EVALUATION OF SOME HALON SUBSTITUTE AGENTS IN A SMALL SCALE AIRCRAFT ENGINE SIMULATOR

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INTRODUCTION

Fire suppression on aircraft has always been considered a particularly serious and demanding operation. As such, exhaustive qualifications must be carried out before a system change may be permitted. Recognizing this requirement and the eventual replacement of Halon 1301, Walter Kidde Aerospace designed and built a Small Scale Aircraft Engine Simulator for use in screening substitute agents, potentially of both the alternative and replacement kinds. In this paper, we will discuss the important characteristics of this machine and some preliminary results achieved with some Halon replacement agents.

MACHINE DESCRIPTION

The small scale aircraft engine simulator is essentially a wind tunnel and was adapted from an earlier design by Hirst, Farenden and Simmons.[1] The purpose of this design is to create a worst case scenario simulating an engine nacelle fire. The machine consists of blower, plenum chamber, dust, fire pan section, scrubbing tower, agent dispensing system and a control console (see Figure one).

The blower is connected to a 24 inch square., 5 foot long plenum chamber which tapers to match the 12 inch square duct. The duct is 12 feet long and terminates in a large scrubbing tower. An airfoil and fire pan is placed in the duct so that the fire pan is at least 7 feet from the duct entrance. Details of the airfoil and fire pan are shown in Figure two. The Air foil is a holder for the fire pan and an air baffle placed in front of the fire pan. The air baffle acts as a flame holder. As shown in Figure two, a variety of air baffle and fire pan sizes may be selected. The agent dispensing system is made up of an agent bottle mounted on an electronic scale. The bottle may be pressurized from a nitrogen tank through a pressure regulator. The agent flows through a flexible line to a solenoid valve and n o d e mounted in the plenum chamber.

INSTRUMENTATION

In addition to the standard items for speed controls, pressure and temperature indication; the instruments used specifically for this machine are an Omega HHF7-10 anemometer with HHF7-P1 probe and a Mettler ID-1 KC-120 platform scale. The anemometer is used to set the blower to a specific air speed each time the blower speed is changed. It is useful from 10 to 100 feet per second at relative humidities from 20 to 95 percent and at temperatures from -60 to 200 °F.

The platform scale holds the agent bottle in a mount and has a capacity from 0 to 250 pounds. Weighing resolution is 0.02 pound.

There is an electronic firing circuit which provides a variable discharge time normally set to 1.0 second with about a 50 millisecond resolution.

MACHINE CAPABILITY

There are three parts of the machine that control its general capability, the blower, the fii pan and the agent delivery system.

The blower can produce air flows up to an average speed of 12 meters per second. The equivalent volume and mass flows are shown in Table 1. Specification MIL-E-22285 helps put these mass flows into some perspective by defining high and low engine nacelle air flow rates as 1 pound per second and greater as high rate and 1 pound per second and lower as low rate. It is clear from Table 1 that the SSEFS machine air flow capability is well centered around this 1 pound per second flow rate. The duct work most nearly fits the definition of a smooth nacelle.

There are five sizes of fire pans, 16, 32, 80, 96 and 160 square inches. In addition, there are five different air baffles or flame holders. All the current work has been done with a 32 square inch fire pan and a flame holder which protrudes 1 inch above the edge of the fire pan. Earlier work had shown this combination to produce the most tenacious fire.

The f i suppression agent is controlled by orifice size and pulse time. We are able to introduce quantities of agent from 0.2 to 1.0 pound per second into the air stream in a controlled way. The nozzles are a simple straight orifice to simulate an open tube. They are specially machined to minimize any open space between them and the electrically operated valve in order to give a more reproducible pulse. The agent delivery system is under constant pressure to maintain a liquid full condition from the bottom feed bottle through a flexible pressure hose to the valve. When this condition is not maintained, we noticed an erratic multiple pulsing delivery of the agent. We have used 8 different nozzles with 0.035, 0.0465, 0.076, 0.1405, 0.2019, 0.250, 0.3125 and **0.375** inch orifice diameters.

OPTIMIZING SYSTEM PERFORMANCE

- A constant pressure of **600 ± 3** psig is maintained in the agent tank with nitrogen. This simulates the aircraft engine bottle conditions. The amount of agent mass flow is varied with the discharge orifice size.
- An accurate (**± 0.005** second) and repeatable discharge timing circuit provides enhanced agent discharge control.
- The agent discharge is weighed. Repeatability was improved by using a small, bottom feeding, **224** cubic inch bottle. A wind screen protects the platform balance from the perturbations of wind gusts.
- A fuel cooling system was added to the pan fire in order to provide a controlled fuel temperature. Tests are currently conducted at a fuel temperature of **300 ±** 8 **°F**.
- A fuel level control system was installed to maintain a constant (**± 0.25** inch) fuel level in the pan during burning.

TEST PROCEDURE

1. Set up SSEFS machine.
   a. Agent tank pressure to 600 psig.
   b. Record barometric pressure, air temperature and dew point.
   c. Preset discharge time to 1.0 second.
   d. Fill fire pan with fuel.
   e. Install orifice.

2. Ignite the fuel in the fire pan.
3. Set airflow with anemometer.
4. When the fuel temperature levels out at **300 ±** 8 **°F,** fire the agent pulse.
5. Beginning with the smallest orifice, range over the possible air speeds from low to high, taking approximately ten discharges with each orifice.
6. Note whether or not the fire is extinguished.

Table 1
SSEFS Blower Airspeed Data

Average Air Speed (m/sec)	Air Speed Std Deviation	Volume Air Flow (m^3/sec)	Mass Air Flow (kg/sec)
0.88	0.087	0.082	0.099
1.29	0.117	0.120	0.145
2.08	0.176	0.194	0.233
2.49	0.175	0.23 1	0.279
3.57	0.322	0.332	0.400 1 lb./sec.
4.96	0.403	0.461	0.555
7.17	0.587	0.666	0.803
9.20	0.849	0.855	1.030
11.24	0.984	1.045	1.259
12.07	1.165	1.122	1.390

NOTE: Each airspeed is an average of nine measurements over the duct crossection in front of the fire pan.

The purpose of this procedure is to bracket the region of extinguishment as closely as possible. With 8 different orifice sizes, about 80 agent discharges are accomplished per test. These data are reduced to percent mass concentration of agent as a function of air speed. If gaps occur in the data, testing is repeated varying the discharge time.

RESULTS

The data analysis consists of determining the agent concentration in air at specific test air speeds. Changes in agent concentration are made to identify the extinguish/no extinguish transition range. A plot of these critical agent concentrations as a function of airspeed is shown in Figure 3. The relative merit of these Halon 1301 replacement materials can be obtained by comparison with the 1301 baseline data.

In order to understand the behavior of these mixtures in this application, we need to know more about the pan fire which obviously is changing in flame temperature and from fuel rich to perhaps fuel lean as the air speed changes from low to high.

We plan to optimize the mixtures, test at other fuel temperatures, add to the program second generation replacement materials, when available and to test alternative agents such as dry powders.

We are planning the addition of analytical capability in order to study the agent concentration and pulse characteristics in the SSEFS machine.

ACKNOWLEDGMENTS

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REFERENCE

1. Hirst, R., Farenden, P.J., and Simmons, R. F., "The Extinction of Fires in Aircraft Jet Engines - Part 1, Small - Scale Simulation of Fires," Fire Technology, Vol. 13 (1977).

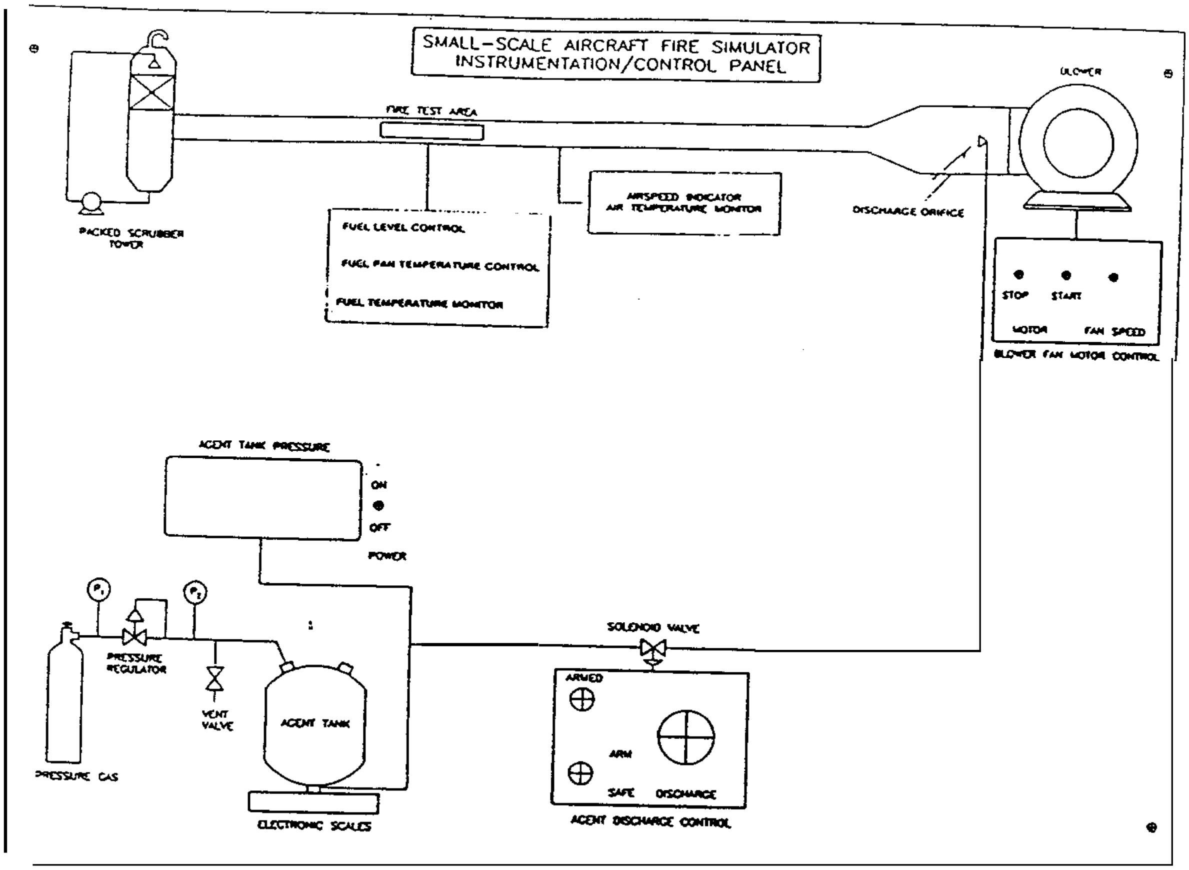
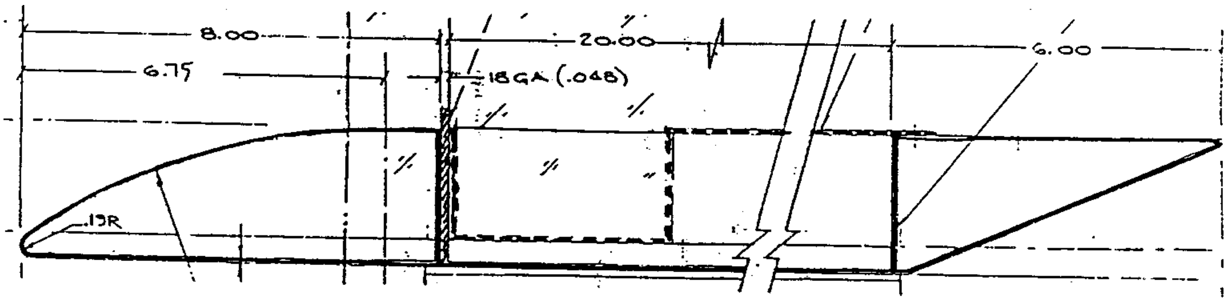


Figure 1 - SMALL SCALE ENGINE FIRE SIMULATOR



PAN TABLE	
DASH No	"A" DIM.
-1	2.00
-2	4 00
-3	10.00
-4	12.00
-5	20.00

AIR BAFFLE	
DASH No	"A" DIM
-1	2.875
-2	3.000
-3	3.500
-4	4 000
-5	5.000

Figure 2 - AIRFOIL AND FIRE PAN

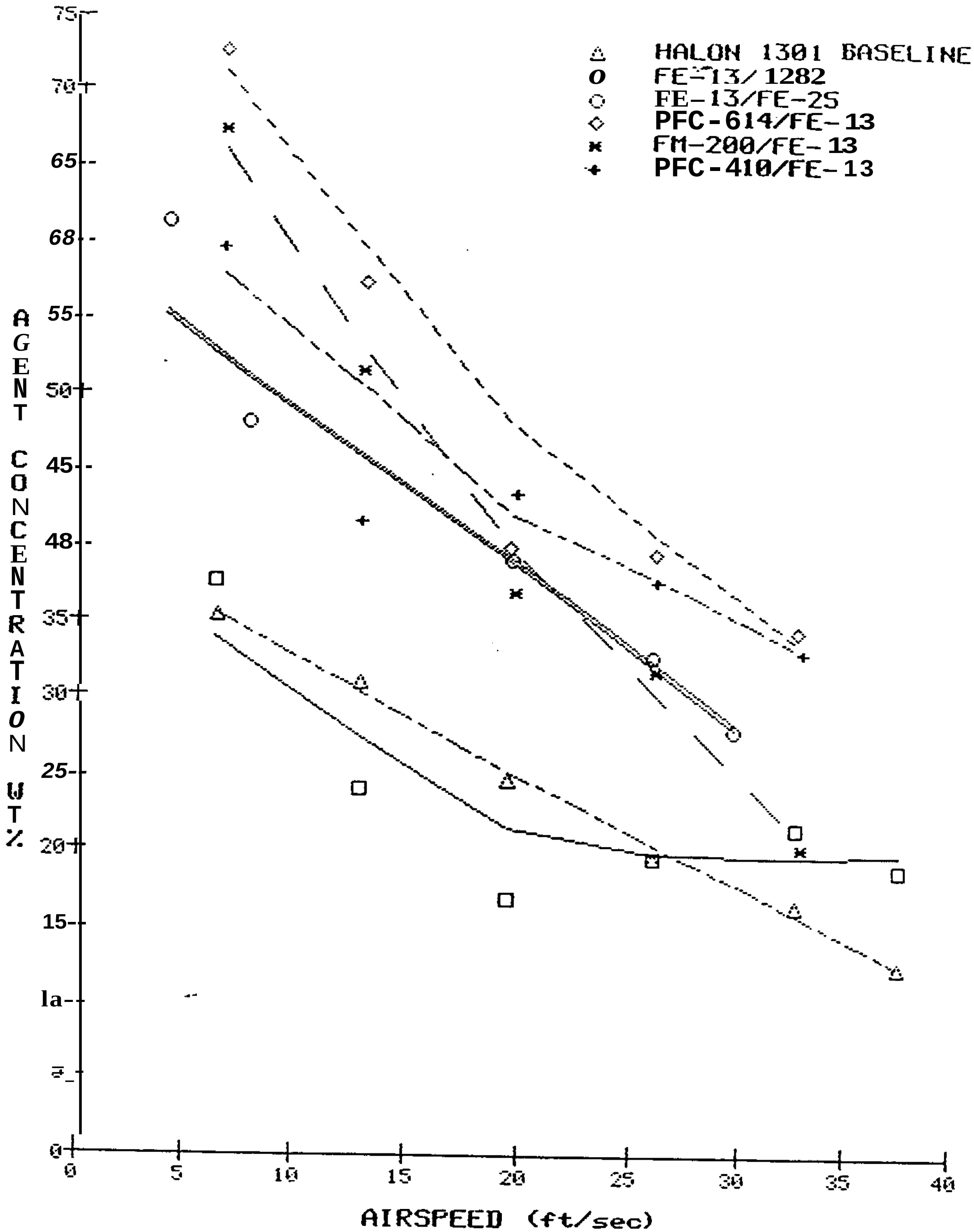


Figure 3 - AGENT PERFORMANCE DATA