give some degree of fire protection. It may lack alarm repeatability, but in any event, it will not cause a false warning.

Q. Will this detector comply with the proposed revision to FAR 25.1203(b)(1) in NPRM 69-7, i.e., the detector must remain in an operable condition in the event it is severed at one point?

A. Unless this proposal is modified or the interpretation recognizes the system characteristics, we will not remain in the aircraft business.

Q. How do you comply with FAR 25.1203(d)?

A. We have a system flying that provides for monitoring it electrically, but integrity monitoring is used currently.

Q. If your detector element was burned in two by a burn-through flame would it detect the fire?

A. The ability of the element to detect the fire would depend on the seal remaining at the end of the tube. If it welded over it would detect and remain operable. If the end was open it would detect the fire but probably not be able to repeat.

Q. What is the practical minimum length that has to be heated to detect a fire?

A. Three inches.

Q. How much does the set temperature rise when you lose the averaging gas?

A. Not much.

GRAVINER FIRE PROTECTION SYSTEMS

PETER C.C. BROWN

VICE PRESIDENT-ENGINEERING

GRAVINER INC.

of a 50 ft. system installed in an ambient of 300°C with a set point of 350°C. The alarm temperature of various lengths heated beyond the 300°C ambient is shown at Figure 3.

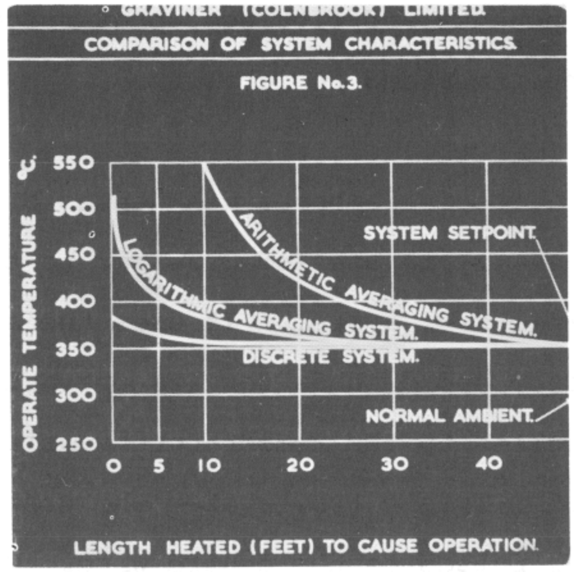


Fig. 3

Early service experience showed that it was difficult to prevent damage to a long length of capilliary clipped at intervals to nacelle structural members or to the engine itself, particularly as it is necessary to site the detector in areas where fire is most likely to occur, and which are frequently areas vulnerable to damage during engine servicing. Displacement of elements invariably resulted in element damage from fretting against adjacent structure. Although the design of the system is such that the detector loop can still detect fire when the element is severed, a direct short circuit of the centre wire to earth will cause a false fire warning.

Much effort was put into improving design standards of clips, bushes, interconnectors and fittings. During this phase Graviner resisted the continuing pressure to miniaturize its of a 50 ft. system installed in an ambient of 300°C with a set point of 350°C. The alarm temperature of various lengths heated beyond the 300°C ambient is shown at Figure 3.

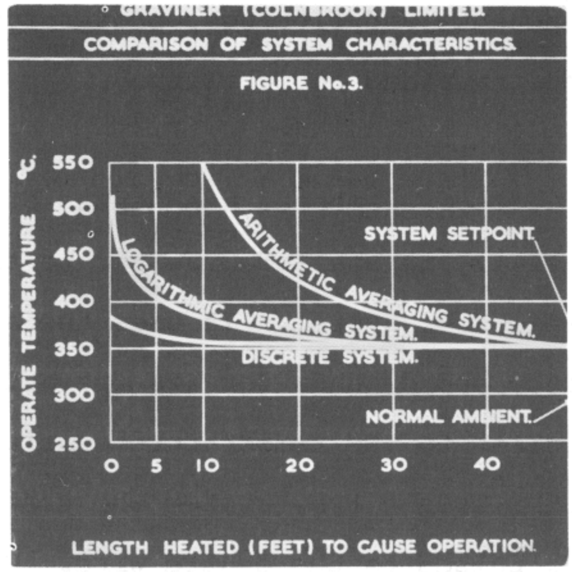


Fig. 3

Early service experience showed that it was difficult to prevent damage to a long length of capilliary clipped at intervals to nacelle structural members or to the engine itself, particularly as it is necessary to site the detector in areas where fire is most likely to occur, and which are frequently areas vulnerable to damage during engine servicing. Displacement of elements invariably resulted in element damage from fretting against adjacent structure. Although the design of the system is such that the detector loop can still detect fire when the element is severed, a direct short circuit of the centre wire to earth will cause a false fire warning.

Much effort was put into improving design standards of clips, bushes, interconnectors and fittings. During this phase Graviner resisted the continuing pressure to miniaturize its components and fittings, preferring instead to concentrate on robustness and reliability.

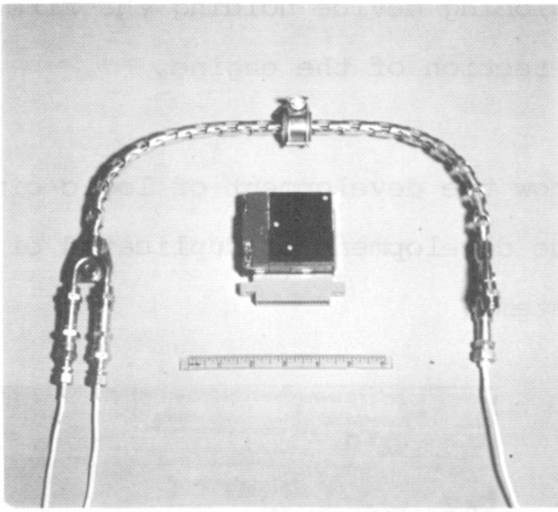
The fundamental weaknesses of the "conduction" systems then generally in use led Graviner to the development of the Graviner Triple F.D. system. It uses the same elements as the conductive system and depends for its operation on a feature that is peculiar to the temperature sensitive filling used in FIREWIRE. With a Triple F.D. system the control unit supplies a series of D.C. pulses to the centre wire. When the element is heated, these pulses are stored by an electrochemical process in the filling and can be detected by the control unit during the spaces between the D.C. pulses. Short circuits in this case inhibit this charge and readout process so that no false warnings can result.

A further refinement of this system allows the input current to be monitored in addition to the charge readout and a separate fault signal generated in the case of a short circuit.

Having virtually eliminated the false warning problem which threatened at one stage the complete removal of fire detection systems from aircraft, the problem remained of unserviceability caused by element breakages. This problem has been tackled three ways:

1. By the provision in the installation of mounting

Fig. 5



tracks of the elements are assembled in the sheath with a 12 inch pitch helix. Duplicated armored FIREWIRE Triple F.D. systems of this type are fitted to Boeing 747 airplanes and illustrated at Figure 5.

The fire detection requirement of the Concorde raised some interesting configuration problems. Full scale fire testing has revealed that typical fires are of an intensity considerably beyond that represented by the T.S.O. 6 inch torch. Detection time, therefore, was not a problem but the standard of fire resistance required was far in excess of that demanded by the T.S.O. Consequently, special flexible conductors were required in conjunction with normal diameter duplicated FIREWIRE in a perforated shroud.

Figures 6 and 7 show typical Concorde hardware including the

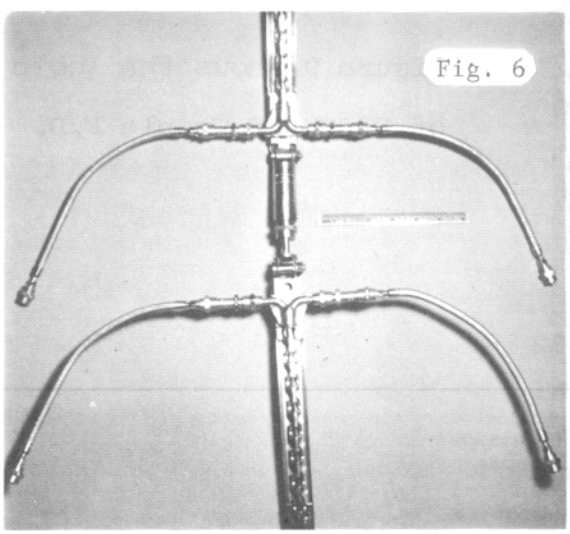


Fig. 6

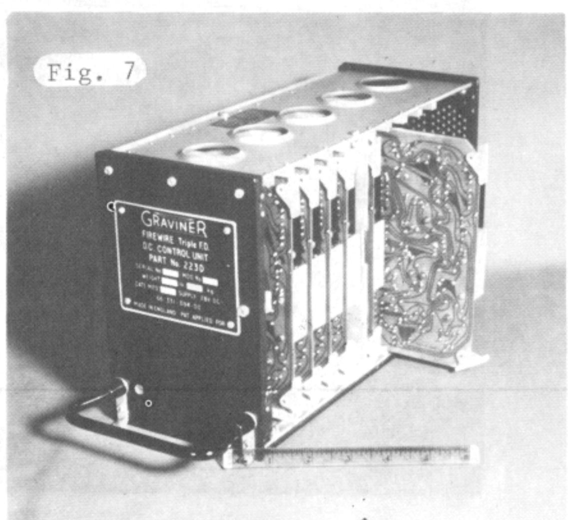
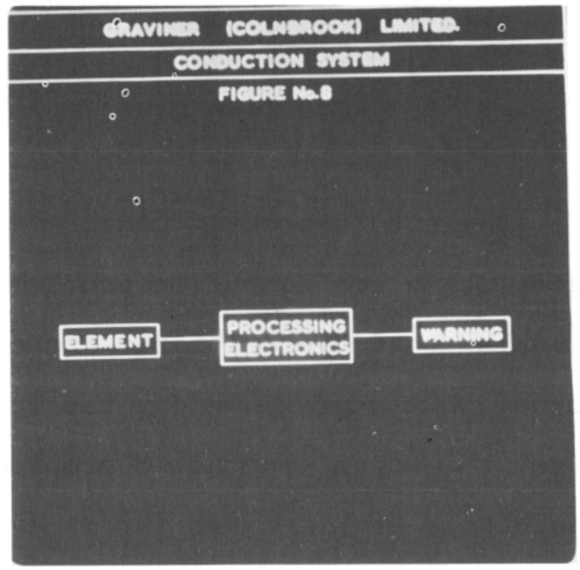


Fig. 7

fireproof quick release tensioning device holding the fire detector assembly to the rear section of the engine.

It is of interest to show the development of logic circuits that has taken place with the development of duplicated circuits and fault discriminating systems.

Figure 8 shows the logic of a conductive system.



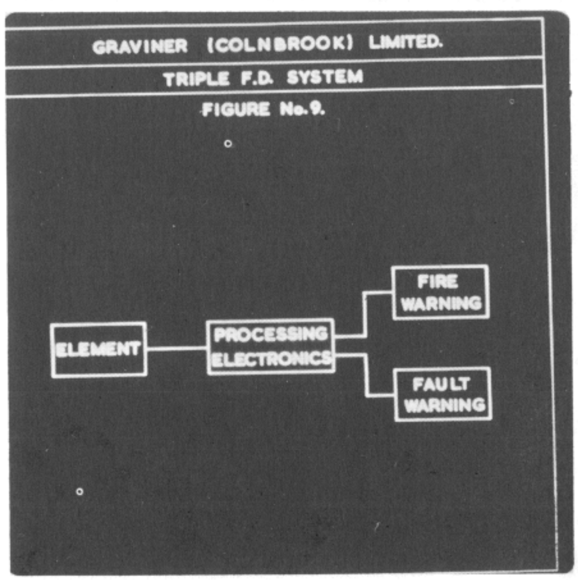


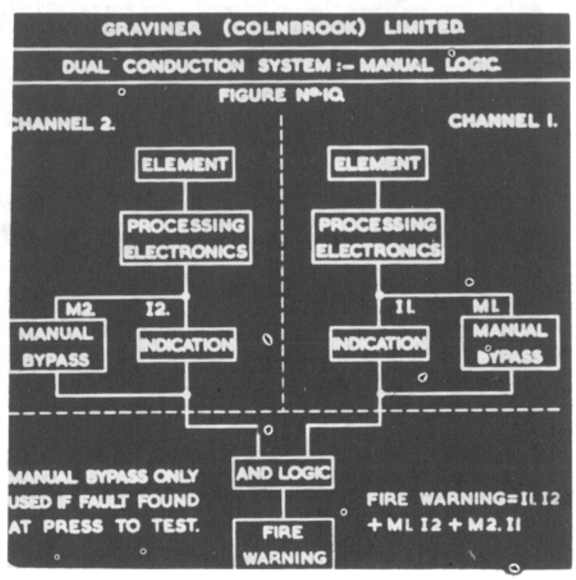
Figure 9 shows the logic of FIREWIRE Triple F.D.

When duplicated systems are installed it is normal to arrange the outputs of each detector in AND logic, that is to say, both elements must give a warning before the "FIRE" warning is presented to the pilot. With a conductive system a single warning light is taken to indicate a false warning and that system is deactivated leaving one half of the AND gate armed and the system left to operate in the single channel conductive mode.

With the Graviner Triple F.D. system, a fault light is provided to indicate one system shorted. This channel is deactivated and the system left to operate in single channel mode with short circuit immunity.

To relieve pilot workload, to avoid ambiguity, and eliminate the possibility of errors, the isolation of the faulty channel can be achieved by automatic logic and this is designed into the Concorde system. Figures 10, 11, and 12 show typical dual system logics and Figure 13 shows the detail of the auto logic circuit.

Fig. 10



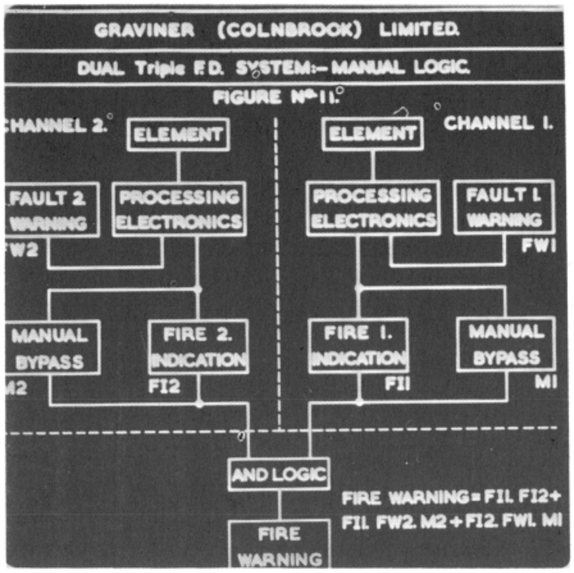


Fig. 11

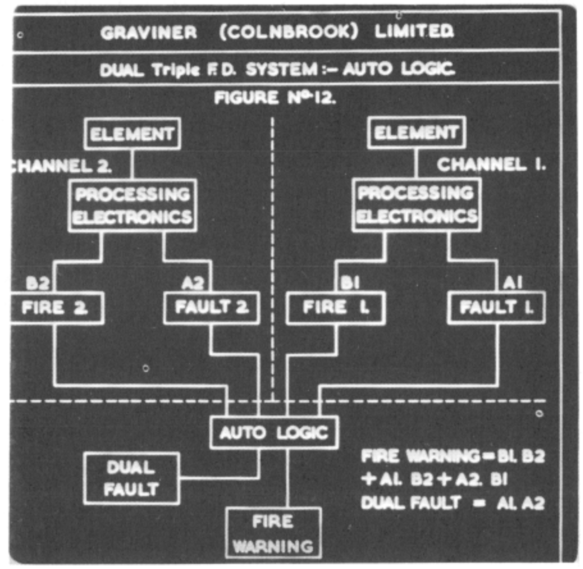


Fig. 12

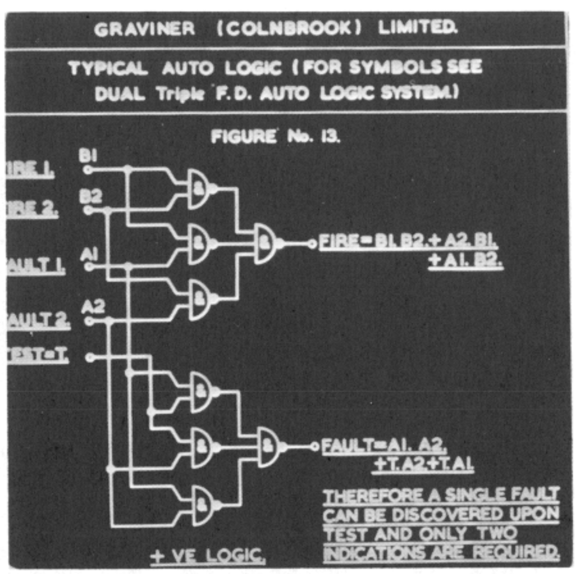


Fig. 13

SUGGESTIONS FOR T.S.O. RULE MAKING

1. It is felt that there would be great benefit in cockpit standardization if additions were made to the T.S.O. or possibly F.A.R.s to specify the manner in which dual systems should be engineered into civil aircraft and the information presented to the flight crew.

2. Where duplicated systems are installed, it is also suggested that it would be logical to specify that the T.S.O. 5 second detection time should apply to flame testing of the assembly complete with the logic circuits, the detection time being the time from flame immersion to operation of the AND gate. The possibility of delay in detection or even failure to detect due to shielding of one of the elements, could be significant in the case of localized highly stratified flames such as those associated with combustion chamber burn through.

3. There now appears to be enough operational evidence for F.A.A. to include combustion chamber burn through as a fire detector case. It is suggested that a standard for such a fire should be defined and built into the T.S.O.'s.

SURVEILLANCE FIRE DETECTION

Graviner has long recognized the limitations of thermal detectors when related to some particular nacelle fire/flame cases and, therefore, began development of a radiation sensing system. After careful study, the principle of detecting the ultraviolet radiation content of the combustion process was selected.

The Graviner surveillance flame detector system consists of a number of detector head assemblies which comprise a photosensitive gas-filled tube, a quartz protective cover, and a U.V. test emitter. The detector heads are connected to a control unit. The principle of operation is based on three basic parameters:

1. The detector head is sensitive only to radiation between 200 and 290 N.M.
2. Hydrocarbon flames emit appreciable radiation energy between 260 and 290 N.M.
3. There is no radiant energy from sunlight of wavelengths to which the detector head is sensitive.

Figure 14 shows the fundamental spectral characteristics applicable to an ultraviolet flame sensing system.

Figure 15 shows a sensing head currently in service.

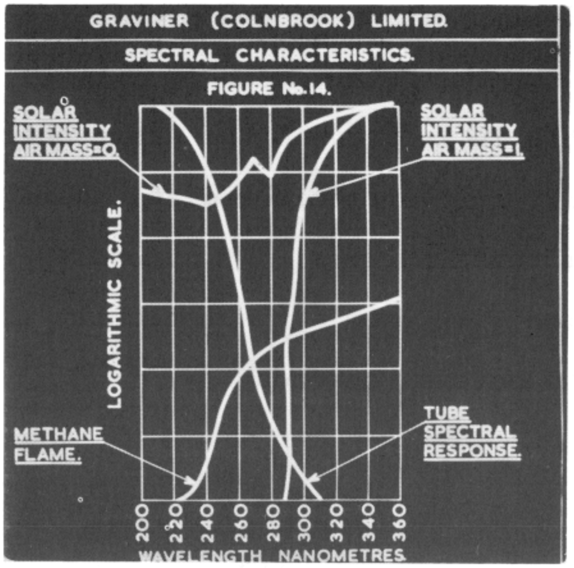
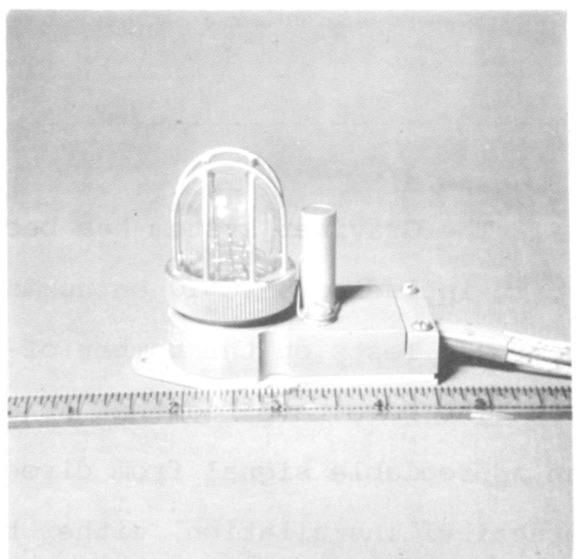

GRAVINER (COLNBROOK) LIMITED.
SPECTRAL CHARACTERISTICS.
FIGURE No.14.
SOLAR INTENSITY AIR MASS=O.
SOLAR INTENSITY AIR MASS=1.
LOGARITHMIC SCALE.
METHANE FLAME.
TUBE SPECTRAL RESPONSE.
200
220
240
260
280
300
320
340
360
WAVELENGTH NANOMETRES.

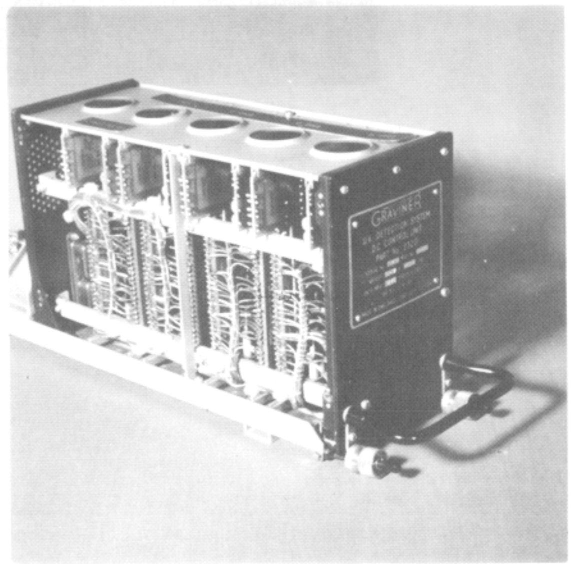
Fig. 14

Fig. 15



This is an oversimplification of the problem; there exists cosmic radiation to which the detector is sensitive, the statistical occurrence of this is known, and the electronics associated with the system can differentiate this radiation and prevent spurious warnings from these sources. This results in the extension of the detection time from a theoretically achievable fraction of a second to several seconds.

Figure 16 shows a typical electronics package for a duplicated four engine (eight system) installation.



The Graviner system has been flight tested on several aircraft including a VC-10 on normal world routes and a Canberra bomber. Tests on the bomber of detectors installed in direct sunlight have revealed that at altitudes of 40,000 ft. there is an appreciable signal from direct sunlight and, therefore, in a practical installation, either the detector sensitivity to flame would have to be reduced, or some degree of protection from sunlight by the aircraft structure would have to be achieved. It is in this area of simulation of sunlight at altitude, specification of flame to be detected and definition of degree of protection from direct solar radiation, that the current T.S.O. C79 is not meaningfully definitive.

It is not the intention of this paper to be destructively critical. The Graviner U.V. system has passed all the tests specified in T.S.O. C79 but it is felt that a better match between practical operational requirements and the T.S.O. could be achieved.

T.S.O. Para 7.1 - Response Time

The 5 inch white gasoline pan fire with optional airflow up to 10 ft/sec. besides being an inconvenient fire for laboratory use, is not typical of an aircraft fire situation. In selecting a standard flame for radiation detectors we face difficulties not encountered with the T.S.O. C11 torch. This flame was logically selected as representing a fire situation of a typical heat output to be destructive to the installation and it is this primary property that is detected with thermal detectors. In the case of radiation sensors, a secondary property actuates the detector but it would still appear logical to use a simulation of a destructive fire. Ideally, therefore, it is felt that aviation fuel should be used and that the flame should be fed with air to achieve temperatures typical of the 6 inch torch. A blow lamp as specified in British Civil Airworthiness Requirements, Chapter D5-8,7.3.2(b) fuelled with JP1 with additives would achieve this, although it could be argued that a somewhat larger device would be more satisfactory.

Another suggestion which should be helpful is to modify the detection distance requirement so that a manufacturer may declare the maximum range at which the standard flame can be detected, rather than qualifying it at a standard range of 5 ft. Clearly if a particular installation has a requirement only for detection at short range, great benefit in terms of insensitivity to external radiation would accrue from detuning the detector sensitivity to flame.

Observations on the requirement for a combustion chamber breakout standard flame previously made, apply equally to radiation sensors. Response times considerably less than 5 seconds should be considered for this extremely destructive flame.

<u>T.S.O. Paras. 7.3.3.; 7.3.6 - Sunlight & Restricted Light</u>

These are both problem areas for certain types of radiation detectors. The tests specified for full and chopped light are practical but not sufficiently exhaustive to guarantee that detectors that pass the test will operate reliably at altitude and in all climatic conditions when exposed to full solar radiation. Attempts have been made to simulate sunlight using artificial light sources. These attempts have by no means been successful. The definition of restricted light in meaningful terms is equally problematical. There appears to be no alternative to special to type flight trials.

T.S.O. Para 7.3.5 - Sunsets and Signal Lights

Logically these sources of external illumination should be modulated in the same manner as that required by 7.3.4.

T.S.O. Para 7.14 - Fire Resistance

This is an extremely severe test for an optical detector and it is certain that no radiation sensor will survive exposure to the combustion chamber flame. A more practical requirement would be to demand that a system rather than an individual sensor should survive exposure to the standard flames. This could be ensured by demanding that the destruction by fire of a single sensor should not cause the system as a whole to become unserviceable and that sufficient overlap of fields of view of the remaining detectors is provided to ensure that a premature reset of the system does not occur in the case of the destruction of a single sensor.

SUMMARY

In summary, therefore, of Graviner systems design and characteristics, we have shown how we prefer robust hardware with a full range of mounting accessories. We deprecate over-miniaturization, and we prefer to avoid both "very small" signal strengths and control units which can be adjusted in the field.

Finally, we recognize that it is most difficult for the needs of today's powerplants to be met by thermal or surveillance sensing systems in isolation, and a combination of both seems called for. Where thermal detectors alone are deemed sufficient then a duplicated armored sensing system of the Triple F.D. type appears very capable of providing appropriate performance and reliability.

INSTALLATION RECOMMENDATIONS

While we have found these helpful to our customers, we have also found there is no substitute for a full installation review by our own staff of installation/sales engineers. Graviner issues Sheet 2 drawings which are in fact a second sheet of the top assembly drawing endorsed with all information necessary and pertinent to proper installation of the component. In the case of continuous fire detector sensors, these drawings are supplemented with data sheets depicting the various "dos and don'ts"of sensor installation practices.

Finally, each component drawing is supplemented with a D.D.P. (Declaration of Design and Performance) defining exactly the performance limitations of the component and limits to which it has been qualified.

COMPLIANCE WITH T.S.O.

Because our design and development work is mostly completed in England, T.S.O. approval of our designs is obtained through our "design approval channels with the U.K. Air Registration Board". We find this channel very strict and all-embracing.

It is normal for A.R.B. representatives to review our design and design practices in detail during the development phase. Prior to the qualification testing a test schedule together with the mode and levels of test results to be recorded is agreed with A.R.B. During the qual test - normally conducted by Graviner with in-house facilities - all tests will be subject to witnessing by a visiting A.R.B. inspector at their discretion.

Finally, NO recommendation that T.S.O. approval be granted is made by the A.R.B. until a full and complete test report recording all results previously agreed as necessary has been formally lodged with them. This tight control by A.R.B. can at times be irksome when flexibility is necessary, but we have found them always helpful and undoubtedly the close liaison required by such working conditions has worked to the benefit of the industry overall.

DISCUSSION FOLLOWING GRAVINER PRESENTATION

Q. What recommendations do you have for improving the present TSO?

A. The standard five-inch pan fire is an inconvenient test. For radiation detectors, the test flame should be aviation fuel plus air in a six-inch diameter torch. This is the standard specified in British CAR Section D5-8 paragraph 7.3.2(b) amd 7.3.4.

The manufacturers should declare the distance at which sensing occurs rather than state that a minimum distance has been met.

Five seconds is too long for a combustion burn through type flame to be sensed.

The chopped light test is inadequate when considering incident radiation at high altitude.

Requiring sensors to survive a flame test is unnecessary. The system rather than each sensor should survive a fire, thus allowing redundancy to detect flames or reignition.

A standard definition of burn-through flame shoutd be included in the TSO. Three thousand degrees F to thirty-five hundred degrees F at 255 psia burner pressure is recommended.

Q. What is the reaction of your surveillance detector to a magnesium flame?

A. Tests with all types of combustibles found in aircraft have had satisfactory results.

The USAF representative interjected the comment that all burning aircraft materials result in release of 10 to 100 times the radiation energy of high carbon fuel.

Q. Do you have any other recommendations regarding the rule changes or TSO changes?

A. We recommend an investigation to determine whether standardization could be developed in cockpit arrangement of warnings and controls, or in the use of systems where various systems logic is involved.

TABLE OF CONTENTS

I. INTRODUCTION

The EDISON Type B Continuous Cable Detection System was developed to meet present and future aircraft requirements for a reliable method of detecting fire or overheat condition with a detecting element sensitive at any and all points along its length. Aircraft applications may include engine and accessory sections, hydraulic, electrical equipment and cargo compartments as well as similar potential fire zones and regions subject to possible excessive temperatures.

Depending upon the control assembly employed, the system operates on 115 Volts, 400 Hz AC and 28 Volts DC, or entirely on 28 Volts DC. Features of the system include the following:

1. The system operates at low impedance and standby power drain levels insuring against false warnings from moisture accumulation or other contaminations.
2. The detector cable is extremely rugged, although small in diameter and light in weight, and is designed to survive repeated flame or mechanical damage, permitting the system to function continuously to normal fire or overheat conditions.
3. The system is also designed so that a break in the detector cable or a connecting wire in the sensing cable loop will not render the system inoperative.
4. Sensing cable loop continuity and operation of all circuit components may be checked at will by means or a test switch.

5. All connectors are constructed of stainless steel, self-sealing against moisture and resistant to damage from exposure to 2000°F temperatures.

6. Maintenance operations are minimized by use of replaceable hermetically sealed units. No special tools are required.

2. DESCRIPTION AND OPERATION

2.1 PARTS OF THE SYSTEM

2.1.1 Detector Cables

The temperature sensitive element of the system consists of fabricated lengths of a special coaxial cable equipped with hermetically sealed high-temperature connector plugs at both ends. The cable is basically a temperature sensitive resistor, commonly referred to as a "thermistor." It has a negative temperature coefficient, where its electrical resistance becomes less as its temperature increases. This change in electrical resistance is an exponential relationship, and therefore the rate of change for a given increment of temperature increase is much greater than is obtained from other materials which behave in a linear manner.

The value of resistance which a given type and length of cable reaches for a particular temperature is essentially constant within its tolerance limitations. If anything less than the full length of cable is heated, the value of resistance will be higher than that if the full length of cable were heated. This means that two variables must be considered in application, <u>temperature</u> and <u>length</u>.

Physically the cable appears to be a length of wire having threaded connectors on both ends. The outer diameter of the wire portion is .070 inches. Inside this wire is a central conductor (ion wire) surrounded by a highly compacted metal oxide layer (semi conductor), which is in turn covered by a seamless sheath which makes up the O. D. The central conductor is insulated from the outer sheath by the metal oxide semiconductor which is highly homogeneous.

The properties of this metal oxide semiconductor form the basis of operation for the fire detection cable. The behavior of this semiconductor is altered during manufacturing to provide various ranges of temperature characteristics to meet the needs of varying applications. The cable is extremely rugged and can be subjected to hammering and severe bending and flame temperatures of up to 2000°F without detrimental effects.

Cables are normally supported at approximately 8 inch intervals by means of spring-type cable clamps. These may be opened by finger pressure to permit installation or removal of the cable.

2.1.2 <u>Fire Detection Controls</u>

A Fire Detection Control is an electromechanical assembly which accepts the fire detection cable resistance input and provides either an output voltage or contact closure at a predetermined "Fire" alarm point. After an alarm the control will reset automatically when the cable resistance increases above the alarm point as a result of fire extinguishment or a lower compartment temperature.

EDISON Type B solid state fire detection control assemblies are available in two varieties, one of which, designated Model 377, is a short discriminating type, and the other, Model 324, is of a non-short discriminating design. The first being a short discriminator which locks out the fire alarm should the low resistance be a result of an input short circuit rather than a fire. The second being a straight control which merely provides a fire alarm on low resistance and automatic reset when resistance rises above alarm reset point. Both utilize a single cable loop as a sensor.

Both types sense the fire detection cable resistance input and provide either an output voltage or contact closure at a predetermined temperature (resistance) alarm point. These controls are designed to fully conform with the requirements of FAA TSO-C11d and MIL-F-7872C. Capability of bi-level function, such as discreet fire and overheat warning, is an inherent feature of EDISON fire detection control design.

Physically the controls are small rectangular boxes two to three (2 to 3) inches on a side, with mounting provisions and electrical connector. The military units per MIL-F-7872 are hermetically sealed. Commercial application units are usually non-hermetic and meet the requirements of FAA TS -C-11d.

The MIL spec (MIL-F-7872C para 4.6.33.1 & 2) defines two types of systems, active and deactivated. The active system continues to function and will produce a fire alarm with the sensor center wire grounded to the sheath. The deactivated system is one that is incapable of signaling a fire if a short circuit should occur in the sensor leads. In order to meet the active system requirements EDISON employs a dual loop, dual control (redundant system) with alarm contact function controlled by a loop selector switch. The deactivated system employs a single cable loop with a short discriminating control (Model 377). The single loop, single alarm amplifier control will give a false fire alarm should the sensor lead become shorted to ground. This is what occurs with simple controls such as the Model 227. This is not permitted per MIL-F-7872C para 4.6.33.

Customary usage of the Model 377 Control with a single sensing loop system complies with the requirements of MIL-C-7872C (deactivated system) and TSO-C11d. While the Model 377 Control may be used with a dual redundant cable system providing complete redundancy of the short discriminating function, the Model 324 non-short discriminating control is usually selected for this purpose as short discrimination control circuitry is not needed for false fire alarm prevention in this instance.

2.1.3 Cable Connectors

Connectors are supplied in two basic styles. Inter-cable connectors are equipped at both ends with coaxial receptacles to mate with plugs on the ends of detector cable assemblies. Cable terminating connectors have the cable-mating receptacle on one end and a one-pin receptacle on the other end to mate with either a one socket plug or similar special flameproof plug. Both type connector receptacles are provided in various configurations: straight style with and without flanges, right angle style, the flanged style being mounted on the firewall or other structural member.

2.1.4 Warning Light and Test Switch

These devices, which are not ordinarily supplied by the manufacturer of the system, vary with the installation involved. Any standard lamp unit requiring not more than two amperes may be used. For heavier loads a slave relay requiring a maximum of 1-1/2 amperes may be employed.

A single pole single-throw-normally open momentary contact switch is suitable for most applications.

2.1.5 Connecting Wiring

Wiring in potential fire zones usually consist of No. 16 Firezone wire, while all other wiring can be standard unshielded aircraft wire.

2.2 PRINCIPLES OF OPERATION

2.2.1 Fire Detection Cable

Fire detection cable is normally used for detecting fire or overheat conditions which may develop in aircraft power plants. The cable can be used to protect various sections of the engine by routing a continuous loop over and around the areas in which critical conditions are likely to develop. The cable actually performs as a temperature averaging device, its absolute resistance being a function of its surrounding ambient temperatures. For this reason it can also be used in other applications (not necessarily aircraft) where this characteristic is preferable to a discrete device which depends on a fixed value of temperature to alarm. When the resistance value reaches the set point of the control, an alarm is signaled.

The use of a continuous loop enables the system to be monitored for open circuit conditions, and in the event of a single cable break, the system remains operative. Many of the controls used in conjunction with the cables have a short discriminating feature that will in the event of a cable short lock out the fire warning and prevent a "false alarm" occurrence.

Perhaps the best method of describing its application is to go through a sample computation for an actual system that might be encountered in actual practice.

2.2.1.1 Given Information

Engine Fire Detection Installation

Single loop

Single control

Short Discrimination Required

Two Zone System	Zone 1	Zone 2
Length	20 feet	15 feet
Normal ambient	150°F	350°F
Fire warning req'd	1 ft @ 325°F	2 ft @ 550°F

2.2.1.2 Considerations

A. The Alarm Point for the Control should be sufficiently low (300 ohms or less) to minimize low resistance false warnings that might occur as a result of exposure to salt water of high humidity conditions. (A general guideline is tc maintain voltage on the cable at less than 1 volt at alarm condition.)

B. The Alarm Point must be high enough to allow for the operation of a discriminator circuit. This is largely determined by system length. The wire resistance also is affected by ambient temperature.

C. The cable selected must have a value of resistance at the ambient temperature which is greater than the resistance of the given length exposed to the alarm temperature, by an amount sufficient to allow for cable tolerance plus a suitable safety factor.

2.2.1.3 Required

A. Cable Selection

In most applications the controlling factor in the selection of a cable is the length heated to the highest temperature.

1. From Zone 1 data: 1 ft. section heated to 325°F should result in an alarm

- Assume an alarm resistance of 150 ohms
- Select curve having characteristics close to 150 ohm @ 325°F for 1 foot [R x L = 150 x 1 = 150 ohm feet]
- By inspection curve E.S.651-7 has the closest characteristics - 150 ohm feet @ 336°F
- Zone 1 cable will use E.S. 651-7 Temperature Resistance characteristics which is a 200°F cable
- Temperature characteristic Definition - The temperature at which 50 feet of a given cable type has a resistance of 100 ohms. For curve E.S. 651-7 this condition occurs @ 200°F, hence it's defined as 200°F cable.

2. From Zone 2 data: 2 ft. section heated to 550°F should result in an alarm

- Alarm point still is 150 ohms
- Select curve having characteristics close to 300 ohms @ 550°F for 1 foot. [R x L = 150 x 2 = 300 ohm feet]

- By inspection curve E.S. 651-8 has the closest characteristics - 300 ohm feet @ 530°F.

- Zone 2 cable will use E.S. 651-8 Temperature Resistance characteristics which is a 400°F Cable.

3. Determine normal ambient resistance of system

   - Zone 1 has 20 feet at a nominal ambient of 150°F. A 200°F cable is equivalent to 30,000 ohm feet @ 150°F. Resulting in 1500 ohms resistance for 20 feet of cable in Zone 1.

   - Zone 2 has 15 feet at a nominal ambient of 350°F. A 400°F cable is equivalent to 18,000 ohm feet @ 350°F. Resulting in 1200 ohm resistance for 15 foot cable in Zone 2.

   - Total equivalent resistance of system is the parallel combination of both cables. Resulting in 667 ohms nominal ambient resistance of system.

4. Determine true alarm temperature

   - Zone 1: For the system to operate at 150 ohm alarm resistance effectively, the parallel combination of 667 ohm system resistance and the resistance of 1 foot of 200°F cable must be equal to the alarm resistance.

     1 foot of 200°F cable will therefore be approxi-

mately 194 ohms or 194 ohm feet.

From the curve for a 200°F cable this results in an equivalent alarm temperature of 325°F.

- Zone 2: Again for the system to operate at 150 ohm alarm resistance, effectively the parallel resistance of 667 ohms system resistance and the 2 feet of 400°F cable must be equal to the alarm resistance.

  2 feet of 400°F cable will therefore be qpproximately 194 ohms or 388 ohm feet.

  From the curve for a 400°F cable this results in an equivalent alarm temperature of 515°F.

- Zone 1 alarm temperature is correct. For Zone 2 alarm temperature is too low. By assuming a different alarm resistance, 100 ohms, and repeating calculations the results are:

  Zone 1 alarm = 350°F

  Zone 2 alarm = 545°F

- The conclusion is that 100 ohm alarm setting would be a better choice.

5. Determine true alarm temperature for entire length of each zone.

   - Zone 1: $\dfrac{1200 \times 100}{1200 - 100} = 109$ ohms

$R \times L = 109 \times 20 = 2180$ ohm feet

Equivalent alarm temperature from 200°F curve is 225°F.

- Zone 2: $\frac{1500 \times 100}{1500 - 100} = 107$ ohms

$R \times L = 107 \times 15 = 1600$ ohm feet

Equivalent alarm temperature from 400°F curve is 450°F.

6. Compare alarm temperature tolerance (+6%) with alarm temperature to ambient temperature differential.

- Alarm temperature tolerance

Zone 1: $.06 \times 225°F = \pm 13.5°F$

Zone 2: $.06 \times 450°F = \pm 27.°F$

- Alarm temperature to Ambient temperature differential

Zone 1: $225°F - 150°F = 75°F$

Zone 2: $450°F - 350°F = 100°F$

By inspection no tolerance problem exists when entire cable is subjected to temperature rise.

B. Discriminator and Test Resistor

The Short Discriminator alarm resistance and test resistor are determined as follows:

1. Calculate max test resistor

$R(\text{Test Max}) + R(\text{Cable max}) + R(\text{wiring max}) \leqq R$ Fire Alarm Min

$R(\text{Test Max}) + 16.8* + 1 \leqq 100 - .1\ (100)$

$R(\text{Test Max}) = 90 - 17.8 = 72.2$ ohms

2. Select a test resistor, say 50 ± 5 **ohms. Calculate maximum** discriminator resistance.

$$R(\text{Test Min}) + R(\text{Cable Min}) + R(\text{wiring Min}) \geqq R(\text{Discriminator max})$$

$$45. + 5.25^{*} + 0 \geqq R(\text{Discriminator Max})$$

$$50.25 \geqq R(\text{Discriminator Max})$$

3. Select discriminator setting of 40 ohms $\pm 10\%$ and recheck calculations 1 and 2 above

$$55 + 16.8 + 1 \leqq 90$$

$$72 \leqq 90 \text{ (O.K.)}$$

$$45 + 5.25 + 0 \geqq 45$$

$$50.25 \geqq 45 \text{ (O.K.)}$$

* Cable center conductor max and min values.

C. Final Design

1.	Discriminator alarm	= 40 ohms ± 5 ohms
2.	Test resistor	= 50 ohms ± 5 ohms
3.	Fire alarm setting	= 100 ohms ± 10 ohms
4.	Zone 1 Cable	= 200° F Characteristic
	Zone 2 Cable	= 400°F Characteristic
	Zone 1 Alarm	= 1 ft @ 350°F Entire length 225°F
	Zone 2 Alarm	= 2 ft @ 545°F Entire length 450°F

2.2.2 Fire Detector Control Assembly

2.2.2.1 Model 377 - Short Discriminating Control

The 377 Control Assembly employs two separate alarm channels, operated from a single sensor. The two channels, Fire and Ground Fault, are interconnected and time-phased in order to discriminate against false fire warnings as a result of any normally ungrounded conductor accidentally making a continuous or intermittent contact with the sensor cable sheath, or any other grounded portion of the aircraft.

The control unit consists of two Wheatstone bridge circuits, two silicon solid state null sensors, operating into the Fire and Ground Fault warning relays, and suitable silicon diode protection networks. These components are housed in hermetically or non-hermetically sealed cases, which are electrically insulated from the control circuit. All connections are brought out of the control unit through a miniature hermetic solder seal, quick disconnect connector.

The compact, transistorized, dual-bridge assembly is designed for bulkhead mounting. Weight is approximately .7 lbs.

The input power is 28 volt DC which is transient suppressed by resistor R1 and zener diode CR4. The bridge circuit shown on the left side of the schematic (Figure 3) and consisting of the resistors R2, R3, R7, R8 and the sensing cable assembly will be referred to as the fire warning bridge, while that to the right R13, R14, R7, R8 and sensing cable assembly will be called the short discriminating bridge. Note that the two bridge circuits share the resistors R7, R8 and the cable assembly in common.

In normal operation, the sensor cable resistance decreases as its temperature rises. As the sensor cable is heated and its resistance falls below the fire alarm point the fire relay K1 actuates, disabling the short discriminating lockout circuit by disconnecting its output and simultaneously closing the "Fire"warning lamp circuit. Should the cable resistance continue falling, the electronic short discriminating circuit will operate but have no effect on the alarm since its output is disconnected.

If a fire detection sensor cable center conductor short circuit to ground occurs and the apparent cable resistance falls through the fire and short discriminating points essentially at the same time electronic lockout will occur. This disables the fire relay K1 and "Fire" alarm by biasing the emitters of fire alarm circuit transistors Q1 and Q3 through the normally closed K1 contacts. The fire relay circuit is deliberately delayed to provide this lockout feature for continuous or intermittent short circuits. The induced delay is short with respect to the thermal response of the cable and therefore does not interfere with normal operation.

The basic control discriminates between a true fire and a short circuit by having the control recognize the manner in which the sensor cable resistance falls. An instantaneous change in cable sensor resistance to a value below the short discriminator alarm resistance is rejected as a fire but is accepted as a short.

Because of the relationship between the sensor cable and control circuit response time, operation of the control is completely unaffected by the rate of sensor cable temperature change.

System integrity is verified through use of an internal test resistor R15. The test switch when actuated opens the sensor center wire loop and applies test resistor R15 to the open end of the sensor cable. The sum of the test resistance plus sensor cable center conductor resistance is lower than the fire alarm point and therefore actuates and operationally tests sensor cable continuity, fire bridge and amplifier, fire relay K1 and "Fire" warning light. The short discriminator alarm point resistance is lower than the sum of the test resistor and sensor cable resistance. Therefore, the short discriminating disabling circuit is not actuated or tested when the test switch is actuated. Because of the disabling action of the short discriminating circuit on the fire relay, a system verification test cannot be accomplished when a short is present.

Master warning light and short warning light outputs are provided as optional features.

2.2.2.2 Model 324 - Non-Short Discriminating Control

Although this control is available for a single sensing loop system, the logical application for false fire alarm free requirements is a dual redundant bridge type control, operating in conjunction with a dual reduncant sensing cable system, a typical example of which is the EDISON Type B system installation on the DC-10 aircraft. The inclusion of the Model 324 solid state control increases the reliability of the EDISON System, and at the same time results in a more flexible system increasing aircraft dispatch rates.

The Model 324 Dual Control employs a single channel, solid state alarm amplifier controlled by two sensor cable loops in a mechanically redundant configuration. The sensors are coupled to the alarm amplifier using "and" diode logic, such that both sensor cables must be heated by fire or overheat condition, and be in their low resistance state, for an alarm to be given. Neither cable by itself can trigger an alarm, which eliminates the possibility of alarm errors as a result of a normally ungrounded sensor element or associated wiring accidentally making a continuous or intermittent contact with the sensor cable sheath, or any grounded portion of the aircraft.

The function of the assembly is to actuate external alarms and a master warning when two independent, adjacently located, sensor cables in a protected area detect a fire or overheat condition. The control assembly consists of two independent control circuits. Their output is interconnected so that both are required to operate in order to actuate the alarm. When the temperature falls below the danger point, the alarm automatically resets.

An external reset switch permits the master warning circuit to be disconnected from the control assembly during an alarm, thus acknowledging the alarm and making the master warning signal available for other engines or protected areas. In the event of a power interruption, the control will remain in the mode of operation it was in prior to the interruption.

In the event of a single fault occurring in either of the loops, a selector switch will allow dispatch of the system on a single loop basis. All normal tests of the single loop system can be performed while in this mode of operation, and the master warning operation is retained.

The control is housed in an aluminum enclosure and weighs only 0.5 pounds. The control is not hermetically sealed and may be disassembled for repair purposes. The control features an external, **built-in test switch with press-to-test** indicator lights used in conjunction with the test function. An instruction plate is provided on the control to describe the test function and aid in the location of a system fault.

Each circuit of the control consists of a Wheatstone bridge operating into a four transistor null sensor amplifier which operates an alarm relay. The output contacts of the alarm relays for each circuit are in series so that both must operate to produce an alarm when the control is in the dual operation mode.

The master alarm reset relay is of the magnetic latching type and the latch coil is operated directly off the 28 volt DC input. The reset coil operation is controlled by an additional transistor which allows the control to retain its mode of operation in the event of a power failure or interruption.

During standby conditions or at sensor resistance levels above the alarm point, transistor Q9 is biased on by the 28 volt input through the alarm lamps and fire bell. This allows current to flow through the reset coil and maintain connection of the normally closed contacts of Relay K3.

When an alarm occurs, the voltage at the base of Q9 fails essentially to zero, but the relay retains its initial state since no power is applied to the latch coil. Transistor Q9 is now biased off.

When the reset button is pressed, the latch coil is energized and the contacts of K3 are transferred to an open condition disconnecting the fire bell and master warning lamps.

If a power interruption now occurs, relay K3 remains in its present state but relays K1 and K2 are de-energized. Resistor R30 and Capacitor C1 form a timing delay network such that when power is returned relays K1 and K2 operate before the reset coil of the latch relay K3. This assures that Q9 remains biased off, and relay K3 remains in the latch condition.

If the sensor resistance rises to a level above the alarm point, relays K1 and K2 de-energize and allow Q9 to be biased on, resetting relay K3 so that a re-occurrence of fire conditions can be detected.

Diode CR13 minimizes any transformer action that could occur in the latch relay and CR17 protects Q9 against reverse E.M.F.'s. Zener diode CR18 protects Q9 against transients while R31 serves both to bias the emitter of Q9 off ground and limits coil current.

Diodes CR4 and CR8 are used for protection against possible damage to the control resulting from inadvertent reversal of power supply polarity during bench tests or upon installation in the aircraft.

Should either or both diodes CR4 or CR8 fail in a "short" condition, there will be no effect whatsoever on the normal alarm or reset function of the system. Should either or both diodes CR4 or CR8 have an "open" failure, there would be no effect on the other engine systems or on the fire alarm function, but the master warning could not be reset during an alarm condition. If the diode(s) opens prior to an alarm condition, there would be no effect on the alarm function of all systems or reset capability of the other engine systems until such time as the control having the defective diode would go into an alarm condition.

3. Installation Recommendations

For each installed fire detection system there are three main functional items -- the control assembly, the sensor cables and the customer provided interface, such as, power supply, alarm lamps, test switch, etc.

Since most systems differ from aircraft to aircraft, it is difficult to establish much more than general installation guide lines. Details that should be provided by the Fire Detection System manufacturers should include:

Schematic diagram-showing total electrical system interface.

Control Assembly outline drawing-showing sufficient detail on size, connector type and mounting provisions.

Cable Assembly outline drawings-showing sufficient detail on size plus an indication of mating connector types that can be employed.

Cable connector outline drawings--indicating fire zone wiring type, if applicable.

Plus installation information relative to cable support clamps as to type, spacing and method of inserting cables.

Data concerning the installation in a particular make and model of aircraft must be secured from the aircraft manufacturer or airline engineering department.

4. COMPLIANCE WITH FIRE DETECTION TSO

Original approval of EDISON Type B Fire Detection System utilizing Control Assembly Model 227 was obtained in 1955 under TSO-C11a.

TSO approval was extended in 1958 under TSO-C11b for previously approved systems.

Type B Fire Detection System utilizing Control Model 297 was obtained in 1959 under TSO-C11b.

Type B Fire Detection System utilizing Control Model 377 was obtained in 1964 under TSO-Ciid-T.

4.1 TSO-C11d

Para 3.3.3 Altitude: compliance to requirement of altitu le were reported per EDISON Report No. 562 to FAA covering

Para 7.10.1 High Altitude and rate of climb

Para 7.10.2 Low Altitude

Para 7.10.3 Pressurization Test

Para 3.3.4 Vibration: compliance to requirements of vibration were reported per EDISON Report No. 562 and No. 743 to FAA covering:

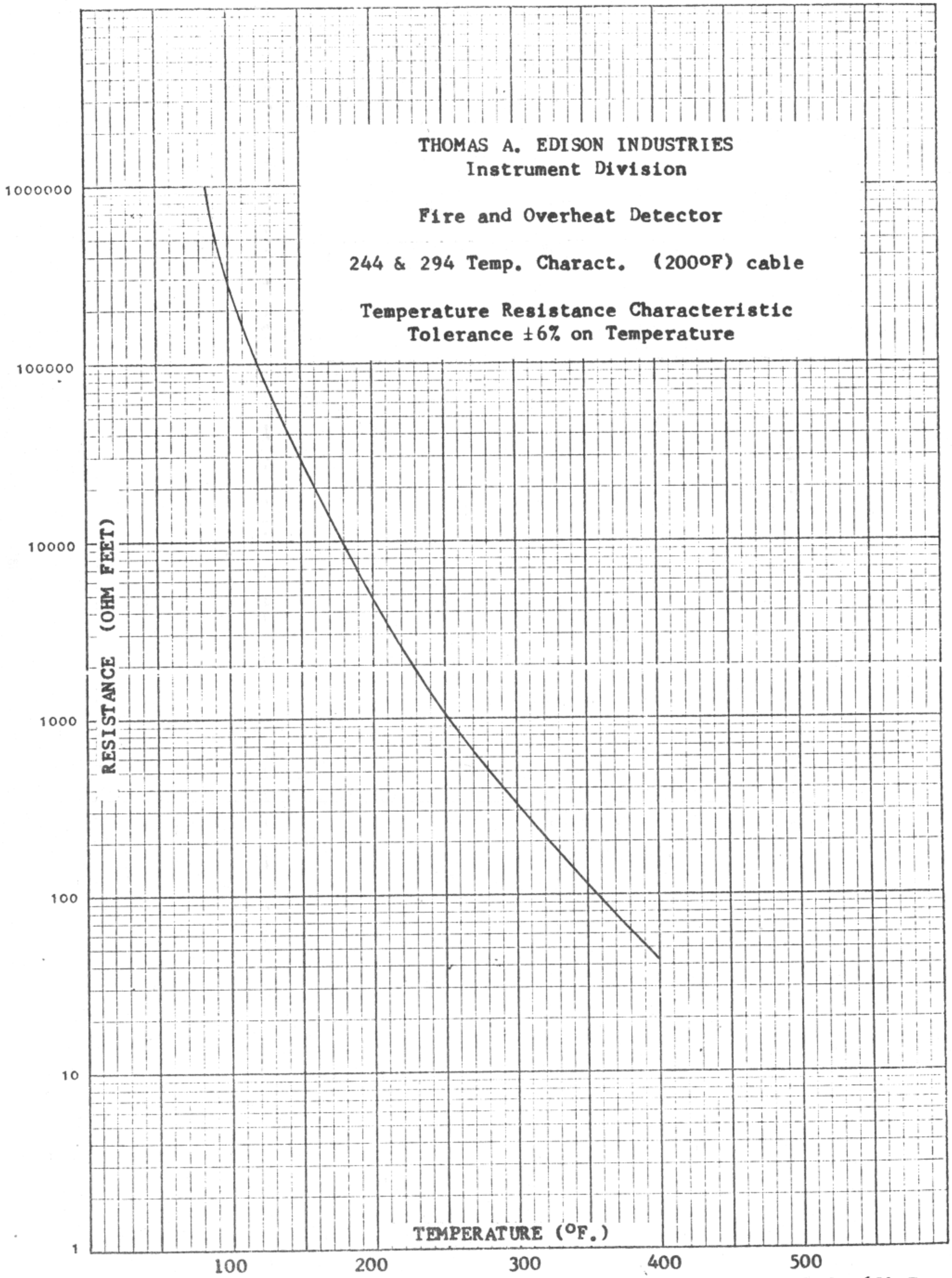
Para 7.3 Vibration

Para 3,5 Magnetic Effect: No testing is required per TSO since the requirement is subject to the operation of other instruments in the same aircraft. However, EDISON has always acknowledged responsibility if any field problems were encountered. To the best of our knowledge no problem has ever arisen.

Para 4.2 Reliability: No test is required per TSO, however EDISON Systems have been service proven which demonstrates its capability of meeting the reliability demands of modern day aircraft. Typical reliability information on the DC-8 System is as follows:

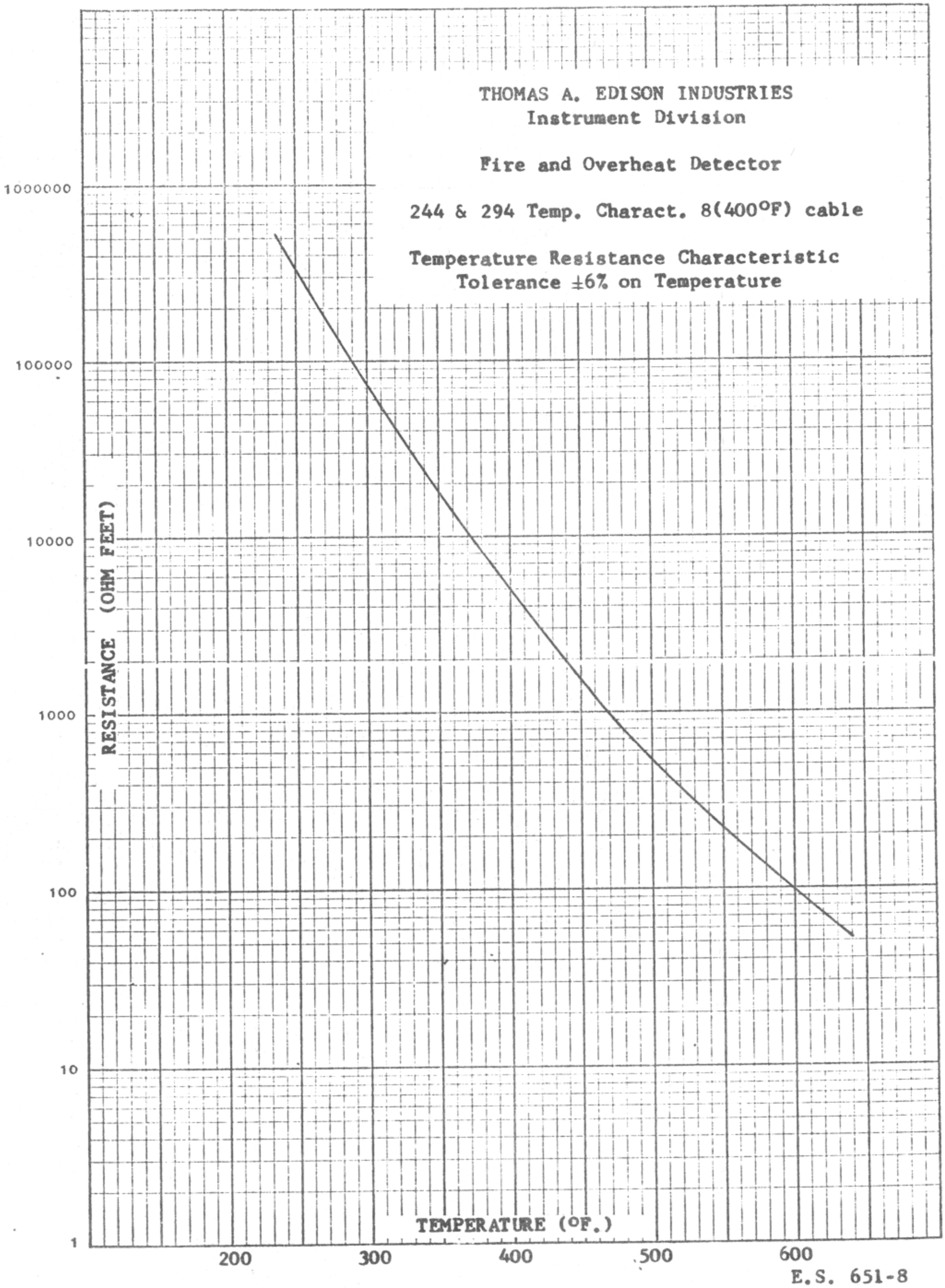
Controls	460,000 hours MTBF
Cables	450,000 hours MTBF

Para 4.4.1 Adjustable Detector System - This paragraph is applicable to adjustable systems only. EDISON's systems are not adjustable, and as such each control type is totally interchangeable from unit to unit.


THOMAS A. EDISON INDUSTRIES
Instrument Division
Fire and Overheat Detector
244 & 294 Temp. Charact. (200°F) cable
Temperature Resistance Characteristic
Tolerance ±6% on Temperature
1000000
100000
10000
1000
100
10
1
RESISTANCE (OHM FEET)
TEMPERATURE (°F.)
100
200
300
400
500

E.S. 651-7

FIG. 1



THOMAS A. EDISON INDUSTRIES
Instrument Division
Fire and Overheat Detector
244 & 294 Temp. Charact. 8(400°F) cable
Temperature Resistance Characteristic
Tolerance ±6% on Temperature
1000000
100000
10000
1000
100
10
1
RESISTANCE (OHM FEET)
TEMPERATURE (°F.)
200
300
400
500
600
E.S. 651-8

FIG. 2

NOTE:

1. Reference Drawing: (0)377-02801 Outline Dwg.
2. Symbol ⊥ Denotes internal common connection electrically insulated from case & is grounded externally through connector.
3. External fire alarm adjusting, ground fault alarm adjusting & test resistors to be determined by application requirements.

MODEL 377 SCHEMATIC

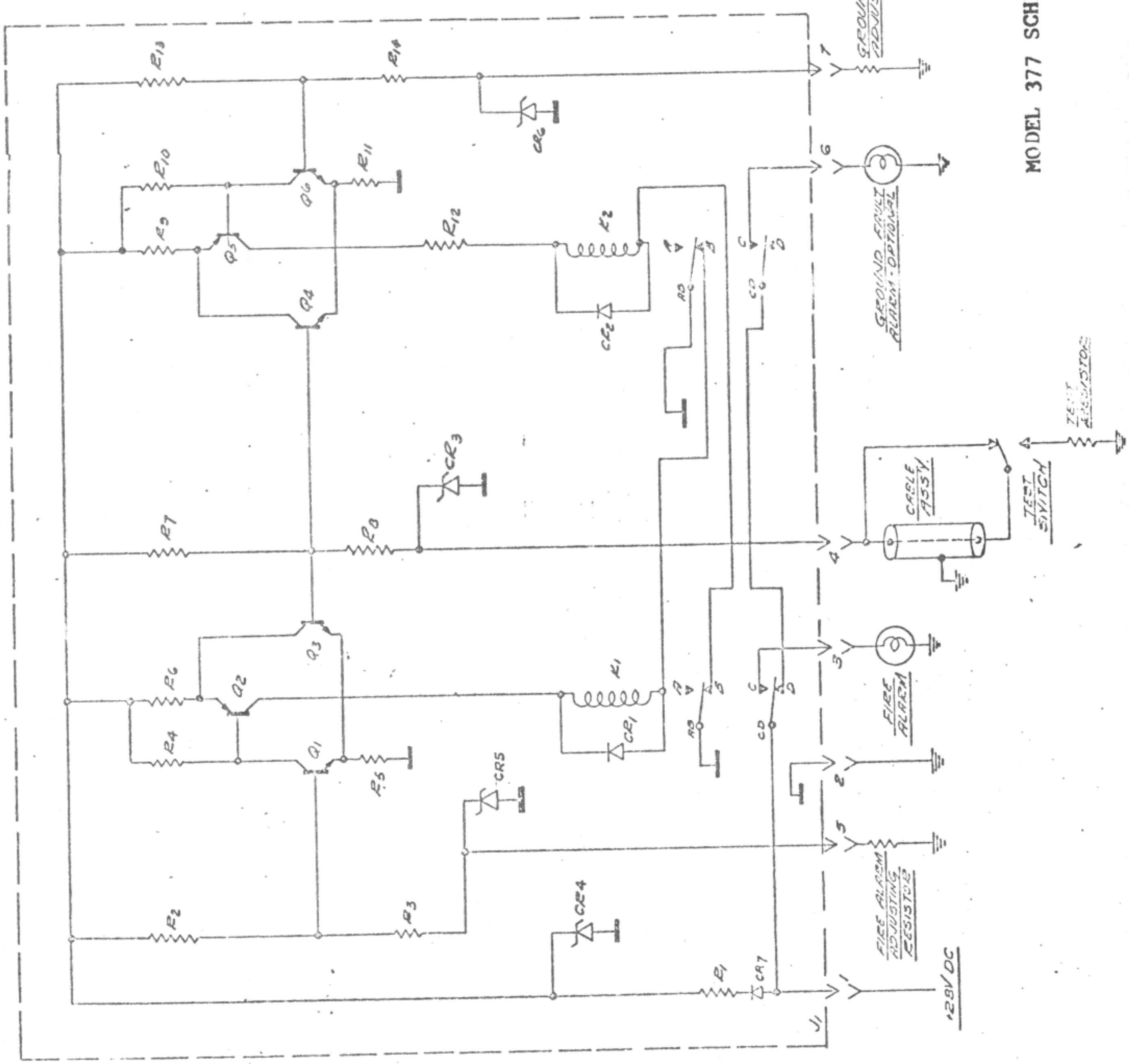
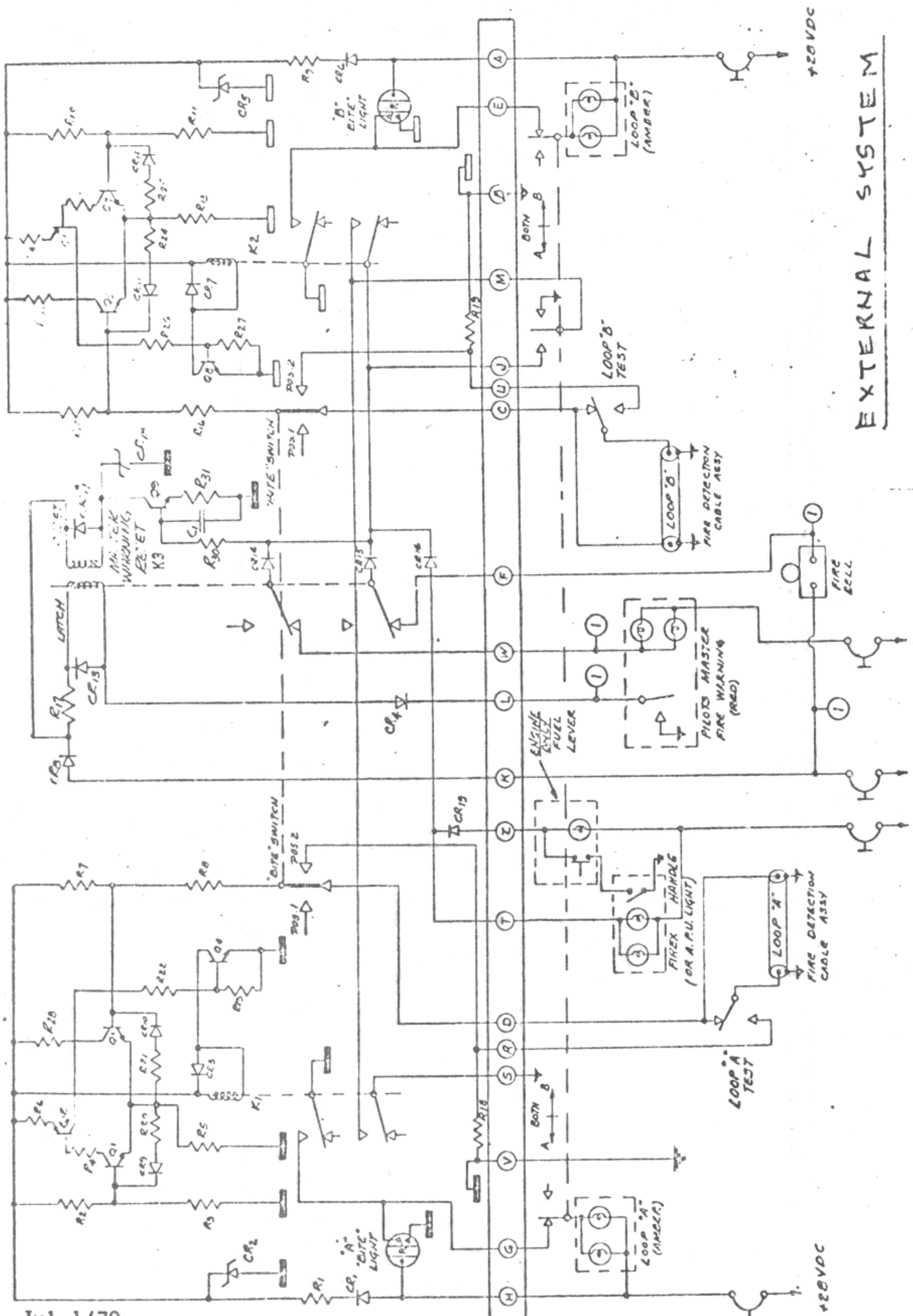


Fig. 3



Notes:

1. Symbols and denote internal common connection electrically insulated from the case and each other but externally grounded through the connector.
2. Symbols (1) denote connections to other control/cable assemblies.

Jul 1/70

Schematic Diagram, Control Assembly Model 324

Fig. 4

DISCUSSION FOLLOWING EDISON PRESENTATION

Q. Do you have any recommendations for revising the fire detector TSOs?

A. No recommendations. We have observed that no reliability testing is required.

PYROTECTOR

FLAME AND SMOKE DETECTION SYSTEMS

EDWIN R. HATHEWAY

VICE PRESIDENT - SALES

PYROTECTOR, INCORPORATED

PYROTECTOR, INCORPORATED
333 Lincoln Street
Hingham, Massachusetts

November 16, 1970

Pyrotector, Incorporated developed their initial aircraft flame and smoke detection systems in 1959 and have been improving on the initial concept since that time. These systems are primarily designed to detect various type fires in engine nacelle, cargo compartments, and other unattended areas in aircraft. The systems are comprised of three major components: Optical flame detectors, reflective light smoke detectors and a control amplifier that can be used with either type detector. System components can be all flame detectors in the case of engine installations or all smoke detectors in the case of baggage and cargo compartment installations, or a combination of both utilizing the same control amplifier.

Principle of Operation:

The Pyrotector Optical Flame Detector utilizes two photo-conductive cells to analyze the light radiation being received by the detector and provide a signal to a control amplifier. The photo-conductive cell circuit within the detector can be considered a voltage divider network. A photo-conductive cell that is responsive to visual infrared is connected in series with a photo-conductive cell that is responsive to the visual blue-white region of the spectrum. Power (28 volts) is fed into the infrared cell, a signal wire is connected between the two cells and the other end of the blue cell is connected to ground. Also, a second wire is connected to the junction of the signal lead between the two cells and this wire is utilized to test the detector circuitry.

Three broad conditions can be taken to describe the detector's operation: In total darkness both cells are at maximum resistance and the signal output is practically nil. The control amplifier requires 14 ± one volt to produce a fire alarm signal in the cockpit. The second condition would be noontime daylight in which a mixture of visual infrared and blue-white light are present. In this case the infrared responsive cell drops in its resistance but simultaneously the blue-white responsive cell also drops in its resistance so that most of the 28 volts goes to ground but part of it appears in the signal lead in the order of 5 to 7 volts. The third condition would be a fire occurring at any time during the first two conditions described. In the first instance, the infrared responsive cell would drop drastically with no change in the blue-white responsive cell so that signal level would immediately go to approximately 20 volts. In the second instance, the blue-white responsive cell would be a little lower in its resistance but the drastic drop in the infrared responsive cell would still produce a fire signal in the order of 17 volts. This changing of resistances with ambient light conditions allows the detector to maintain the same relative sensitivity to a standard fire regardless of light conditions.

The Pyrotector smoke detector operates on the reflective light principle wherein a light beam is directed at right angles to the viewing path of a photo-conductive cell inside a small circular chamber which has the ends covered with cup-shaped covers mounted on spacers so that smoke can pass freely through the interior by convection. Another design of this detector has a sealed labyrinth and the smoke is piped in and out through tubes. In all smoke detectors a third light is beamed directly at the photo-conductive cell and is utilized for functional test purposes. In operation, the photo-conductive cell sees nothing inside the labyrinth as long as there is clear air. When smoke enters the small chamber, the beacon light beam reflects off the smoke particles to the photo-conductive cell causing an alarm. The calibration point for each smoke detector is set to the amplifier alarm point of 14 ± 1 VDC (same as for flame detections). Calibration settings are within the requirements of FAA TSO-C1a or C1b and tailored to fit each manufacturer's requirements. Settings vary from $70 \pm 10\%$ light transmission to as high as $94 \pm 1\%$ light transmission. The high settings have proved to be very practical in actual operation: Freedom from false alarms because of dust or ordinary cigarette smoke but early enough to alarm in a hazardous smoke condition. To give a comparison of this particular smoke setting, we set our commercial home and industrial smoke detectors as high as 97 ± 1% and still have no problems with false alarms. The aircraft smoke detector incorporates resilient mounts and all electrical connections are made through a single pin connector. All electronics and the smoke detector labyrinth are protected by an outer perforated cover. To functionally test the smoke detector system, a switch in the cockpit translates the beacon and test light bulb circuits into a single circuit so that the test light causes the photo-conductive cell to produce an alarm voltage and at the same time both bulbs are tested for proper functioning. If either bulb is out or the photo-conductive cell or any of the circuitry defective, then the system will fail to test.

The control amplifier is used for either the flame detectors or smoke detectors and will receive signals from 6 or 7 individual detectors depending upon the particular control amplifier. Signal input from the detectors is fed into a diode mixing network so that each channel is separated from the other channels, thereby preventing any cross-feed from channel to channel. The signal is fed through two-stage transistor amplification which operates a mechanical relay. The contacts of the mechanical relay are arranged to produce 28 volts output alarm signal, or in the case of certain amplifiers a second set of contacts allows grounding of an alarm circuit. The control amplifier is temperature compensated with a thermistor and voltage is regulated by a zener diode. Some control amplifiers have negative protection up to 400 VDC min. and others as high as 600 VDC positive or negative. The 303 amplifier is built in a light but rugged aluminum housing and is mounted directly to the airframe. Two connectors are provided: 1 connector receives all the signals from the various detectors and the other connector is utilized for power, ground, alarm, signal and test connections. Our newest amplifier 30-326, which is presently being submitted for TSO and MIL Spec. approval, is built of the proven components of our 30-303 series, however the size and weight have been reduced substantially and a single pigmy connector is used for all wire connections.

System Design:

The Pyrotector Fire and Smoke Detection Systems are designed to meet the requirements of FAA TSO-C79, TSO-Cla and Clb, and MIL-F-23447. Ruggedness in each of the units commensurate with light weight has been one of the prime objectives so that the units will withstand the rigors of everyday maintenance and handling. This concept has proven highly successful in that units received back from service that have been severely damaged have been found to be still operational and within the specified calibration limits. System continuity testing of the flame detection system has proved adequate in service and the functional tests of the smoke detector has proved to be excellent. We provide a ground test kit for the flame detection system which functionally tests the operation of each flame detectors by actually exercising the cells. Fail-safe design has been uppermost wherever possible. Redundant grounds are utilized in the flame and smoke detectors as well as the amplifiers. One series of control amplifier utilizes a descrimination circuit so that a false alarm will not occur as a result of a direct short between power and signal wires. Complete failure or grounding of any single conductor will not cause a false alarm but will cause a failure to test.

System Characteristics:

The optical flame detectors are calibrated to meet the requirements of TSO-C79 and MIL-F-23447 along with all the environmental conditions required by both of these specifications. The detectors are set to produce an alarm signal level when exposed to a 5" pan of hydrocarbon fuel burning at 4' distance in an ambient light level of 10' candles or less. Actually, we set the detectors in the area of 5½ to 6½' in order to remain within specifications during high/low line voltage and temperature. The smoke detectors, as previously stated, are set to alarm as the customer requires within the TSO limitations, namely, 60-96%. All detectors produce the same level of alarm signal voltage, and amplifier signal is adequate to drive the usual alarm devices. All of our aircraft systems are designed to operate on 18-32 VDC.

Installation Recommendations:

Each new aircraft type installation must be considered individually and the layout of detectors, control amplifiers and system wiring is a joint effort between Pyrotector and customer engineering personnel. The final locations of detectors are determined in an actual aircraft or reasonable mock-up and then finally tested with an infrared light source in the case of flame detectors to determine the amount of coverage being obtained in a given compartment, and with smoke generators or smoke bombs in an actual airplane compartment to determine that smoke detectors will alarm within the requirements of the controlling specifications. Final locations and proper functioning of installed systems are usually determined on a cooperative effort between our own engineering personnel, customer engineering personnel and representatives of the FAA. Generally speaking this method of obtaining an optimum installation has worked out satisfactorily although in one or two instances utilization of the infrared lights has, perhaps, been overexercised in gaining final acceptance of an installed system. In these one or two instances the time and associated costs have caused adverse comments from our customers.

Methods of demonstrating compliance with TSO requirements:

We have all of our products tested by an independent laboratory to demonstrate final compliance with TSO and MIL specification requirements. We have utilized Acton Laboratories in Acton, Massachusetts, for all this testing as they are more than adequately equipped with the proper equipment and instrumentation to conduct all of the environmental and electronic requirements of the various specifications. In the case of altitude testing, we exceed the requirements of specifications in many instances to make certain no problems will occur. This is also true of vibration as we feel that certain installations, particularly in helicopters, could exceed the vibration requirements of the FAA and military specifications. In recent years, we have tested our flame detectors to the requirements of the FAA and military specifications and then required Acton Laboratories to run full scans from 0 to 10,000 CPS with amplitudes ranging up to .036" DA and loadings as high as 100 G. Magnetic effect is tested with the proper magnetic field generators and recorders in accordance with specification requirements. Reliability testing has been conducted in accordance with specification requirements and we also conduct our own independent laboratory testing where necessary. An instance of this would be the light bulbs utilized in our smoke detectors. In recent years, we have recommended Chicago Miniature CM-327-LSV because of proven reliability both in our laboratories and in service. These bulbs were tested under continuous vibration conditions at 32 volts and on/off every four hours with 6 minutes off pause. GE, Westinghouse and the usual run of 327 bulbs were almost all out before we got the first failure of the Chicago Miniature. First failure occurred approximately 2300 hours and the final failure in ten bulbs occurred 8,112 hours of operation. Average life 3472 hours. Given an even chance, the CM bulbs have proved to be very reliable in service. We have recently qualified the Oshino, OL-327-LSV bulb under the same test conditions and will be shortly recommending this bulb as an alternate.

Suggestions for improving TSO or rules:

We have found that TSO-C79 has been quite good as an overall specification for optical flame detectors. We question the practicability of the 2,000°F. fire test. The object of using optical surveillance is the fast response to a fire and therefore the ability to extinguish a much smaller fire than normally encountered. Assuming the system (including the operation) functions properly, it is very unlikely that temperatures will approach the 2,000°F. point. And even if they did there had to be a fire source to produce that amount of heat and that source would have been detected by the flame detector. With several optical flame detectors present in any given installation it would not appear that all detectors would be exposed to 2,000° simultaneously and if they were it would seem that the fire hazard had exceeded the point where the flight crew would not worry much whether they had repeatability in the flame detectors. In the eight years of operation of our systems in helicopters and other aircraft, we know of only one instance which has occurred where high temperature gas ejection had destroyed a detector and the reliability of the alarm could be questioned. In this instance, the detector failed in an alarm condition but simultaneously a change in engine perameters had occurred indicating an engine problem existed. Other fires that have occurred, range from electrical bus fires that were picked up in C-130 aircraft, a fire of unknown origin in a New York Airways Vertol Model 107 and a Northeast Airlines Viscount engine fire caused by loose burner can cross-over tubes, and a few others on which we have no details. The 2,000° requirement has ruled out certain types of cells for utilization in optical flame detectors that otherwise could have provided improved flame detector characteristics. We feel that an upper limit of perhaps 1400° to 1600° could be acceptable.

We also question the requirement of detecting a pure magnesium flame. As far as we know, the only instance where pure magnesium fires existed were in reciprocating engines some 20 years ago as the result of blower problems. Since that era, we are not aware of any engines that have produced a pure magnesium fire either as an original hazard or a pure magnesium fire burning during flight after a fuel or oil type fire had started and been extinguished. On the other hand, if such a fire has occurred, then by all means this requirement should be kept in the TSO.

We were rather surprised at the leniency shown in TSO-C1b in detector setting. Perhaps this was allowed to cover earlier systems such as those installed in the C-141 which was FAA approved for commercial operation and other installations some eight or ten years ago. However, we strongly feel that any new installation should not be set lower than 90-93% calibration. We set commercial-industrial systems at 96-98% and have no difficulty with false alarms and yet have excellent early warning systems.

Again, the specifications for our systems, FAA-TSO-C79, TSO-C1a, TSO-C1b and MIL-F-23447 have been found to be good tight workable specifications that have guided us to produce reliable equipment.

Some time back the ATA & FAA were presented with the possibility of utilizing a new approach in detection - use the present overheat detection systems for detecting overheat conditions and install pure flame detectors (optics) for the fire detection system. One airline commented in 1964 that "the industry should now recognize that fire and overheat are not one and the same - they have different causes, attributes and effects and they will require different flight crew corrective action. It is, therefore, essential that FAA and the airframe manufacturing industry agree upon these locations, zones or areas where either fire or overheat detection is specifically required - in no case should a system type be extended to cover an application which is beyond its true scope of capability".

We also suggest consideration be given to a semi-automatic system wherein a small amount of extinguishing agent would be discharged automatically by the fire detection system. This would give the pilot time to decide whether or not to manually pull his main fire bottles but in the meantime some immediate action had been started.

DISCUSSION FOLLOWING PYROTECTOR PRESENTATION

Q. Do you have any recommendations regarding the installation of surveillance fire detectors?

A. We believe it is nearly impossible to put good ground rules for making detector installations into one instruction book such as an Advisory Circular.

Q. What changes would you like to see in TSO-C79?

A. We believe the TSO vibration test is inadequate. We test "g" and frequency until failures occur.

The 2000 °F flame test of surveillance detectors rules out some types but can be met by current Pyrotector units.

TSO-C79 and C1a have been used and are workable but need to be brought up to date.

In lieu of such guidelines, we believe there should be cooperation between the detector and the aircraft manufacturers and the FAA.

The standard flame should be fairly stable, which the present one in the TSO is not. There is a variation in the TSO flame spectrum. This test is very old and should be changed. The USAF is working to define a standard test flame.

Q. What radiation source is used in simulating a flame when evaluating detector location and coverage?

A. GE ruby red 250 watt heat lamp operated at 68 to 72 volts is equivalent to the 5-inch pan fire.

Q. How would you compare FAA and ARB certification?

A. ARB qualification is a 90 day operation - far more rigorous than FAA requires for testing and approval.

Q. Can the smoke detector be adapted to use for powerplant fire detection?

A. It is possible. This would be the third way to detect fire in addition to heat and flame surveillance detectors.

FIRE DETECTION
IN
BOEING HELICOPTERS

GEORGE C. HOPKINS

SUPERVISOR, POWER PLANT DESIGN

BOEING - VERTOL DIVISION

INTRODUCTION

IN EARLY PRODUCTION HELICOPTERS, USING RECIPROCATING ENGINES, FIRE DETECTION DEVICES CONSISTED OF A WARNING LIGHT ACTIVATED BY THERMOCOUPLES LOCATED IN THE ENGINE COMPARTMENT. MOST MILITARY HELICOPTERS ONLY HAD FIRE DETECTORS WITH NO PROVISION FOR EXTINGUISHING; HOWEVER, COMMERCIAL HELICOPTERS HAD FIRE EXTINGUISHERS INSTALLED TO MEET FAA REGULATIONS. THE FOLLOWING CHARTS WILL SHOW DETAILS OF FIRE DETECTOR INSTALLATIONS ON CURRENT BOEING TWIN-TURBINE HELICOPTERS, SERVICE EXPERIENCE, AND AREAS FOR POSSIBLE IMPROVEMENT IN FIRE DETECTION SYSTEMS. IT IS NOTEWORTHY THAT TODAY'S MILITARY TROOP CARRYING HELICOPTERS HAVE THE SAME PROBLEM OF "NO PARACHUTES" THAT EXISTS ON COMMERCIAL HELICOPTERS AND FIXED WING AIRCRAFT; THEREFORE, FIRE DETECTION AND EXTINGUISHING SYSTEMS IN TODAY'S MILITARY HELICOPTERS HAVE TO MEET ESSENTIALLY THE SAME REQUIREMENTS AS DO COMMERCIAL HELICOPTERS.

FIRE DETECTION IN BOEING HELICOPTERS

- BOEING-VERTOL HELICOPTER SYSTEMS
- 107/CH-46/CH-47 SERVICE EXPERIENCE
- FACTORS IN DETECTION SYSTEM SELECTION
- RECOMMENDED IMPROVEMENTS
- SUMMARY

FIRE DETECTION SYSTEMS IN BOEING HELICOPTERS

This chart shows the various models of Boeing Twin-Turbine Helicopters with the different Fire/Smoke Detection Systems now in service. The selection of systems depends on the customer's preference in many cases. Installation details are shown on the following pages.

FIRE DETECTION SYSTEMS
IN
BOEING-VERTOL
TWIN TURBINE MODEL HELICOPTERS
IN SERVICE

HELICOPTER	CUSTOMER	QTY	ENGINE COMPARTMENT	APU COMPARTMENT	CABIN HEATER	BAGGAGE & CARGO
CH-47	U.S. ARMY	635	CONT. LOOP OVERTEMP DETECTOR	NONE	NONE	N/A
CH-46	USMC	597	RADIATION SENSING DETECTORS	RADIATION SENSING DETECTOR	NONE	N/A
UH-46	U.S. NAVY	24	"	"	NONE	N/A
NYA & PAA	COMM.	7	"	N/A	THERMAL SWITCH SYSTEM	SMOKE DETECTION SYSTEM
CH-113	CANADIAN AIR FORCE	6	CONT. LOOP OVERTEMP DETECTOR	N/A	"	N/A
CH-113A	CANADIAN ARMY	12	RADIATION SENSING DETECTOR	RADIATION SENSING DETECTOR	"	N/A
HKP-4	SWEDISH AIR FORCE NAVY	10 3	" "	N/A	" "	N/A N/A
KV-107 BY KAC	JAPANESE ARMY NAVY AIR FORCE COMMERCIAL	82 14 46 10	" " " "	N/A N/A N/A N/A	" " " "	N/A N/A N/A SMOKE DETECTION SYSTEM

CH-47 Fire Detection System

1. System

The fire detection system consists of a continuous type circuit. One circuit protects each engine compartment of the helicopter. Each circuit consists of three series-connected sensing elements routed around the engine and a control unit mounted on a frame within the fuselage. When either circuit is energized by an abnormal increase in engine compartment temperature. It lights the corresponding fire handle on the center instrument panel.

A test switch marked "Push to Test" is also located on the instrument panel.

2. Components

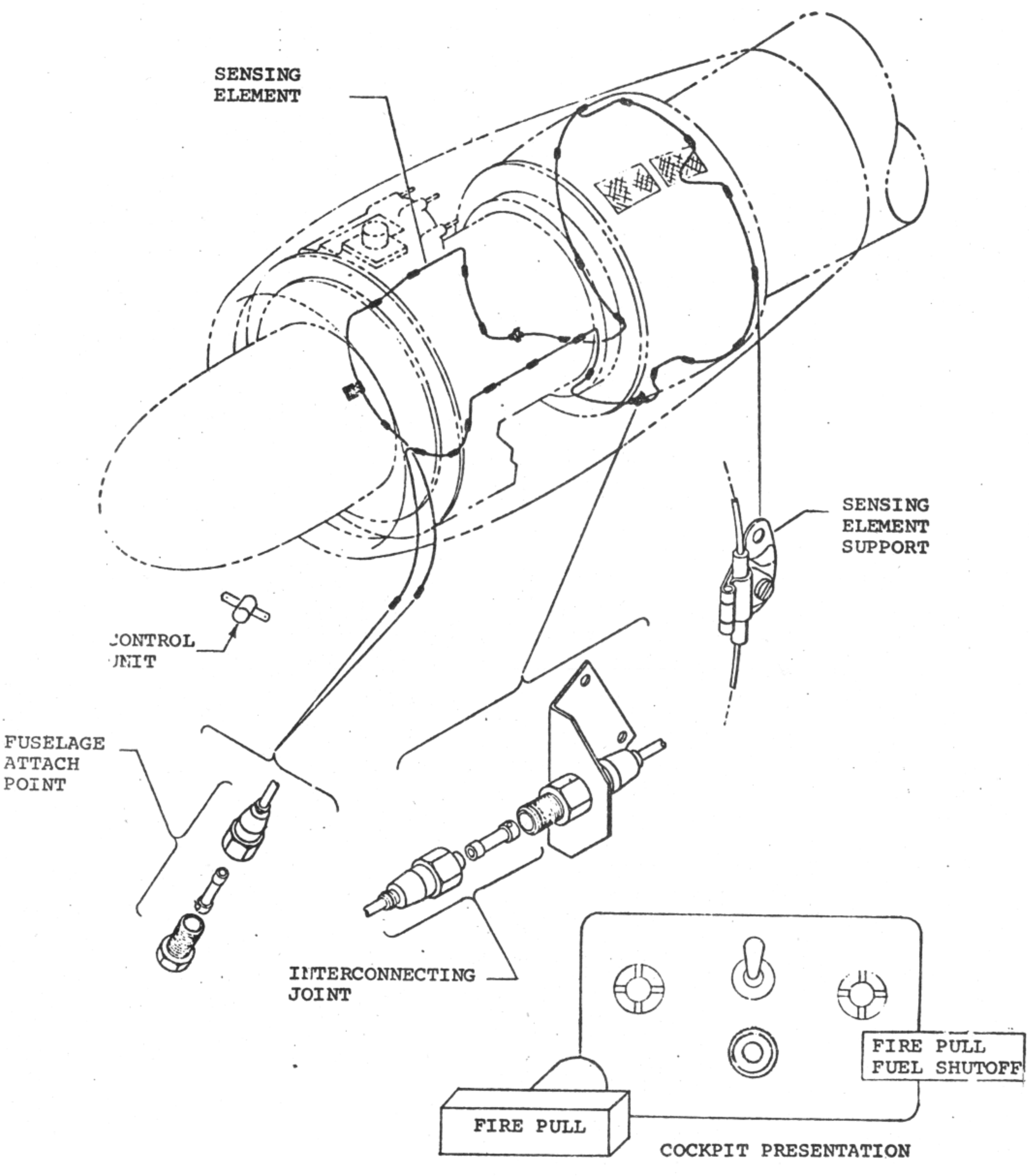
Detectors

The sensing element is a thin metallic tube with an insulated center wire. The resistance of the insulating material varies inversely with the temperature applied to it. A temperature of 301°C to 350°C (573-662°F) will lower the resistance in the element to 25 ohms. This will cause the fire warning lights to come on. The elements are equipped with closed-entry, chip proof connections which aid in the prevention of false fire warning indications. Care must be exercised to avoid pinching or crushing an element during removal or installation.

3. Control Unit

The control unit, one for each engine, is located within the fuselage. Each unit is a hermetically sealed assembly consisting of a magnetic amplifier and a test circuit. The magnetic amplifier consists of six components which perform the function of amplifying the signal from the detectors to power the warning lights and to check out the system. Electrical connections are made through a receptacle on one end of the unit.

CH-47 ENGINE FIRE DETECTION SYSTEM



CH-46, CH-113A, HKP4, 107-II, AND KAC

ENGINE FIRE DETECTION SYSTEM

1. System

   A. An infrared, flame surveillance, fire detection system is employed in each engine compartment with fire warning indication installed in the cockpit. The system is electrically operated and has provisions for checking to ensure that its components and wiring are functioning properly.

2. Components

   A. Detectors

   The detector is a solid state photoconductive cell that senses flame-emitted infrared radiation, and transmits a signal to the control amplifier. A total of eight detectors are used in the engine fire detection system with four detectors in each engine compartment. Two of the detectors are located in the frame at the forward end of the compartment and two in the frame at the aft end of the engine compartment so that the complete compartment is within the range of at least one of the detectors.

   B. Amplifier

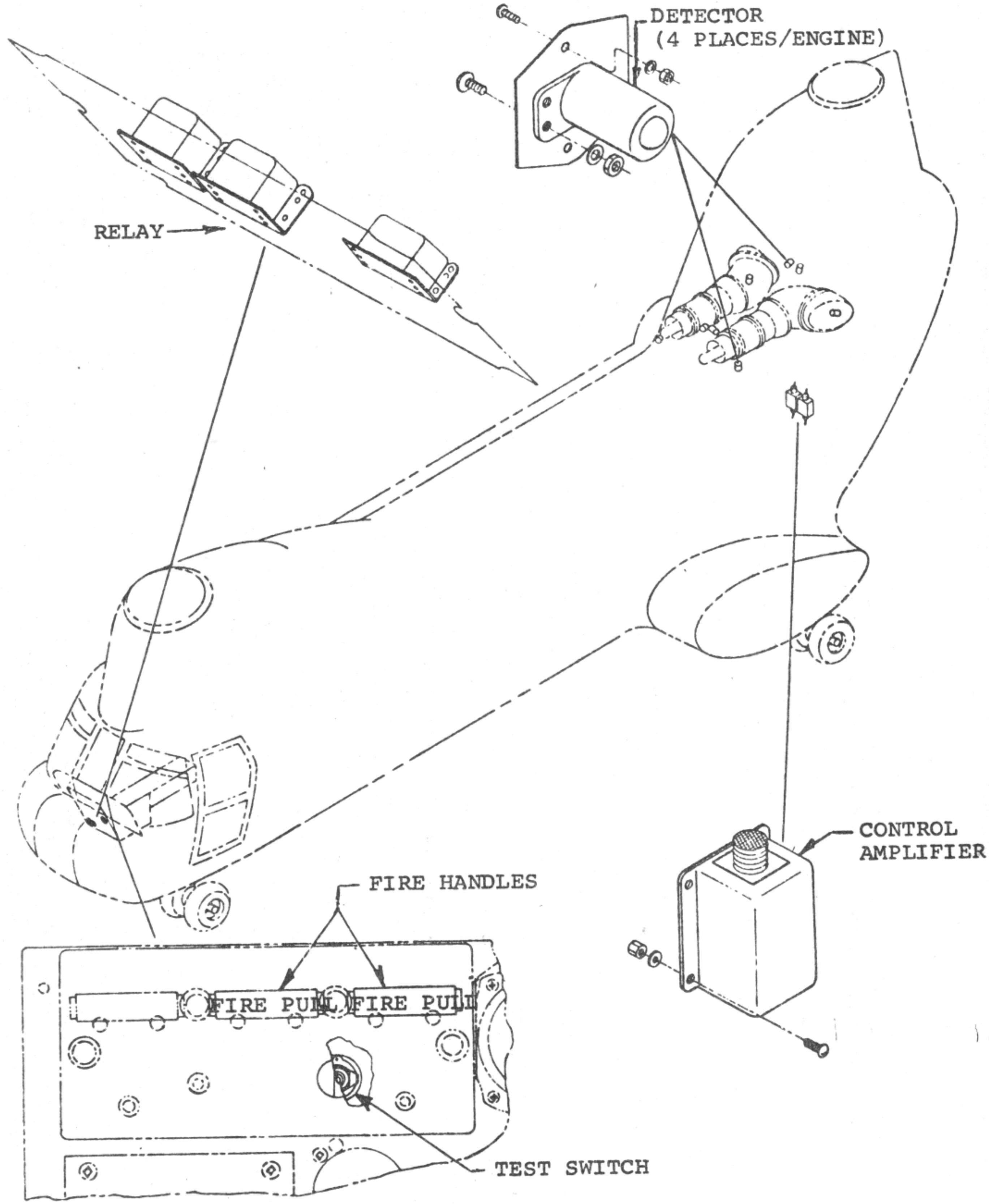
   Two control amplifiers are provided, one for each engine fire detection circuit. The diode mixing network within the amplifier receives the voltage output signal from the fire detector and transfers it to the input of the transistor relay circuit where it is amplified to energize a relay that completes a circuit for the lamp in the fire control handle in the cockpit.

   C. Test Switch

   The fire detector test switch is located on the pilots' fire warning panel. The switch is placed in its NORM position except when one of the detectors is being tested. When the switch is placed in positions 1, 2, 3, or 4, the corresponding fire detectors of both engines are tested. A voltage is directed into the detector which in turn energizes the control amplifier relay circuits, thereby completing the circuit to the lamp in the fire control handle.

CH-46, CH-113A, HKP4, 107-II AND KAC

ENGINE FIRE DETECTION SYSTEM



COCKPIT PRESENTATION

RCAF ENGINE

FIRE DETECTION SYSTEM

1. System

The engine fire detection system for the RCAF helicopter consists of a continuous-type circuit. A circuit protects each engine compartment of the helicopter. Each circuit provides a fire warning in the cockpit by illuminating a fire warning handle on the center instrument panel should the temperature within the engine compartment rise abnormally. Each system consists of three series-connected sensing elements within the engine compartment, a control unit mounted in the fuselage cabin, and four frame-mounted connectors. A test switch is also provided to check system operation.

2. Components

A. Control Unit

The control unit consists of a magnetic amplifier and a test circuit.

B. Sensing Element

The sensing element is a wire which is enclosed in, but insulated from, a thin metal tube. The resistance of the insulating material varies inversely with the temperature applied to it so that a high temperature will lower the resistance in the element and cause the warning light to come on. The elements are equipped with closed-entry chip-proof connectors which aid in the prevention of false fire warning indication.

3. Operation

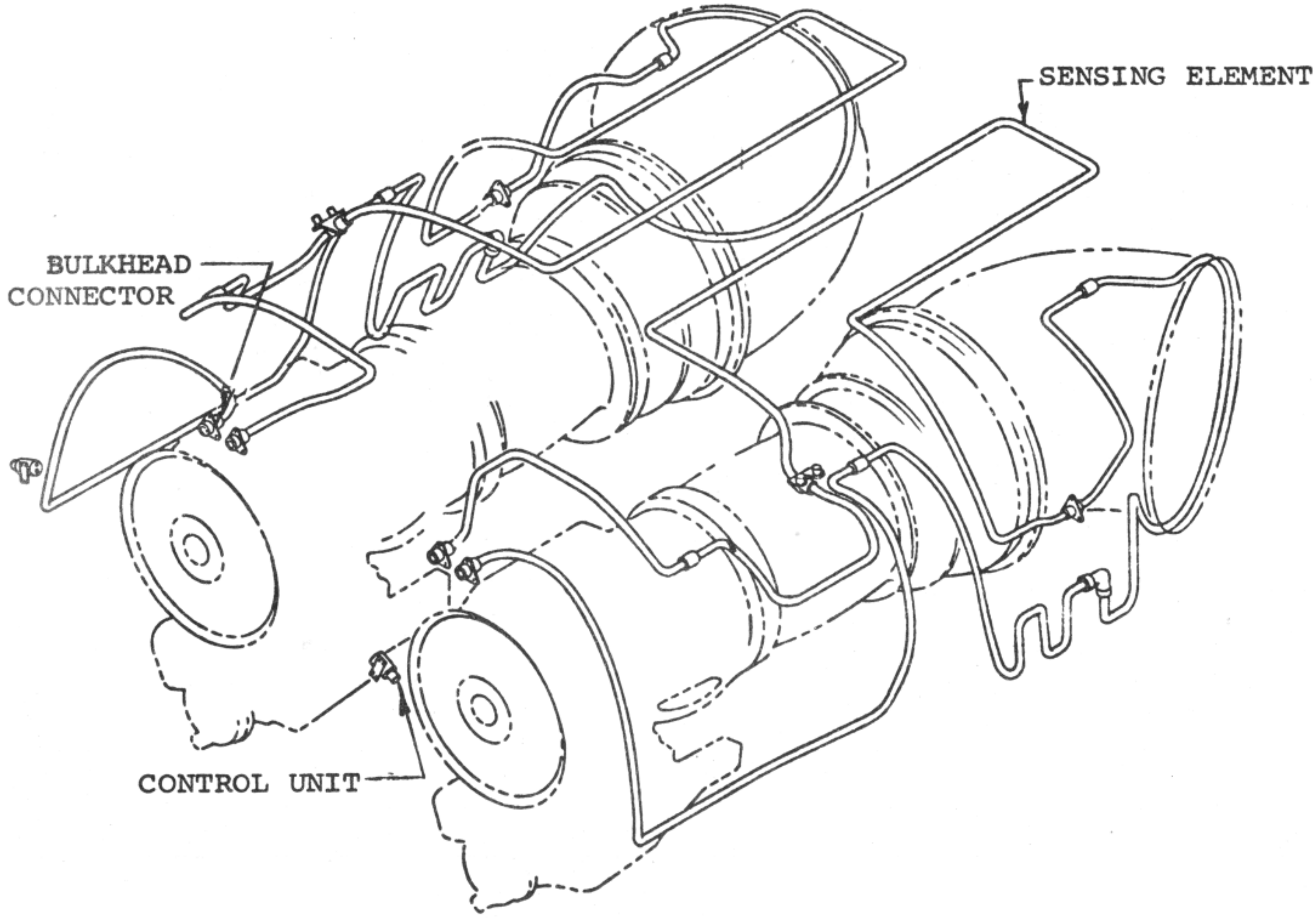
A. In standby condition, the power and reset windings of the magnetic amplifier in the control unit are energized on alternate half cycles of the ac voltage supply. Thus, any step toward saturation in the core of the power winding is offset by the equal and opposite effect of the reset winding. Without saturation of the core, little or no current flows through the power winding or the fire handle lights.

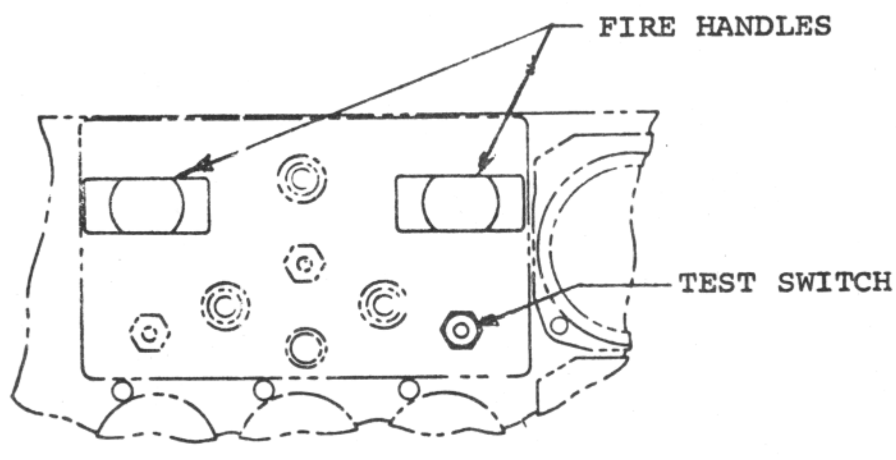
B. When the sensing element is heated, the resistance between the inner and outer conductors is lowered, and the impedance of the control winding of the magnetic amplifier is reduced. Hence, the magnetic amplifier is out of balance; the core approaches saturation, and the increase in power winding current is sufficient to light the fire handle lights.

C. By placing the test switch to TEST, 28-volt dc is connected to the test relay which grounds the center conductor of the sensing element, reducing the impedance of the control winding, thereby simulating an overheat condition.

RCAF ENGINE

FIRE DETECTION SYSTEM





COCKPIT PRESENTATION

CH-46 AND CH-113A

AUXILIARY POWER UNIT

FIRE DETECTION SYSTEM

1. System

A. The apu fire detection system consists of two infrared sensing detectors and a control amplifier installed in the lower aft pylon and two warning lamps and test switch installed in the cockpit. The system is electrically operated and provides constant flame surveillance of the auxiliary power unit compartment by means of the detectors, and visual fire warning indication through the two fire warning lamps in the fire control handle. The system can be functionally tested to ensure proper operation of its wiring and components by means of the test switch in the cockpit.

2. Components

A. Detectors

Each detector is a solid-state photoconductive cell which senses flame-emitted infrared radiation and transmits a signal to the control amplifier.

B. Control Amplifier

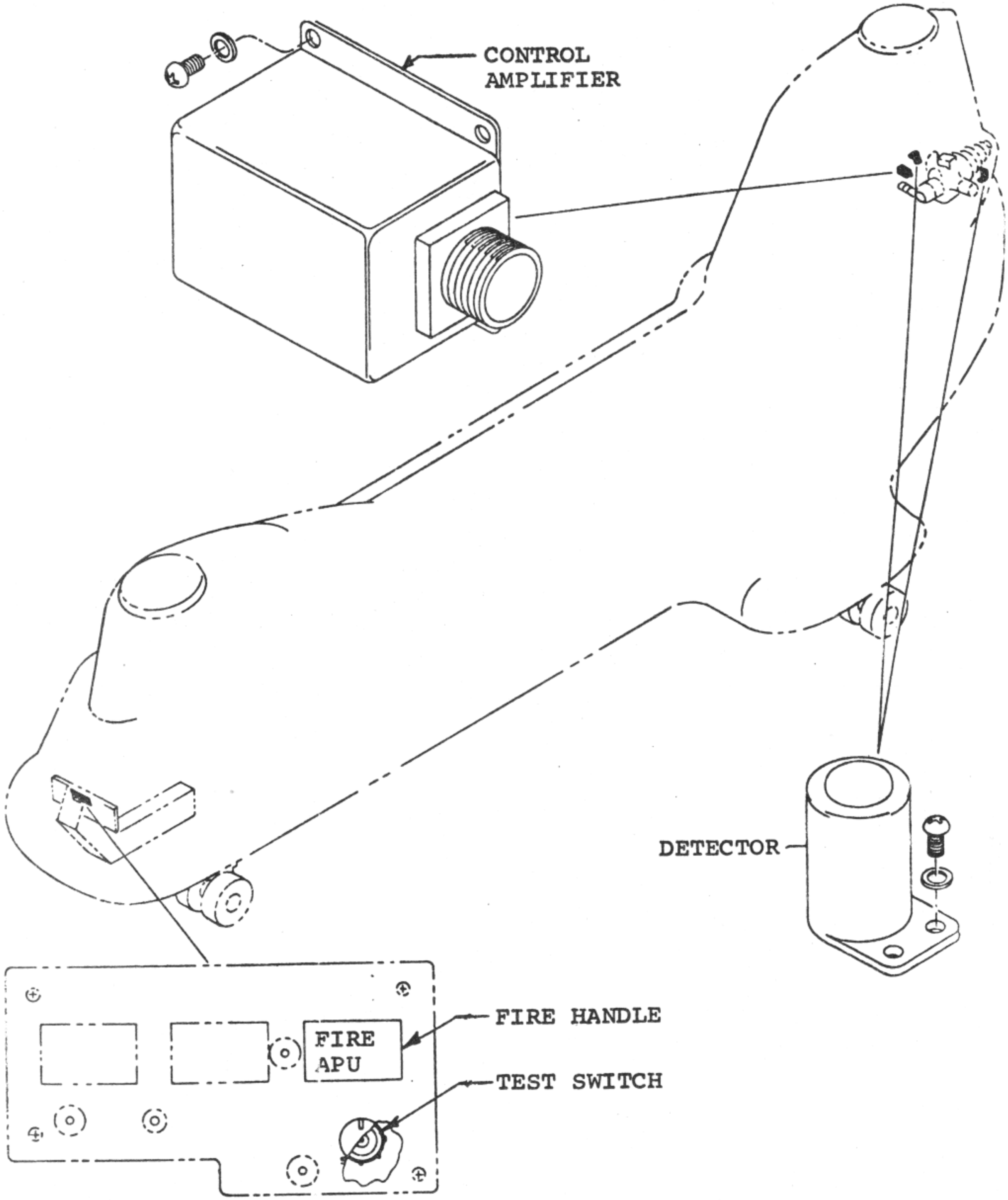
The control amplifier mixing network receives the output signal from the detector and transfers it to the input side of the relay control where it is amplified to energize a relay. The relay powers the fire warning lamp circuit.

C. Test Switch

The fire detector test switch is located on the pilot's instrument panel. With the switch in position 5, a voltage of sufficient value to energize the control amplifier relay circuits, is induced into the fire detectors causing the fire warning lamps to come on.

CH-46 AND CH-113A APU

FIRE DETECTION SYSTEM



COCKPIT PRESENTATION

CH-113, CH-113A, HKP4, 107-II, and KAC
HEATER FIRE DETECTION SYSTEM

1. System

(a). A thermal switch system detects fire and overheating in the heater area. The system is electrically operated and consists of two thermal switches installed in the heater enclosure, two warning lamps which are part of the fire control handle, a test switch, a heater diode, and the necessary wiring. Excessive heat closes the switch contacts in the thermal switches and causes the lamps in the fire control handle to come on.

2. Components

(a) Detectors (Thermal Switches)

The heater fire detectors in the heater fire detection system consist of two bimetallic temperature-sensitive thermal switches which are installed in the heater enclosure. When an overheat condition occurs in the heater, either switch will close and illuminate the warning lamps in the heater fire control handle in the cockpit. The detectors are preset, are non-adjustable, and will indicate a fire warning condition when the temperature reaches 316°C (600°F).

(b) Test Switch

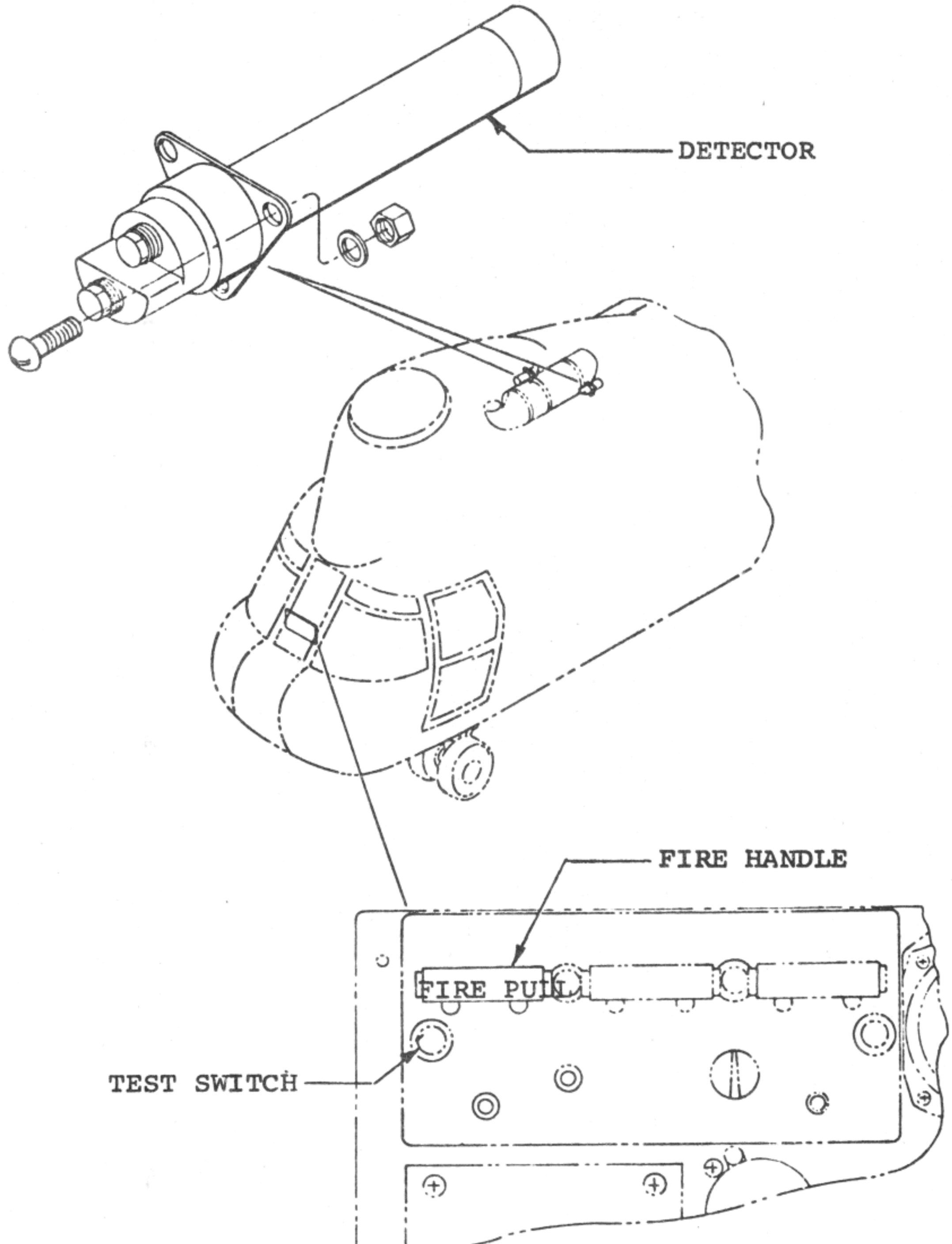
The test switch on the fire warning panel checks system operation. When the switch is closed, the warning lamps should illuminate, indicating that the system is operating correctly.

(c) Heater Diode

The diode isolates the dc test circuit from the other warning circuits when the test switch is closed to check the warning lamps in the fire control handle. The diode is installed in the console. This prevents all the master warning panel lights from coming on in case of a heater fire with a defective diode in the system.

CH-113, CH-113A, HKP4, 107-II, AND KAC

HEATER FIRE DETECTION SYSTEM



NYA AND KAC

BAGGAGE BIN AND CARGO COMPARTMENT

SMOKE DETECTION SYSTEM

1. System

(a) The purpose of the smoke detection system is to sense the presence of smoke in the baggage bin and in the cargo area. The system is electrically operated and consists of an amplifier, two smoke detectors, an indicator light installed in the warning panel, a test switch, and the necessary wiring. Provisions are incorporated so that the pilot or copilot can test the system for wiring continuity and the function of all components.

2. Components

(a) Smoke Detectors

The smoke detectors are photosensitive electrical units that detect infrared light reflected by smoke particles. When smoke of sufficient density is present to cause alarm, the detectors will transmit a pulsating signal to the amplifier. The amplifier output, in turn, will energize the indicator light in the warning panel to warn the pilot or copilot.

(b) Amplifier

The amplifier contains the circuitry and components to amplify the warning signal received from the smoke detectors. This signal is transmitted to the indicator light on the warning panel located in the cockpit.

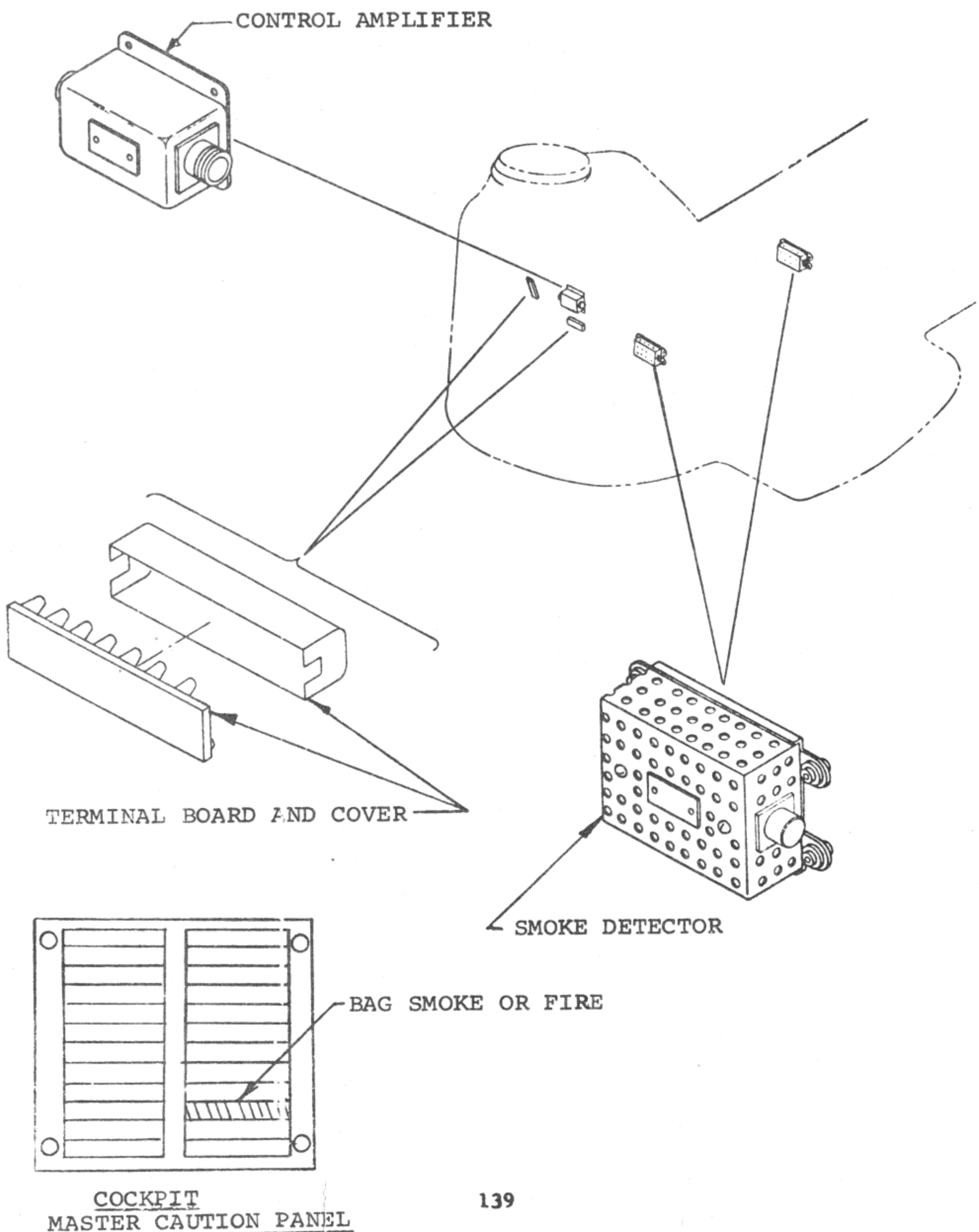
(c) Test Switch

The test switch is a double-pole, 3-position, toggle switch and it enables the pilot and copilot to test the capabilities of the smoke detection system. If a pulsating signal is indicated on the indicator light when the test switch is placed in TEST for either detector, it is an indication that all the wiring and components are functioning properly. Upon return of the test switch to ON, the system should recycle and give no further indication of alarm.

NYA AND KAC

BAGGAGE AND CARGO COMPARTMENT

SMOKE DETECTION SYSTEM



SERVICE EXPERIENCE ON BOEING HELICOPTERS

(EXCLUDING COMBAT)

The upper table shows service experience on inflight engine compartment detected fire in the Boeing twin-turbine helicopter fleet. A total of 21 inflight engine compartment fires haveoccurred in 1,318,372 flying hours for a rate of 1.59 fires/100,000 flying hours. False fire warnings have occurred 28 times for an overall rate of 2.13/100,000 flying hours. Before attempting to draw conclusions it may be helpful to breakdown these incidents in more detail.

As shown in the lower table the majority of the inflight fires resulted in forced or precautionary landings. Only two (2) resulted in major accidents; one in which the fire was successfully detected and extinguished but the pilot made a hard landing and the aircraft sustained structural damage, and the other in which fire was not completely extinguished and during a hard landing the aircraft caught fire and burned

DISTRIBUTION OF INFLIGHT ENGINE FIRES VS. FALSE FIRE INDICATIONS
THROUGH 1969 (EXCLUDES COMBAT)

	H-46 440,172 FH		107 153,645 FH		CH-47 724,555 FH		Total 1,318,372 FH	
	No.	Rate*	No.	Rate*	No.	Rate*	No.	Rate*
Inflight Engine Fires	8	1.81	2	1.30	11	1.51	21	1.59
False Fire Indications	6	1.36	11	7.15	11	1.51	28	2.12
Total	14	3.17	13	8.45	22	3.02	49	3.71

DISTRIBUTION OF INFLIGHT FIRES BY TYPE OF MISHAPS
THROUGH 1969 (EXCLUDES COMBAT)

	H-46		107		CH-47		Total	
	No.	Rate*	No.	Rate*	No.	Rate*	No.	Rate*
Major	0		0		2	.27	2	.15
Forced Landing	1	.22	0		7	.97	8	.61
Precautionary Landing	5	1.13	1	.65	2	.27	8	.61
Incidents	2	.45	1	.65	0		3	.22
Total	8	1.80	2	1.30	11	1.51	21	1.59

*Rate per 100,000 Flight-Hours

FALSE FIRE WARNINGS AND CAUSES

The upper table shows a breakdown of the false fire warning results. The predominant result is the same as that of actual fires, forced and precautionary landings. It is also noteworthy that no major accidents were caused by false fire warnings.

The lower table breaks out the causes for false fire warnings. Faulty detectors are the chief reason for false warnings, with moisture the next prevalent cause.

The reasons for moisture problems associated with the 107/CH-46 model helicopter are:

(a) Early detector units having pigtails that were not fluid resistant; and due to the low voltage system even minor moisture weeping into the cable assemblies was sufficient to provide a fire signal.

(b) Terminal board configuration and location was poor. Standard terminal board in an area that became damp when the aircraft sat out for extended periods in driving rains.

The above problems have now been corrected.

The results of false warnings can be humorous provided the confusion and panic created does not result in crash landings or the like.

Example:

During a training flight, both engine fire warning lights illuminated. The pilot had been cautioned about false indications so he asked the crew chief to investigate. The crew chief, forgetting his "hot mike" yelled to another crew member to check for "fire". The pilot mistook this for confirmation of fire and secured both engines immediately (50' - 100' alt.), discharged both extinguishing systems, and auto-rotated to a landing. This was a case of one detector failing in the #2 engine compartment, and sunlight triggering off the #1 engine compartment detector.

DISTRIBUTION OF INFLIGHT FALSE FIRE WARNINGS
BY TYPE OF MISHAPS
THROUGH 1969 (EXCLUDES COMBAT)

	H-46 440,172 FH		107 153,645 FH		CH-47 724,555 FH		Total 1,318,372 FH	
	No.	Rate*	No.	Rate*	No.	Rate*	No.	Rate*
Major	0		0		0		0	
Forced Landings	0		0		1	.13	1	.08
Precautionary Landings	5	1.13	8	5.20	9	1.25	22	1.67
Incidents	1	.23	3	1.95	1	.13	5	.37
Totals	6	1.36	11	7.15	11	1.51	28	2.12

DISTRIBUTION OF CAUSES FOR FALSE FIRE WARNING INDICATIONS
THROUGH 1969 (EXCLUDES COMBAT)

	H-46 440,172 FH		107 153,645 FH		CH-47 724,555 FH		Total 1,318,372 FH	
	No.	Rate*	No.	Rate*	No.	Rate*	No.	Rate*
Faulty Detector	2	.45	2	1.30	5	.69	9	.68
Moisture	1	.22	5	3.25	1	.13	7	.53
Sunlight	1	.22	2	1.30	0	.26	3	.22
Short Circuit	0		0		2	.26	2	.15
Loose Wire	0		1	.65	1	.13	2	.15
Unknown/Other	2	.45	1	.65	2	.26	5	.37
Totals	6	1.36	11	7.15	11	1.51	28	2.12

*Rate per 100,000 FH

DETECTION SYSTEM SELECTION CONSIDERATIONS

- OVERHEAT TYPE
  - CAN BE DAMAGED EASILY BY CARELESS HANDLING, BENDING AND SHORTING THE UNIT
  - FIRE COULD BE WELL DEVELOPED BEFORE DETECTION UNDER ADVERSE AIRFLOWS
- RADIATION TYPE
  - MUST BE CAREFULLY LOCATED AND TESTED TO AVOID FALSE ALARM FROM EXTERNAL LIGHT SOURCES
  - CAN DISREGARD A HIGH TEMPERATURE LOW EMISSION BURN-THRU OF ENGINE

OPTIMUM SYSTEM FOR MOST ENGINE COMPARTMENTS

- COMBINATION OF THE OVERHEAT TYPE AND THE RADIATION TYPE
- SENSE BOTH FLAME AND OVERTEMPERATURE PERMITTING PROMPT ACTION TO AVOID A LARGE FIRE
- A SYSTEM WAS DEVELOPED FOR NEW YORK AIRWAYS MODEL 107 WHICH CONSISTED OF FOUR RADIATION DETECTORS AND FOUR OVERHEAT DETECTORS IN EACH ENGINE COMPARTMENT. FIRE WOULD BE INDICATED BY A STEADY RED LIGHT AND OVERTEMPERATURE WOULD BE INDICATED BY A FLASHING RED LIGHT.
- IT MUST BE REALIZED, HOWEVER, THAT THIS TYPE OF A COMBINED SYSTEM COULD BE A CONSTANT SOURCE OF FALSE INDICATIONS. THEREFORE, IT IS IMPERATIVE THAT THE SYSTEM RELIABILITY BE VASTLY IMPROVED.

RECOMMENDATIONS

- **CONNECTORS IN LIEU OF PIGTAILS**

  HAVING PIGTAILS RESTRICTS THE CONTRACTOR TO SATISFACTORILY PROTECT THE SYSTEM FROM MOISTURE.

- **ENVIRONMENTAL SEALED CONNECTORS**

  THE TYPE OF CONNECTOR TO BE SPECIFIED SHOULD BE SIMILAR TO MIL-C-26500 OR MIL-C-26482.

- **ENVIRONMENTAL SEALED TERMINAL BOARDS**

  THE TYPE OF TERMINAL BOARD TO BE SPECIFIED (IF REQUIRED AT ALL) SHOULD BE SIMILAR TO MIL-T-81714.

- **DETECTOR SENSITIVITY** (RADIATION TYPE)

  DETECTORS SHOULD BE DESIGNED TO ONLY DETECT FLAME, NOT SOME OTHER OUTSIDE SOURCE OF LIGHT; OR THE EMPHASIS SHOULD BE PLACED ON LOCATION AND/OR SHIELDING.

- **SYSTEM TESTING**

  PROVIDE A BETTER TEST PROCEDURE FOR SYSTEM ACCEPTANCE, BEING SURE TO COVER ALL ITEMS SUCH AS:

  - MOISTURE AREAS
  - OUTSIDE LIGHT
  - VULNERABILITY TO HANDLING
  - RAPID RESPONSE (SIMULATING MAXIMUM AIRFLOW)
  - VIBRATION PECULIAR TO HELICOPTERS

- **POWER SUPPLY**

  REQUIREMENTS PRESENTLY STATE THAT BOTH THE FIRE DETECTION AND EXTINGUISHING SYSTEMS BE WIRED TO THE EMERGENCY BUSS FOR POWER. THIS SHOULD BE REVISED TO STATE THE BATTERY BUSS SINCE THE EMERGENCY BUSS IS POWERED BY AC GENERATORS (IN BOEING HELICOPTER). THIS BEING THE CASE, THERE ARE TIMES WHEN POWER IS NOT AVAILABLE FOR SYSTEM OPERATION; AND THERE SHOULD BE. FOR EXAMPLE, DURING ENGINE STARTING AND AFTER ENGINE SHUTDOWN.

SUMMARY

- BOEING HELICOPTERS USE A VARIETY OF FIRE/SMOKE DETECTION SYSTEMS.
- ENGINE FIRE RATES ARE 1.59 FIRES PER 100,000 FLIGHT-HOURS (.15 FIRE ACCIDENTS PER 100,000).
- ENGINE FALSE FIRE INDICATIONS ARE 2.12 INDICATIONS PER 100,000 FLIGHT-HOURS.
- MOST FIRE/FALSE WARNINGS HAVE RESULTED IN EITHER FORCED OR PRECAUTIONARY LANDINGS - NONE SERIOUS.
- DETECTION SYSTEMS MUST BE MADE MORE RELIABLE PARTICULARLY IN THE ELIMINATION OF FALSE INDICATIONS.

DISCUSSION FOLLOWING VERTOL PRESENTATION

Q. Do you have any recommendations regarding fire detector system installations?

A. Any type electrical connector used with a new detector system should be an environmentally sealed type. Use sealed terminal boards when these are required.

Guidelines should be in general terms.

Systems should be tested for qualification and approval on prototype aircraft.

Systems should incorporate both radiation and heat sensing techniques.

Problems of false indication such as those caused by sunlight at any time of day (sunrise to sunset) in conjunction with any operation of the the aircraft must be determined on the installation before production.

FIRE DETECTION CONSIDERATIONS AND PRACTICE

JOSEPH L. MAGRI
DESIGN PROJECT ENGINEER

SIKORSKY AIRCRAFT

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FIRE DETECTION CONSIDERATIONS AND PRACTICE

Joseph Magri
Design Project Engineer
Sikorsky Aircraft, Division of United Aircraft

Sikorsky Aircraft experience with fire detection systems in helicopters dates back to the early 1950's and includes installations in the Sikorsky S-56 and S-58 helicopters. Both of these aircraft were powered by reciprocating engines and used continuous detector systems. The S-61 twin-turbine and the S-62 single turbine helicopters designed in the late 1950's also use continuous detectors. Later and larger helicopters such as the S-64 Sky Crane and the S-65 transport incorporate either optical fire detection systems or combinations of optical and continuous detectors. The learning process which took place during the course of these installations, both from the standpoint of vendor equipment and airframe installation, materially reduced existing inadequacies. This learning process continues today.

CONSIDERATIONS ENTERING INTO SELECTION OF A FIRE DETECTOR SYSTEM

Considerations affecting the selection of a fire detection system revolve primarily around system RELIABILITY and MAINTAINABILITY. System weight and cost, while secondary in nature, are also items to be considered. Before entering into a discussion of these factors however, a brief review of the features required of a detection system may be useful in establishing the background against which the above factors are normally evaluated.

Ideally, a fire detection system should have the following capabilities.

1. Indicate the existence of a fire, through actuation of fire warning lights in cockpit, immediately after ignition.
2. Indicate the compartment or fire zone in which the fire is located.
3. Remain on for the duration of the fire.
4. Indicate when the fire is out.
5. Indicate re-ignition of fire (if such is the case).
6. Provide for system continuity test from cockpit.
7. Cause no false fire warnings under any flight or ground operating condition.

Reality converts the "immediately" of item (1) to "within five seconds" and, the capability expressed in item (7) can today only be approached.

The primary concern in selection of a fire detection system is, in our view, reliability. By that is meant that (a) the system must indicate the existence of a fire when a true fire exists and (b) the probability of a false fire warning should be minimal. Both of these objectives are, of course, directly related to the detecting system's inherent qualities, its ability to live in the extreme temperature and vibrational environmental conditions to which it is likely to be exposed and its ability to avoid damage due to normal aircraft maintenance procedures.

The same factors which contribute to a detection system's reliability also have a considerable influence on the maintenance required by a given system. Abrasion, vibrational failures, accidental system damage during routine maintenance etc. reduce reliability and add to maintenance requirements. The design of a particular engine installation is also a factor in the selection of a fire detector system in that it may be especially suited to a particular detection system. For example, in the Sikorsky S-65, each engine nacelle, as shown in Figures 1 and 2, is made up of four separate panels all hinged from a "strong-back" running along the top of the engine. Each panel can be opened individually to service localized areas of the engine, or simultaneously to service larger areas. When the panels are in the closed and locked position they become load sharing structural members of the nacelle. Use of this structural panel arrangement reduces the fixed structure required to the single structural beam or "strong-back". Hence, for an installation of this kind, a continuous fire detector system mounted on the existing fixed structure and the nacelle panels would have required a considerable number of flexible assemblies and connectors, thereby reducing system reliability and increasing maintenance requirements. Mounting the entire system directly on the engine would have compromised engine accessibility for maintenance and contributed to a probability of accidental system damage due to routine maintenance. An optical, radiation sensing fire detection system was selected as optimum for this engine installation. Three flame detectors located on the inboard firewall, Figure 3, provide continuous volume surveillance of the engine compartment, without interfering with normal engine maintenance or engine change, and are unaffected by the structural hinged nacelle design. The weight and cost differentials between the surveillance and other competitive systems were not considered significant.

INSTALLATION PRACTICES

Fire detection system installation practices generally reflect the particular requirements of a given detection system and experience gained on previous installations. These practices are shaped to a considerable degree by the basic objectives of a detection system installation, namely high reliability and low maintenance. In aircraft presently in operational use, our installations include radiation sensing, continuous detectors and, in one case, a combination of the two. Our practice, generally, has been to locate the detecting system on fixed aircraft structure rather than on the engine. Experience indicates that this approach minimizes accidental damage to the system, reduces interference with routine engine compartment maintenance and simplifies engine removal and installation. In fire detector installations using radiation sensors, only the flame detector is located within the engine compartment. Other system components are located in areas not subject to the temperature, vibration and maintenance activity associated with the engine compartment. As a result, system integrity has been demonstrated to a high degree. The area of concern with this type of system has been false warnings due to sunlight under special early morning and late afternoon conditions. As experience was accumulated however, installation techniques were developed which, together with improvements to the photo conductive flame detector units themselves,removed this phenomenon as a problem. Among the techniques developed as shown by Figure 4, were:

(a) Flame detector shrouds to protect the photoconductive cells from stray glints of sunlight.

(b) Internal orientation of the flame detector units, through the use of indexing pins. A discussion of the objectives and reasoning behind this technique is presented later.

(c) Control of flame detector viewing direction,as installed, through built-in angularity of detector mounting flanges and airframe mounting brackets in conjunction with the indexing pins.

A continuous fire detection system is used in all military and commercial versions of the S-61 helicopter. The system, Figure 5, provides warning in the event of excessive temperature rise in either engine compartment. The sensing loops are attached to aircraft structure in the engine compartment and the portion of the nacelle which serves as the engine service platform. Initially, many teething problems were experienced with this installation especially with regard to the required flexible connecting cables. However, with increasing experience, fixes and vendor improvements to the detector system, this installation developed into a reliable, low maintenance system.

DETERMINATION OF SYSTEM LOCATION AND SETTING

As opposed to continuous detector systems whose sensors should be located in close proximity to anticipated flame areas, with due consideration for engine compartment cooling airflow patterns, radiation sensing optical fire detectors are located to provide volume surveillance of the compartment being monitored. This volumetric coverage capability can be used to determine initial detector locations which can later be improved and/or verified by the use of a simulated fire in the form of an infra-red light. The ability of the detectors to sense both direct and reflected infra-red radiations when installed in an enclosure, was used in the S-65 installation to minimize the number of detectors required. Tests conducted originally by the vendor and later by Sikorsky in the S-65 engine compartment, demonstrated the ability of the detector to sense reflected infra-red radiation as much as 260° from a simulated standard fire source. Three flame detectors, Figure 6, mounted on the inboard firewall provide full fire detector coverage for each engine compartment. A shield is installed around the aft fire detector to eliminate false fire warnings experienced during early test periods from a sun low on the horizon (10°) shining on the tail of the helicopter.

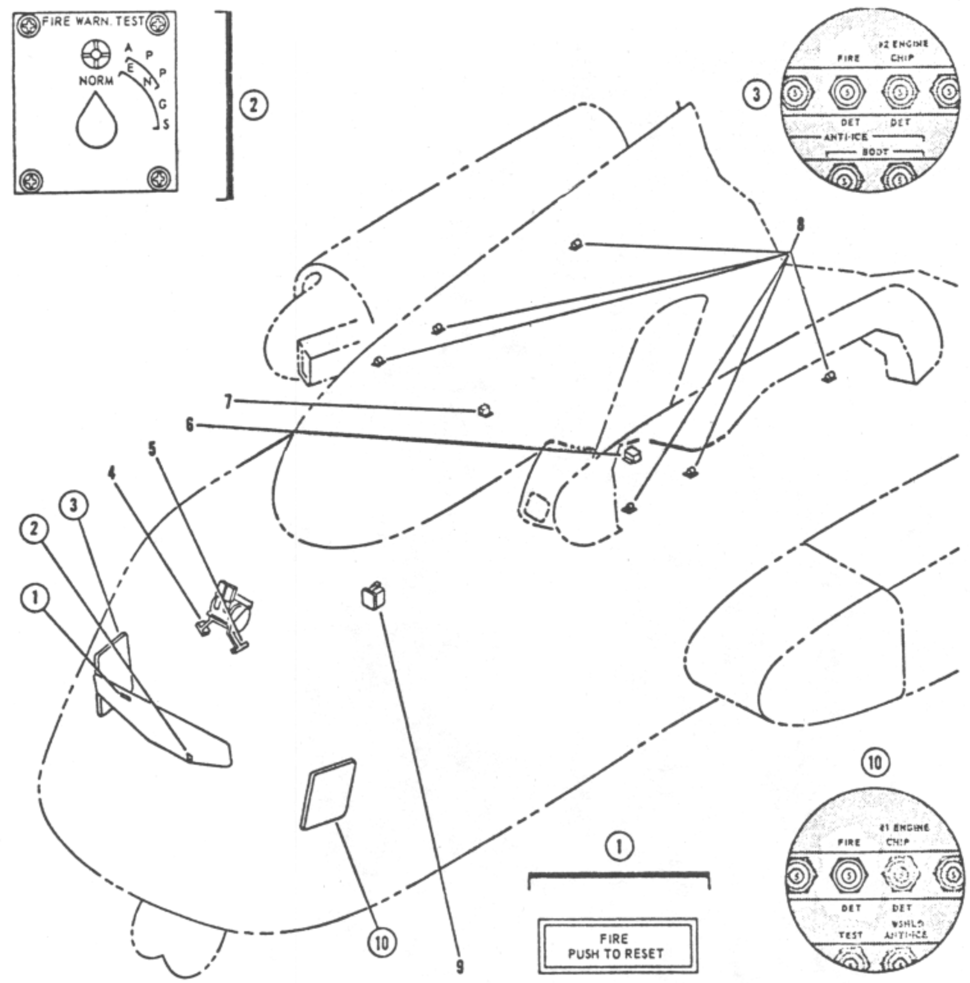
As opposed to the S-65 installation with its annular, reflective nacelle fully enclosing the engine, the fire detection installation on the S-64 Flying Crane, Figure 7 presented a considerably greater challenge. As may be seen, this engine installation includes appropriate fire walls to separate each engine and protect the aircraft in the event of fire and the engines are completely uncowled. The fire detection system evolved for this aircraft consists of both surveillance and continuous detectors. Five shielded surveillance detectors and one continuous fire detector independently monitor each engine. Surveillance detector locations, shielding and fields of view are shown on Figure 8. Three of the detectors are located at approximately the same station as the engine front face and the remaining two at approximately the same station as the engine combustion chamber. Shields on these detectors limit their overall view to the boundaries of the firewall installation and the outboard edge of the helicopter in order to confine detection to pertinent engine areas. The continuous detector mounted on the firewall below the engine and running from the engine front face to the aft firewall, was installed originally to protect against a magnesium fire in the gas generator gearbox housing. Unlike earlier detectors, presently available surveillance detectors, qualified to TSO-C79 for both hydro-carbon and magnesium fires, have removed the necessity for the continuous system.

Precise location of the flame detectors on this installation was found to be a very important factor in eliminating false fire warnings due to sunlight. Controlled orientation of the positions of the internal light sensing elements through the use of an index pin, Figure 4, was an important step in determining the location of the sensor. Figure 9 illustrates the principle of operation of these units, As shown, the detector includes two sensing elements identified as a red element and a blue element. The make up of the sensor is such that if the light spectrum is in normal balance, the resistance of the two elements remains in balance and the voltage load at the indicator is below the threshold value. The effect of light on the two elements is to reduce their resistance. During normal sunlight conditions the intensity of the blue and red parts of the light spectrum is such that the resistance of both elements is decreased but the electrical circuit shown in Figure 9 remains in balance. Fire warning occurs when the resistance of the red element is less than that of the blue element such that alarm voltage is reached. This occurs if the composition of the spectrum is altered due to fire (infrared effect) or under certain specific conditions, due to sunlight impinging upon the red element only. The sunlight actuation is possible if the blue element is shaded and the red element is in sunlight during certain sunrise or sunset conditions when the infrared penetration is greatest. It was determined that orientation of the positions of the red and blue elements could be controlled such that for any sunlight impingement on the detector, the red element would be shaded. This was arranged by positioning the blue element nearest the engine in all cases. The engine and aircraft structure then interferes with the path of the sunlight to the red element. Areas of detector surveillance and discrimination between engines were not affected by this indexing of the detector.

The alarm and reset voltages for the above radiation sensing system are established by the vendor as a part of his system certification effort. These setting points are generally constant for all installations of this type of detecting system even in units that provide protection against a magnesium fire. The alarm and reset points are controlled by the detection system control amplifier.

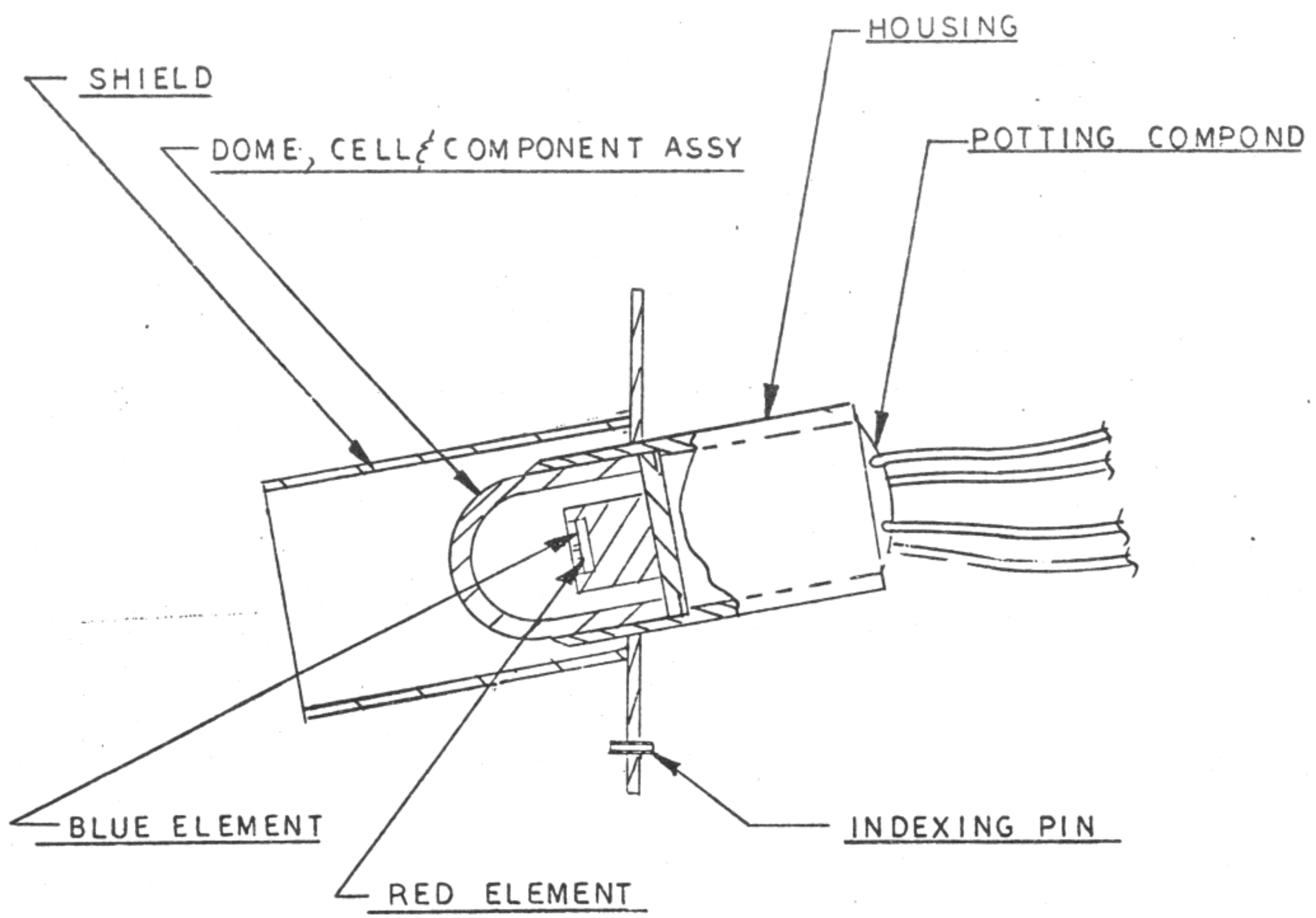
DEMONSTRATING ADEQUACY OF INSTALLATIONS

Locations and field of view of the radiation sensing fire detectors are first checked to establish compliance with design. An infra-red lamp is then used to simulate a fire and demonstrate the ability of the system to detect and signal the existence of a fire in all pertinent areas of the compartment being monitored. A flight test to check for false warnings is then conducted under representative flight conditions and conditions selected as most critical to the fire detection system.



1. Master Fire Warning Lights
2. Fire Warning Test Control Panel
3. Pilot's Circuit Breaker Panel
4. No. 2 Engine T-Handle
5. No. 1 Engine T-Handle
6. No. 1 Engine Control Amplifier
7. No. 2 Engine Control Amplifier
8. Flame Detectors
9. Fire Warning Assembly
10. Copilot's Circuit Breaker Panel

FIGURE 3 S-65 ENGINE FIRE DETECTION SYSTEM



FIRE DETECTOR ASSEMBLY

FIGURE-4

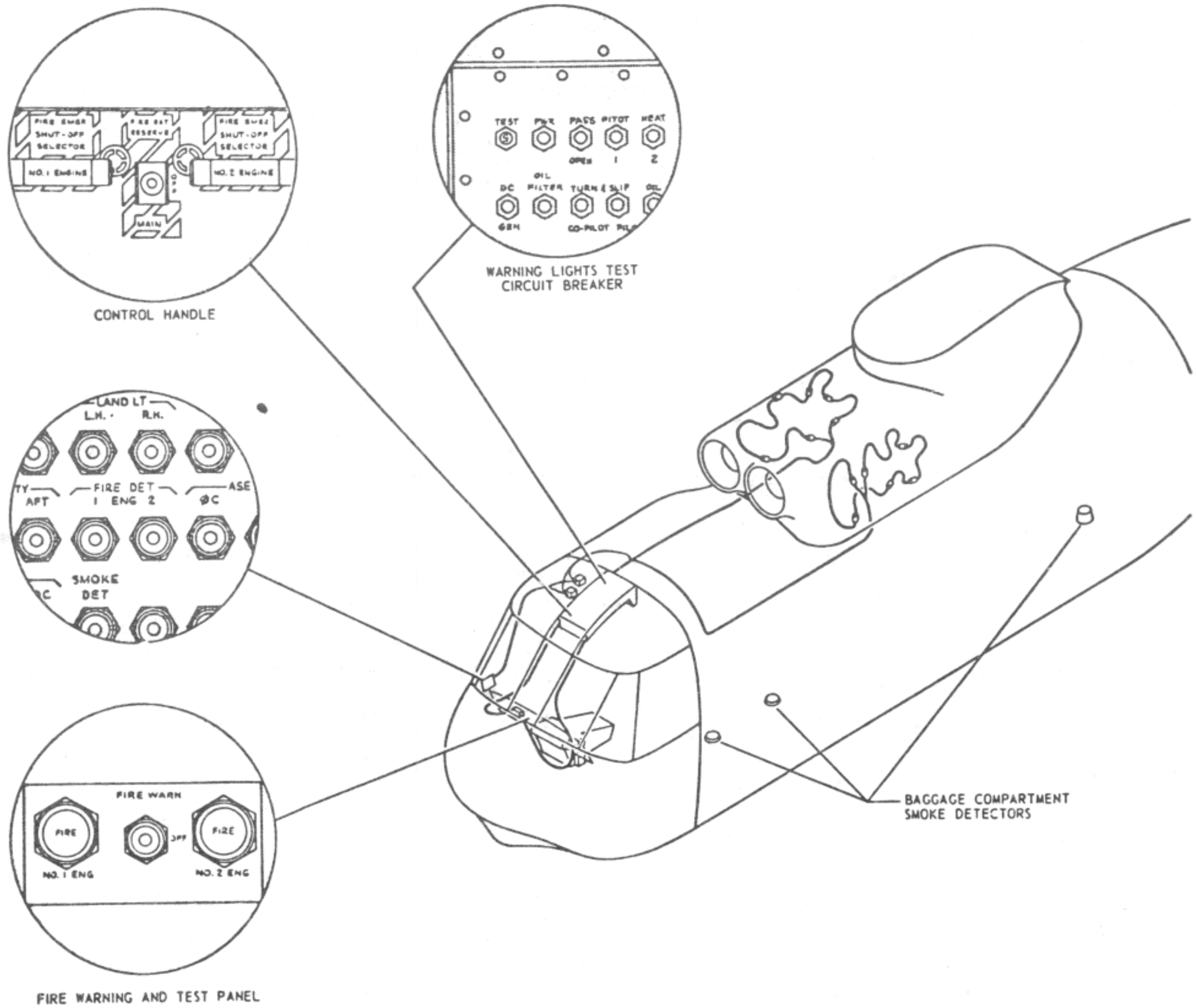


FIGURE 5 S-61 FIRE DETECTOR SYSTEM

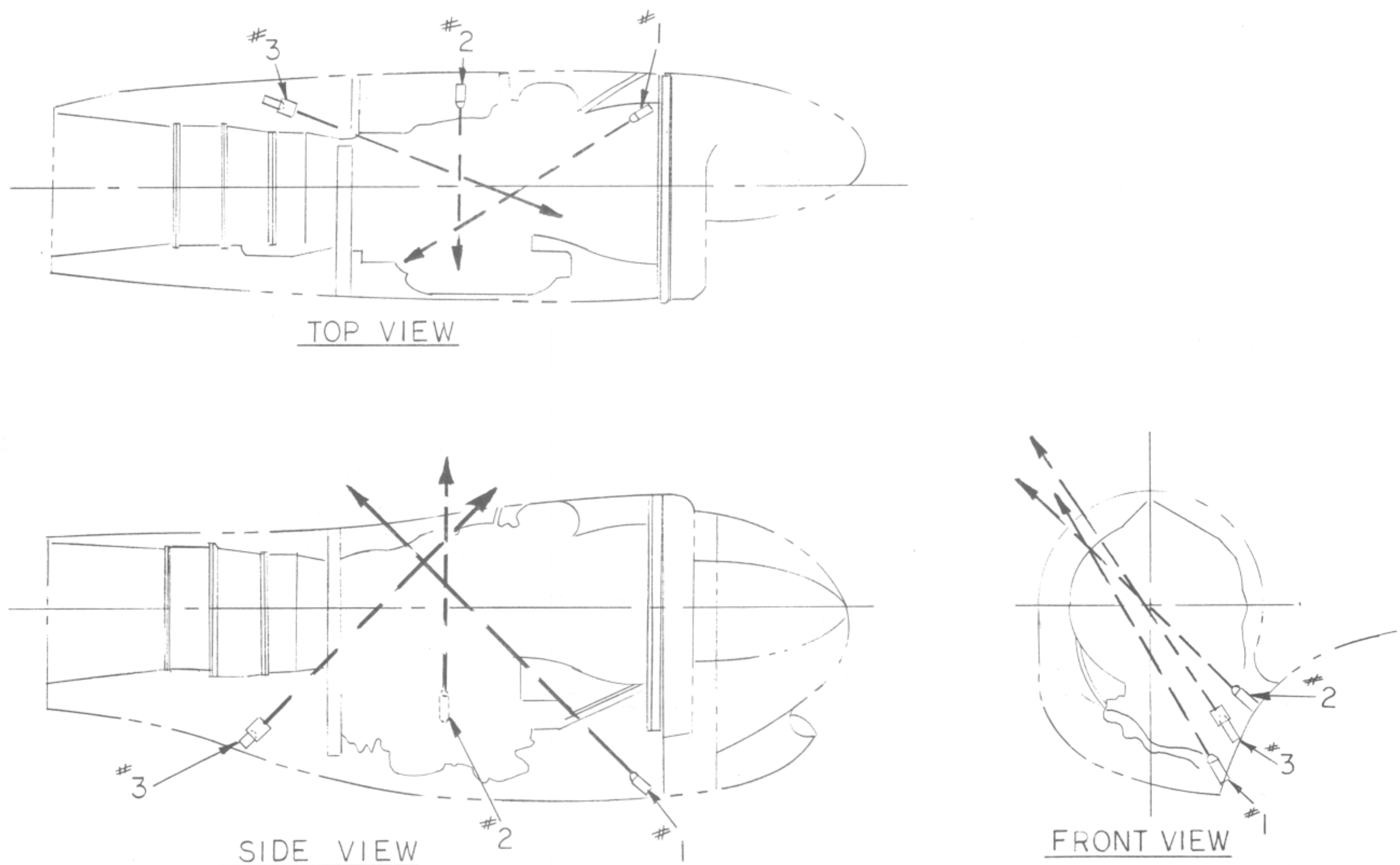


FIGURE-6-FLAME DETECTOR LOCATION

FIGURE 7 SIKORSKY S-64

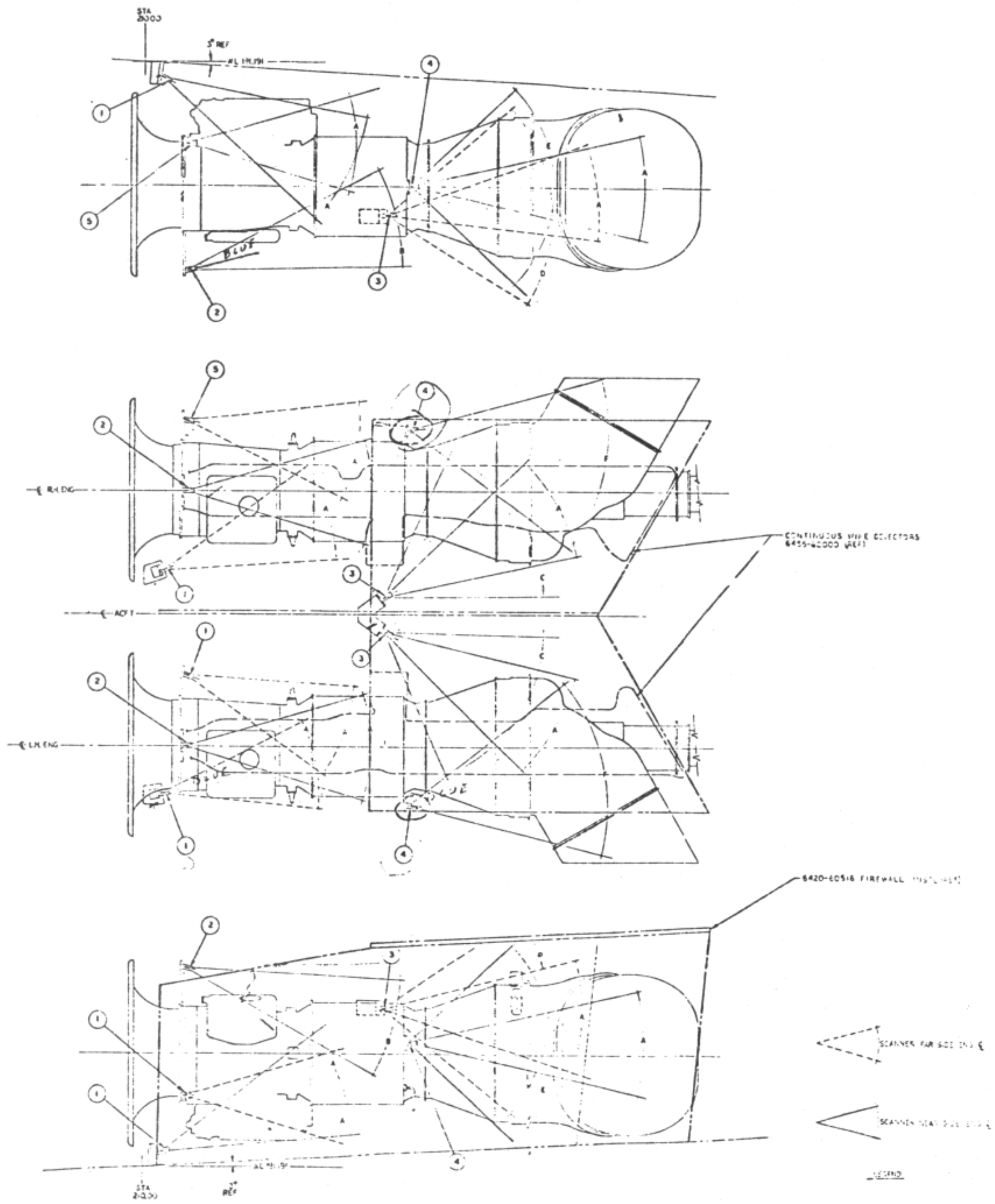
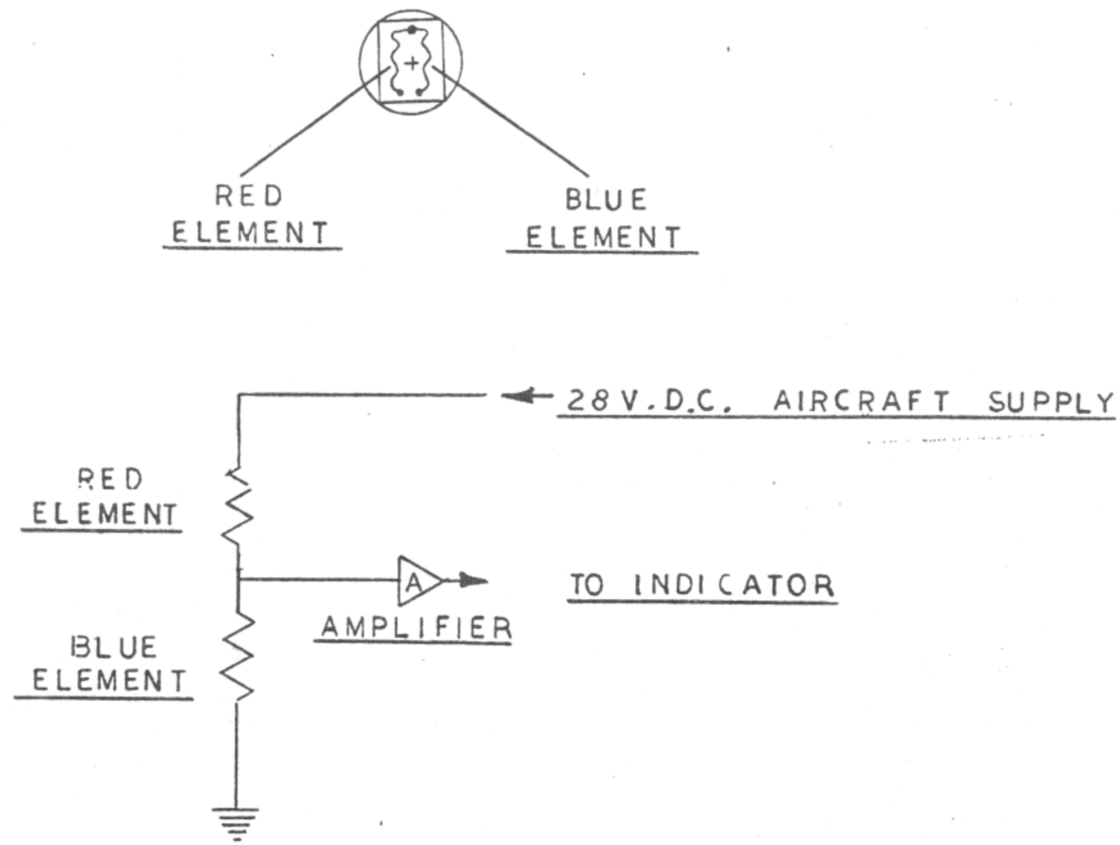


FIGURE 8 S-64 FIRE DETECTOR LOCATION



FLAME DETECTOR SCHEMATIC

FIGURE- 9

DISCUSSION FOLLOWING SIKORSKY PRESENTATION

Q. Considering the fact that reflectivity of surfaces is relied upon to some extent, what is the effect of service, aging, oil film, dirt, etc. on flame detection capability for the surveillance detector system used in Sikorsky helicopters?

A. (Supplied by Pyrotector) Paint or inherent material, color, condition, oil, dirt, or other normal conditions found in engine installations do not affect radiation reflection (to detectors) as much as surface finish such as matte or soft material vs hard metallic surface.

Q. Does the Sikorsky experience with detectors parallel the Vertol experience?

A. Sikorsky hasn't had the experience of Vertol in Viet Nam operations. In addition we have not had a fire in one of our helicopters. Sikorsky has not experienced the problem of moisture in the system that Vertol experienced in the "rain forest" of Viet Nam.

APPROVING A FIRE WARNING SYSTEM ON NAVY AIRCRAFT

E. A. MULLER

FIRE PROTECTION ENGINEER

NAVY AIR SYSTEMS COMMAND HEADQUARTERS

Gentlemen:

At this time I would like to thank Lyle Tarbell and Steve Rolle for inviting me to this meeting. My assigned topic for discussion is "Typical procedures used in approving a Fire Warning System on Navy Aircraft", or our established way of doing something. To give you a back ground picture; what is required on Navy Aircraft is listed in the aircraft detail spec. This aircraft detail spec requires a Fire Warning System to be provided in accordance with a subordinate spec either MIL-F-7872 or 23447. Since the lions share of the systems are in accordance with MIL-F-7872, I will use the continuous type system as a basis in my discussion. This MIL-F-7872 specification describes the requirements for the design, manufacturer, testing, and installation of continuous type fire and overheat warning systems for use in aircraft. The requirements therein are arrived at through previous history, service, and maintenance. A few of the more important system design requirements are:

1) Fire Response time
2) Automatic repeat ability
3) Loop Circuit
4) Prevention of false warnings
5) Moisture accumulation
6) Voltage variations
7) Alarm temperature settings
8) Response limits
9) Design operating life
   Total operating life
10) Electromagnetic interference

Component Design Requirements:

1) Control Unit hermetically sealed
2) Sensing element lengths (logistics)
3) Bend radius
4) Support clamps

Installation Requirements:

1) Zones requiring firedetection. Sensing elements shall be routed to monitor the following zones and in such other areas as may be determined by the aircraft contractor to be fire or overheat zones:

   (a) Power sections and accessory sections of reciprocating engine compartments.
   (b) Compressor, burner, tailpipe (if necessary) and afterburner compartments of turbine engine installations.
   (c) The accessory section of turbine engines, if flammable fluid system components and sources of ignition are both present.
   (d) Engine compartments of rocket engine installations.
   (e) Auxiliary power plant compartments if not normally occupied.
   (f) Compartments containing electrical or electronic equipment in the vicinity of combustibles where such compartments are not normally occupied.

(g) Bleed air ducting when in combination with fuel and ignition source.
(h) Auxiliary heater systems located in unoccupied areas.

2) Temperature survey. A temperature survey shall be conducted analytically to determine the maximum temperatures occurring at proposed locations of sensing elements during each of the aircraft operating conditions listed in 4.6.38. Results of this analysis shall be used to determine the required temperature characteristics of individual sensing elements.

3) Accessibility. Components shall be located to facilitate repair, replacement and test, preferably without the use of special tools or the movement of other parts in the airplane. Connection points shall be readily accessible for required checks of the sensing element resistance values.

4) Location of sensing elements. Sensing elements shall be located as close as practicable to sources of combustibles, such as fuel strainers, and ignition sources, such as electrical equipment, where the proximity of these combustibles and ignition sources constitutes a possible source of fire. The selected locations shall also comply with the following requirements:

(a) Sensing elements shall be placed in the path of the most probable flame travel, including all air exits from potential fire zones and "dead" airspaces, so that fire can be detected under both flight and ground conditions.
(b) Sensing elements shall be within the airflow path to be monitored and shall not be shielded, insofar as practicable, by ribs, formers, tubing or other obstructions.
(c) Sensing elements shall be located to monitor regions where flammable fluids may drain, drip, or accumulate.
(d) Where airflow reversal may occur, such as the forward portion of turbine engines, fire detection shall be provided at all air outlets and inlets connected to areas containing combustible materials or fluids.
(e) Sensing elements shall be located out of the path of normal exhaust gas discharge.
(f) Sensing elements shall not be mounted in any manner which interferes with ready repair or replacement of an engine.
(g) Sensing elements located in the lower portion of turbine engine compartments shall, where practicable, be routed longitudinally for maximum fire detection.
(h) Sensing elements and connectors shall be readily accessible to connect circuit measuring devices during maintenance of the system.
(i) Unless specifically authorized by the preparing activity, sensing elements in engine compartments shall be mounted on the airframe. Consideration will be given to mounting sensing elements on the engine where (1) such method of installation can be shown to provide markedly superior flame detection properties or (2) the engine enclosure consists mainly of hinged or removable sections.

With these requirements in mind the airframe contractor provides, prior to the initial installation in the Aircraft, the following data for review and concurrence:

(a) Calculated operating and maximum temperatures for zones or sections in which elements ar located
(b) Location of warning system control units, warning lights and test switches.
(c) Estimated maximum temperatures to which control unit will be subjected.
(d) Schematic deagram snowing electrical circuitry, test circuitry and warning light but not the control box circuitry.
(e) Sketch of sensing element location in relation to engine firewalks, shrouding and adjacent bullsheads.
(f) System weight.

Also at sometime early in the aircraft life an engineering inspection is made on a moch-up aircraft or on one of the first aircraft to determine conformance with the MIL Spec requirements. This inspection is usually conducted concurrently with similar engineering inspection of other systems in the aircraft.

Concurrently with the above the contractor is preproduction testing the fire warning system to be provided. This testing consists of a complete fire warning system duplicating the configuration to be installed in the Aircraft, and calibration tests. Some of the preproduction tests are:

1) Product (length size ect....)
2) Resistance within design limits
3) Control unit calibration
4) Flame Tests
5) High and low temperature tests
6) Altitude tests
7) Rain, humidity, salt spray
8) Vibration
9) Radio interference
10) Power Variation
11) Response time and several others

Upon completion of these tests, the test data is submitted and authenticated by the NAVPRO or the cognizant Government Inspector witnessing the tests. Approval and release by NAVAIR indicates this system is satisfactory for the intended aircraft.

Later on in the aircraft program flight tests are required to be performed by the contractor. These tests will demonstrate that the system will not produce false warnings under flight operating conditions with any combination of atmospheric conditions that may be encountered. Flight tests are usually conducted during other system flight tests on one of the first aircraft. They are:

(a) Engine start and quick warm up to maximum allowable temperature
(b) Ground run up to full power
(c) Take off
(d) MIL power climb from take off and maximum thrust
(e) Level flight at full MIL power at altitude providing maximum heating of engine compartment

(f) Prop feathering - if applicable
(g) Engine restart during flight at minimum allowable airspeed (if permissable)
(h) Landing roll with maximum allowable reversed thrust operation.
(i) Dive from service ceiling under conditions resulting in both maximum increase in ambient air and aircraft speed
(j) Missed approach or go around after low power approach

Now at this point in the aircraft life a system has been approved and is in production aircraft. But history usually repeats itself. We have problems that must be corrected. Most common problems:

(a) element chafing or breakage.
(b) inadequate coverage

These are some of the problems the contractor does not foresee. How are these problems corrected after the system has been approved and flight tested to our satisfaction you guessed it - We now pay for the change by an Engineering Change Proposal. The problem is corrected by an Airframe Change.

The last symposium was held nine years ago in October 1961 for the purpose of discussing design objectives and to contribute advice and guidance for the operating characteristics of the new fire warning system. Today the systems are all in operation and with many improvements. These systems are doing a good job and are a credit to the people in the industry. In conclusion I do not want to review again the procedures in approving a Fire Warning System. What I want to do is state what is necessary to further improve our Fire Warning Systems in our Aircraft.

1) Improve Specs with sound requirements
2) Good preliminary design and installation (System should not be installed as an afterthought.)
3) Debugging after in service since service experience dictates deficiencies.
4) Good maintenance manuals - Good reporting of systems in operation - The why of the malfunction -

Its been a pleasure to speak to you.

DISCUSSION FOLLOWING U. S. NAVY PRESENTATION

Q. What alarm temperature settings have been found to give acceptable degree of freedom from false warnings, yet result in fire and overheat warnings when necessary?

A. A minimum setting of 500° F is prescribed, with a buffer of 150 to 250° F over the maximum normal ambient.

Q. What constitutes average coverage of typical engine fire zones by fire detection systems?

A. Particular attention to the compartment volumes in the vicinity of 4 and 8 o'clock is necessary. Protection in these areas provides coverage also of the lowest area of the compartments and includes the volume in which fire is most likely to occur.

PRESENT SYSTEMS & FUTURE TRENDS

ENGINE FIRE DETECTING SYSTEMS

DAVID L. REIDA

GROUP ENGINEER

BEECH AIRCRAFT CORPORATION

FORWARD

This paper was prepared for presentation at the FAA Systems Conference on Tuesday, November 17, 1970. The meeting is to be held at the Federal Aviation Administration's Washington Headquarters Building, 800 Independence Avenue, S. W., Washington, D. C. The meeting will be attended by approximately 30 FAA personnel who have the responsibility of approving fire detector system installations.

INTRODUCTION

Beech's experience with engine fire detector systems dates back to the early days of the Model 18; however, our first experience with fire detector systems as an FAA requirement was on the Model 99 commuter. The engine fire detector system is a special requirement on the Model 99 for certification for operation in accordance with FAR, Part 135. Engine fire detectors are an ARB requirement on the Beech Model 90 and 100 series aircraft.

There are engine fire detector systems included with fire extinguisher installation kits, which are STC approved for most Beech models, available on the market today and have been for some time. The approval on these STC's was on the basis of not affecting the safety of the aircraft, not on the basis of tests which proved the system would detect a probable fire. These systems will not be discussed further in this paper.

ENGINE FIRE DETECTOR

SYSTEM DESCRIPTION

FIRE DETECTOR

The specific purpose of an aircraft fire detection system is to provide a warning to the crew at the earliest possible moment if an accidental fire should occur within the monitored area.

Two basic principals are used in the most popular detection systems today. One of these principals is to sense the heat created by a fire. The other principal is to sense the light radiation from the fire.

The system which senses light is called an Optical Surveillance Fire Detection System. The Beech turbo-prop engine systems are of this type. It is designed to provide instantaneous alarm by sensing the heavy infrared radiation imposed on the sensor from a remote fire which occurs within the 120^{o} conical viewing field of each detector.

The optical surveillance type fire detection system used by Beech provides the following major advantages:

(A) MUCH GREATER DETECTION COVERAGE - -

Because of ability to detect both remote and near fires within the 120 degree conical viewing area covered by each detector, fewer detectors are required.

(B) MUCH FASTER FIRE ALARM - -

Instantaneous alarm due to optical viewing since no temperature rise is required and airflow has no effect. Fires will be detected even when flowing away from detector. When fire is out, alarm will immediately cease and be ready for recycle.

(C) RELIABILITY - -

Cuts or breaks in wiring or shorts to ground will not cause alarm, but only a failure to test.

(D) FUNCTIONAL TEST CAPABILITY - -

A functional test of each detector may be made on the aircraft at any time during field service to prove that system is still capable of detecting fires. Hidden damage which might prevent all or part of detector from functioning is not possible in this system.

(E) REDUNDANCY - -

Multiple detector installations provide detection capability redundancy, since failure of any detector(s) has no effect on other detectors.

(F) EVALUATION TESTING - -

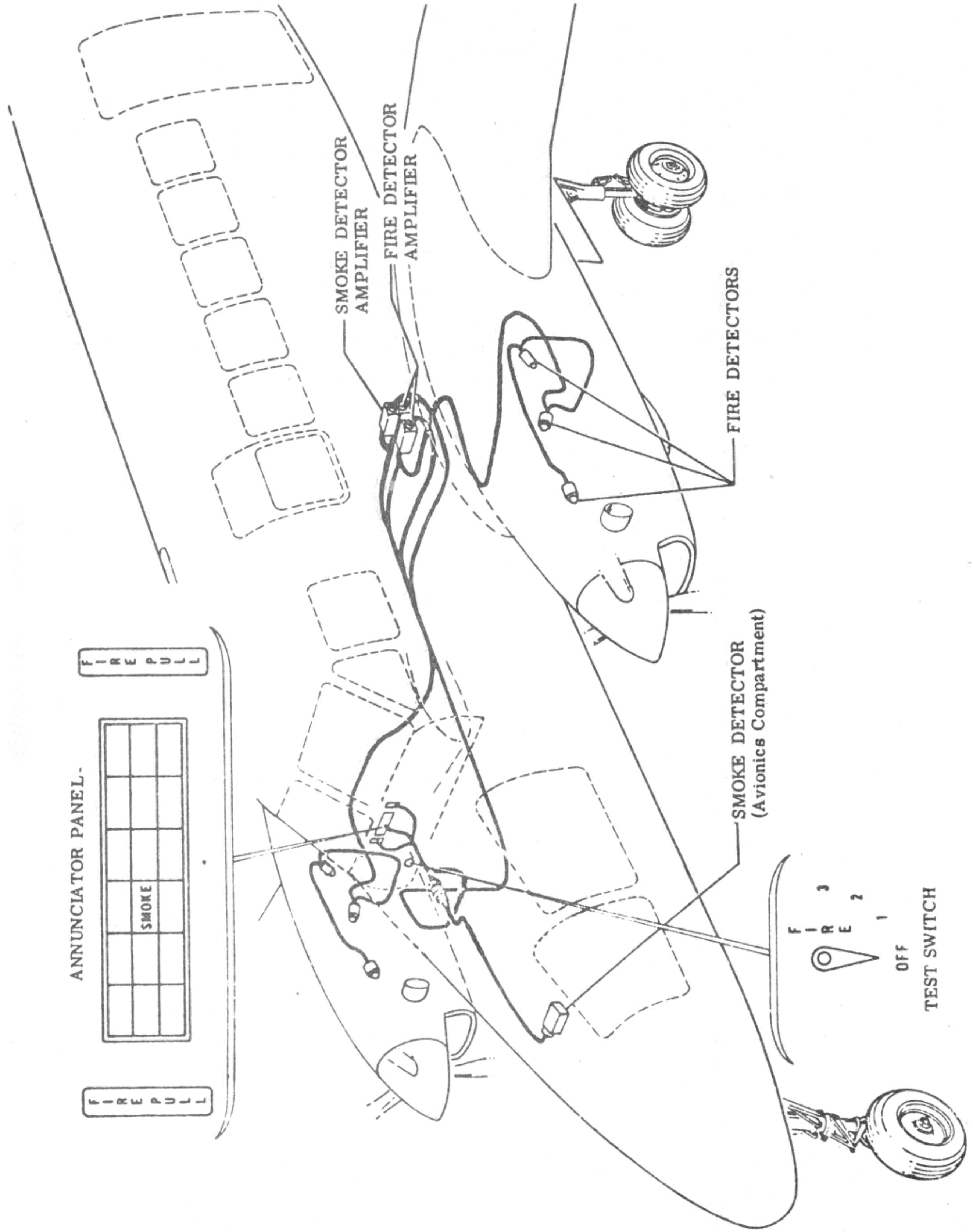
With the aid of an infrared light, testing to prove that the system will detect a probable fire is a very simple task. We question the adequacy of any approval of a thermal system short of a test which entails actual inflight engine fires. Airflow around the engine is critical with respect to thermal sensor location.

Our complete engine system consists of three detectors, one control amplifier, associated wiring, test switch and warning light. The detectors are small, rugged units which are hard-mounted directly to the airframe structure in positions to optically view, either directly or by reflection, fire which may occur within the nacelle and to provide an instantaneous warning to the pilot. Opens or short-to-ground in any of the detector circuits or associated wiring will not cause an alarm or adversely affect the operation of other detectors, but will only cause a failure to "test" on that particular circuit.

The inherent design of the solid-state photo conductive optical detectors permits discrimination between daylight and fire. As the light intensity and ratio of infrared/ultraviolet from a fire increases the detector signal, output increases until it reaches a predetermined value for an alarm signal. Fire produces a minimum of 14 volts, whereas bright sunlight produces only 3.5 volts.

An electrical continuity preflight check of each individual detector circuit, the amplifier circuit and relay may be made from the cockpit by use of a test switch, if desired. At each test position, an alarm condition will be shown if continuity exists.

A functional test of each individual detector and circuit may be made during ground service by subjecting each detector to an infrared light source (red flashlight).



Fire and Smoke Detection System

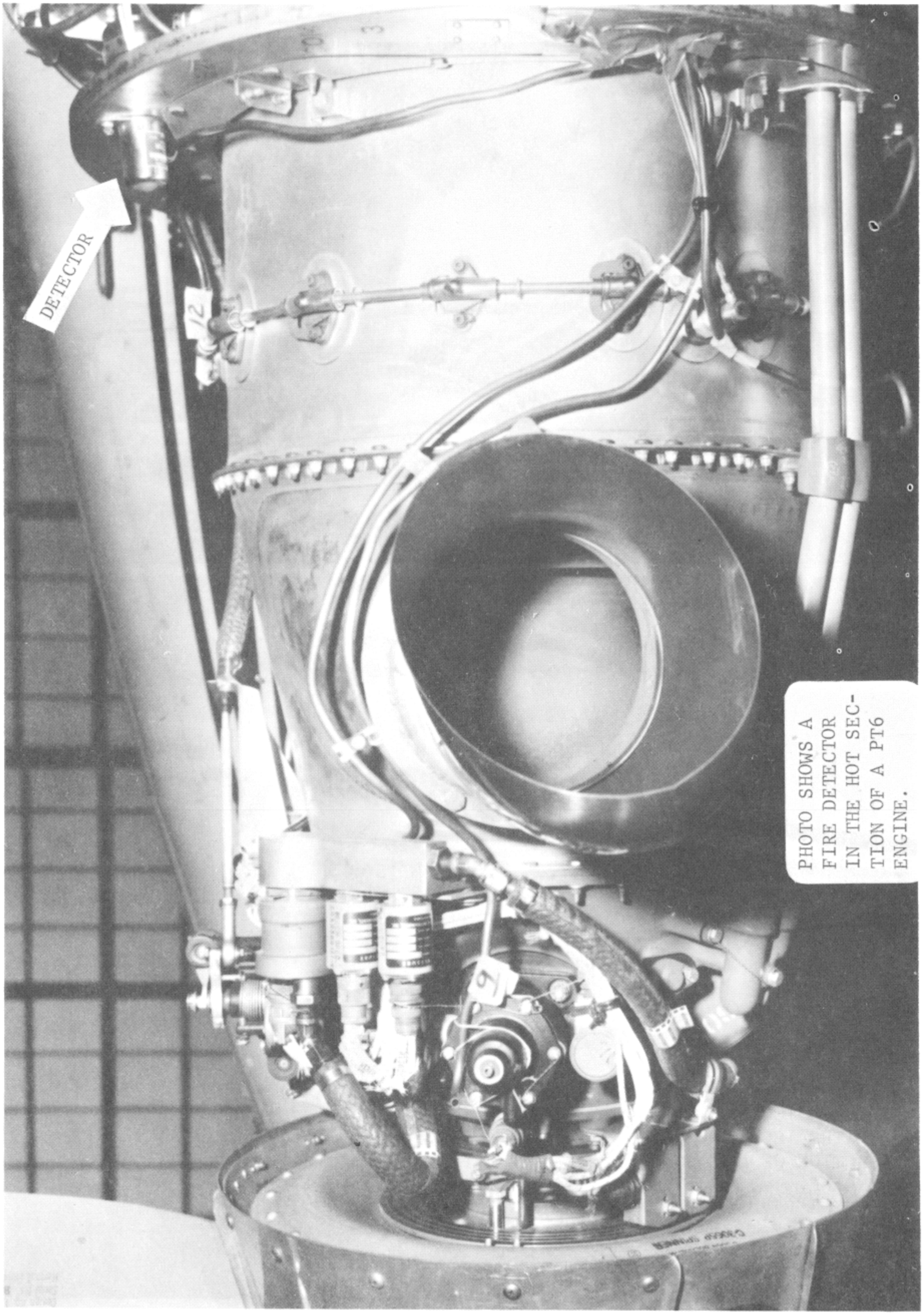


PHOTO SHOWS A FIRE DETECTOR IN THE HOT SECTION OF A PT6 ENGINE.

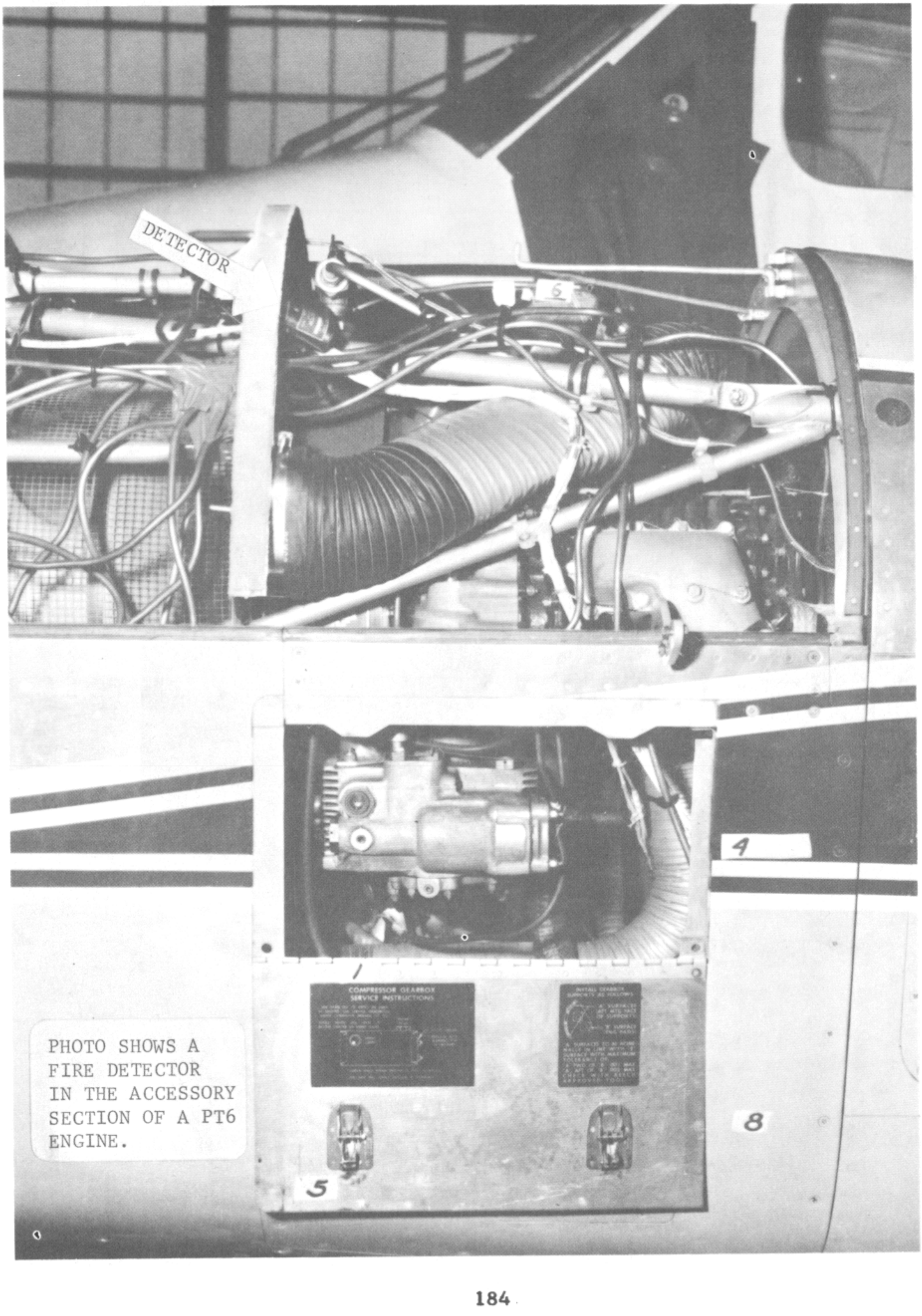


PHOTO SHOWS A FIRE DETECTOR IN THE ACCESSORY SECTION OF A PT6 ENGINE.

SELECTING THE SENSOR LOCATIONS

Detector locations are selected to provide direct viewing of those areas determined to be major potential fire sources. The detectors are calibrated to the sensitivity standards of FAA TSO C79 and will provide an instant alarm when such flames are present within their viewing area. Each detector's viewing angle is described by a 120 degree conical volume with it's apex at the center of the detector lens.

The configuration of a Pratt & Whitney PT6 engine necessitates installing sensor for monitoring two separate compartments. The accessory section and the hot section are separated by the inlet or plenum section. Fire-wall integrity is maintained between these sections.

Two sensors are installed in the accessory section; one in the forward upper lefthand corner viewing aft and down. The second is in the aft lower righthand corner viewing forward and upward. These two sensors can adequately monitor the entire compartment except for small blockage from accessories and tubing which is not sufficient to prevent a fire from being detected before it gets very large.

One sensor is located in the aft upper portion of the hot section viewing forward which monitors the entire upper half of this section. It was concluded that a fire in the lower half of the hot section could not be contained in the lower section of the enclosure because of the limited volume of this cavity and the general ventilation air flow pattern through louvered air outlets in the cowling sides. These factors would carry the fire to the detectable area.

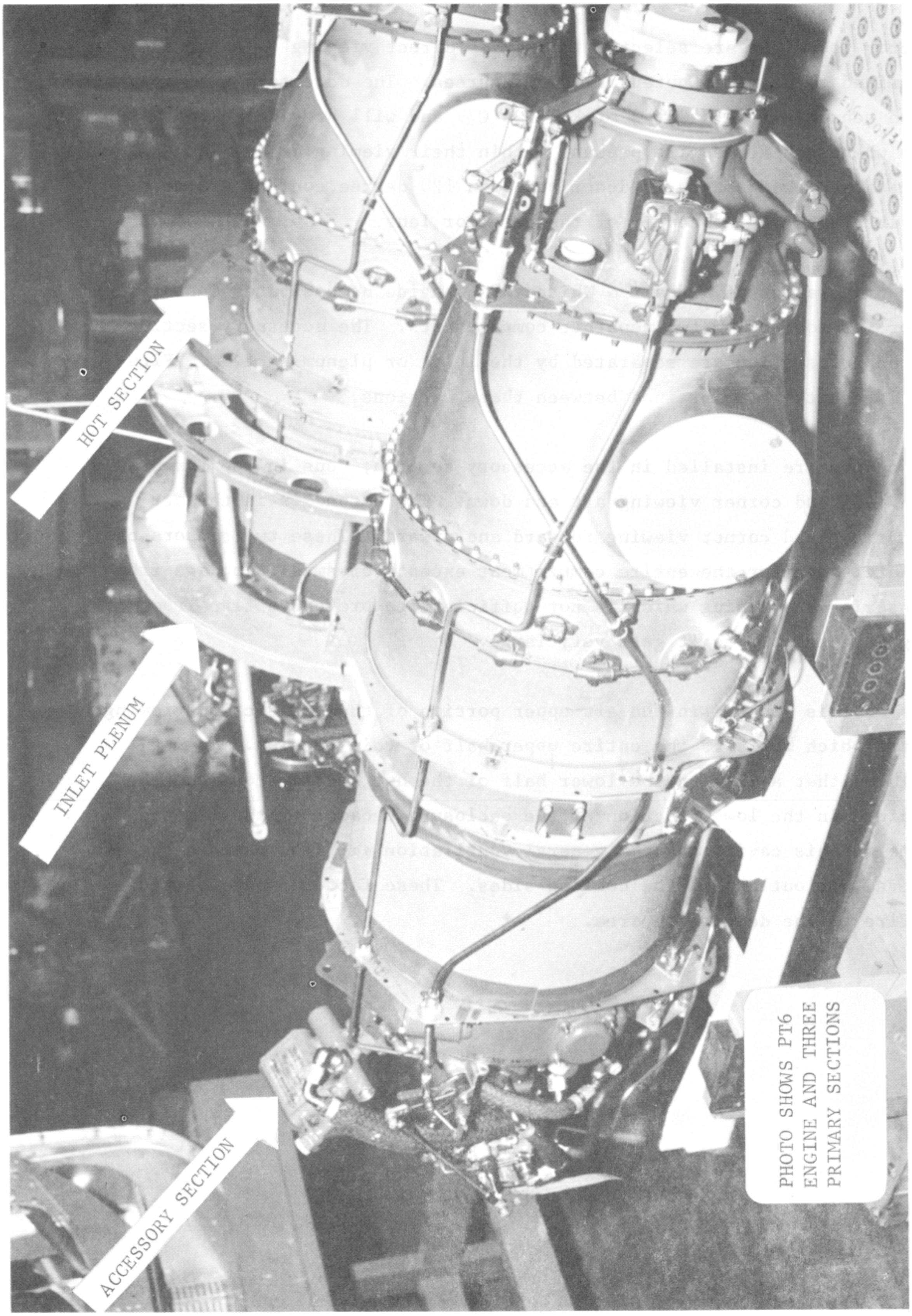


PHOTO SHOWS PT6
ENGINE AND THREE
PRIMARY SECTIONS

SHOWING COMPLIANCE

The greatest advantage in using an optical surveillance type system as used on the Beech turbo-prop aircraft is the ease and simplicity of testing to be confident that the system will detect any probable fire. A ground test using an infrared light bulb will adequately insure a satisfactory system.

It had been determined by the detector manufacturer that 79 volts A.C. applied to a 250 watt ruby red infrared flood lamp produces the same infrared radiation as the standard fire defined in TSO-C79 (the infrared radiation produced by a 5-inch pan of burning JP-4 viewed four feet away).

This 250 watt bulb @ 79 volts was placed in various positions within each fire zone (engine accessory and hot sections) and the ability to detect this simulated fire was observed.

The detection system was capable of detecting the simulated fire as anticipated; therefore, the detector locations were deemed satisfactory and capable of detecting any probable fire.

REQUIREMENTS IN THE FUTURE

There have been very few reported power plant fires in general aviation aircraft in the past 10 to 15 years. The science of designing into the power plant installations fire preventiveness is so well perfected that fires very rarely occur. Of the over 130,000 general aviation aircraft in service, the Federal Aviation Agency's Aeronautical Center, Oklahoma City, Oklahoma, has on record only 27 reported engine fires in the past three years. This is an average of less than one reported engine fire in every 14,000 aircraft each year. Of these, over 50% are on relatively new power plant installations - - - for example, the turbocharged power plants. It is doubtful that the severeness of the above fires would have been any less by possible earlier detection with the aid of a fire detection system.

Also, we should consider the location of the engine with respect to the pilot on most general aviation aircraft as compared to most transport category aircraft. With the power plant located immediately in front of the pilot, as on single engine aircraft, or 3 or 4 feet away on the wing, as on most twins, the probability of the pilot noticing a fire is much greater than on transport category aircraft where the engine may be more than 100 feet away and aft of the pilot.

We, in general aviation, cannot see any logical reason, based on the record and the location of the engine with respect to the pilot, for implementing fire detector systems as a requirement in the future. In the case of systems offered as a factory option or STC'd kits, we question the approval on the basis of not affecting the safety of the aircraft, without proof that it will detect a probable fire. We feel the general public is being mislead by the statement STC approved.

DISCUSSION FOLLOWING BEECH PRESENTATION

Q. Is 5 seconds a proper response time for surveillance detectors?

A. Surveillance detectors have the capability of responding in microseconds. The entire system will respond when the signal source energy is sufficient to trigger the alarm.

INVESTIGATION OF BURNER-CAN BURN-THROUGH CHARACTERISTICS AND MEANS OF DETECTION

THOMAS RUST

AEROSPACE ENGINEER

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NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER

Investigation of Burner-Can Burn-Through Characterisitics and Means of Detection

This paper will be concerned with a project which deals with the detection of burner-can burn-through or torching type-failures. The purpose for the initiation of this project was to determine the feasibility of detecting burner-can failures through ultraviolet, infrared, sonic, and other means. To more fully understand the reason for the origination of the project, the following background information is presented. The subject of the investigation results from a failure in the combustion section of a jet engine, and is termed a combustion chamber burn-through or burner-can burn-through. A burn-through occurs in an engine when the hot combustion gases within the combustion chamber are deflected from their normal path by the failure of a related component, and impinge on the wall of the combustion chamber, thus causing a hot spot on the wall. The heat on the wall, of course, weakens it, and the high pressure in the chamber causes a bursting-type failure at this weak point. This results in a high-temperature, supersonic flame escaping from the hole in the combustion chamber wall. The severity of the flame depends on the temperature and pressure inside the chamber, and, of course, this depends on the pressure ratio of the engine and the power setting at which the failure occurs. The flame was produced from a modified burner-can of a J-47 engine, which has a relatively low-compression ratio of 5.5:1 at 100% power. The engines presently used on commercial aircraft have compression ratios of 12:1 and higher. Thus, a failure in a JT3C or D will result in a longer, more severe flame than is shown here. As shown in Figure 1, a review of the Mechanical Reliability Reports for the years 1962 through September 1969 revealed that an average of 10 burn-through failures occurred per year. Here is seen the yearly breakdown of occurrences according to aircraft and engines. It is noted that the years 1965 and 1966 appear to have had very few failures. However, a more careful examination of the MRR's will reveal that there were failures in these years which apparently were not included in this summary. Of all of these occurrences, approximately 70 percent were detected by the aircraft engine fire warning system. This means that the pilots received no indication that there was an engine fire in the other 30 percent of the failures. Because of the highly dangerous nature of this type of failure, which will be more apparent shortly, the number of undetected failures is of considerable concern.

Figure 2 shows a detailed breakdown of the failures over a 7-month period. It is seen that most of the failures gave the pilot a warning of some kind, except for the next to the last one. This failure was also quite dangerous since it impinged on the engine pylon. This occurrence could have resulted in the separation of the engine from the aircraft. It should also be noted that the major cause for these failures is the failure of the locating lug for the combustion chamber. This allows the combustion chamber to move away from the fuel nozzle which allows the fuel to be deflected to the wall of the outer case.

Figure 3 shows two typical combustion chamber arrangements. The one on the right is typical for the JT3 and JT8 engines. It is seen that there is a large area to be covered by the detectors since a burn-through can occur anywhere around the periphery of the engine. There is also the possibility that a burn-through could occur with the resulting flame breaking out toward the center of the engine. In fact, two of the failures noted on Figure 2 were examples of this. When this happens their is usually considerable internal engine damage. The engine arrangement shown on the left of Figure 3 is typical for the J-47 engine which was used to produce the test flame under another NAFEC project which dealt with firewall materials. The number one can was modified to produce the flame as will be seen in Figure 4. This Figure shows that a steel baffle-plate was welded to the forward end of the burner-can and a hole cut in the liner. The baffle produces a low-pressure area behind it which draws the flame to the wall of the can. Through experimentation, the proper location of the exit hole was determined, and a steel bushing was welded in this location to keep the hole from eroding. The hole was 1-inch in diameter since this is typical for most actual burn-throughs. Figure 5 shows the baffle welded in place, looking aft through the can. Figure 6 shows a tabulation of the tests performed on various thicknesses of stainless steel and titanium. You can see that tests performed on the thicker specimens indicate no failure or penetration of the specimens with the engine running at 80-percent power, while when the power is increased to 85 percent, failure occurs rather quickly. Figure 7 shows the flame impinging on a steel plate with the engine running at 70 percent. Compare the strength of the shocks in this one to Figure 8, which was with the engine running at 80 percent, and to Figure 9 with the engine running at 90 percent. Again, the modern engines have much higher compression ratios, and the flame resulting from a failure in these engines will be much more severe. The next Figure (Fig. 10) gives an idea of the properties of the flame. These are conservative figures, since they reflect the properties of a low-compression ratio engine.

Now that it has been shown what must be detected, it will be shown what is planned for the project covering a study of the feasibility of detecting burn-through failures. The studies will be performed with a J-57 engine, which is basically the same engine as the JT3C. Plans involve the procurement of two B-57 aircraft, which have two J-57 engines each. A procedure will be developed for producing a burner-can burn-through at a predetermined time. The engine nacelles will be instrumented for temperature, pressure, sound, and light measurements before, during, and after the burn-through occurs. The tests will be conducted at takeoff power, climb power, and cruise power. From this testing, the following results are expected:

1. The temperature change in the nacelle between normal operating conditions and burn-through conditions will be noted, thus determining the feasibility of the use of a strategically located thermal detector system.

2. The pressure change in the nacelle between normal operating conditons and burn-through conditions will be noted, thus determining

the feasibility of the use of a nacelle pressure differential detector system.

3. The sound spectrum change in the nacelle between normal operating conditions and burn-through conditions will be noted; thus determining the feasilbility of the use of a discriminating audio detector system. Some work has begun along these lines with a few sound measurements being taken with the J-47 engine running with and without a burn-through. The results look fairly promising at this point. There is quite a noticeable change in audio frequency when a burn-through occurs, and it is even discernable by the human ear.

4. Spectral energy curves denoting the wavelengths at which the energy from the burn-through flame is greatest will be available for six different engine power settings. With this information, the wavelengths at which detectors should operate can be defined. This information will be gathered by use of a wide range spectrophotometer.

Even though the detector has not officially begun, some work has been performed in the way of an evaluation of an ultraviolet detection system. The system was on loan form the Air Force for another project, but it was felt that a few tests could be run to determine whether or not the UV system could be used to detect burn-through failures. The system was mounted on the burner-can section of the J-47 engine in a number of different positions to simulate possible in-flight detector configurations. There was no cowling at all on the engine, thereby exposing the detector heads to environmental conditions, including sunlight. Figure 11 shows an overall view of the engine with the mounting plate for the sensor and the location of the sensor relative to the burn-through hole. Figure 12 shows the two detectors in one of the test positions. They are located on what would be the firewall between Fire Zone 1 and Fire Zone 2 in a normal aircraft installation. The detector heads are located about 4 inches from the burner-cans here, which means that, for this to represent an actual installation, there would have to be at least 6 inches between the diffuser case and the cowling. This is plausible, since this distance can vary between 2 inches and 30 inches, which is the case for the DC-10 aft engine. Figure 13 shows the detectors mounted differently, with the viewing opening facing the burner cans. A frequency meter was used to determine the strength of the UV being picked up by the sensors. The meter registered pulses per second, with a maximum count of 840 per second being noted. It should be noted that the level for alarming was set at 50 pulses per second. In order to determine just what each sensor was picking up, tests were run with one detector hooded as shown in Figure 14. The pulse rate was still about 800 pulses per second when the flame was in the field of vision of the detector. Thus, from these few tests, it can be concluded that it is feasible to use a surveilence detection system which operates in the ultraviolet light frequency range, for detection of burner-can burn-through type fires.

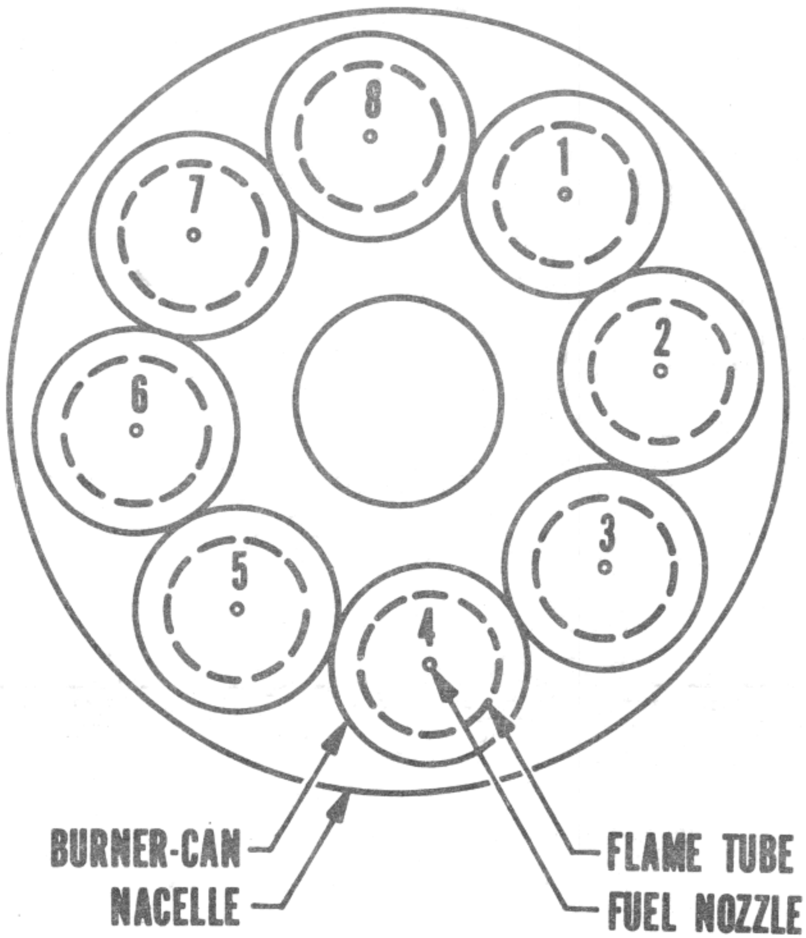
STATISTICAL SUMMARY
BURNER CAN & RELATED PROBLEMS
1962 THRU SEPTEMBER 1969

AIRCRAFT	POWERPLANT	62	63	64	65	66	67	68	69
		NUMBER OF MRR'S							
CL-44	R/R AVON	1							
SE-210	R/R AVON	2							
V-810/812	R/R DART 525	1							
F-27A	R/R DART 528			1			1		
FH-227	R/R DART 532						1	1	
S-61L	C/T 58-110		1						
B-707	P&W JT3D	1	1						
	JT3							1	2
	JT3E	1							
	JT4		1	1					
	UNKNOWN							1	1
B-720	JT3C	5	4				1		1
	JT3D	1			1		5	3	3
B-727	JT8D			1				2	
CV-880	GE-CJ805	1	2	1				1	
CV-240T	R/R DART 542							1	2
DC-8	P & W JT3D			1					
	1JT4A	1							
	UNKNOWN							1	
DC-9	JT8D								1
		14	9	5	1	0	8	11	10

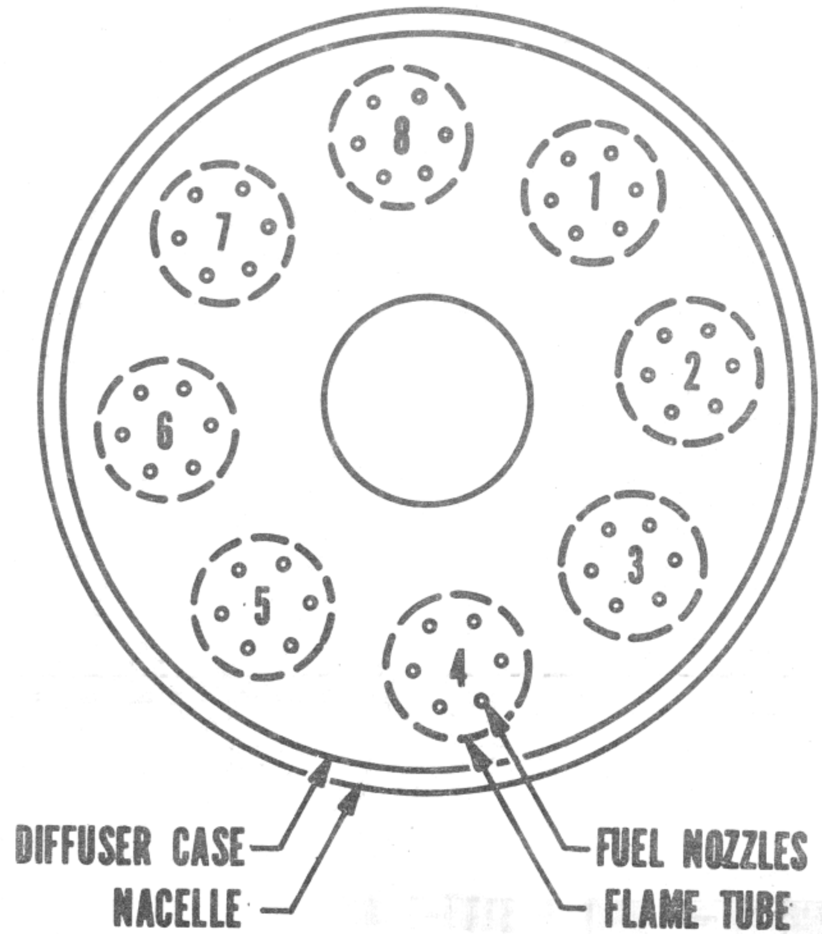
BURNER-CAN BURN-THRU REPORTS FROM MRR's JAN. 1, 1969 – AUG. 26, 1969

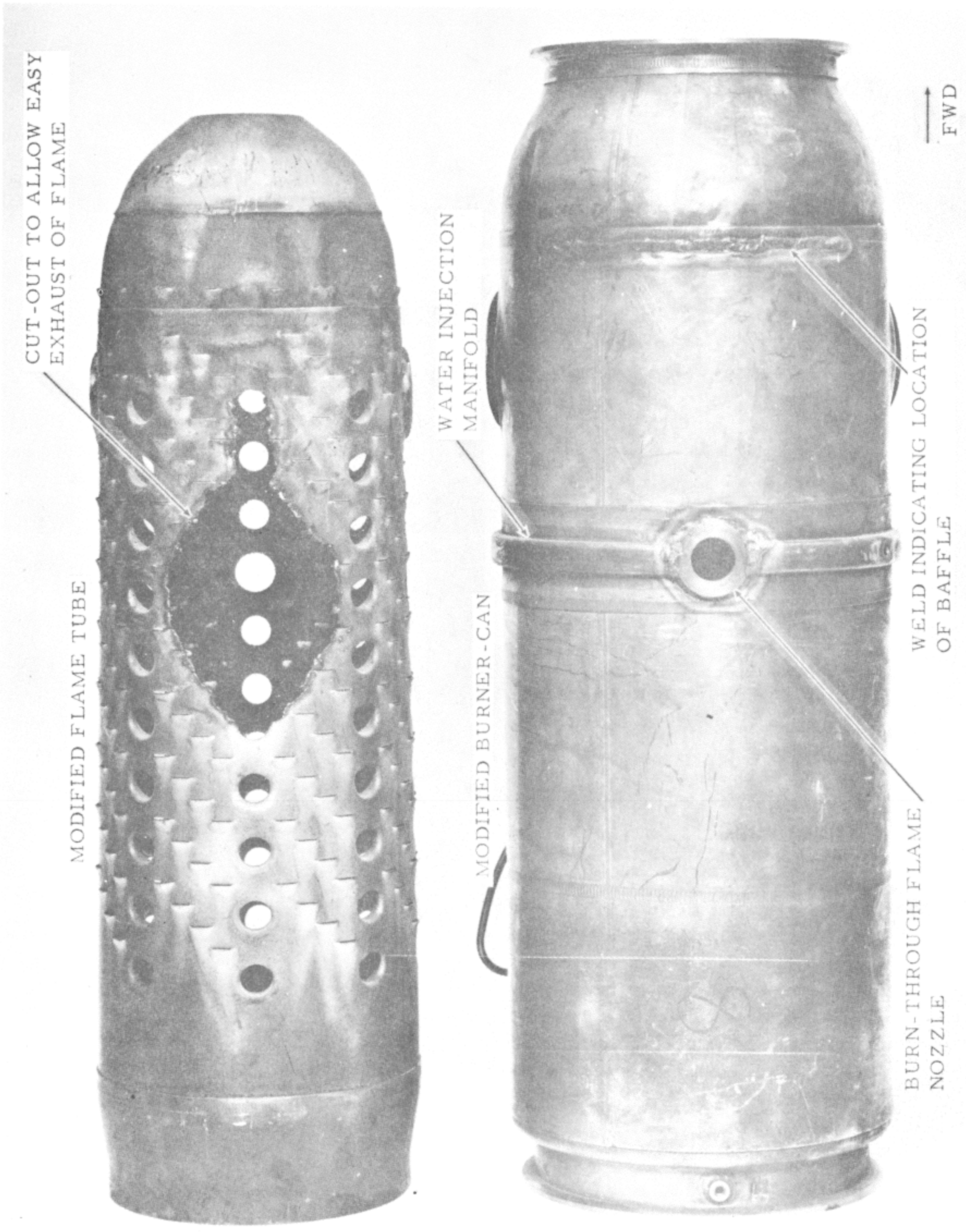
AIRPLANE TYPE	ENGINE TYPE	TYPE OF WARNING	LOCATION AND DAMAGE	CAUSES	DATE OF BURN THRU	AIRLINE & PLANE I.D. NO.	FLIGHT	MRR NO.
B707/023B		Overheat During Cruise	Hole Thru Case Just Forward of Ignitor Plug. No. 4 Engine	Unmodified Intermediate Case Inner Duct Failure	12/17/68	PAA 781PA		68-249-01
DC9/30	P@WAJT8D 7	During Power Reduction Vibration, Rise in TGT.	Internal Left Engine	Combustion Chamber Outlet Inner Duct Failure	1/1/69	HAL 905H	806	69-004-22
CV 240T	P@WA 2800CA-18	Loss Of Power Fire Warning	No. 5 Burner Can Ruptured Right Engine	Burner Can Weld Failed	1/4/69	TTA 9-1249	648	69-005-18
B707/331C	P@WAJT3D-3B	Fire Warning, Slight Increase in Fuel Flow	Hole in Diffuser Case at Nine O'Clock Position 1¾'' by 5/8''. Hole in Left Cowl Panel. No 2 Engine.	Lug Worn Off End of No. 6 Burner Can. Slid Aft 1'', Fuel Sprayed on Sides of Burner Can.	3/21/69	TWA 791TW	608	69-060-04
B720/051B	P@WAJT3C-7/-12	During Cruise Fire Warning	Hole Burned Thru Diffuser Case and Front Outer Combustion Chamber at 12 O'Clock Position. Heat Damage On Strut. No. 1 Engine.	Locating Lug, No. 8 Combustion Chamber Worn Thru. Moved Off Fuel Nozzles and Deflected Fuel Spray.	4/8/69	NWA 732US	30	69-070-01
B720/025	P@WAJT3C-7/-12	In Cruise Overheat Warning	Hole In Diffuser Case 5 O'Clock Position, Severed Bearing Oil Pressure Line No. 3 Engine	Fuel Manifold Inlet Adapter Heatshield Weld Failed. Heatshield Chafed thru Manifold Causing Fuel Leak Internal To Diffuser	5/4/69	EAL 870E	4331	69-089-35
B707/321B	P@WAJT3D-3B	Loss of Power Noted	Hole Thru Diffuser Case No.1 Engine		6/11/69	PAA 402PA	2	69-116-04
B720/047B	P@WAJT3C-7/-12	Unable to Spool No.1 Engine on Ground After Landing No Fire Warning	Hole In Diffuser Case Damage to Airduct to Starter, 2'' Hole in Cowling and Pylon. No.1 Engine	No.8 Burner Can Lug Worn into Forward Combustion Case Allowing the Can to Slip.	6/19/69	WAL 93150	623	69-122-02
DC9/31	P@WAJT8D-7	Engine Vibrating and Quit During Climb Power	Internal Left Engine	Combustion Chamber Inner Duct Failed	12/10/68	CBA 967PR	921	68-245-05

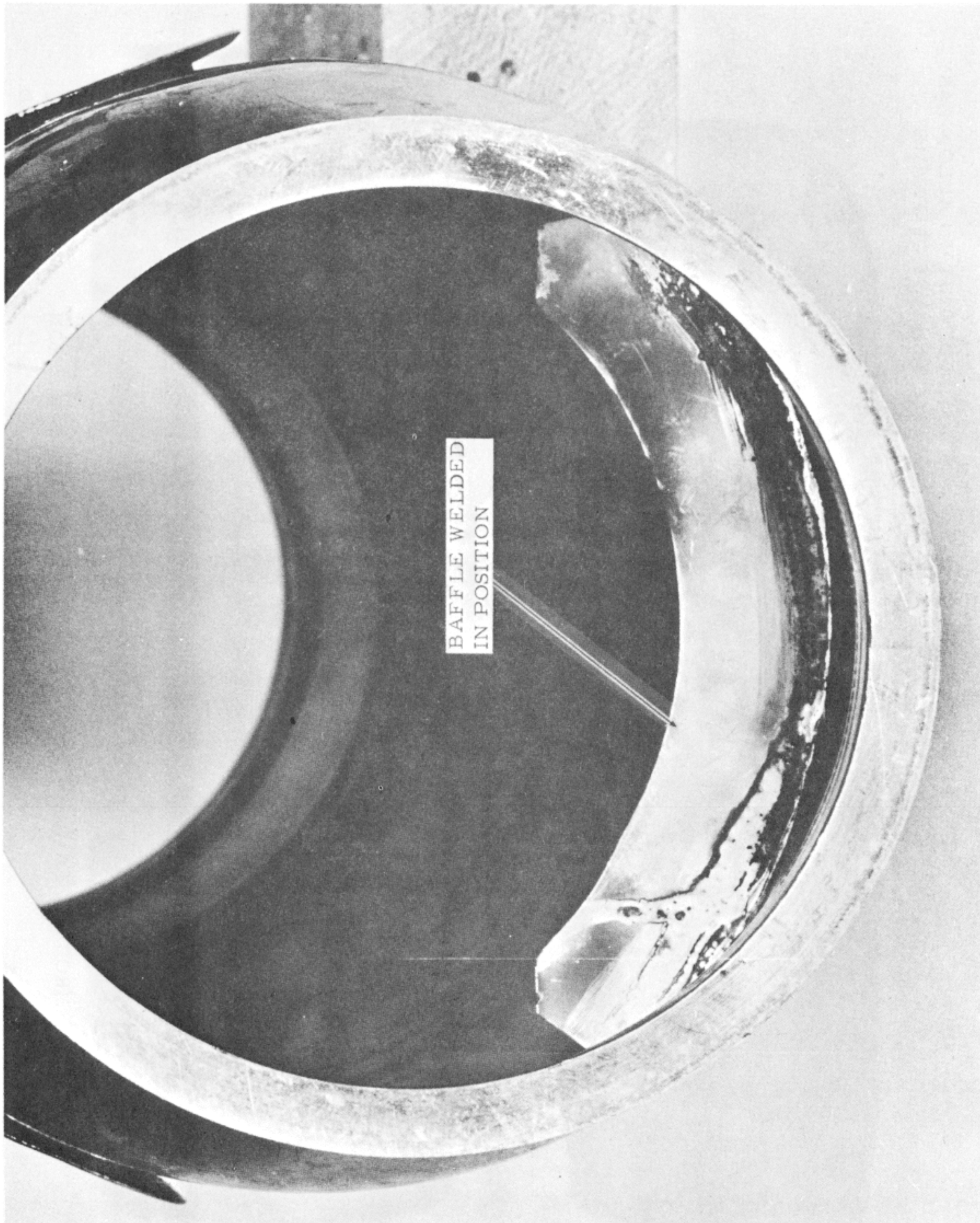
SECTION OF AN 8 BURNER-CAN COMBUSTION CHAMBER



SECTION OF A CAN-ANNULAR COMBUSTION CHAMBER



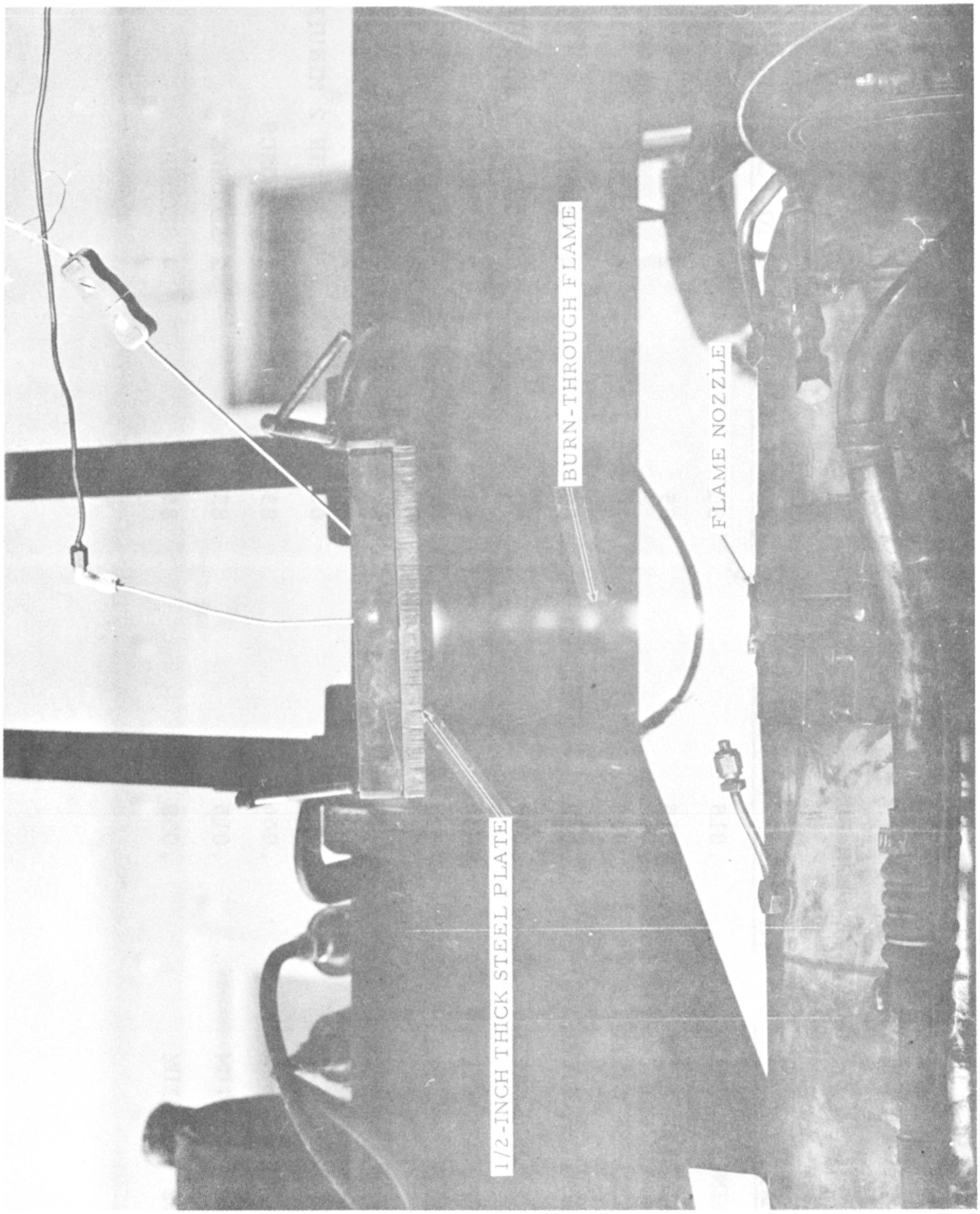

CUT-OUT TO ALLOW EASY
EXHAUST OF FLAME
MODIFIED FLAME TUBE
WATER INJECTION
MANIFOLD
MODIFIED BURNER-CAN
WELD INDICATING LOCATION
OF BAFFLE
BURN-THROUGH FLAME
NOZZLE
FWD

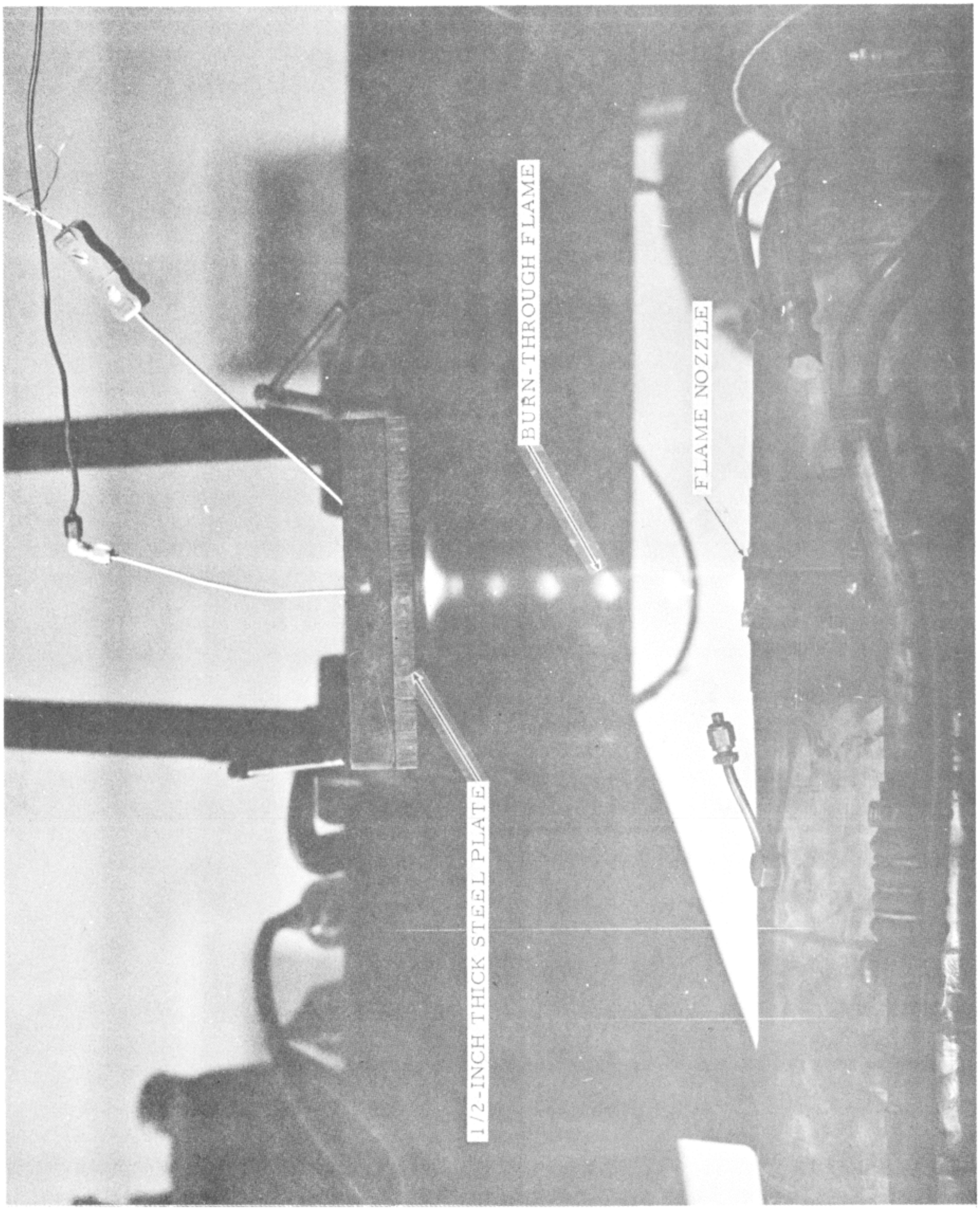

BAFFLE WELDED
IN POSITION

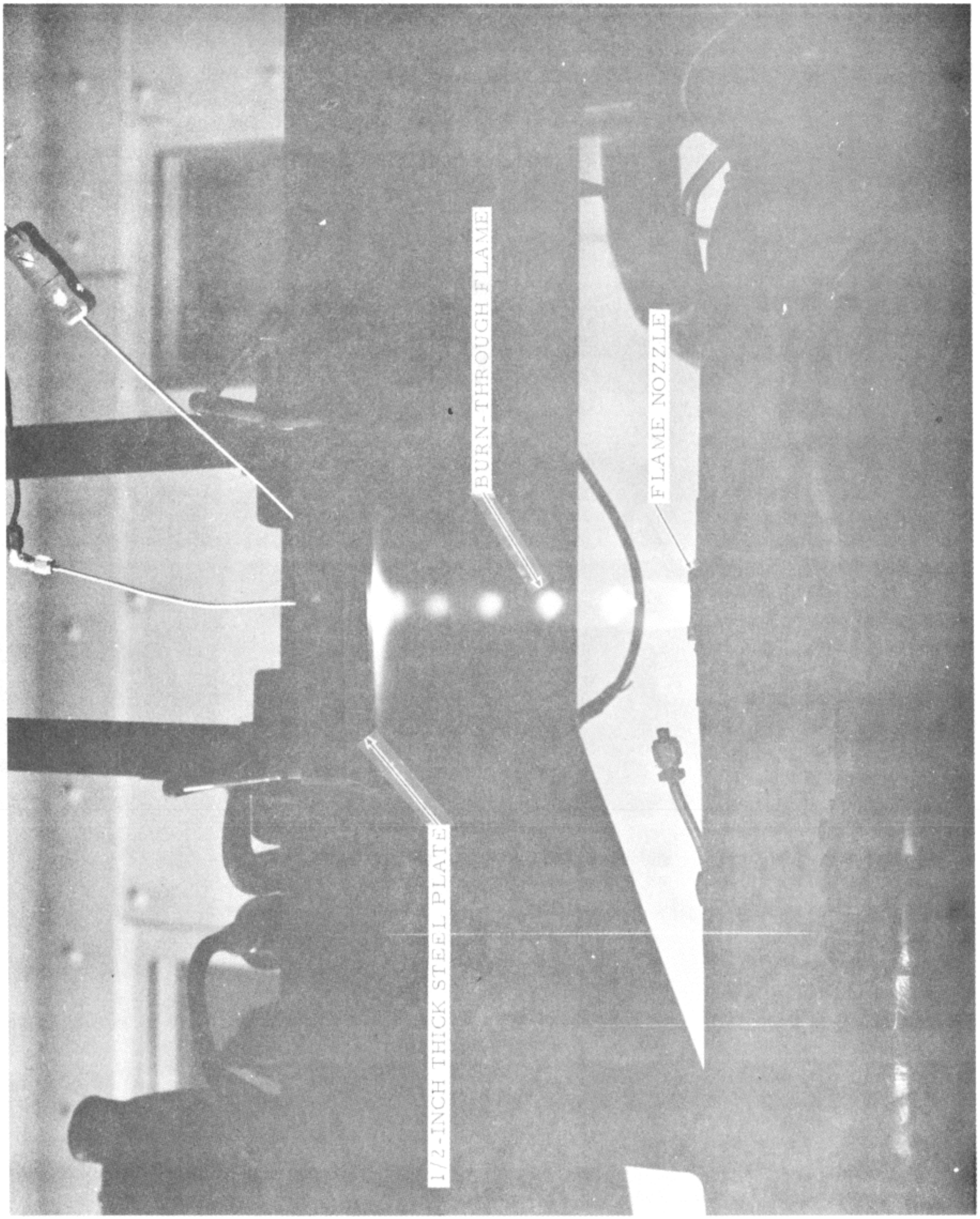
POTENTIAL FIREWALL MATERIALS
(METALS)

DISTANCE FROM BURNER-CAN: 3 INCHES

MATERIAL	THICKNESS (INCHES)	ENGINE RPM (%)	TIME TO PENETRATION
347 STAINLESS STEEL	.015	80	2 SECONDS
347 STAINLESS STEEL	.015	85	2 SECONDS
347 STAINLESS STEEL	.032	80	6 SECONDS
347 STAINLESS STEEL	.032	85	4 SECONDS
347 STAINLESS STEEL	.039	80	NO FAILURE IN 2 MINUTES
347 STAINLESS STEEL	.039	85	7 SECONDS
347 STAINLESS STEEL	.050	80	NO FAILURE IN 2 MINUTES
347 STAINLESS STEEL	.050	85	16 SECONDS
347 STAINLESS STEEL	.064	80	NO FAILURE IN 2 MINUTES
347 STAINLESS STEEL	.064	85	16 SECONDS
AMS 4902 TITANIUM	.015	85	2 SECONDS
AMS 4902 TITANIUM	.032	85	4 SECONDS


BURN-THROUGH FLAME
FLAME NOZZLE
1/2-INCH THICK STEEL PLATE

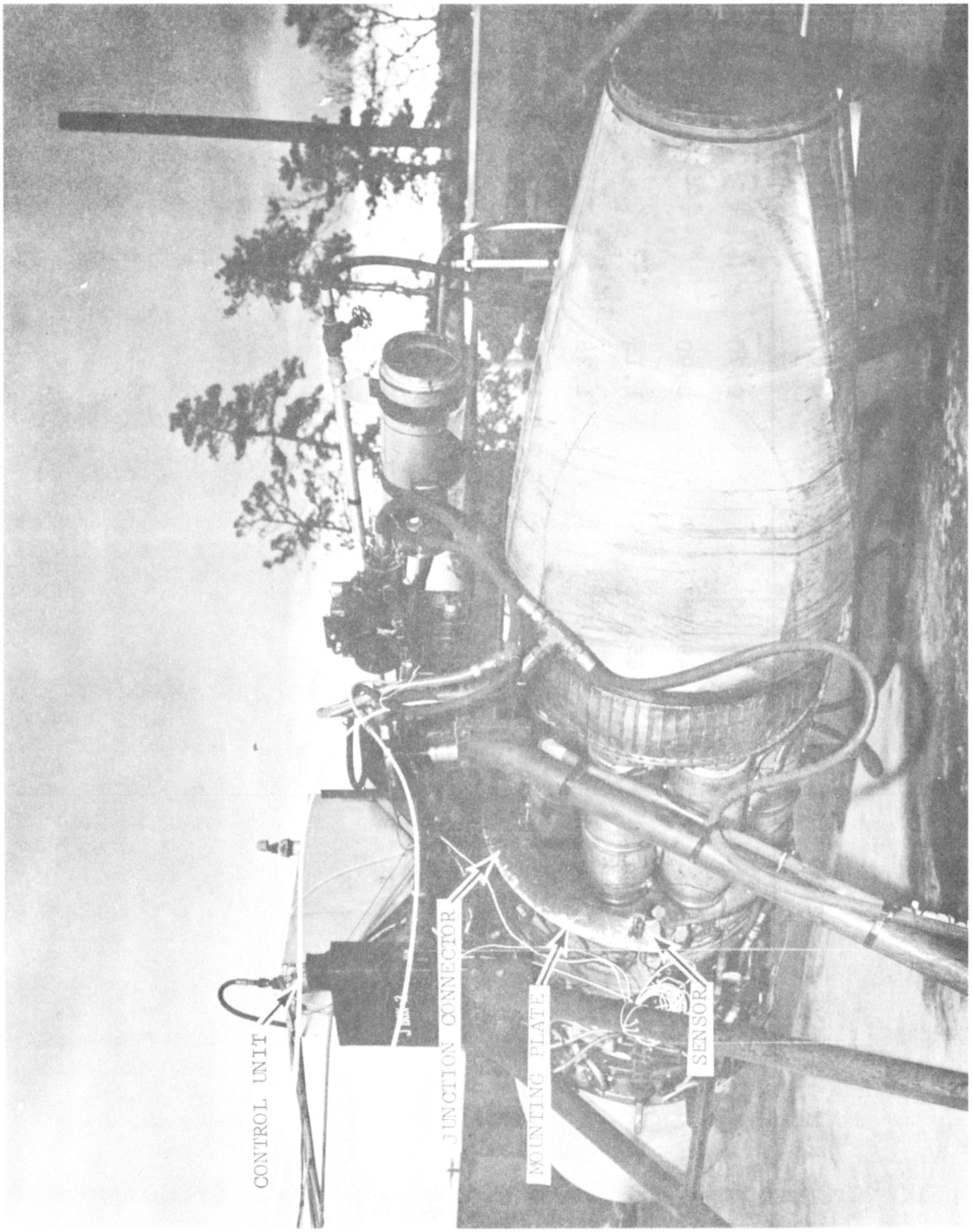

BURN-THROUGH FLAME
FLAME NOZZLE
1/2-INCH THICK STEEL PLATE

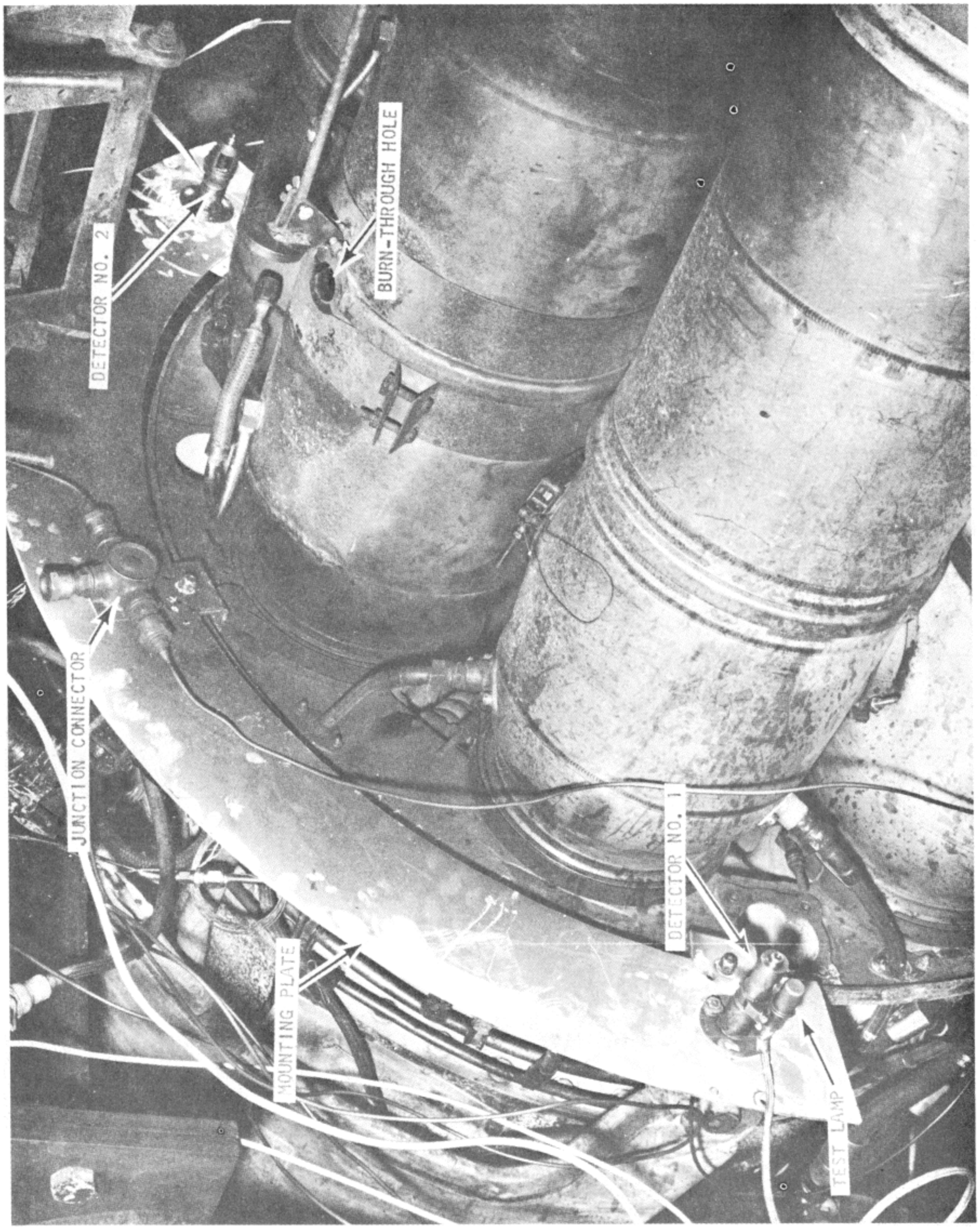


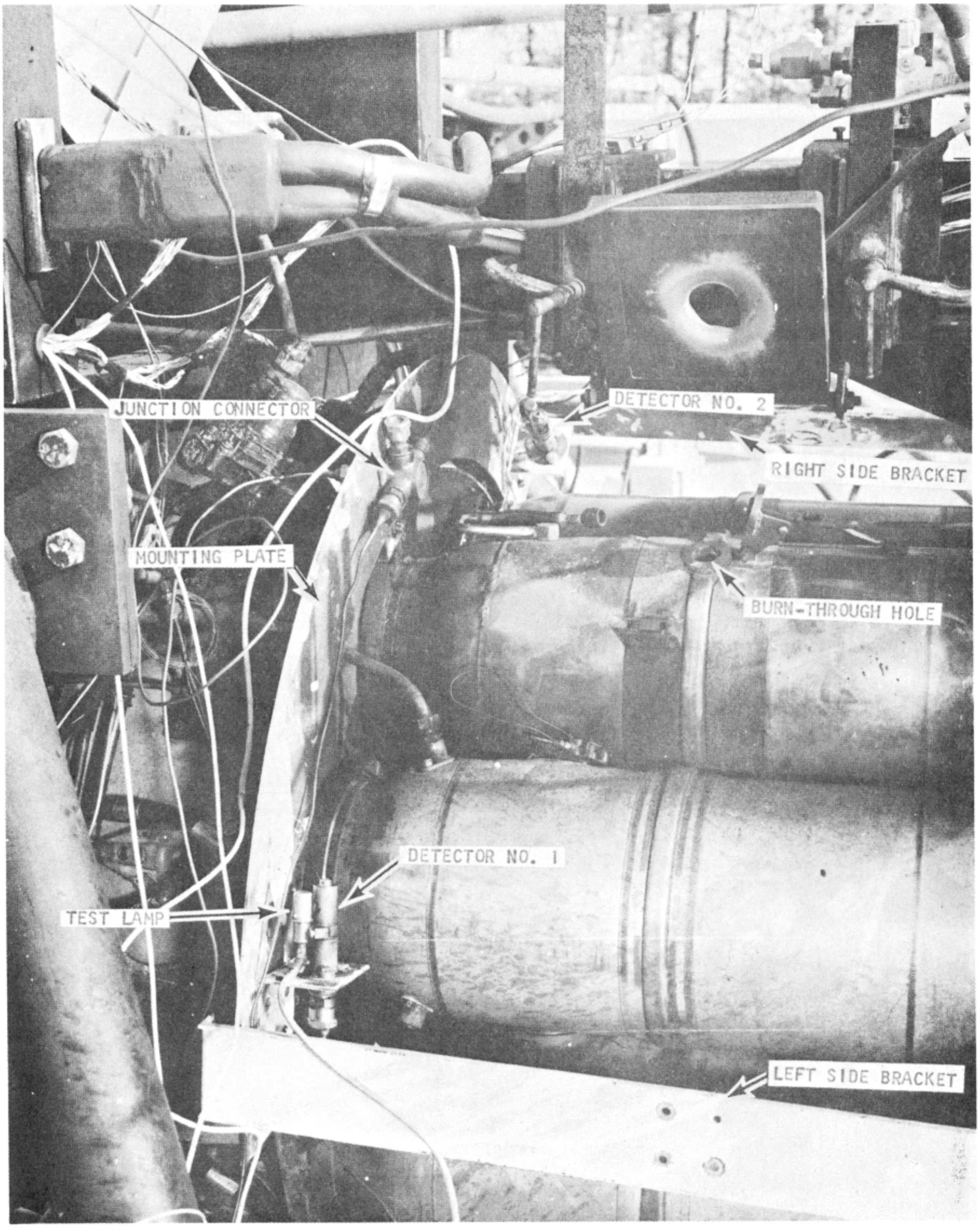
BURN-THROUGH FLAME
FLAME NOZZLE
1/2-INCH THICK STEEL PLATE

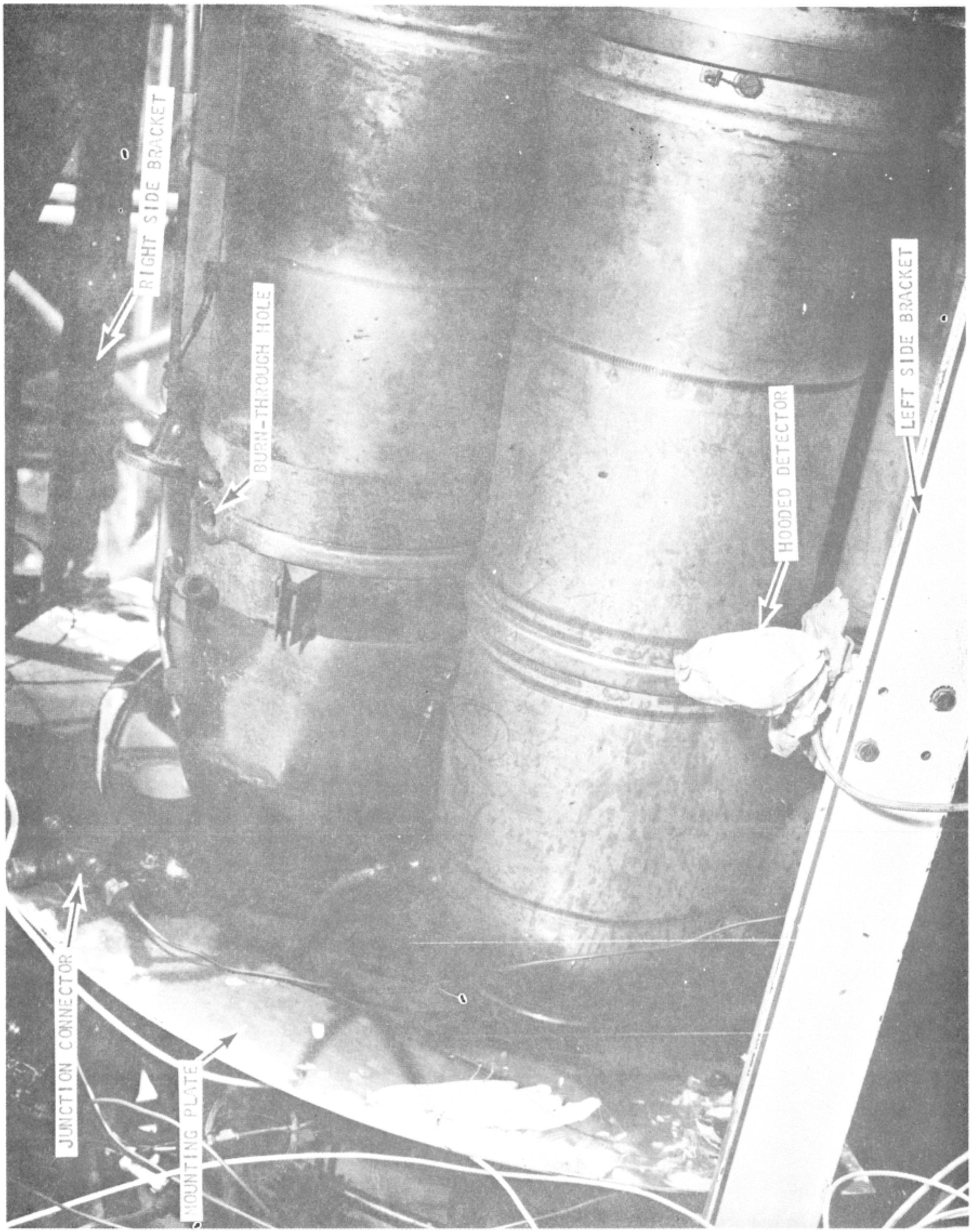
CHARACTERISTICS OF BURN-THROUGH FLAME AT 4-INCHES FROM THE BURNER-CAN

ENGINE RPM (%)	FLAME TEMPERATURE (°F)	DYNAMIC PRESSURE (INCHES Hg ABS)	MACH NUMBER	VELOCITY (FEET PER SEC)
50	1350	39.56	0.70	1320
60	1600	49.76	0.90	1860
70	2050	65.31	1.15	2490
75	2175	73.31	1.25	2715
80	2425	77.06	1.30	2910
85	2525	80.56	1.35	3020
90	2750	94.81	1.45	3350
95	2850	94.06	1.45	3390


CONTROL UNIT
JUNCTION CONNECTOR
MOUNTING PLATE
SENSOR


DETECTOR NO. 2
BURN-THROUGH HOLE
JUNCTION CONNECTOR
MOUNTING PLATE
DETECTOR NO. 1
TEST LAMP


JUNCTION CONNECTOR
DETECTOR NO. 2
RIGHT SIDE BRACKET
MOUNTING PLATE
BURN-THROUGH HOLE
DETECTOR NO. 1
TEST LAMP
LEFT SIDE BRACKET


RIGHT SIDE BRACKET
BURN-THROUGH HOLE
HOODED DETECTOR
LEFT SIDE BRACKET
JUNCTION CONNECTOR
MOUNTING PLATE

DISCUSSION FOLLOWING NAFEC PRESENTATION

A motion picture was shown revealing the results of NAFEC tests of engine combustion chamber simulated burn through using a full scale J-47 engine modified to provide the torch flame. The material found most resistant to burn through was Goodyear Airmat which uses transpiration cooling provided by engine bleed air to provide protection against damage by the torchlike flame.

Mr. Vergilio of the FAA Western Region briefly discussed the results of tests he observed of composite materials being developed for the Lockheed L-1011 which are capable of resisting the burn through flame for five minutes. He also reported that Rolls Royce have developed a special burner that uses an air supply and fuel and gives a 3500° F flame at a typical engine combustor pressure (600 psi).

Mr. Trumble of USAF remarked that a four-inch diameter torch with a flame temperature of 3500° F is being developed by USAF as a burn through flame standard.

Q. Is there a change in sound when burn through occurs?

A. There was an obvious and apparent increase in sound when the burn through flame emanated from the opening in the engine.

Q. What type of detector would be most effective in detecting burn through?

A. Analysis of the spectral frequency with a wide-range photospectrometer indicated that ultra-violet detection system would be feasible for detection of burn through.

Q. Didn't NAFEC attempt to build a burner to simulate burn through?

A. NAFEC attempted to build a torch to simulate burn through flames but its capability was limited because of the large air flow requirements necessary.

STATE-OF-THE-ART REVIEW

OF FIRE AND OVERHEAT DETECTION TECHNIQUES

DEVELOPED BY THE UNITED STATES AIR FORCE

TERRY M. TRUMBLE

ENGINEER (RESEARCH)

AIR FORCE AERO PROPULSION LABORATORY

WRIGHT PATTERSON AFB

STATE-OF-THE-ART REVEIW OF FIRE AND OVERHEAT DETECTION TECHNIQUES DEVELOPED BY THE UNITED STATES AIR FORCE

PAST TECHNOLOGICAL DEVELOPMENTS

In the early 1960s the art of fire detection had essentially reached a technical plateau from which it became impossible to provide adequate protection for advanced aircraft by modifying existing systems. Rate of rise discrimination for differentiation between a fire and overheat and short discrimination by rate of voltage change and/or its true value, had diligently been applied to the continuous element overheat sensor.

These sensors are not specific to fire, and as such are limited in both their coverage and specificity. The only true fire sensors are those which detect the light emitted from a flame. Light sensing detectors were examined as far back as the mid 1940s, but even until the early 1960s only one system had gained nominal acceptance. Problems encountered, that had essentially been solved in the continuous systems, shed a dim light on the future of this type of system being widely accepted. False alarms were prevalent, installation geometry became a new problem,and failure rates were initially higher than expected.

The sensors themselves were limited in temperature capability and could not be upgraded without using cooling. With only two types of sensors available and neither sensor capable of upgrading,it became evident that advanced aircraft then on the drawing boards would not be adequately protected.

In 1960 a general plan was formulated to improve the posture of the detection area. It was recognized that commercial manufacturers of fire detection equipment were not properly equipped to develop new semiconductor,or multiplier type, optical sensors, or hybrid electronic modules. Thus, the beginning of a complementary in-house and contractual effort was initiated by the Air Force. The results of this program were encouraging even at the beginning. An optical fire detection system employing the first environmentally qualified, coherent 12½ Ft fiber optical bundle coupled to a light sensor using a 20 hz low pass electronic filter was built and successfully laboratory tested. The optical bundle found use on the Atlas and Titan missiles, although admittedly not for fire detection. The fiber bundles exhibited excellent transmission in the visible spectrum and were qualified for use in 1000°F areas where existing infrared, ultraviolet visible sensors could not operate.

The development of homogeneous fuzed quartz fiber optic bundle coated with magnesium floride (M_gF) in 1966 provided an extension of the temperature and spectral capabilities of long fiber optic bundles. Multiplier phototubes in the ultraviolet regiona and lead sulphide infrared detectors could now be used too with fiber optic bundles.

In 1965 an in-house effort was completed proving the feasibility of using ultraviolet sensitive gas multiplication tubes for hydrogen flame detection. Further analysis proved conclusively that his sensor could be used in high temperature environments without a substantial increase in background noise, and little if any loss in gain. A contract awarded to International Telephone and Telegraph Industrial Laboratories in 1965 resulted in a working bi-planer, molybdenum photocathode, gas multiplication UV tube capable of operating at 1000°F. Continued efforts along these lines resulted in a flight qualified UV fire detection system. The McGraw Edison Company of West Orange,New Jersey under a 3 year contract,provided the flight test hardware to qualify their 550°F system for acceptance into the USAF inventory.

The final development in the area of fire and overheat detection prior to 1970 was not in the area of sensors, but in the way they could best be used. As early as 1963, it became evident that advances in technologies other than that of fire and overheat detection were not being used for detection systems. Manufacturers were skeptical as to the advantages that could be provided by utilizing integrated circuits (ICs) or digital logic. In order to prove the value of both these technologies,a formal in-house program was undertaken in September 1965. The result of this program introduced to the industry the following improvements and their attendant advantages:

1. Physical Sensor Redundancy
2. Electronic Redundancy
3. Continuous Self-Interrogating Sensor System

4. True Fail-Safe Techniques

5. Optical Sensors Only for Fire

6. Overheat Elements for Overheat Detection and Fire Verification

7. Readout for FIRE, FAIL, OK, AND OVERHEAT, as opposed to Indicator Lamps

8. Use Rules for Readout

9. Optical Redundancy

10. Three Level Continuous Sensor Test with FAIL-the Predominant Mode of Readout over FIRE or OVERHEAT.

11. Volume and Weight Reduction in the Electronics Packaging While Keeping or Improving the Mean Time Between Failure(MTBF)

12. Allowance to Fly with Failed Sensors without Grounding an Aircraft.

Since the industry had reached the point of diminishing returns on improving MTBFs using conventional approaches, it became obvious that the probability of two elements of a physically redundant system (1) failing would be substantially less and thus would decrease red-lined aircraft.

If regulations would permit, the aircraft could now fly with a failed sensor and a good one(12). A self-interrogating two channel comparator computer provided electronic redundancy (2) to insure that false warnings due to the electronics failing would be minimized, if not eliminated altogether. Self-checking(3) of the sensors themselves was accomplished by continuously testing them with a +10 volts which indicates OK. When the voltage reduces to 5 volts the sensor is indicating a fire or overheat, and when the output voltage goes to zero volts the sensor is read as a FAIL (10). True fail safe techniques were used throughout such that a + signal must be the result of a detected hazard and it must be 5 volts. The probability of a failure occurring which would be read as a FIRE or OVERHEAT is very small, but when it is required that one sensor detect and another sensor verify, it is almost in the realm of an impossibility ($<$ 1 chance in 10^6 hours)

Overlapping field of view of optical sensors provides the most optimum method of providing redundancy (1)(9). Optical sensors are specific for fire as continuous elements are for overheat (5)(6). This inherent specificity reduces the probability of reading one hazard for another which can be extremely valuable. This provides an increase of information transmitted to the pilot at no real expense in design. The readout (7) therefore provides better, more reliable information, more quickly when a fire does occur.

Finally, the volume and weight reduction from discrete component sub-assemblies and magnetic amplifiers has been accomplished while improving the MTBF due to redundancy in the IC packages (11).

PRESENT TECHNOLOGICAL DEVELOPMENTS

The development of the Integrated Fire and Overheat System for Aircraft, AFAPL-TR-67-129, was continued under a contractual effort to Delco Radio of Kokomo, Indiana. **The result of this contractual effort was** a 3.6 cubic inch 4.3 ounce computer. This computer tied together 4 each infrared, ultraviolet and continuous elements in 5 modes. The NORMAL mode requires one sensor to detect and another sensor to verify the presence of a fire or overheat. The EMERGENCY mode requires only that any sensor detect a fire or overheat in order to provide an indication. The other three modes are normally used for checking the integrity of the computer. These modes are UV, IR and continuous.

Figure Nr 1 illustrates a flight test computer which has the analog to digital (A/D) processing blocks for mating the sensors to the computer as an integral part of the computer. The A/D block is called a sensitizing module because it performs all the required electronic witchery to convert a raw signal into a reliable and specific input. This computer is presently planned for flight testing on a KC-135 aircraft in February 1971. A Fenwal infrared sensor, an Edison UV sensor and a continuous element will be used. A Light Emitting Diode (LED) Alpha Numeric Display is being developed for the readout. This readout will provide the words FAIL, FIRE, OK and OVHT. Flight testing of a similar computer system using Honeywell UV sensors in place of the Edison UV sensors is being planned for flight tests on a NAFEC Convair 880 sometime in early 1971.

A recent contractual development has resulted in a non-solar blind, gas multiplication, ultraviolet detector tube capable of sustained operation at 1157°F. This GE developed tube is being developed further by the Owensborrough Microwave Tube Division. It is a strong contender for engine nacelle fire detection for the American SST. The Anglo French Concorde is using thermally protected commercially avialable Edison type tubes for fire detection on at least one prototype aircraft.

Drawbacks of the GE tube are not limiting but must be carefully handled in order to provide a good installation. These tubes use Molybdenum photocathodes which are sensitive to radiation at 2900 Å at sea level, and thus are not truly solar blind. As the temperature of the environment is increased, the tube increases in sensitivity to all forms of signal. Thus, the tube will show a decrease in signal to noise ratio and will require some voltage tracking of the sensor to maintain the proper sensitizing voltage.

A second UV sensor is a solid state silicon carbide (SiC) device which was designed specifically as a burner can burn through detector. This sensor, also not solar blind, operates at 1000°F and has an extremely low output. A 9 nanoamp signal from a 1×10^5 ohm load exemplified sensors delivered on a contract in 1969. Present sensors can deliver a signal 10 times to 100 times greater. In order to use this signal with the computer concept, it is necessary to furnish substantially larger output signals than are now available. This can now be done as a result of the successful development of a SiC junction field

field effect transistor (J-FET) that operates at 500°C. A contract with the Astronuclear Laboratory of Westinghouse in Pittsburgh, Pennsylvania will use the transistor as a part of an operational amplifier to be directly coupled to the SiC sensor. Signals should be capable of being sent at least 100 ft away through coaxial cable with no loss in signal to noise ratio or reliability.

The development of this SiC, J-FET complements the diode regulator ,thermistor,and resistor devices made from SiC and thus provides a technical basis for solving many size, weight, heat dissipation and radiation hardening problems intendant the use of Silicon, Indium Antimonide, Galium Arsenide, or Cadmium Teluride.

The concept of locating a fire or overheat along a cable has been solved simply by the use of an unbalanced current/voltage bridge. The technique is not discrete, and the possibility of a multiple fire occurrence being misread as to location is very high. To solve this problem the mating of Time Domain Reflectometry (TDR) with continuous cable has been made. TDR is simple technique whereby a pulse sent down a line, reflects back to the transmitter from a discontinuity. By measuring the time the signal makes its round trip, dividing it by two and scaling time to distance, the discontiniuty can be located within 3 feet. The use of the Fenwal salt type continuous cable with a 1 volt 9 nanosecond wide pulse generator provides this type of discontinuity location such as would be caused when the localized cable temperature causes the salt to become conductive. This sensor can be used to check the connectors as well,and reduce the probability of false alarm due to contamination in the connectors.

The final effort in the sensor area which is a contractual development by the Edison Company,is a self-generating continuous thermocouple element. Primary effort is being expended on developing good connectors and a synthetic cold junction. This effort is due to be completed in February 1971.

Although all of the pertinent detection oriented research has been discussed, one additional area of research currently being pursued at W-PAFB has not been covered. A comprehensive detector analysis program of all available sensors is being conducted and a new optical JP-4 burner standard has been developed.

First, the sensor evaluation program will be discussed. It is a well known fact that no two sensors behave alike nor can they easily be compared. It is therefore imperative that a method for comparing them be fair and equitable such that the best use of any sensor available off-the-shelf be made. Two methods are presently being pursued to accomplish this end. The first method is to provide the standard Detectivity (D* or DD**) measurement or equivalent using sophisticated lamps for sources, monochromators, phase lock amplifiers and NBS traceable thermopiles. Data taken by this method will provide information such as maximum sensitivity, quantum efficiency, optimum signal to noise ratio and spectral sensitivity.

The second method depends fully upon the new JP-4 standard under development, so it would be appropriate to discuss the development of the standard first. The new JP-4 standard burner is designed to stably burn JP-4 in air without a flame holder so that the spectra in the UV, visible, and IR is repeatable, measurable and constant. The flame embodies the characteristics of the minimum flame that could be expected to occur in a jet engine macelle. This flame has been measured spectrally both for spectral distribution and total power. With this standard, which is inexpensive to build, and the technical report, a comparison of any sensor with any other kind of sensor can be made on a practical basis. In-house tests will be conducted using available sensors and this standard. A report containing this information will be completed by July 1971.

SURVEY OF STATE-OF-THE ART FIRE AND OVERHEAT SENSORS

The Typical Sensor Characteristics, Figure Nr 2, illustrate most of the available sensors and their limiations. The first device shown is the McGraw Edison Nr 42262 Ultraviolet tube that is in use in hypobaric chambers, commercial buildings and boiler controls. Edison makes a high sensitivity tube which is not normally sold, but is used in their product line of fire detectors. The tube looks the same as the Nr 42262 tube,however, it has a different gas fill and its number is 42743. The nominal temperature limitation is approximately 300°F for this type of tube. Limitations as shown in Figure 3 are most appropriate to this device and its uses.

The second sensor shown is again a McGraw Edison ultraviolet sensor, however, this sensor is useful to 550°F, and it is designed for flight use. The limitation in the use of this tube is not shown in Figure Nr 2. This limitation is the count from the background solar radiation which is essentially -

based on the altitude of the aircraft. The background is a function of the reduced absorption of the high altitude ozone layer as the aircraft flys at increasing altitudes. The second source of background count is cosmic radiation. Proper electronics can reduce both problems, but they cannot be totally eliminated.

The third detector shown is the General Electric 1157°F ultraviolet gas multiplication tube. This tube possesses the same inherent characteristics as the McGraw Edison devices with two notable exceptions. It operates at 500°C (1157°F) and it has a lower but more accurate voltage supply requirement. The problem with oil or fuel coatings is substantially less as the environmental temperature is increased due to lower viscosity resulting in thinner films.

The infrared region has only a few sensors that will operate at continued elevated temperatures, and of these, only one device is known to be a semi-conductor. The device illustrated is a silicon 500°F sensor which discriminates a fire from background by 20 hz or less flicker. It has been successfully tested at W-PAFB on an F-4 without any failures during about a three year period. It is made by Fenwal.

There are several other manufacturers of good optical sensing systems, however testing of their systems at W-PAFB has not been accomplished to-date,and as such, they will not be discussed.

The overheat elements shown in Block Nr 3, Figure Nr 2, are typical of those used in the industry for years. The two continuous element overheat detector cables represent semi-conductor and "salt" type insulation cables whose impedance is reduced as the temperature rises. Both types have been used extensively.

One addition type not shown is the gas filled tube system which operates a miniature snap action diaphram. This system is presently in operational use on many of the airlines. The bimetalic switch is still used on many Air Force aircraft and although it provides an extremely rugged, high MTBF unit, its coverage is minimal and its further use as exclusive fire detection method is not recommended.

The final device shown in Figure Nr 2 is a broadband light sensor used as an explosion sensor in conjunction with the Edison 42262 tube for explosion detection in aircraft fuel tanks. The system has operated successfully during simulated tests. This system is the result of a contractual effort with Fenwal.

SUMMARY

The discussion embodied in this paper is merely a digest of the fire detection work being pursued in the Air Force Aero Propulsion Laboratory(AFAPL). Work in the areas of inerting, fire suppression, extinguishants, JP-4 versus JP-8 and other allied areas is being conducted. The previous discussion has also avoided any detailed analysis of the electronics or other proprietary aspects of systems under evaluation. Much of this information is available, however, and with permission of the vendor it will be provided to those who require it.

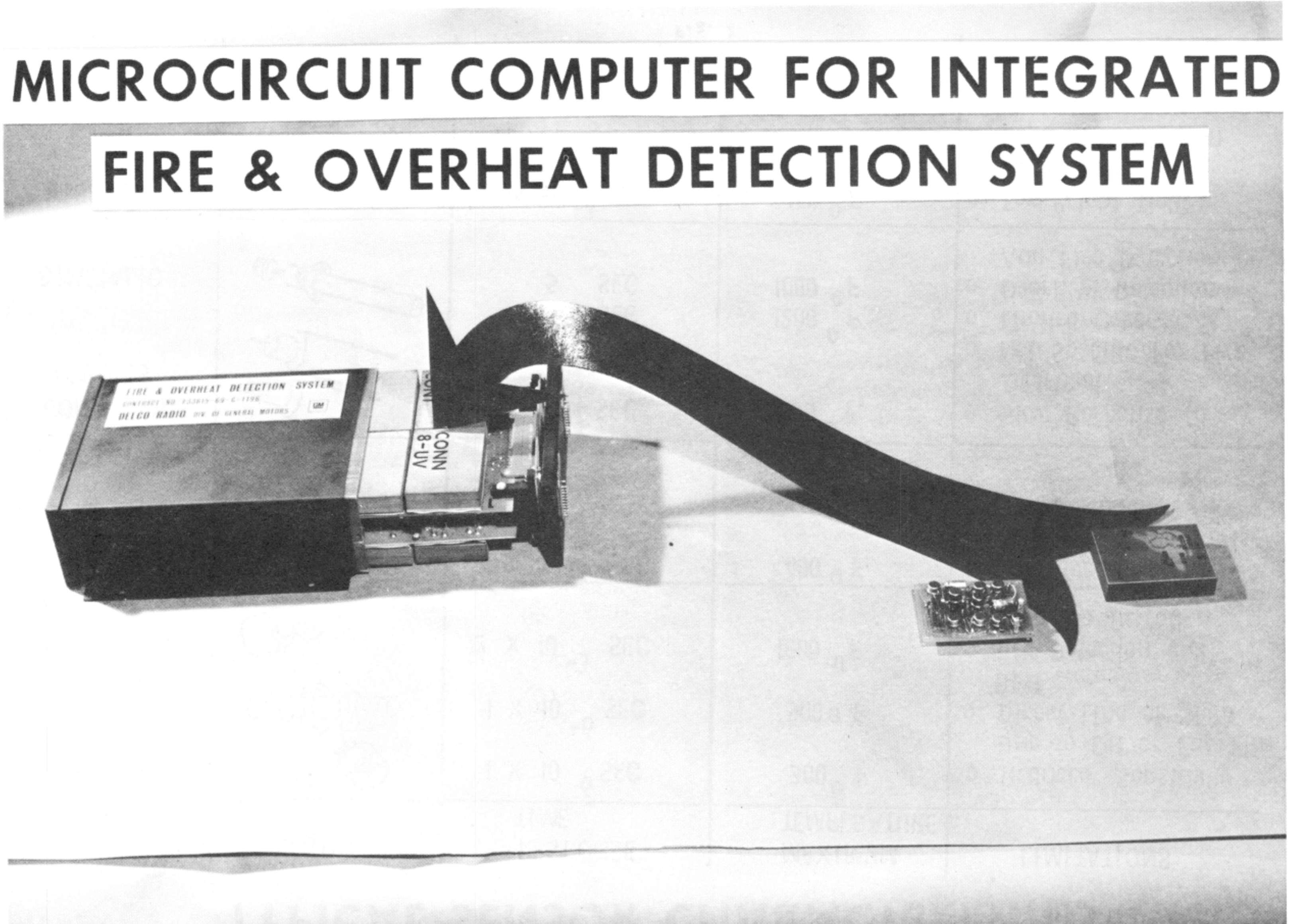

MICROCIRCUIT COMPUTER FOR INTEGRATED
FIRE & OVERHEAT DETECTION SYSTEM
FIRE & OVERHEAT DETECTION SYSTEM
DELCO RADIO DIV OF GENERAL MOTORS
CONN
8-UV

Fig. 1

TYPICAL SENSOR CHARACTERISTICS

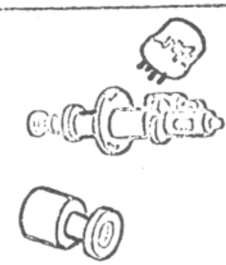
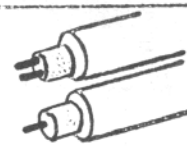
TYPE	DESIGN	RESPONSE TIME	MAXIMUM TEMPERATURE	LIMITATIONS
UV		1×10^{-6} SEC 1×10^{-6} SEC 12×10^{-3} SEC	300^{0} F 500^{0} F 1000^{0}F	o Reduced Sensitivity Due to Oil or Fuel Film o Direct Line of Sight Best o Fire Detection and Explosion Detection
IR		1×10^{-3} SEC	400^{0} F	o Sensitive to Sunlight and Hot Engine Parts o Fire Detection
CONTINUOUS ELEMENTS BIMETALIC	 	5 SEC 5 SEC 5 SEC	1200^{0} F, 1200^{0}F 1000^{0}F	o Slow Response To Overheat o Not Specific For Fire o Limited Coverage o Overheat Detection And Fire Detection
VISIBLE		$.1 \times 10^{-3}$ SEC	165^{0} F	o For "Light Tight" Areas Only o Explosion Detection

Fig. 2

DISCUSSION FOLLOWING USAF PRESENTATION

Q. Is the USAF encouraging efforts to provide means for preventing burn through of the hot gas section?

A. There is some work now in process directed toward solving this problem but I'm not at liberty to discuss it.

Mr. Trumble informed those present that USAF would be glad to consult with and advise any agencies or manufacturers regarding any aspects of fire and overheat detection.

APPENDIX A

ATTENDEES
FIRE DETECTION CONFERENCE
16, 17 NOVEMBER 1970

NAME	COMPANY
Donald J. McCaffrey	Walter Kidde & Company, Inc.
Roger B. Jones	Walter Kidde & Company, Inc.
Barry L. Warner	Walter Kidde & Company, Inc.
A. Hobelmann	Walter Kidde & Company, Inc.
George J. Grabowski	Fenwal, Inc.
Fred W. Newman	Fenwal Protection Systems Div.
Donald E. Snowdon	Fenwal, Inc.
Philip G. Leigh	Lindberg Div., Systron-Donner Corp.
John S. Winter	Lindberg Div., Systron Donner Corp.
Peter C.C. Brown	Graviner, Inc.
Vincent Vesuvio	Thomas A. Edison
R. Sibole	Thomas A. Edison
Edwin R. Hatheway	Pyrotector, Inc.
Robert L. Mitton	Pyrotector, Inc.
George C. Hopkins	Boeing - Vertol Division
C.E. Shappell	Boeing - Vertol Division
Joseph L. Magri	Sikorsky Aircraft
E. A. Muller	Navair, Air-530313A
David L. Reida	Beech Aircraft
Thomas Rust	FAA/NAFEC
Julius J. Gassmann	FAA/NAFEC
C. M. Middlesworth	FAA/NAFEC
Terry M. Trumble	USAF
Stephen H. Rolle	FAA
Robert J. Auburn	FAA
R. A. Peterson	FAA
L. E. Tarbell	FAA
E. R. Lambert	FAA
W. S. Thomas	FAA
Joseph Haddad	FAA
Charles H. Sweeney	FAA
Pat Perrotta	FAA
A. C. Caviness	FAA
John R. James	FAA
Floyd T. Melton	FAA
Anthony J. Vergilio	FAA
Geo. W. Wells	FAA
James C. Webster	FAA
Richard McMurray	FAA
Peter Hallick	FAA
Robert B. Karp	FAA
Robert O. Love	FAA
Henry H. Osborne, Jr.	FAA
E. P. Burke	FAA

GPO 909.031