DESIGN RECOMMENDATIONS FOR FIRE PROTECTION OF AIRCRAFT POWERPLANT INSTALLATIONS

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OF AIRCRAFT POWERPLANT INSTALLATIONS

INTRODUCTION

The Civil Aeronautics Administration is engaged in the conduct of a program involving fire tests on aircraft powerplant installations looking to the development of adequate fire detecting and extinguishing systems, the minimization of potential ignition sources, and the development of fire-resistant construction. This work was first undertaken by the Technical Development Division in the latter part of 1939 in accordance with urgent requests from the air transport industry and from the Administration's Aircraft Engineering Division.

To date, test programs involving the Douglas DC-3, the Curtiss-Wright CW-20, and the Waco YKS-37 installations have been completed and are discussed in detail in three reports entitled, "Determination of Means for Safeguarding Aircraft from Powerplant Fires in Flight," Part I, Part II, and Part III. This program is continuing and reports will be published periodically.

Although approximately 3,000 individual fire tests have been conducted, only two types of engines have been involved. The first was a typical fourteen-cylinder, double-row, radial engine, while the second was a seven-cylinder, single-row type. Perhaps the most significant fact that has emerged from the conduct of those tests is that a seemingly minor change in a given installation can seriously affect its fire protection requirements and often necessitates

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considerable testing before adequate protection is obtained. It is therefore important, in applying the following recommendations, to appreciate the limited number of engine installation types upon which they are based.

The purpose of this technical note is to present, in concise form, an interpretation of the material contained in the above reports in the form of recommendations, which it is hoped will aid engineers in their design of specific engine installations and fire protection systems.

RECOMMENDATIONS

A. General Requirements

Extinguishers

A-1 Sections of a powerplant installation which must be protected against fire include all potential fire zones on the powerplant side of a flame-tight, fire-resistant firewall.

A-2 Potential fire zones shall include all sections through which flow inflammable liquids.

A-3 Zones into which vapors of inflammable fluids may enter shall be considered as potential fire zones.

A-4 Zones into which fire may penetrate through materials of low fire resistance shall be considered as potential fire zones.

A-5 The carburetor air induction system shall be considered a potential fire zone.

A-6 Segregated potential fire zones shall be individually protected against fire.

A-7 In general, potential fire zones involving the flow of great quantities of air past systematic arrangements of identical obstructions, i.e., cylinders, should be protected by systems which provide equal distribution of the extinguishing agent across the air flow. The nozzles should be so located with respect to the obstructions that overlapping double-spray patterns are obtained.

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A-8 Potential fire zones through which flow great quantities of air, but which are clean aerodynamically, shall be protected by an arrangement of nozzles or perforated tubing which shall discharge extinguishing agent between the air inlet and the hazardous region.

A-9 The agents mentioned in paragraphs A-7 and A-8 shall be applied with a force sufficient to cut directly across the air stream to the regions most remote from the nozzle locations.

A-10 Potential fire zones, subject to low air flow rates in comparison with the volume of the zone, do not require equality of agent distribution, but do require reasonable distribution at an agent discharge rate sufficient to flood the zone.

A-11 Potential fire zones through which no air flows do not require equal agent distribution, but do require sufficient agent to flood the zone.

A-12 Discharge rates of extinguishing agents into all potential fire zones shall be sufficient to arrest and prevent combustion for a minimum duration of 2 seconds.

A-13 Extinguishing agents shall be discharged simultaneously to all zones protected.

Detectors

A-14 Fire detectors should be installed in all major potential fire zones excluding the carburetor induction systems, and zones where fire may penetrate or burning fluids enter.

A-15 All fire detecting systems should incorporate supervisory circuits to indicate that the system is in operating condition.

A-16 In general, wire type continuous detectors are preferable to unit type detectors.

A-17 Suitable detectors can be obtained which operate on the following principles:

1. Flame contact.
2. Expansion of metals due to heat.
3. Fusing of metals due to heat.
4. Rate of temperature rise (thermocouples).

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Materials

A-18 Structural members, ducts, and firewalls in potential fire zones should be steel or equally fire-resistant material.

A-19 In general, tubing on the engine side of the main fire-resistant bulkhead should be steel, copper, or material of equal fire resistance. Tubing carrying flows of oil can be made of aluminum alloy.

A-20 Conventional NACA aluminum alloy ring cowls and flaps are suitable from the fire hazard standpoint.

A-21 With the exception of the NACA cowl, all cowling, all nacelle skin, and all wing skin within 18 inches of the engine nacelle, should be of stainless steel or material of comparable fire resistance.

A-22 Standard neoprene hose connections are sufficiently fire resistant for use in engine installations.

A-23 If rubber engine mounting bushings are used, support design should prevent loss of engine in event that bushings are destroyed.

A-24 Ferrule type or flared type fittings should be used in all engine installation tubing systems. Silver soldered connections are not sufficiently fire resistant.

Design

A-25 Powerplant installations in general, and external surfaces of engine cowls in particular, should be as clean as possible aerodynamically.

A-26 Firewalls and cowl pieces should be flame tight and fire resistant.

A-27 Exhaust system outlets should be located as near the top of the engine installation as possible.

A-28 Air inlets for oil coolers, intercoolers, blast tubes, and similar equipment, should be so located as to prevent entrance of flame or burning fluids.

A-29 Muffs, shrouds, or baffles around exhaust systems should be vapor tight or well ventilated. Stagnant volumes of air and oil vapor can be serious ignition sources.

A-30 Shut-off valves should be incorporated in all inflammable fluid systems passing through the engine installation; such valves should be located on the rear of the firewall, or, if this is impossible, close to the fluid supply tank.

A-31 Landing gear tires should be protected from flames by full-closing bays, or so located as to be out of flame path from engine installation.

A-32 A placard should be located in the cockpit which includes the following:

1. In case of powerplant fire, open air inlets to oil coolers, intercoolers, and similar equipment.

2. Cut off flows of inflammable fluids through engine installation.

3. Feather propeller.

4. Shut down engine.

5. Set extinguishing agent selector valve, if any, to proper engine installation.

6. Release extinguishing agent.

7. DO NOT START ENGINE AGAIN.

NOTE: Lower landing gear (if this is necessary to remove tire from flame path).

B. Detail Requirements

Extinguishers

B-1 In potential fire zones of the type described in paragraph A-7, the minimum quantity of agents required shall be computed as follows:

Methyl Bromide (pounds) =

$$0.28 \times \left(\begin{array}{l}\text{pounds air through} \\ \text{zone in 2 seconds}\end{array}\right) \times \frac{\text{No. of engine cylinders}}{14}$$

Carbon Dioxide (pounds) =

$$0.35 \times \left(\begin{array}{l}\text{pounds air through} \\ \text{zone in 2 seconds}\end{array}\right) \times \frac{\text{No. of engine cylinders}}{14}$$

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B-2 The quantity of agent mentioned in paragraph -1 shall be distributed equally as between discharge nozzles (within plus or minus 10 percent). One suitable radial engine installation is illustrated in figure 1. A special case requiring additional nozzles (CW-20) is shown as figure 2, the required agent increased in proportion to number of nozzles.

NOTE: Equal distribution to the nozzles can be obtained by means of a distributor ring and leads (figures 2, 3, and 4).

B-3 For equal distribution, lines from the distributor to nozzles must be of approximately equal length.

B-4 For protecting potential fire zones as described in paragraph A-8, the minimum quantities of agents required shall be computed as follows:

Methyl Bromide (pounds) = 0.20 x (pounds of air through zone in 2 seconds)

Carbon Dioxide (pounds) = 0.25 x (pounds of air through zone in 2 seconds)

B-5 The system for discharging agent quantities of paragraph B-4 shall consist of spray nozzles or perforated tubes, providing approximately equal distribution (plus or minus 25 percent), which produce a sheet of agent spray across the cross section of the zone at right angles to the air flow (figures 5 and 6; views A and B).

B-6 Total agent outlet area for systems described in paragraphs A-7 and A-8 should equal approximately 0.11 square inch per pound agent discharged per second.

B-7 Cross sectional area of nozzle feed lines or ring tubes for systems described in paragraphs A-7 and A-8 should equal approximately 110 to 125 percent of total connected outlet area, and the main feed line cross sectional area should equal approximately 110 to 125 percent of the total area of connected nozzle feeds or ring tubes.

B-8 In potential fire zones of the type described in paragraph A-10, the minimum quantities of extinguishing agents required should be computed as follows:

Methyl Bromide (pounds) = 0.16 x zone volume (cu. ft.)

Carbon Dioxide (pounds) = 0.20 x zone volume (cu. ft.)

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B-9 In potential fire zones of the type described in paragraph A-11, the minimum quantities of extinguishing agents required should be computed as follows:

Methyl Bromide (pounds) = 0.11 x zone volume (cu. ft.)

Carbon Dioxide (pounds) = 0.14 x zone volume (cu. ft.)

B-10 Equality of distribution is unnecessary in systems for zones described in paragraphs A-10 and A-11. To insure agent flooding in all regions of the zone, the discharge of agent from no part of the system should be less than 50 percent of the discharge which would result if equal distribution existed. This is necessary to assure rapid placement of agent in all regions.

B-11 In zones discussed in paragraphs A-8, A-9, and A-10, agent should be distributed without regard to particular fire hazards or obstacles using perforated tubes or, if desired, nozzles for use with methyl bromide. (See figures 5 and 6.)

B-12 The total outlet areas for systems described in paragraphs A-10 and A-11 shall equal approximately 0.07 square inches per pound agent per second.

B-13 The cross sectional area of the feed rings for systems described in paragraphs A-10 and A-11 shall equal 100 to 110 percent of the total outlet area and the main feed line area shall equal 100 to 110 percent of the feed ring area.

B-14 Rates of discharge of agents in systems described in paragraphs A-7, A-8, A-10, and A-11, shall equal one-half the quantities mentioned in paragraphs B-1, B-4, B-8, and B-9, and shall be in terms of pounds of agent per second.

B-15 The proper rate of agent discharge for each potential fire zone described in paragraph B-14, should be maintained in each zone for a minimum duration of 2 seconds.

B-16 When equal agent distribution is unnecessary and circular perforated tubes or nozzles supplied by tubular rings are used, the feed line should enter the ring near the bottom of the zone.

B-17 In any of the potential fire zones, the <u>rate</u> of agent application is most important. Any increase in duration of discharge should be accompanied by a proportional increase in agent quantity rather than a decrease in agent discharge rate.

B-18 Nozzle designs for providing sheet type spray patterns for zones carrying high air flows are shown in figure 7.

B-19 Nozzle designs for distributing methyl bromide in zones of low air flow are shown in figure 8.

B-20 Perforated tubing is shown in figure 5, view C.

B-21 Nozzles, feed lines, rings, tubing, fittings and distributors located in the powerplant installation should be of copper, brass, bronze or material of equal heat resistance.

B-22 Nozzles should incorporate means for excluding foreign matter from slots until operation of the system.

B-23 When properly located, nozzles and tubing should be fastened to other members to prevent such parts from being enveloped by flame due to the adverse effect of heated tubing on distribution.

B-24 Release valves used in extinguishing systems should be absolutely leak-proof, quick-operating, and of large cross section, due to the high rate of agent discharge required.

B-25 Mechanisms for releasing discharge of extinguishing agents should be designed to operate with a minimum of effort on the part of the airplane crew.

B-26 Agent containers should incorporate means for checking the quantity of agent and the pressure without removal from the airplane.

B-27 Agent containers should be so located in aircraft that the containers will be subjected to minimum temperature variations under flight conditions. A temperature range between 60 and 100 degrees Fahrenheit is preferable as it is difficult to obtain the necessary high discharge rates at lower temperatures, particularly in the case of carbon dioxide.

B-28 Three general extinguishing systems can be designed for any multi-engined aircraft:

1. Supply of agent located in or near each engine nacelle.

2. One supply of agent located in each wing with a selector valve for directing agent to any one engine.

3. One supply of agent located in the fuselage with a selector valve for directing agent to any one engine installation in the airplane.

B-29 An accurate estimate of the weights of each system described in paragraph B-28 should be made to determine the system giving the greatest fire protection for the least weight.

B-30 Simplicity and lightness of the extinguishing system can be obtained by using a single main feed line from the agent supply to the powerplant installation and by branching off from this main line to the segregated potential fire zones.

B-31 Sharp turns should be eliminated from the entire system in order that proper distribution and rate may be more easily obtained.

B-32 Methods by which agent discharge rates may be increased include:

1. Shortening and/or increasing cross section of main feed line.

2. Shortening and/or increasing cross section of nozzle leads or secondary feed lines.

3. Increasing nozzle bore diameters or slot width.

4. Increasing pressure of expellant in agent container.

5. Increasing container outlet area, valve area, and the speed of valve opening.

Detectors

B-33 Fire detectors should be located around areas of air egress from the zones to be protected.

B-34 In potential fire zones of large volume, it is necessary to provide additional fire detectors in central location to detect small fires which might never reach areas of air egress. (Figures 11 and 12.)

B-35 Unit fire detectors must be placed close together, exact locations being determined by smoke flow tests to determine the flow pattern through the potential fire zone and the degree of stratification present. (Figures 10 and 12.)

B-36 All fire detectors should be installed 1 or 2 inches away from supporting surfaces to insure flame contact.

B-37 Fire detecting circuits should be so designed as to require no current through the circuit until it is actually providing alarm.

B-38 Fire detectors should be so designed as to become inoperable in the event of detector failure rather than to produce a false alarm.

B-39 Materials used in fire detecting systems and supports should resist fires of 2000 - 2100 degrees Fahrenheit for at least as long as it takes the detector to operate.

B-40 Fire detectors of the fusible alloy or metal expansion types shall operate at temperatures 50 to 100 degrees higher than the maximum temperature possible under ordinary flight conditions in the particular potential fire zone. Rate-of-rise type detectors should be designed to operate under conditions of abnormal temperature increases. Flame type detectors require no setting.

B-41 Fire detectors should operate within 3 to 5 seconds of the start of a gasoline or oil fire.

B-42 Fire detectors should not be affected by exposure to vibration, water, or any of the liquids used in aircraft powerplant installations.

B-43 Fire detectors should be capable of positive operation during, or after, exposure to conditions of paragraph B-42.

C. Method of Inspecting and Tests

Extinguishers

C-1 The entire extinguishing system for each engine installation should be tested prior to installation in the airplane as hereinafter specified.

C-2 The extinguishing system should be mocked up exactly as it is to be finally installed.

C-3 Due to the volatility of methyl bromide, systems designed for use with this liquid should be tested with carbon tetrachloride.

C-4 Distribution of liquid to the various parts of the system can be obtained by collecting and measuring the discharges from each nozzle or part of the system, and the system revised accordingly.

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C-5 Rate of liquid discharge can be tested photographically by collecting liquid over various time intervals from the starts of successive discharges. Movies taken at a rate of 32 frames per second with given time intervals will give data from which a time-quantity curve can be plotted. Slope of this curve is actual rate at any point. Average slope over 2 seconds gives average rate.

C-6 Distribution of carbon dioxide can best be made by examination of motion pictures taken at a rate of 32 frames per second.

C-7 Rate of carbon dioxide can be approximated by determining duration of discharge of required quantity. Motion pictures taken at 32 frames per second can be used for determining duration of discharge.

C-8 Proper rate and distribution tests should be conducted as discussed in paragraphs C-1 to C-7, with the agent container and contents at the same internal temperature and pressure which will prevail in the container under flight conditions. Any change from this condition may result in rate or distribution variations which can be critical.

Detectors

C-9 Fire detectors should be tested by plunging detector into a gasoline blow torch flame of 2000 degrees Fahrenheit and determining operating time as time elapsed from instant detector enters flame to time of operation. A chromel-alumel thermocouple of #18 gage wire should be used to measure flame temperature.

C-10 Fire detectors should be tested to assure no operation at temperatures possible in engine compartments without fire.

C-11 Detectors should be tested to assure no faulty operation due to exposure to vibration, oil, water, or any other condition normally present in engine compartments.

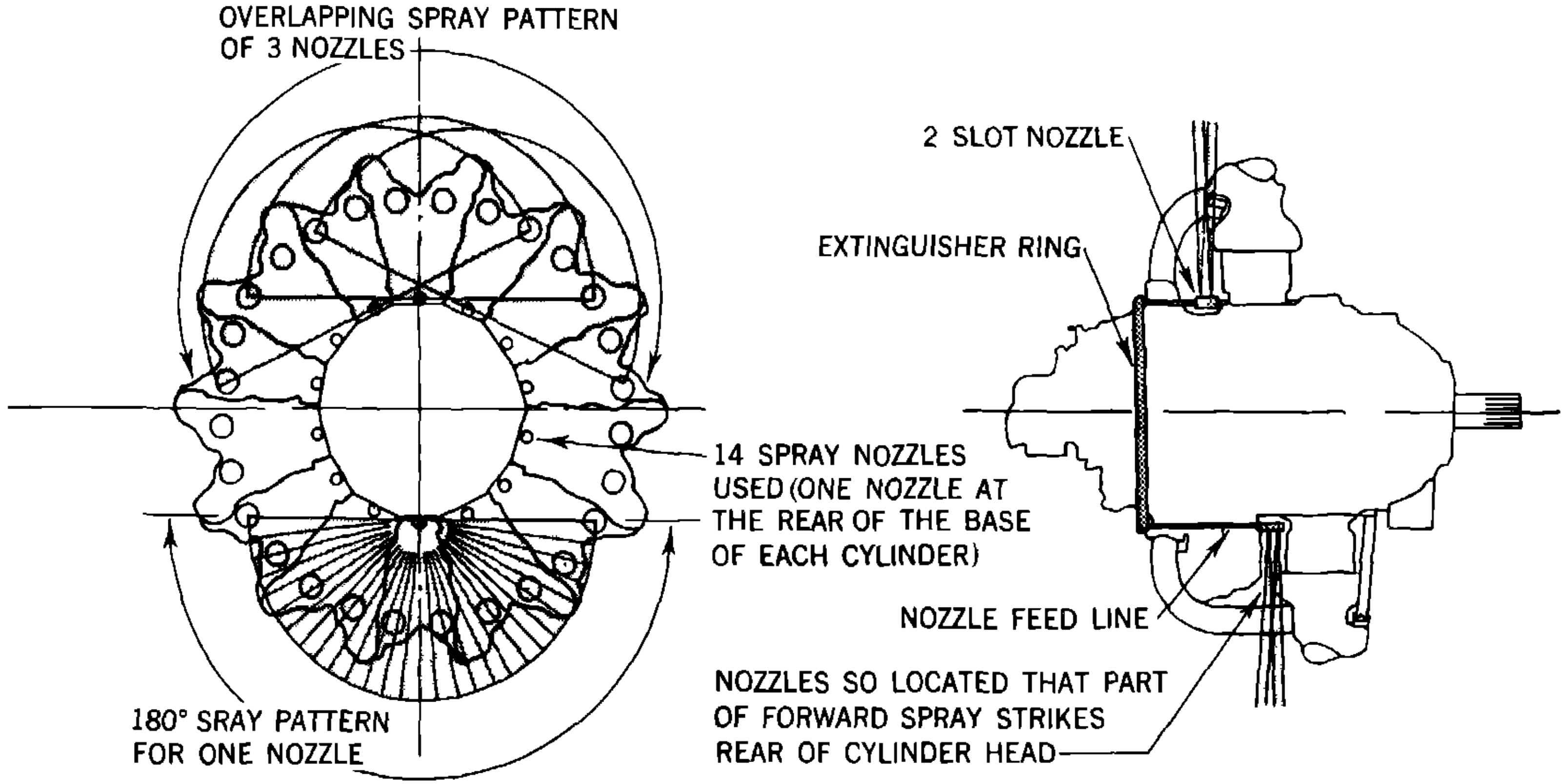

FIGURE 1. Typical System for Power Section Protection
(of Radial Engine Installation)

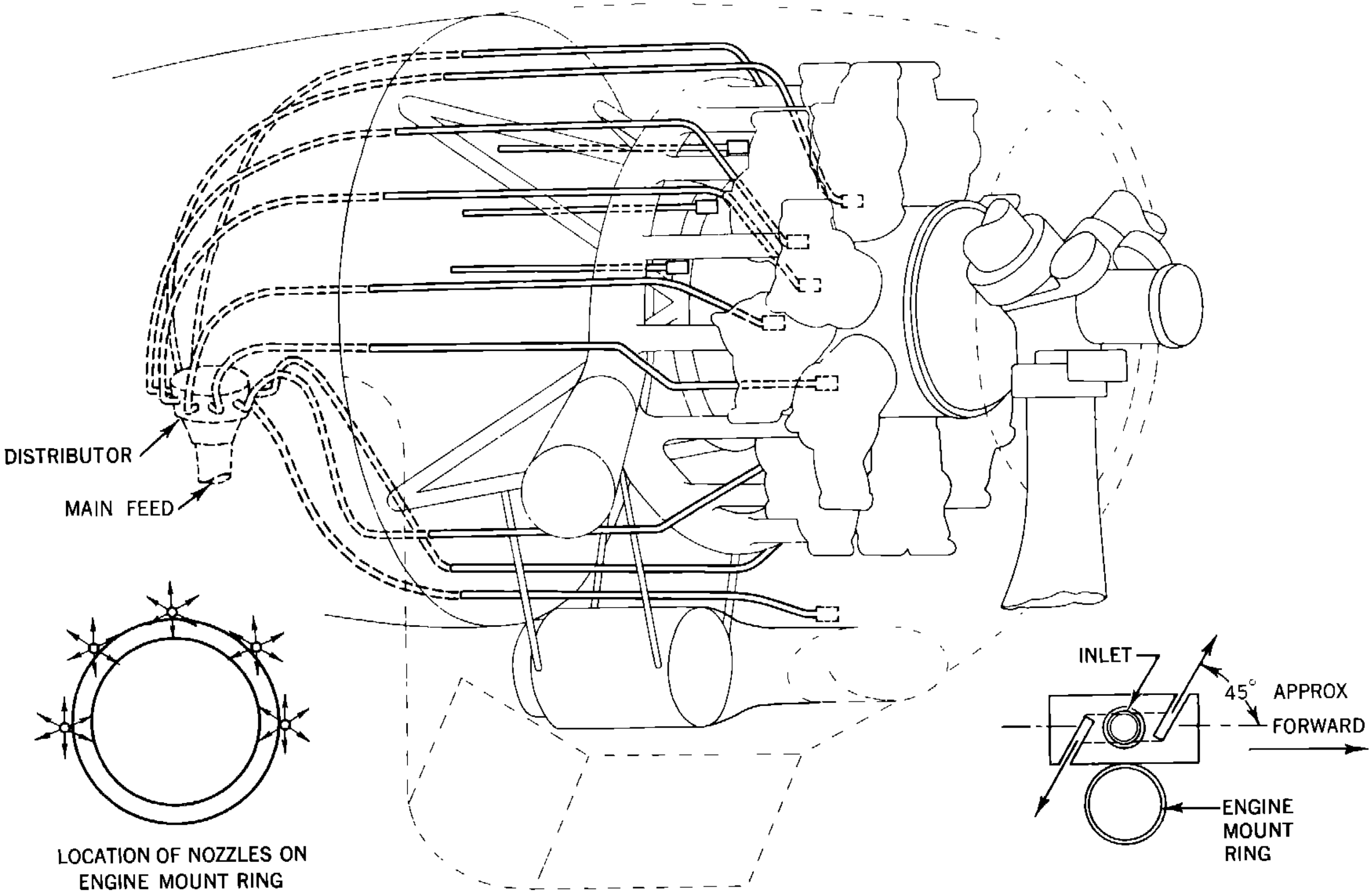

FIGURE 2. Typical System for CW-20 Type Installation
(No Diaphram)

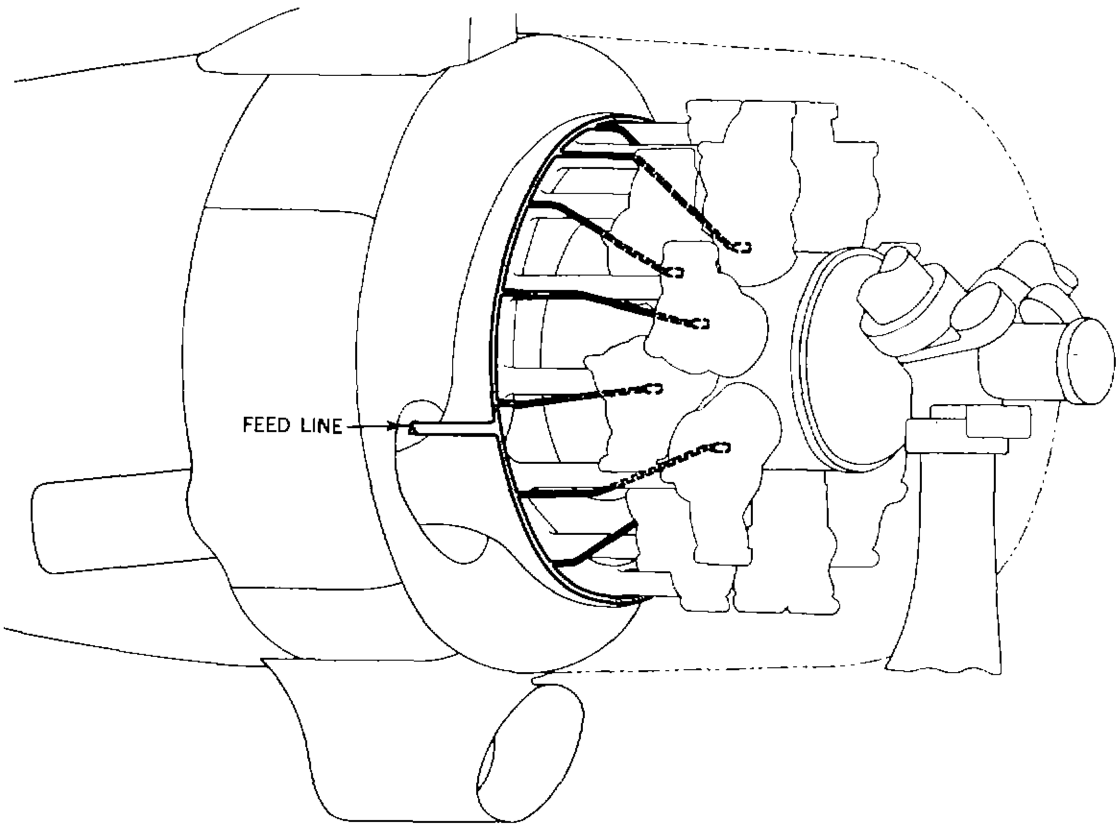

FIGURE 3. Ring Type Power Section Extinguishing System

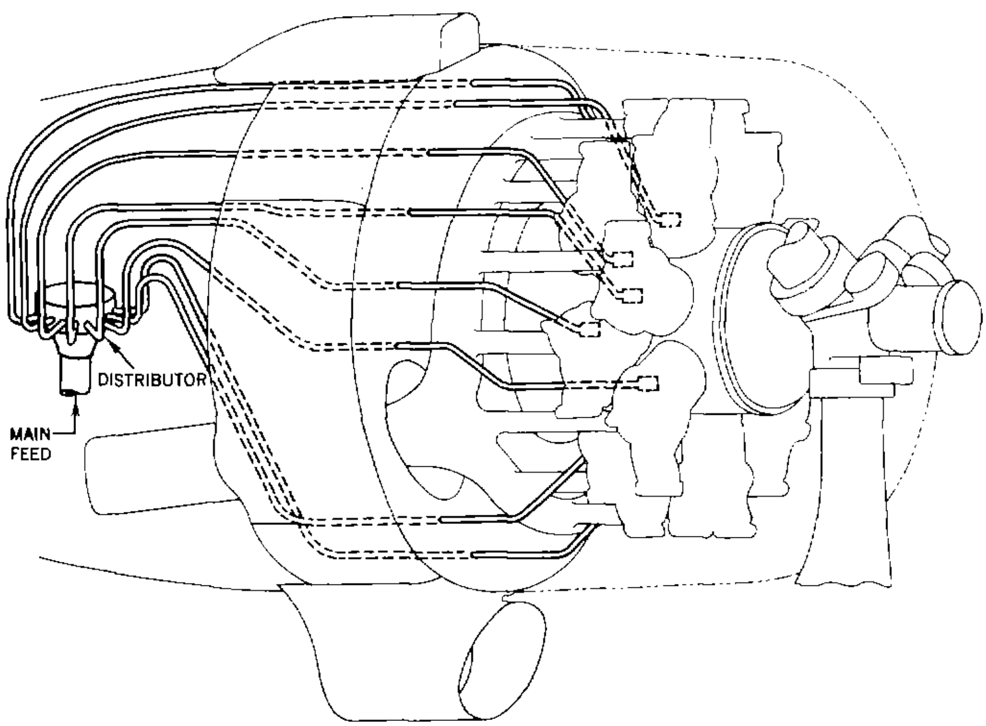

FIGURE 4. Distributor Type Power Section Extinguishing System

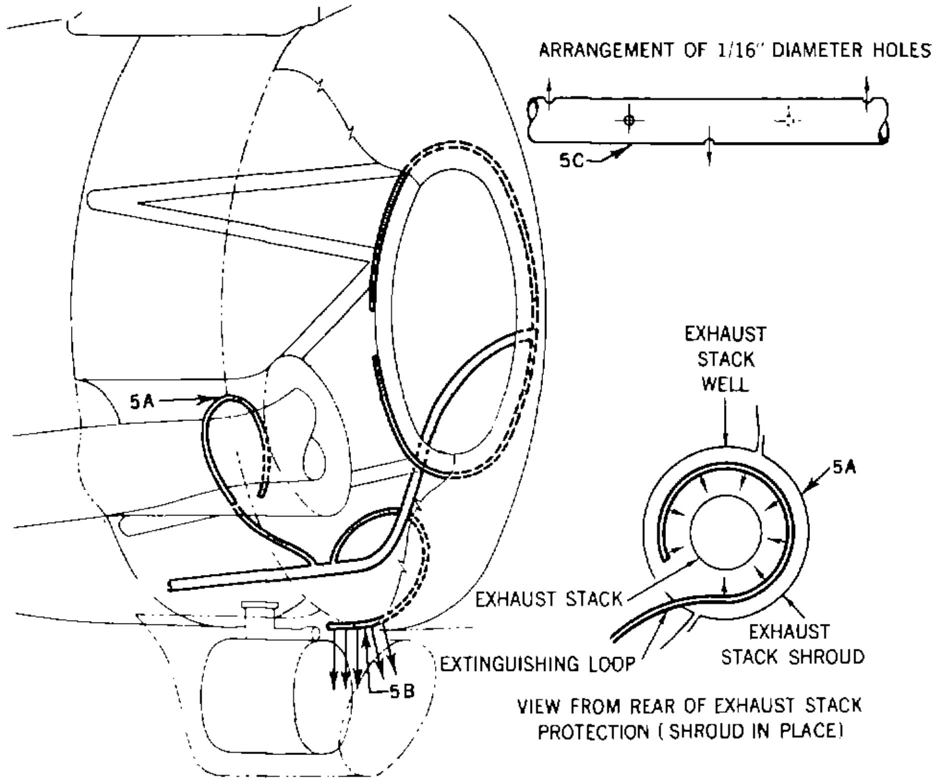

FIGURE 5. Typical Accessory Section System for Gaseous Agents

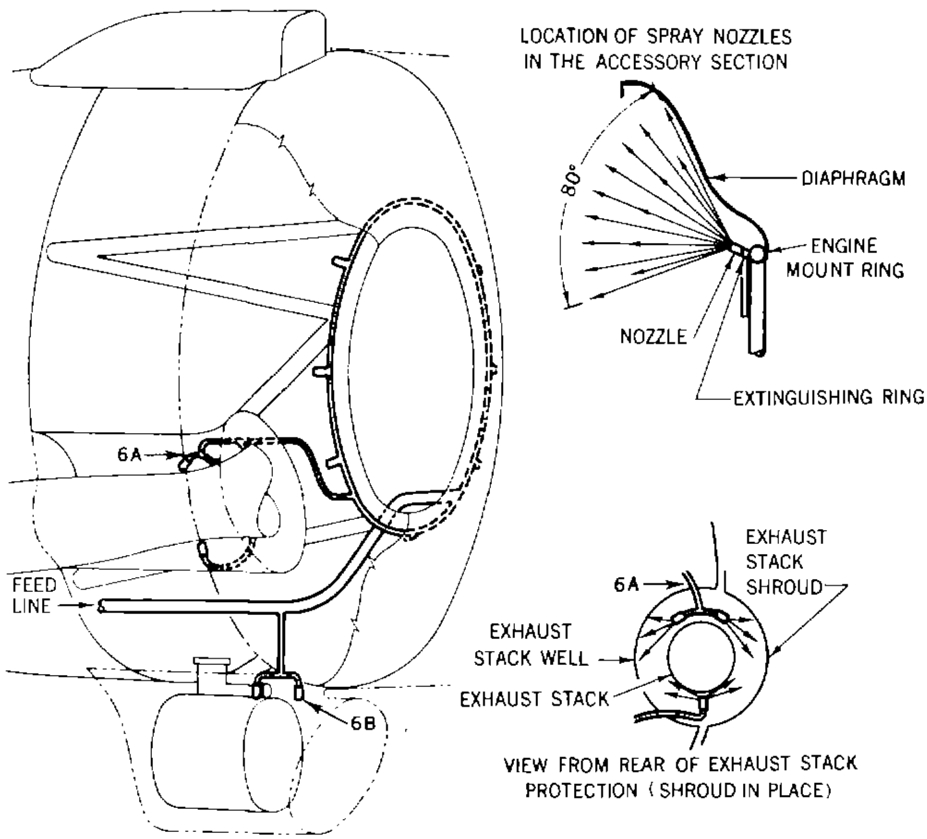

FIGURE 6. Typical Accessory Section System for Liquid Agents

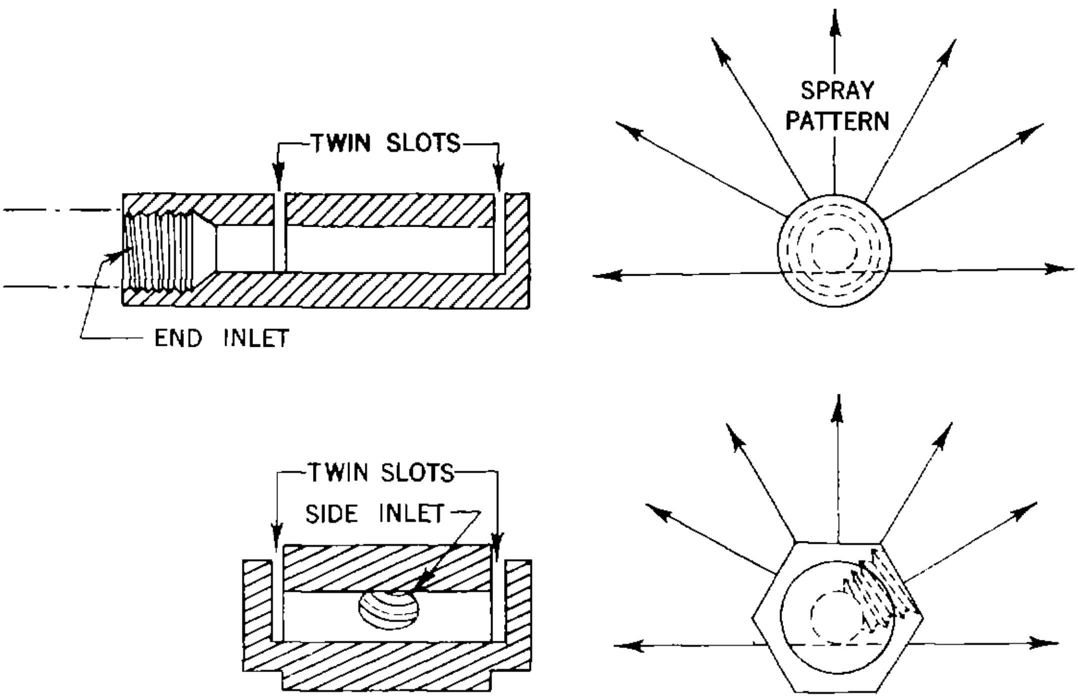

FIGURE 7. Types of Power Section Discharge Nozzles

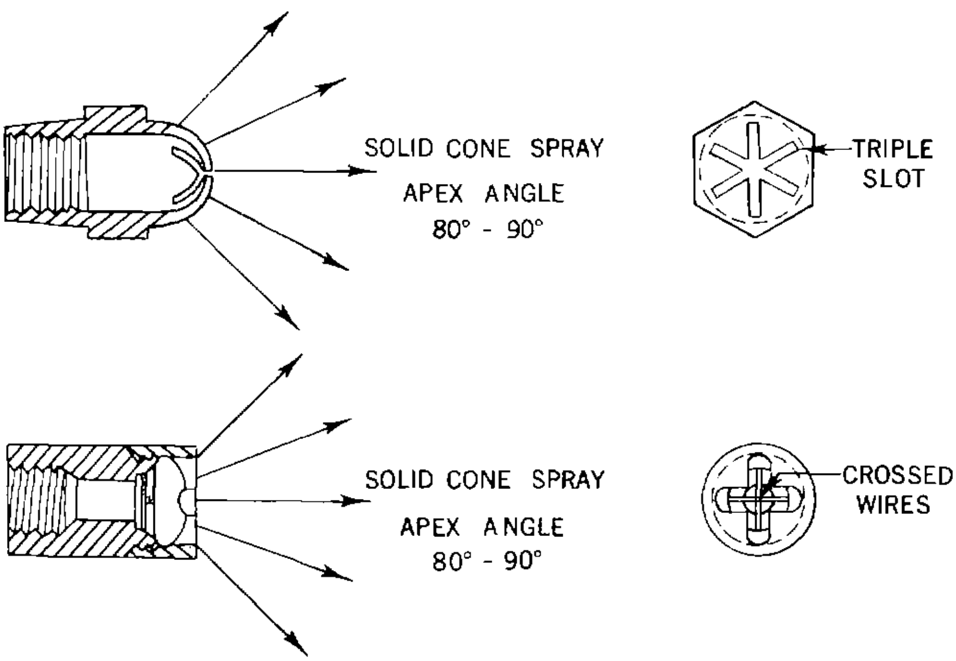

FIGURE 8. Types of Accessory Section Discharge Nozzles

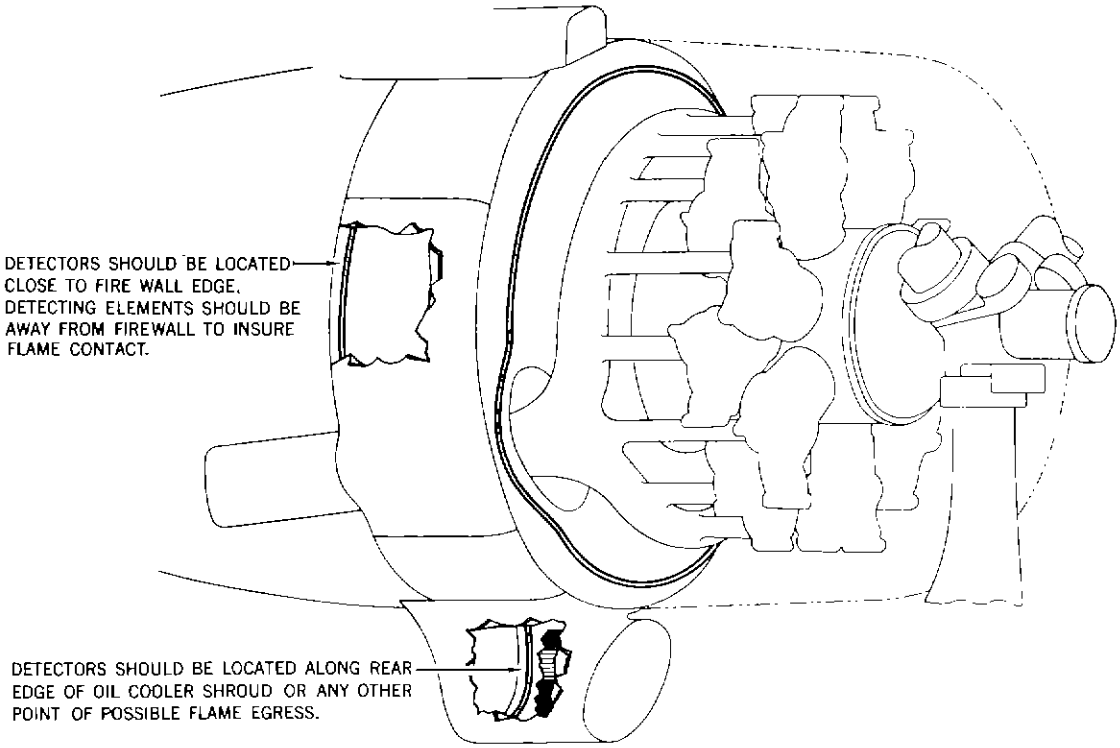

FIGURE 9. Continuous Detector in DC-3 Type Installation

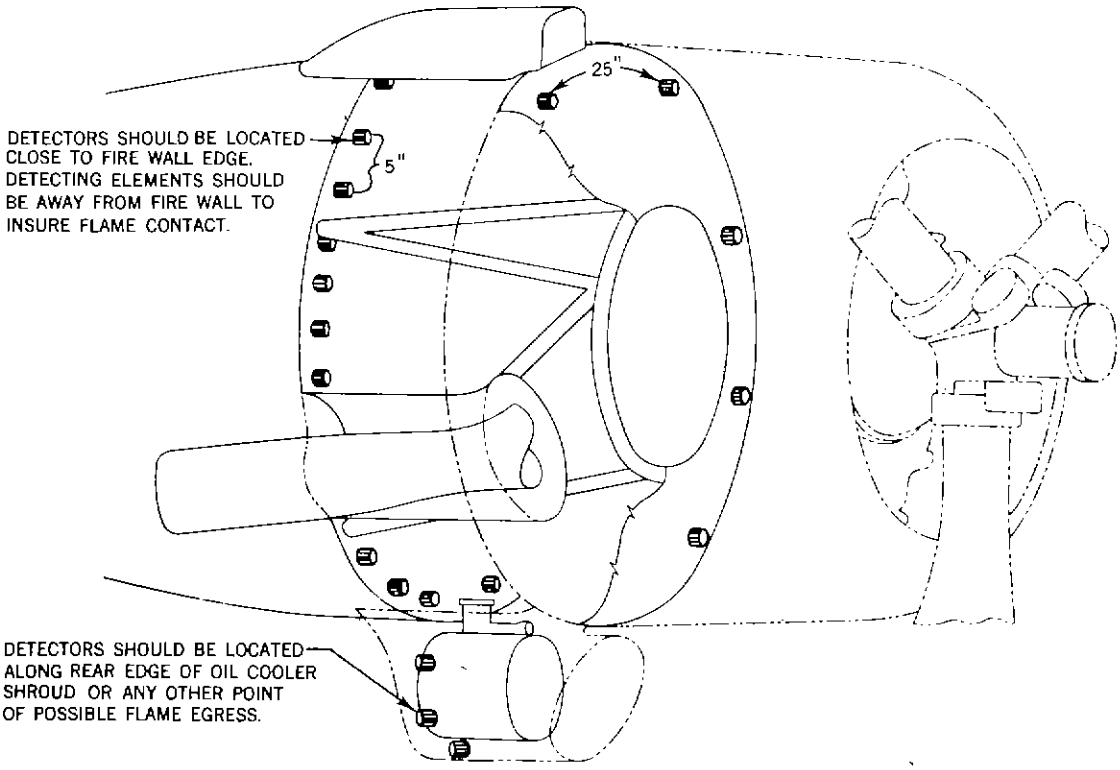

FIGURE 10. Unit Detectors in DC-3 Type Installation

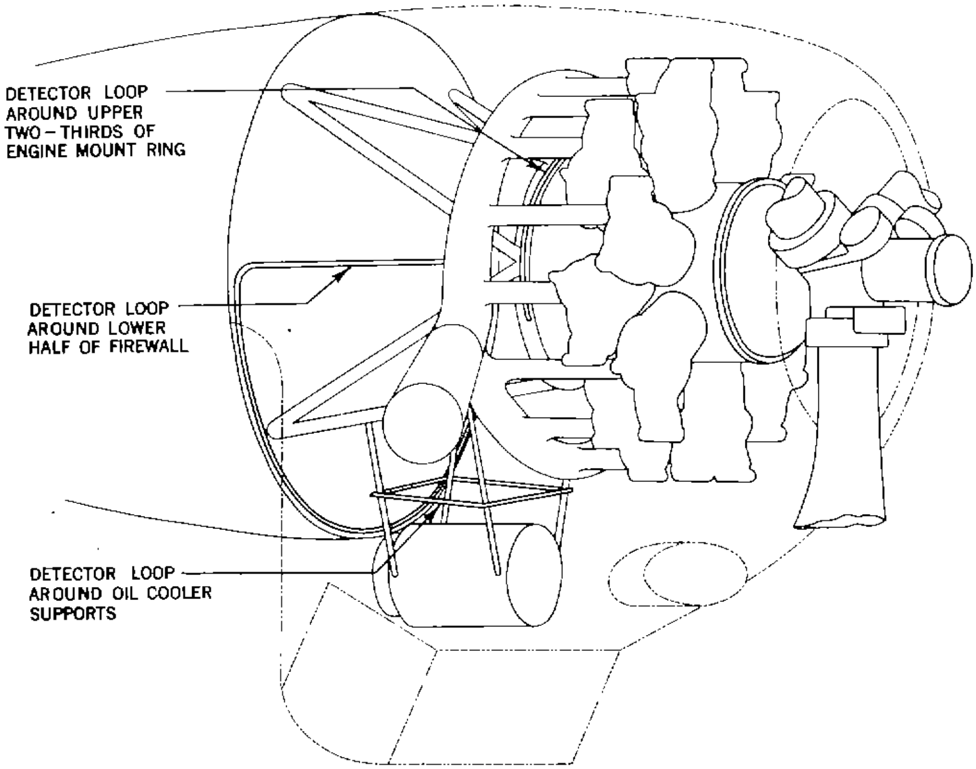

FIGURE 11. Continuous Detector in CW-20 Type Installation

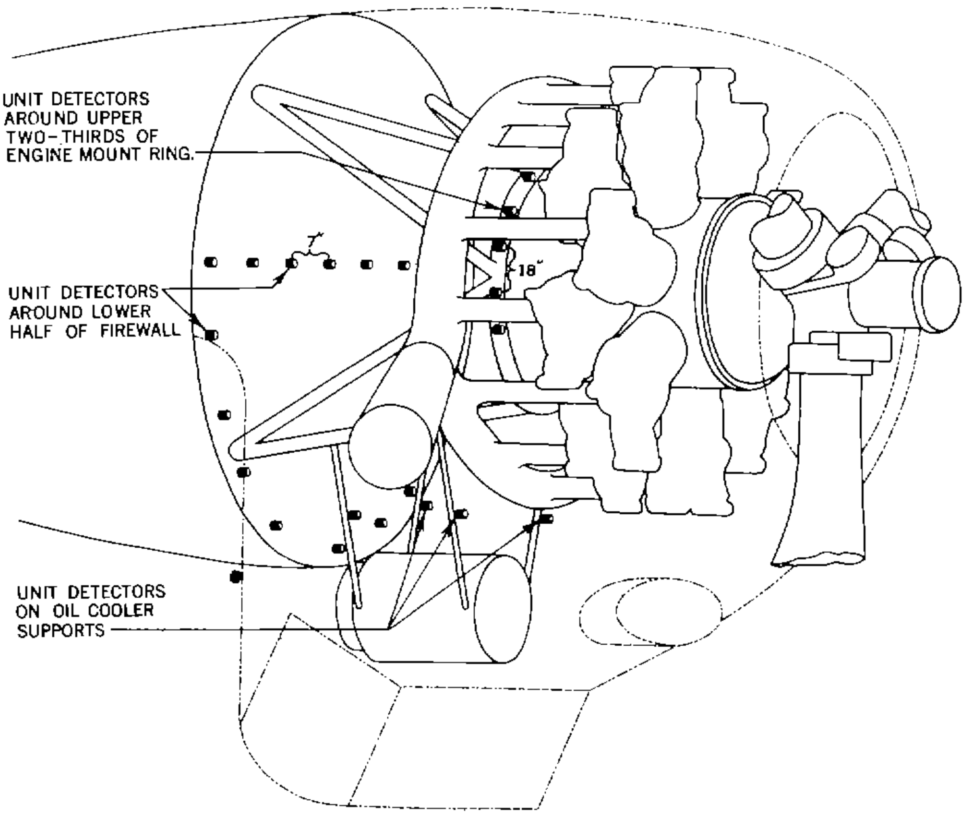

FIGURE 12. Unit Detectors in CW-20 Type Installation

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