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A BURNER AND TEST BENCH FOR EVALUATING AIRCRAFT FIRE AND HEAT DETECTORS

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A BURNER AND TEST BENCH
FOR EVALUATING AIRCRAFT FIRE AND HEAT DETECTORS

SUMMARY

In order to provide industry with a uniform, reproducible flame for comparing the sensitivity and flame resistance of fire and heat detectors, a burner was developed which was capable of producing a six-inch-diameter flame at temperatures of 1500° F and 2000° F with not more than 25° F variation over the entire cross-sectional area of the flame.

A test bench incorporating this standard burner was developed to provide an automatic means for comparing the response time and the flame resistance of aircraft fire and heat detectors and to determine their compliance with the Society of Automotive Engineers Specification AS-401A, Paragraphs 7.1 (response time), 7.1.1 (repeat response time), and 7.14 (flame resistance). The use of this arrangement eliminates the human error usually associated with observation and accurate timing.

INTRODUCTION

Heretofore, fire and heat detectors for aircraft were tested and compared by various testing agencies, manufacturers, and prospective buyers by subjecting these detectors to flames of relatively high temperature to determine response times. There was used a gasoline blowtorch or other burner which produced what the testing agency believed to be a fair and representative flame which could readily occur in aircraft. The detector was subjected to such flame in a manner which seemed to the operator to be fair and reproducible. The response time was usually measured by a stop watch.

After various detectors had been accepted on the basis of the afore-mentioned test procedure, thousands of units were installed and put into service. During the next few years a large number of false alarms occurred, as well as some failures to detect fires. However, the false alarms were not all caused by improper detector design. Many of the malfunctions which occurred were caused by wiring faults, which developed in the detector circuits during service use, and by a lack of knowledge of temperature conditions existing in aircraft in the vicinity of the detectors. There is also a lack of knowledge concerning rates of temperature rise and concerning actual or radiated temperatures in various regions of the power plant during infrequent maneuvers.

As a result, the Society of Automotive Engineers (SAE) was requested to establish specifications for qualification tests and the Technical Development and Evaluation Center of the Civil Aeronautics Administration was asked to develop a standard burner to be used in determining the response time and the flame resistance of the detectors. This burner was accepted and later specified as the one to be used in testing for compliance with Paragraphs 7.1, 7.1.1, and 7.14 of Specification AS-401A established by the SAE.

This burner was later incorporated in a test bench which automatically subjects detectors to the standard test procedures outlined in the three paragraphs of the cited specification.

OBJECTIVE REQUIREMENTS

The burner was designed to provide a standard, reproducible flame not less than six inches in diameter at temperatures of 1500° and 2000° F, with not more than 25° F variation over the entire cross-sectional area of the flame.

The test bench, which includes the burner, was designed to provide an accurate means for automatically exposing detectors to the standard flame and to record the time intervals required by Paragraphs 7.1 (response time), 7.1.1 (repeat response time), and 7.14 (flame resistance) of Specification AS-401A. The sequence of events followed during each of these paragraphs is hereinafter given.

Response Time.

The sensing element of the detection system being tested is placed in the 1500° F standard flame. As the element passes over the edge of the burner producing this flame, a timer is started and continues to run until the system gives the alarm at which time the timer stops. Thus, it indicates time for detection, or response time.

Repeat Response Time.

This portion of the test is a continuation of the response-time test. After the response time has been determined, the element is retained in the flame until 60 seconds have elapsed from the time that it was first placed in the flame. At the end of the 60 seconds, the element is removed from the flame and allowed to cool in still air at room temperature. Five seconds after the system has cleared the alarm, the element is replaced in the fire, starting the timer. When the system signals the alarm, the timer stops. It then indicates the repeat response time.

Flame-Resistance Test.

The sensing element is placed in the 2000° F flame of the standard burner. The time for detection is indicated by a timer as described previously. The element is retained in the flame for a total of 60 seconds. Upon removal of the element from the flame, a second timer is started. This timer continues to run while the element cools in still air at room temperature until the system has cleared the alarm. The time indicated by the second timer is the time required to clear the alarm.

DESCRIPTION OF EQUIPMENT

Standard Burner Assembly.

The complete standard burner assembly is shown in Fig. 1. Details of the components of this assembly are given in Figs. 2, 3, and 4.

Fig. 2 shows the details of the burner and the burner grill which consists of two plates connected by ⅛-inch copper tubes. Gas and air are mixed in the burner base and travel upward through the tubes. The burning takes place above the top plate of the burner. Cooling air is admitted to the burner through the four ⅛-inch pipe-tapped holes between the plates of the burner grill. This air passes upward through the No. 38 drill holes in the top plate and serves as a means for controlling the over-all temperature of the flame. The location of the four ⅛-inch pipe-tapped holes is critical. They must be located directly in line with the center row of ⅛-inch copper tubes in each of the four quadrants. Improper location of these connections will result in an unequal radial distribution of cooling air and will affect the distribution of the flame temperature in a like manner.

Fig. 3 shows the details of the burner base. When the two 11/32-inch-diameter holes in the burner plug are drilled, care should be taken that the center line connecting these holes will be at right angles to the center line connecting the two 19/64-inch-diameter holes in the base. When these 11/32-inch-diameter holes are properly located, the 19/64-inch-diameter holes cannot be seen when one looks vertically downward into the burner base. This misalignment of holes aids in the mixing of the gas and air before they ascend to the burner grill.

Fig. 4 shows the details of an orifice and of an orifice chamber. Three are required. Two of these orifice chambers have end plates with the ⅜-inch Parker thread fittings on both ends and are fastened

Fig. 1 Standard Burner Assembly

directly into the burner base. The third orifice chamber has an end plate with a Parker thread fitting on one end and the plate with four ¼-inch-diameter holes in the other end. This end of the chamber is connected to the burner by four copper tubes, each ¼ inch in outside diameter (OD) and 13½ inches long. One of the orifice chambers connected to the base is for measuring the gas supplied to the burner and has an orifice 5/32 (0.01625) inch in diameter. The other orifice chamber connected to the base is for measuring the mixing air supplied to the burner and has an orifice ¼ (0.25) inch in diameter. The third orifice chamber connected to the burner by four ¼-inch OD copper tubes is for measuring cooling air supplied to the burner and has an orifice 5/16 (0.3125) inch in diameter.

The gas should deliver approximately 2500 British thermal units (BTU) per cubic foot. The burner should consume 26 cubic feet of gas per hour for the 2000° F (1100° C) flame and 12 cubic feet of gas per hour for the 1500° F (815° C) flame.

The differential manometer readings of the pressure drops across the orifice should be:

1. For the 2000° F (1100° C) flame:
   a. Gas orifice (5/32-inch diameter), 0.99 inch of water.
   b. Mixing-air orifice (¼-inch diameter), 9.25 inches of water.
   c. Cooling-air orifice (5/16-inch diameter), 11.0 inches of water.
2. For the 1500° F (815° C) flame:
   a. Gas orifice (5/32-inch diameter), 0.22 inch of water.
   b. Mixing-air orifice (¼-inch diameter), 4.2 inches of water.
   c. Cooling-air orifice (5/16-inch diameter), 6.5 inches of water.

In order that the burner might produce the right amount of heat, the differential pressure for the gas and the mixing air should be accurately controlled. A slight variation in the cooling air may be necessary in order to obtain the proper temperature.

Test-Bench Assembly.

Fig. 5 is a photograph of the detector test bench and shows the controls and the exposed components. Fig. 6 shows the underside of the test bench. This view shows the relative positions of all components not visible in Fig. 5. The thermocouple for measuring the flame temperature is mounted on one leg of the spider and can be seen above the center of the burner. The detector mounted on the other leg of the spider is protected by the shield from radiation from the flame. The spider is mounted on a hub which rotates about a vertical shaft which is operated by a 30-volt direct-current (d-c), motor-driven, reversible actuator equipped with limit switches. The two legs of the spider are made of stainless steel tubing ⅜ inch in diameter. They are mounted radially from the hub about 90° apart. This angle is determined by and should be the same as the angular movement of the spider hub. The spider and the burner should be so located that: (1) when the detector is out of the fire the spider leg to which a thermocouple is attached is in such a position that the thermocouple will be 1¼ inches above the center of the burner grill and (2) when the detector attached to the second leg is in the fire it will be 1¼ inches above the center of the burner. A cam attached to the spider shaft should be located in such a manner that it will actuate switch M_1 as the detector passes over the edge of the burner. A second cam attached

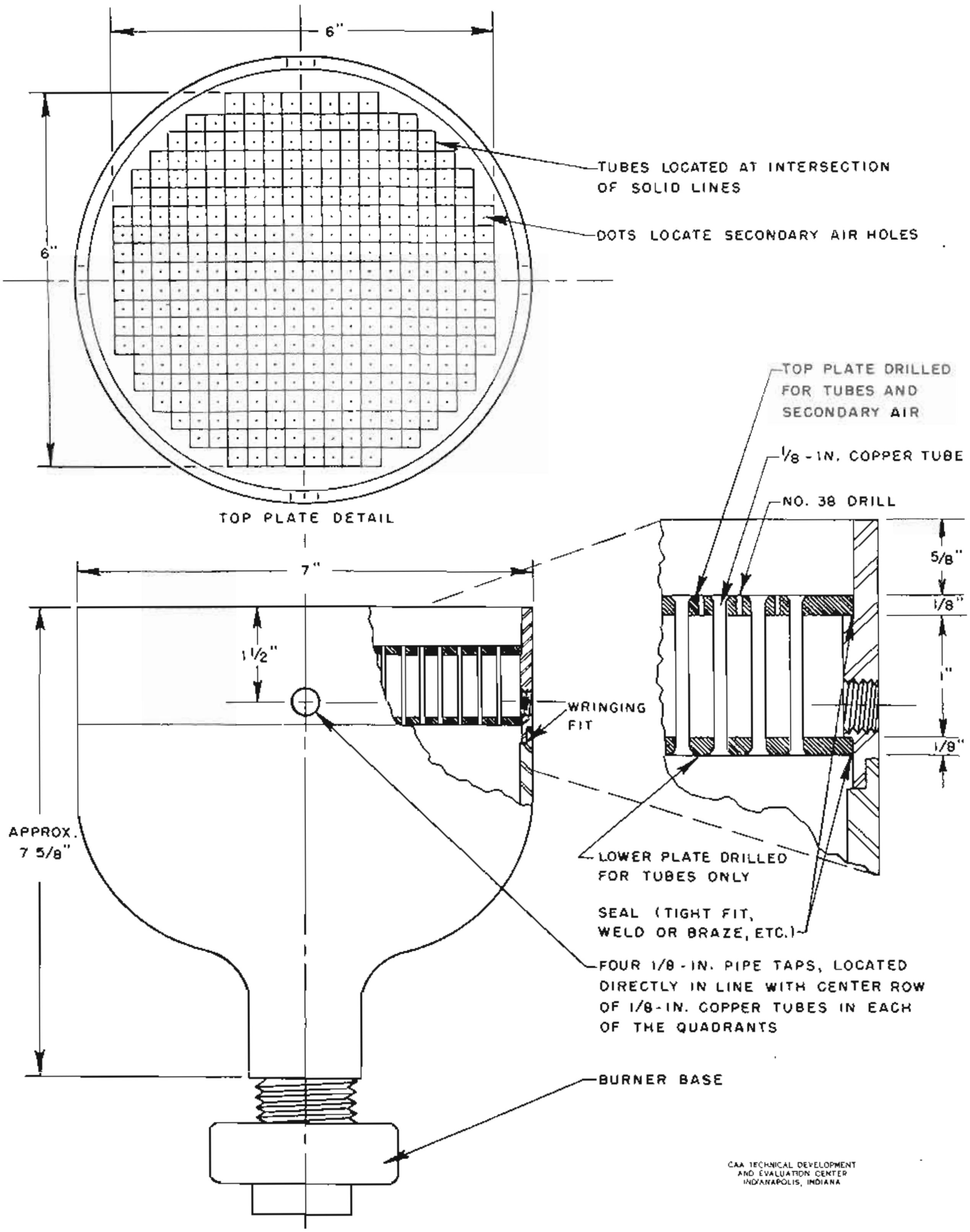


Fig. 2 Standard Burner

to the spider shaft should be located so that it will actuate switch M_2 just before the "out-of-fire" cycle is completed.

The shield is made of thin aluminum-alloy sheet. It is so located and of sufficient size to prevent radiation from the burner flame from affecting the sensing

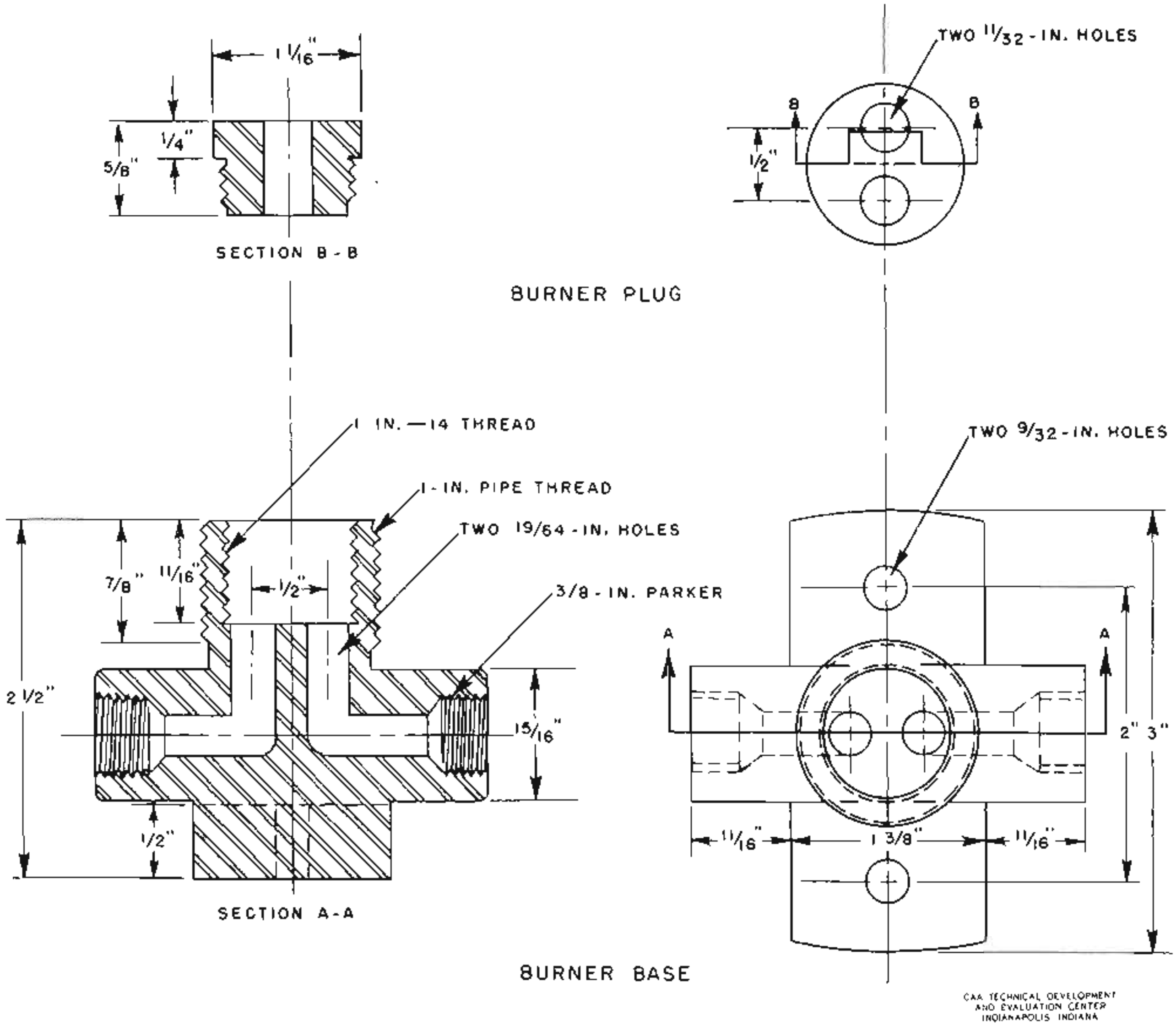


Fig. 3 Burner Base

element of the detector before it is brought into the flame and after it is removed. The movement of the shield is controlled by an actuator similar to the one controlling the movement of the spider. Switch M_3 is located so that it is triggered just before the shield completes its down stroke.

The timer is of the synchronous-motor type which operates on 110 volts alternating current (a-c) and has a normally open circuit that closes 60 seconds after voltage is applied and resets automatically when the voltage is removed. A vibrator, with a frequency of about 2000 vibrations per minute and an amplitude of 0.002 to 0.003 inch, is mounted near the center of the detector leg of the spider. This is to overcome any slight friction between parts in the detecting element.

Special clamps must be made for each different design of detector to fasten it to the spider arm so that the detector will be 1¼ inches above the center of the burner grill when the arm is in the IN position. The clamp should be such that it does not transmit excessive amounts of heat between the spider legs and the sensing element of the detector.

The schematic diagram of the electrical circuits is shown in Fig. 7. Switches S_1 and S_2 connect the bench to the 110-volt a-c and the 24-volt d-c power supplies, respectively. When the starting switch S_3 is closed, the following events take place. Actuator A_2 lowers its shield and closes M_3. This causes actuator A_1 to swing the detector over the burner. In doing so, M_1 is moved from position X to position Y, and M_2 is opened. The moving of M_1 to position Y starts operation recorder L_1 and timer T. (This much of the cycle occurs in less than a second.) The cam on the shaft of A_1 is adjusted so that M_1 is moved as the detector passes over the edge of the burner. Since L_1 starts when M_1 is moved to position Y, L_1 accurately indicates the time that the detector is in the flame. L_1 records the time required for the detector to pick up and relay the signal of fire. When the detector senses the fire, it completes the 24-volt circuit through R_1 to ground. The energizing of R_1 opens the circuit through L_1 and connects L_2 to X on M_1, which is open at this portion of the cycle. The completion of the circuit through the detector also lights the indicating light L_3. The timer T is then maintaining a 60-second time interval from the time the detector passed over the edge of the burner. At the end of this 60-second period, timer T completes the circuit through R_2 and causes actuator A_1 to remove the detector from the fire. This moves M_1 and M_2 back to their original positions, as shown in

Fig. 7. M_2 then causes the actuator to raise the shield, and M_1 completes the circuit through operation recorder L_2. (Relay R_1 is still energized.) Within a reasonable time after the detector is removed from the flame, it will clear the signal of fire by sensing the absence of fire and will open the circuit. Thus R_1 will return to its original position and will open the circuit through L_2. The timer resets automatically when M_1 returns from position Y to position X. The opening of switch S_3 allows relay R_2 (the self-holding relay) to return to the starting position, and the test bench is ready to repeat the same cycle when S_3 is again closed.

Operation recorders L_1 and L_2 record the time required for the detector to give the signal of fire and the time required to clear the signal, respectively. Switch S_4 energizes relay R_2 and causes the same sequence of events to occur as is normally caused by timer T at the end of its timing cycle. It can be used for removing the detector from the fire at will. Switch S_5 can be used for energizing relay R_1, which action normally occurs when the detector senses fire. Switch S_6 can be used for clearing the signal of fire at any time, provided the detector is completing the circuit (signaling fire).

The detector connections shown in Fig. 7 are for a thermal-switch unit type of detector. In any other detection system, a normally open relay should be substituted for the detector and should be operated by the electrical fire-warning signal given by the detecting system which is undergoing testing.

OPERATING PROCEDURE

For determining the response time and the repeat response time of a detector, the following steps should be performed:

1. Mount the detecting element on the proper leg of the spider so that the element will be 1¼ inches above the center of the burner grill when switches S_1, S_2, and S_3 are ON. This must be measured in less than 60 seconds after switch S_3 is turned on, because the detector will automatically be removed from the above burner at that time.
2. With switches S_1 to S_6 inclusive in the OFF position, adjust the burner to give the 1500° F flame.
3. Place switches S_1, S_2, and S_3 in the ON position.
4. Immediately after timing device L_2 has indicated that the signal of fire has cleared, place switch S_3 in the OFF position.
5. Within five seconds after the clearing of the signal as described in step 4, place switch S_3 in the ON position.
6. As soon as detection is obtained, press switch S_4 momentarily, then place switch S_3 in the OFF position.

The test is thus completed, and the response time and the repeat response time are taken from line 1 of the operation recorder chart. If indicating chronometers are used instead of recorders L_1 and L_2, the response time as indicated should be noted and chronometer L_1 should be reset during the first 60 seconds of the test. Thus, the repeat response time will be the second indication on chronometer L_1.

For determining compliance of a detector with the flame test, the following steps should be performed:

1. Mount the detecting element as described in step 1 of the preceding section.
2. Adjust the burner to give the 2000° F flame.
3. Place switches S_1, S_2, and S_3 in the ON position.
4. After the clearing of the signal, place switch S_3 in the OFF position.

The time for detection is indicated on line 1 of the operation recorder, and the time required to clear the signal after removal from the flame is indicated on line 2 of the operation recorder.

After the detecting element has cooled to room temperature, steps 2, 3, and 4 should be repeated. After the detecting element has again cooled to room temperature, steps 2 and 3 should be repeated. As soon

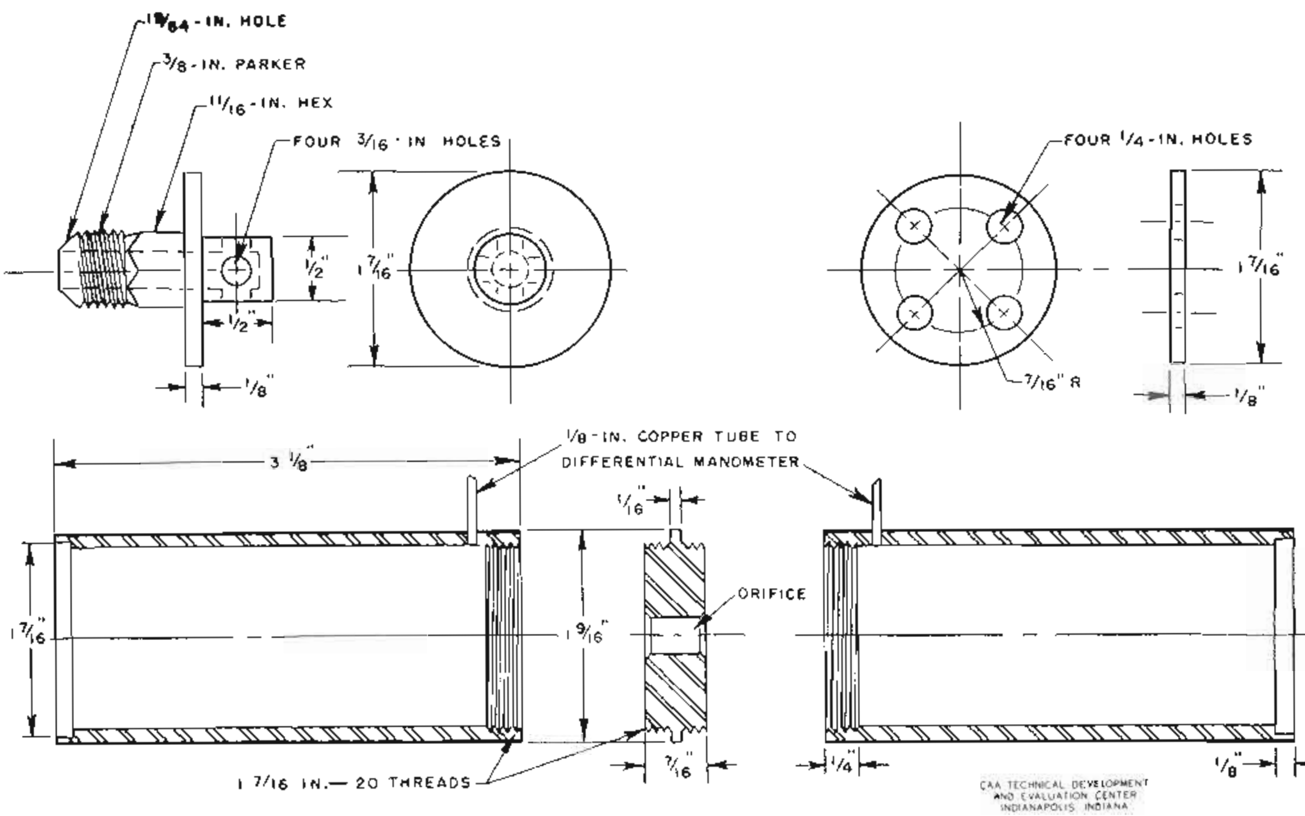


Fig. 4 Orifice Chamber

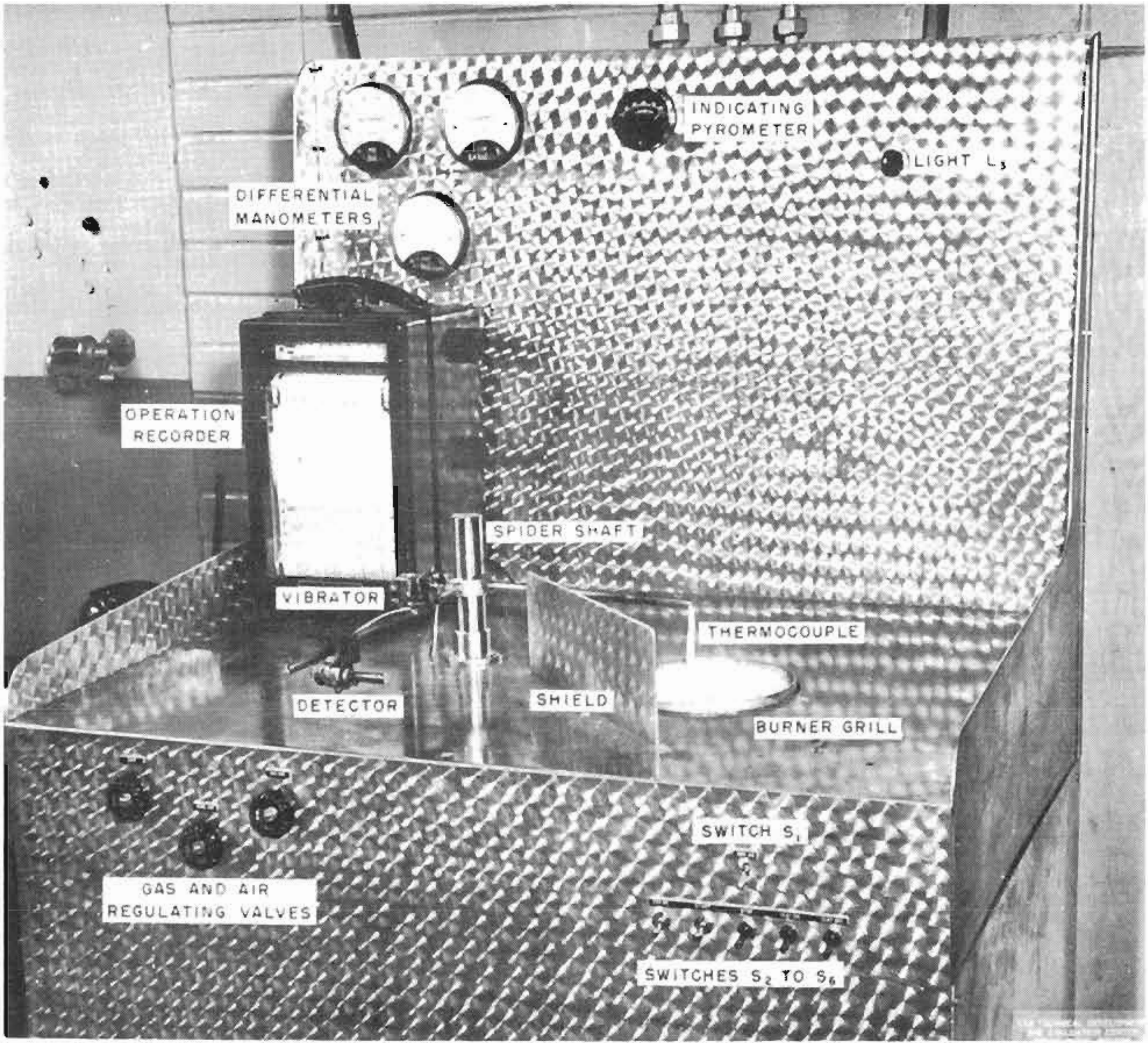


Fig. 5 Detector Test Bench

as detection is obtained, press switch S_1 momentarily and then place switch S_2 in the OFF position. The time required for detection on each of the three exposures to the flame should be noted. The time required to clear the signal should be noted after the first two exposures only.

Switches S_5 and S_6 are test switches. The detector circuit can be completed by pressing switch S_5. If the detector circuit is closed, it may be opened by pressing switch S_6. Light L_3 is an indicating lamp which lights whenever the detector senses fire. This enables the operator to note the condition of the detector without scrutinizing the chart on the operation recorder.

TYPICAL TEST RESULTS

The test bench has been used successfully for testing unit and continuous types of detectors in accordance with Specification AS-401A, as described under the section entitled "Objective Requirements." Typical results on the following detectors are presented.

Edison Model 108-8, manufactured by Thomas A. Edison, Incorporated.

This is a rate-of-rise, unit type of detector consisting essentially of a thermocouple junction. The system generally consists of a number of units connected in series with a control box. Tests conducted in this project utilized a circuit consisting of a single unit connected to the control box.

Fenwal No. 17343-61, manufactured by Fenwal Incorporated.

This is a fixed-temperature, thermal-switch, unit type of detector and operates on the principle of thermal expansion.

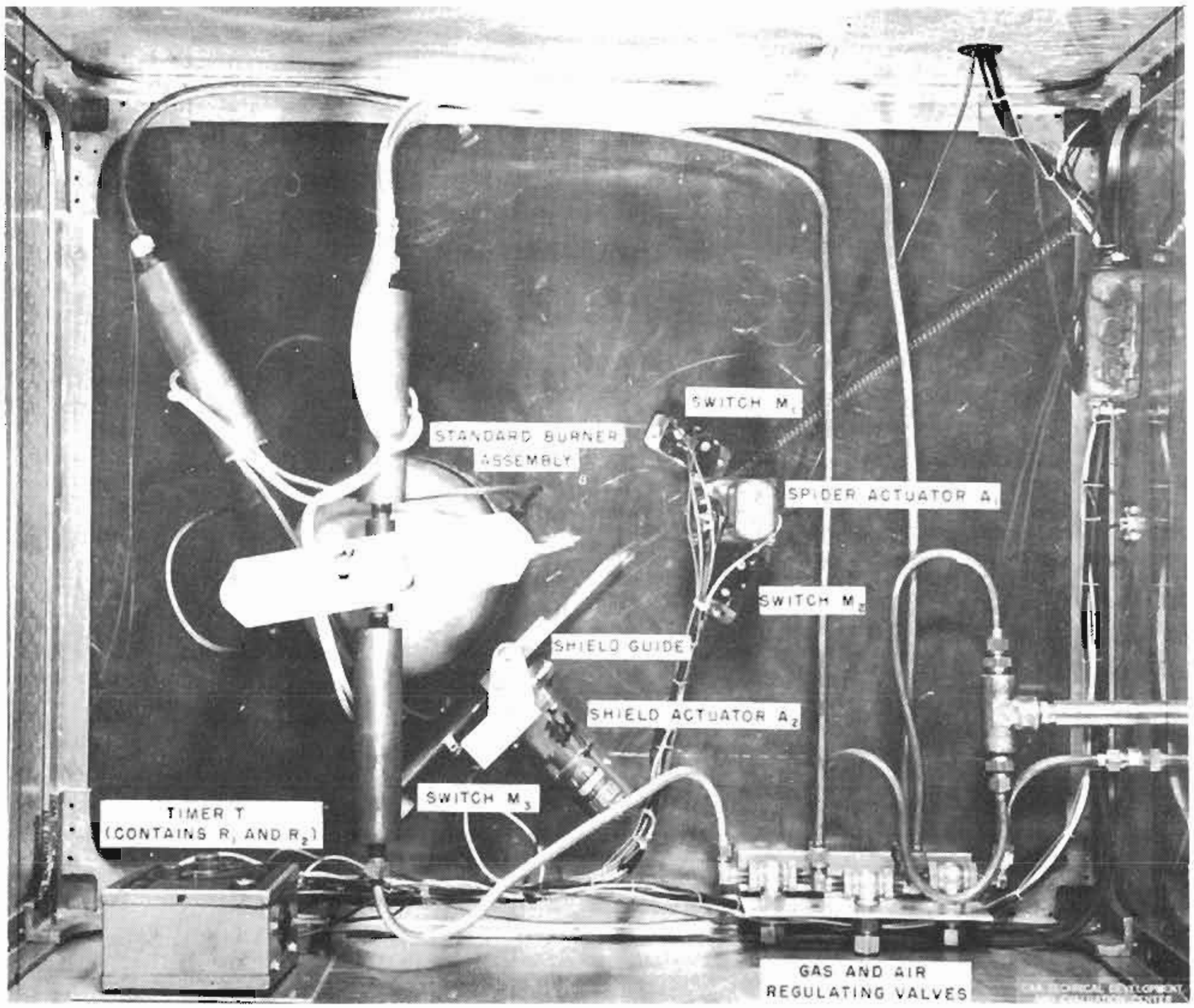


Fig. 6 View of Underside of Test Bench

Viking B-331, manufactured by Viking Instruments, Inc.

This is a fixed-temperature, thermal-switch, unit type of detector and operates on the principle of thermal expansion.

Wilcolator No. A-4981, manufactured by The Wilcolator Company.

This is a fixed-temperature, thermal-switch, unit type of detector and operates on the principle of thermal expansion.

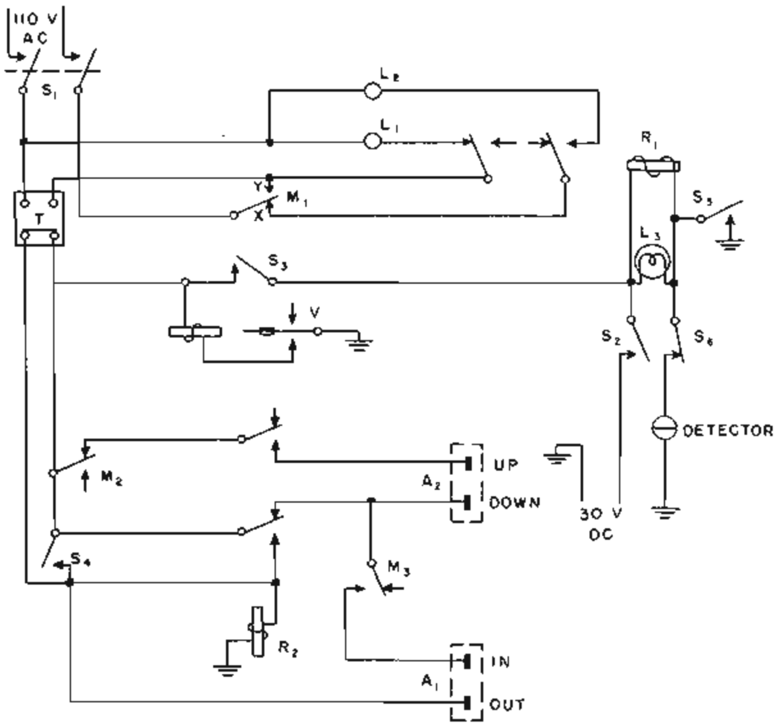
Walter Kidde Continuous Resetting Type, manufactured by Walter Kidde & Company, Inc.

This is a fixed-temperature, continuous type of detector approximately 1/16 inch in diameter and of any reasonable length. The continuous sensing element consists essentially of two conductors separated by an insulating material with a resistance which decreases appreciably at a predetermined temperature. An eight-inch portion of the element was subjected to the flame during the tests.

Results of tests conducted on these detectors and using the equipment described in this report are given in Table I. Results of the unit type of detectors are the averages obtained from three or more units.

CONCLUSIONS

It is concluded that this test arrangement automatically and accurately determines the response time, the repeat response time, and the flame resistance of aircraft heat and fire detectors as specified in Paragraphs 7.1, 7.1.1, and 7.14 of the SAE Specification AS-401A.



LEGEND:
A_1 — ACTUATOR (SPIDER)
A_2 — ACTUATOR (SHIELD)
R_1 — DPDT RELAY 24 V DC COIL
R_2 — DPDT RELAY 24 V DC COIL
M_1 — MICROSWITCH SPDT
M_2 — MICROSWITCH NORMALLY CLOSED
M_3 — MICROSWITCH NORMALLY OPEN
S_1 — DPST SWITCH
S_2 — SPST SWITCH
S_3 — SPST SWITCH
S_4 — SP SWITCH NORMALLY OPEN (MOMENTARY)
S_5 — SP SWITCH NORMALLY OPEN (MOMENTARY)
S_6 — SP SWITCH NORMALLY CLOSED (MOMENTARY)
L_1 — OPERATION RECORDER
L_2 — OPERATION RECORDER
L_3 — 24 - VOLT LIGHT
T — TIMER
V — VIBRATOR

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Fig. 7 Electrical Circuit Diagram for Detector Test Bench

TABLE I

RESULTS OF BENCH TESTS ON AIRCRAFT FIRE DETECTORS
(Tests Conducted in Accordance With SAE Specification AS-401A, Paragraphs 7.1, 7.1.1, and 7.14)

Detector Manufacturer	1500° F Flame 30,000 BTU Per Hour		2000° F Flame, 65,000 BTU Per Hour				
			1st Exposure		2nd Exposure		3rd Exposure
	Response Time (seconds)	Repeat Response Time (seconds)	Response Time (seconds)	Clearing Time (seconds)	Response Time (seconds)	Clearing Time (seconds)	Response Time (seconds)
Edison Model 108-8	2.0	3.2	1.2	15.7	1.3	7.5	1.35
Fenwal No. 17343-61	3.0	0.5	1.5	26.0	1.7	19.6	1.65
Viking B-331	3.2	1.4	1.5	2.1	1.8	1.5	1.7
Wilcolator No. A-4981	3.0	1.6	1.9	16.0	2.3	12.5	2.5
Walter Kidde Continuous Resetting	4.0	1.5	2.4	20.5	2.2	20.5	2.3

Table I. Results of Bench Tests on Aircraft Fire Detectors

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