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PROPOSED CRITERIA FOR EVALUATION OF FIRE HAZARDS IN AIRCRAFT POWERPLANT FROM HOT ENGINE SURFACES

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There exists a need for establishing a maximum allowable surface temperature inside a powerplant, where it may be possible for flammable fluids to come into contact with hot surfaces. The function of isolating the hot surfaces at the burner section from other sections of the engine is normally accomplished effectively by the use of firewalls. However, because offspace limitations, imposed as in certain past helicopter engine design, this may not be possible. In such installations, part of the hot section forward of the burner cans with temperatures considerably above 400°F may remain included within the compressor section and, as a result, constitute a possible fire hazard. The following observations and recommendations represent an attempt to relate known flammability data to an analysis of the mechanism of hot surface ignition specific to jet engine application.

For maximum safety, it may be desirable to limit the maximum hot surface temperature of the engine to the autogenous temperature (also spontaneous ignition temperature or S. I. T.) of the flammable mixture with which it may come into contact. For kerosene fuels and oils, this temperature approaches 400°F. However, due to certain design limitations, it may not be possible to limit the maximum temperature to such a low figure in an actual engine installation. A study of the factors affecting hot surface ignition indicates that it may be possible to operate safely at higher surface temperature. Temperature for hot surface ignition is dependent essentially on lag time or time of contact between the ignition source and the surrounding mixture, which in practice is difficult to measure. Decrease in time with increase in temperature is caused not only by external airflow, but also by air circulation caused by convection air currents arising from the surface of the heated body. Kerosene fuels and oils which ignite at S. I. T. [1] temperature of about 450°F require a hot surface temperature in excess of 900°F when ignited on a heated plate in the open atmosphere. The low S. I. T. temperatures are only obtainable under ideal stagnant airflow conditions of uniform heating surrounding the flammable mixture. This condition is never reached in an actual engine installation. The temperature of the mixture inside the enclosure would always be lower than that of the hot surface, the temperature difference depending on both the rate that heat is supplied to the mixture and its degree of confinement. Zabetakis [2] has investigated the problem of hot surface ignitions which should be applicable to the aircraft powerplant. Ignition hazards occurring from the hot walls of fuel tanks subjected to aerodynamic heating were determined. The test data show that the factor determining ignition is not so much the hot surface temperature as it is the heat capacity or rate at which heat is supplied to the fuel/ air mixture contained in the tank. For example, for hot surface ignition to occur inside a tank uniformly heated on all sides at different rates, it was found that although the temperatures of the walls were higher with the higher rate of heating as expected, the flammable mixture did not ignite until it reached a temperature approximately equal to that of the S. I. T. temperature. For a range of hot surface ignition temperatures from 728°F to 520°F, the ignition temperature of the JP4/ air mixture itself remains practically constant between 420°F and 460°F. Even at 885°F surface temperature, the corresponding ignition temperature of the mixture is only 520°F. These data show that within the range of hot surface temperatures of 400°F to 900°F, the important factor is capacity and degree of confinement of the heat source. These two factors determine the air temperature attained by the flammable mixture. This suggests a method of determining the safe hot surface conditions below 900°F by measuring the temperature of the air some distance (protected from radiation and airflow) away from the heated surface and limiting this temperature so that it does not exceed 400°F. Zabetakis [3] has shown in other data the effect of lag time on temperature for hot surface ignition when the surface is subjected to external airflow as distinggished from air circulation due to convection currents as above. In these tests, the hot surface consisted of the interior of a heated pipe 2.0 inches in diameter and 3 feet long, though which JP4 fuel and pre-heated air were injected at velocities of 0 to 30 feet per second. The hot surface ignition temperature is shown to increase rapidly from 450°F to 1220°F as airflow is increased from 0 to 15 feet per second. For airflows of 1.0, 2.0, 4.0, and 7.0 feet per second, the corresponding surface ignition temperatures are 700, 800, 900, and 1000°F. These figures are conservative, since the test data are for airflow already pre-heated, which would not be the case for secondary airflow. The data show that in a powerplant with straight-through airflow (no firewall), as in certain types of high performance aircraft, the high air velocities would permit higher operating surface temperatures of the engine.

Based on the analysis of available ignition data, the following recommendations are presented for consideration and action to reduce fire hazards from hot surface ignition:

1. Increase the airflow over hot surfaces, especially if these surfaces are shielded or confined.

2. Insulate or enclose hot surfaces to prevent their contact with flammable fluids.

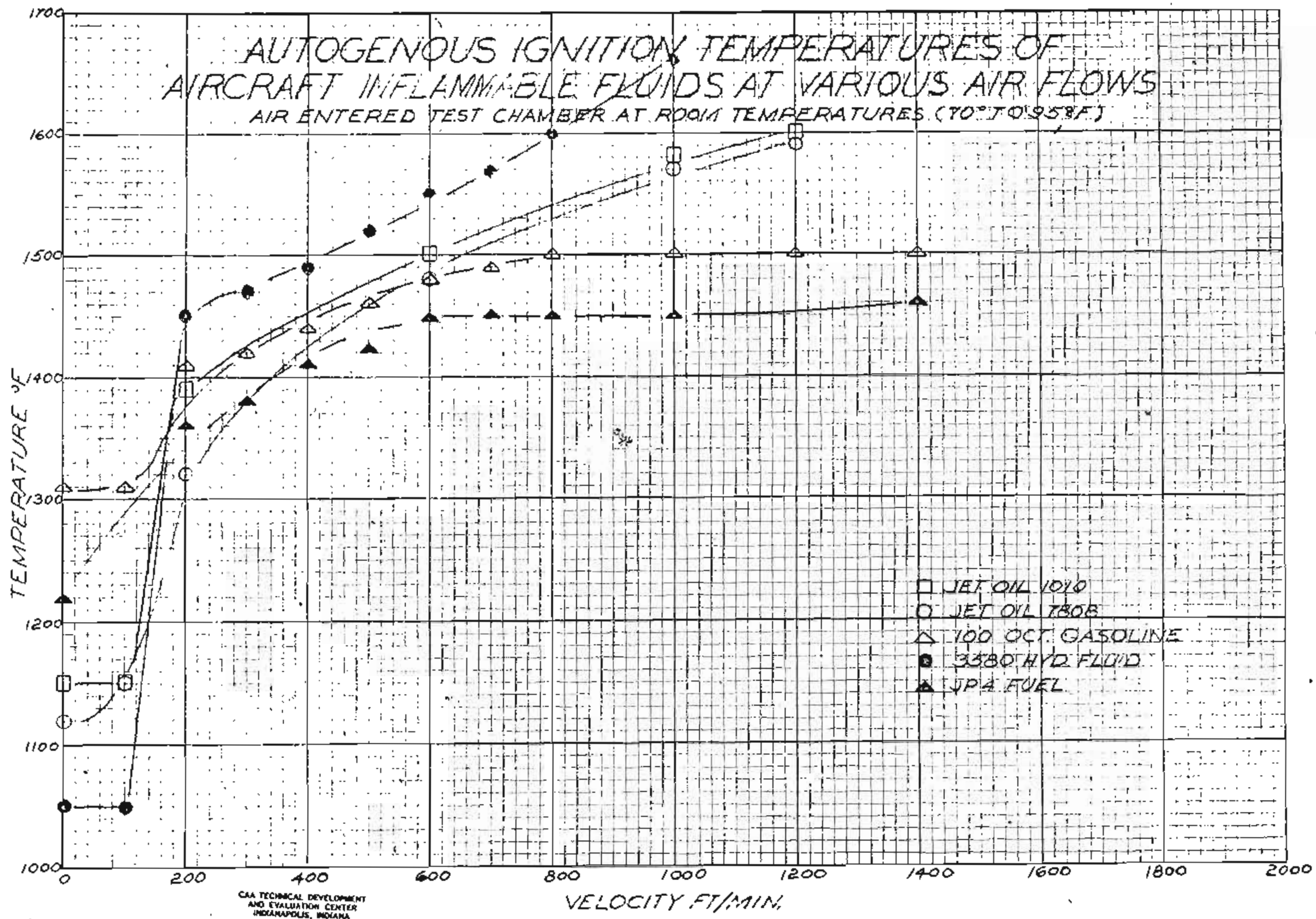
3. Measure the air temperature surrounding the hottest part of the engine (below 900°F). If the maximum air temperature inside the enclosure is less than 400°F, no fire hazard should be possible from hot surface ignition. Some experimentation with this method will be needed, in order to establish more confidence in the test methods.

REFERENCES:

1. Scull, W. E., "Relation between Inflammables and Ignition Sources in Aircraft Environment," NACA Technical Note 2227, pp. 13.

2. Zabetakis, M. G., "Flammability Characteristics of High Temperature Hydrocarbon Fuels," WADC Technical Report 59-663, pp. 21.

3. Zabetakis, M. G., "Research on the Flammability Characteristics of Aircraft Fuels," WADC Technical Report 52-35, Supplement 1, pp. 17.



AUTOGENOUS IGNITION TEMPERATURES OF
AIRCRAFT INFLAMMABLE FLUIDS AT VARIOUS AIR FLOWS
AIR ENTERED TEST CHAMBER AT ROOM TEMPERATURES (70° TO 95°F.)
TEMPERATURE °F
1000
1100
1200
1300
1400
1500
1600
1700
0
200
400
600
800
1000
1200
1400
1600
1800
2000
VELOCITY FT/MIN.
JET OIL 1010
JET OIL 7808
100 OCT. GASOLINE
3580 HYD. FLUID
JP4 FUEL
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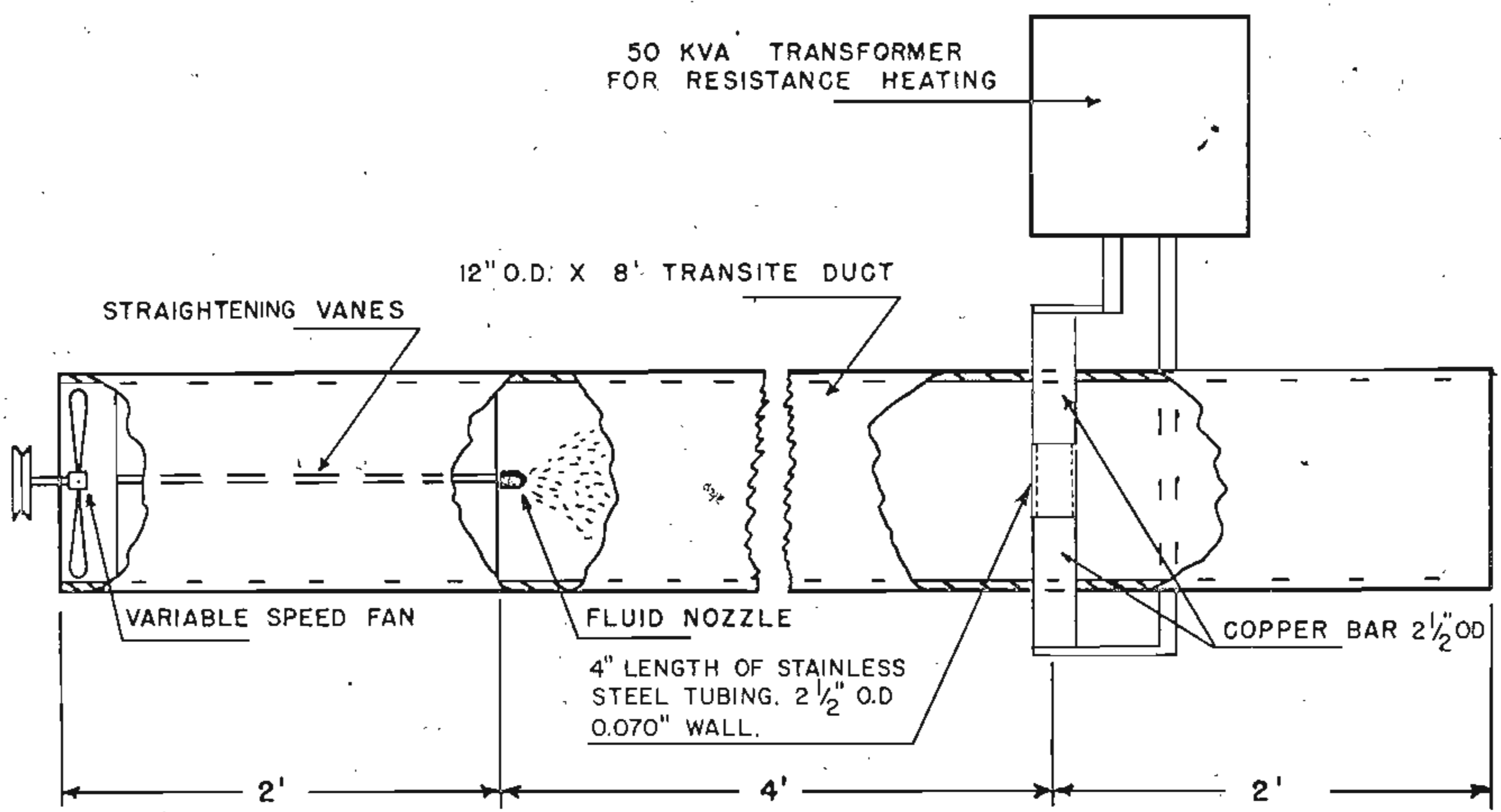
FIGURE 2



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TEST BENCH FOR INVESTIGATING
EXHAUST SYSTEM FIRE HAZARDS

FIGURE 1.