TECHNICAL DEVELOPMENT REPORT NO. _____

EVALUATION OF A FLAME SURVEILLANCE TYPE DETECTOR

FOR LIMITED DISTRIBUTION

by

Marvin F. Rammelsberg
and
Paul R. Dierdorf

Aircraft Division

FEDERAL AVIATION AGENCY
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

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A surveillance-type [illegible] system of the [illegible] was evaluated in laboratory [illegible] and by exposing [illegible] than 250 small-magnitude JP-4 test fires in a modified KC-135 nacelle [illegible] a comparatively low internal air flow.

Laboratory bench testing showed the detector's sensitivity [illegible] as the ambient light increased. In the KC-135 power plant tests the [illegible] detected 93 per cent of all the fires to which it was exposed. It [illegible] satisfactorily under several engine power conditions and had a [illegible] short response time.

INTRODUCTION

The Pyrotector flame detector is a new design of aircraft power plant surveillance-type fire detector. Tests were conducted by the Federal Aviation Agency (formerly Civil Aeronautics Administration), Technical Development Center, Indianapolis, Indiana, during the period from August 1957 to May 1958 for the purpose of obtaining information and data on this detector system when subjected to simulated in-flight fire conditions.

A single unit was subjected to laboratory testing to determine maximum field of vision of a unit and the effect of ambient light on the detector's sensitivity to actual fire. Five detector units were installed in a modified KC-135 airplane nacelle configuration and subjected to test fires burning JP-4 fuel to determine the efficacy and performance characteristics of this detector.

Five Pyrotector flame detector units, Part No. [illegible]

unit, Part No. 30-301, were supp[illegible] Inc., [illegible]

setts. Figure 1 shows the components of this flame surveillance [illegible]

which were used throughout the testing.

The full-scale power plant in which the system was installed consi[illegible] of the No. 2 engine, pod, strut, and 12 [illegible] of wing section of the KC-135 [illegible] mounted on a supporting structure in a test cell as shown in Fig. 2. [illegible] changes were made in the KC-135 cowling to obtain conformance with the [illegible] version of the Boeing 707. These changes consisted of (1) adding an 8-inch wide titanium strip along the hinge lines of the cowling thus giving a 90° included angle of fireproof material over the top of the engine, (2) closing the [illegible] louvers located just forward of the fire wall and near the hinge lines, and re- placing them with a single 3-5/8 inch diameter flush port at a point 15 inches below the engine centerline and 6-1/2 inches forward of the fire wall on the right-hand cowl, (3) adding twelve 1/2-inch diameter holes at the low points of the cowl latch line to provide additional fluid drainage, (4) reworking the nose cowl to allow the introduction of air to simulate anti-icing air flow conditions, (5) installing an air seal at a point 46.8 inches aft of the fire wall, (6) adding a 2-inch diameter hole in the right-hand cowl at 2:30 o'clock, 3.8 inches aft of the fire wall, and (7) installing a flame seal at the hinge joints.

To more accurately duplicate test fires a synchronous motor driven, single cycle, multicam timer was used to schedule, operate, and control the instrumentation, ignition, fuel flow, and CO_2 discharge. A magnetic tape re- corder was connected in an aircraft-type intercom system to record test conditions, pertinent test data, and visual observations during the course of a test. This information was stored on the tape and later transcribed to a permanent record. An Esterline-Angus operation recorder was used to record the sequence and duration of each individual phase of the tests.

LABORATORY TEST

Procedure

A Pyrotector surveillance type fire detector system consisting of a control unit, Part No. 30-21[illegible]; and two detector sensing units, Nos. 33 a[illegible] 34 (manufacturers designation); were used. Information obtained on the system from the Pyrotector Inc., General Data sheet includes the following:

> The one ounce sensing unit consists of a solid photoconductive cell potted within a metal housing with a viewing cap fabricated of high temperature glass. The system produces an alarm when the radiation falling on the cell increases in infrared ratio and intensity thereby increasing the cell output to the control unit. A diode mixing circuit receives the cell output voltage and transfers it to the input of a transistor circuit which amplifies the input current to a magnitude sufficient to close a relay completing a warning lamp circuit. The operating temperature range is from -65° F to 300° F.

A series of tests was conducted to determine the effects of ambient light on the sensing unit's sensitivity, field of vision, and maximum range. In the first test the sensitivity of the detector system was determined in the laboratory under daylight conditions in the absence of direct sunlight and without overhead lighting. A 3-inch diameter pan filled with burning 100 octane aviation gasoline was used as the flame source with an input voltage to the control unit of 18 volts d.c. The test was conducted by moving the flame source in arcs of different radii around the detector sensing element and noting the maximum distances and angular positions where detection was obtained. In the second test this procedure was repeated using a 5-inch diameter pan filled with burning 100 octane gasoline, controlled ambient light conditions, and a 24-volt d.c. power supply to the control unit.

The maximum range of the sensing unit was determined by placing unit No. 34 in a darkened room where the ambient light level was below 6.5-foot candles. The 3-inch diameter pan of burning 100 octane aviation gasoline was placed on the longitudinal centerline of the metal housing of the detector and in its field of vision. The flame source was moved along this line away from the detector and the maximum distance between the detector and the flame source at which detection occurred represented the range of the sensing unit.

A third test was conducted to determine the effect of a hot surface on the operation of the detector. In this test a section of 2-inch o.d. stainless steel tubing, 4 inches long was located transversely in a 10-foot length of transite duct having a diameter of approximately 12 inches. To simulate a hot exhaust stack the stainless steel tubing was heated electrically. The detector sensing unit was directed toward the heated tube. The unit was moved along the axial centerline of the transite duct and away from the heated tubing in increments of 3 inches, and the tubing temperature increased until an alarm was obtained. Using this procedure, data were obtained with the ends of the duct open to allow ambient light to enter the duct, and also with the end opposite the detector closed to exclude ambient light from that portion of the duct.

Results and Discussion

Figure 3 shows the resultant field of vision plots obtained by exposing the two sensing units to the 3-inch diameter pan fire when the control unit input voltage was 18-volt d.c. and the ambient light conditions were not controlled. Figure 4 is a similar plot for a unit exposed to a 5-inch diameter pan fire when ambient light was controlled at 6.5 and 30-foot candles and the control unit input voltage was 24-volt d.c. These plots also show the maximum range of the detector under each of the test conditions. A study of Fig. 4 shows the affect of ambient light on the detector's range. Raising the ambient light level from 6.5 to 30-foot candles reduced the maximum range from 60 inches to 12 inches. The adverse affect of ambient light on detector range also was demonstrated by the results obtained when unit No. 34 was placed in a darkened room. The ambient light level was below 6.5-foot candles and the detector exposed to a 3-inch pan of burning gasoline. Under these conditions the maximum range was 55.5 inches.

The open and closed duct conditions were investigated to determine the possible effect of ambient light on detector sensitivity when a glowing metal rather than flame was the source of radiation. The results of the hot surface detection test are shown in Table I.

TABLE I

RESULTS OF PYROTECTOR HOT SURFACE DETECTION TESTS

Distance from Detector to Hot Surface (Inches)	Hot Surface Temperature Duct Open (°F)	Hot Surface Temperature Duct Closed (°F)
1	1280	1280
3	1360	1360
6	1445	1445
9	1515	1515
12	1565	1555
15	1615	1600
18	1650	1640
21	1690	1675

Procedure

In preparation for fire a study to [illegible] the nacelle the following determinations were made: (1) location of [illegible] lease points in the nacelle, (2) amount of fuel discharge [illegible] time [illegible] the test fire to be used, (3) initial detector locations, and (4) [illegible] tion of a schedule and sequence of events for all test fires. The [illegible] tained from previous tests showed that the nacelle [illegible] temperature [illegible] the compressor section during engine operation was a minimum of [illegible] F in the forward areas and a maximum of 370° F near the fire wall. As the sensing units are moved toward the fire wall, the maximum ambient temperature limitation of the detector can be exceeded. The detector in the compressor compartment at nacelle station 171 which observed the burner section through a Vycar window in the fire wall was heavily insulated to protect the unit from the high ambient temperatures in that area.

Based on the results of a previous study the four fuel release locations shown in Fig. 5 were chosen as being representative of the general areas where fires could be ignited during flight. At each of these locations combination ignitor-nozzle units were installed. These units had individual controls for the ignitor and fuel nozzle. The nozzle was set to provide a 0.3 gpm flow of JP-4 fuel.

Tests were conducted by igniting a 10-second discharge of JP-4 fuel flowing at 0.3 gpm. The discharging fuel impinged on a baffle to break up the fuel stream in the immediate vicinity of the nozzle. Table II shows the engine power conditions, fuel release locations, and rates used in this study.

[illegible]

[illegible] only at [illegible]

[illegible] burning time of 1[illegible]

the second test fire [illegible] was based on (1) the [illegible]

could be burned [illegible] the rather limited [illegible]

the aft nacelle compartment, and (2) the size [illegible]

to the test article. Burning time was controlled by discharging [illegible]

nacelle after the prescribed [illegible] time had elapsed.

Initial detector locations were based on industry recommendations [illegible]

were changed as the testing progressed in an attempt to obtain a higher percent-

age of detection or improve the detector system performance. [illegible]

locations shown in Fig. 5 gave a higher per cent detection than any other [illegible]

locations for the five units. All data for the nacelle test portion of this re-

port were obtained using the locations shown in Fig. 5.

Throughout the testing the sequence of events as scheduled by the

electric timer was identical. Figure 6 shows a record of this sequence and of

detector response in one test. It also shows the duration of events during a

standard test fire and their relation to a common starting point.

After selecting one of the fuel release points shown in Fig. 7 and

stabilizing the engine at one of the power conditions listed in Table II the

sequence timer was energized. During the cycle, temperature in the vicinity of

fuel release was recorded on a Brown temperature recorder. Detector system re-

sponse and reset times, total burning time, and length of fuel discharge were

automatically recorded on an operation recorder.

[illegible]

[illegible]

[illegible]	Fire Location*		Test Fire			[illegible]**
	[illegible]	Clock Position	[illegible] Fuel Release		[illegible]	
			[illegible]	Time (sec)	[illegible] (sec)	
[illegible]	[illegible]	6	[illegible]	10	18 - 22	I, II, [illegible]
2	130	12	[illegible]	10	18 - 22	I, II, [illegible]
3	117	8	0.3	10	18 - 22	I, II, III, [illegible]
4	181	6	0.3	10	18 - 22	I, [illegible]
4(y)	181	6	0.3	5	18 - 22	I, II, III, [illegible]

* Refer to Fig. 5 of this report.

** I - Engine power setting, idle; tunnel speed, 0 mph.
II - Engine power setting, idle; tunnel speed, 25 mph.
III - Engine power setting, 90% normal rated thrust; tunnel speed, 165 mph.
IV - Engine power setting, 90% normal rated thrust with nacelle anti-icing air flow; tunnel speed, 165 mph.

Results

Table III shows the per cent detection of the system when test fires were conducted at each location. Response and clearing times for the system were between one and three seconds throughout the testing and were not noticeably changed by the accumulation of a film of soot, dust or oil on the sensing unit viewing cap, viewing windows or engine cowling.

Installation of the aft air seal during the detection study affected the results obtained with heat-sensitive type detectors and necessitated a change in the testing procedure at the No. 4 fuel release location. Most directly affected were the flame paths, burning characteristics, and intensity of test fires

[illegible]

[illegible]

[illegible] Locations	Engine and Tunnel Settings	[illegible]	Alarms	
	DATA TAKEN AFTER AIR SEAL INSTALLATION			
1	I	20	13	
	II	19	5	
	III	15	15	
	IV	10	10	
		Per cent detection		67.2
2	I	17	17	
	II	17	17	
	III	15	15	
	IV	9	9	
		Per cent detection		100
3	I	17	17	
	II	17	17	
	III	15	15	
	IV	8	8	
		Per cent detection		100
4	I	13	13	
	II	11	11	
	III	13	13	
	IV	8	8	
		Per cent detection		100
4(y)	I	10	10	
	II	11	11	
	III	10	10	
	IV	8	8	
		Per cent detection		100
	DATA TAKEN PRIOR TO AIR SEAL INSTALLATION (KC-135 Nacelle Configuration)			
4	I	11	11	
	II	11	11	
	III	11	11	
	IV	3	3	
		Per cent detection		100

I - Engine power setting - Idle; tunnel speed, 0 mph.
II - Engine power setting - Idle; tunnel speed, 25 mph.
III - Engine power setting - 90% normal rated thrust; tunnel speed, 165 mph.
IV - Engine power setting - 90% normal rated thrust with nacelle anti-icing air flow; tunnel speed, 165 mph.

conducted at that location which in turn could affect the detector system effec- tiveness in the compartment. The per cent detection obtained with the Pyrotector system was unaltered by these nacelle configuration changes.

Because of the very limited oxygen supply available in the altered compartment, test fires of the standard magnitude tended to become overrich. To reduce the affects of this condition a shorter fuel discharge test fire was used in this location for the remainder of the testing. Results obtained when using test fires with a shorter fuel release time in the altered compartment are shown in Table III, 4(y). The table also shows the Pyrotector system detected [illegible] all test fires conducted at the No. 4 fuel release location regardless of fire magnitude, flame paths, air flow conditions or the compartment configuration.

Only 46 per cent of the test fires conducted at location [illegible] engine power settings I and II were detected by the system [illegible] Fig. 5. More than three sensing units are [illegible] pressor section volume. A sixth sensing unit mounted [illegible] between nacelle stations 136 and 148 probably would have given [illegible] No unit was placed in this area during the tests because exposure [illegible] would exceed the designed ambient temperature [illegible] cause premature failure of this sensing unit.

For normal operational installation [illegible] in the lower nacelle areas will [illegible] positions to view the areas. [illegible]

[illegible]

is recommended because it is slightly forward of the higher temperature zone.

OBSERVATIONS

During the laboratory tests the following observations were made:

1. The detector's maximum range and sensitivity are noticeably reduced as ambient light levels are raised.

2. The detector's most effective range and field of vision is approximately defined by a spherical sector having an included angle of 120°.

3. Detector system alarms can occur when the sensing unit views a glowing metal surface.

4. The detector's maximum field of vision is a modified hemisphere having a plan view as shown in Fig. 4.

During the nacelle tests the following observations were made:

1. Average response time to nacelle fires of the test magnitude was 2.1 seconds after ignition. Clearing time was slightly less than 0.9 second.

2. The detector was not noticeably affected by a film of oil, dust, or soot on the sensing unit view cap, viewing windows, and engine cowling.

3. False alarms caused by overheat did not occur during the tests.

4. Ability to place sensing units in nacelle areas of higher ambient temperature would improve the system's per cent detection for fire location 1.

5. The field of vision of a unit can be restricted by engine accessories or other obstructions and permit a small fire to be hidden from the detector.

During a study of the general data sheet of the Pyrotector surveillance detector the following observations were noted:

1. The control unit and individual sensing units are very light in weight.

2. Sensing units should not be located in areas where the normal ambient temperature exceeds 300° F.

3. The relatively low impedance high output signal leads do not require shielding.

4. Reflection within an enclosed area will increase the effectiveness of the detector.

5. Shock mounting of control or sensing units is not required.

CONCLUSIONS

The following conclusions are based on the test data and results obtained:

1. The Pyrotector system is a flame surveillance-type detector having quick response and clearing times.

2. The six unit locations shown in Fig. 8 is considered a minimum Pyrotector system for detecting power plant fires in the Boeing 707/KC-135 nacelle.

3. Ambient light appreciably affects the range and sensitivity of the detector units. An increase in ambient light decreases the range and sensitivity.

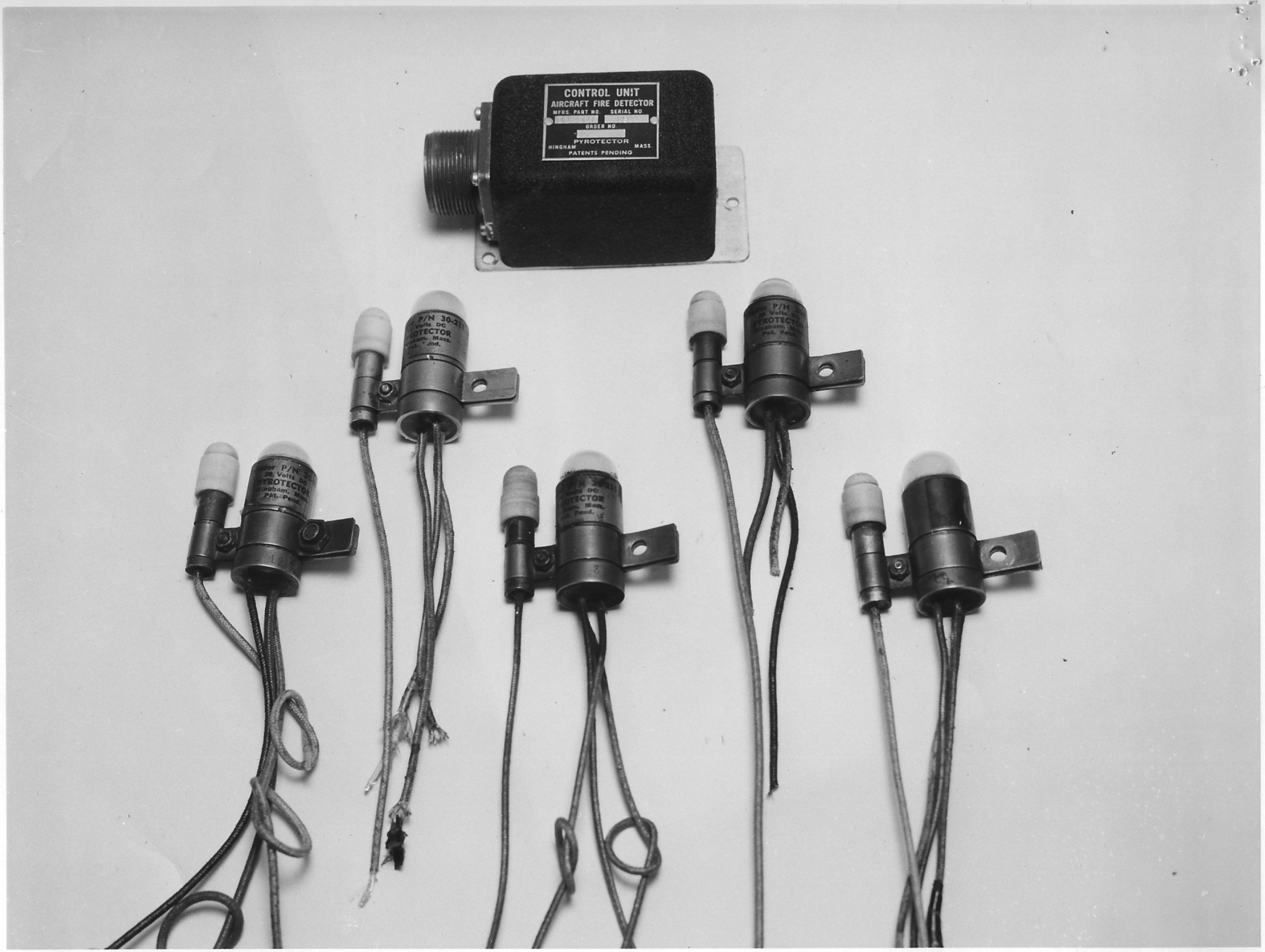
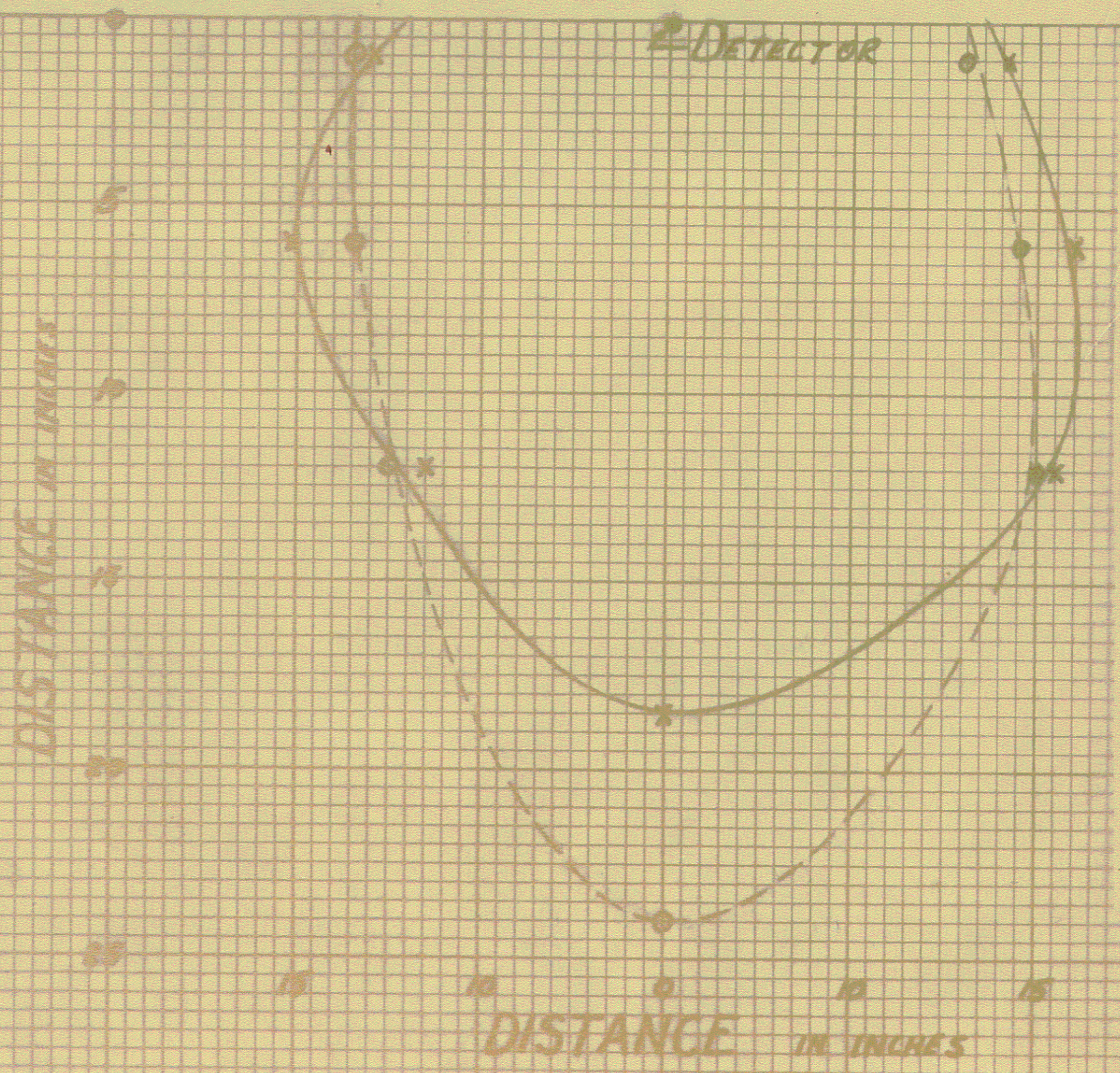


Fig. 1 Control Unit and Sensing Units - Pyrotector Flame Surveillance Type Detector System

Fig. 2 Podded Turbojet Fire Test Facility



Central Unit Input
Voltage: 18V DC

Lighting Conditions:
Normal Room Daylight,
No Direct Sunlight,
No Artificial Light

Flame Source: 3 inch
Diameter pan of burning
100 octane gasoline

Flame Location:
O - Flame location for
unit No. 33

X - Flame location for
unit No. 34

Fig. 3 FIELD of VISION PLOT--PYROTECTOR FLAME SURVEILLANCE SENSING UNIT