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FAA TECHNICAL CENTER
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N.J. 08405

Halon Extinguishment of Small Aircraft Instrument Panel Fires

G.R. Slusher
J. A. Wright
L. C. Speitel

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NOTICE

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16. Abstract

Hand-held Halon 1211 and Halon 1301 fire extinguishers of 2.5-pound and 3-pound capacity, respectively, were discharged to determine their effectiveness on instrument panel fires in a small aircraft. The fires consisted of aircraft wire insulation and hydraulic fluid located below and behind the instrument panel in a Piper Model PA-30 Twin Comanche fuselage.

The extinguishers were discharged using two methods; (1) by directing agent upward under the instrument panel, and (2) by directing agent behind the instrument panel by discharging through Fireports mounted on the instrument panel.

Except for one test, the fires were extinguished rapidly upon discharge of the Halon extinguishers. The two methods of discharge were equally effective in extinguishing the fires. Extinguishers charged with Halon 1211 and Halon 1301 were both effective for fire extinguishment. In the test where the fire was not extinguished, the fire was located under the instrument panel on the copilot's side and the extinguisher was discharged through a Fireport located on the extreme opposite side (pilot's side). In this test, the fire was knocked down but continued to burn.

Measurements of the decomposition products of the Halon agents demonstrated toxic gas concentrations significantly below levels considered dangerous.

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EXECUTIVE SUMMARY

The effectiveness of Halon 1211 and Halon 1301 hand fire extinguishers in extinguishing fires under the instrument panel in a small aircraft was evaluated. The extinguishers were of 2.5-pound and 3-pound capacity, respectively. The fires involved electrical wire insulation and hydraulic fluid. The fires could not be maintained without a small quantity of hydraulic fluid applied as a coating on the wiring harness.

The fire extinguishers were discharged using two methods; (1) by directing the agent upward under the instrument panel, and (2) by directing the agent behind the instrument panel through Fireports mounted on the instrument panel. The Fireports were installed through the instrument panel to provide direct access of the fire extinguisher agents to the space behind the panel.

The fires were extinguished rapidly by both types of agents when the discharge was directed at the fire. The methods of discharge, either through Fireports or directed upward under the instrument panel, were equally effective.

A special test was performed to examine extinguisher effectiveness with the fire located under the instrument panel, copilot's side, but with extinguisher application through a Fireport located on the pilot's side. Although the fire was momentarily suppressed, reignition occurred and the fire became out of control. The fire had to be extinguished by application of backup extinguishing agent from outside the aircraft.

During several tests, measurements were also taken to examine the levels of toxic Halon decomposition gases; hydrogen chloride, hydrogen fluoride, and hydrogen bromide. The decomposition levels were consistently low, and significantly below the levels considered dangerous.

INTRODUCTION

PURPOSE.

The objective was to evaluate the effectiveness of Halon hand extinguishers on fires involving electrical wire insulation and hydraulic fluid beneath the instrument panel in a small airplane.

BACKGROUND.

Previous efforts involving testing of Halon fire extinguishers in general aviation were completed in a Cessna Model 210 aircraft (references 1 and 2). The Cessna aircraft was installed in an airflow facility and tested at an airspeed near cruise conditions. These tests produced realistic aircraft cabin ventilation rates in order to examine dissipation of the fire extinguisher agents. The tests were without fires, and the toxicity of the neat Halon gases was addressed. It was determined that ventilation and stratification of the Halon gases produced safe conditions in the cabin of unpressurized single engine aircraft such as the Cessna Model 210.

The Cessna aircraft tests included discharging the extinguisher up under the instrument panel on either the pilot's side or the copilot's side and measuring the agent concentration on both sides, simultaneously. The measured concentration on the discharge side of the instrument panel was typically 10 percent by volume, and opposite the discharge side the concentration varied from 3.8 to over 4 percent. The question to be answered by fire testing was whether there was sufficient agent to extinguish a fire located opposite the side of agent discharge.

The following Halon extinguishing agents were evaluated:

1. Halon 1211, bromochlorodifluoromethane ($CBrClF_2$)

2. Halon 1301, bromotrifluoromethane ($CBrF_3$)

Halon is an abbreviation for halogenated hydrocarbon, which is a hydrocarbon with hydrogen atoms replaced with atoms from the halogen series: fluorine, chlorine, bromine, and iodine. The United States Army Corps of Engineers established a logical series of numbers (1211, 1301, etc.) for quick and convenient identification of the Halon extinguishing agents. The first digit is the number of carbon atoms in the molecule, the second is the number of fluorine atoms, the third is the number of chlorine atoms, the fourth is the number of bromine atom, and the fifth digit is the number of iodine atoms (reference 3).

DISCUSSION

TEST ARTICLE.

The test aircraft was a Piper Model PA-30 Twin Comanche fuselage. The aircraft was without seats, and was unfinished in regard to upholstery. Aircraft of this type in service have four main seats (with a modification, 1 or 2 jump seats could be added, bringing the total number of passengers, including the pilot, to 5 or 6). The fire testing was conducted on the ground in the test aircraft. Ventilation was simulated by the addition of compressed air through the aircraft vent system. In this specific aircraft, a ram air port in the nose forces air through ducts in the foward baggage compartment into the cabin. The aircraft test article is shown in figure 1.

Eighty-six percent of cabin fires in general aviation aircraft are electric in origin (references 1 and 2). The electrical systems for the most part are located behind the instrument panel. Thus, the fire tests in this report were directed behind the aircraft instrument panel.

MEASUREMENT OF EXTINGUISHING AGENTS.

An environmentally controlled trailer incorporated instrumentation for measuring the fire extinguishing agents of interest. The extinguisher agent was measured at three aircraft instrument panel locations with Beckman model 865 gas analyzers, with appropiate detectors purchased from Beckman Instruments Company, and an optical filter to eliminate sensitivity to water vapor. Calibration gases at 3.0, 6.0, and 8.0 percent of Halon 1211 and 1301 were used. Calibrations were checked before and after each test. The signals were recorded by a computer and plotted against time. Interior temperatures were tracked with a programmable data logger in order to ascertain the effectiveness of the extinguishing agent in suppressing the fire on a time resolved basis.

ACID GAS COLLECTION.

Absorption tubes were used to collect acid gas samples during the tests. This procedure was developed previously at the Federal Aviation Administration (FAA) Technical Center (reference 4).

The absorption tube was glass lined, stainless steel, 16 1/2 centimeters long with a 4-millimeter inside diameter. It was packed to a depth of 14 centimeters with glass beads (3-millimeter diameter) which were held in place by a slice of Teflon pressed into the tube at each end (references 4 and 5). The beads were rinse-coated with one molar sodium carbonate solution just prior to use. Excess solution was blown from the tube by a syringe. A 2-inch length of 2 millimeter i.d. capillary tubing was attached to the upstream end of each tube. The absorption tubes were then sealed with plastic caps for protection.

The tubes were placed in the fuselage at the nose level of the pilot, about 8 inches below the ceiling in the center of the fuselage. The horizontally mounted tubes were attached to copper vacuum lines leading outside the fuselage to the solenoid valve assembly. One tube, capped on the downstream end, was used as a blank for each test. A flow calibration check of each sample tube was made with a wet test meter prior to each test.

The solenoid valve assembly is an array of solenoid valves, remotely controlled by a multipole relay timer. The main vacuum line is "teed" to two solenoid valves, each connected to a 3 1/2-liter vacuum bottle. As one bottle is evacuated, the other draws a sample into an absorption tube. The multipole relay timer sequentially opens the solenoid valves (one every 30 seconds) joined to each absorption tube. This technique allows short sampling intervals and can handle a large number of samples.

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ACID GAS ANALYSIS.

After each test, the sample tubes were removed from the fuselage, capped, and brought to the laboratory for analysis. The anions are recovered by rinsing each absorption tube in a backflush mode with a 10-milliliter aliquot of 0.05 molar sodium carbonate solution dispensed by syringing. The luer tipped syringe is adapted to the absorption tube with a female Swagelok fitting to a female luer connector. The washings are collected in autosampler plastic cuvettes for subsequent analysis. Hydrogen fluoride (HF), hydrogen chloride (HCl), and hydrogen bromide (HBr) were identified and quantified with a Dionex Model 10 Ion Chromatograph with potentiometric detectors. A fluoride ion selective electrode was used for fluoride. A silver/silver chloride electrode was used for chloride and bromide. The reference electrode was a silver/silver chloride electrode with a potassium nitrate salt bridge (reference 5).

FIREPORTS.

Fire extinguishers charged with Halon 1211 of 2.5-pound capacity and Halon 1301 of 3-pound capacity were tested. Two types of application of the extinguishers were employed; (1) the extinguishers were discharged directly up under the instrument panel and (2) the extinguishers were discharged through Fireports (provided by White Manufacturing Marketing, Inc., of Omaha, Nebraska) mounted directly through the instrument panel. Fireports were installed as a means to provide direct fire extinguisher agent access to an inaccessible area. The Fireports were of two types. One type consisted of five exit or distribution ports. Four distribution ports were located radially on a cylinder barrel, directing agent in the radial directions, and the fifth port was located in the cylinder barrel cap end, directing agent directly toward the firewall (figures 2, 3, and 4). The second type Fireport was a single port design and directed agent to a specific location. The Fireports incorporated a plastic insert in the front section through which the extinguisher nozzle was inserted to discharge agent through the Fireport into an inaccessible area. A special nozzle adaptor had to be installed on Halon 1301 extinguishers to provide a proper fit with the Fireports. This was a Teflon™ bodied orifice assembly that was used as a substitute for the hand extinguishers discharge horn. It must be noted that use of such a replacement assembly in practice will nullify the basis for the extinguisher's approval status.

TEST DESCRIPTION.

The ignition source was wiring insulation wrapped with Nichrome resistance wiring. Electric current through the Nichrome was regulated with a variac. In addition, to help the fire buildup within the instrument panel wiring area, 1 ml per second of aircraft 5606 hydraulic fluid was sprayed onto the bundle for approximately one minute. This helped to keep the fire burning as the insulation burned away at the Nichrome heat source.

The fire extinguishers were mounted into a bracket designed to hold the extinguisher in place for discharge. The bracket was positioned to either discharge the extinguishers up under the instrument panel on the pilot's or on the copilot's side. The bracket mechanism could be adjusted to discharge through the Fireports. A solenoid was used to apply pressure from a nitrogen filled cylinder to discharge the extinguisher by means of a pneumatic piston assembly.

TEST RESULTS.

The ignition of fires and the discharge of extinguishers were accomplished remotely. The fire tests were observed and recorded with video systems. The extinguishers were discharged one minute after ignition of the fire. The fire was allowed to develop for a full minute in order to create more severe thermal conditions for the extinguishing agent to overcome. A preburn time of one minute led to very smokey conditions and loss of visibility. Once the fire is extinguished, immediate ventilation or dissipation of the smoke would be a high priority item.

A description of tests is contained in table 1.

The fires of tests 1 through 7 (figures 5 through 11) were extinguished upon discharge of either Halon 1211 or Halon 1301. These results included fires on the pilot's and the copilot's sides of the cabin instrument panel. The exception to these results was in test 8 (figure 12) which was a special test of an extinguisher charged with Halon 1211. The fire was ignited under the instrument panel on the copilot's side. The extinguisher was discharged through a Fireport on the pilot's side. This was a multi-port type Fireport located 6 inches from the instrument panel edge. The Halon 1211 extinguisher when applied in this manner failed to completly extinguish the fire. The fire was knocked down but then increased and went out of control. Two additional Halon 1211 extinguishers were discharged from outside the aircraft without completely extinguishing the fire. After four to five minutes, a CO_2 extinguisher of 25 pounds was discharged and extinguished the fire. Test 8 was designed to address the problem of extinguisher discharge location relative to the fire. The results emphasized the importance of discharging the extinguisher as close to the fire source as possible.

The method of discharge of the fire extinguishers was one of two ways. They were either directed up under the instrument panel and discharged directly to the fire or discharged through Fireports through the instrument panel. The methods of application of the extinguishers, through Fireports or directed up under the instrument panel, were both effective in extinguishing the fires. Test 1, 3, and 5 involved agent directed up under the instrument panel. Tests 2, 4, 6 and 7 involved agent discharged through Fireports into and behind the instrument panel. In all these tests, the fires were quickly extinguished.

In unconfined areas, fire extinguishers charged with Halon 1211 have a throw range of up to 12 feet. When they are utilized in a confined space such as under the instrument panel, liquid is discharged and may splatter on surfaces such as the firewall, instruments, or panels. A short period of time is required for the liquid to become gasified. The agent has a tendency to remain concentrated at the point of discharge. Conversely, Halon 1301 is discharged directly as a gas. A wider dispersal of Halon 1301 agent is evidenced by Halon 1301 measurement behind the instrument panel as compared to Halon 1211. Test 1 and test 3 (figures 5 and 7) utilized Halon 1211 discharged directly up and under the instrument panel. Only one Halon 1211 gas measurement reached a high level, and this was in the direction of application. Halon 1301 was discharged directly up under the instrument panel in test 5 (figure 9). Halon 1301 gas measurements were high across the instrument panel at the three measurement locations. Thus, Halon 1301 was dispersed more extensively under the instrument panel than Halon 1211 when the agent was discharged directly under the panel.

TABLE 1. DESCRIPTION OF TESTS

Test No.	Fire Location	Halon Type	Type Discharge		Figure
			Fireport	Direct	
1	Below Instrument Panel-Copilot's Footwell	1211		Co-Pilot's Footwell	5
2	Under Instrument Panel-Copilot's Side	1211	Multi-Port Center		6
3	Below and Behind Instrument Panel-Pilot's Side	1211		Pilot's Side	7
4	Below and Behind Instrument Panel-Pilot's Side	1211	Multi-Port Pilot's Side		8
5	Below and Behind Instrument Panel-Pilot's Side	1301		Pilot's Side	9
6	Below and Behind Instrument Panel-Copilot's Side	1301	Multi-Port Center		10
7	Below and Behind Instrument Panel-Pilot's Side	1301	Single Port Pilot's Side		11
8	Under Instrument Panel-Copilot's Side	1211	Multi-Port Pilot's Side		12

While fire extinguishers charged with Halon 1211, when discharged up under the instrument panel, produced only one high level of gas measurement, Halon 1211 extinguisher discharged through a Fireport (multi-port) located at the center of the instrument panel produced high Halon gas measurements at all three sample locations, as shown by test 2 (figure 6).

The two types of Fireports tested were the multi-port and the single port. The multi-port consisted of five ports. The distribution was a cylinder barrel with four radial distribution ports and the fifth port was in the end plate and directed agent toward the firewall. The single port contained only one port in the cylinder barrel. This was a directional type Fireport. Testing location for the single port was on the pilot's side 6 inches from the edge of the instrument panel.

In test 4 (figure 8), Halon 1211 was discharged through a Fireport multi-port located on the pilot's side 6 inches from the edge of the instrument panel. This resulted in only one Halon gas measurement of significantly high concentration, also on the pilot's side. In test 2, Halon 1211 (figure 6) was discharged through a Fireport multi-port located at the center of the instrument panel. This test produced high Halon gas concentrations across the instrument panel at the three measurement locations.

In test 7 (figure 11), Halon 1301 was dischared through a Fireport single port on the pilot's side (6 inches from the edge) and the measurement levels were high across the instrument panel. In test 6 (figure 10), Halon 1301 was discharged through a Fireport multi-port at the center of the instrument panel, and provided even higher Halon measurement levels across the instrument panel.

In the final analysis, Halon 1301 gases are distributed well in almost any condition whereas Halon 1211 gases perform well in only the Fireport (multi-port) at center location. Further, the replacement of the Horn on the Halon 1301 extinguisher with the Teflon adapter, for use with the Fireports, reduces the effectiveness of the 1301 extinguisher with this modification during direct agent discharge. However, hand held 1301 extinguishers cannot be utilized with the Fireports without eliminating the discharge Horn. This would invalidate the bottle approval status.

During fire extinguishment using Halon 1211, a portion of the agent decomposes to produce the acids gases HCl, HF, and HBr. Samples of gases were acquired during some of the fire tests and analyzed. Typical sample results are plotted on figure 13.

Table 2 tabulates the maximum levels of decomposed Halon 1211 products as measured at the pilot's nose. The acid gases are low. Table 2 also lists the dangerous levels of these gases (reference 3). The maximum levels were significantly less than the dangerous levels.

The Halon 1211 molecule includes one bromine and one chlorine atom. As may be noted, hydrogen chloride concentration should be approximately identical to the concentration of hydrogen bromide. However, the levels are 780 ppm and 9 ppm, respectively. The high hydrogen chloride levels are attributed to combustion of electrical wire insulation. Toxic Halon decomposition gas concentrations resulting from fire extinguishment were minimal and significantly below levels considered dangerous.

TABLE 2. MAXIMUM LEVELS OF HALON 1211 DECOMPOSITION GASES

Gases	Maximum Concentration (PPM)	Dangerous Concentration (Reference 3) (PPM)
HCl	780*	1000 - 2000
HF	6	50 - 250
HBr	9	50 - 250

* HCl produced from Halon decomposition is masked by high concentrations produced from the wiring insulation. It is probably similar to HBr levels.

SUMMARY

A series of fire tests were conducted in the cabin of a Piper Twin Comanche fuselage. The tests involved extinguishment of electrical wire insulation and hydraulic fluid fires, located under and behind the instrument panel, using 2.5-pound Halon 1211 and 3-pound Halon 1301 hand held extinguishers. The extinguishers were either discharged directly up under the instrument panel or through Fireports installed through the instrument panel. As long as the discharge was reasonably near the fire, the Halons extinguished the fires rapidly, irrespective of the method of application.

The fires produced dense black smoke in the cabin due to the intentional 1-minute burn period before discharge of the fire extinguishers. Visibility of the pilot would be seriously impaired, in this short interval, and this demonstrates the need for extinguisher application as early as possible.

A special fire test was designed to evaluate the effect of agent discharge at some distance from the fire. The fire was initiated under the instrument panel, copilot's side, and the extinguisher, Halon 1211, was discharged through a Fireport on the pilot's side (6 inches from side). Although there was suppression accompained by a momentary drop in temperature, the fire reignited, intensified and became of control. This experiment indicates the importance of discharging the extinguishing agent as close to t[illegible] fire source as possible.

The decomposition products resulting from application of Halon 1211 on the fires were sampled and measured. Hydrogen flouride and hydrogen bromide concentrations were either zero or less than 10 ppm. Hydrogen chloride concentrations were significantly higher and this is attributed to the decomposition of electrical wire insulation. The levels of acid gases directly attributable to Halon decomposition were less than levels considered dangerous.

CONCLUSIONS

1. Hand extinguishers of Halon 1211 and 1301 were effective in the extinguishment of electrical/hydraulic fires behind the instrument panel of a small aircraft cabin.

2. The method of application of the extinguishers, through Fireports or directed up under the instrument panel, were both effective in extinguishing the fires.

3. The fires produced large quantities of dense black smoke in the cabin, in less than 1 minute, emphasizing the need for rapid extinguishment.

4. Hand extinguishers of Halon 1301 provide effective agent distribution over a larger volume behind the instrument panel compared to Halon 1211.

5. Hand extinguishers with Halon 1211 provided most effective distribution under the instrument panel when discharged through a Fireport multi-port at the center location compared to a location on the pilot's side of the instrument panel.

6. Hand-held Halon 1301 extinguishers cannot be used with the Fireport design without removing the discharge horn and thereby invalidating the approval status of the hand extinguisher.

7. Toxic Halon decomposition products resulting from fire extinguishment were low and below levels considered dangerous.

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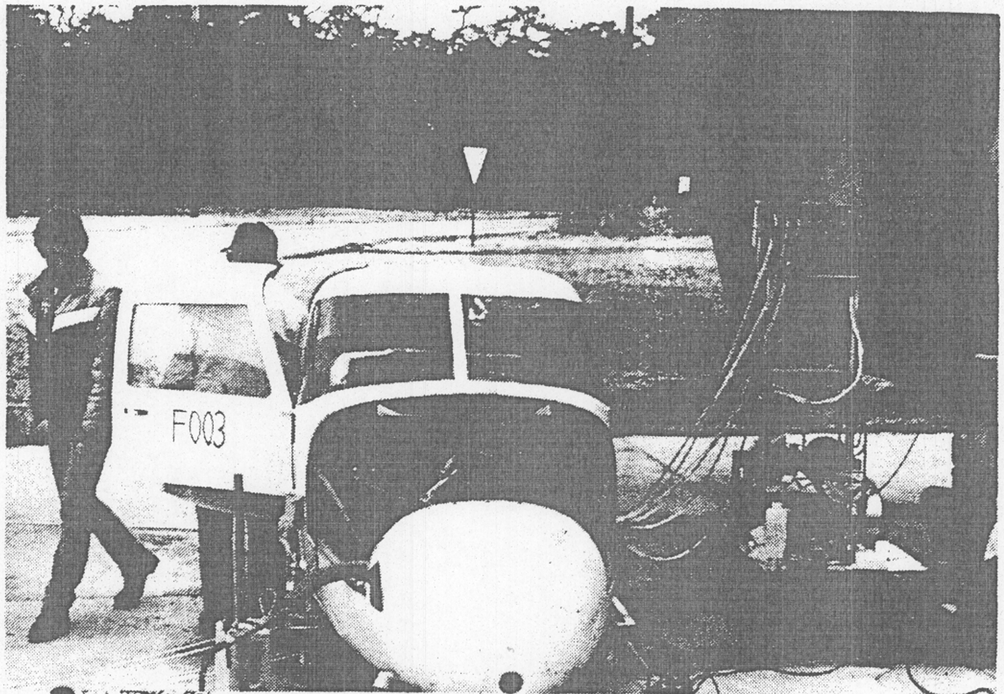

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FIGURE 1. PIPER MODEL PA-30 TWIN COMANCHE FUSELAGE

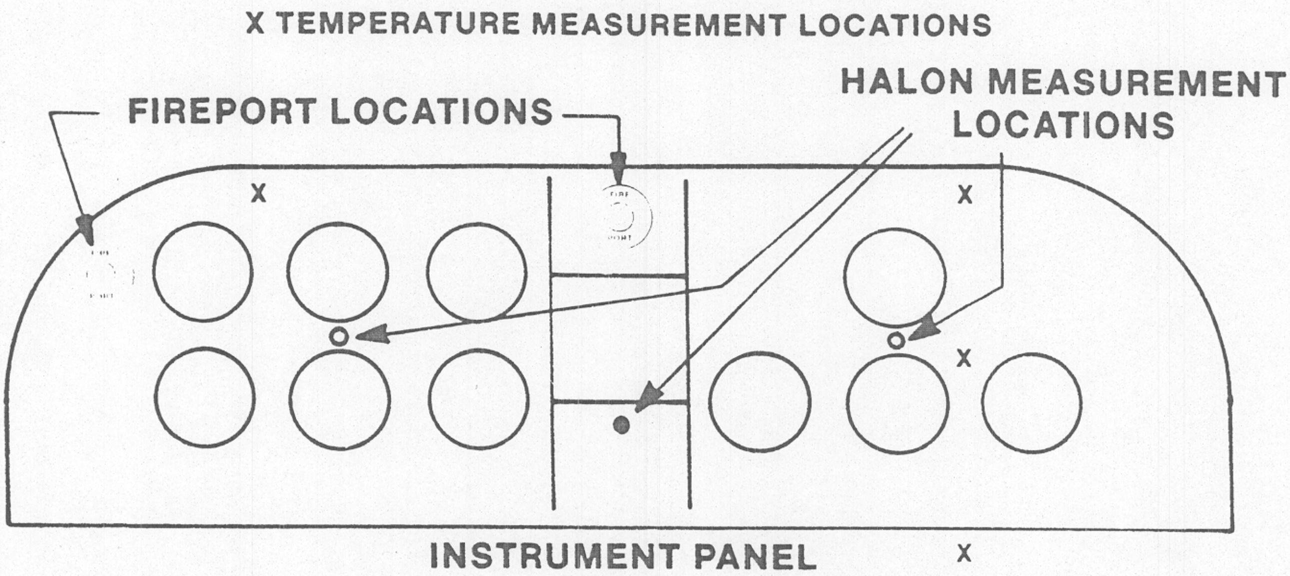

FIGURE 2. INSTRUMENT PANEL HALON AND TEMPERATURE MEASUREMENT, AND FIREPORT LOCATIONS

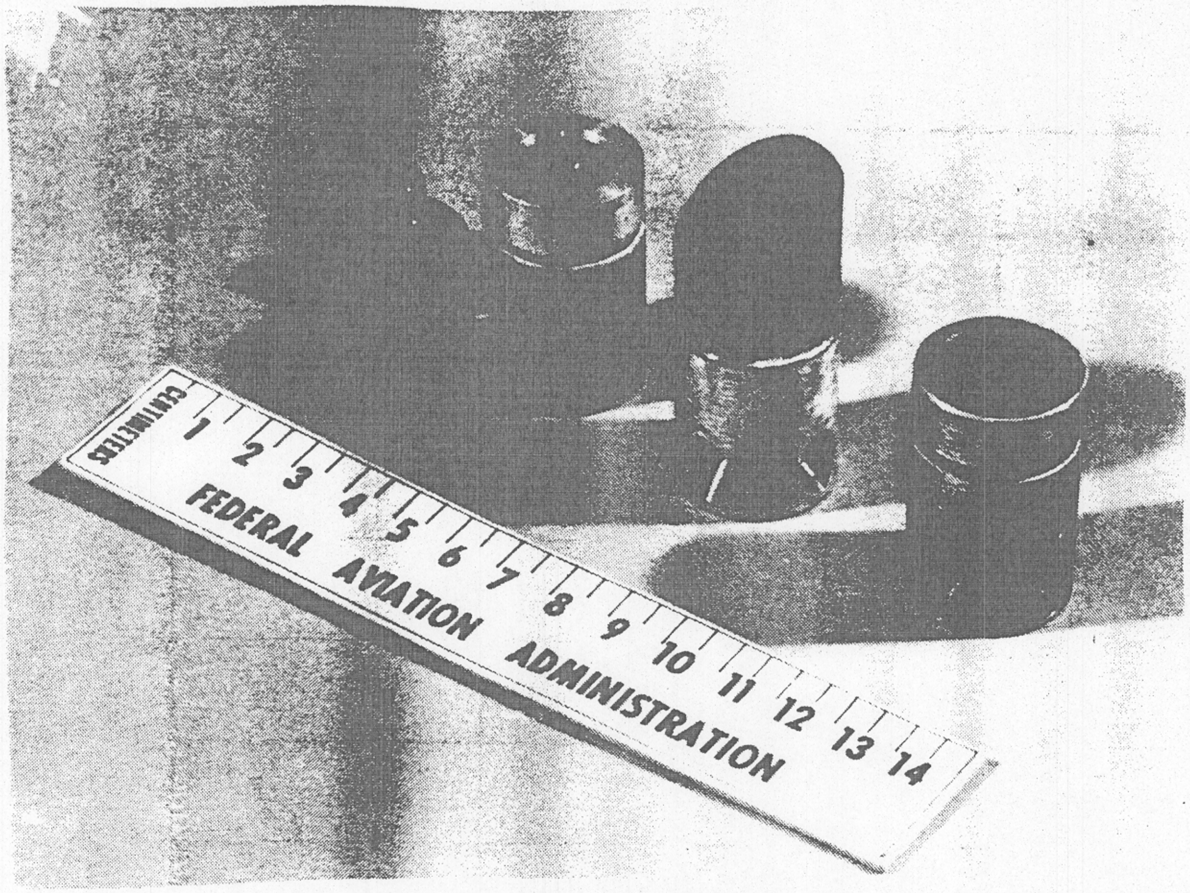

FIGURE 3. FIREPORTS - FRONT VIEW

FIGURE 4. FIREPORTS - REAR VIEW

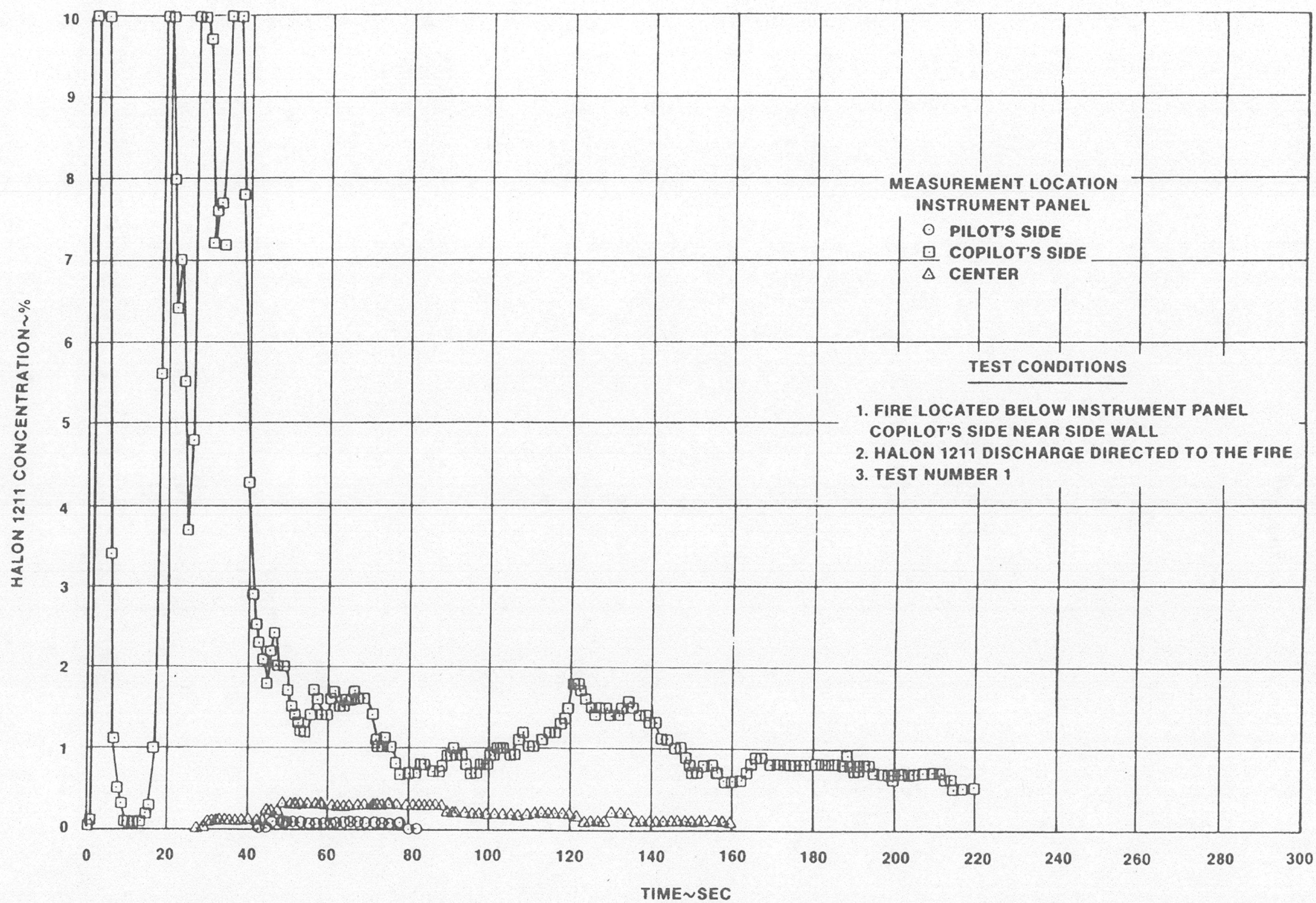

FIGURE 5. HALON 1211 CONCENTRATIONS - FIRE BELOW INSTRUMENT PANEL - COPILOT'S FOOTWELL (TEST 1)

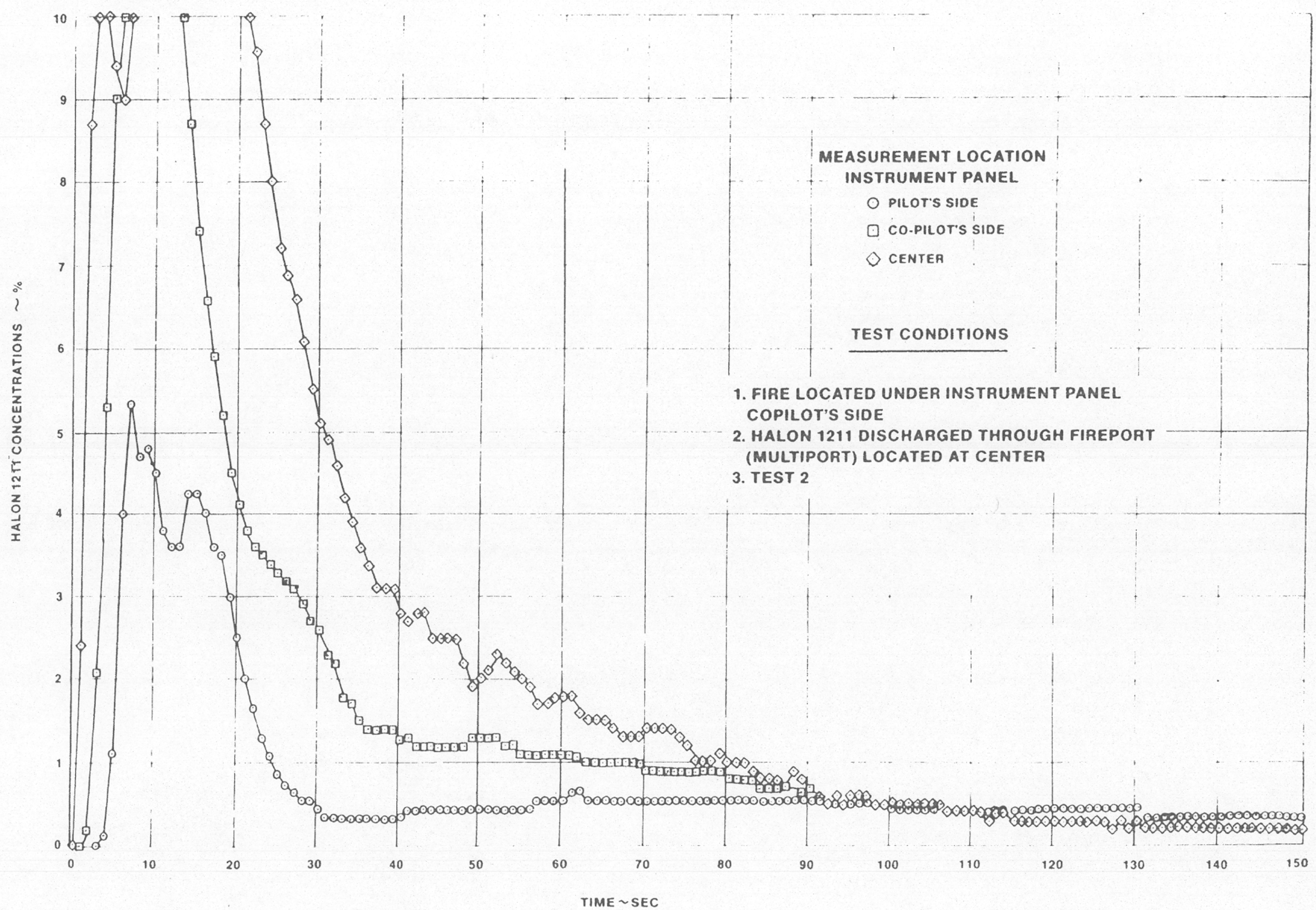

FIGURE 6. HALON 1211 CONCENTRATIONS - FIRE UNDER INSTRUMENT PANEL - COPILOT'S SIDE (TEST 2)

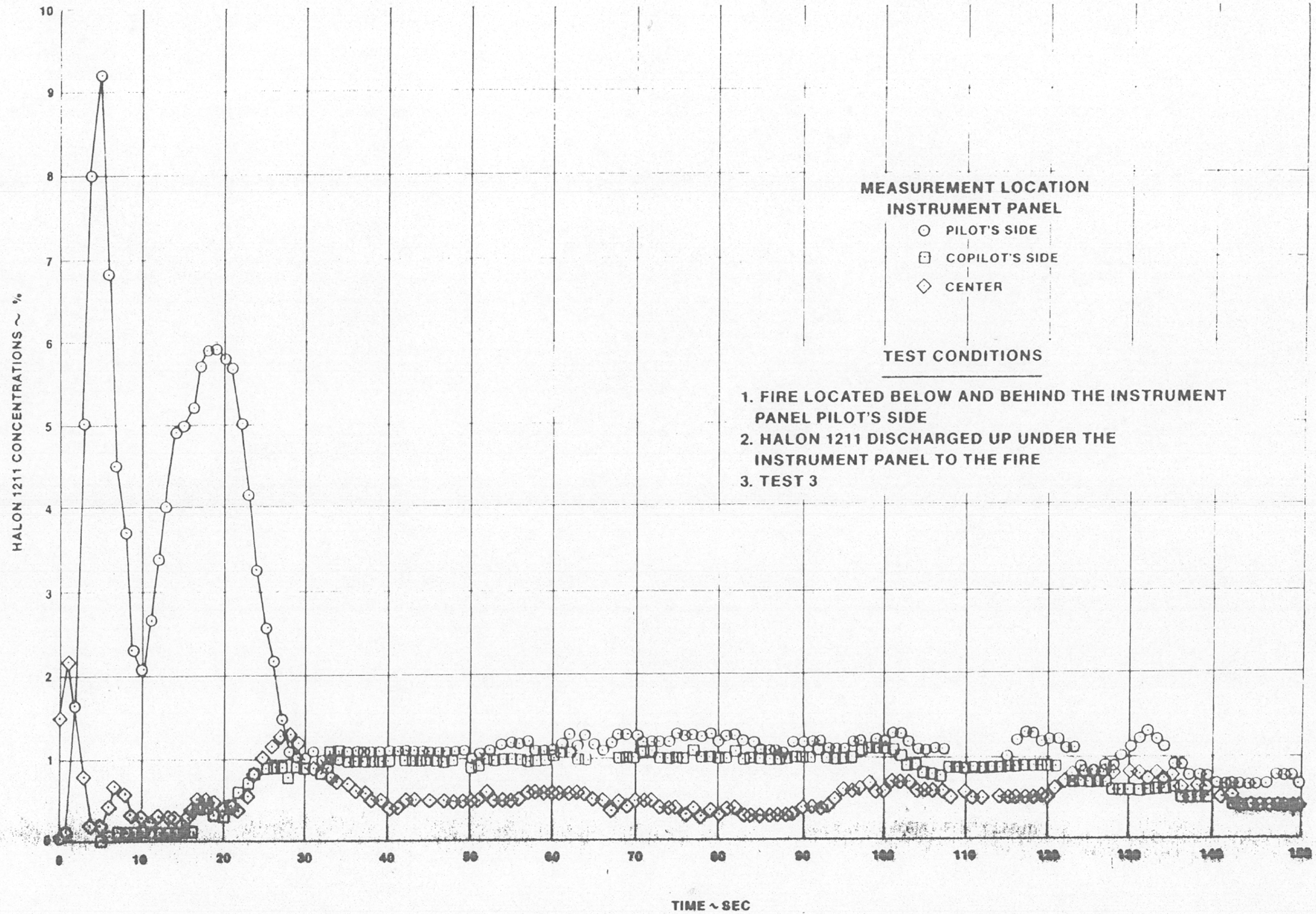

FIGURE 7. HALON 1211 CONCENTRATIONS - FIRE BELOW AND BEHIND INSTRUMENT PANEL - PILOT'S SIDE (TEST 3)

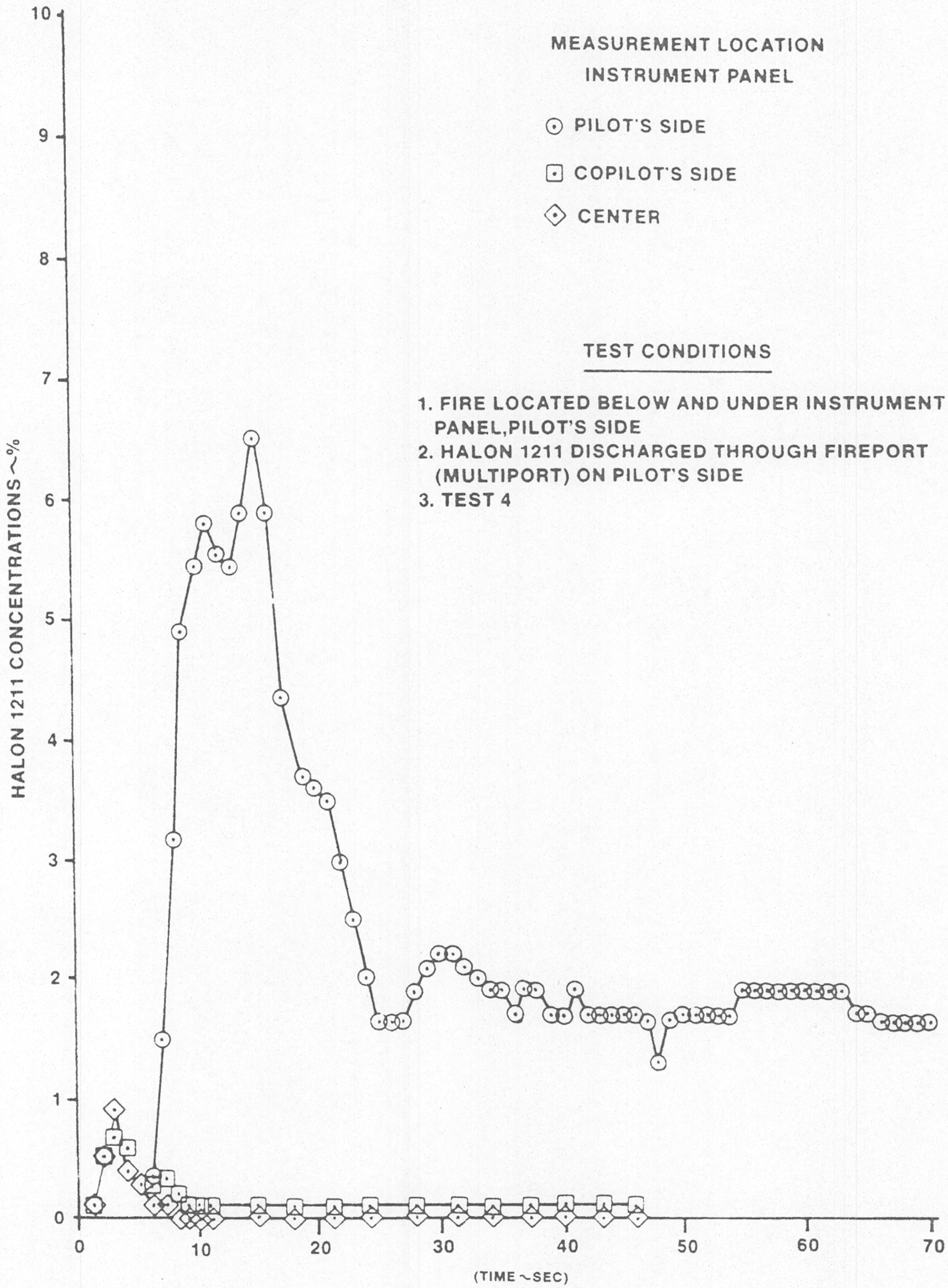

FIGURE 8. HALON 1211 CONCENTRATIONS - FIRE BELOW AND BEHIND INSTRUMENT PANEL - PILOT'S SIDE (TEST 4)

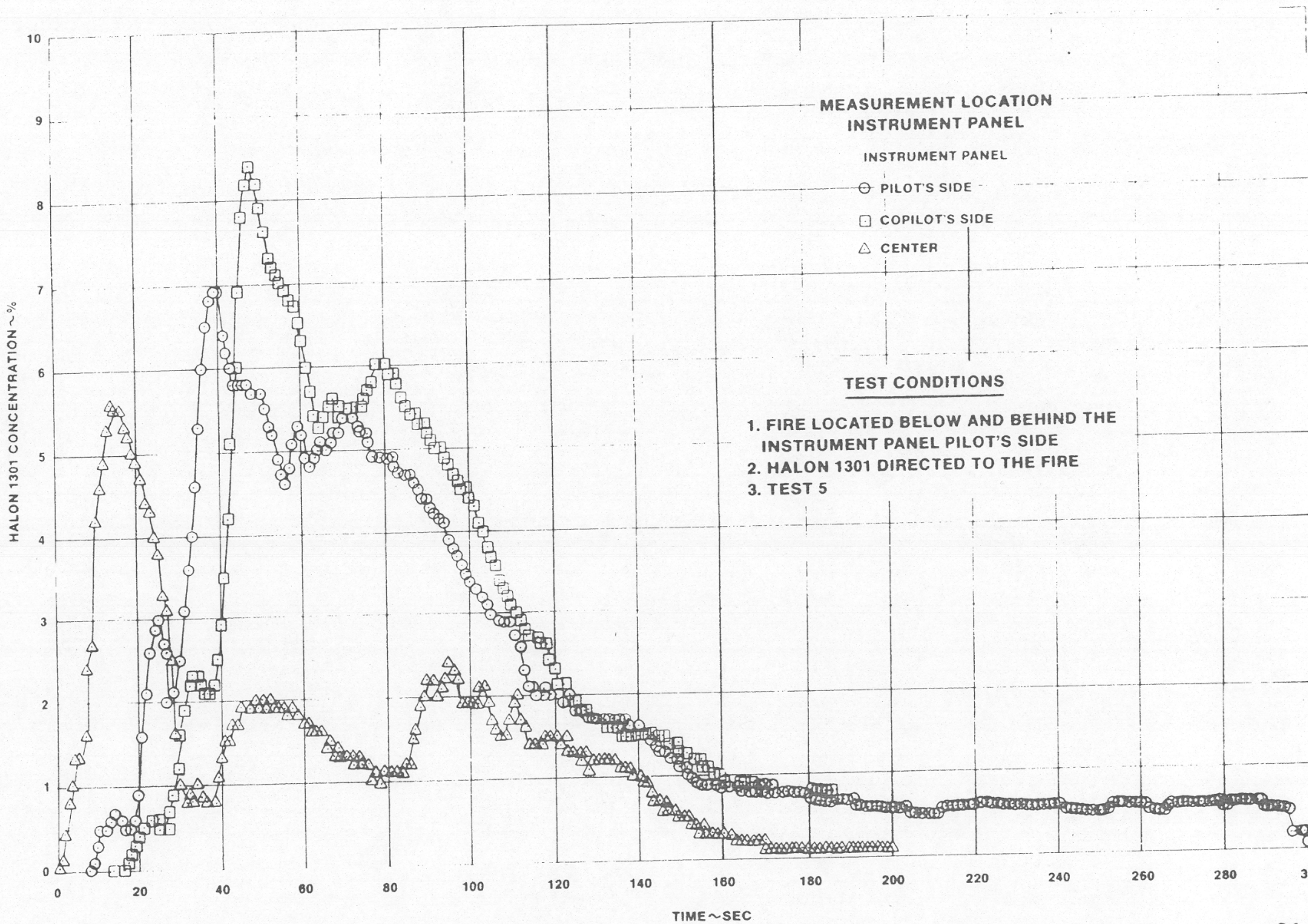

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FIGURE 9. HALON 1301 CONCENTRATIONS - FIRE BELOW AND UNDER INSTRUMENT PANEL - PILOT'S SIDE (TEST 5)

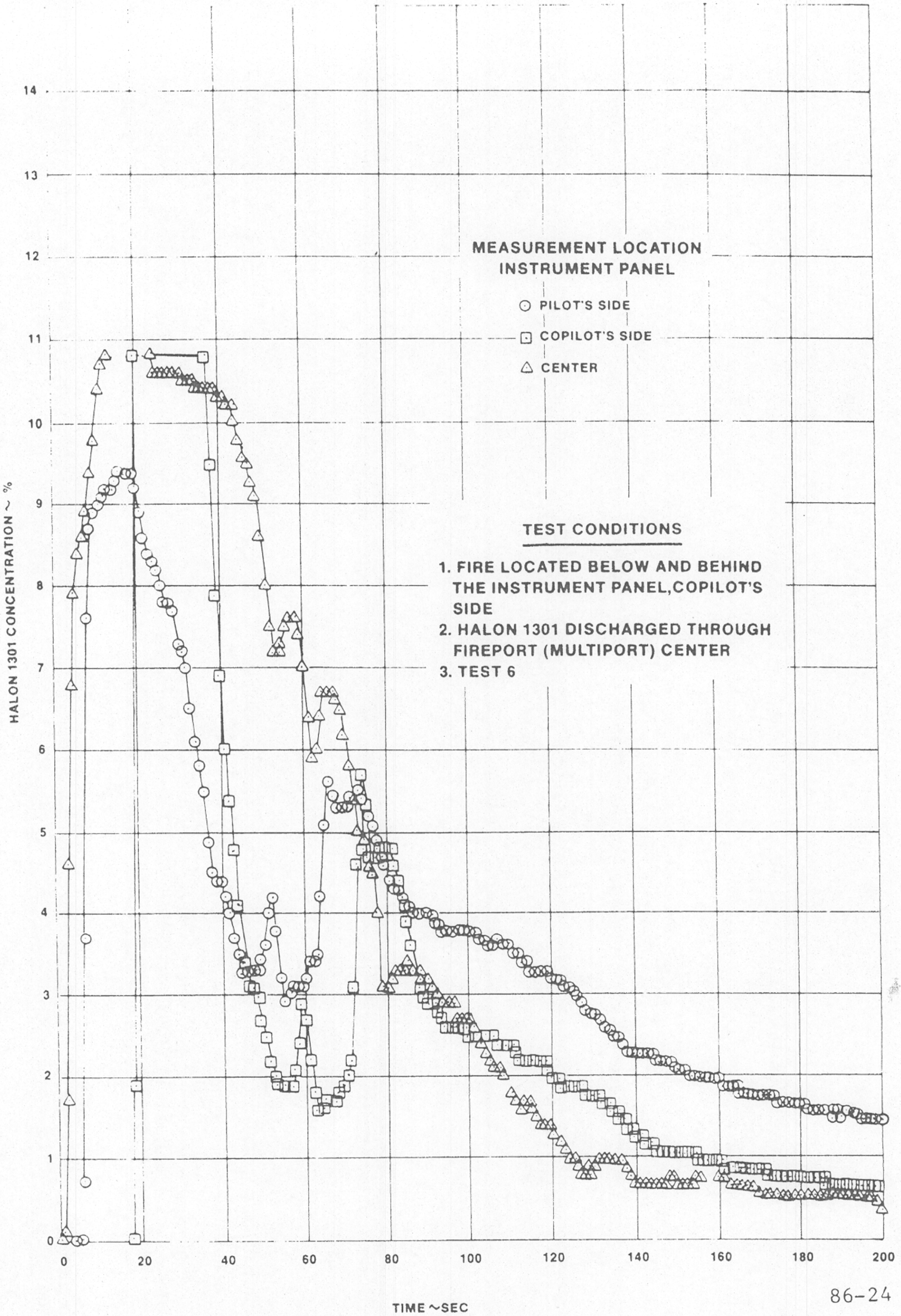

FIGURE 10. HALON 1301 CONCENTRATIONS - FIRE BELOW INSTRUMENT PANEL - COPILOT'S SIDE (TEST 6)

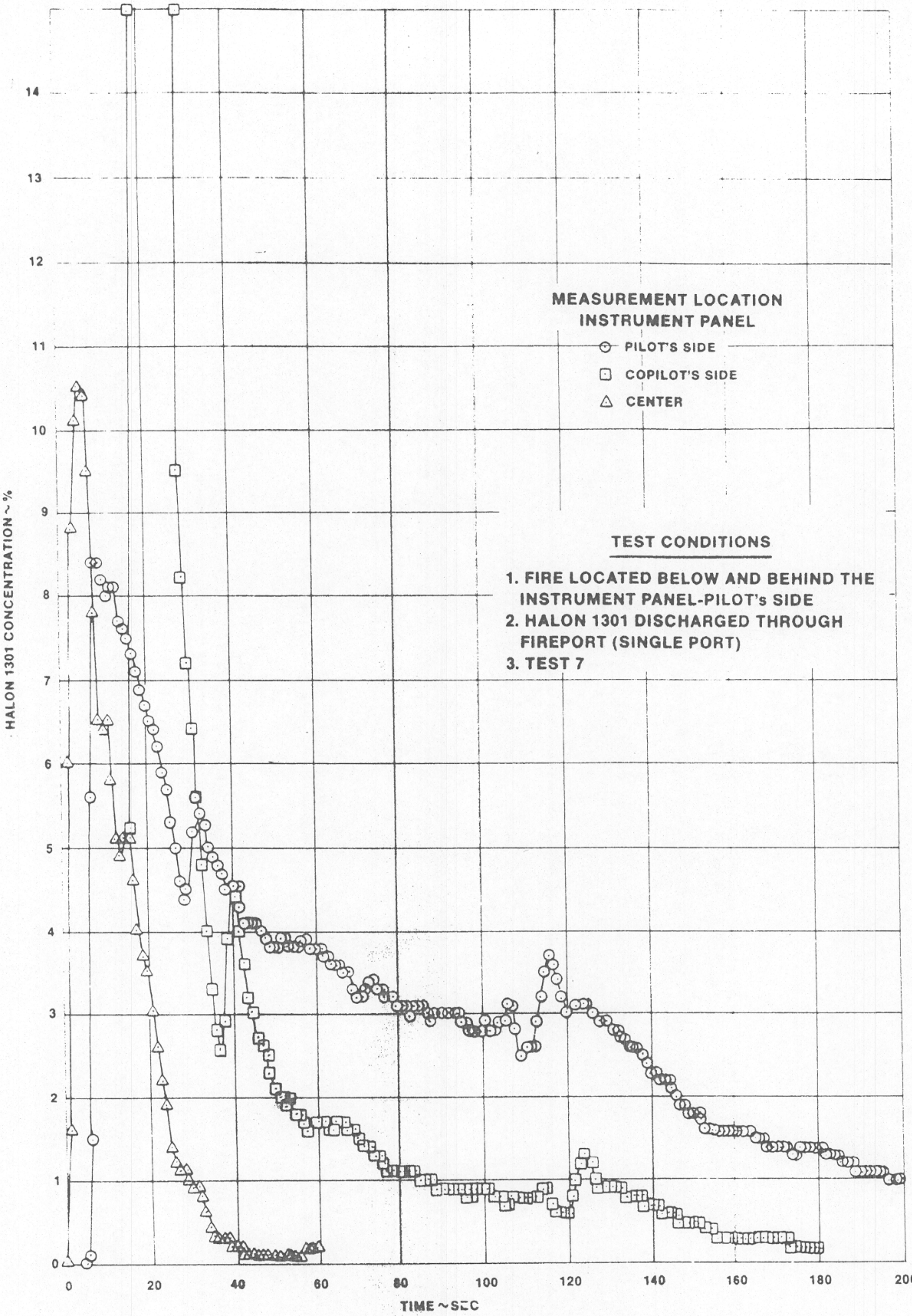

FIGURE 11. HALON 1301 CONCENTRATIONS - FIRE BELOW INSTRUMENT PANEL - PILOT'S SIDE (TEST 7)

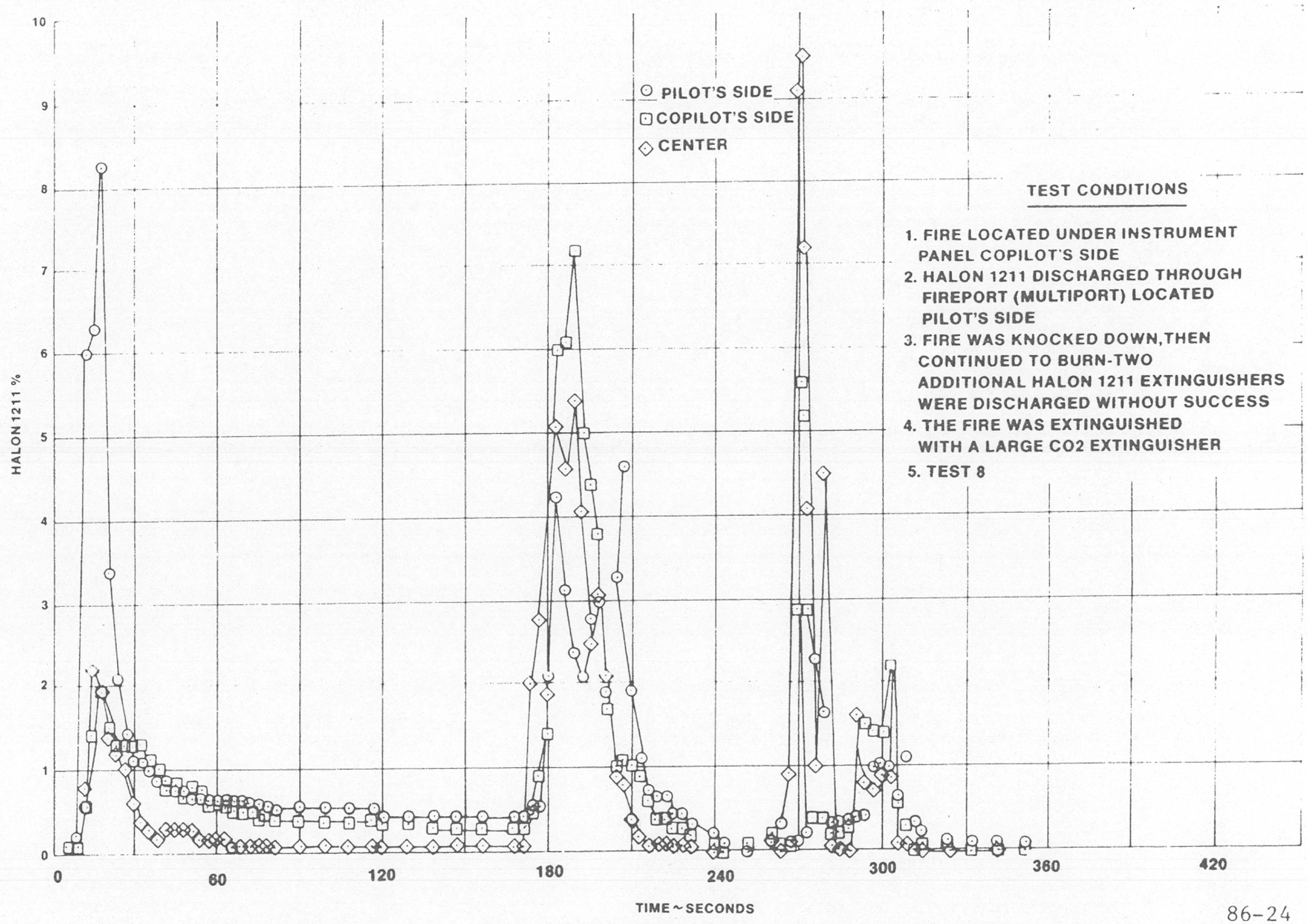

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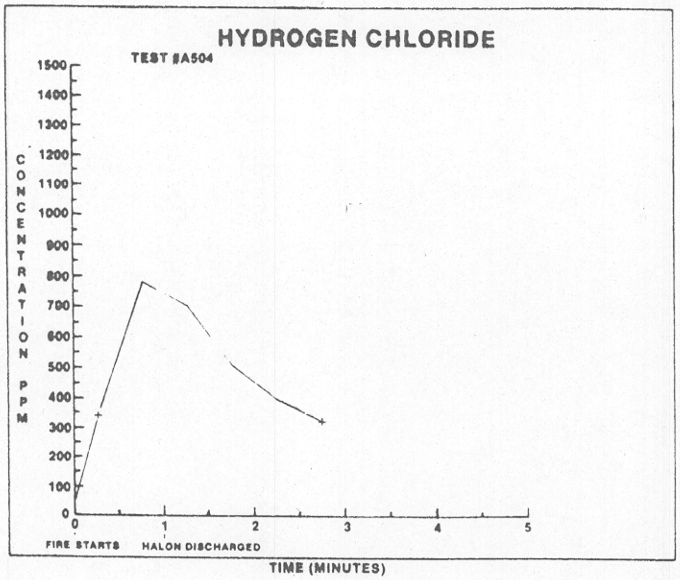
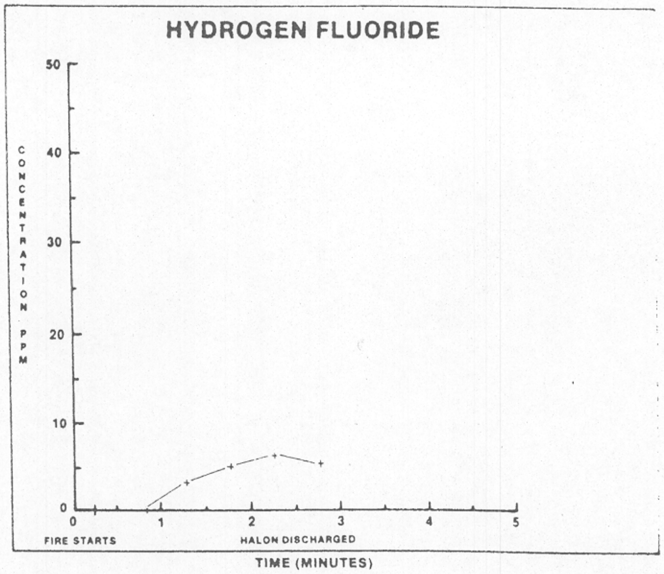
FIGURE 12. HALON 1211 CONCENTRATIONS - FIRE ON COPILOT'S SIDE - EXTINGUISHER DISCHARGE THROUGH FIREPORT PILOT'S SIDE (TEST 8)

TEST 1



TEST 1



TEST 1

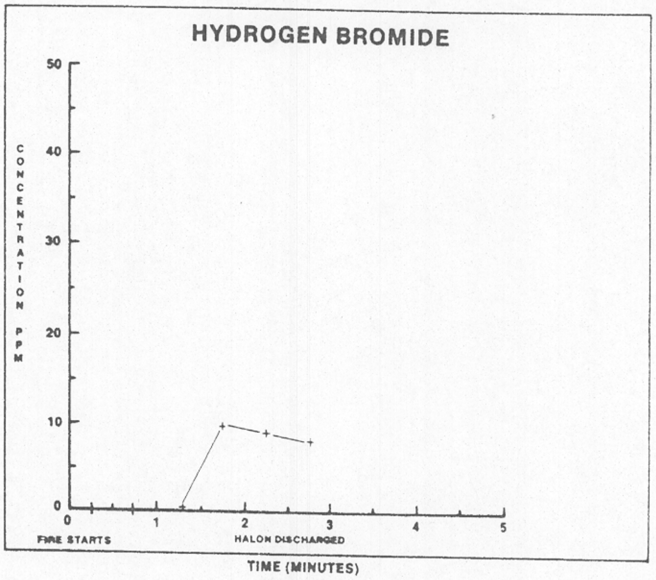


FIGURE 13. HALON DECOMPOSITION ACID GASES (TEST 1)

APPENDIX A

DISTRIBUTION LIST

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Aviation House
129 Kingsway
London WC2B 6NN England

Embassy of Australia (1)
Civil Air Attache
1601 Mass. Ave. NW
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Al Astorga (1)
Federal Aviation
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American Embassy, Box 38
APO-New York 09285-0001

Dick Tobiason (1)
ATA of America
1709 New York Avenue, NW
Washington, DC 20006

Burton Chesterfield, DMA-603 (1)
DOT Transportation Safety Inst.
6500 South McArthur Blvd.
Oklahoma City, OK 73125

FAA Anchorage ACO
701 C Street, Box 14
Anchorage, Alaska 99513

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1075 Inner Loop Road
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Burlington, Mass. 01803

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Wichita, KA 67209

Mr. Fred Jenkins, ANM-130L
Federal Aviation Administration
4344 Donald Douglas Drive
Long Beach, California 90808

Mr. Dan Gross
B-66 Technology Building
National Bureau of Standards
Washington, DC 20234

Dr. James M. Peterson
The Boeing Company
MS/73-43
Seattle, Washington 98124

Dr. John O. Punderson
E.I. Dupont De Nemours
P.O. Box 1217
Parkersburg, West VA 26102

Commander
U.S. Army AVSCOM
Attn: DRSAV-EI (Mr. John P. Dow)
4300 Goodfellow Blvd.
St. Louis, MO 63120

Mr. L. C. Virr
Civil Aviation Authority
Barbazon House
Redhill
Surrey RH1 1SQ
England

Mr. Ray Young
Engineering and Air Safety Dep't
Airline Pilots Association
1625 Massachusetts Ave., NW
Washington, DC 20036

Dr. Calyton E. Hathaway
Monsanto Company
800 N. Lindberg BLvd. Mail Zone R3B
St. Louis, MO 63166

Dr. Leo P. Parts
Monsanto Research Corp.
1515 Nicholas Road
Datyton, Ohio 45407

Mr. Matthew M. McCormick
National Transportation Safety Board
Bureau of Technoloty
Washington, DC 20594

Mr. A. Delman
The Wool Bureau, Inc.
Technical Services Center
225 Crossways Park Drive
Woodbury, L.I., New York 11797

Dr. L. Benisek
International Wool Secretariat
Technical Center, Valley Drive
Ilkley, West Yorkshire, LS29 8PB
England

Mr. John A. Leland
Username:
Dept E-29
Douglas Aircraft Co. 35-14
3855 Lakewood Blvd.
Long Beach CA 90846

Mr. Stan Ames
Fire Research Station
Borehamwood
Hertfordshire WDG 2BL
England

Mr. Arthur G. Thorning
Civil Aviation Authority
CAA House
45-59 Kingsway
London WC2B GTE
England

Mr. Lee Hoyt
Weber Aircraft Co.
2820 Ontario Street
Burbank, CA 91505

Julia M. Baer
Celanese Fibers Marketing Comp.
P.O. Box 32414
Charlotte, NC 28232

Mr. James O. Price
Heath Tecna Corp.
19819 84th Avenue South
Kent, Washington 98031

Mr. Richard M. Harrison
Custom Products Company
P.O. Box 699
Sun Valley, California 91352

Mt. T. E. Waterman
IIT Research Institute
10 West 35th Street
Chicago, Illionis 60616

Mr. Henri Branting
FAA Headquarters
AWS-120
800 Indepednce Avenue SW
Washington, DC 20591

Dr. James E. Mielke
Science Policy Research Div.
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Mr. Thomas Madgwick
British Areospace p.l.c.
Aircraft Group
Weybridge-Bristol Division
Filton House
Bristol BS99 7AR Englang

Mr. Joseph L. Buckley
Factory Mutual System
1151 Boston-Providence Turnpike
Norwood, Mass. 02062

Mr. John Hoffmann
Port of New York & New Jersey
Authority
One Path Plaza (4th Floor)
Jersey City, NJ 07306

Mr. Robert E. Kraus
Raychem Corp.
300 Constitution Drive
Menlo Park, California 94025

Mr. John A. Blair
Manager, Standards
E.I. Dupont deNemours & Co. ;PP+R
Chestnut Run
Wilmington, Delaware 19898

Mr. Bill Martinez, Mgr. Data Service
AMI Industries, Inc.
P.O. Box 370
Colorado Springs, California 80901

Mr. J. J. Brenneman
Fire Protection Engineer
United Airlines, Inc.
P.O. Box 66100
Chicato, Illionis 60666

Mr. Edward L. Lopez
Lockheed Aircraft Corp.
Dept. 74-75, Bldg. 229-A
Box 551
Burbank, CA 91503

Dr. D. Kourtides
Chemical Research Center
NASA/AMES Research Center
Moffett Field, CA 94035

Mr. C. Hayden Leroy
TE-10 Bldg. 10-A
National Transportation Safety Board
Washington, DC 20594

Mr. Richard Nelson
ANM-110
17900 Pacific Highway South
C-G8966
Seattle, WA 98168

Dr. Charles R. Crane
FAA, CAMI, AAC-114
P.O. Box 25082
Oklahoma, OK 73125

Mr. Reginald Utting
The Boeing Company
Commercial Airplane Group, 747 Div.
P.O. Box 3707
Seattle, Washington 98124

Dr. Joseph C. Reed
E.I. Dupont de Nemours & Co.
Plastics Department
Fluorocarbons Division
Wilmington, Delaware 19898

Dr. Fumiharu Saito
Building Research Institute
Ministry of Construction
Tatehara-1 Oho-Machi
Tsukuba-Gun
Ibaraki Prefecture, Japan

Dr. Robert Keith
Laboratory Industrial Medicine
Eastman Chemical Company
Kingsport, Tenn. 37662

Mr. Kenton D. Warner
Puritan-Bennet Aero Systems Co.
10800 Pflumm Road
Lenexa, Kansas 66215

Mr. Geroge Veryioglou
Systems Technology Staff
Boeing Commercial Airplane Co.
P.O. Box 3707, MS 77-70
Seattle, WA 98124

Mr. Donald Schroeder
Federal Aviation Administration
APM-710
800 Independence Ave. SW
Washington, DC 20591

Mr. Calvin J. Cruz
Textile Fibers Dept.
E.I. Dupont deNemours & Co., Inc.
Wilmington, Delaware 19898

Dr. C. Perry Bankston
Energy and Materials Research Sec.
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Mr. Joseph A. Krist
Athol Manufacturing Corporation
1350 Broadway
New York, New York 10018

Mr. W. G. Dye
Director of Engineering
Fairchild Burns Company
1455 Fairchild Drive
Winston Salem, NC 27023

Mr. Peter Meiklem
Civil Air Attach's (Safety)
British Embassy
3100 Massachusetts Ave. NW
Washington, DC 20008

Dr. H. R. Dvorak
Wesson and Associates, Inc.
510 South Webster
Postal Box 1082
Norman, OK 73070

Mr. Erich Feldkirchner
Airbus Insustrie
Headquarters, BP No. 33
31700 Blagnac, France

Ms. Diane Boulavsky
American Textile Mfgrs. Institute
1101 Connecticut Ave. NW
Suite 350
Washington, DC 20036

Mr. Gregory Smith
B.F. Goodrich Technical Center
P.O. Box 122
Avon Lake, Ohio 44012

Mr. George M. Johnson
Cheif Chemist
Pan American Airways, Inc.
Bldg. 208 Room 2228
J F Kennedy Int'l Airport
Jamaica, New York 11430

Dr. Lloyd H. Back
Energy and Materials Research Sec.
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Dr. A. Carlos Fernandez-Pello
Mechanical Engineering Department
University of California, Berkely
Berkely, California 9420

Mr. S. F. Taylor
College of Aeronautics
Cranfield Institute of Technology
Cranfield, Bedford MK30AL England

Mr. William R. Kane
System Engineering Group
ASD/ENFEF
Wright-Patterson AFB, Ohio 45433

Mr. A. J. Christopher
Royal Aircraft Establishment
Materials Department
South Farnborough
Hants, England

Manager
Flight Attendant Training & Standard
Western Airlines
6060 Avion Drive
Los Angeles, California 90009

Mr. Everett A. Tustin
Boeing Commerical Airplane Company
P.O. Box 3707, M/S GF-26
Seattle, Washington 98124

Mr. R. G. Clodfelter
AFWAL/POSH
Wright-Patterson AFB
Ohio 45433

Dr. Edwin Smith
Ohio State University
140 W. 19th Avenue
Columbus, Ohio 43214

Mr. Walter Perkowski
The Boeing Company
Commercial Airplane Group
P.O. Box 3707, MS/73-43
Seattle, Washinton 98124

Mr. William Snoddy
American Airlines
P.O. Box 51009 Mail Stop #10
Tulsa, Oklahoma 74151

Mrs. Charlotte Gebhart
Rohm & Haas Company
Independence Mall West
Philadelphia, PA 19105

Wm. Kirkham, Phd., Md, AAC-144
DOT/FAA/ CAMI
Aeronautical Center
P.O. Box 25082
Oklahoma City, Oklahoma 73125

Mr. Henry J. Roux
Product Fire Performance
Armstrong World Industries, Inc.
Lancaster, PA 17604

Mr. John Ed Ryan
National Forest Products Assoc.
50 North Franklin Turnpike
P.O. Box 314
Hohokus, New Jersey 07423

C. M. Sliepcevich
Flame Dynamics Laboratory
University of Oklahoma
1215 Westheimer Street
Norman, Oaklahoma 73069

Mr. Louis Frisco
Wire & Cable Division
Raychem Corp.
300 Constitution Drive
Menlo Park, California 94205

Dr. John A. Parker
Chemical Research Projects Office
NASA/AMES Research Center M.S. 223-6
Moffett Field, California, 94035

Bernard Grendahl, Mgr. Tech. Service
Aerospace Division
Universal Oil Products Company
Bantam, Conn. 06750

A. Tewarson
FMRC
1151 Boston-Providence T'Pke
Norwood, Mass. 02062

Dr. Rosalind C. Anderson
Arthur D. Little, Inc.
Acorn Park
Cambridge, Mass. 02140

Mr. Matthew Finucane
Aviation Consumer Action Project
P.O. Box 19029
Washington, DC 20036

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Crest Foam
100 Carol Place
Moonachie, NJ 07074

Mr. Philip J. DiNenno
Professional Loss Control, Inc.
P.O. Box 446
Oak Ridge, TN 37830

Mr. James A. Milke
Department of Fire Protection Engineering
University of Maryland
College Park, MD 20742

Mr. John P. Reese
Aerospace Industries Association of America, Inc.
1725 Desales Street, N.W.
Washington, DC 20036

Mr. Jim Brown
General Dynamics Electric Boat Div.
Station CG2
Eastern Point Road
Groton, Conn. 06340

Mr. John R. Powers
Delta Airlines, Inc.
Hartsfield Atlanta
International Airport
Atlanta, Georgia 30320

Mr. S. M. Hooper
Eastern Airlines
Miami International Airport
Miami, Florida 33148

Dr. Charles P. Lazzara
US Bureau of Mines
Pgh. Research Center
P.O. Box 18070
Pittsburgh, PA 15236

Dr. James G. Quintiere
National Bureau of Standards
Bldg. 224, Room B-356
Washington, DC 20234

Mr. Stan Martin & Assoc.
860 Vista Drive
Redwood City, California 94062

Mr. A. L. Bridgman
General Electric Company
Plastics Technology Department
1 Plastics Avenue
Pittsfield, MA 01201

Mr. Walter T. Clark Jr.
Clark Engineering Service
312 E. Main Street
Lancaster, Texas 75146

Commanding General
U.S. Army Test & Evaluation Command
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Aberdeen Proving Ground, MD 21005

Mr. Charles Macaluss
U.S. Testing
5555 Telegraph Road
Los Angeles, CA 90040

Mr. Steve Waldrip
Republic Airlines
7500 Airline Drive
Minneapolis, Minnesota 55450

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Lockheed-California Company
D/98-01, B/90-4, A-1
P.O. Box 551
Burbank, California 91520

Kirke Comstock
Manager of Interior Engineering
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