SUPPRESSION OF IGNITION OVER A HEATED METAL SURFACE

by

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Introduction

Halon 1301, or trifluorobromomethane (CF_3Br), has been used as a fire extinguishing agent for protecting aircraft engine nacelles because of its many positive attributes. Due to its high ozone depletion potential, however, its production will soon cease. The search for a replacement has led to testing of candidate alternatives to halon 1301 in a full scale Engine Nacelle Test Facility. Because testing cannot be performed for all possible aircraft and conditions, knowledge is needed which will provide guidance in the extension of the full-scale data to untested systems and conditions.

Recently, the Air Force, Navy, Army, and FAA funded an experimental study which simulated an idealized engine nacelle fire.[1-3] A coaxial turbulent spray burner was used, with jet fuel and hydraulic fluid as the fuels. The research presented here extends that study by investigating the ignition of fuel and air in the presence and absence of fire suppressants, which is representative of flame reignition in an engine nacelle.

The engine nacelle encases the jet engine compressor, combustor, and turbine. A nacelle fire is typically a turbulent diffusion flame stabilized behind an obstruction in a moderately high speed air flow. The most likely source for a fire in the nacelle are leaks in the fuel lines carrying jet fuel or hydraulic fluid, that can feed the fire either as a spray or as a pre-vaporized gas. Extinguishment occurs when a critical amount of agent is transported to the flame, where it is entrained into the primary reaction zone.

Flame reignition should be considered independently from the extinction phenomena. After suppression of a nacelle fire, hot fuel vapor may exist at levels which may lead to flame reignition. A puddle of hydraulic fluid or jet fuel from a leaking fuel line will vaporize as heat is transferred from nearby hot metal surfaces, which had been heated by the fire itself. Reignition may then arise from contact of the reactive fuel/air mixture with a hot metal surface. Under normal engine operating conditions, hot metal surfaces which could cause ignition occur along the interior wall of the nacelle which separates the jet engine combustor from the nacelle. In addition, hot metal surfaces may occur due to heating by the fire itself. Conditions which lead to reignition are thought to be controlled by the time temperature history of the reactive mixture and to a lesser extent, by the type of metal surface and the chemical composition of the fuel.

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The objective of this work is to investigate the effectiveness of various agents in suppressing ignition.

Experimental Method

Experiments were first conducted to determine the amount of agent needed to suppress the ignition of a JP8 spray flame. There were difficulties, however, in obtaining repeatable results. Thus, a gaseous propane flow replaced the liquid spray. Use of a gaseous fuel represents a most dangerous case, when a liquid fuel has completely vaporized. A schematic diagram of the apparatus is shown in Fig. 1. Propane flowed through a 3 mm od tube in a stagnation point flow towards a heated metal disk located approximately 5 mm away. The disk was 14 mm in diameter and was a wound ribbon composed primarily of nickel. The metal surface was heated by a regulated power supply which provided up to 200 W. An optical pyrometer was used to measure the surface temperature of the heated disk. With power applied to the metal disk, a fairly uniform temperature (±30 °C) was measured in an annular section of the disk, from approximately 2 to 6 mm from the disk center. The surface temperature of the disk became less uniform with time as power was applied, requiring replacement of the metal disk. A coflowing mixture of air (10 l/s) and gaseous fire suppressant flowed through a 78 mm tube around the fuel flow. Ignition occurred in a repeatable fashion. Various amounts of agent were added to the air flow and the temperature of the heated metal disk was measured at ignition using an optical pyrometer. The effectiveness of N_2, HFC-125, HFC-227 and CF_3I were compared in suppressing the ignition event.

Results and Discussion

For small fuel flows (<10 cc/min), the critical temperature of the hot metal disk at ignition was measured to occur at approximately 1000 °C, not unlike autoignition temperatures reported previously for stoichiometric propane-air mixtures over a heated nickel surface.[4] Once ignited, the flame could then be extinguished by decreasing the applied power through the metal disk. Figure 2 shows that the critical ignition temperature increased with increasing fuel flow. This is interpreted as being related to the residence time of the reactive mixture on the hot metal surface. As the residence time decreases, key chemical reactions involving chain initiation and branching have less time to proceed and higher temperatures are necessary to initiate ignition. This is consistent with the Damköhler criteria for ignition.[5] Measurements showed that increasing or decreasing the air flow by 30% had a negligible effect on the critical ignition temperature.

Figure 3 shows the critical ignition temperature of the heated metal disk as a function of agent concentration in the oxidizer stream. For small CF_3I concentrations, ignition required substantially higher metal surface temperatures than the other agents. Thus, CF_3I was significantly more effective than HFC-125 and HFC-227ea, which were more effective than N_2, in suppressing ignition. These results suggest that selection of an agent for the nacelle application must carefully consider the hazard associated with flame reignition.

In addition, a second series of experiments will be discussed where agent effectiveness is measured under premixed conditions. A complete description of the experimental apparatus and procedures has been given previously.[4] In these experiments, fuel, air and agent are all combined before contact with a heated metal surface. A number of metals will be tested including stainless steel, titanium, and nickel. The effectiveness of N_2, HFC-125, HFC-227, CF_3Br, CF_3I and a number of other agents will be compared in suppressing ignition in this apparatus. Preliminary results using N_2 as the agent show a close correspondence between the critical ignition temperatures measured in this apparatus and those measured in the first set of experiments as described above. Measurements using the other agents will be discussed.

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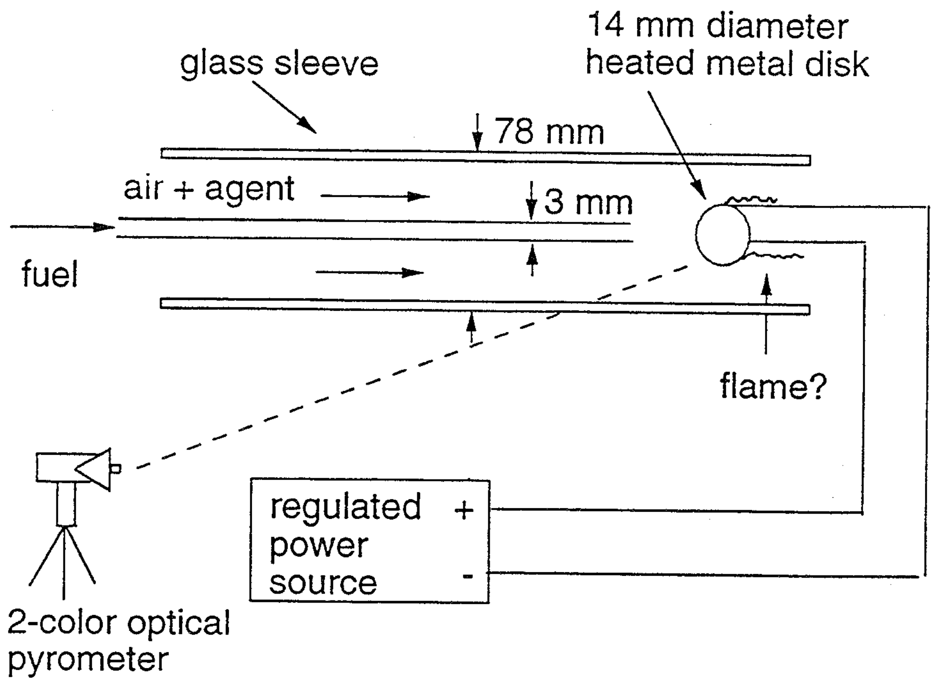

Figure 1 A schematic diagram of the experimental apparatus.

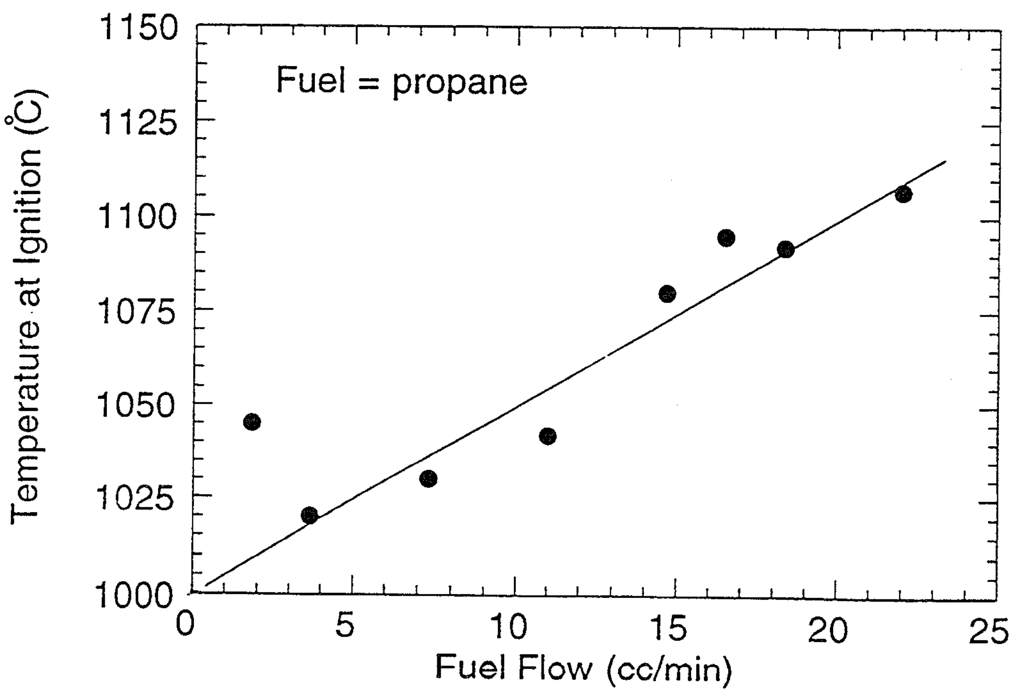

Figure 2 The critical ignition temperature of the heated metal disk as a function of the propane fuel flow.

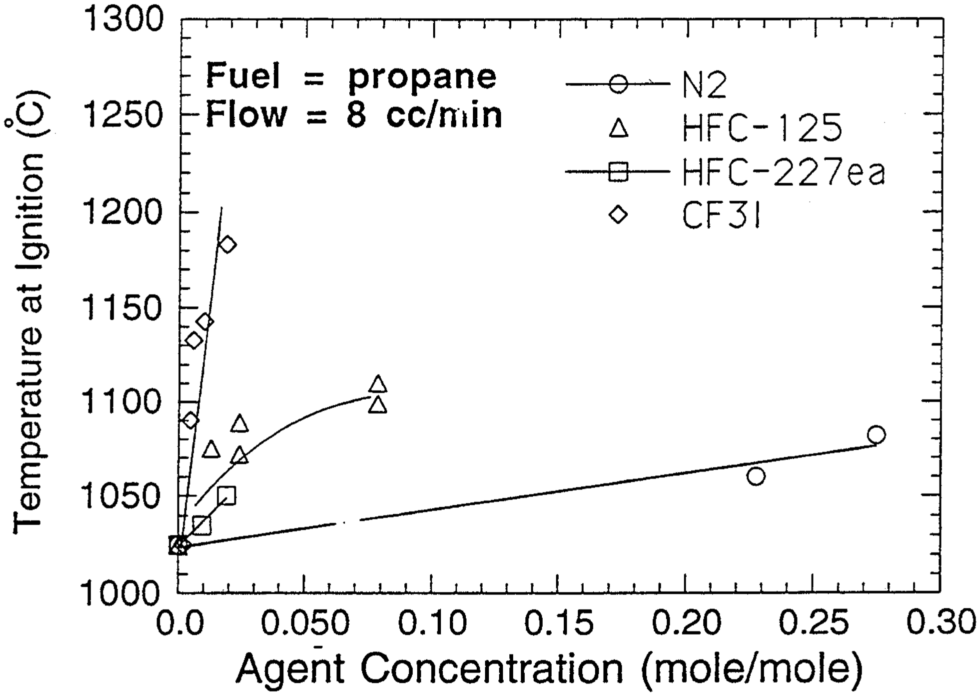

Figure 3 The critical ignition temperature of the heated metal disk as a function of the mole based agent concentration in the oxidizer stream.