AIRCRAFT FIRE EXTINGUISHMENT

PART II
THE EFFECT OF AIR FLOW ON EXTINGUISHING REQUIREMENTS OF A JET POWER-PLANT FIRE ZONE

By

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SUMMARY

Test fires were conducted in the fire zone of a jet power plant in order to determine the minimum amounts of fire-extinguishing agents required for extinguishment under different conditions of air flow through the zone. The tests were conducted with four extinguishing agents which were discharged through conventional and experimental systems: first, with the zone in its original condition, and later, with a lining in the lower portion of the fire zone to provide a smoother flow of air.

Results indicate that the rate of air flow influenced the amount of extinguishing agent required for extinguishment of the test fires. With the lining installed, the quantity of fire-extinguishing agent required was approximately a linear function of the rate of air flow. Without the lining and at the lower rates of air flow, burning fuel fell to the bottom of the nacelle and collected between the structural members or ribs. This resulted in increased extinguishing-agent requirements. The results also indicate the effectiveness of each of the four extinguishing agents tested and provide a comparison between the two systems.

INTRODUCTION

Hot engine surfaces of jet-propelled aircraft are generally cooled to some degree by a flow of air. In most aircraft, the flow of air in the vicinity of hot engine surfaces is rather turbulent because of the exposed structure which surrounds such surfaces. The turbulent flow of air which contains fire can complicate the extinguishment problem and, under some conditions, can make extinguishment with a marginal extinguishing system very difficult.

The work described in this report was conducted to determine the effect of various conditions of air flow, to evaluate new methods of fire extinguishment, and to evaluate newly developed extinguishing agents. Although the test article used in this work was the XB-45 nacelle, the test results are of a general nature and apply to any similar type of power plant.

DESCRIPTION OF TEST EQUIPMENT

The aft compartment of an XB-45 right twin-engine nacelle was used as the fire zone in these tests. It is shown in Fig. 1. The compartment contained a net volume of approximately 237 cubic feet and was 17.5 feet in length. During the test program, it was modified by covering the aft bottom door and the two intermediate doors with an inside lining of 0.018-inch stainless steel to cover all the transverse stiffeners in the lower portion of the compartment and to prevent excess fuel from draining into the recesses between the stiffeners. This is shown in Figs. 2 and 3. Ventilation and drainage were provided for the enclosed regions between the lining and the outer skin. In the XB-45 nacelle, the outlet ends of the jet-engine tail pipes are recessed sufficiently to cause an air ejector action and thus induce air to pass through the compartment from the inlet louvers at the forward end of the compartment. This is also shown in Fig. 1.

The two extinguishing systems used in the tests were: (1) a perforated tubing system, and (2) an experimental High Rate Discharge (HRD) system. The perforated-tubing system is a modification of the carbon dioxide (CO_2) system installed in the nacelle by the manufacturer of the air frame. For these tests the line to the forward compartments was plugged in order that all of the extinguishing agent would be discharged into the aft compartment only, as shown in Fig. 4. Elimination of the forward distribution line would normally require reduction of the feed-line area; however, the next smaller normal tube size (1 1/4-inch) was too small and therefore the original feed lines were retained. This system was originally designed to use five carbon dioxide containers, each equipped with a one-inch flood valve. During these tests, only four 646-cubic-inch carbon dioxide containers were discharged through the system, because the part of the system in the forward compartments was not used. When liquid agents were used, they were discharged through the system by two 536-cubic-inch Walter Kidde extinguisher spheres.

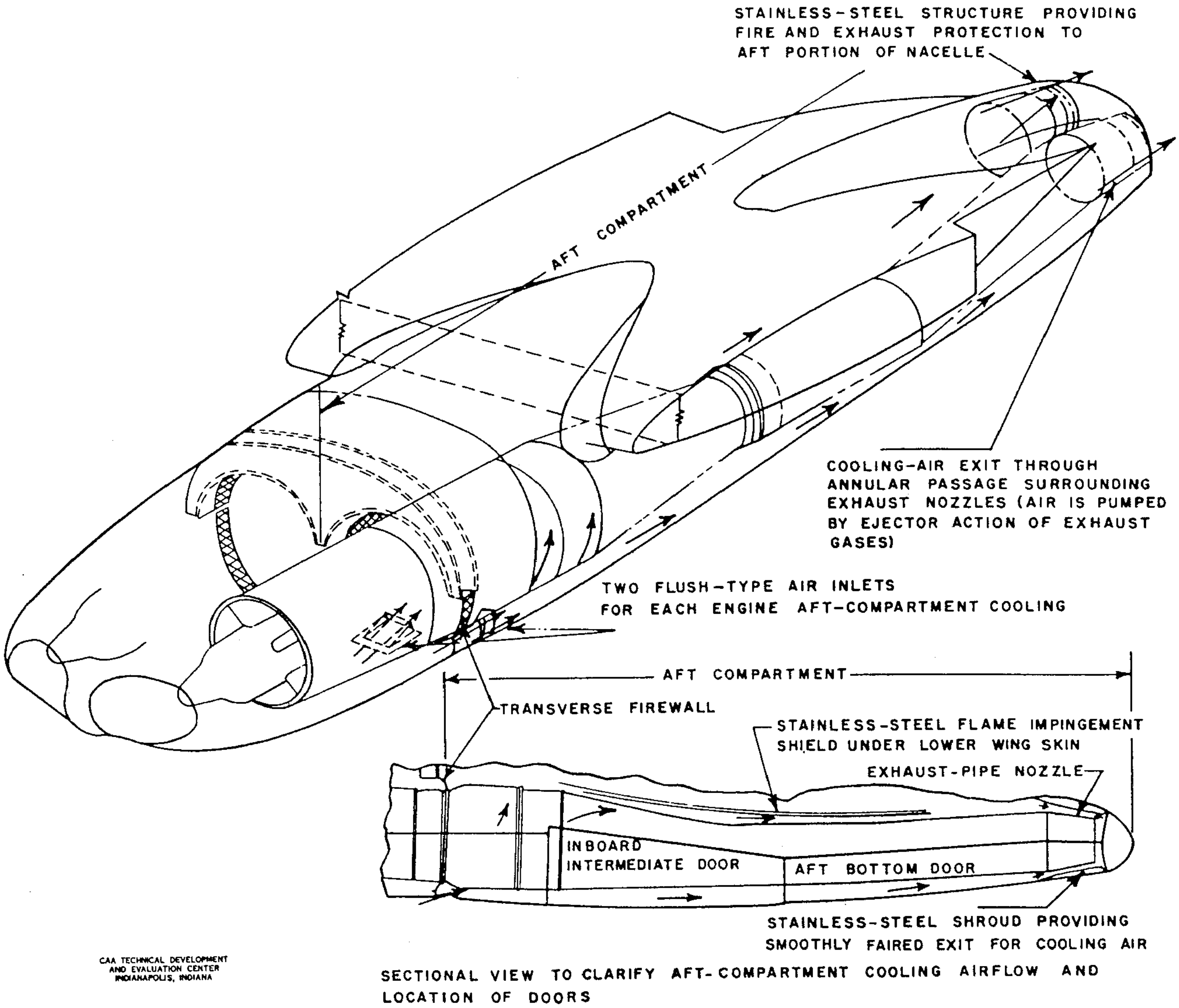

Fig. 1 XB-45 Nacelle Showing Aft Compartment

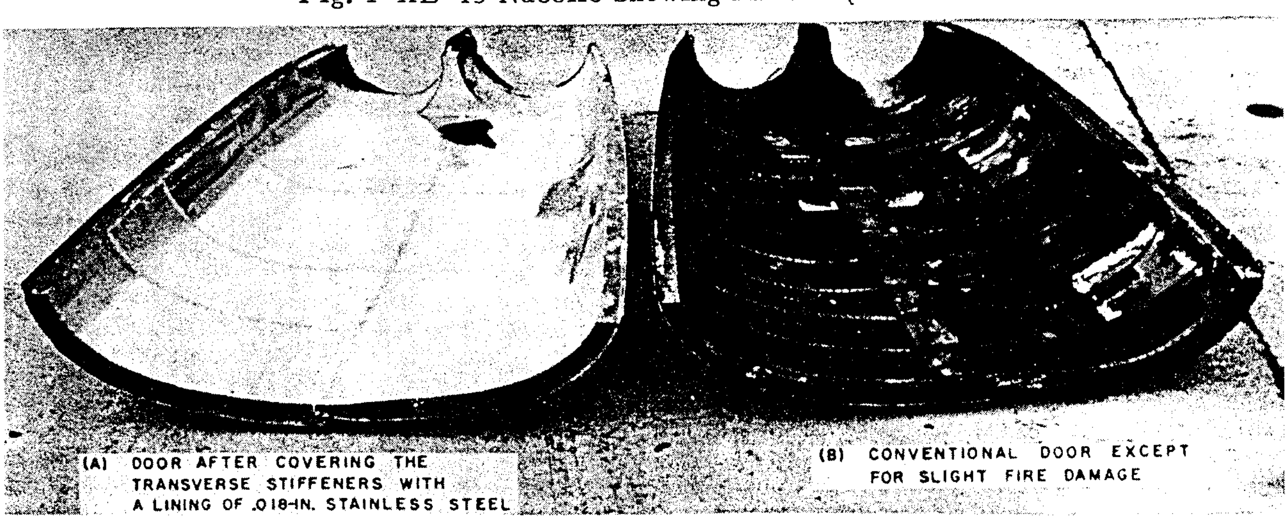

Fig. 2 Aft Bottom Doors Used in Tests

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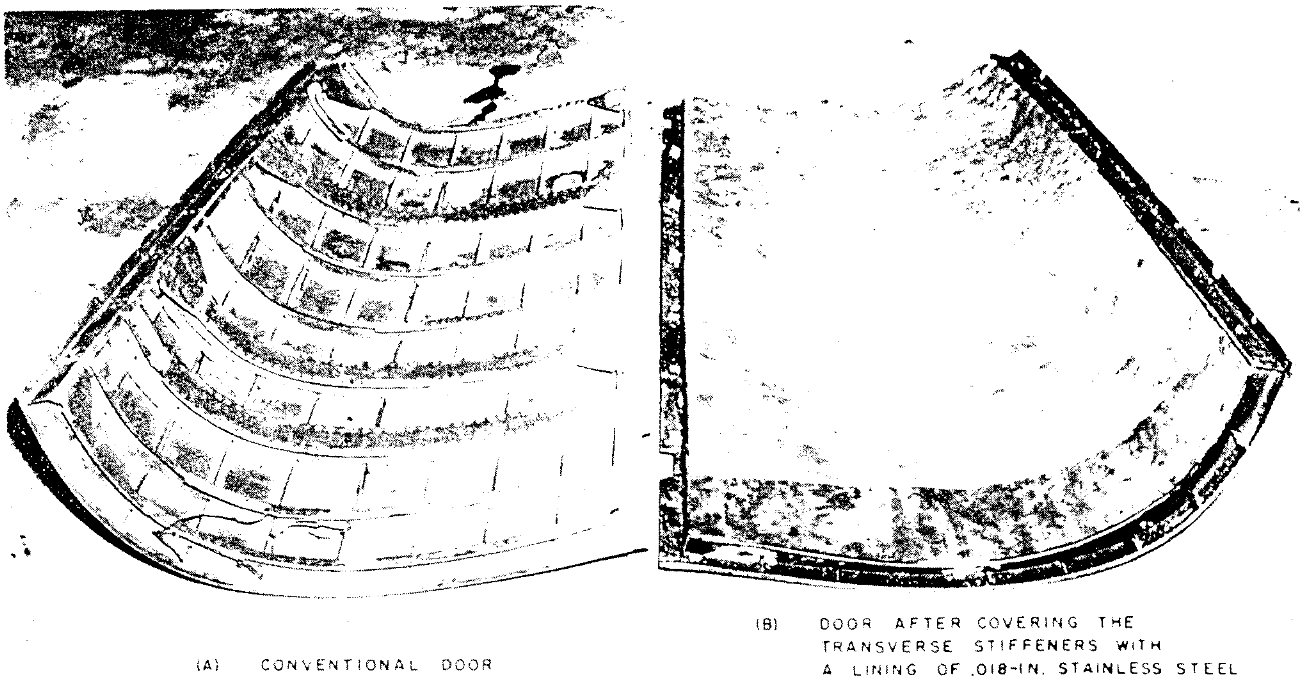

Fig. 3 Intermediate Doors Used in Tests

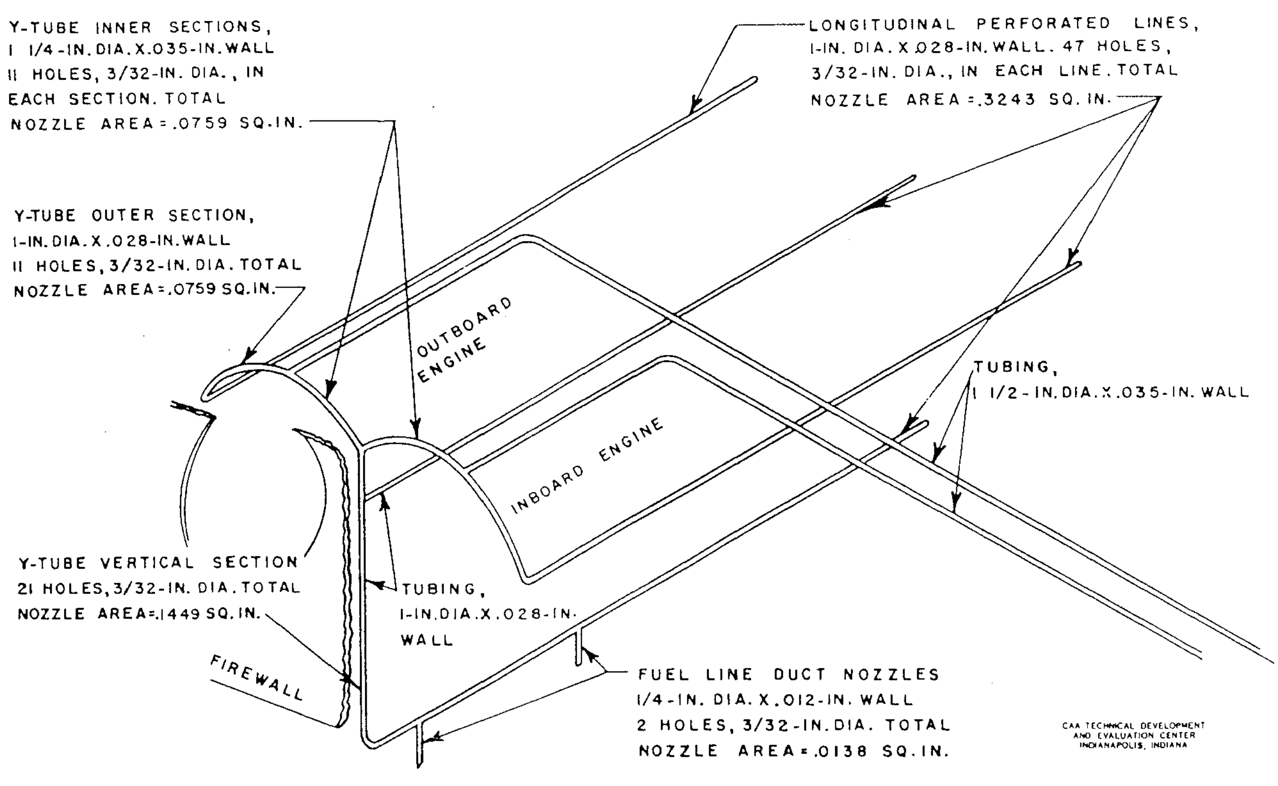

Fig. 4 Conventional Perforated-Tubing Extinguishing System in the Aft Compartment of the XB-45 Nacelle

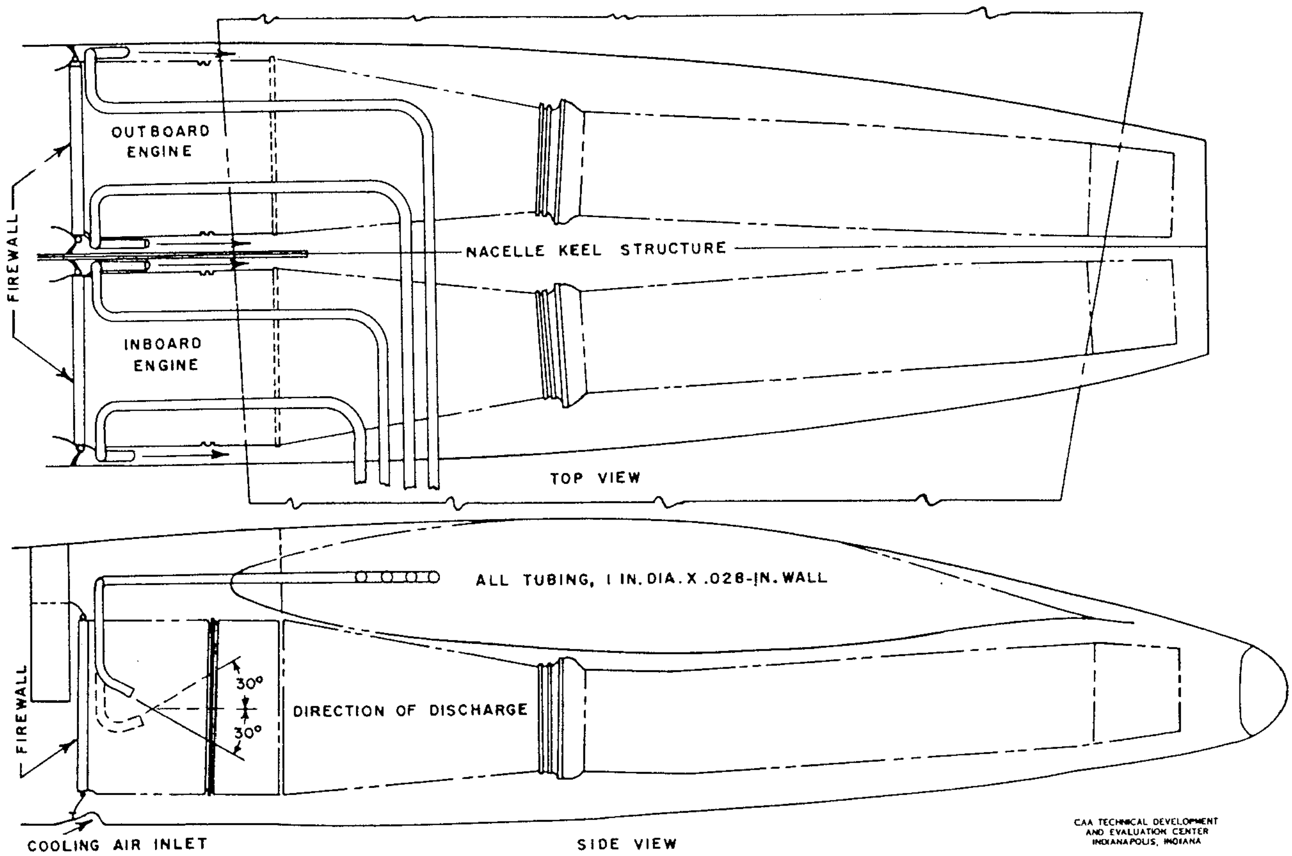

Fig. 5 Experimental HRD Extinguishing System in the Aft Compartment of the XB-45 Nacelle

The HRD system tested is shown in Fig. 5. This system was experimental and should not be considered as an optimum design. It consisted of four 1-inch outside diameter (OD) tubes, each leading to a single point of discharge. The extinguishing agent was discharged from the unrestricted open ends of these tubes. The discharge ends were located in the forward part of the aft compartment so that they were adjacent to the cooling-air inlet louvers. They were mounted along the horizontal center line of the fire wall, with one tube on each side of each engine. In order to obtain good distribution of the extinguishing agent, the tube on the keel side of each engine was directed aft and approximately 30 degrees above horizontal and the tube on the outside of each engine was directed aft and approximately 30 degrees below horizontal. During the carbon dioxide tests, four 386-cubic-inch carbon dioxide cylinders equipped with 1-inch flood valves were each attached to one of the four discharge tubes. During the tests with the liquid agents, one 536-cubic-inch Walter Kidde dual-outlet extinguishing sphere was used. The two sphere outlets were connected to two tubes each so that the extinguishing agent would be discharged through four tubes.

Because of the shorter distribution lines and consequently the smaller volume, smaller containers for the extinguishing agent were used with the HRD system than with the conventional perforated-tubing system. The volume of the perforated-tubing extinguishing-system lines in the aft compartment was 875 cubic inches compared to 290 cubic inches for the lines of the HRD system. All extinguishing-agent containers for the liquid agents were pressurized with nitrogen to 400 pounds per square inch (psi). During the period of no air flow, when the quantities of agent used were small, a larger volume of nitrogen was used for pressurization. The initial pressure and container size remained constant for each series of tests at the various rates of air flow.

The four extinguishing agents used in the tests were carbon dioxide, methyl bromide, bromochloromethane, and dibromodifluoromethane, the latter three being considered liquid agents.

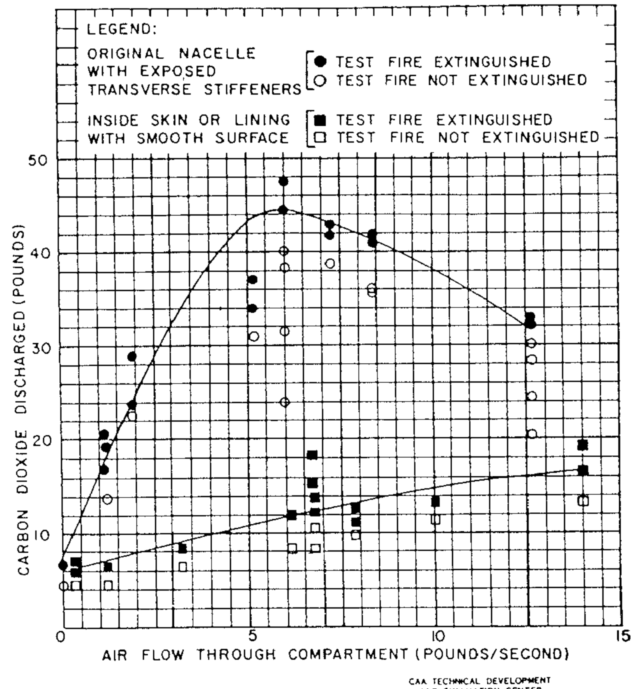

Fig. 6 Fire-Extinguishing Test Results With Carbon Dioxide Under Various Conditions of Air Flow (Conventional Perforated-Tubing System)

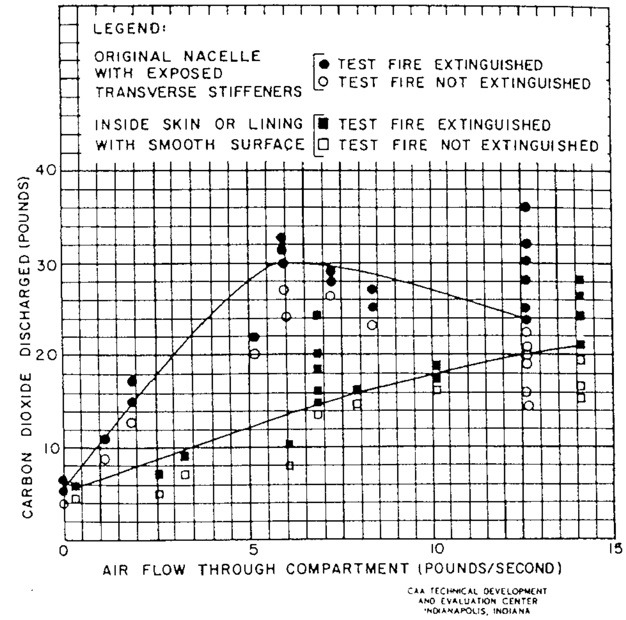

Fig. 7 Fire-Extinguishing Test Results With Carbon Dioxide Under Various Conditions of Air Flow (Experimental HRD System)

TEST PROCEDURE

Since the blowers were coupled directly to the engine intakes, air flow through the compartment was induced by the ejector action of the ends of the tail pipes; therefore, various rates of air flow for the tests were obtained by controlling the revolutions per minute (rpm) of the jet engines. Test fires simulated burning fuel from fuel-line and fuel-filter leaks in the aft compartment. These fires burned aviation gasoline at a rate of 3.6 gallons per minute (gpm). The fires were spark-ignited and allowed to burn for five seconds before the extinguishing agent was discharged. The extinguishing agent was discharged ten seconds prior to the time the fuel supply of the test fire was cut off and while the engines were operating. No engine-shutdown procedure was used, and the rpm of the jet engines was held constant during any one test. The engine-shutdown procedure was necessarily eliminated in order to cover a reasonable range of air-flow conditions.

Tests were repeated at identical rates of air flow until the minimum agent quantity required to extinguish the test fire was determined. Tests which resulted in extinguishment or in failure to extinguish were of equal importance, because the final evaluation was made by comparing the minimum quantities of the agent required for extinguishment under each of the different test conditions.

RESULTS AND DISCUSSION

Results of the tests are shown in Figs. 6 to 13. Only small quantities of the extinguishing agents were required for extinguishment of all of the test fires when there was no air flow through the fire zone. In the absence of air flow, the quantities of agents required were determined by the volume of the fire zone. Flow of air introduced another factor that increased extinguishing-agent requirements.

During the tests conducted with the fire zone in its original state and under rates of air flow from zero to approximately six pounds per second, the minimum quantities required of all agents to extinguish test fires increased with increased rate of air flow. Under rates of air flow above approximately six pounds per second, the required quantity of the extinguishing agent decreased with increased rates of air flow.

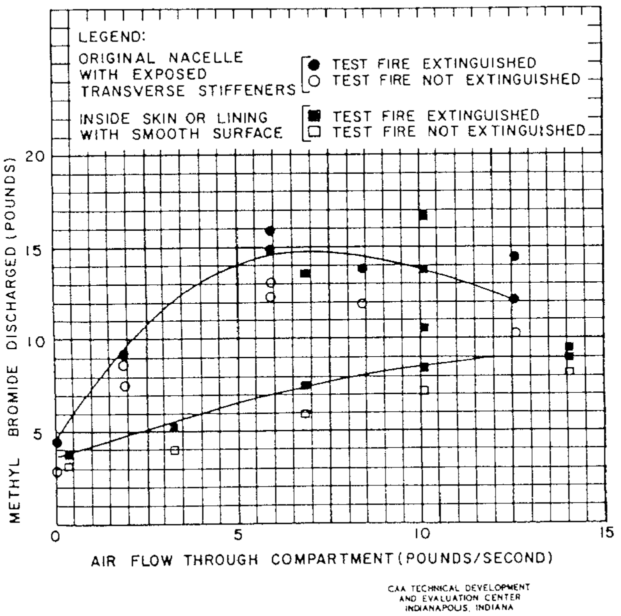

Fig. 8 Fire-Extinguishing Test Results With Methyl Bromide Under Various Conditions of Air Flow (Conventional Perforated-Tubing System)

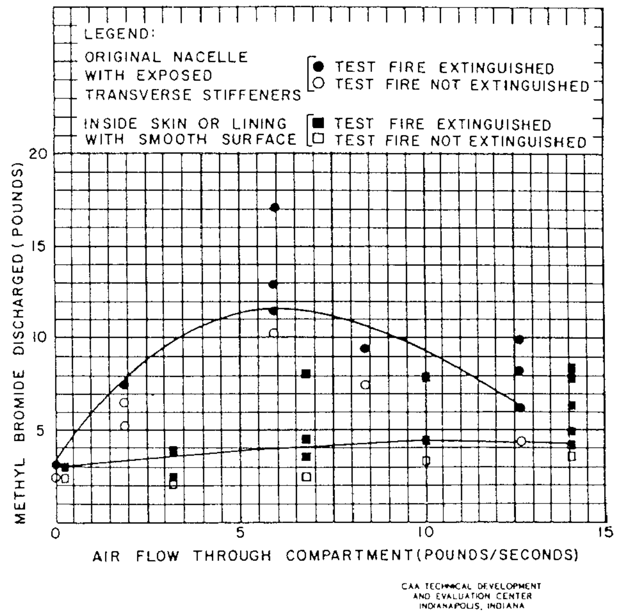

Fig. 9 Fire-Extinguishing Test Results With Methyl Bromide Under Various Conditions of Air Flow (Experimental HRD System)

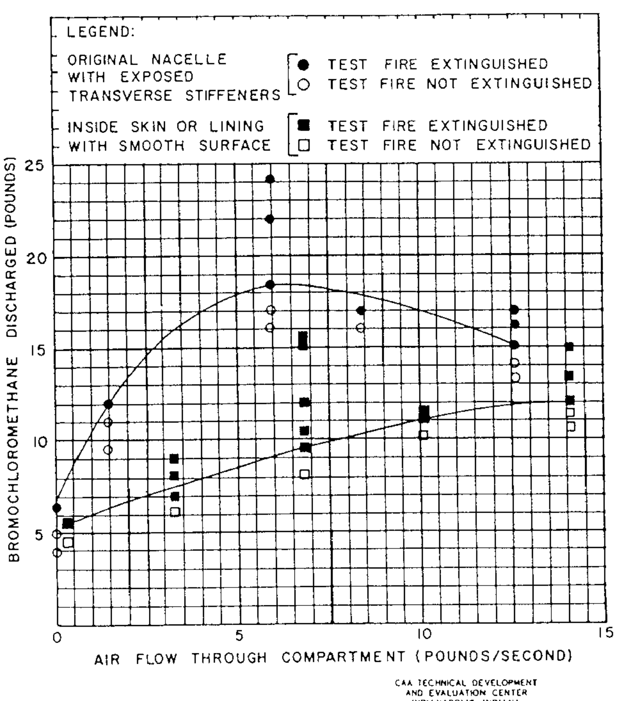

Fig. 10 Fire-Extinguishing Test Results With Bromochloromethane Under Various Conditions of Air Flow (Conventional Perforated-Tubing System)

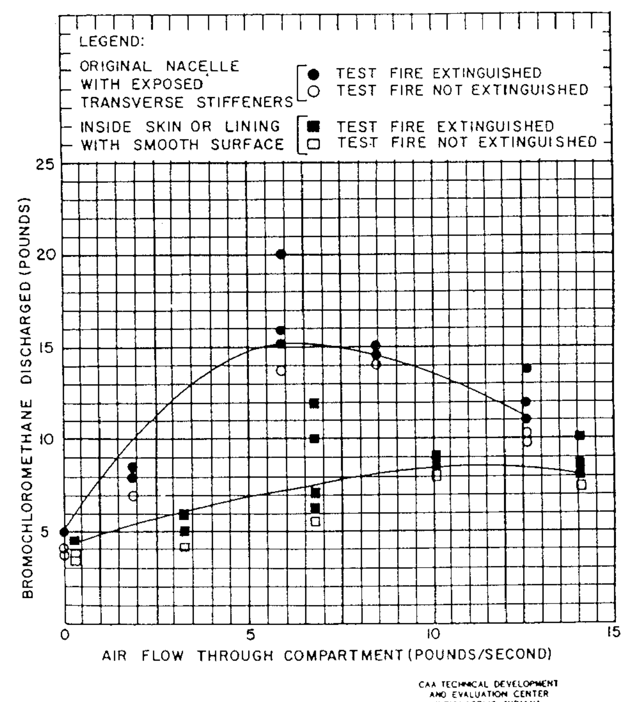

Fig. 11 Fire-Extinguishing Test Results With Bromochloromethane Under Various Conditions of Air Flow (Experimental HRD System)

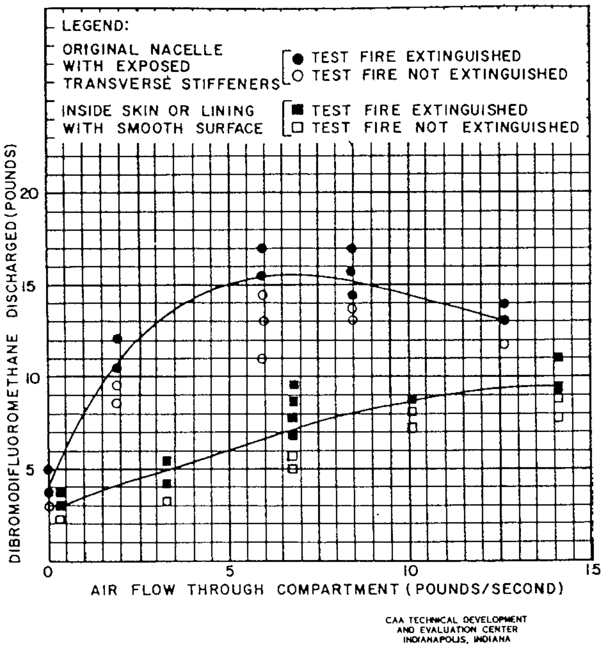

Fig. 12 Fire-Extinguishing Test Results With Dibromodifluoromethane Under Various Conditions of Air Flow (Conventional Perforated-Tubing System)

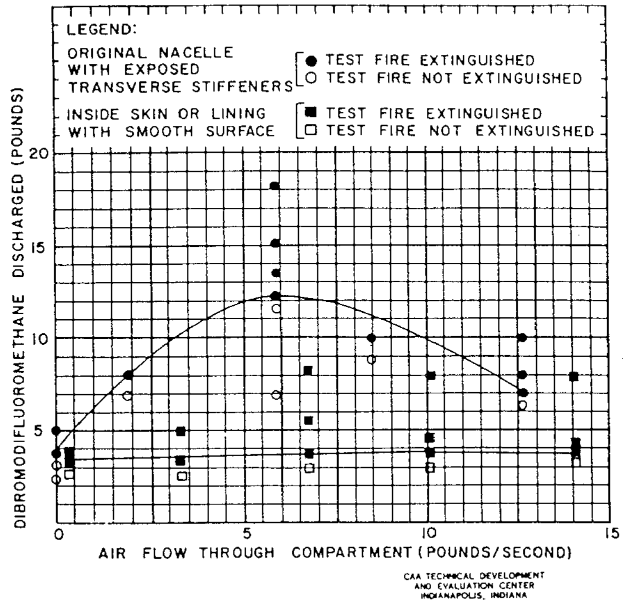

Fig. 13 Fire-Extinguishing Test Results With Dibromodifluoromethane Under Various Conditions of Air Flow (Experimental HRD System)

When the rate of air flow was less than six pounds per second, burning fuel fell to the bottom of the compartment between the transverse stiffeners of the bottom doors and was supplied with air for combustion from the exterior of the nacelle. This supply of air was drawn into the nacelle through small openings, such as door joints, by the negative static pressure which is created by the ejector action and which induces cooling air to enter the forward louvers and flow through the compartment. During many of the tests, the extinguishing-agent concentration in the compartment was sufficient to extinguish the fire near the point of fuel release, but small fires in the bottom of the compartment at locations of air leakage were not extinguished and would reignite the fuel at the main fire location as soon as the cooling air flow reduced the extinguishing-agent concentration in the compartment. This was evidenced by the total disappearance of the main fire upon discharge of the extinguishing agent and, after approximately two seconds, a reignition of the main fire, often in the form of a mild explosion.

When the rate of air flow was greater than six pounds per second, there was visible evidence of fuel being carried out of the compartment with the air. This condition was evidenced by a wetting effect on the stainless steel structure which provided fire and exhaust protection to the aft portion of the compartment at the ends of the engine tail pipes where the cooling air emerges. See Fig. 1. Fuel carried by the cooling air from the compartment could not fall to the bottom of the compartment and burn. This benefited extinguishment at the higher rates of air flow.

When the compartment was in its original state, the agent requirements for the experimental HRD system were less than for the perforated-tubing extinguishing system. The unrestricted open ends of the HRD system produced very-high-velocity discharges, and this sudden release of the agent increased the pressure in the compartment to overcome partially the negative static pressure and thus decreased the flow of air into the compartment. After the lining was installed, the agent requirements for the experimental HRD system were less than for the perforated-tubing extinguishing system in all instances except when carbon dioxide was used.

Installation of the lining on the bottom doors of the compartment prevented the accumulation of fuel in that area. No attempt was made to prevent leakage of air through the door joints. The lining slightly increased the rate of air flow and reduced its turbulence.

The smooth surface provided for the rapid removal of excess fuel from the nacelle. The significant reduction in extinguishing-agent requirements which resulted from the installation of the lining may be noted in Figs. 6 to 13.

In order to cover the widest possible range of air flow, the emergency procedure was not used in these tests. Therefore, in order to relate these test results to any particular installation, the rate of air flow in that installation at the time that the extinguishing agent is discharged must be known. In the XB-45 nacelle tested, when emergency procedure was used the rate of air flow at the time of agent discharge was between 5.5 and 7.3 pounds per second.

CONCLUSIONS

1. Extinguishing-agent requirements in this jet power-plant fire zone were greatly influenced by the rate of air flow; however, the tests indicated that fire-zone configuration is the most important factor to be considered in determining fire-extinguishing-agent requirements when the rate of air flow is also a factor.

2. Smooth fire-zone interiors considerably aid fire extinguishment when air flow exists.

3. The HRD method of extinguishment showed promise particularly when the extinguishing problem was complicated by the fire-zone construction.

4. In the order of effectiveness of the extinguishing agents tested (on the basis of weight), methyl bromide and dibromodifluoromethane were approximately equal. Bromochloromethane was less effective than those agents but was more effective than carbon dioxide.

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