ATTACHMENT A

File 510-001-10X

ALPA CLEVELAND FIRE TEST RESULTS

by

Captain Don Heine, NOR, Member
ALPA Rescue & Fire Committee

&

Mr. Jim Brenneman
Fire Protection Engineer, UAL

Members of ALPA
Crashworthiness Panel

Presented at the Thirteenth
ALPA Air Safety Forum
October 4-5, 1966

The August, 1966 issue of THE AIR LINE PILOT featured an article describing the recent Cleveland Fire Tests, conducted by ALPA and the aviation industry to try to find out, among other things, what happens inside an airliner's cabin when fire breaks out. The AIR LINE PILOT article reported on the tests' procedures; this paper reports on the results that were obtained.

The Cleveland Fire Tests were unique in many ways. There were many valuable lessons learned which would have been lost, had it not been for the utmost cooperation of many agencies, including Union, Management, Industry, and Government, both Local and Federal. The ALPA Rescue and Fire Committee initiated this project, but only through the cooperative efforts of many was it brought to a successful conclusion.

The organizations participating actively in the tests were the Air Line Pilots Association, United Air Lines, National Aeronautics and Space Administration, Cleveland Hopkins Airport Fire Department, Bliss-Rockwood Corporation, The Ansul Company, Duracote Corporation, E. W. Bliss Company, Crowbaugh Laboratories and Walter Motor Truck Company.

Origination

The two test aircraft were retired by NASA and given to the Cleveland Airport Fire Department for training purposes, and subsequently provided to us for the tests. Requests were then made to the organizations we have listed for their aid in providing material and technical assistance in various aspects of the tests. A meeting was held with the FAA in Washington, D. C., at which time they expressed interest in the results of such a project. A later meeting was held in Cleveland, when representatives from all the participating organizations discussed the objectives and outlined test procedures. These meetings resulted in the scheduling of the Cleveland Fire Tests on June 30 and July 1.

Objective

The Cleveland tests were conducted to determine if survival time in an aircraft cabin could be extended under post-crash fire conditions by using high expansion foam to completely fill the occupied portions of the cabin interior. It was hoped that the high expansion foam would hold the temperature within survivable limits while controlling smoke, toxic gases , and other products of combustion. Thus, we would provide cool, breatheable atmosphere for a prolonged period of time for the occupants, pending ultimate evacuation or rescue.

As a secondary objective, we hoped to determine the exact nature of the smoke, gases, etc., that may be present in a post-crash fire in which typical modern aircraft cabin materials such as vinyl, polypropylene, polyvinyl chloride, etc., and plastics are installed and are involved in the fire.

To these ends, the tests were only to prove the concept, since the foam equipment used was "off the shelf" hardware, and not suitable for use as an installed system. It would also not be suitable for use in its present form by ground fire fighting personnel, since it is too slow and cumbersome to put into operation.

Procedure

Aircraft: Two North American AJ-2P patrol bombers. The airplanes were in an all-gear-up landing configuration with the wings level.

Cabin Mock Up: The center section (bomb bay) of each aircraft was fitted out as closely as possible to represent the insulation and interior of a typical commercial aircraft passenger cabin. The cabin mock-up section measured approximately 5' wide, 5-1/2' high, and 14-1/2' long, fiberglass insulation (approximately 3" thick) with a resin binder and an aluminum color plastic skin, was installed in the sidewalls and ceiling. Interior finish panels were vinyl-coated dynel fabric, fiberglass sheet, vinyl-coated dynel fabric bonded to sheet aluminum, and vinyl-coated fiberglass with vinyl foam padding. The forward and aft bulkheads of the cabin section were honeycomb panels. The forward had a resin-impregnated paper core; the aft was aluminum-cored. Plastic sheets were bonded to the honeycomb panel. Twelve complete seat cushions and backs were suspended from steel wires in the cabin. Half of the cushion materials were latex foam, and the remainder were urethane foam. The floor was covered with carpeting composed of a polypropylene pile with a Jute base and polyethylene back. The total weight of cabin materials and insulation was 238-3/4 lbs. per airplane.

Instrumentation: Twelve thermocouples were located in mock-up sections and cockpits. The thermocouples were located at floor level, seat back height, ceiling level, and the high point of the aircraft beneath the cockpit canopy. Eight of the thermocouples had simple metallic tubing shields and four were completely shielded, each in a blackened copper sphere. All thermocouples were connected to 3-12 channel continuous recorders to provide a constant temperature record throughout the test period. The recorders were remotely located, about 75' from the test aircraft.

Two smoke detectors were located in each aircraft cabin section; one suspended about 6" from the ceiling and the other about 20" from the ceiling. The smoke detectors consisted of a light source, lens and photo cell, all mounted in a suitable frame. A shroud was provided to eliminate stray light from reaching the photo cells. The detectors were wired to a continuous recorder to provide a constant record of smoke density from ignition of the test fire to destruction of the detector by the fire.

Smoke and gas samples were obtained from three points in each aircraft. Stainless steel tubing sample lines were used for this purpose, taking samples from the cockpit at head height, cabin center seat height, and cabin center head height. The sample lines were connected by copper tubing to banks of 500 cc copper flasks. Thirty flasks were available for each test, ten connected to each sample point. Each bank was connected to a vacuum pump to draw the gas sample through the flask as it was opened. Simultaneous samples from the three sampling points were taken at approximately 20-second intervals.

Fuel Pan: A 3' x 5' x 10" deep steel pan was located immediately adjacent to the fuselage, the long dimension of the pan parallel to the longitudinal axis of the airplane. The pan straddled the bulkhead between the cabin mock-up and the vacant after section of the fuselage. An approximately 4" deep water bottom was placed in each pan to provide a level base for the fuel. Two pans were positioned at each aircraft. Only the upwind pan, however, was fueled and ignited in each test.

Test #1 Set-up: The port pan was fueled with 20 gallons of Type A (kerosene) aviation turbine fuel.

Test Fire #1

Wind Direction was variable. Velocity was 0-3 K.

All times referred to in this text shall be construed as total elapsed time in minutes and seconds from ignition of the fuel pan. All temperatures referred to shall be those taken from the records of thermocouples located throughout the aircraft in degrees Fahrenheit.

As previously stated, four of the twelve thermocouples in each aircraft were completely shielded in copper spheres. These shielded radiometers measured only radiant heat, whereas the other eight were exposed directly to the flames, measuring ambient heat. The temperature chart (Figure 5) was made from readings taken from the shielded radiometers. Temperatures referred to in the text are from the unshielded instruments.

Although the temperature curves for both types of instruments would be similar in appearance, Figure 5 will show slower temperature reactions than those outlined in the text, because of the shielding.

The initial burn-through of the fuselage skin occurred in the area at the left rear of the mock-up section, approximately two feet above the cabin floor. The skin thickness at this point was .035 inches, and skin failure occurred at 1:03. The first indication of smoke in the cabin was at 1:30 (See Figure 4), and the first temperature rise occurred at 1:40 at the cabin ceiling. At approximately 2:45, the smoke detector located 6 inches from the ceiling indicated smoke saturation. At the same time, the detector located 14 inches lower indicated only 30 per cent indicating extreme stratification in smoke density (Figure 4). At 2:30, the ambient center cabin ceiling recorded 200°F and at this time no other stations had recorded a significant temperature rise. At 4:30, the center cabin ceiling had reached a temperature of 570°F., while at seat height indication was 150°F. At approximately 5:30, the ceiling temperature had risen to 650°F., while at seat height it was 200°F. At about 7:40, the ceiling temperature had risen to 760°F and the seat height temperature to 300°F., while the cockpit temperature was still ambient. At this point, the recorder tapes indicate a flash-over of the entire cabin and within seconds the temperatures soared to the 1700°-2000°F. range. The test was allowed to continue until the test section of the aircraft was totally destroyed, although no additional significant data was obtained.

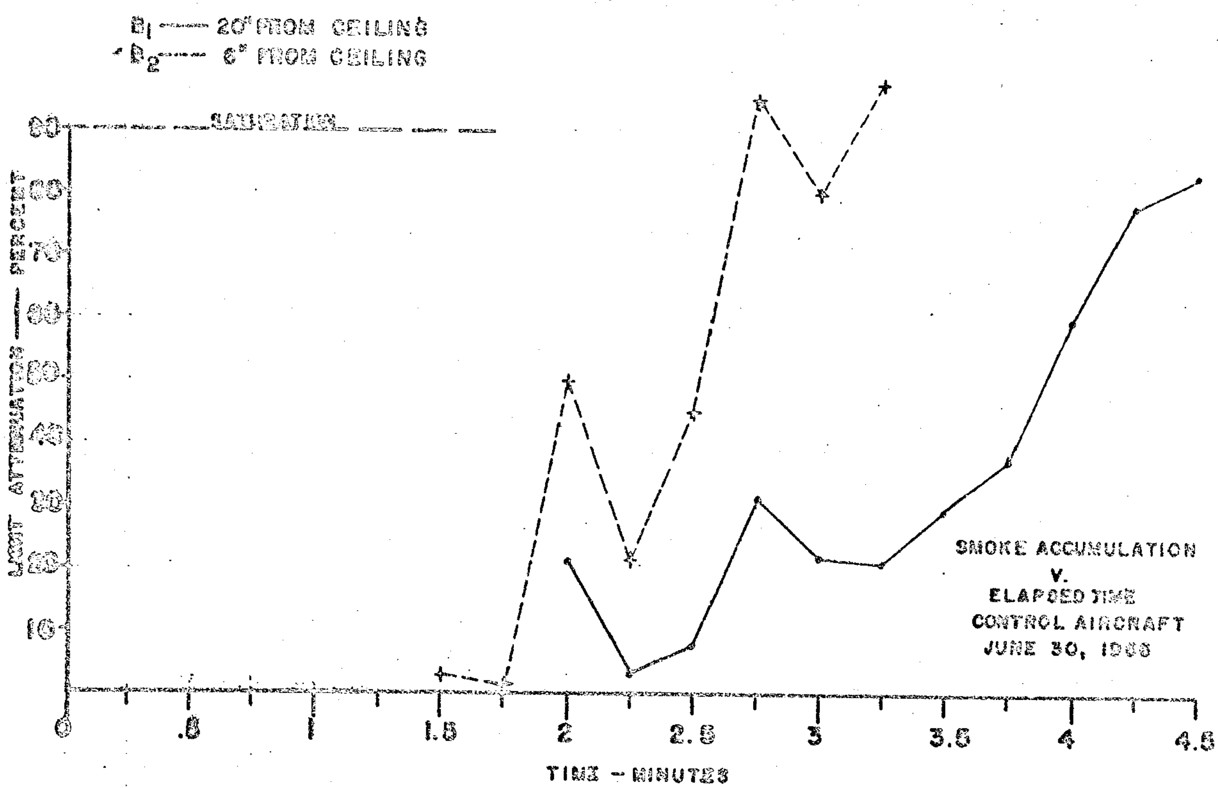
B1 —— 20" FROM CEILING
B2 ---- 6" FROM CEILING
SATURATION
LIGHT ATTENUATION — PERCENT
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
TIME — MINUTES
SMOKE ACCUMULATION
V.
ELAPSED TIME
CONTROL AIRCRAFT
JUNE 30,

Figure 4.

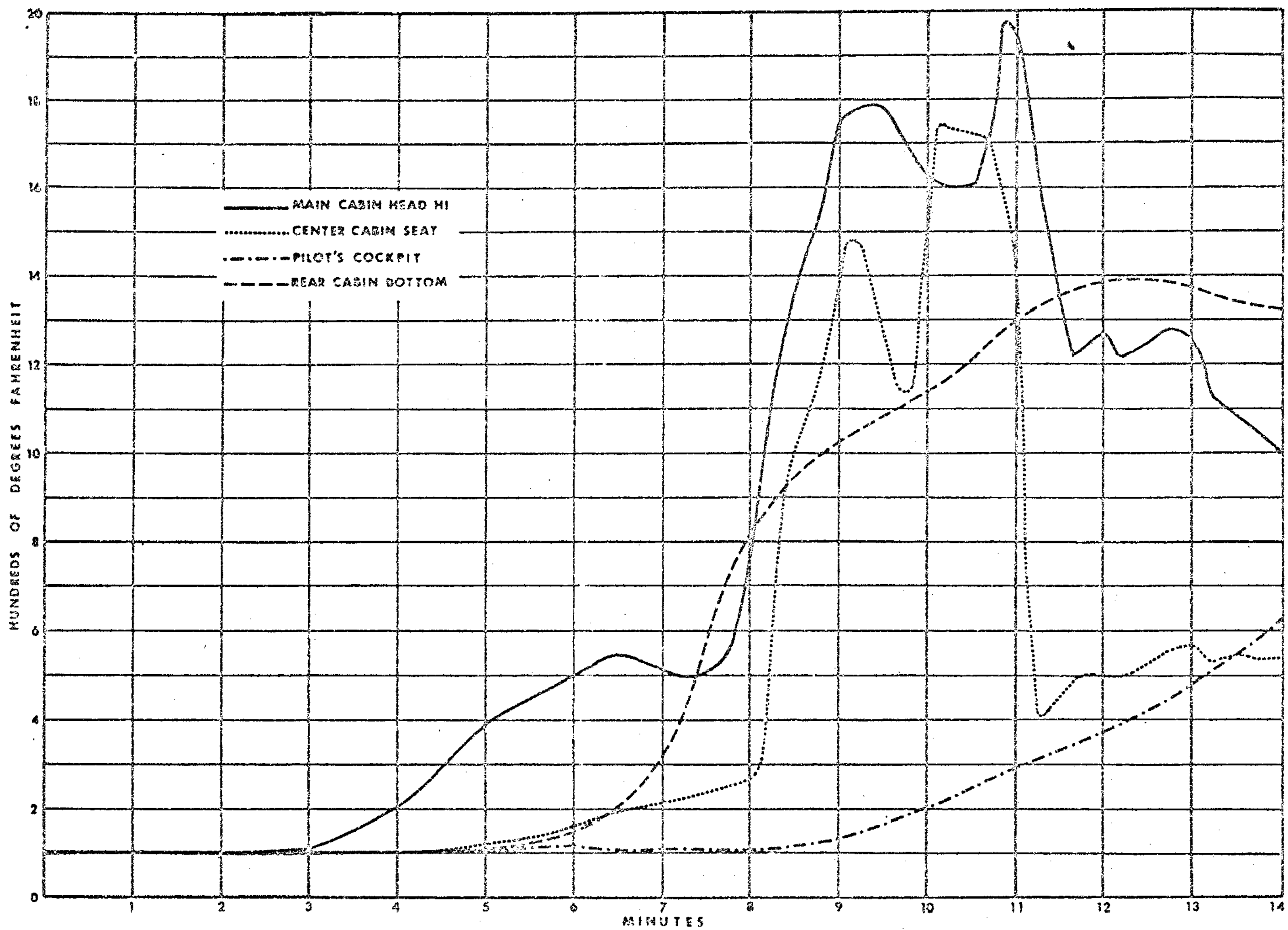

Figure 5.

Test #1 - Shielded Radiometers

Test #2 Set-Up: Cabin mock-up and instrumentation were identical with Test #1. Forty gallons of fuel were placed in the port pan. The additional fuel was used to provide a fire with a longer period at maximum intensity. Since the exposed surface (3' x 5') remained constant, the maximum intensity of the fire, i.e., maximum heat output, was not significantly increased above the Test #1 level.

In this test, a 2,000 CFM, Rockwood X-2 high expansion foam generator was installed in the cockpit, located so the finished foam would flow down the short access passageway (6') into the cabin mock-up section. Five gallons of foam liquid concentrate was located adjacent to the generator and connected to a device which metered the concentrate into the water stream at the pre-determined two per cent rate. Water supply for the generator was a fire department pumper-tanker, connected via a 1-1/2" hose line. Water pressure was a constant 125 psi during the periods of operation.

Wind Direction: ENE   Velocity: 10-12 Kts.

All times referred to in this text shall be construed as total elapsed time in minutes and seconds from ignition of the fuel pan. All temperatures referred to shall be those taken from the records of thermocouples located throughout the aircraft in degrees Fahrenheit.

As with Test #1, the temperature chart for the second test (Figure 7) depicts readings from shielded radiometers, while temperatures referred to in the text are from unshielded instruments.

The initial burn-through of the fuselage skin occurred in the vacant section of the fuselage, aft of the mock-up cabin, and progressed through the aft cabin bulkhead which consisted of a melamine laminate (Formica) bonded to aluminum sheet and aluminum honeycomb material. The actual time of this burn-through was not precisely detected. In this test, the first indication of smoke in the cabin occurred at 1:15, and at 2:00 the smoke detector 6" from the ceiling indicated smoke saturation. At the same time, the lower detector indicated 26 per cent showing almost the same stratification as Test #1 (See Figure 6). At 2:30, the foam generator was turned on and allowed to run for a period of 45 seconds. Because there was no foam readily apparent, it was restarted at 3:20 and allowed to run an additional 45 sec. The first indication of a temperature rise was recorded at 2:00 on an ambient thermocouple, although at 3:00 the center cabin ceiling temperature had risen only 20° above ambient. At 4:10, the ceiling temperature was 125°, and at 4:50 had reached 200°. At 4:50, the thermocouple at seat height had reached only 130° and did not reach 200° until 5:35. At about 6:10, the temperatures at various stations started rising very rapidly and reached over 1500° at 7:00, when the test was discontinued.

Test #3 Reason & Purpose

It was apparent from visual observation of Test #2 that for some reason we had not reached our objective of smoke control, even though a preliminary readout of the temperature data showed the cabin temperatures remained at or near ambient for a much longer period after burn-through than in Test #1. In Test #2, the foam generator depended on ambient cabin air which was heavily charged with smoke and other products of combustion/pyrolisis for foam generation. After carefully checking for possible mechanical failure of the foam generating equipment, the theory was advanced that some ingredient in the smoke, etc., was "poisoning" the foam, causing an early breakdown or only partial formation. Calculations made prior to the test had

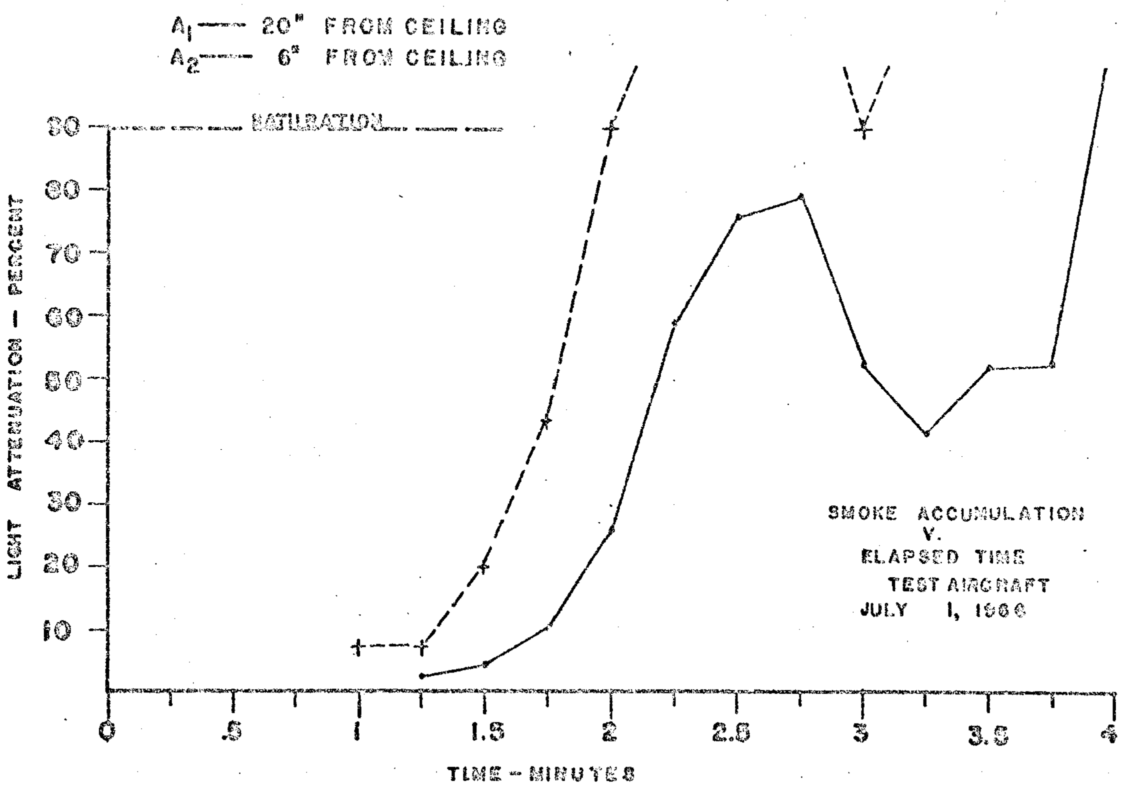
A1 —— 20" FROM CEILING
A2 ---- 6" FROM CEILING
SATURATION
90
80
70
60
50
40
30
20
10
LIGHT ATTENUATION — PERCENT
0
.5
1
1.5
2
2.5
3
3.5
4
TIME - MINUTES
SMOKE ACCUMULATION
V.
ELAPSED TIME
TEST AIRCRAFT
JULY 1, 1966

Figure 6.

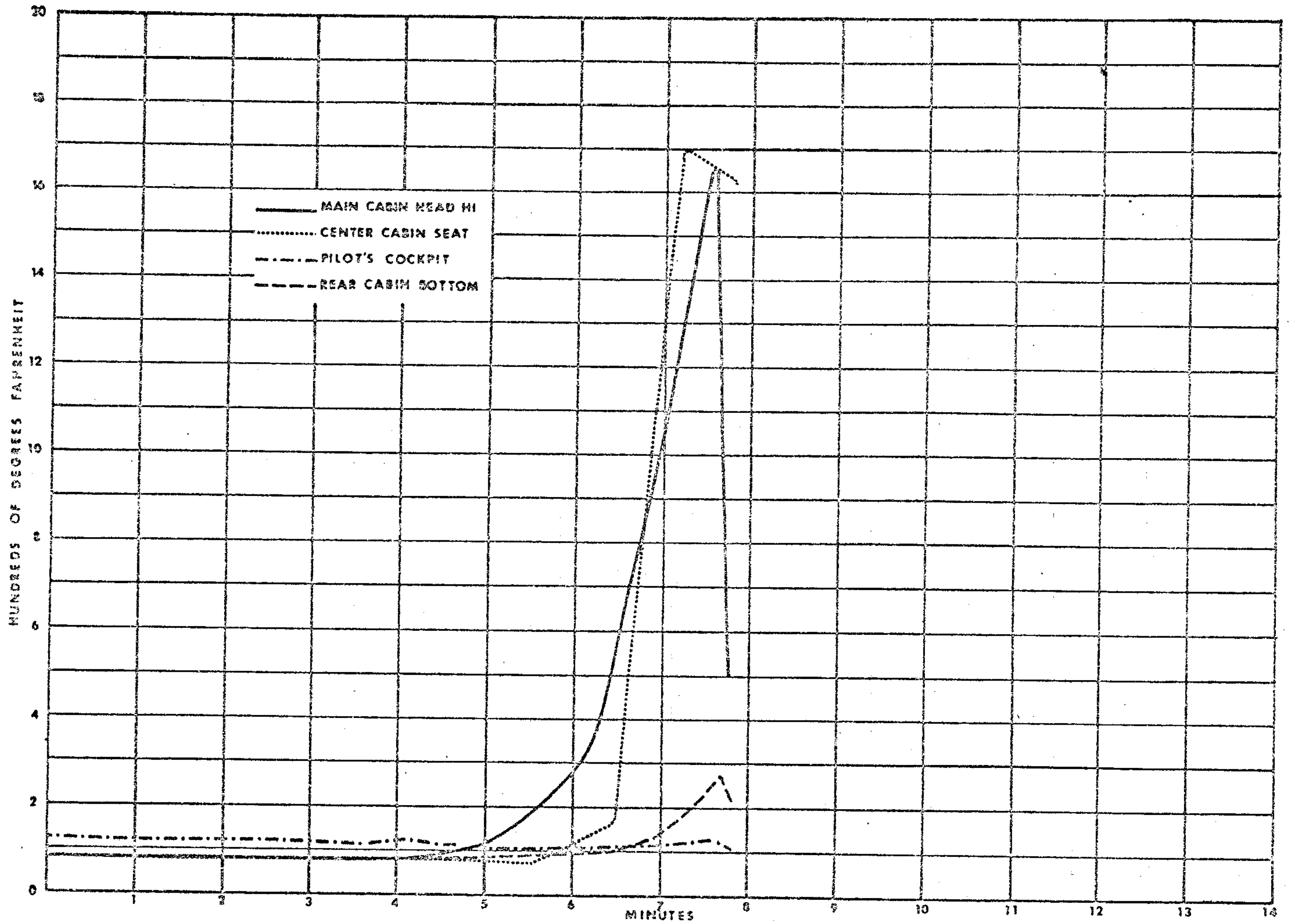

Figure 7.

Test #2 - Shielded Radiometers

shown that with the generator running 45 seconds, 1-1/2 aircraft volumes of foam should have been generated. No foam was visible in Test #2.

Since a considerable amount of the cabin mock-up remained after Test #2, it was decided to re-burn the aircraft, fueling the starboard pan with 40 gallons of Type A (kerosene) fuel. Prior to ignition of this fuel, the cabin would be pre-filled with foam made from fresh air.

While the results of this test could not be considered conclusive, since the mock-up had been partially destroyed, portions were water soaked, and complete instrumentation was not available, it was believed that valuable additional data could be obtained concerning the foam's resistance to breakdown under flame attack, ability to hold temperatures down, and smoke control.

Test Fire #3

In Test #3, the fuselage was allowed to completely fill with foam before the fuel pan was ignited. About two-thirds of the thermocouples in the aircraft were still operable and from these it was apparent that the foam had very good insulating properties. Any thermocouples that were covered by foam remained at or near ambient temperatures, and only after a prolonged burn (in excess of 3:30) did the foam start to break down noticeably. The foam generator was restarted when temperatures reached approximately 180^{o} at the cabin ceiling, and the fuselage again filled with foam. The foam cooled all the temperatures recorded to near ambient, and held them there for a period in excess of 5 minutes, when they slowly started to go up in the area of the ceiling where foam breakdown was occurring. After about 17 minutes, the remaining insulation was pulled away permitting the foam free access to the pan fire. The foam promptly flowed out and extinguished the fire.

Conclusions

1. Further research must be done to find the specific reason for the apparent failure of the foam to form properly or break down at a rapid rate, as happened in Test #2. At the time of this writing, a series of tests are scheduled where the smoke, etc., of burning cabin materials will be intentionally ducted through an operating foam generator. The liquid from the foam will be analyzed to determine the chemical composition. This knowledge is extremely important since all proposals known to the writers for an airborne foam fire suppression system are predicated on using ambient cabin air for generation. This air could be heavily smoke-charged under post crash fire conditions.

2. While the laboratory reports are not yet available concerning the specific components of the smoke and other products of combustion/pyrolisis, which may or may not have significant toxic values, it is apparent that the sheer volume and density of the smoke generated early in a post-crash fire involving cabin materials can severely restrict vision and have an extremely adverse effect on evacuation.

3. All cabin materials used in the mock-up cabin met or exceeded existing FAA criteria for flame resistance. This criteria is based on a small laboratory sample tested under ambient temperature conditions. The Cleveland test only added to the mounting evidence that the existing standard tests do not simulate conditions

encountered in post crash fires. The standards are now under re-evaluation and revision, and undoubtedly, more stringent flame spread requirements will be made. However, in view of the large amounts of dense black smoke and possibly toxic products contained therein, it is felt that the new criteria should include realistic limitations on permissible smoke generation and highly toxic products of combustion and/or pyrolisis.

4. We strongly feel that high expansion foam could be of major value in extending survival times under post crash fire conditions. While existing hardware for foam generation is not suitable for airborne use, and all proposals for this application have some serious drawbacks, research and development should continue to attempt to produce an effective, practical, and economical airborne unit(s). Further development is also needed on equipment for use by ground fire fighting personnel. Hardware available today, while probably effective, is too difficult and slow to be set up to be of real value in post crash fire where time is of the utmost importance.