FIREPAC TEST PROGRAM

SUMMARY

FIREPAC Test Program

The following is a summary of the FIREPAC Test Program. The initial testing and evaluation commenced on 24 January 1968 with the first series being completed on 14 March 1968.

A test module was constructed at Fenwal's Holliston, Mass. facilities. The dimensions of the module are as follows:

Length - 32 feet
Width - 12 feet
Height - 8 feet

Figure 1, attached, shows the cross section of the test module with the DC-8 and DC-9 cabin cross sections superimposed.

A total of 55 fire test, 12 pattern tests and a series of detection comparisons were conducted. The fires were positioned at floor level at a distance of 3.5 feet from one wall in order to provide a 360 degree dispersal of heat and smoke at the ceiling.

The detectors were placed at the ceiling at a distance three feet from the other wall. This configuration is considered to represent the "worst" condition within an actual curved fuselage.

The horizontal distances from the fire to the detectors were varied from test to test.

Of the total of 55 tests, 31 tests were run to establish the sensitivity and reliability of the various detection principles. The detectors tested included Rate of Rise, Rate Compensated, Fixed Temperature, Optical Smoke, Ionization Smoke and Variable Resistance.

The horizontal distances between detectors and the fire were varied from 10 feet to 25 feet.

The fire sizes varied from 1/2 square feet to nine square feet.

A total of nine tests were conducted in order to establish the thermal energy pattern at the ceiling. The test fires were all Class B fires using flammable liquids such as Methyl Ethyl Ketone (MEK) and Pentane. Again, the sizes of the fires were varied from one square foot to nine square feet. The horizontal distances between fire and detectors were varied from 10 feet to 24 feet.

Several spreader designs were evaluated for most effective extinguishment. High speed motion pictures were taken to reveal the patterns developed.

From these studies, a design was selected which provides a discharge pattern of approximately 25 feet in diameter and covering a cross section from the cabin ceiling to three feet below the spreader. The spreader itself was located 50 inches above the cabin floor.

Extinguishing is reached in about two seconds, and the remaining agent is expelled in the next 1.5 seconds. The preferred spreader design was used in all extinguishing tests.

A total of seven extinguishing tests were performed under Class A category. The materials included Kraft paper covered wall, cardboard boxes, seat cushions and cushion covers.

For Class B fires, eight tests were performed. The fuels were MEK and Pentane. The fires varied in sizes from one square foot to nine square feet. In these tests, the extinguishing units were spaced 15 feet apart. In all eight tests, candles were placed at three levels along the wall, the levels being ceiling, mid-wall and floor. In five tests, kerosene lanterns were also used. The object was to check agent distribution.

In six of these tests, the discharge times were also varied between 3.5 seconds and 60 seconds in order to check the effect on extinguishing effectiveness and design the decomposition levels produced.

All tests extinguished the fires as well as the candles and lanterns.

Complete details of the test data are shown in Figure V.

Conclusions

As a result of this test program, we determined that for reliable detection, a Rate Compensated Thermal Detector should be used. Spot units in a system should also use ionization (two per aircraft) for early warning only. This combination will give needed protection for endangered aircraft automatically when a rapid fire hazard exists and will also provide room for effective individual action in case of a smoldering fire that seems to propagate at a slow speed. A fire of this type may be put out manually when detected.

Rapid agent application further insures extinguishment even when aircraft is being ventilated. It further insures that the visibility is not reduced and it provides a cleaner extinguishment. In all fire tests where extinguishing agent (Halon 1301) was used, all fires were extinguished.

The next step in the FIREPAC Test Program was an evaluation under actual conditions. At the request of United Air Lines, tests were conducted at their San Francisco facilities.

These tests were conducted by United Air Lines and witnessed by representatives of most major airframe manufacturers and major airlines. There were three tests, two run on Tuesday, June 25, and one run on Wednesday, June 26.

Test No. 1 - FIREPAC fully operational, partial ventilation

Aircraft fuselage 5600+ cubic feet

Four FIREPACs utilized

Two doors open on right side of the aircraft

Front door - 45 inches wide by 60 inches high

Rear door - 23 inches wide by 50 inches high

All FIREPACs installed normally with detectors at ceiling on right side of the aircraft. FIREPAC No. 1 at rear of cockpit area, No. 2 and No. 3 in cabin area forward of main door, No. 4 in rear cabin just forward of the lounge.

Two 16 inch square pans were placed on the left side of the aircraft. Each pan contained a low water base, 2-1/2 gallons of JP-5 turbine fuel and a "salting" of gasoline for ignition. The forward pan was located between two seats just ahead of the forward cabin "window-type" emergency exit. The second pan was located at the intersection of the honeycombed plywood partition (forward of the main passenger exit door) and the cabin wall behind a passenger seat. Thermocouples were strung four inches below the ceiling throughout the aircraft at ceiling height and four were spaced down to the floor at midsection.

One FIREPAC unit was located in the cockpit with end-of-line relay installed. The next FIREPAC was located at the forward section of the cabin, the third was placed in the rear of the forward cabin and the fourth in the first-class section of DC-7B near the rear lounge.

The test was run at approximately 11:00 a.m. Wind speed was low, (5 to 10 knots). The pans were ignited by torches simultaneously. Jim Brenneman of United Air Lines ignited the front one and Don Heine of the Airline Pilots Association and Northwest Airlines ignited the rear pan. The temperature reached about 160°F at the nearest thermocouple when the units fired, approximately 26 seconds after ignition.

Both fires were extinguished. Damage at the rear pan consisted of one seat and approximately 10 square feet of wall surface scorched. Damage from the front fire consisted of two partly charred seats and approximately four square feet of wall covering. Flame height did not exceed hat rack level. No products of decomposition were noted.

Test No. 2 - FIREPAC Detection System crippeled, partial ventilation

Test No. 2 duplicated conditions in the first test with the exception that one pan was used in the rear position and the seat just forward of it was laid back against the partition. Thus, the pan was in a little cave on the floor about 18 inches under the sloping seat back.

The FIREPACs were in the same position, but the rear cabin detector on FIREPAC No. 3 was disconnected from its mast and placed on a seat so it could not detect. The forward cabin detector on FIREPAC No. 2 was lowered to minimum extension, approximately 1-1/2 inches below the finished ceiling level. This test was run in the afternoon and the San Francisco breeze had started.

Lloyd Nygren of Boeing took velocity measurements inside the aircraft and at the cabin doors during the extinguishments. Air flow was from aft to forward. The Boeing hygienist, Nick Novak, performed gas sampling tests during this second test only. The pan was ignited by Mr. Brenneman. Temperature at the nearest thermocouple reached 260°F at the firing point. Thirty-six seconds after ignition the fire was detected and extinguished.

Damage consisted of surface burning on one seat above the fire and a four foot wide strip of wall covering to the center of the ceiling plus some damage to the plywood partition which started the delaminating.

Test No. 3 - FIREPAC Detection System crippled, full ventilation

In response to considerable interest on what our system would do with the ventilation when the cabin doors were wide open, the DC-7B cabin was opened on all available access ports.

These consisted of 10 openings as follows:

Left Side (forward to aft) - Cockpit window - 20" by 20"

Forward over hatch - 22" wide by 37 " high

Rear over hatch - 22" wide by 36" high

Passenger door - 36" wide by 72" high

First class hatch - 21" wide by 25-1/2" high

Right Side - Forward door - 43" wide by 60" high

Forward over hatch - 21" wide by 25-1/2" high

Rear over hatch - 21" wide by 25-1/2" high

First class cabin hatch - 21" wide by 25-1/2" high

Rear door - 23" wide by 50" high

By the time the tests were run, the afternoon breeze had started again. Outside air hit 1800 feet per minute 205 mph maximum 10 degrees off the left nose of the aircraft, blowing almost directly into the pilot's open window. The interior fuselage air speed measurements ranged from 100 feet per minute to 200 feet per minute at various locations within the aircraft. Movement of the air was from forward to aft.

The position and condition of the FIREPAC units was the same as in Test No. 2.

The fire was created in the rear section again, but moved forward one chair section to permit use of unburned wall area. A seat cushion was propped up above the seat cushion in the chair about two inches. It extended over the space beyond the chair. It was hoped that a shielded fire would incubate here. Several sheets of waste paper and newspaper were stuffed into the back pocket of the chair in front. The fire was ignited by Jim Brenneman. Considerably more flame was permitted. Temperatures reached 265°F in 37.5 seconds when the Halon discharged. Unlike the two previous tests, the paper in the chair back pocket continued to smolder. Ernest Yohn of Pan American timed from discharge to reignition. The paper required 7-1/2 minutes to reignite and another 30 to 40 seconds before it reached a level large enough to require a 2-1/2 gallon water-filled extinguisher which easily completed final extinguishment.

COMMENTS

1. No external aircraft damage was visible.
2. "Total Damage" (fire - smoke - extinguishment) damage was held to an absolute minimum.
3. Halon 1301 concentration measurements made by Charles Ford of duPont indicated concentrations at 6.8% during Test No. 2 and 6.7% during Test No. 1. This concentration is relatively high due to the fact that no allowance was made for interior chairs or partitions.

A second "line" test series was conducted with, and at the request of, Boeing at their Everett, Washington facilities. These tests are outlined as follows:

Test No. 1

On Sunday, July 21 at 10:00 a.m., the first Boeing test was run.

The test vehicle was the nose-tail mock-up of the 747. This vehicle is worth between $4 and $10 million. The fuselage was cut by asbestos curtains at the 400 inch and 820 inch positions. The 400 inch position falls directly behind the cockpit on the upstairs level. The 820 inch curtain fell behind the second deck about 10 inches into the second doorway. The enclosed volume was approximately 10,000 cubic feet.

The fires in Test No. 1 were two in number. One 23 inch circular pan (the bottom of a 55 gallon drum), the other, eight inch by 20 inch pan. The 55 gallon drum was located at the center line of the aircraft at approximately the 750 inch position. The smaller pan was placed over the hole in the second deck for the circular staircase. Above each pan was a bailing wire "ladder". On this ladder were hung samples of all Boeing's interior fabrics and materials.

The FIREPAC 360 System to Cover the Area

Seven FIREPAC 360's were used. The upper deck was protected by a standard unit and by a "Stretch Model" located on the main floor reaching up into the overhead. The lower deck was protected by five standard units.

These tests were witnessed by representatives of Pan American and various insurance agencies.

Shortly after 10:00 a.m., the 55 gallon drum and the 20 inch pan were ignited simultaneously. Chief Morris of the Boeing Fire Department, Mr. Ford of duPont and Mr. Wilson of Fenwal remained in the airplane during the fire and subsequent extinguishment.

At 51 seconds, the units fired extinguishing the fires completely with no noticeable discomfort produced. Flame height from the 55 gallon drum was reported at four to six feet. Following the discharge, people began to enter the aircraft. Within three minutes, all spectators were inside.

Test No. 2

On Wednesday, July 24, at Boeing's request, a fire extinguishing test was conducted in the 727 fire test vehicle on Boeing Field. Two FIREPAC 360 units were used.

The fire consisted of a pile of rubbish including sawdust, two sheets of plywood, two 2 by 4's (one fire retardant treated and one plain), rolled up newspaper, crumpled newspaper, plain newspaper, cardboard boxes, rolled burlap bags, hard foam plastic, honeycombed plastic, two aircraft seats, aircraft cushions and the "ladders" of Boeing materials used in the Sunday test. Ignition was from a gasoline soaked cotton rope.

The fire was ignited by a blow torch on the gasoline soaked cotton rope and on a rolled burlap bag hung from the ceiling. One unit was seven feet from the fire, the other 17 feet from the fire.

Unlike the test on Sunday, the plane was loaded with people including the cameraman, the Manager of Security, the Fire Chief, Chief Fire Protection Engineer, FIA observers and other insurance personnel.

The smoke signal activated on the FIREPAC system between 20 and 25 seconds from ignition. The fire alarm and extinguishing activated about a minute after ignition.

As in the previous United test, rekindling occurred in some scrap paper eight minutes after original extinguishment.

Figure No. II is a detailed listing of the parameters monitored during the Boeing tests conducted on 20 July 1968.

In addition to these test programs, several "work around" evaluations were conducted. FIREPAC 360s were supplied to various airframe manufacturers and airline companies for their evaluation of the equipment with regard to ease of installation - work around and removal.

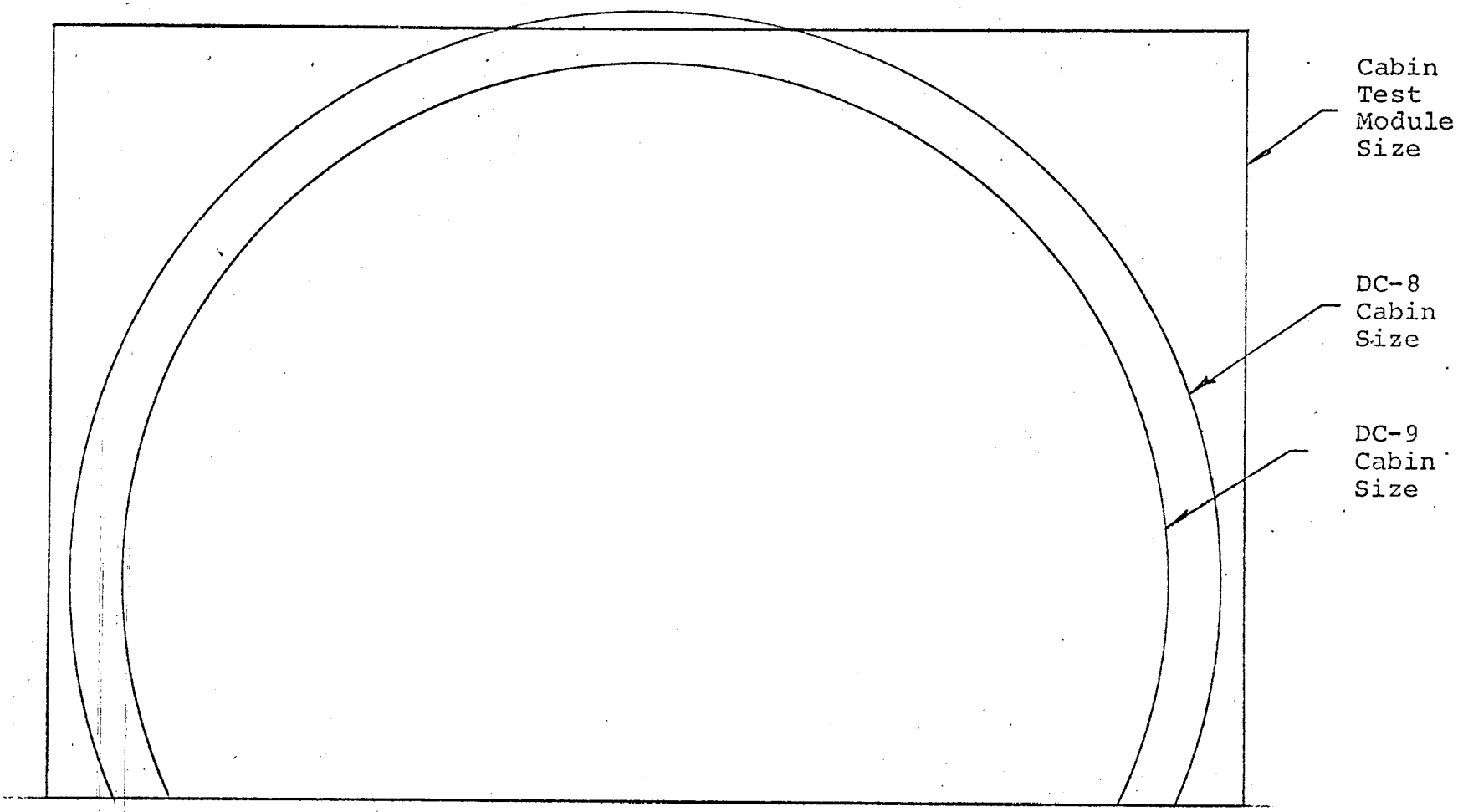
Figure No. III illustrates the number of units supplied, to whom and for what type of aircraft.

As a result of these "work arounds", and the resultant comments, several minor modifications are being incorporated in the final FIREPAC design.

Some specifics of these modifications are:

1. The units will be painted "fire protection" red.
2. More flexibility of mast length.
3. No mar top for combustion products detector.
4. Stronger hinges on doors.
5. Redesign of umbillical cord connection.

These modifications have been incorporated on the latest drawings.



F I G U R E I

Douglas Cabin Test Module
at Fenwal Fire/Explosion Laboratory

FIGURE II

Results of Gas Analysis On Board

Fire Protection Test - 747 Mockup

20 July 1968

ON-BOARD FIRE PROTECTION, 747 TEST

JULY 20, 1968

Sample Number	Time (Sec)	O_2 (%)	CO_2 (%)	CO (ppm)	NO_2 (ppm)	HCN (ppm)	Free Acids (ppm)	Freon 1301 (%)	Carbonyls (ppm)
A-1	15	20.5	0.03	0	0	0	0	0	0
-2	55	19.5	0.05	40	0	trace	0	11.0	0
-3	85	19.5	0.06	50	0	0	30	6.6	0
-4	115	20.0	0.07	20	0	trace	0	2.1	0
-5	145	20.0	0.06	10	0	0	0	2.1	0
-6	175	20.5	0.06	trace	0	0	0	1.4	0
B-1	15	20.5	0.05	0	0	0	0	0	0
-2	55	19.5	0.05	25	0	0	0	10.2	0
-3	85	20.0	0.06	50	0	0	0	4.5	0
-4	115	20.0	0.07	20	0	0	0	2.2	0
-5	145	20.5	0.05	20	0	0	0	1.3	0
-6	175	20.5	0.05	trace	0	0	0	0.8	0
C-1	15	20.5	0.05	trace	0	0	0	0	0
-2	55	19.5	0.10	40	trace	2	0	11.0	0
-3	85	20.0	0.06	70	0	0	15	3.1	trace
-4	115	20.0	0.05	25	0	0	0	1.8	0
-5	145	20.5	0.05	10	0	0	0	1.0	0
-6	175	20.5	0.05	trace	0	0	0	0.8	0

NOTES:

1. Time zero is time of fuel ignition.

2. Freon was discharged at T + 48 seconds.

3. Sampling time for flas samples was approximately 1-2 seconds. (Only the free acid determination was made on the flas samples).

4. Sampling time for bag samples was 10 seconds.

5. Sampling locations were as follows:

   A 12 inches above floor level - 2 1/2 feet from sidewall (frame 600).

   B 40 inches above floor level - 2 1/2 feet from sidewall (frame 600).

   C 12 inches above floor (upper deck) 1 1/2 feet from sidewall (frame 600).

6. Listed free acid concentrations in parts per million parts of air (PPM) apply to any acid. On a weight basis, 1 PPM HCl is equal to 1.492 milligrams/cubic meter (mg/m^3), 1 PPM HF is equal to 0.818 mg/m^3 (25° C and 760 mmHg).

7. Methods of Analysis are as follows:

   O_2 - Johnson and Williams Oxygen Indicator, Model K

   CO_2 - MSA Detector Tubes

   CO - Bacharach Detector Tubes

   NO_2 - MSA Detector Tubes

   Free Acids - Titration with 0.01N Na OH using Alizarin indicator

   Carbonyls- (expressed as phosgene) - Draeger Detector Tubes

   Freon 1301 - Gas Chromatograph

   HCN - MSA Detector Tubes

COORDINATION SHEET

TO ✓ Floyd Vail

C.C. Lloyd Nygren

NO. MST-45-207

ITEM NO.

DATE July 22, 1968

MODEL

GROUP INDEX Mechanical System Test Instrumentation: 6-8245.

SUBJECT Thermocouple Data For Fire Extinguishing Test.

REFERENCE 747 Final Assembly Fire Protection
Charge No. 1-E1424-0001-788030.

Attached are copies of the data from the Fire Extinguishing Test performed in the Freighter Mockup at the Everett Facility on July 21, 1968.

Thermocouple locations are called out on Figure 1.

Figure 2 shows a time history plot of all thermocouples.

Table I gives the time history data in tabulated form.

The shaded area on Figure 2 indicates when the alarm went off. The width of the area indicates the uncertainty of the alarm time. Time zero on the plot is the ignition time.

The thermocouple output was measured on a Minneapolis-Honeywell(TL 8246) Electronik recorder, that sampled at a rate of 1 point per second. Estimated accuracy of the thermocouple measurements was $\pm$ 10°F.

Prepared by R. J. Williams
R. J. Williams

Approved by D. G. Engle 7/23/8
D. G. Engle
6-8245, 27-22
Ext. 5-8183

RJW/pr

Attachment

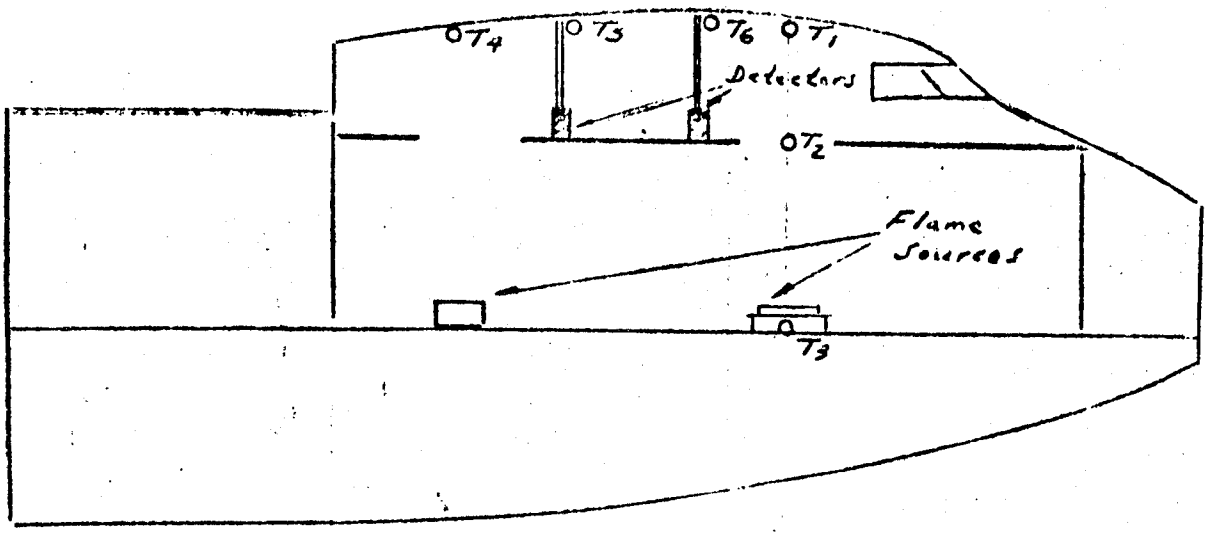


Figure I - Thermocouple Locations

1) T_1 - Ceiling Temperature below asbestos liner (Forward)
   T_2 - Air Temperature at Crew Compartment Floor Level
   T_3 - Air Temperature at Main Deck Floor Level
   T_4 - Ceiling Temperature below asbestos liner (Aft)
   T_5 - Detector Temperature at Upper Level (Aft)
   T_6 - Detector Temperature at Upper Level (Forward)

2) T_5 and T_6 located midway on detector sensors, two inches from sensor.

ENGR.	RJW	7-22-68	REVISED	DATE	FIRE EXTINGUISHING TEST FENWAL SYSTEM	
CHECK						
APR						
APR					THE BOEING COMPANY RENTON, WASHINGTON	

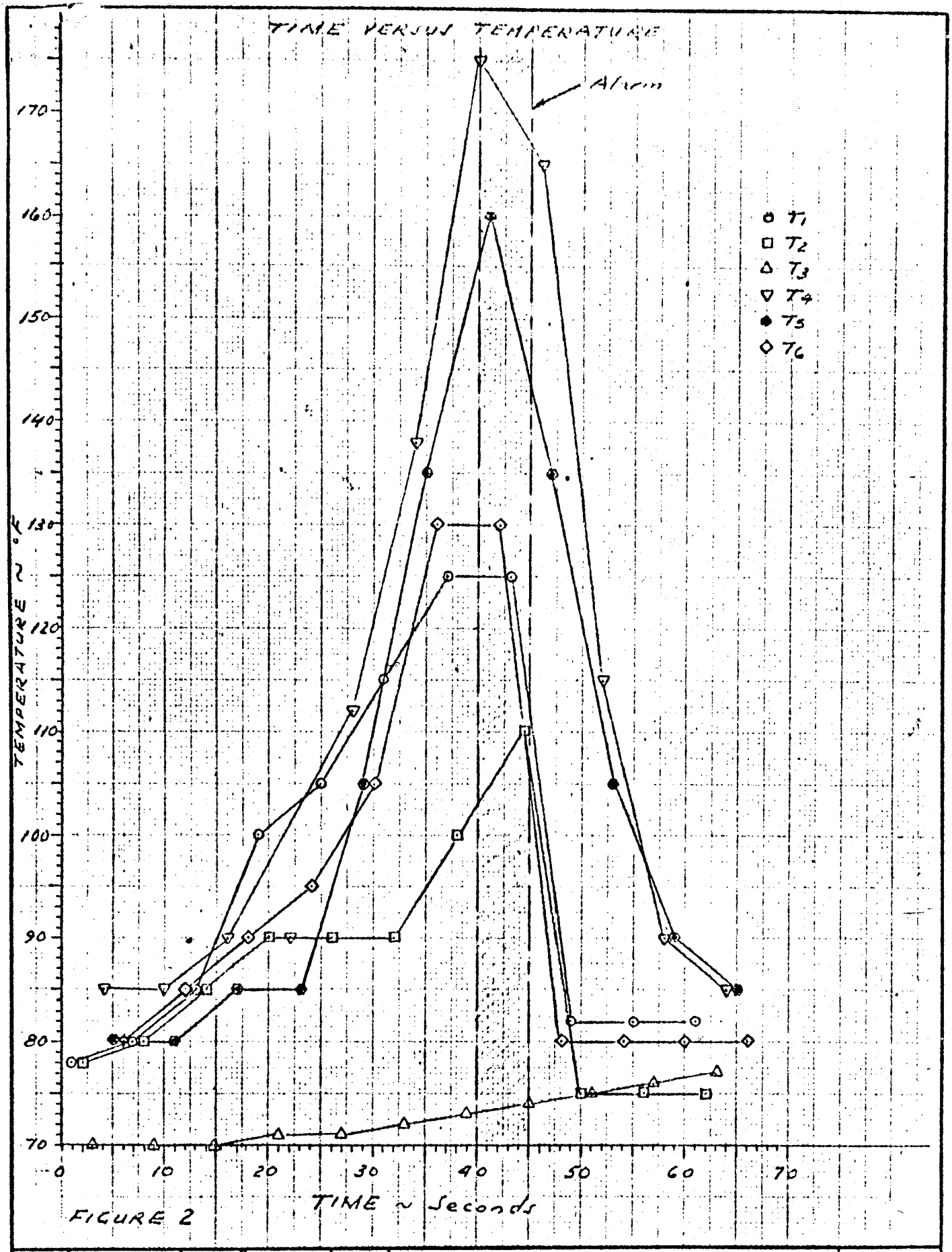


FIGURE 2

CALC	RJK	7-22-69	REVISED	DATE	FIRE EXTINGUISHING TEST FENWAL SYSTEM
CHECK					
APR					
APR					THE BOEING COMPANY

PAGE

TABLE I

(sec) TIME	T_1	(sec) TIME	T_2	(sec) TIME	T_3	(sec) TIME	T_4	(sec) TIME	T_5	(sec) TIME	T_6
:01	78	:02	78	:03	70	:04	85	:05	80	:06	80
:07	80	:09	80	:09	70	:10	85	:11	80	:12	85
:13	85	:14	85	:15	70	:16	90	:17	85	:18	90
:19	100	:20	90	:21	71	:22	90	:23	85	:24	95
:25	105	:26	90	:27	71	:28	112	:29	105	:30	105
:31	115	:32	90	:33	72	:34	138	:35	135	:36	130
:37	125	:38	100	:39	73	:40	175	:41	160	:42	130
:43	125	:44	110	:45	74	:46	165	:47	135	:48	80
:49	82	:50	75	:51	75	:52	105	:53	105	:54	60
:55	82	56	75	:57	76	:58	90	:59	90	:60	80
:61	82	:62	75	:63	77	:64	85	:65	85	:66	80

CALC	RJW	7-22-68	REVISED	DATE	FIRE EXTINGUISHING TEST FENWAL SYSTEM
CHECK					
APR					THE BOEING COMPANY
APR					PAGE

FIGURE III

WORK AROUND PROGRAM

Date	Company	No. of Units	Type of Aircraft
July 7 - 11	United Air Lines	6 (complete system)	DC-8
Sept. 17 - 27	McDonnell Douglas	3	DC-8 63
Sept. 30 to Oct. 8	Delta Airlines	3	CV880 & DC-9
Oct. 7 - 11	Eastern Airlines	3	DC-8