HALON REPLACEMENT PROGRAM: TEST EXPERIENCE WITH THE F/A-18E/F ENGINE RAY FIRE EXTINGUISHING SYSTEM

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INTRODUCTION

Boeing has been conducting research and testing to develop halon alternative fire protection systems for our aircraft products. Considerable effort has gone into development in military aircraft applications. Recently **a** series of tests was conducted in conjunction with the Naval Air Systems Team and the Northrop Grumman Corporation to select an alternate system for the new F/A-18E/F series of aircraft. As a result of this testing, HFC-125 was selected by the team to replace halon in this application. This selection was made after considerable testing to define the halon baseline performance and evaluate a number of alternate concepts. This paper summarizes some of the test experiences and data obtained in achieving this step toward minimizing the environmental impact of our products. The principal findings related to instrumentation are that the equipment needs to be robust to survive the repeated fire conditions and that improved concentration measurement techniques are needed.

SIMULATOR DESCRIPTION

The F/A-18E/F requirement was to provide an engine bay fire protection system performance equal to or better than the existing F/A-18 halon approach without the use of ozone-depleting halon. The first question is, what is the “equivalent” performance level for halon’? No live fire testing had been conducted. the engine bay fire protection had been qualified by concentration measurement for 6% halon for a minimum of 0.5 sec. The search for the “equivalent” answer began in testing at China Lake in 1996. A full-scale live fire simulator was constructed and submitted to various fire threats using halon to determine what fires halon could extinguish. From this series of tests a worst case fire scenario was developed. One of the central concepts was to build a fire that stressed halon to the point where it may not be successful at extinguishing the fire and preventing **a** relight. This concept was considered important since any alternative may extinguish the fire under the test conditions but may not be successful at extinguishing a somewhat worse fire that halon could have extinguished. The halon limit needed to be known. At the end of this series of tests the test article had been *so* badly damaged by the repeated fires that a new test article needed to be constructed. **A** new more robust F/A-18 E/F Engine Nacelle Simulator was constructed to depict accurately the full size engine bay including the engine volume and simulated clutter. This F/A-18 E/F Engine Nacelle Simulator is shown in Figure 1.

The instrumentation included **3** internal view video cameras; 1 external view camera; inlet air-flow rate: fuel flow rate: approximately 20 pressure transducers: humidity: approximately 150 temperature thermocouples: and agent, CO_2, and O_2 concentrations. This instrumentation was used to various degrees during the test program. depending on the needs of the specific test. General discussions of their value and difficulties encountered are identified below.

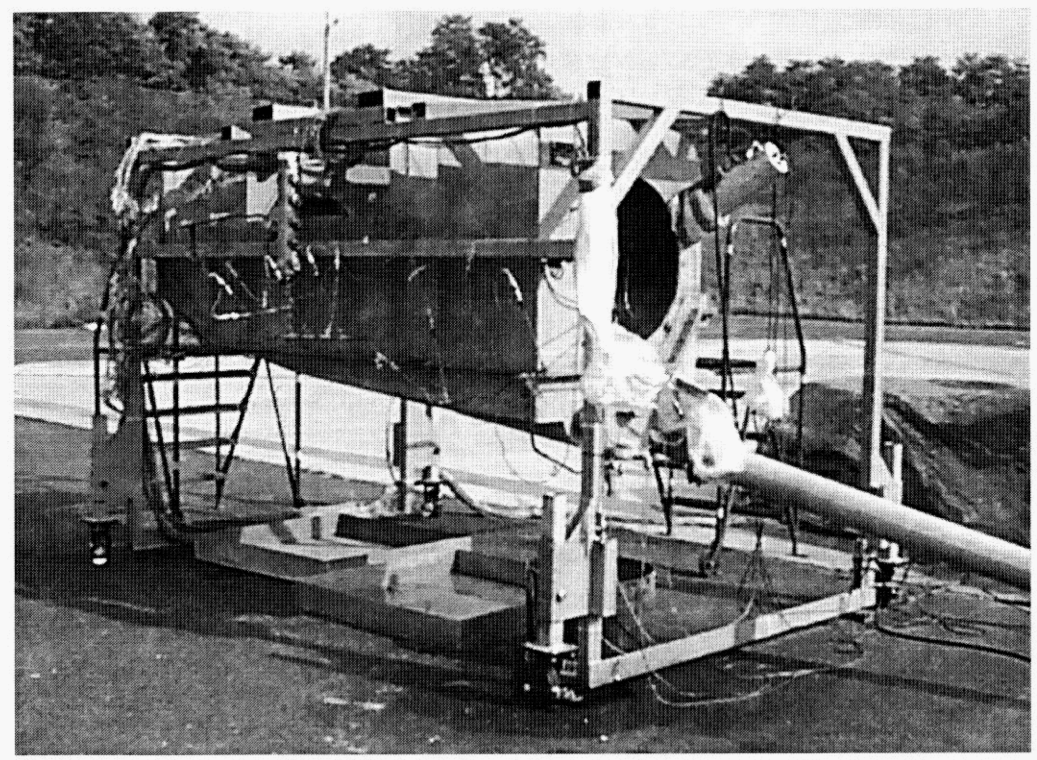


Figure 1. F/A-18E/F full-scale engine bay fire simulator.

The video cameras were very helpful in monitoring the fire conditions. determining agent effects on the fire, and determining the sequence of events. Multiple view ports were located in the test simulator, and the cameras were moved around to obtain the best views for the various tests. High-temperature glass was used for view windows to keep the cameras outside the high temperature test area. These windows required frequent cleaning and were subject to breakage due to thermal growth of the test fixture and handling, but were valuable in determining what was happening inside the test fixture. Figure 2 shows a typical view of a fire.

The fire is an opposed flow spray fire, where the fuel is being sprayed in the opposite direction to the local air flow. **An** atomizing spray nozzle is used to create a fan shaped spray pattern with a fuel flow of 0.15 gpm, using JP-8 as a fuel. The fire is ignited with an electric spark that is then turned off after the fire starts. The airflow mixes with the spray pushing the fire forward and inboard across a pattern of tubes, which are heated by the fire and act as a hot surface to reignite the fuel air mix should the fire extinguishing agent put out the fire. This method was developed to produce a fire and relight scenario that was repeatable and would stress the performance of halon.

The repeatability of the fire and relight was important and was controlled by measuring the temperature of the clutter in the fire area. Approximately 150 thermocouples were used to develop a thermal map of the test fixture for use in identifying the flow patterns with the nacelle. These data have been used by the Navy in a data visualization program to depict graphically the changing temperatures within the nacelle and to provide a visual guide to the fire conditions. Various surface and air thermocouples were used in the fire area to map and identify the hottest part of

Typical View of Fire

Video Camera Looking Down Through Window in Top of Rig Directly over Fire

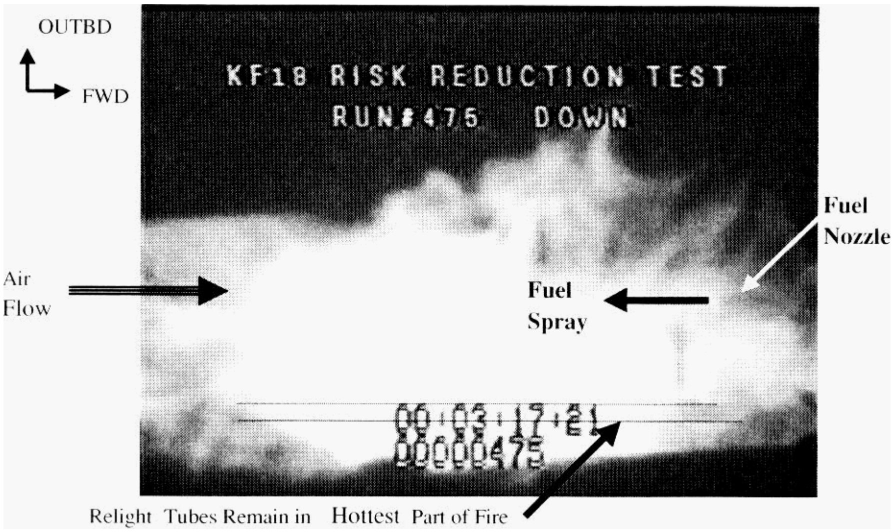


Figure 2. Video image of typical fire,

the fire. This hot part of the fire was used to define the test conditions that were likely to result in a relight condition. The hottest surface temperature used to assure a relight condition existed was 1790 °F. Figure 3 shows the simulated engine plumbing used as a hot surface to assure that a relight could occur. This high temperature was very hard on the clutter tubing as seen in the before-test and after-test pictures; the hot surface tubing warped severely requiring frequent replacement and the thermocouple wiring became brittle and subject to handling damage.

Re-ignition Tubes

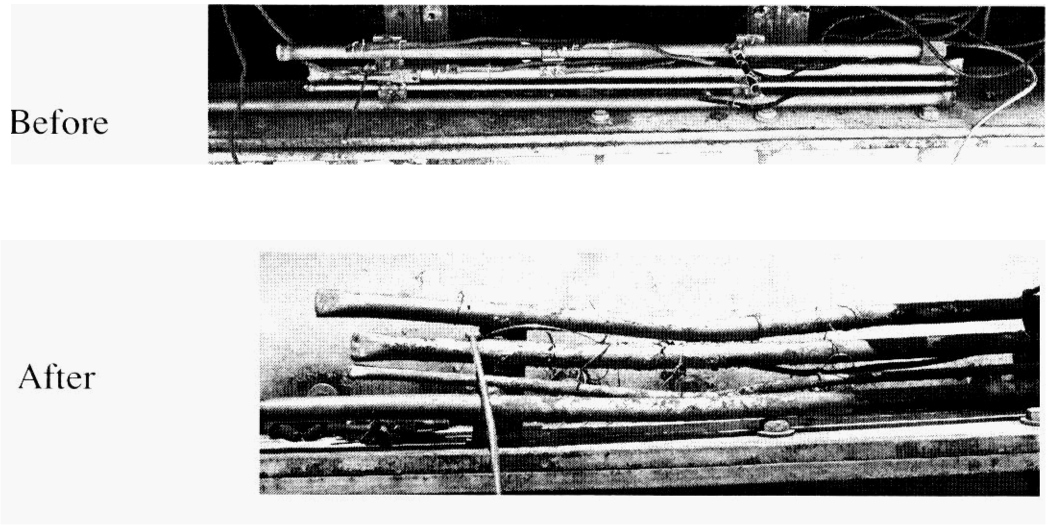
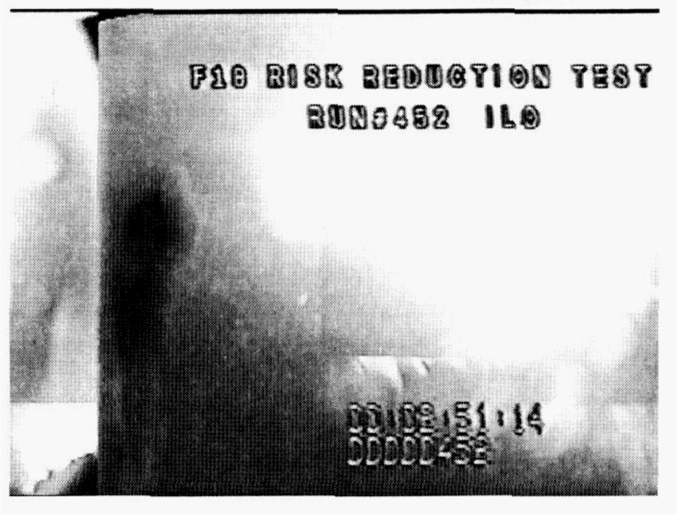


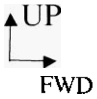
Figure 3. Simulated clutter tubing used as hot surface relight source.

FIRE SEQUENCE

Figures 4 through 7 show a typical fire sequence—the camera is located low on the inboard side looking horizontally through a window and under the simulated engine toward the outboard side where the fire is located. The fuel is ignited and allowed to preburn for 2 to 3 min until the clutter surface temperature reaches the trigger temperature as defined by the test procedure (Figure 4). When the hot surface trigger temperature was reached, the fire extinguishing agent was released and a light came on that could be seen in the video image to signal that the agent release had begun (Figure 5). Figure **6** shows the time approximately 0.3 sec after the start of the agent release when the fire is nearly extinguished. The time seen on the video picture is in hours: minutes:frames with 30 frames/sec. The fuel continues to flow after the fire is extinguished, and the hot tubes can be **seen** glowing in the video image ready to relight when conditions return to a flammable state. Figure 7 shows the first frame where the fire relights; the flame can be seen to be spreading from the location of the hot relight tubes.

Fire Extinction Sequence, Step 1
Preburn





Video Camera
Through Window on
Inbd Keel Toward Fire
on Far Side of the
Engine Near Outbd
Moldline

Simulated
Eng Eqpt

2 to 3 Min Preburn to heat clutter and
based on stressed HALON

Figure **4.** Initial fire to warm the relight hot surfaces.

CONCENTRATION MEASUREMENT

Agent concentration was measured during the test program in an effort to predict agent performance without having to build a fire. Figure **8** shows a typical test run where a halonyzer **is** used to measure the concentrations during agent release. Twelve (12) channels are used with the sensor points at various locations through out the engine bay. The halonyzer can not be used during a **fire** due to the amount of soot, so aifflow conditions are set up similar to the fire test conditions. Figure 8 also shows the agent bottle pressure during the discharge. The bottle has almost completely discharged in the first 2 sec; however, the measured concentration does not

Fire Extinction Sequence, Step 2
Agent Release

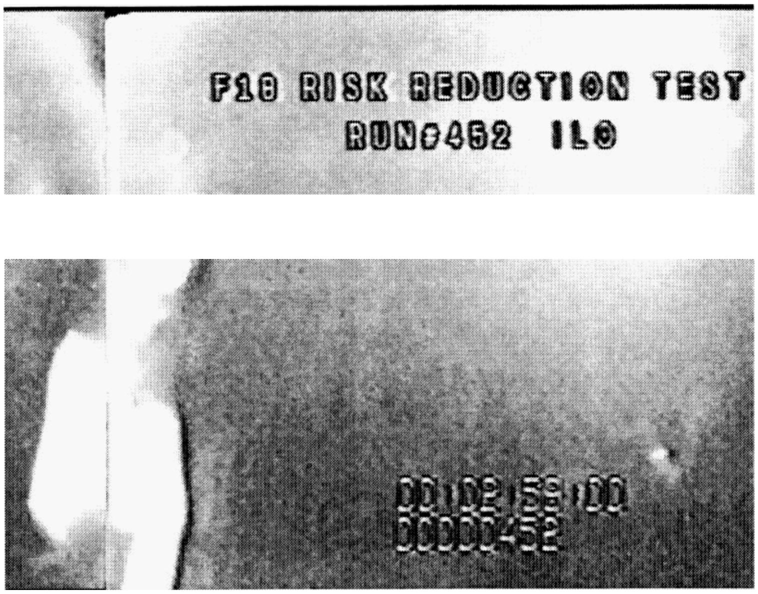
Figure 5. Agent release. time zero of the extinction event.

Fire Extinction Sequence, Step 3
Fire Going out

Last Frame with Fire. Extinction Counted at **Next** Frame 0.3 Sec After Agent Release

Figure 6. Fire nearly **extinguished.**

Fire Extinction Sequence, Step 4
Fire Re-lights



Fire Re-lights After 4.5 Sec at Re-light Tubes

Figure 7. Fire relights at hot surface.

Measured Concentration for Test Condition

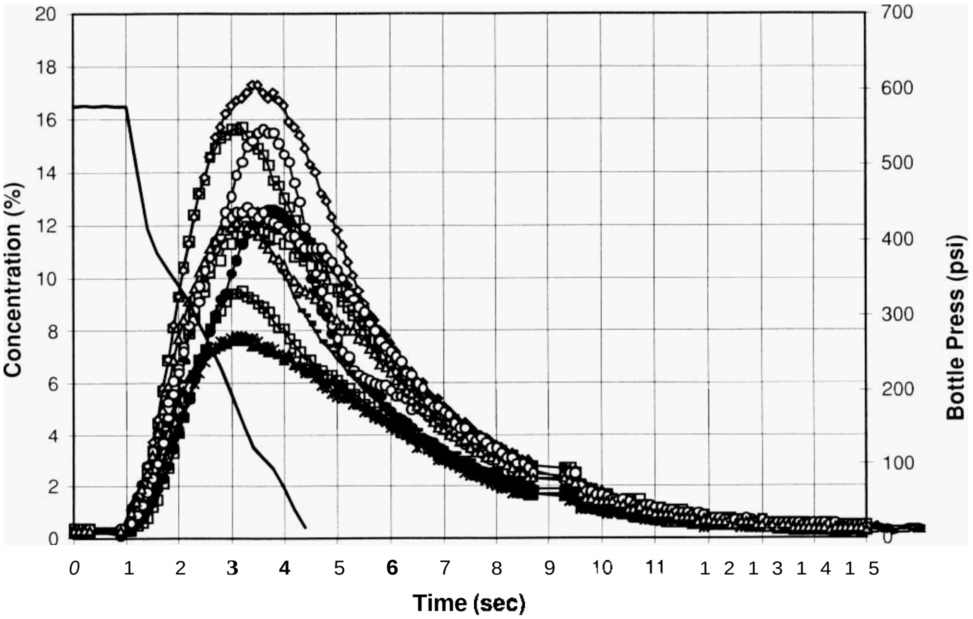


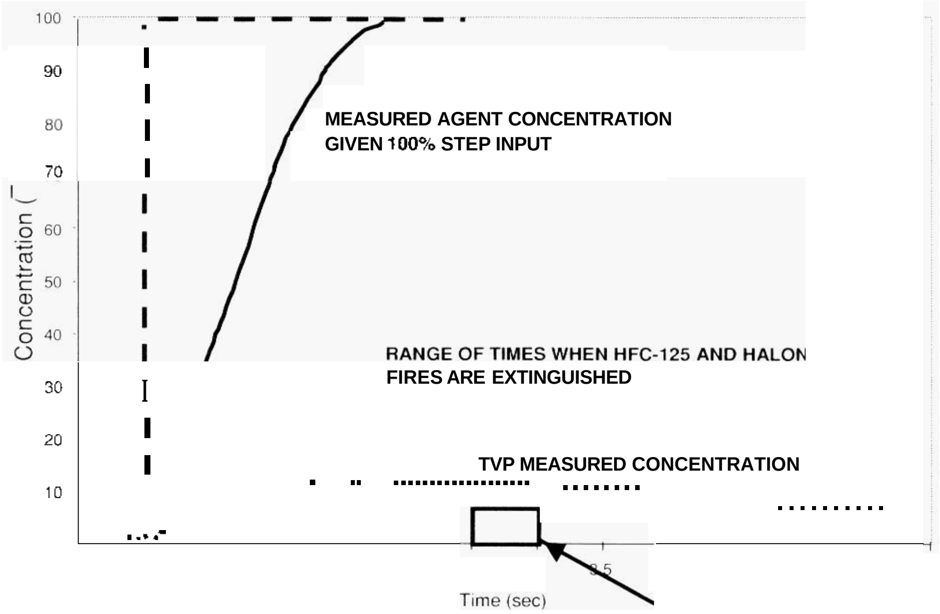
Figure 8. Typical agent concentration measurement.

peak until 2 to **3** sec after the start of the discharge. This indicates that the response time of the halonyzer was not adequate to measure the agent concentration in the critical initial seconds of the fire extinction event.

Figure 9 displays the problem with attempting to predict fire extinguishing performance of alternate agents with the halonyzer equipment. **A** simple test was conducted in which a 100% agent concentration was rapidly applied to the end of the halonyzer sense tube. The equipment required over 2 sec to actually reach the full 100% level. In measuring the time required to extinguish typical fires, the fire was out in the first 0.2 to 0.7 sec after the agent release was initiated. The response time of the halonyzer will therefore miss the concentration measurement that is actually extinguishing the fire. For halon. the required concentration of 6% for 0.5 sec will likely result in a very conservative assessment of extinguishing performance. The halonyzer may be **a** good technique for agents that are primarily chemically reactive but may be limited in use with agents such as HFC-125, which function more with a combination of inerting. cooling, and disruption of the fire. Reference 1 discusses some of these halonyzer characteristics.

Agent Concentration Measurement

HALONYZER DOES NOT RESPOND TO THE INITIAL HIGH LEVELS THAT ARE EXTINGUISHING THE FIRES



CONCLUSIONS

Certifying the performance of halon replacement agents will require establishing test data to show the performance will be comparable to halon. To perform fire tests a robust simulator is required and considerable testing is needed to verify that the test simulator performance will be similar to the aircraft and to define the baseline halon performance. Improvements to agent concentration measurement techniques are needed to aid in predicting fire extinguishing performance and eventually to reduce the cost of certifying new agents.

REFERENCE

1. Richard G. Gann, “Fire Suppression System Performance of Alternative Agents in Aircraft Engine and Dry Bay Laboratory Simulations,” SP 890: Vol. II, p 457-465, November 1995.