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ARROW 2

FIRE PROTECTION SYSTEM

REPORT No.72/SYSTEMS 23/31-2

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED.

CONFIDENTIAL

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FIRE PROTECTION SYSTEM

Report No. 72/Systems 23/31-2

MAY 1958

This brochure is intended to provide an accurate description of the ARROW 2 system(s) or service(s) at the time of writing, and is not to be considered binding with respect to changes which may occur subsequent to the date of publication.

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Authorized by

Engineering Division
AVRO AIRCRAFT LIMITED
Malton - Ontario

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ILLUSTRATIONS

1.0 INTRODUCTION

The ARROW 2 fire protection system is divided into two sub-systems; the fire detection system and the fire extinguishing system. The detection system is designed to detect fires in the potential fire areas of both engines, and in the equipment bay. A Walter Kidde detection system is employed which provides fire warning and overheat warning signals. The detection system also incorporates a rate of temperature rise feature to ensure adequate fire warning. The high rate discharge extinguishing system is capable of discharging extinguishing agent into any fire area within 0.45 to 0.90 seconds.

2.0 DESIGN CONSIDERATIONS

2.1 RATE OF DISCHARGE

It is considered that the high rate discharge system gives better fire protection, and shows a considerable weight saving over the standard system.

2.2 CHOICE OF AGENT

Temperature considerations have dictated that Freon be used as the extinguishing agent. At high temperatures, the vapour pressure of Freon is considerably lower than that of Methyl Bromide, or Bromochloromethane. Thus by using Freon, the internal container pressure is reduced. In addition, Freon is equal to Methyl Bromide in fire extinguishing properties, and is less toxic and less corrosive.

2.3 DISCHARGE VALVE

Due to the high ambient temperature (250°F) in the region of the containers, it has been found impossible to use the standard pyrotechnic type discharge valve. Consequently, a solenoid operated valve has been developed to operate satisfactorily at this temperature.

2.4 DETECTION SYSTEM

The detection system contains a rate sensitive feature which improves the detector sensitivity (speed of operation). False alarms due to rapid change of temperature during normal aircraft operation are eliminated, and the time required to produce a fire-out signal is reduced. With a conventional system, the trip point temperature must be maintained as close as practicable to the maximum ambient temperature in an effort to gain sensitivity. However, with the ARROW 2 detection system, the fire is detected at a very early stage so that the trip point can be set for a higher temperature as determined by structural considerations. When the fire is extinguished, the warning lights will go out at a correspondingly higher temperature, and in a shorter time. In addition, should a discrepancy exist in the trip point temperature setting, false warnings will not occur. This is due to the fact that the heating curves approach maximum temperature asymptotically with time, and therefore at a low rate.

2.5 CRASH SWITCH

In the event of a crash it is desirable to have some rapid and simple means of discharging the extinguishant into potential fire areas. An inertia type crash switch was at first considered, which would automatically set off the extinguishing system at a deceleration of 5g. (During a crash) However, this type of crash switch was found to be unreliable on some aircraft, especially during manouvres involving high accelerations. The inadvertant operation of the crash switch and subsequent discharge of extinguishant under these conditions could cause the loss of the aircraft. A manually operated crash switch has therefore been chosen for the ARROW 2.

3.0 FIRE DETECTION SYSTEM

The fire detection system employs continuous wire type detectors which are located in three potential fire areas. The system is further divided to provide signals for overheat warning and fire warning. The system operates when the average temperature in any area reaches a predetermined level above normal, or when the rate of temperature rise at any point exceeds a given value. The detectors are thus capable of detecting general fires covering a large area, or small jets of flame which could occur as a result of a punctured engine casing.

The red fire warning lights are located on left-hand console, just aft of the throttle box, and the amber overheat warning lights are located in the master warning panel on the right-hand console. A master red warning light operates in conjunction with the fire warning lights, and a master amber warning light operates in conjunction with the overheat warning lights.

3.1 CONTINUOUS WIRE DETECTOR

The continuous wire detector element consists of two conducting wires embedded in a non-metallic core material, which in turn is contained in an Inconnel tube. One wire is grounded through the Inconnel tube at various locations. The outer wire froms a complete loop which terminates within the fire detection control unit as shown in Figure 2. The current flow between the two conducting wires is therefore dependent upon the conducting qualities of the non-metallic core material, as determined by the temperature. This characteristic is then utilized to provide the overheat warning and fire warning signals. The resistance value of the non-metallic core material is established by two variable resistors placed in the bridge balance sensing circuit of the respective fire detection control units.

Figure 2 shows that the amount of current flow through the detector element, for any particular temperature, is not primarily dependent upon the continuity of the two wires within the element. It follows that a single break will not effect the current flow. However, if two breaks should occur, for example at points S and T, the result would be the elimination of that length of element from the circuit. Consequently, hot spots would not be detected in the affected area.

3.2 CONTROL UNIT

A wheatstone bridge, forms the basis of the fire detection system. The usual unknown resistor is replaced by the continuous wire detector and is common to each of the two separate bridge balance sensing circuits. The trip point temperatures for overheat warning and fire warning are different and therefore a separate trip point adjusting resistor is placed in each sensing circuit. The use of variable resistors in the circuits permits interchanging of the fire detection control units. The fire warning bridge balance sensing circuit incorporates a rate sensitive feature, the bridge input voltage being regulated by a transistor type voltage regulator to make the rate sensitive components insensitive to variation of bridge input voltage. Output signals from the transistorized circuits operate the warning light relays.

The control unit monitors the sensing element resistance and energizes the circuit when the detector element resistance drops below a predetermined point. This is due to an increase in the element temperature, or when the resistance of the element changes at a high rate because of a temperature change (caused by fire). The sensing of either of these conditions will cause the respective relay to close and the appropriate warning signal to be initiated. The control unit circuit is included in Figure 2.

3.2.1 FIRE WARNING CIRCUIT

The fire warning bridge circuit consists of resistors R101, R106 and R108 along with the detector element (Ref. Fig. 2). The trip point adjusting resistor R108 may be varied in value to provide a null at various detector element resistances from 200 to 2,000 ohms. The error voltage in the circuit will be applied across diode CR101 and the input terminals of the common emitter connected transistor TR101. When the detector element resistance is high (low temperature), the point of the element connection (pin L and C) is more positive than the base of TR101 and therefore CR101 is in a non-conducting state. However, resistor R103 permits enough base current to keep TR101 fully conducting (saturated), As the detector element is heated, it decreases in resistance and pin C of the connector becomes less positive. When the potential at pin C equals the potential at the base of TR101, the diode CR101 starts to conduct and will cause a reduction of the potential at the base of TR101. As the detector element is heated still further, the potential at C continues to decrease until the potential at the base of TR101 is sufficiently reduced and TR101 will be bypassed in the circuit.

TR102 is also a common emitter connected transistor, but has the fire warning relay as its load. Although the variable resistor R108 may be set at its highest selected value, the emitter potential of TR102 is sufficiently positive to be greater than its base potential, provided that TR101 remains saturated. As the detector element is heated and its resistance decreases sufficiently to start TR101 towards cut off, the collector of TR101 (and base of TR102) begins to rise in potential. When this potential exceeds that of the emitter of TR102, this increase coupled to the emitter of TR101 through resistor R107, introduces positive feed-back, causing TR101 to cut off. The collector current of TR102 is then sufficient to close the fire warning relay.

3.2.1.1 Temperature Rate Sensitivity - Fire Warning Circuit

Capacitor C101 is the additional circuit element which produces the rate of temperature rise feature. As mentioned in para 3.2.1, a fire indication is established when the voltage is decreased on the base of TR101, and the transistor is placed in a cut off condition. In this condition, the current must flow through CR101 or some other path. When the detector element resistance is high, pin C is positive with respect to the base of TR101, and C101 is charged to the different potential. The effect of a fire will be a rapid decrease in the detector element resistances and the subsequent rapid decrease in potential at C. With this rapid change, the capacitor C101 will act as a battery, and while tending to maintain a constant potential across its terminals, the potential at the base of TR101 is reduced, causing the transistor to be cut off. TR101 will then remain cut off, thus providing a fire signal if either the rate of change of potential at C is maintained, or if the potential is reduced sufficiently to cause CR101 to conduct.

3.2.2 OVERHEAT WARNING CIRCUIT

The overheat warning circuit is very similar to the fire warning circuit, except that it does not contain a temperature rate of rise feature.

The overheat bridge circuit consists of resistors R101, R113 and R117, and the detector element (Ref. Fig 2). The overheat trip point adjusting resistor, R117 may be varied to provide a null at various element resistance from 750 - 7500 ohms, On the ARROW 2, the resistor it set to provide a null at an element temperature below that at which the setting of the fire trip point adjusting resistors would provide a null.

3.3 TEMPERATURE DESIGN POINTS

The fire detection system is based on the maximum ambient temperature, overheat trip setting temperature and fire trip setting temperature. These temperature design points are illustrated in Figure 6 for a typical 20-foot detector element exposed to a uniform temperature distribution.

Below the maximum ambient temperature (A) no warning signal is provided, regardless of the rate of temperature rise. At a temperature corresponding to point B, the system becomes sensitive to the rate of temperature rise. Should the rate rise be characteristic of a fire, a fire warning signal is given immediately. For temperatures between the overheat trip setting temperature (B) and the fire trip setting temperature (C) an overheat warning signal is given, provided the rate rise is below the characteristic rate rise of a fire. For temperatures in excess of the fire trip setting temperature (C), a fire dignal is given, regardless of past temperature history or existing rates of temperature rise.

If the temperature distribution along the length of detector is not uniform, the total resistance of the detector determines the localized temperatures at which overheat and fire signals are given.

The temperature design points for the three fire areas are given in Table 1.

TABLE 1

Fire Area	Average Max Ambient	Overheat Trip Point Temp.	Fire Trip Point Temp.
L.H. Engine and R.H. Engine			
Fwd. of stn. 644	280°F	340°F	425°F
Aft. of stn. 778	345°F	400°F	550°F
Hydraulic Bay	250°F	330°F	425°F

3.4 RESETTING OF FIRE DETECTION SYSTEM

The fire detection system is reset automatically. when a fire has been extinguished and the temperature lowers in the fire area, the red fire warning light will be extinguished and the overheat warning light will be illuminated at a temperature slightly lower than point C in figure 6. As the temperature in the fire area continues toward the normal condition, the amber overheat warning light will be extinguished at a temperature slightly below point B in figure 6.

3.5 GROUND TEST SWITCH - FIRE AND OVERHEAT DETECTION

A ground test switch, located on the fire and fuel panel, is used to check the functioning of the fire and overheat detection system. Operation of the switch to either FIRE TEST or OVERHEAT TEST energizes the ground test switch relay. This causes the current to be bypassed from the detector loop to ground through the corresponding resistor in the ground test switch (Ref. Fig. 2).

During normal operation of the fire detection system, the current must flow from the fire detector loop, through the non-metallic core material, to the grounded detector wire. When the temperature is sufficient to reduce the core resistance to the value required for overheat or fire detection, the appropriate indication is given. The resistance of each resistor within the ground test circuit therefore replaces the resistance normally provided by the core material in the detectors. In order to ensure that a signal is given, the resistance value of the test switch resistors is slightly less than the value required to produce a detection signal. The inability to establish a test signal for each of the three fire areas indicates either a break in the detector loop (which is not usually significant in the normal operation of the fire detection system), or malfunction of the detection system components.

4.0 FIRE EXTINGUISHING SYSTEM

4.1 GENERAL

The fire extinguishing system provides for the discharge of extinguishing agent to any two of the three fire areas selectively, or two shots to any one fire area. The three fire areas are: the L.H. engine fire area (area 1), R.H. engine fire area (area 2) and the hydraulic bay fire area (area 3), which contains fuel, electrical and hydraulic equipment. The engine fire areas are further divided into three zones; zone 1 forward of the restrictor ring, zone 2 aft of the restrictor ring, and zone 3 (tertiary fire zone), containing all the engine accessories and encased in a separate shroud.

4.2 DISTRIBUTION

The contents of the fire extinguisher bottles are discharged as detailed in Table 2

TABLE 2

Area Selection	Contents of Bottle No. 1 Discharged	Contents of Bottle No. 2 Discharged
1 (L.H. engine)	First shot - from #1 connection.	Second shot (only) - from #2 connection.
2 (R.H. engine)	Second shot (only) - from #2 connection.	First shot - from #1 connection.
3 (Hydraulic bay)	First shot - from #3 connection.	Second shot (only) - from #3 connection.

Figure 3 shows the distribution of extinguishing agent to the three fire areas. The percentage discharge of extinguishing agent to each nozzle of each fire area is given in Table 3:

TABLE 3

Nozzle (Ref. Fig. 2)	Percent Discharge		
	L.H. Engine	R.H. Engine	Hydraulic Bay
A	5.5	5.5	-
B	5.5	5.5	-
C	5.5	5.5	-
D	8.4	8.4	-
E	8.4	8.4	-
F	25.0	25.0	-
G	8.3	8.3	-
H	8.4	8.4	-
K	25.0	25.0	-
L	-	-	33 1/3
M	-	-	33 1/3
N	-	-	33 1/3
	100%	100%	100%

4.3 OPERATION OF FIRE EXTINGUISHING SYSTEM

The system is activated electrically, by means of combination push-button switch and fire warning light units. Operation of the switch for the appropriate area energizes the appropriate circuit, thus discharging extinguishing agent into the respective fire area. The triggering of the first shot to any fire area automatically established a "lock-on" in preparation for the second shot to the same area. Alternatively, the remaining extinguishing bottle may be discharged to either of the two other fire areas. The second shot to any fire area is accomplished by means of the second shot toggle switch, located on the same panel as the combination push-button switches.

A pilot-operated crash switch is located on the fire and fuel panel and installed so that in the event of a crash, all potential fire areas will receive a discharge of extinguishing agent. Bottle #1 is discharged to the hydraulic bay and bottle #2 is discharged into the two engine fire areas.

4.4 FIRE EXTINGUISHING CONTAINERS

Two non-shatterable 378.0 cu. in. capacity containers are located between the engines in the aft engine bay. The charge in each container is 12.0 lbs of CF_2BR_2 (Freon) pressurized with nitrogen gas at 400 psig. Each container is equipped with a pressure gauge, a safety disc and three solenoid operated discharge valves.

4.4.1 SOLENOID OPERATED DISCHARGE VALVES

The three discharge valves on each bottle are independently operated and connected to each of the three potential fire areas as shown in Figure 3. The valve is shown in Figure 5. Pressure within the fire extinguishing container, acting upon the full area of the main valve, keeps the discharge valve on its seat and maintains a leak-proof seal between the extinguishing agent and the outlet port. When the solenoid is energized (by the fire extinguishing switch, second shot switch or crash switch,) the pilot valve is withdrawn from its seat, admitting pressure to the lower side of the piston, which is attached to the main valve stem. Since this piston is of a larger area than the main valve seat, and pressures above and below the main valves are equalized, the main valve is pushed open. This allows the extinguishant to be forced through the outlet port by the gaseous nitrogen pressure.

4.4.2 SAFETY DISC

A safety pressure disc is installed at top of each container, and is designed to melt at a predetermined temperature to allow the gas to escape, and thus prevent the container from rupturing. In order to minimize the blast effects on the adjacent structure, the flow of escaping gas is restricted.

4.5 SHUTTLE VALVE

The outlet ports on the containers are interconnected. To prevent extinguishing agent from a second shot entering a container previously emptied on the first shot, a flap type shuttle valve is fitted between the discharge valves. Thus, the agent from either container is positively directed to the common line leading to each of the three fire areas.

4.6 SYSTEM PIPING

All piping in the fire extinguishing system is thin walled stainless steel. Since this is a high-rate discharge system, spray rings are not required and the agent is discharged through nozzles.

4.7 OPERATION OF FIRE EXTINGUISHING SYSTEM

The following combinations of two single shots to two different fire areas may be obtained:

(1) Discharge of bottle #1 to area 1, followed by the discharge of bottle #2 to area 2.

If fire occurs in the L.H. engine fire area, the L.H. push button switch is depressed, thus closing the extinguishing circuit. This supplies power through the hydraulic bay lock-on relay (B2-B3) to the #1 connection of extinguisher bottles #1 (Ref. Fig. 1). The discharge valve solenoid is then energized, releasing the contents of the bottle through the appropriate piping to the L.H. engine fire area. Simultaneously, the L.H. engine fire protection relay is energized, closing the circuit from the emergency d-c bus, through the relay (B2-B1) to the second shot relay this produces the lock-on position for a second shot to the L.H.

engine compartment from bottle #2.

For the first shot of extinguishant to the R.H. engine fire area, the R.H. engine fire warning push button is depressed which activates the discharge valve at connection #1 on #2 extinguishing bottle.

(2). Discharge of bottle #1 to area 1 followed by the discharge of bottle #2 to area 3.

Bottle #1 is discharged to area 1 as described in (1).

The L.H. engine fire protection relay remains energized after the discharge to the L.H. engine fire area. This maintains a closed circuit for discharge to the hydraulic bay, except for the open hydraulic bay extinguishing switch. The L.H. engine and hydraulic bay extinguishing switches. After #1 extinguishing bottle has been discharged to the L.H. engine, the energized relay will provide circuit connection to #2 extinguishing bottle for the first shot to the hydraulic bay fire area.

(3). Discharge of bottle #1 to area 3 followed by the discharge of bottle #2 to area 1.

The first shot to the hydraulic bay, from #1 extinguishing bottle, is initiated by operating the hydraulic bay extinguishing switch. This closes the circuit, through the L.H. engine fire protection relay (A2-A3), to the #3 connection on #1 extinguisher bottle. At the same time, the hydraulic bay lock-on relay is energized.

The discharge of #2 extinguishing bottle to the L.H. engine fire area will be initiated by operating the L.H. engine extinguishing switch. This will complete the circuit through the hydraulic bay lock-on relay (B2-B1) to #2 connection of #2 extinguishing bottle.

Alternatively, #2 extinguishing bottle may provide a second shot to the hydraulic bay fire area by closing the second shot switch. This will energize the #3 connection of #2 extinguishing bottle through the hydraulic bay lock on relay (A2-A1) and second shot relay (A2-B3).

(4). Discharge of bottle #1 to area 3 followed by the discharge of bottle #2 to area 2.

Bottle #1 will discharge to the hydraulic bay fire area as described in (3).

Bottle #2 will discharge into the R.H. engine fire area as described in (1).

(5). Discharge of bottle #2 to area 2 followed by the discharge of bottle #1 to area 1.

Bottle #2 will discharge to the R.H. engine fire area and bottle #1 will discharge to the L.H. engine fire area as described in (1).

(6). Discharge of bottle #2 to area 2 followed by the discharge of bottle #1 to area 3.

Bottle #2 will discharge to the R.H. engine fire area as described in (1).

Bottle #1 will discharge to the hydraulic bay fire area as described in (3).

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APPENDIX 1

EQUIPMENT LIST

FIRE PROTECTION SYSTEM

Description	Qty.	Part No.	Spec.	Manufacturer and part no. where applicable
Supply unit assembly	1	7-2358-15021	AVROCAN E 634	Kidde
Container and valve assembly	2	7-2358-15023	E 634	Kidde
Valve, double check, tee	3	7-2358-15025	E 634	Kidde
Bracket	1	7-2358-15027	E 634	Kidde
Sensing Element L.H. Engine	1	7-1158-15027	E 614	Kidde
	1	7-1158-15029	E 614	Kidde
	1	7-1158-15031	E 614	Kidde
	1	7-1158-15033	E 614	Kidde
	1	7-1158-15041	E 614	Kidde
R.H. Engine	1	7-1158-15027	E 614	Kidde
	1	7-1158-15029	E 614	Kidde
	1	7-1158-15031	E 614	Kidde
	1	7-1158-15033	E 614	Kidde
	1	7-1158-15041	E 614	Kidde
Equipment Bay	1	7-1150-5027	E 614	Kidde
	1	7-1150-15023	E 614	Kidde
Control Unit	3	7-1154-15097	E 614	Kidde

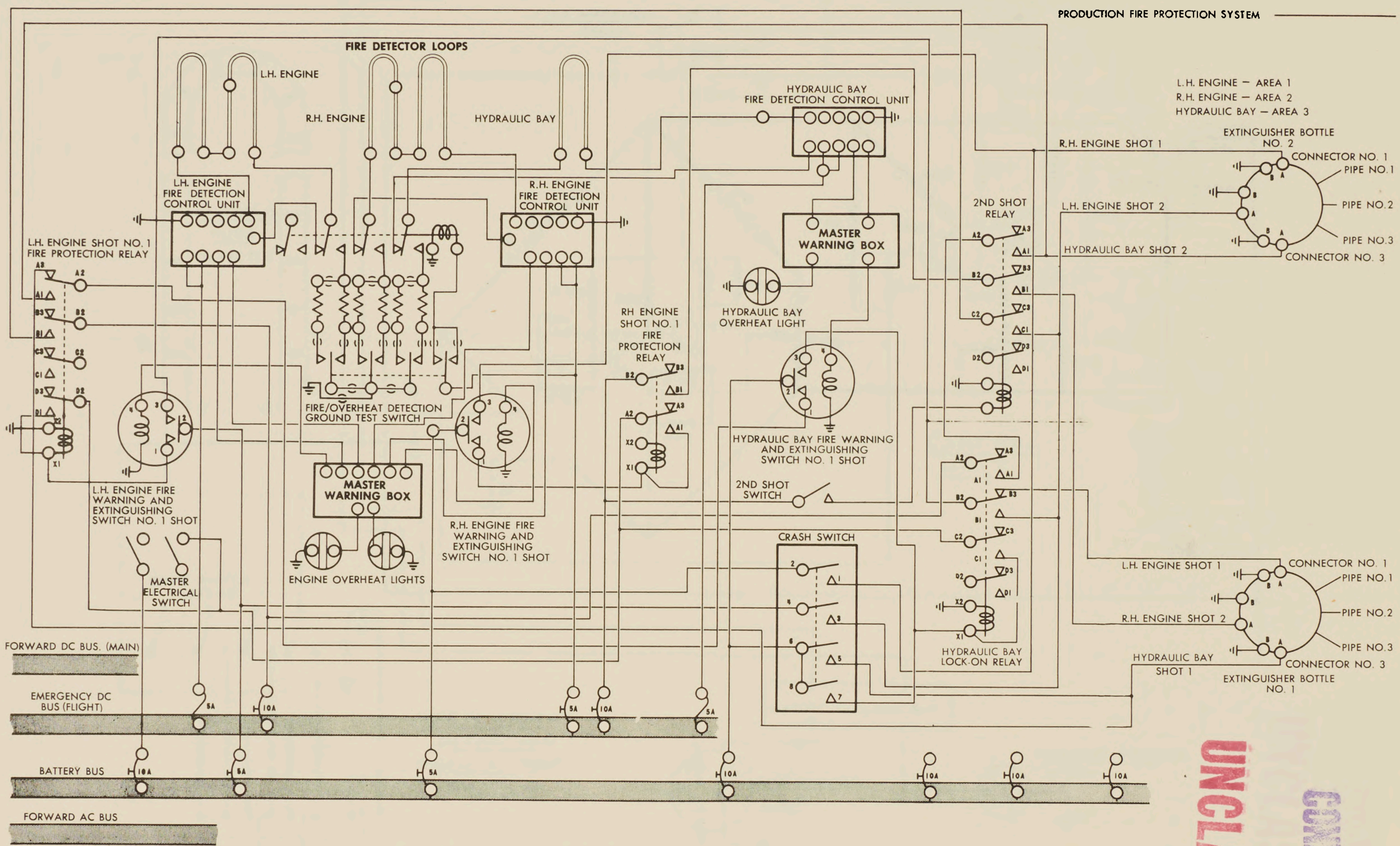

FIG. 1

FIRE PROTECTION SYSTEM WIRING DIAGRAM

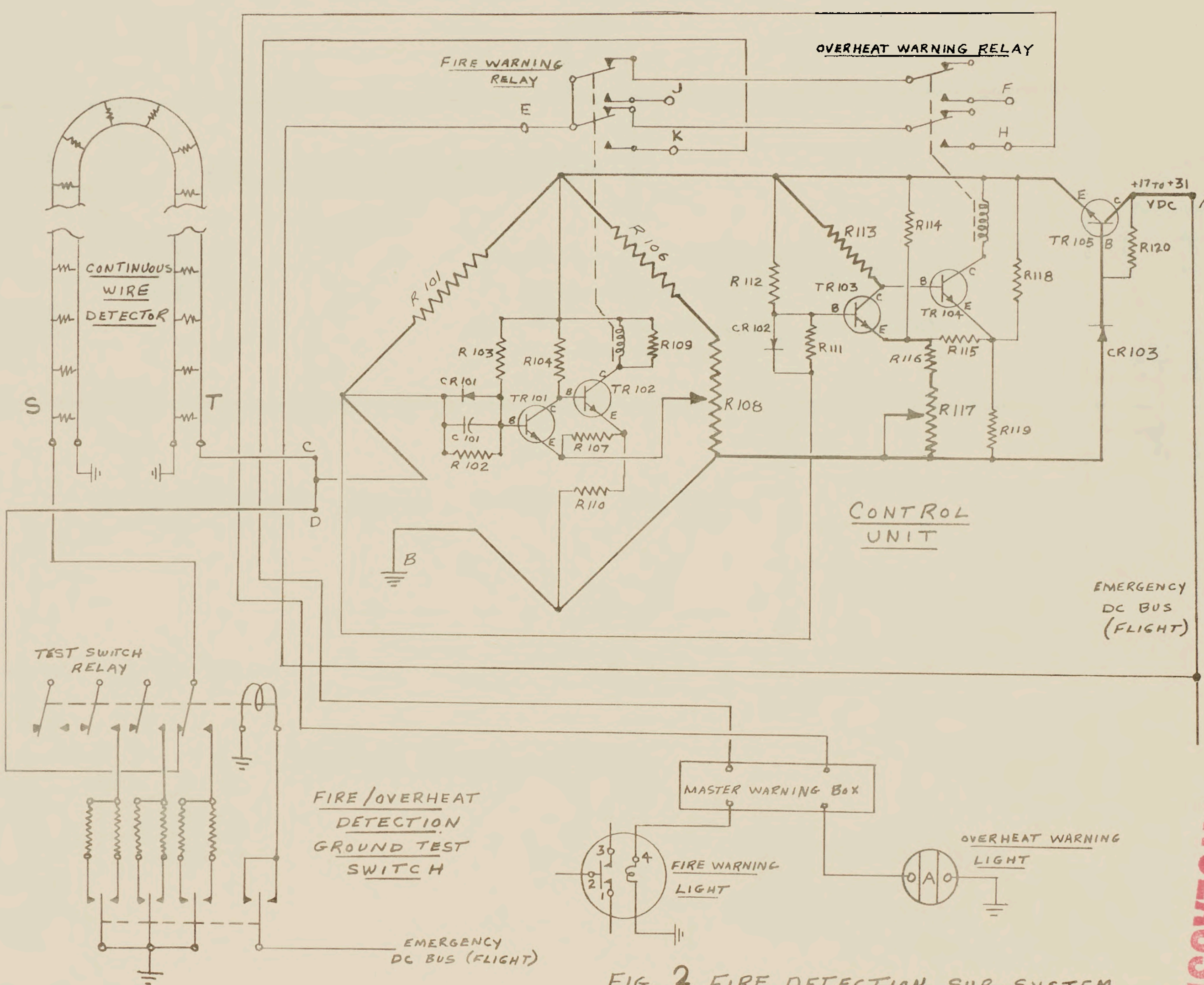

FIG. 2 FIRE DETECTION SUB-SYSTEM

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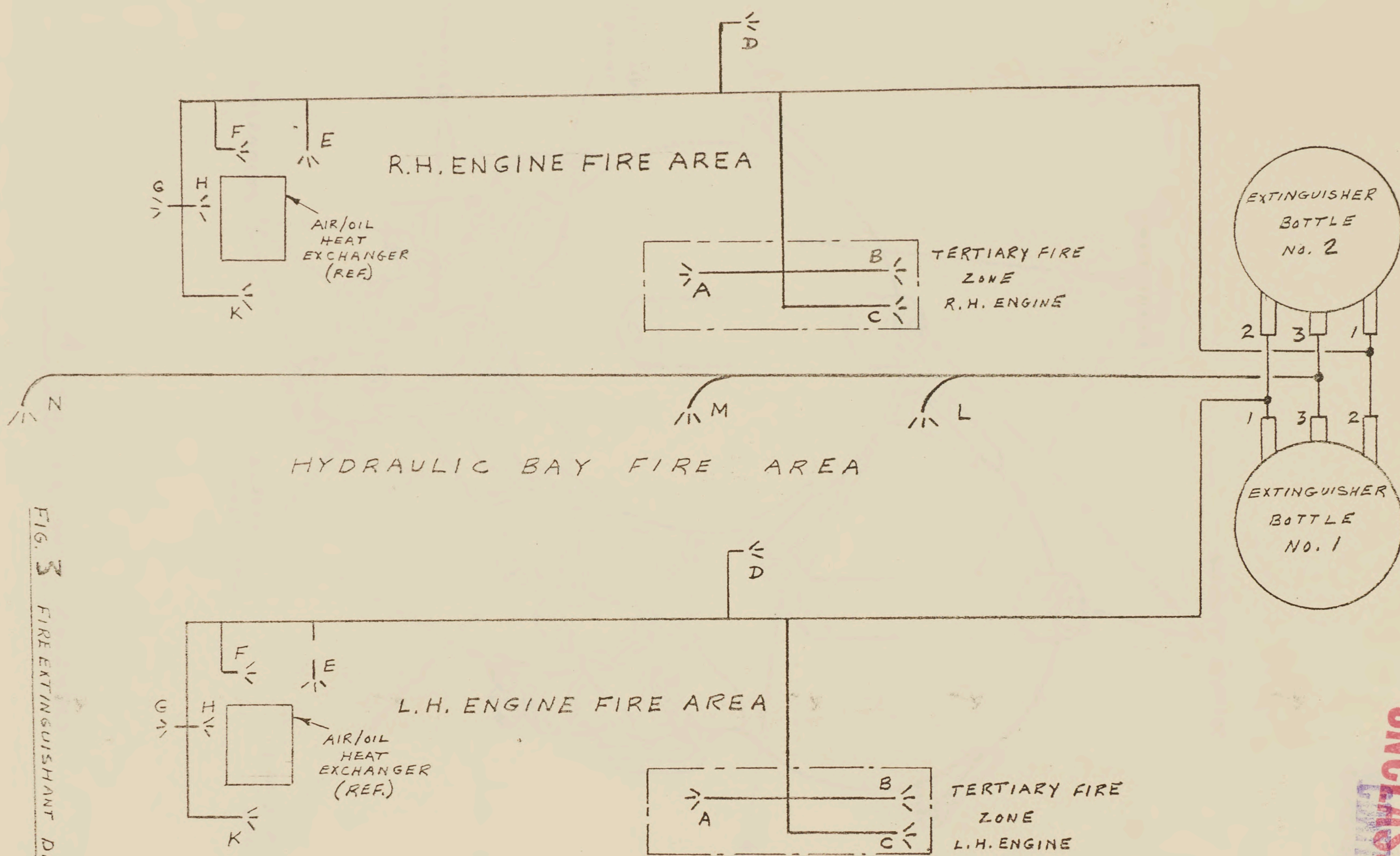


FIG. 3 FIRE EXTINGUISHANT DISTRIBUTION

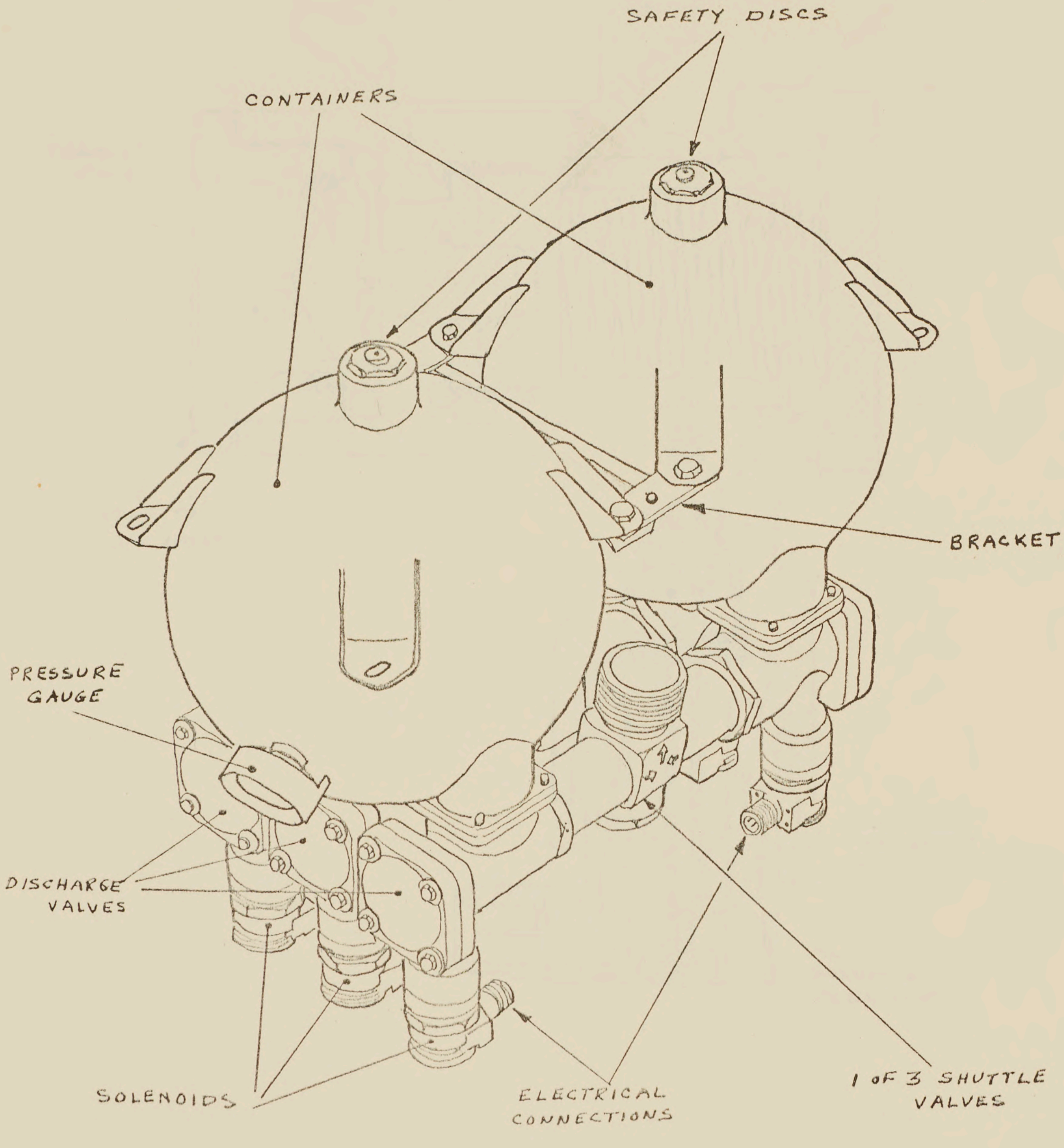


FIG. 4 SUPPLY UNIT ASSEMBLY

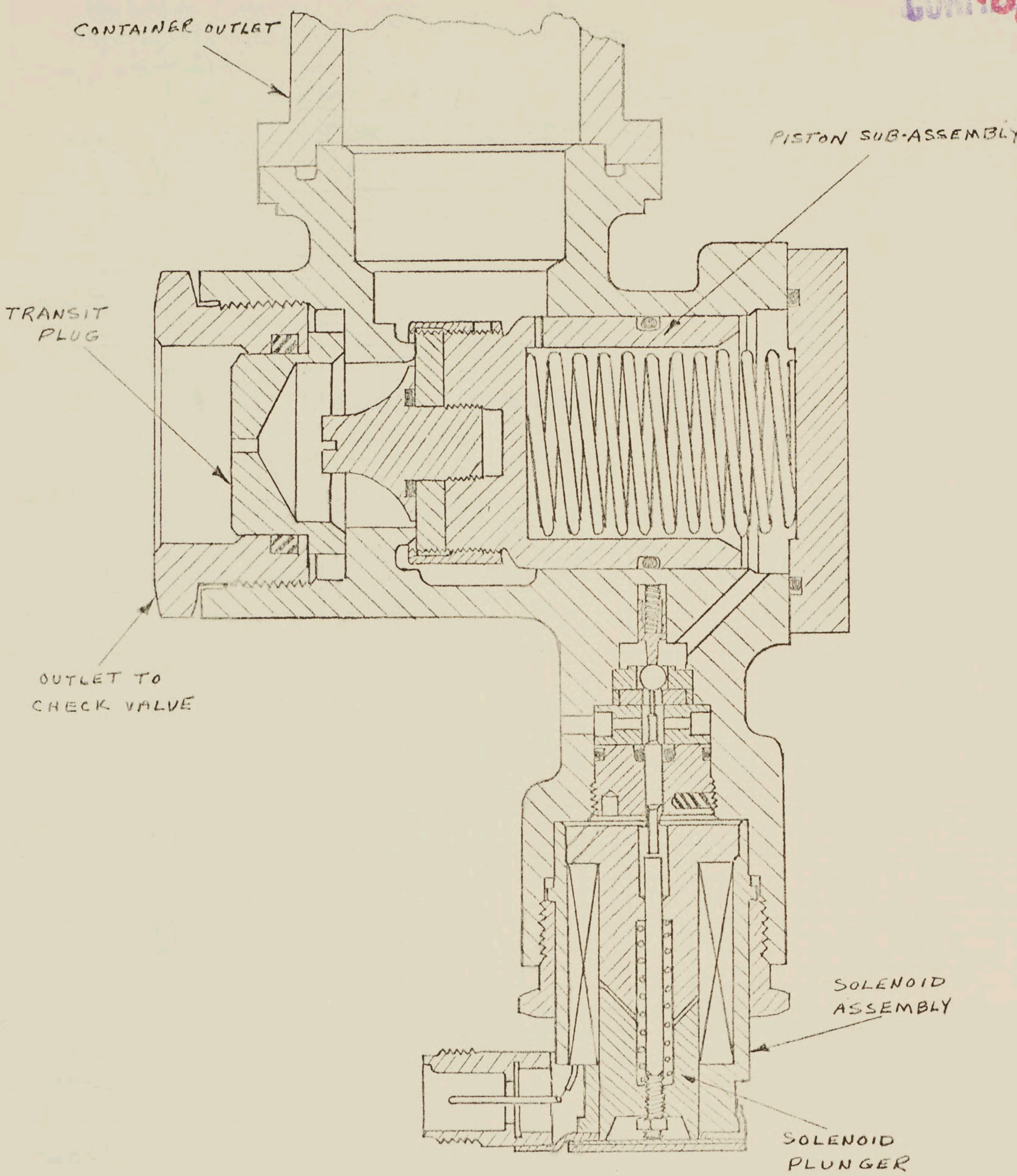
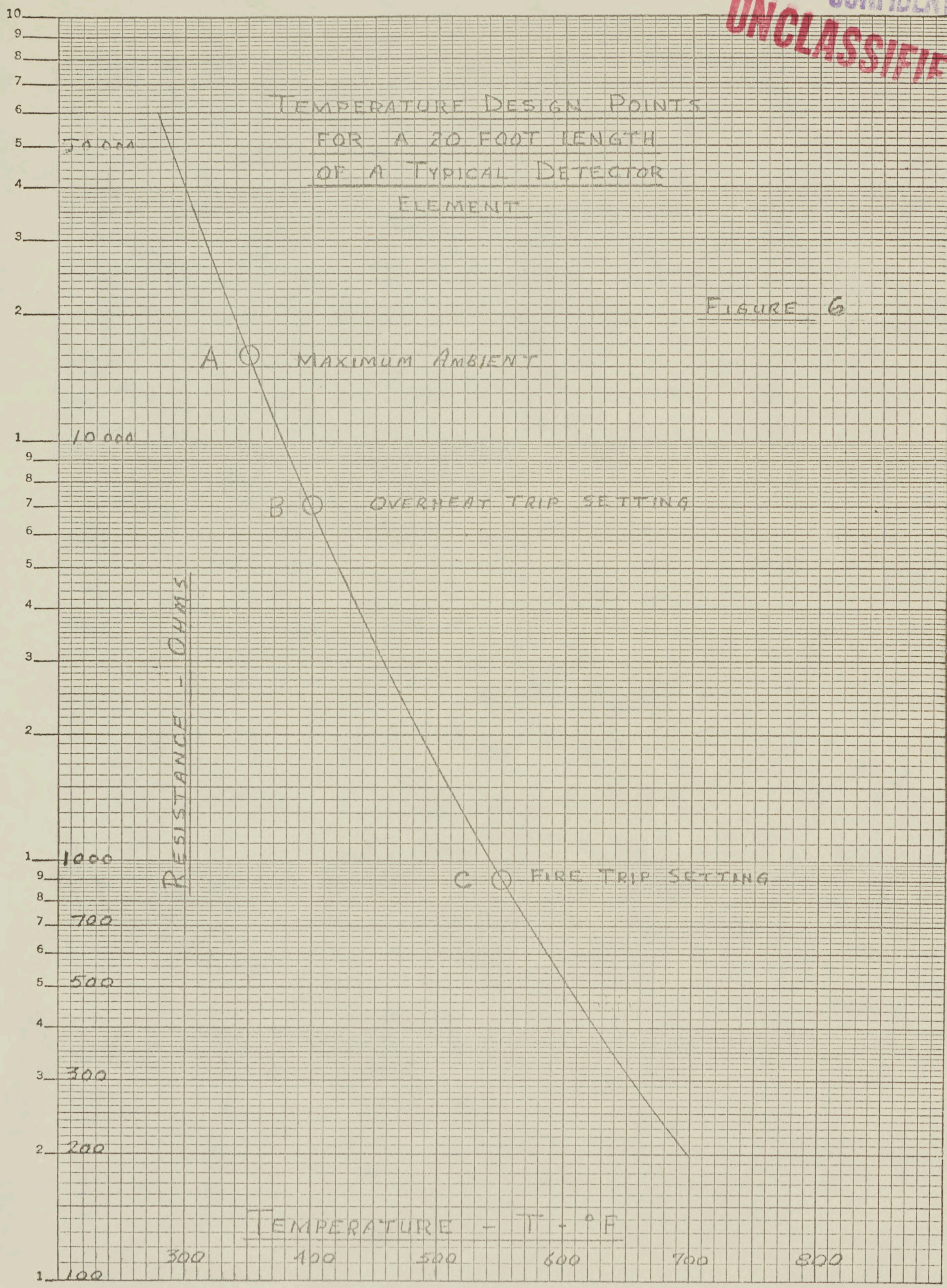


FIG. 5 DISCHARGE VALVE - SOLENOID OPERATED


TEMPERATURE DESIGN POINTS
FOR A 20 FOOT LENGTH
OF A TYPICAL DETECTOR
ELEMENT
FIGURE 6
A MAXIMUM AMBIENT
B OVERHEAT TRIP SETTING
C FIRE TRIP SETTING
RESISTANCE - OHMS
TEMPERATURE - T - °F
50 000
10 000
1000
700
500
300
200
100
300
400
500
600
700
800