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Effect of Element-Wall Thickness on Operation of Continuous Fire-Detector Systems

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UNITED STATES DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES

Effect of Element-Wall Thickness on Operation of Continuous Fire-Detector Systems

By

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Aircraft Division

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EFFECT OF ELEMENT-WALL THICKNESS ON OPERATION OF CONTINUOUS FIRE-DETECTOR SYSTEMS*

SUMMARY

Tests were conducted to study the effect of element-wall thickness on the operation of continuous fire-detector systems. The elements tested were furnished by Walter Kidde & Company, Inc., and by Thomas A. Edison, Inc. They included the standard, thin-wall, and the heavy-wall types from both companies, and a double-wall Edison element with the same diameter as the thin-wall element. This double-wall element was claimed to be more rugged than the thin-wall element.

The elements first were placed in an electric furnace and subjected to a slow rate of temperature increase to check the similarity of the temperature-resistance characteristics of the core materials between the heavy- and thin-wall elements, because differences would influence the test results. The elements then were tested by placing them over a standard burner at 1500° and 2000°F., to obtain response and clearing times.

A second series of tests was conducted on an installation of the heavy- and thin-walled elements placed side by side in an engine bay of a test-cell-mounted F-89 airplane, using controlled test fires during simulated operation of the airplane. The results of the tests indicated that response and clearing times were increased appreciably by use of the heavy-wall elements and that these elements did not meet the requirements of SAE Specification AS-401A, Section 7.1 (Response Time). For the Edison double-wall element, response and clearing times at 1500° F. flame temperature were not appreciably different from those of the thin-wall elements. At 2000° F., however, the response and clearing times of the double-wall element were somewhat longer than for the thin-wall elements. The double-wall element met the specification requirements for response times only when calibrated for ambient temperatures below 450° F.

INTRODUCTION

Handling of the sensing elements of continuous fire-detection systems during engine change and other maintenance functions often has resulted in breakage of these elements. In order to minimize this breakage, sensing elements with thicker walls have been developed. The purpose of this evaluation was to study the effect of the increased wall thickness on response and clearing times. This evaluation was initiated at the request of the Bureau of Aeronautics, Department of the Navy.

DETECTOR ELEMENTS TESTED

The following elements were submitted for testing by Walter Kidde & Company, Inc.:

1. Two lengths, 12 feet each, Part No. 809144, 0.088-inch outside diameter (OD).
2. Two lengths, 12 feet each, no part number, 0.064-inch OD.

These elements were described as having approximately the same core material, Type 1400-34, as that used in the 809 part-number series. They were produced for these tests in order that test results could be obtained to show the effect of the wall thickness without being influenced by differences in core material. After some differences were noted in the temperature-resistance characteristics of the core material used in the first elements submitted by Walter Kidde & Company, Inc., a second set of elements was submitted, as follows:

1. Two lengths, 10 feet each, Part No. 809120, 0.088-inch OD.
2. Two lengths, 10 feet each, no part number, 0.064-inch OD, with the same core material as that used in the first length.

*Manuscript received for publication December 1955.

A Walter Kidde d-c control unit, Serial No. 138, was used with the 809-series elements; and a control unit, Serial No. 182, was used with the thin-wall elements in the tests.

Thomas A. Edison, Inc., submitted sensing elements of three different types. Each type was 25 feet in length and was comprised of three sections. Two of these sections were 10 feet in length and one section was 5 feet. Three control units, Part Nos. 227-28-2, also were supplied. The three types of elements were:

1. Heavy-wall detector, 0.090-inch OD, Part No. 239-54I.
2. Double-wall detector, 0.070-inch OD, Part No. 239-54G.
3. Thin-wall detector, 0.070-inch OD, Part No. 234-54G.

TEST PROCEDURE

The elements supplied by Walter Kidde & Company, Inc., and Thomas A. Edison, Inc., were subjected to similar tests at different times. These consisted of: (1) furnace tests to note the degree of similarity in the core material of the heavy- and thin-walled specimens, (2) burner tests at 1500° and 2000° F. to observe differences in response and clearing times under standard carefully controlled conditions, and (3) full-scale tests in the engine bay of an F-89 aircraft to observe the differences in response and clearing times under simulated flight-fire conditions between the heavy- and thin-walled elements. The latter two tests also permitted a comparison of results obtained from bench- and full-scale-type tests.

Bench Testing.

The sensing elements first were placed in an electric furnace and subjected to a slow rate of temperature increase until a response was obtained. The furnace then was allowed to cool until the response signal cleared. The temperature at which the response and clearing occurred was noted for a series of calibration-resistor settings at the control box between 100 and 5000 ohms.

Following these tests, the elements were subjected to testing on the detector-test bench[1] in accordance with Society of Automotive Engineers (SAE) Specification AS-401A (Fire and Heat Detectors). The same calibration-resistor settings were used as in the furnace tests.

Tests in F-89 Engine Bay.

The sensing elements were installed in the left engine bay, with each type of element completing two loops encircling the engine at airplane stations 310 and 345. A view of this installation is shown in Fig. 1.

Test conditions simulating aircraft taxiing, taking off, cruising, and at maximum power were produced by varying the engine rpm, the pressure of ram air at the engine inlet, and the quantity of air to the cooling-air scoop for the engine bay. The afterburner also was operated during tests simulating takeoff and maximum power.

Fires were ignited within the left engine bay in regions of definite fire hazard. The test-fire locations are shown in Fig. 2. Fire nozzles installed at each of these locations consisted of 1/4-inch-OD copper tubing discharging aviation gasoline at a rate of two pounds per minute (1/3 gpm) and a spark plug and coil to provide ignition. Test-fire temperatures varied between 2000° and 2400° F. Fire size and intensity were greatly influenced by the turbulent airflow through the engine bay and were not consistent for all tests. Cooling airflow through the engine bay measured at the fire locations varied from 17.08 to 73.30 feet per second. Test fires burned until a fire warning was given or for ten seconds, whichever occurred first. The procedure was: (1) establish aircraft operational condition for the tests, (2) switch on the test-fire ignitor, and (3) start fuel flowing to the test fire. The time required for fire warning is the interval between the start of the fuel flow for test fire and a fire-warning indication. The fires were intense, but they were linear in form due to the influence of cooling air passing through the engine bay.

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[1] J. J. Gassmann, "A Burner and Test Bench for Evaluating Aircraft Fire and Heat Detectors," CAA Technical Development Report No. 217, September 1953.

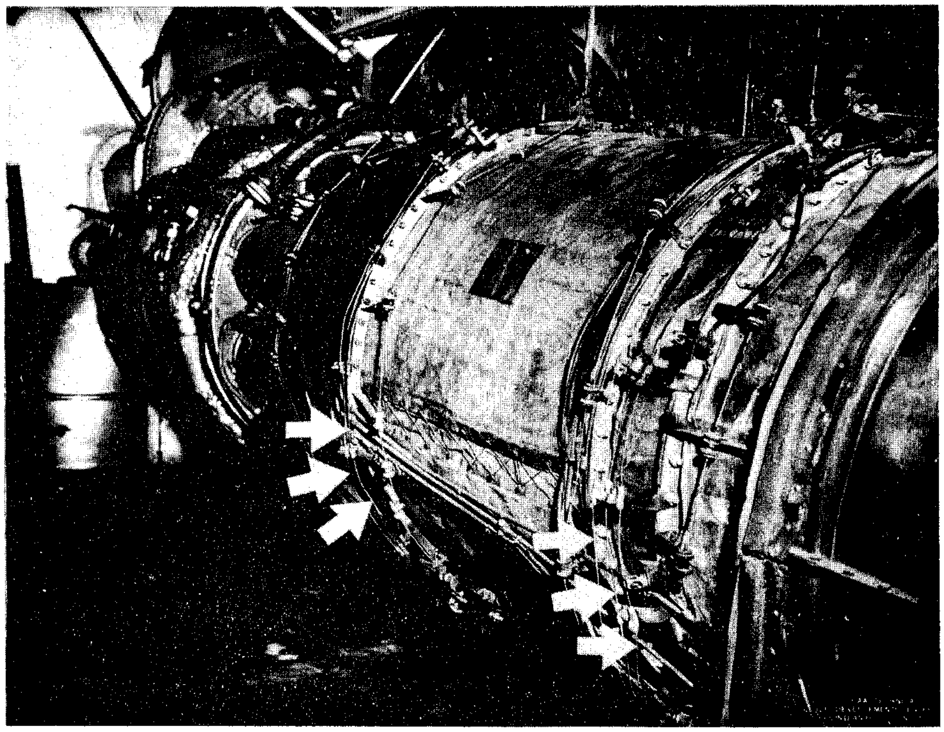

Fig. 1 Location of Sensing Elements for Tests in F-89 Aircraft

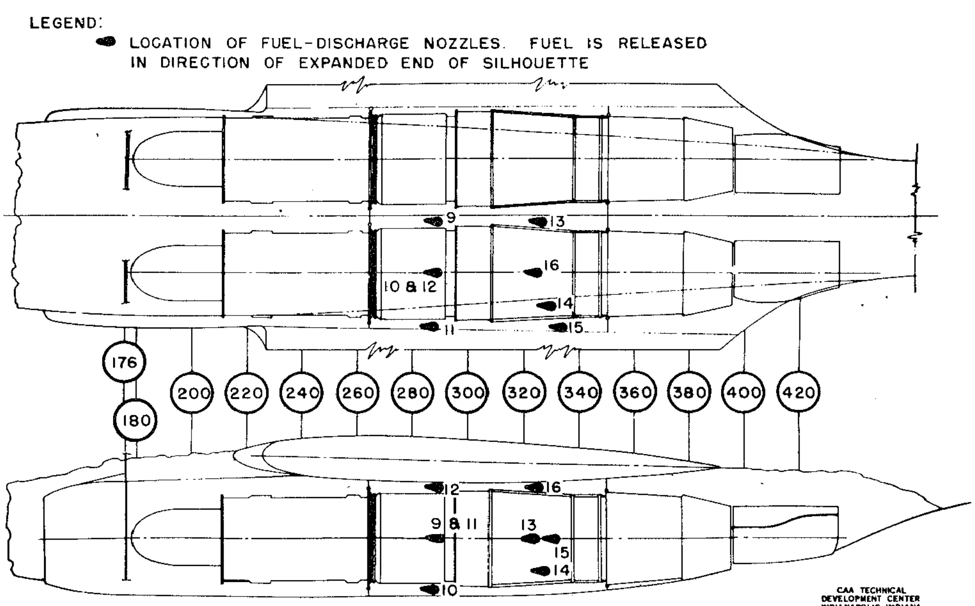

Fig. 2 Test Fire Locations in Left Engine Bay, F-89 Aircraft

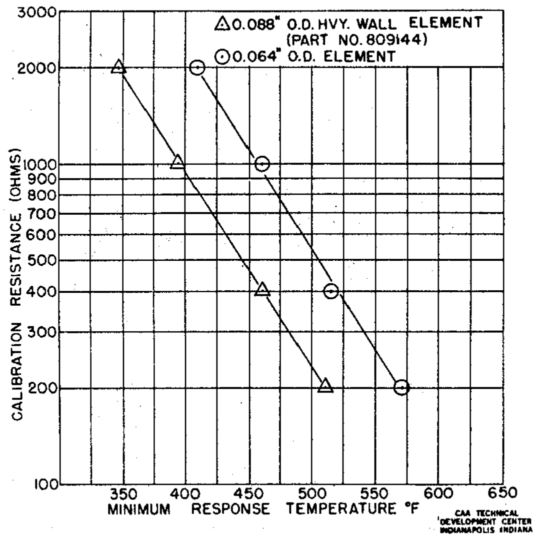

Fig. 3 Furnace Tests, First Set of Kidde Detector Elements

TEST RESULTS

Bench Testing.

The data obtained from the electric-furnace tests of the first elements submitted by Walter Kidde & Company, Inc., are shown in Fig. 3. The temperature-resistance characteristics of the core material for the two elements are quite different.

The response- and clearing-temperature data obtained from the electric-furnace tests of the second set of elements submitted by Walter Kidde & Company, Inc., are shown in Fig. 4. These data indicate that the temperature-resistance characteristics of the core material are similar.

The data obtained during tests on the detector-test bench, when the second set of elements submitted by Walter Kidde & Company, Inc., was tested, are shown in Figs. 5 and 6.

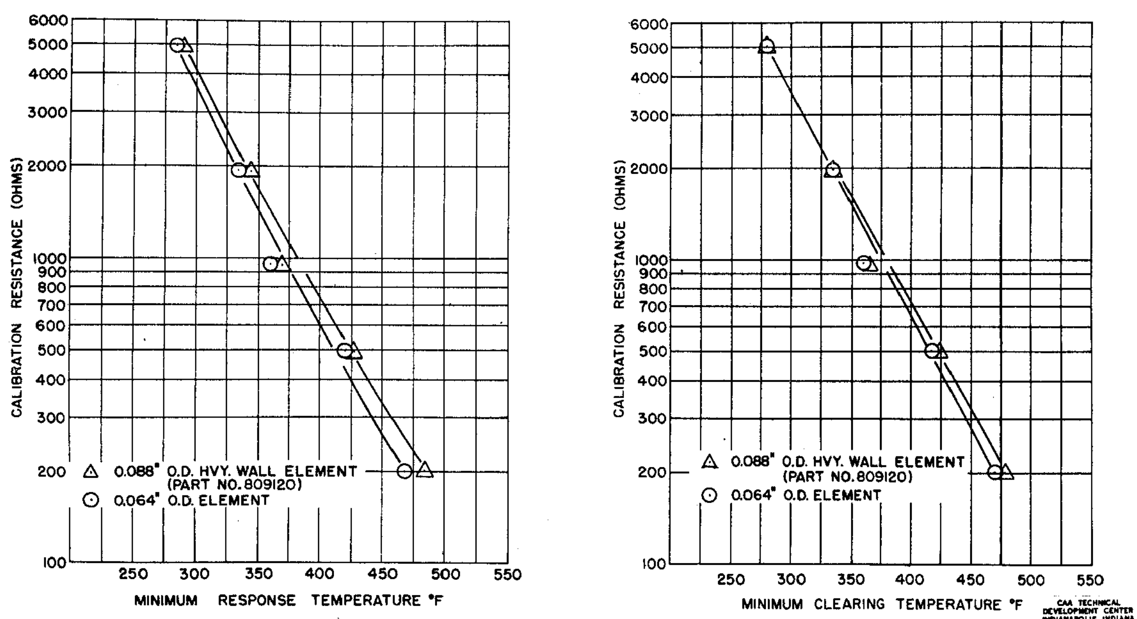

Fig. 4 Furnace Tests, Second Set of Kidde Detector Elements

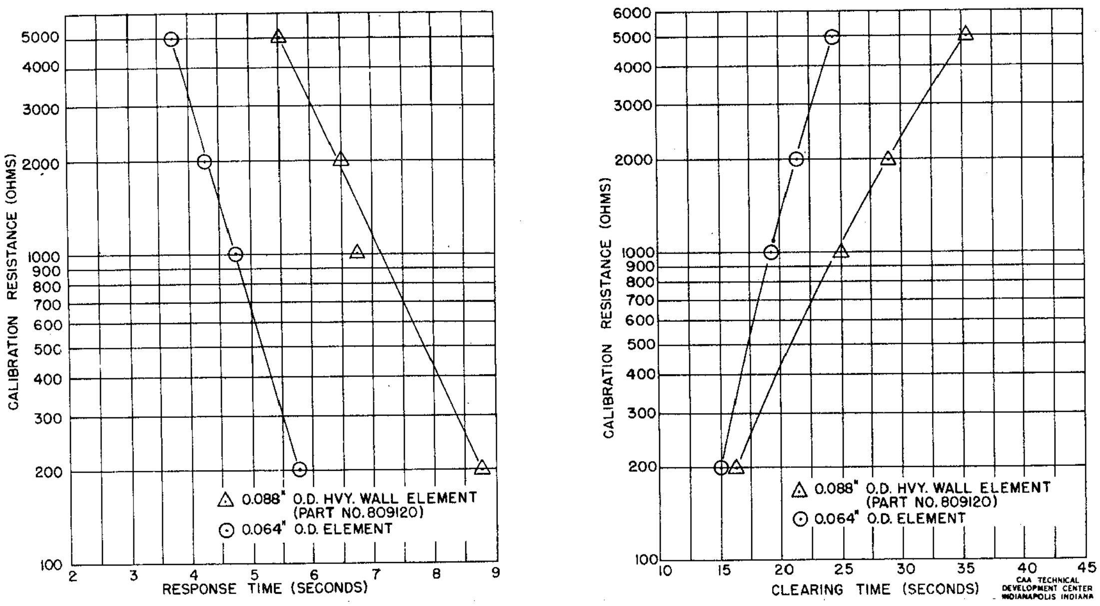

Fig. 5 Bench Tests, 1500° Flame, Second Set of Kidde Detector Elements

Figures 7 and 8 show the response and clearing times obtained during the detector bench tests when plotted against the minimum response-temperature settings as determined in the electric furnace.

The data obtained from the electric-furnace tests of the sensing elements first submitted by Thomas A. Edison, Inc., are shown in Fig. 9. These data indicate that the temperature-resistance characteristics of the core materials of the three types of elements are similar.

The data obtained during tests on the detector bench, when the three elements submitted by Thomas A. Edison, Inc., were tested, are shown in Figs. 10 and 11.

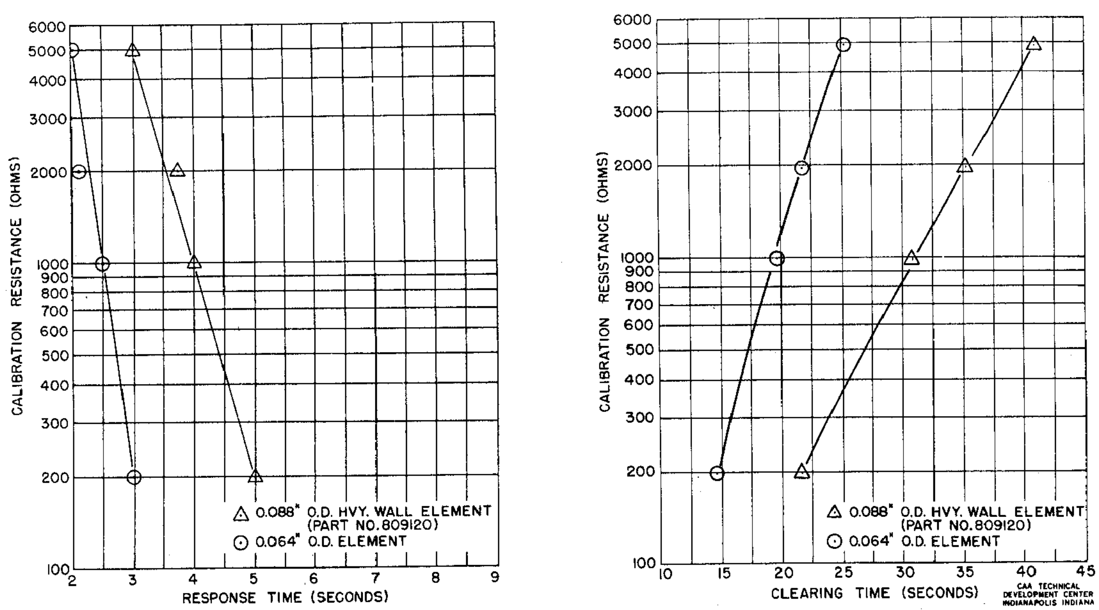

Fig. 6 Bench Tests, 2000° Flame, Second Set of Kidde Detector Elements

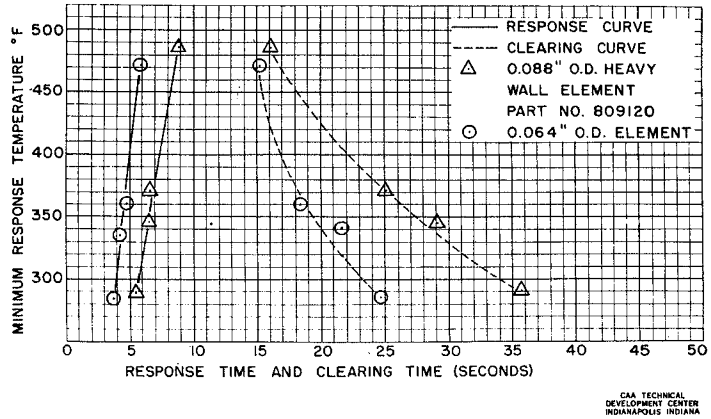

Fig. 7 Bench Tests, 1500° Flame, Second Set of Kidde Detector Elements

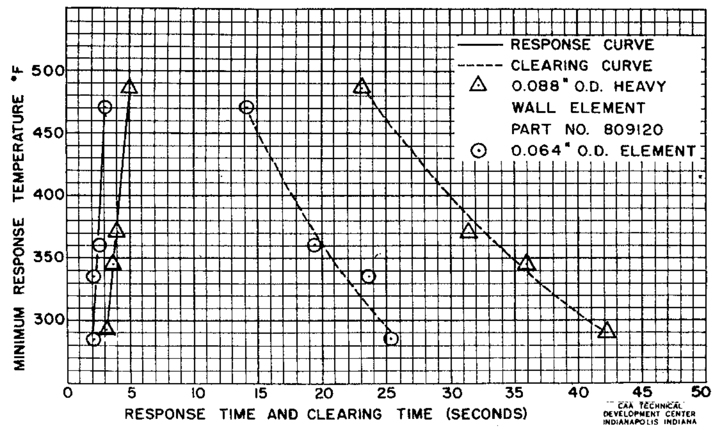

Fig. 8 Bench Tests, 2000° Flame, Second Set of Kidde Detector Elements

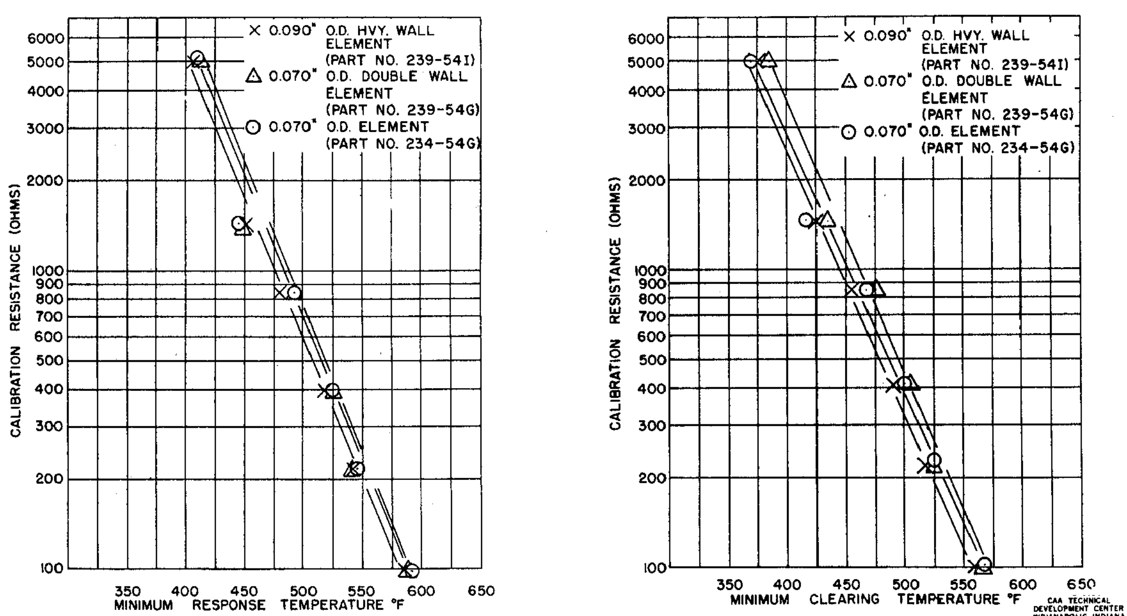

Fig. 9 Furnace Tests, Edison Detector Elements

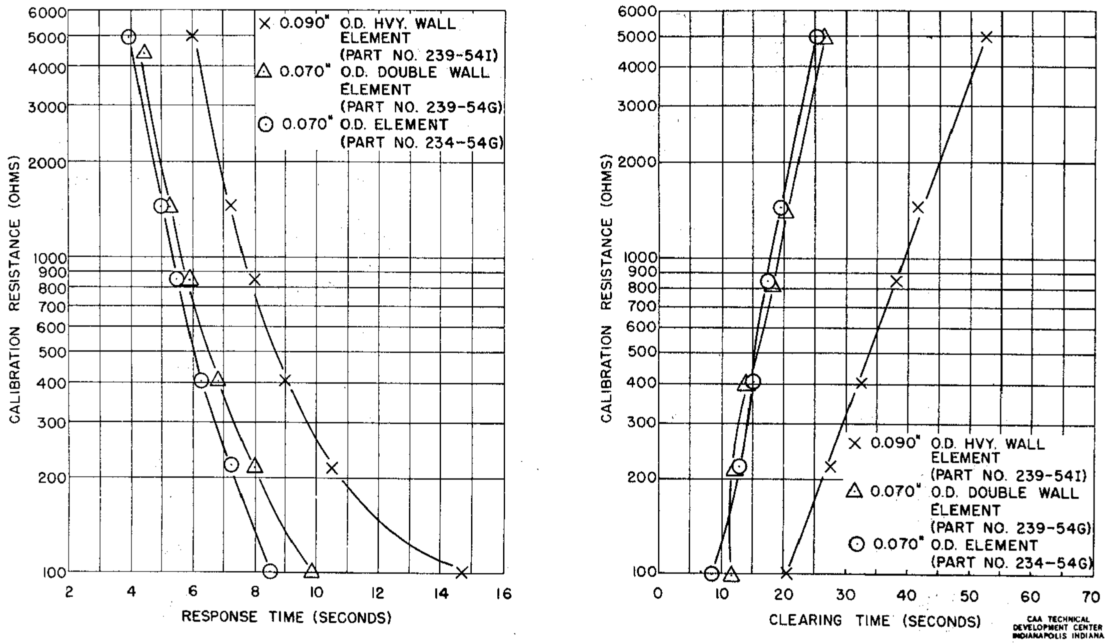

Fig. 10 Bench Tests, 1500° Flame, Edison Detector Elements

Figures 12 and 13 show the response and clearing times obtained during the detector bench tests when plotted against the minimum response-temperature settings as determined in the electric furnace.

Tests in the F-89 Engine Bay.

The first elements installed for testing in the F-89 airplane were the 12-foot lengths submitted initially by Walter Kidde & Company, Inc. Because the temperature-resistance characteristics were quite different, as indicated by the electric-furnace tests, Fig. 3, the

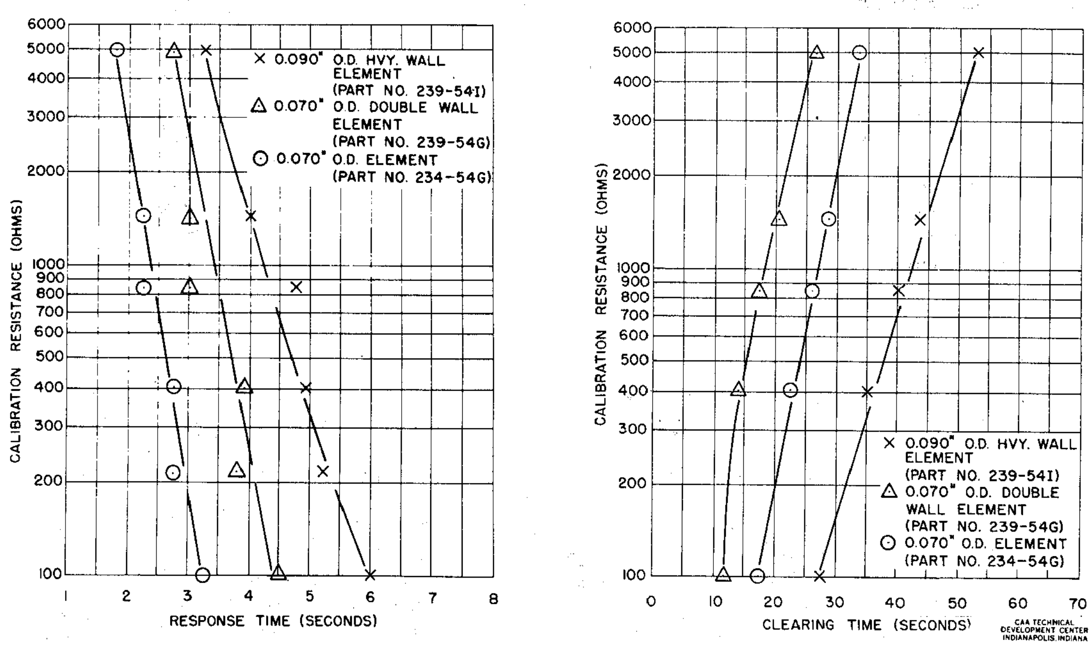

Fig. 11 Bench Tests, 2000° Flame, Edison Detector Elements

TABLE I

FIRE-DETECTION TESTS OF THE WALTER KIDDE CONTINUOUS-TYPE FIRE-DETECTOR SYSTEMS INSTALLED IN AN F-89 AIRPLANE POWER PLANT

First Set of Detector Elements Submitted

Test No.	Condition	Fire* Location (No.)	0.064-Inch-OD Element Alarm Time (seconds)	0.064-Inch-OD Element Clearing Time (seconds)	0.088-Inch-OD Element No. 809144 Alarm Time (seconds)	0.088-Inch-OD Element No. 809144 Clearing Time (seconds)
1	Taxiing	11	5.5	11.0	7.0	12.5
2	Taking Off	11	6.0	3.5	No	
3	Cruising	11	5.5	3.5	No	
4	Maximum Power	11	4.0	4.0	6.0	4.0
5	Taxiing	15	8.7	7.0	10.0	6.0
6	Taking Off	15	No		No	
7	Cruising	15	No		No	
8	Maximum Power	15	No		No	
9	Taxiing	10	3.0	10.0	4.0	12.0
10	Taking Off	10	3.0	7.5	3.6	10.0
11	Cruising	10	3.0	7.0	4.0	10.0
12	Maximum Power	10	5.5	4.0	7.5	5.5
13	Taxiing	14	3.0	12.0	4.0	14.0
14	Taking Off	14	3.5	9.0	4.0	11.0
15	Cruising	14	3.0	9.0	4.5	10.0
16	Maximum Power	14	3.7	10.0	4.2	12.0
17	Taxiing	12	3.0	No Record	4.0	No Record
18	Taking Off	12	No Test			
19	Cruising	12	2.5	22.0	4.0	25.0
20	Maximum Power	12	2.0	17.0	3.0	19.0
21	Taxiing	13	6.3	12.0	10.0	10.0
22	Taking Off	13	2.3	9.0	3.4	11.7
23	Cruising	13	3.5	11.3	5.5	11.5
24	Maximum Power	13	3.0	8.0	3.5	9.0
25	Taxiing	9	9.2	4.0	No	
26	Taking Off	9	6.5	5.5	7.5	5.5
27	Cruising	9	9.0	2.5	No	
28	Maximum Power	9	9.5	2.5	No	

*Refer to Fig. 2.

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resistance settings of the control circuits were altered in order that both systems would have a minimum response temperature of approximately 550° F. The data obtained during the tests are presented in Table I.

Although the two types of elements were approximately in the same location, the system with the thin-wall elements reported 24 fires, whereas the system with the No. 809144 heavy-wall elements reported 19 fires. The average response time on fires reported by systems with both elements (average of 19 tests) was 3.9 seconds for the one with the thin-wall element and 5.3 seconds for the one with the No. 809144 heavy-wall element. The average clearing time (average of 18 tests) was 9.7 seconds for the thin-wall element system and 11.0 seconds for the system with the heavy-wall elements. Complete coverage of the fire zone with those sensing elements was not effected in this installation. It was intended only to determine the difference

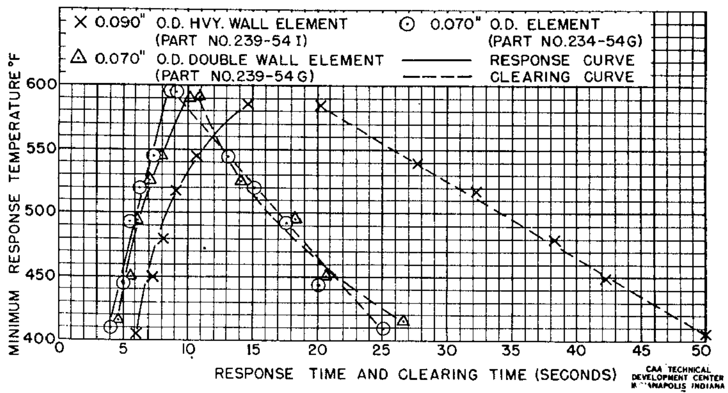

Fig. 12 Bench Tests, 1500° Flame, Edison Detector Elements

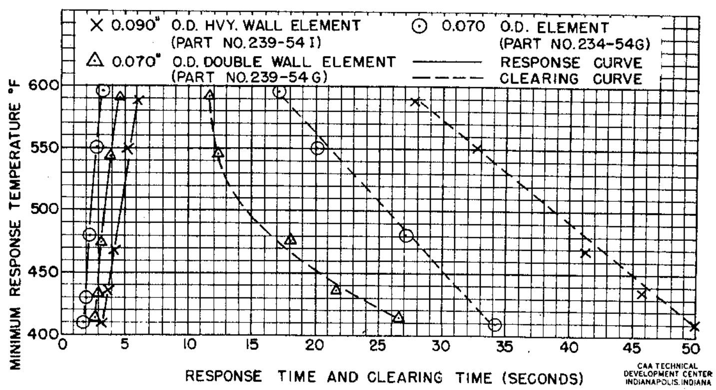

Fig. 13 Bench Tests, 2000° Flame, Edison Detector Elements

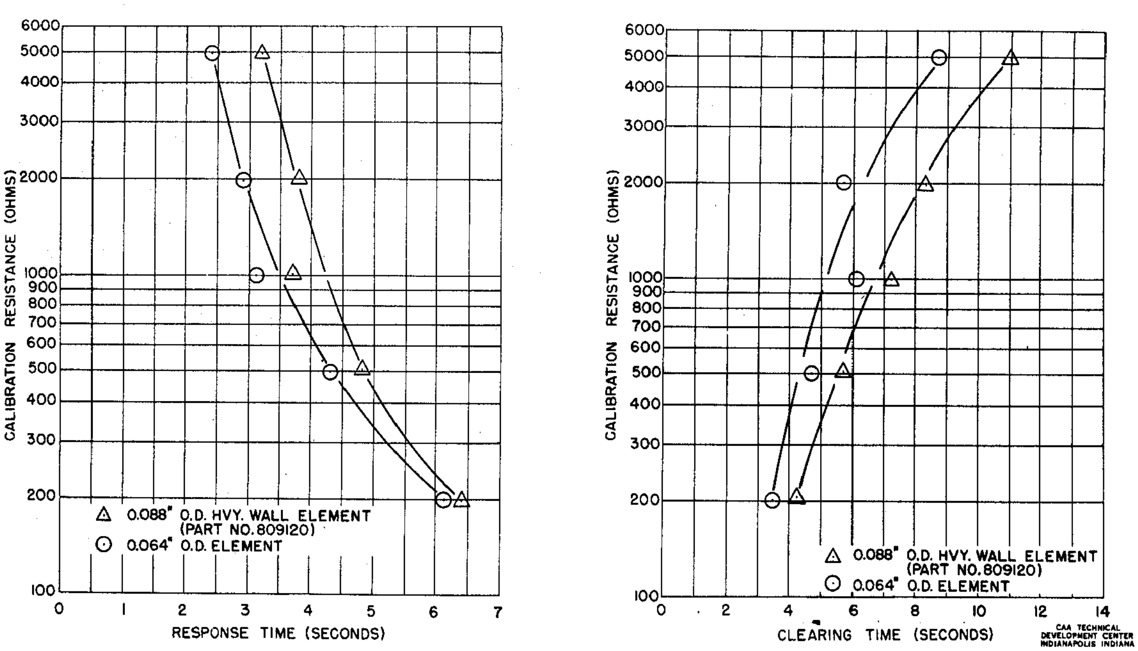

Fig. 14 Fire Tests in F-89 Aircraft, No. 11 Fire Location, Second Set of Kidde Detector Elements

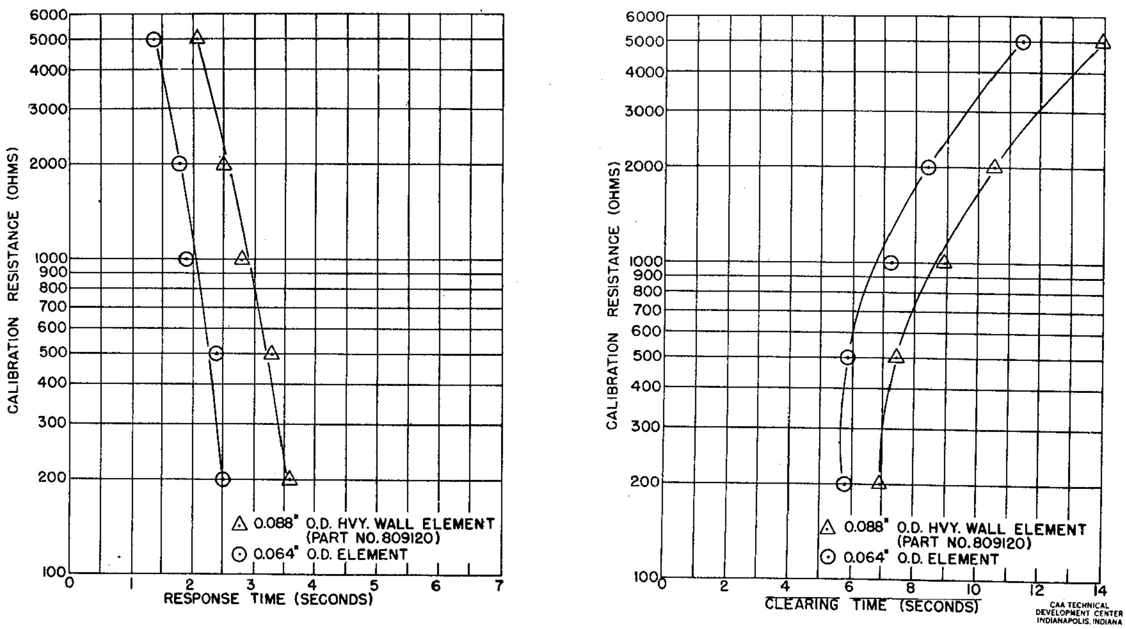

Fig. 15 Fire Tests in F-89 Aircraft, No. 14 Fire Location, Second Set of Kidde Detector Elements

in response of the two elements. Therefore, the fact that some fires were not detected is not significant.

Tests in the F-89 airplane on the 10-foot lengths of elements manufactured by Walter Kidde & Company, Inc., (second set submitted) were conducted with fires at locations Nos. 11 and 14 only. Calibration-resistor settings in the control box were varied through a range of 200 to 5000 ohms. Figures 14 and 15 contain curves drawn from the data obtained during these tests. The curves show the average response and clearing times for test fires at each of the two locations in the engine bay versus the calibration-resistor setting. Each point represents the average time of four tests conducted under simulated conditions of taxiing, taking off, cruising, and maximum power. Figures 16 and 17 show the response and clearing times obtained during these tests when plotted against the minimum response-temperature settings as determined in the electric furnace.

The same series of tests was conducted on the three continuous systems submitted by Thomas A. Edison, Inc. The data obtained in these tests are shown in Table II and Figs. 18 through 21. The average response times were:

1. Element No. 234-54G (thin-wall), 0.070-inch OD	2.54 seconds
2. Element No. 239-54G (double-wall), 0.070-inch OD	2.94 seconds
3. Element No. 239-54I (heavy-wall), 0.090-inch OD	3.8 seconds

The average clearing times were:

1. Element No. 234-54G (thin-wall), 0.070-inch OD	9.05 seconds
2. Element No. 239-54G (double-wall), 0.070-inch OD	8.5 seconds
3. Element No. 239-54I (heavy-wall), 0.090-inch OD	9.0 seconds

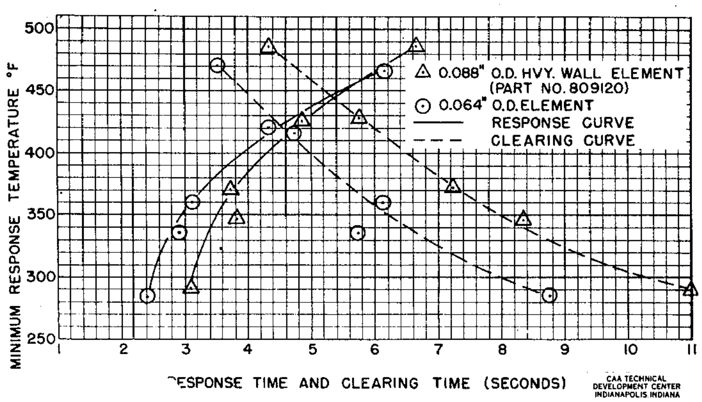

Fig. 16 Fire Tests in F-89 Aircraft, No. 11 Fire Location, Second Set of Kidde Detector Elements

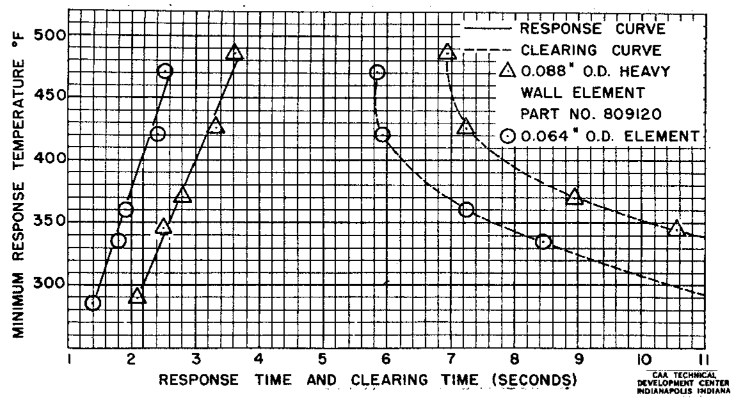

Fig. 17 Fire Tests in F-89 Aircraft, No. 14 Fire Location, Second Set of Kidde Detector Elements

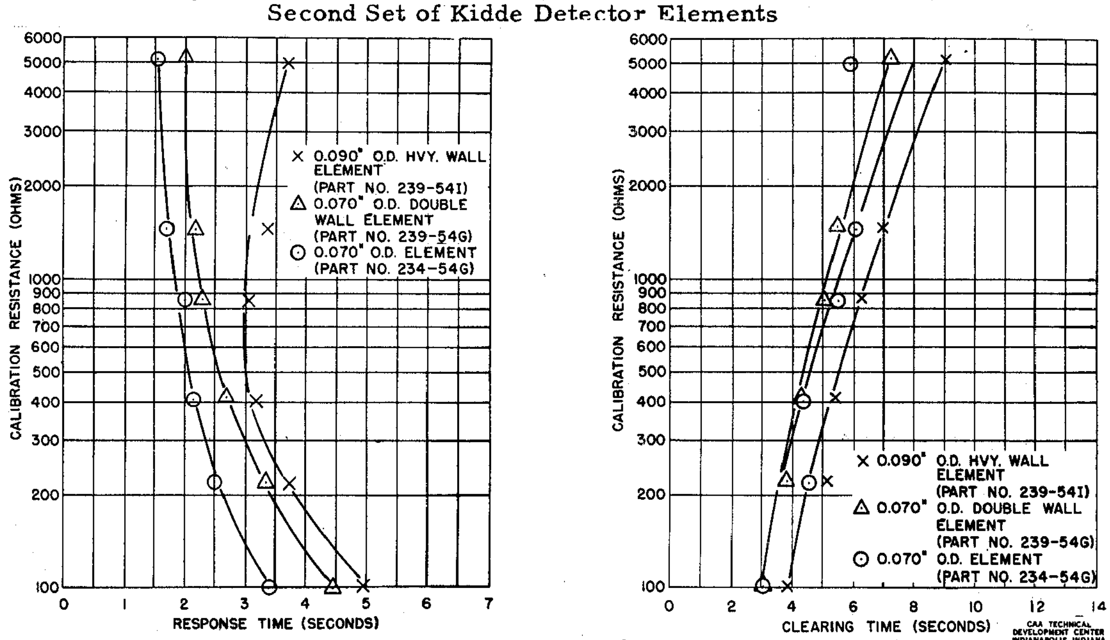

Fig. 18 Fire Tests in F-89 Aircraft, No. 11 Fire Location, Edison Detector Elements

TABLE II

FIRE-DETECTION TESTS OF THE EDISON CONTINUOUS-TYPE FIRE-DETECTOR SYSTEMS INSTALLED IN AN F-89 AIRPLANE POWER PLANT

			0.070-Inch-OD Element No. 234-54G		0.070-Inch-OD Element No. 239-54G		0.090-Inch-OD Element No. 239-54I	
Test No.	Condition	Fire* Location (No.)	Alarm Time (seconds)	Clearing Time (seconds)	Alarm Time (seconds)	Clearing Time (seconds)	Alarm Time (seconds)	Clearing Time (seconds)
1	Taxiing	9	2.7	14.8	4.0	10.2	4.5	11.8
2	Taking Off	9	1.8	Abort	2.3	6.3	2.5	7.2
3	Cruising	9	No	Abort	2.5	7.7	3.3	9.5
4	Maximum Power	9	No	Abort	2.8	6.2	3.1	11.6
5	Taxiing	10	4.3	5.7	4.7	4.0	5.5	3.4
6	Taking Off	10	4.8	3.8	5.5	3.2	6.7	2.2
7	Cruising	10	5.3	3.5	6.0	2.5	6.8	2.0
8	Maximum Power	10	5.7	3.4	6.8	2.8	8.0	2.0
9	Taxiing	11	1.7	9.8	2.2	8.5	2.5	8.8
10	Taking Off	11	2.3	3.5	2.8	2.5	3.3	2.3
11	Cruising	11	2.2	4.7	2.8	3.5	3.2	3.7
12	Maximum Power	11	2.5	3.6	3.0	2.8	3.7	2.6
13	Taxiing	12	2.3	14.6	3.2	10.3	4.2	9.9
14	Taking Off	12	1.3	9.6	1.8	7.8	2.4	8.0
15	Cruising	12	1.6	11.3	2.3	9.0	2.8	9.0
16	Maximum Power	12	1.3	9.0	1.8	7.8	2.2	7.4
17	Taxiing	13	2.7	19.2	3.0	19.5	4.3	26.4
18	Taking Off	13	2.7	9.1	3.0	9.4	3.0	13.5
19	Cruising	13	2.3	12.2	2.8	12.2	2.8	16.1
20	Maximum Power	13	2.6	8.0	2.0	8.0	3.3	12.1
21	Taxiing	14	2.3	6.5	2.5	6.5	2.9	7.9
22	Taking Off	14	1.7	8.0	1.8	8.3	2.8	0.8
23	Cruising	14	1.7	5.8	2.2	5.3	2.7	5.6
24	Maximum Power	14	1.4	5.4	1.7	5.2	2.2	4.0
25	Taxiing	15	3.0	5.3	3.0	5.8	3.6	5.0
26	Taking Off	15	2.2	7.1	2.2	9.5	8.8	12.6
27	Cruising	15	2.0	5.7	2.1	6.3	2.6	6.0
28	Maximum Power	15	1.8	3.3	1.8	4.1	2.4	3.6
29	Taxiing	16	3.6	22.2	3.8	20.8	5.4	20.0
30	Taking Off	16	2.0	13.7	2.3	14.0	2.9	5.8
31	Cruising	16	2.3	19.8	2.7	26.9	3.5	30.9
32	Maximum Power	16	2.1	13.7	2.7	14.2	3.3	14.7

*Refer to Fig. 2.

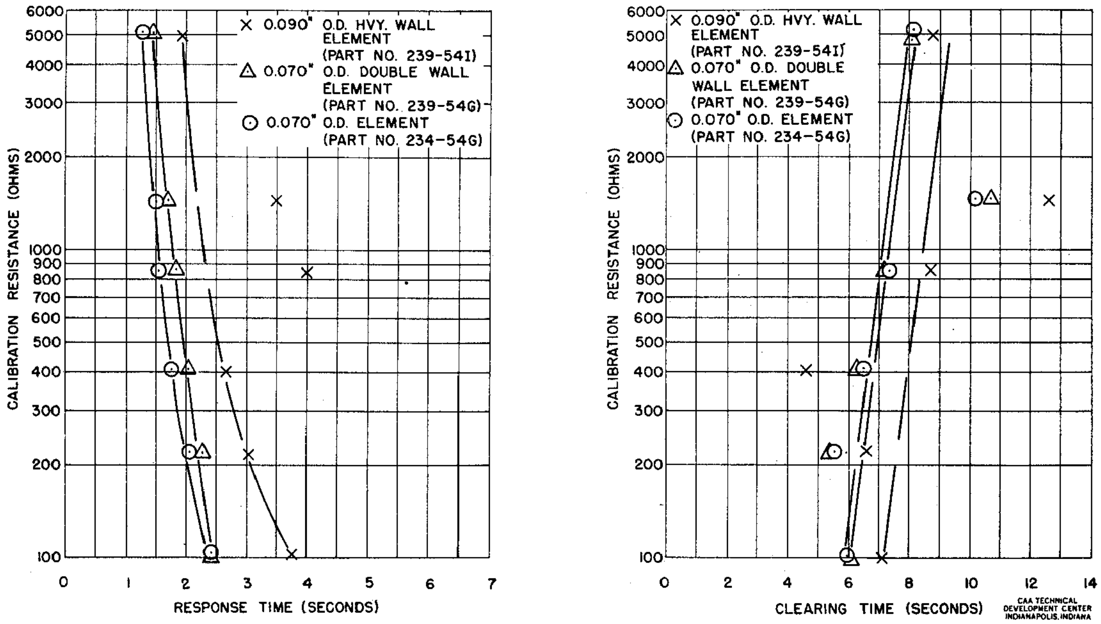

Fig. 19 Fire Tests in F-89 Aircraft, No. 14 Fire Location, Edison Detector Elements

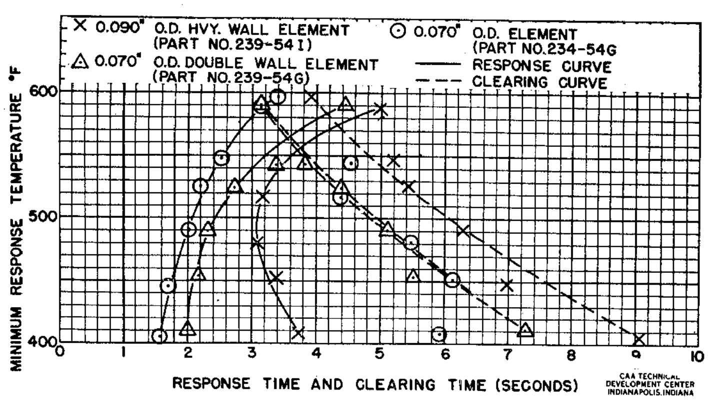

Fig. 20 Fire Tests in F-89 Aircraft, No. 11 Fire Location, Edison Detector Elements

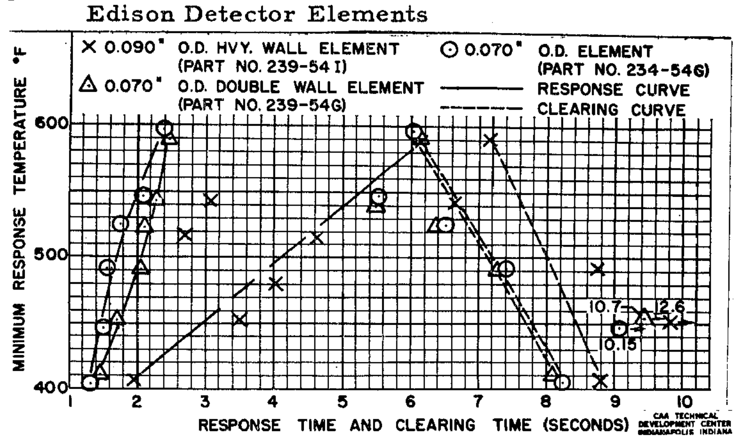

Fig. 21 Fire Tests in F-89 Aircraft, No. 14 Fire Location, Edison Detector Elements

CONCLUSIONS

1. The continuous fire-detection systems with heavy-wall elements required more time to respond and clear than did the systems with the lighter walls.

2. The heavy-wall systems submitted by both manufacturers did not meet the requirements of SAE Specification AS-401A, Section 7.1 (Response Time) at any of the calibrations used during the tests. The double-wall elements submitted by Thomas A. Edison, Inc., responded in five seconds or less only with ambient-temperature calibrations below 450° F.

3. Response and clearing times of all the systems tested were less during the tests with the F-89 airplane than during the tests conducted on the fire-detector-test bench in accordance with SAE Specification AS-401A. This difference in response time was caused by the higher flame temperatures of the test fires in the F-89 airplane, and the difference in clearing time was caused by the rapid cooling effect of air flowing through the engine bay. Test-fire temperatures varied from 2000° to 2400° F., and velocity of the air through the engine bay varied from 17.08 to 73.30 feet per second.

4. In addition to the effect of thickness of the material in the element wall, response and clearing times also are influenced by the following factors:

   A. Ambient-temperature calibration of the control box.
   B. Length of element in the circuit.
   C. Composition of the core material.

5. Because differences existed in element length and ambient-temperature settings between the products of the two manufacturers, and because variations of flame size and intensity occurred between one test and another in the F-89 airplane, the data contained in this report do not provide a reasonable basis for a comparison of the products of the one manufacturer against those of the other.

ACKNOWLEDGMENT

The author wishes to acknowledge the excellent co-operation of Walter Kidde & Company, Inc., and Thomas A. Edison, Inc., during this evaluation.