FSS 000032 R

Status of Onboard Cabin Water Spray Program

Richard G. Hill
Constantine P. Sarkos
Timothy R. Marker

FAA Technical Center

Paper to be presented at
Ninth Annual International Aircraft Cabin Safety Symposium
Sponsor: Southern California Safety Institute, Inc.
The Pasadena Hilton
Pasadena, California
February 17-20, 1992

Status of Onboard Cabin Water Spray Program

By Richard G. Hill, Constantine P. Sarkos, and Timothy R. Marker
FAA Technical Center

Outdoor full-scale fire tests, conducted in the United Kingdom (U.K.) under the auspices of the Civil Aviation Authority (CAA), demonstrated the feasibility of an onboard cabin water spray system (CWSS) for providing a marked improvement in survivability during a postcrash fuel fire (reference 1). Developed and evaluated by SAVE, Ltd., the system produces a fine water spray or mist consisting of a "range of water droplet diameters." A fine water spray system, such as developed by SAVE, Ltd., is capable of providing fire protection with relatively low flow rates of water. The spray system tested was a "breadboard" design for the purpose of demonstration of concept feasibility.

An outline of a program prepared by the Federal Aviation Administration (FAA) to develop a cabin water spray system for safe and effective installation in a commercial transport airplane is shown in figure 1, depicting major projects and order of accomplishment. Portions of this program are a cooperative effort by the FAA, CAA, and Transport Canada. Initially, controlled full-scale tests document the additional time available for escape, as provided by the current SAVE system. Analyses were used to address the various problems associated with an inadvertent discharge of the SAVE water spray system ("disbenefits") while an airplane is in flight or on the ground. The results of these initial studies are factored into a benefit analysis to determine the potential for saving lives (similiar to analysis conducted by FAA for passenger protective breathing equipment) (reference 2). Presuming that the benefits outweigh the disbenefits, the next steps are to optimize the spray system for installation in an airplane and to develop design requirements and specifications. Additional full-scale tests would follow to verify the additional time available for escape provided by the optimized system. Another benefits analysis would determine potential lives saved for the optimized system. Finally, a decision would be made concerning the requirements for installation of onboard spray systems for the commercial airplane fleet.

The following is a brief description of the status of major projects:

1. <u>FULL-SCALE EFFECTIVENESS TESTS (SAVE SYSTEM)</u>

Purpose: Evaluate and determine the additional time available for escape provided by the SAVE water spray system under controlled full-scale test conditions for several postcrash fire scenarios.

Method: Full-scale tests will be conducted under controlled conditions utilizing both narrow body and wide body fuselages for several postcrash fire scenarios. One test will be conducted with the SAVE system installed and one test without the SAVE system for each fire scenario in order to determine the additional time available for escape. A section of the test article will be completely furnished with materials marginally compliant with the FAA seat cushion and low heat release standards.

Responsibilities:

FAA - Preparation and conduct of full-scale tests.
CAA - Coordination delivery of "SAVE" system to FAA.

Expected Outcome and Utilization:

Determination of additional time available for escape provided by the SAVE water spray system for several important postcrash fire scenarios for input into benefit analysis computer program.

Status:

Full-scale effectiveness tests were completed using both a narrow and wide body fuselage configuration. Four scenarios were studied in the narrow body (707) fuselage: (1) a large fuel fire entering a fuselage under zero wind conditions; (2) a large fuel fire entering the fuselage with the assistance of moderate wind; (3) a large fuel fire entering the fuselage with the assistance of high wind; and (4) a large fuel fire burning through the fuselage skin on the underside of the aircraft and entering both the cargo and cabin areas. Full-scale tests completed in the wide body fuselage (similar to a DC-10) consisted of a large fuel fire entering the fuselage with the aid of a moderate wind. An additional series of tests were conducted to investigate the effectiveness of the water spray system during a postcrash fire accelerated by the discharge of oxygen in the cabin area adjacent to the fire.

The major findings for the effectiveness tests of the SAVE CWSS are as follows:

1. CWSS was effective in both the narrow and wide body test articles, providing a significant 2-3 minutes (or more) of additional time to escape. Figures 2, 3, and 4 show the fractional effective dose (FED) calculations for the narrow body tests during zero wind, moderate wind, and burnthrough conditions, respectively. (FED is a survival model that accounts for measured temperatures and toxic gas concentrations; incapacitation occurs when FED=1.0.) Figure 5 illustrates the FED calculations for the TC-10 tests under moderate wind conditions.

2. CWSS was most effective in reducing air temperatures and acid gas concentrations.

3. CWSS delayed the onset of flashover and also reduced the level of fire hazards produced by flashover when it eventually occurred.

4. CWSS was not effective against an extremely severe fire condition caused by high wind, during a narrow body test. In this test, the flames from the fuel fire traversed the cabin ceiling to the side opposite of the entry point.

5. The action of the water spray against the ceiling smoke layer causes the smoke to be redistributed from the floor to the ceiling. During an initial time period, the reduction in light transmission was actually greater with water spray than without water spray. However, at a later point in time the reduction in light transmission without water spray becomes greater than with water spray (and continuously becomes more pronounced in this direction) as the smoke produced by the uncontrolled fire becomes more voluminous.

During the last series of experiments, three full-scale tests were performed in a wide body fuselage to determine the ability of the CWSS to suppress an oxygen enhanced cabin fire. Two fuel fire tests were conducted in which pressurized oxygen was introduced into the cabin interior in the vicinity of a pool fire which was adjacent to a fuselage opening. Water was sprayed throughout the cabin during one of the two oxygen fed fire tests in order to determine the benefits of using a water spray system. A test was performed using the identical pool fire adjacent to the opening without the introduction of oxygen into the cabin in order to establish "baseline" data. Figure 6 displays the FED calculations of these three tests. The main conclusion was that the release of oxygen created a significantly more severe cabin fire. Without oxygen release, the survivability was much greater than five minutes; however, release of oxygen lowered the survivability to only about 2 minutes. Another important conclusion was that activation of the CWSS in the oxygen fed fire improved the survivability by more than 3 minutes (not quite to the level measured without oxygen release).

2. SERVICE CONSIDERATIONS AND DISBENEFITS STUDY (SAVE SYSTEM)

Purpose: Determine consequences of an accidental discharge of an onboard cabin water spray system both on the ground and in flight.

Method: Contractual studies will be awarded to major airframe manufacturers that will include, but not be limited to, the following:

A. Effect of accidental water spray on safe operation of aircraft in flight.

B. Effect of water spray on rapid passenger evacuation and hypothermia during cold weather.

C. Impact of accidental water spray on aircraft airworthiness and extensiveness of repair work necessary to restore aircraft to service.

Responsibilities:

Contracts sponsored mainly by the FAA and CAA. Coordination between these two entities is required in the preparation of work statement.

Expected Outcome and Utilization:

Input into benefit analysis computer program and identification of problem areas that need to be considered during optimization project.

Status:

Contractual studies by Airbus Industrie and the Boeing Company have been completed and final reports are being drafted. Preliminary results indicate that an inadvertent in-flight discharge of a SAVE CWSS could cause serious problems without extensive redesign of present aircraft electrical systems. The studies' results seem to mandate a system design that would eliminate, or at least minimize, the possibility of in-flight activation and allow for rapidly shutting off the system should an inadvertent discharge occur.

The studies also raised questions concerning the human factors aspects of the system. Possible problems of evacuations in water spray and hypothermia were raised. Both the FAA and CAA have initiated projects to examine those concerns.

3. BENEFIT ANALYSIS STUDY (SAVE SYSTEM)

Purpose: Calculate the potential lives saved from the mandatory requirement for an onboard water spray system (SAVE, Ltd.) design based on an analysis of worldwide fire accidents in transport aircraft.

Method: Employ the benefit analysis computer program developed by the FAA Technical Center, to determine potential savings in lives and the cost of system weight and disbenefits. Perform computer analysis for 20 accidents with adequate information on fire development/evacuation and extrapolate results for remaining data base.

Responsibilities:

CAA, FAA, and Transport Canada Airworthiness Group (TCAG) team to work on computer analysis of 20 accidents.

CAA responsible for extrapolation to remaining data base and net safety benefit analysis.

Expected Outcome and Utilization:

Benefit/cost ratio of mandatory requirement of onboard spray system. Basis for decision as to whether or not to proceed to optimization and development of design requirements/specifications.

Status:

Preliminary results presented by the CAA at the "Cabin Water Spray Systems Industry Consultative Conference, May 1991," indicate that a SAVE CWSS may save between 9 to 15 lives per year worldwide, using accident data for the past 25 years. Results of the study are still being analyzed and a final report should be published by the CAA during 1992.

Both the FAA and CAA have agreed to pursue developing a risk analysis program.

4. OPTIMIZATION OF SYSTEM

Purpose: Evaluate important parameters for water spray systems in order to optimize the effectiveness of spray per unit weight of water.

Method: Small-scale tests that lend themselves to parametric studies and complex measurements (such as droplet size distributions) will be conducted to determine the effect of droplet size/distribution and flow rate on water spray effectiveness. Full-scale or mockup tests will be needed to study system parameters. For example, method and time of activation and length of discharge will be studied, as well as possible effects of additives to the water (gas scrubbers and/or antifreeze agents). In addition, the pros and cons of a zoned versus total spray system will be evaluated.

Responsibilities:

CAA, FAA: Full-scale or mockup tests; small-scale tests.

Expected Outcome and Utilization:

Information will be input to develop requirements and specifications.

Status:

Preliminary optimization tests sponsored by the CAA have been conducted by the Fire Research Station in the United Kingdom. Results should be published early in 1992.

The FAA conducted two series of tests in a wide body fuselage. The first series studied the effect of nozzles located in the overhead (attic space) to reduce hazards in the passenger cabin. Test results showed little or no improvement in the cabin conditions due to the overhead spray (reference 3). Elimination of the overhead nozzles would reduce the weight of the water in the SAVE CWSS by 8.6 percent.

The second series of tests studied the effect of different spray locations and the effect of "prewetting" the cabin materials. The preliminary results indicate that a zoned system (one spraying only in the area of a fire) would be almost as effective against heat and toxic gases as a full sprayed cabin and would have advantages from the standpoint of smoke (visibility) and problems associated with wetting passengers (reference 4).

Several private companies in the United Kingdom have been testing and developing their own water spray system. FAA and CAA are monitoring the results of their tests. FAA plans to begin optimization tests in 1992.

5. SOLVE PROBLEMS OF DISBENEFITS

Purpose: Determine system design features for eliminating or reducing the likelihood or impact of problem areas uncovered during service consideration/disbenefits study.

Method: Specific methodology will be dictated by problem areas encountered.

Responsibilities:

To be determined.

Expected Outcome and Utilization:

Input to develop requirements and specifications.

Status:

Awaiting final reports from disbenefits studies.

6. DEVELOPMENT OF REQUIREMENTS AND SPECIFICATIONS

Purpose: Develop requirements and specifications for regulatory provision for an onboard water spray system.

Method: Using data obtained from testing and the benefit and disbenefits studies, develop minimum requirements for system airworthiness, crashworthiness, and performance.

Expected Outcome and Utilization:

Minimum standards for possible regulatory action.

Status:

The CAA is presently developing a design requirement, and the FAA is developing a full-scale performance test requirement.

7. DETERMINE OTHER AREAS OF APPLICABILITY

Purpose: Determine if stored water from this system could be used for fire extinguishment suppression in other required areas of the aircraft.

Method: Test potential usage areas for water spray application; e.g., cargo compartment and powerplant fire protection systems.

Responsibilities:

To be determined.

Expected Outcome and Utilization:

Input into benefit analysis.

Status:

The CAA is sponsoring a test program to evaluate water as a potential fire suppression agent for use in aircraft cargo compartments. Preliminary results look promising. The FAA will begin a study of alternate uses of water in aircraft fire protection in 1992.

8. FULL-SCALE VALIDATION TESTS

Purpose: To validate the effectiveness of a water spray system designed to the minimum requirements for wide body and standard body aircraft and several postcrash fire scenarios.

Method: Full-scale tests will be conducted for several fire scenarios using wide and standard body cabin configurations.

Responsibilities:

FAA conduct tests with input from CAA.

Expected Outcome and Utilization:

Input to final benefit analysis and decision on regulatory action.

9. BENEFIT ANALYSIS STUDY (MINIMUM STANDARD)

Note: Purpose, method, and responsibilities identical to benefit analysis study for SAVE system except in this case, the analysis will be done for a system compliant to the minimum standard. Similarly, the results of the study will be input into the decision on rulemaking.

References

1. Whitfield, R.T., Whitfield, Q.d'A., and Steel, J., "Aircraft Cabin Fire Suppression by Means of an Interior Water Spray System," Civil Aviation Authority, CAA Paper 88014, July 1988.

2. Hill, R.G., and Speitel, L., "Study of Benefits of Passenger Protective Breathing Equipment from Analysis of Past Accidents," Federal Aviation Administration Technical Center, Report No. DOT/FAA/CT-88/03, March 1988.

3. Marker, Timothy, "Effectiveness of Water Spray Within the Cabin Overhead Area," Federal Aviation Administration Technical Center, Report No. DOT/FAA/CT-TN91/29, August 1991.

4. Marker, Timothy, "Onboard Cabin Water Spray System Under Various Discharge Configurations," Federal Aviation Administration Technical Center, Report No. DOT/FAA/CT-TN91/42, October 1991.

ONBOARD WATER SPRAY PROGRAM

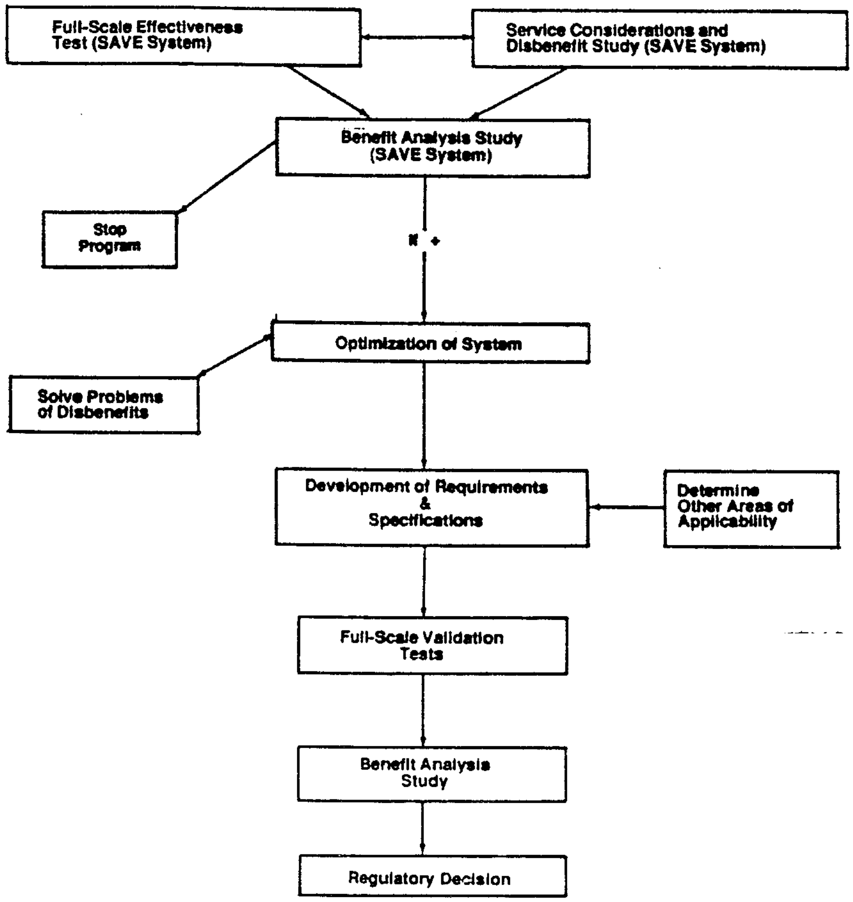

FIGURE 1

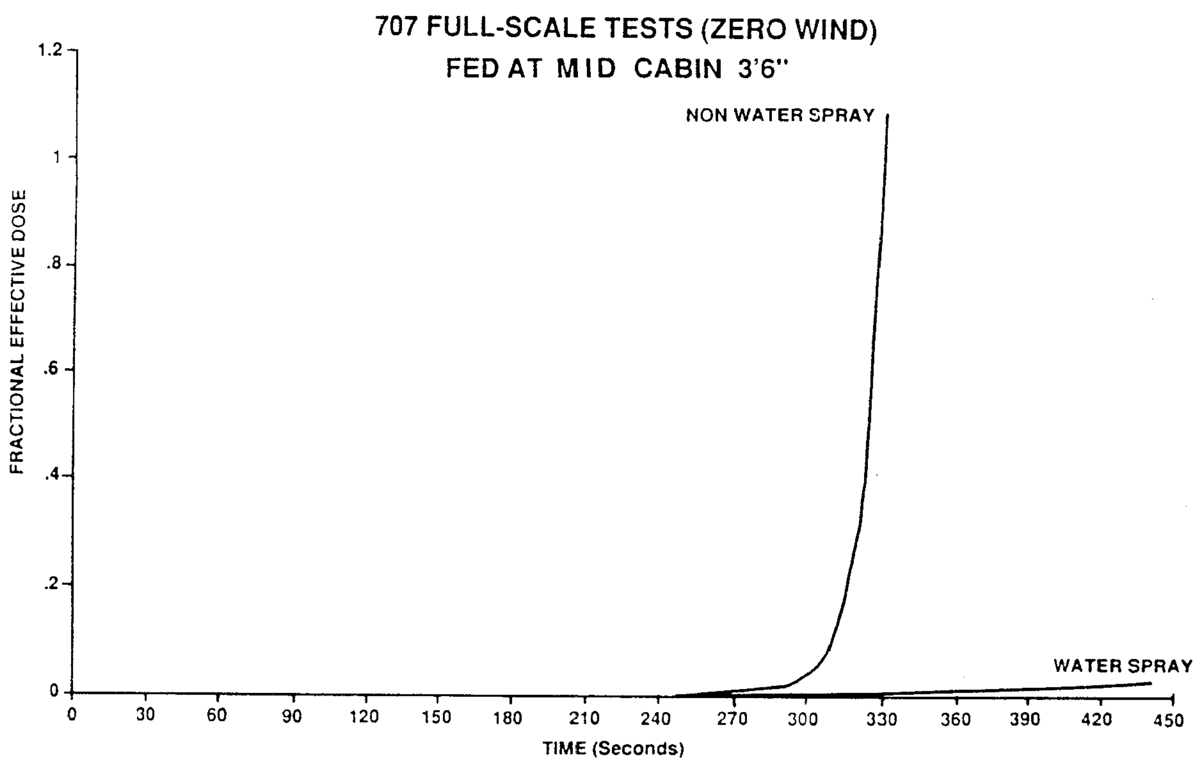

FIGURE 2

707 FULL-SCALE TESTS (MODERATE WIND)
FED AT MID CABIN 3'6"

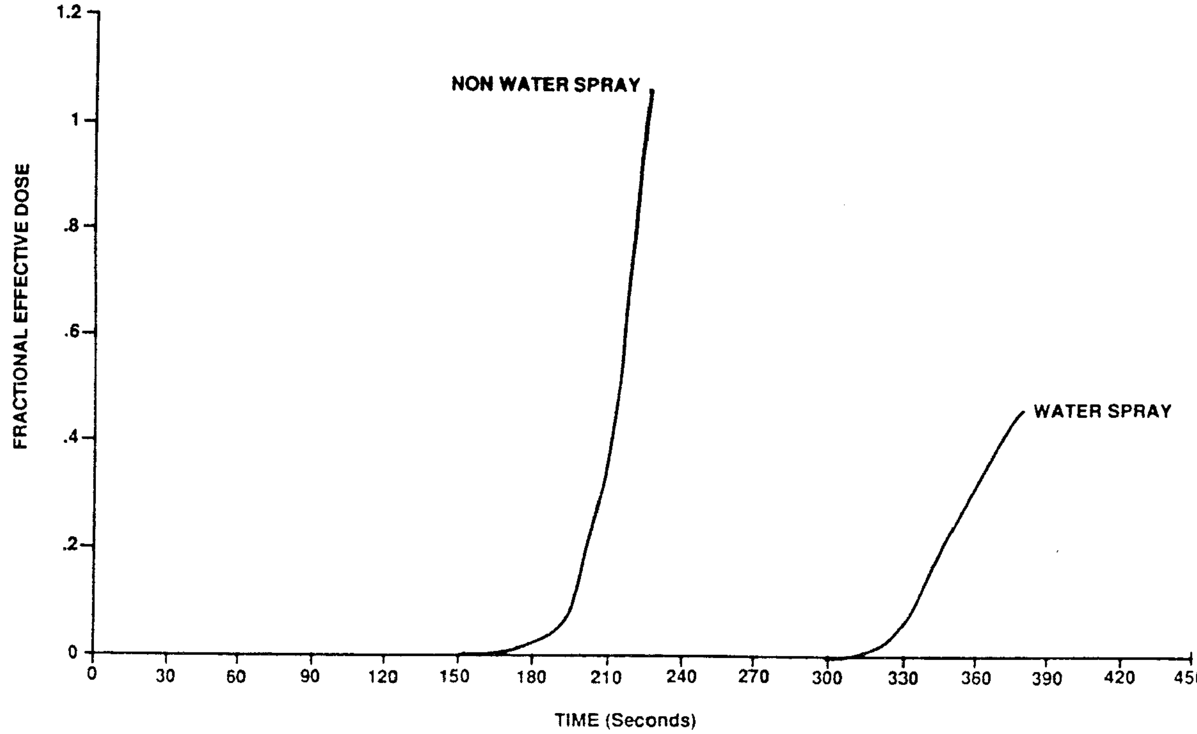

FIGURE 3

707 FULL-SCALE TESTS (BURNTHROUGH)
FED AT MID CABIN 3'6"

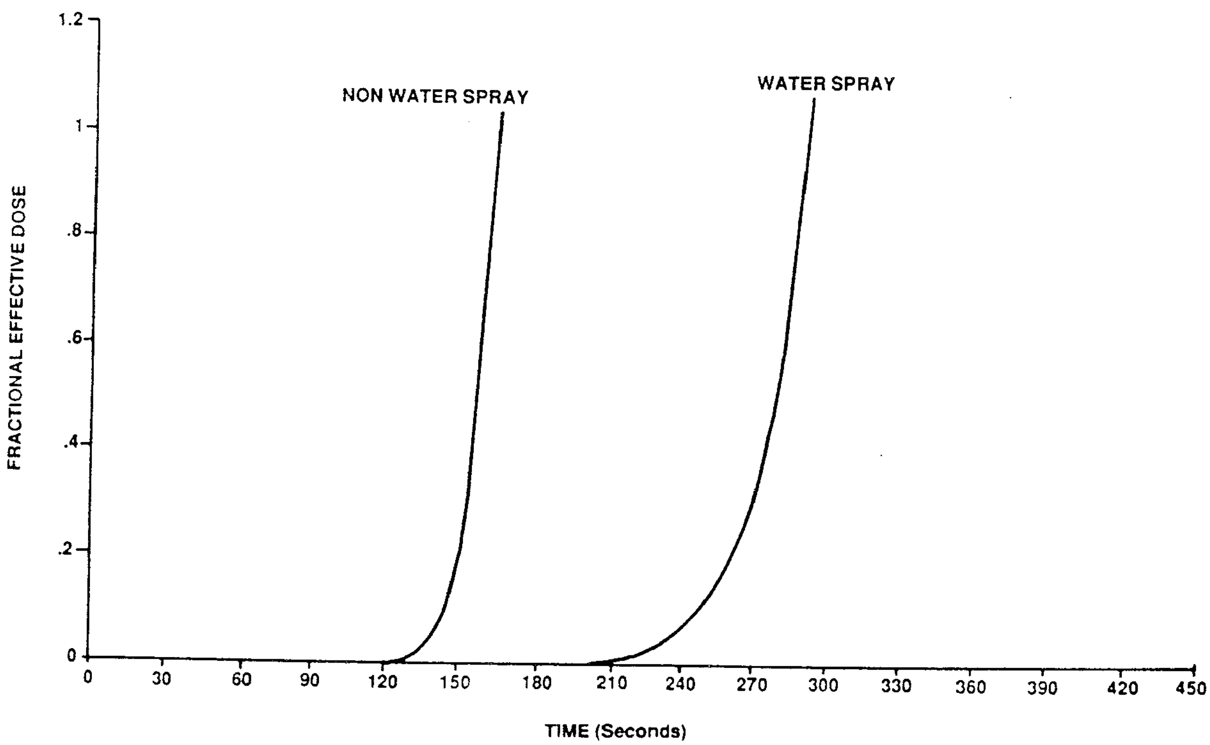

FIGURE 4

TC-10 FULL-SCALE TESTS (MODERATE WIND)
FED AT MID CABIN 3'6"

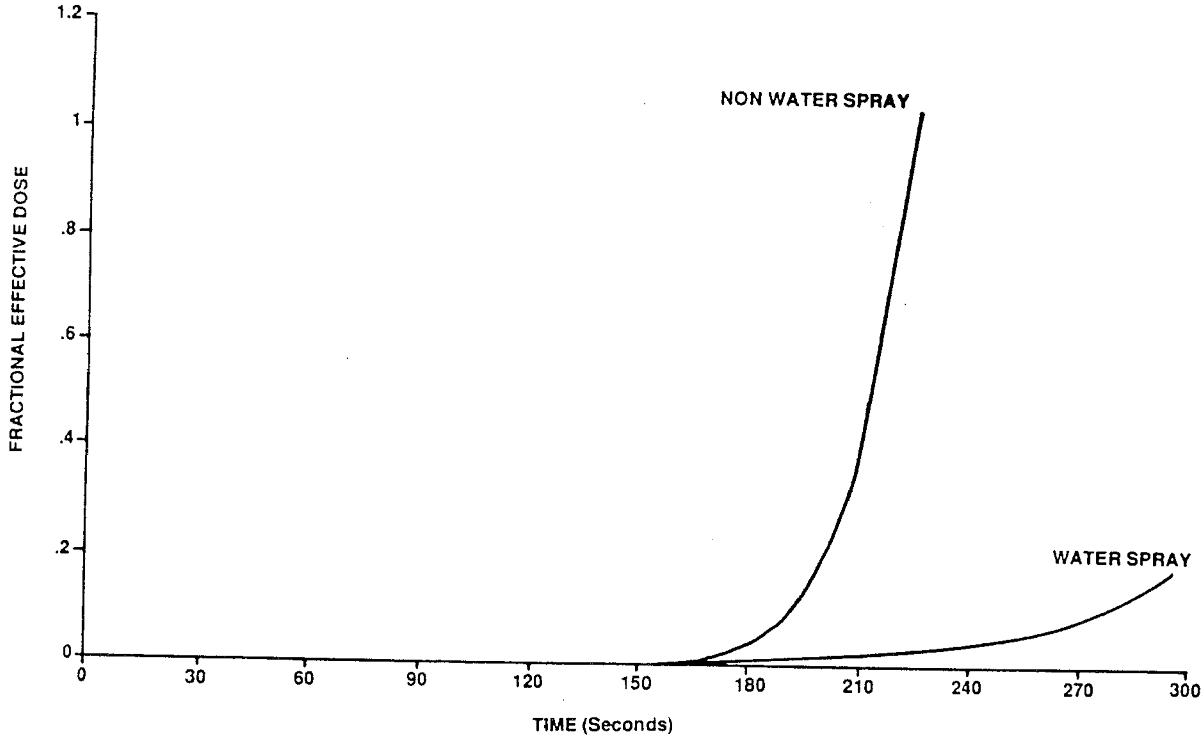

FIGURE 5

FED AT MID CABIN 3'6"

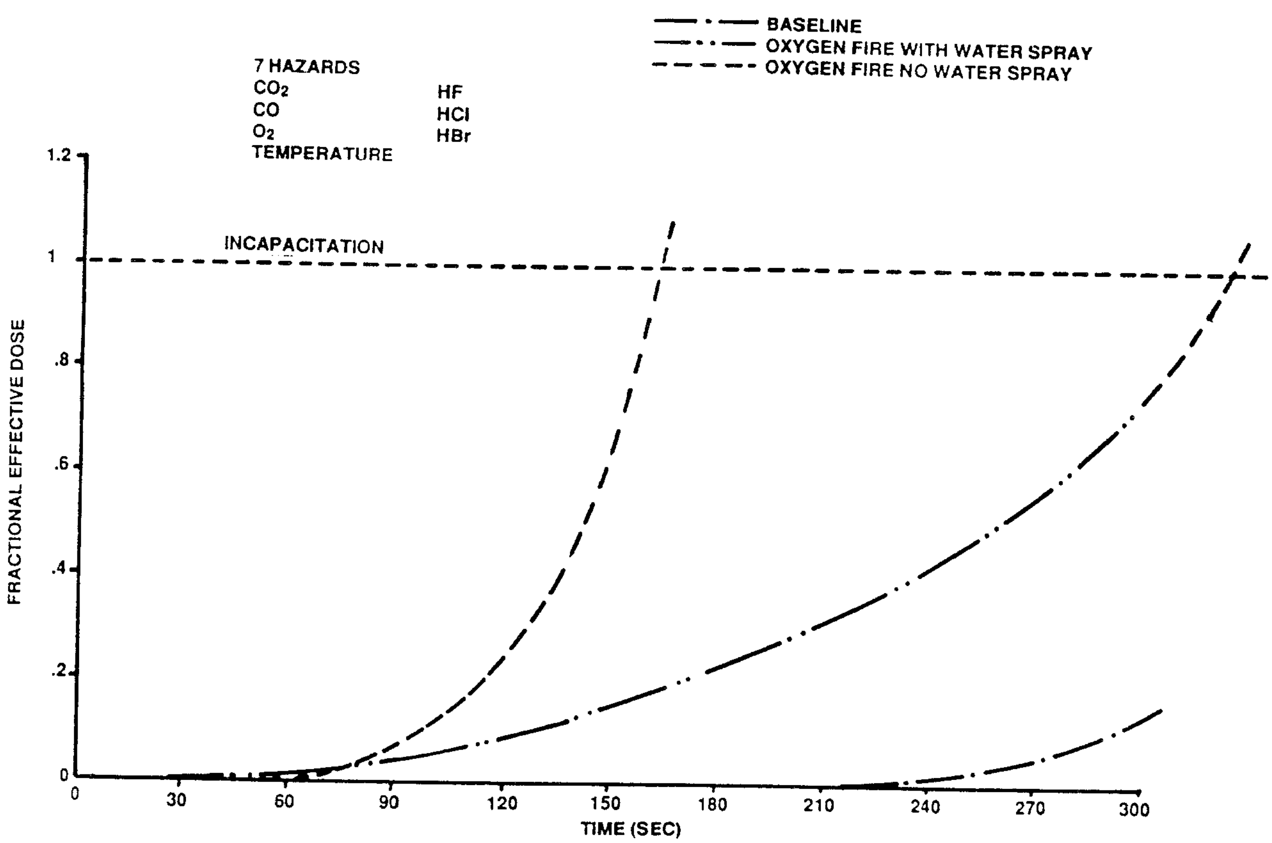

FIGURE 6