J. F. MARCY

TEST PLAN

PROJECT 184-732-03X

DEVELOP TRANSPORT CABIN FIRE CONTROL PARTITIONS AND FIRE SUPPRESSANT SYSTEMS, PART I, COMPARTMENTATION

Constantine Sarkos

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TEST AND EVALUATION DIVISION
AIRCRAFT BRANCH
PROPULSION SECTION

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Purpose

This project is part of a general effort by the FAA to increase passenger survivability following a post-crash fire. More specifically, Part I of this project will determine the protection provided to passengers in a compartmented aircraft cabin from the fire hazards emanating from that part of the cabin involved in the fire. These hazards include smoke, toxic gases, high temperatures and the unpredictable flash-fire, which results from the ignition of combustible gases accumulating near the ceiling and which can severely endanger the life of passengers in sections of the cabin heretofore giving the impression of being relatively safe in terms of human survivability (Report No. FAA-ADS-44). The effect of the following factors on the degree of protection provided by compartmentation will be studied; partition geometry, curtain length, curtain opening and simulated draft air velocities.

Background

A survivable crash has been interpreted in the aviation field as being a crash landing wherein the crash forces encountered do not extensively damage the structural integrity of the fuselage. In this type of accident, if there is a fuel-fire, passenger survivability will depend upon the fire hazard hindering and preventing passenger evacuation. Two of the most often cited survivable crashes in the Unites States which resulted in passenger fatalities were the DC-8 crash at Denver in 1961 and the 727 crash at Salt Lake City in 1965. During the DC-8 accident, fire and smoke entered the cabin through the left forward door. At the Salt Lake City crash, the right gear ruptured the fuselage and fuel line when the 727 landed short of the runway, causing a fire to breakout in the vicinity of seat 18E which extensively involved the interior materials. A study of survivable commercial jet transport accidents occurring before 1967 was made by the Aerospace Industries Association of America (AIA). Their analysis (Report No. AIA CDP-2) concluded that a typical survivable accident in which a fire protection system would have been of most benefit experienced; (1) a large external fuel fire adjacent to the fuselage, (2) fire and smoke entering through a rupture or open door, and (3) an otherwise intact fuselage. The fire hazard characteristics of each of these accidents suggests that strategically located partitions with fire curtains may have enabled the passengers to isolate themselves from the fire hazard and thus increased their available time for evacuation.

The concept of compartmentation has already been studied by the AIA (Report No. AIA CDP-2) and to a lesser extent by NAFEC (Report No. FAA-RD-70-81). The AIA tests, using a 727 fuselage with a fuel-fire entering a simulated rupture, demonstrated that a partition with a closed curtain would significantly reduce smoke and toxic gases, and eliminate fire propagation throughout the protected section of a passenger cabin during a crash fire. Compartmentation was one of the few fire protection concepts recommended for further study by the AIA. The tests at NAFEC were in a small trailer (640 ft^3) and demonstrated that a 37-inch curtain hung from the ceiling was effective in shielding the upper part of the trailer from flash-fire propagation.

The tests proposed in this test plan are felt to be necessary in spite of the similar earlier work by AIA and NAFEC. The AIA tests did use a full-scale aircraft; however, the tests were only made for one set of conditions. Moreover, distribution of the AIA final reports was restricted primarily to the aircraft manufacturers and the FAA; consequently, other agencies and companies have often found it difficult to get access to this information. The NAFEC tests, although widely distributed, were deficient in that the volume and contour of the test enclosure was not representative of that of an aircraft, and only one test condition was varied, the length of the curtain. The tests proposed hereinafter will employ a full-scale aircraft (DC-7 fuselage), and the final report will enjoy wide distribution. In addition, a number of test conditions will be varied; viz, the partition configuration, the draft created by open exit doors and/or a fuselage rupture, the extent of curtain opening and the curtain length.

Test Article Preparation

The test article will be the DC-7 fuselage located behind Building 205 at NAFEC. Previous testing to determine the characteristics of cabin fires (Report FAA-ADS-44) has left the interior of this DC-7 fuselage severely gutted. All surface materials are blackened or charred, and in some areas the hatrack has been removed. Since the interior geometry will influence the distribution of smoke, gases and temperatures, the missing hatrack areas will be replaced. Both the protected and fire-source sections will be entirely covered with new non-flammable materials. The purpose of refurbishing the cabin is threefold: (1) the non-flammable materials will prevent (by insulating) the older flammable materials from becoming involved in the fire and thus guarantee a fairly repeatable fire hazard condition, (2) a high-temperature insulation will prevent burn-through at the fuselage ceiling immediately above the fire load, and (3) the appearance of the cabin will be more presentable. These new materials are Kaowool, an alumina-silica fibrous insulation that can be used up to 2300°F with very little physical change, and fiberglass fabric which did not burn or discolor when exposed to a 2000°F flame during tests at NAFEC. (However, after extended flame exposure this material became brittle and crumbled, thus probably necessitating its replacement after several tests at any high-temperature areas in the cabin). A composite of Kaowool and fiberglass fabric will cover the entire sidewall, hatrack and ceiling area of the fire source section. The protected section, where high temperatures are only possibly expected near the ceiling, will have the fiberglass fabric covering the sidewall and hatrack, and the Kaowool-fiberglass fabric composite protecting the ceiling.

The fuselage will be divided into two sections having nearly equivalent volumes: a section containing the fire source and a protected section (Figure 1). These sections will be separated by a dividing barrier usually consisting of a partition with a door opening and curtain. The partition will be tightly sealed at the sides and top to prevent smoke and gases from entering the protected section at these locations. In AIA Report No. CDP-2, it was recommended that "configurations must be developed to be compatible with interior design and service requirements." The effectiveness of three different partition configurations will be studied (Figure 2):

1. Configuration A: This configuration is a duplicate of the partition geometry separating the tourist and first-class sections in the DC-7. It will probably offer the greatest fire protection of the three configurations to be tested and is similar to the configuration tested by the AIA.

2. Configuration B: This configuration has twice the door width of Configuration A, thus making it more acceptable to the airline companies, since during normal aircraft operations it would not give the passengers as much a sense of confinement as would Configuration A. Also, the larger door width facilitates the movement of passengers and stewardesses during serving.

3. Configurations C-1, 2 and 3: These configurations are merely partitions of various depths placed across the ceiling and would thus provide the least alteration to existing interior design. However, they are expected to provide less protection against the fire hazards than either Configurations A or B.

It was also recommended in AIA Report No. CDP-2 that "the compartmentation devices should be tested under actual fire conditions with simulated wind and fire drafts." The draft created by an open exit door and/or a fuselage rupture near the aft end of the fuselage will be simulated by an axial flow fan mounted at the end of a 14-inch-diameter duct (Figure 3). This flow arrangement was used to simulate the volumetric air flow rate in the section of a C-130 aircraft (Report No. FAA-RD-70-42) and is presently available for use on this project. The duct also contains a set of straightener vanes and a calibrated orifice for measuring the flow rate from 45 to 2800 cubic feet per minute. It is anticipated that only the highest flow rates will alter the test results and, consequently, will be of any interest. (For a flow rate of 2800 cubic feet per minute, the calculated uniform air velocity through the door of Configuration A and B is 167 and 78 feet per minute, respectively). Since the flow conditions within the fuselage can be significantly influenced by the ambient wind velocity magnitude and direction, the over-wing exits will be protected by wind barriers to help insure a continuous air flow from the aft end of the fuselage outward through the four over-wing exits (see idealized air flow pattern in Figure 3).

The fire load will be a horizontal piece of regular (non-fire-retardant) urethane foam similar to what is presently being used in commerical air transports. This material was selected because of its rapid burning rate (Report No. NA-68-30) and presence in large quantities on commercial air transports. Moreover, tests in a 640-cubic foot trailer at NAFEC burning regular urethane foam (Report No. FAA-RD-70-81) produced a flash-fire in 3 minutes preceded by significant smoke generation. These characteristics of regular urethane foam appear to justify its classification next to aviation fuel as the second-most severe fire hazard on a commerical air transport. In order to make a meaningful comparison of the effectiveness of the different partitions, curtain length and extent of curtain opening configurations for a given simulated draft flow rate, it is desirable to have a fire load with a repeatable burning behavior as a function of time. The fire load geometry and ignition source (probably several ounces of alcohol) will be the same for each test, although this does not guarantee a repeatable burning behavior. A total heat flux transducer and thermocouple will monitor the heat flux and temperature near the fire for comparison between each test.

Instrumentation

The purpose of the test instrumentation is to (1) provide a comparison between the smoke, carbon monoxide, oxygen and temperature levels on each side of the curtain, (2) measure the flash-fire propagation, and (3) monitor the burning of the fire load. In order to accomplish this, the following measurements are planned (Figure 1):

1. Temperature measurement

   a. Temperature near fire load - 1 TC

   b. Temperature 1 inch below ceiling - 3 TC's on each side of the curtain.

   c. Temperature at the mouth level of a standing passenger ($\sim$ 5 feet 6 inches above floor) - 1 TC 3 feet from each side of the curtain.

   d. Temperature at the mouth level of a crawling passenger ($\sim$20 inches above floor) - 1 TC 3 feet from each side of the curtain.

   Total of 11 chromel-alumel TC's required (32-2000°F).

2. Total heat flux measurement

   a. Total heat flux near fire load - 1 heat flux transducer (0-10 Btu/ft^2 sec).

3. Carbon monoxide measurement

   a. Carbon monoxide concentration at the mouth level of a standing passenger - sample 3 feet from each side of the curtain (0-1.5 percent).

4. Oxygen deficiency measurement

   a. Oxygen concentration at the mouth level of a standing passenger - sample 3 feet from each side of the curtain (0-21 percent).

5. Combustible gases measurement

a. Combustible gases concentration (equivalent CO percent) at the mouth level of a standing passenger - sample 3 feet from each side of the curtain (0-3 percent).

6. Smoke measurement

a. Percent light transmission across a 1 foot distance at the mouth level of a standing passenger - measure 3 feet from each side of the curtain (0-100 percent).

Note: A total of 20 transducers are required. Recording and calibration will be similar to that used for the titanium fuselage test.

7. Motion picture coverage

a. A motion picture camera located behind the forward bulkhead viewing the dividing bulkhead and fire curtain (including bulkhead periphery).

8. Air velocity measurement

a. Air velocity traverses surrounding the fire load, at the door and at each of the over-wing exits (these measurements will be made for each air flow rate without the presence of a fire and are intended to give an approximate indication of the air velocities at the mentioned locations).

Test Procedure

For each test the foam will be ignited by a small can containing several ounces of alcohol. Ignition of the foam will be the signal for starting the timing lines on the recorder and the clock (the camera will have already been running for 5-10 seconds).

The proposed series of fire tests with various partition configurations, curtain openings, curtain lengths and simulated draft flow rate combinations is listed in Table 1. A minimum number of 15 tests will be run. Most of the tests listed in Table 1 are tentatively planned (see Remarks in Table 1), and whether they are run will depend upon previous test results. For example, Test No. 3 will incorporate

Partition Configuration A, zero flow rate and a full-length curtain opened halfway. In terms of isolating the Protected Section from the fire hazards emanating from the Fire-Source Section, if the results of this test indicate that very little benefit is derived from the partition/curtain configuration used, then Test No. 4 will be eliminated. Thus, the actual number of tests will be somewhere between 15 and 37.

Program Schedule

The Program Schedule shown in Figure 4 indicates major events and the time estimated for their accomplishment. The initiation and/or completion dates of Items 8-12 reflect the tentative nature of the majority of the planned tests.

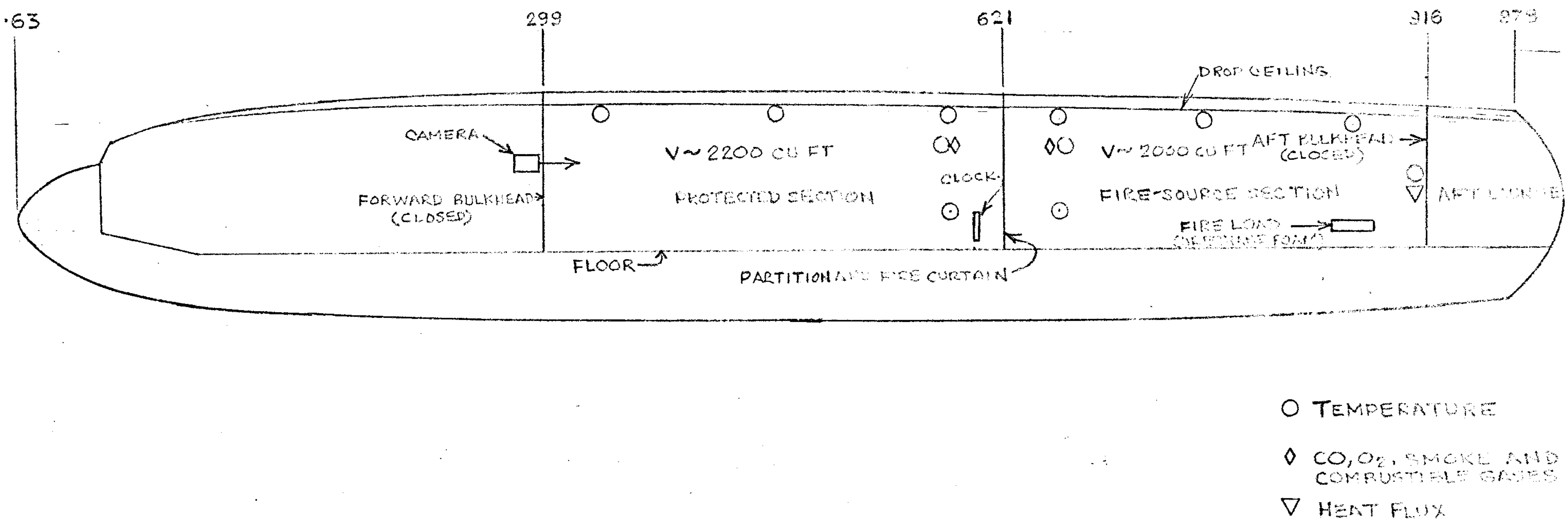
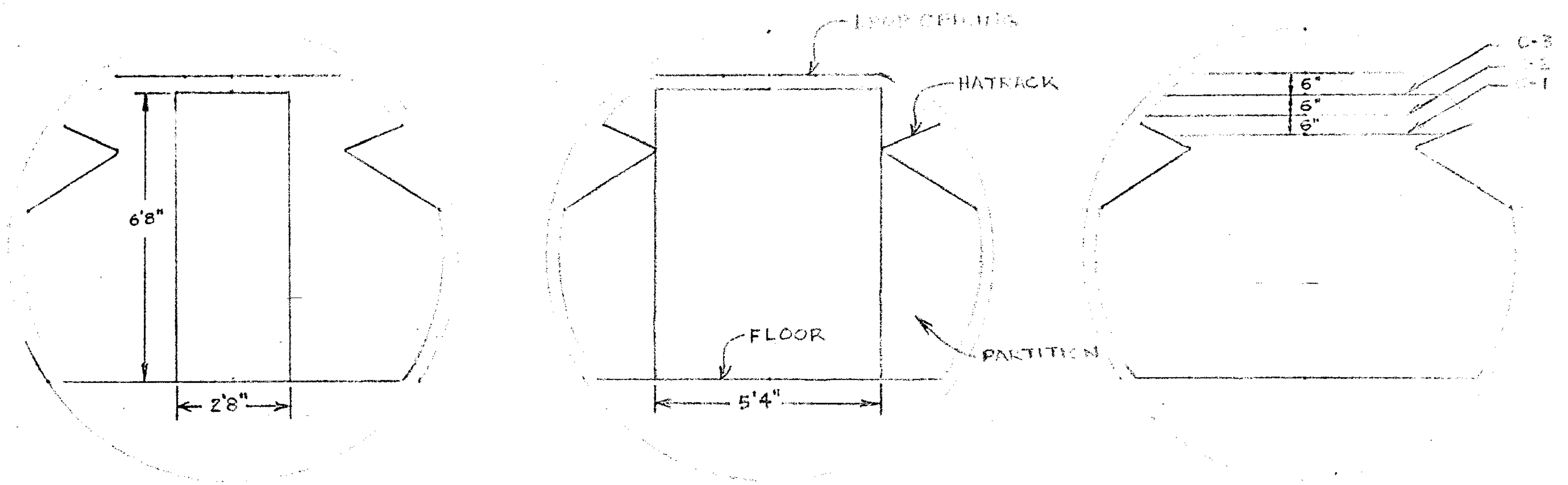


FIGURE 1. SIDE VIEW OF DC-7 FUSELAGE SHOWING TEST SETUP AND MEASUREMENT LOCATIONS

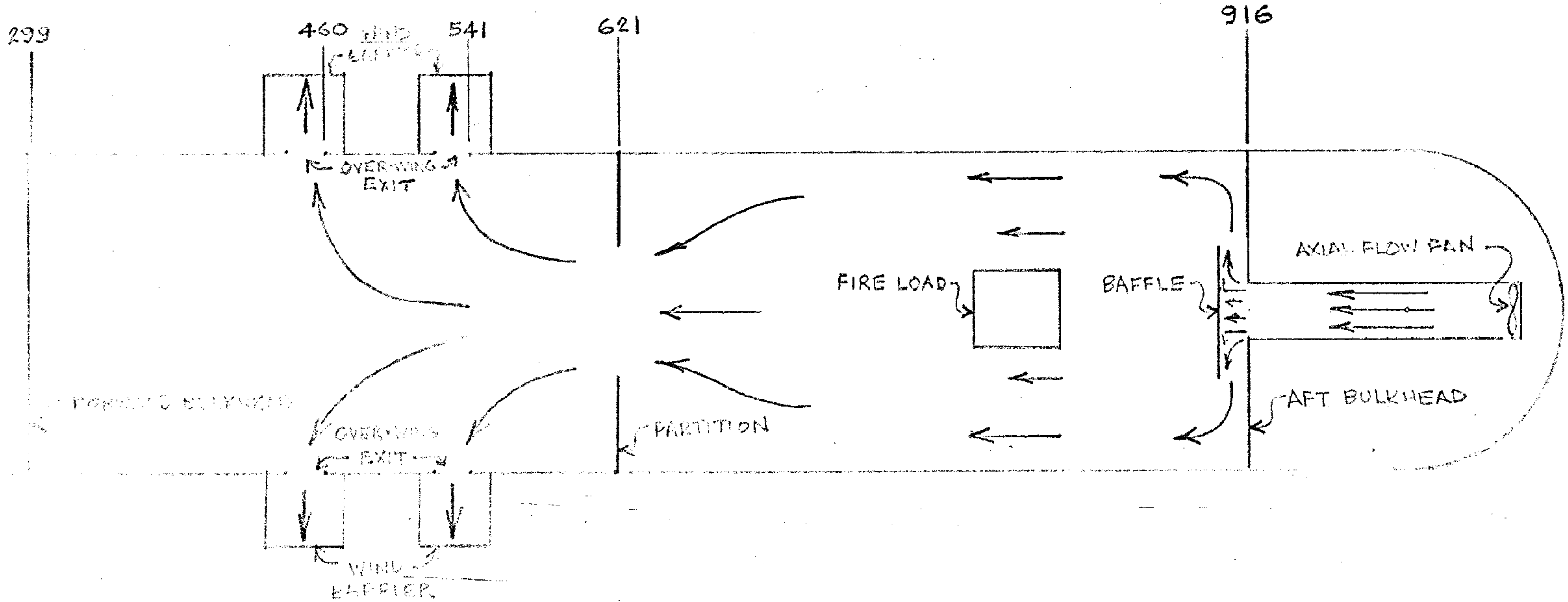


CONFIGURATION A

CONFIGURATION B

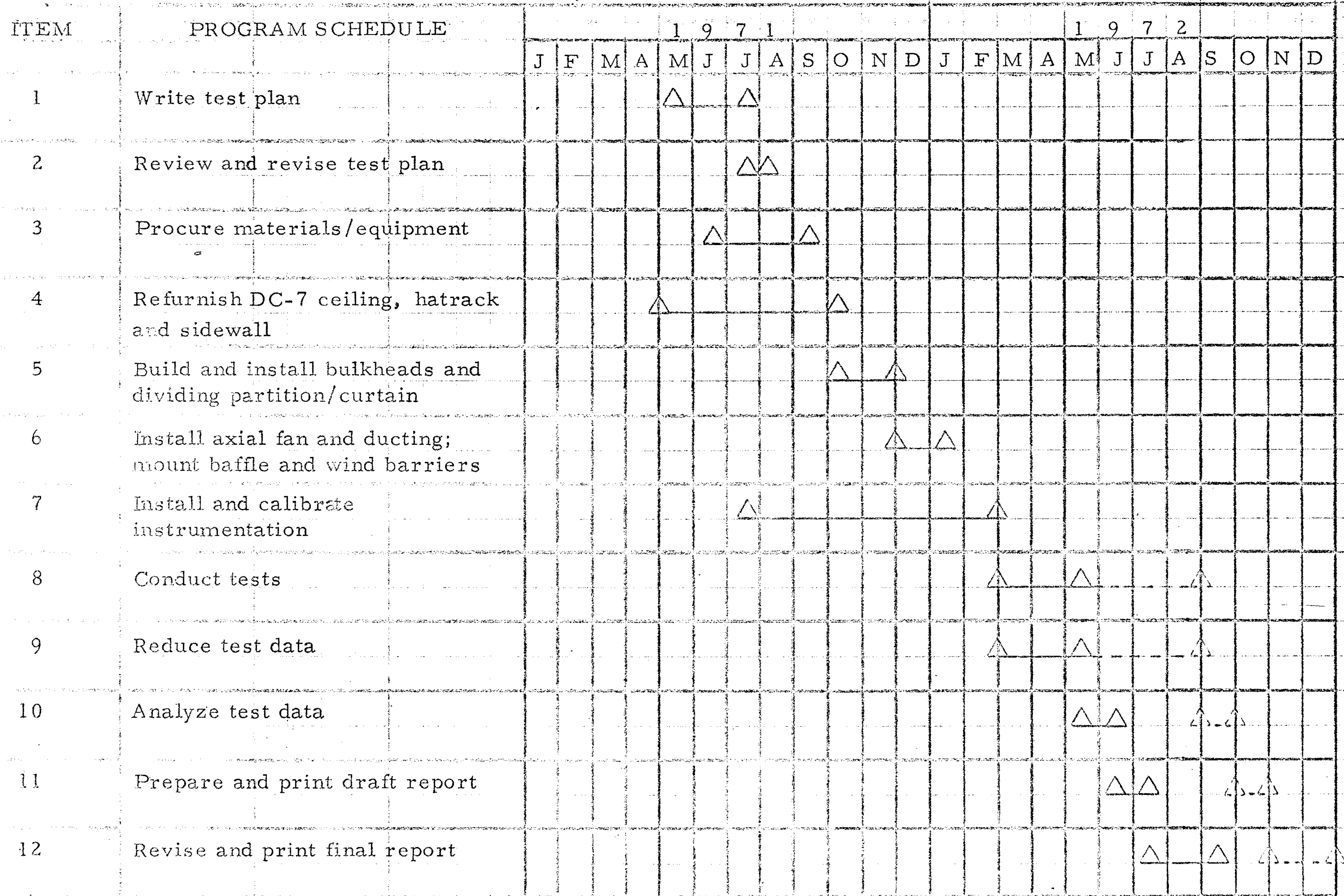
CONFIGURATIONS C-1, C-2 & C-3

FIGURE 2. PARTITION CONFIGURATIONS SCALE: 1/4" = 1'



TOP VIEW OF DC-7 FUSELAGE (NOT TO SCALE) ILLUSTRATING IDEALIZED AIR FLOW PATTERN

FIGURE 4. DEVELOP TRANSPORT CABIN FIRE CONTROL PARTITIONS AND FIRE SUPPRESSANT SYSTEMS, PART 1, COMPARTMENTATION *



15 tests   37 tests

* Schedule based on 2 technicians working full-time from August 1971 until completion of tests.

TABLE 1. COMPARTMENTATION FIRE TESTS

Test No.	Partition Configuration	Flow Rate (cu ft per min)	Curtain		Remarks
			Length	Opening	
1	A	0	Full	Closed	Exit windows closed.
2	A	0	Full	Closed	Determine data repeatability between tests 1 and 2.
3	A	0	Full	1/2	
4	A	0	Full	Open	Tentative upon Test No. 3 results
5	A	0	1/2	Closed	
6	A	2800	Full	Closed	
7	A	2800	Full	1/2	Tentative upon Test No. 6 results
8	A	2800	Full	Open	Tentative upon Test No. 7 results
9	A	2800	1/2	Closed	Tentative upon Test No. 6 results
10	A	1500	Full	Closed	
11	A	1500	Full	1/2	Tentative upon Test No. 10 results
12	A	1500	Full	Open	Tentative upon Test No. 11 results
13	A	1500	1/2	Closed	Tentative upon Test No. 10 results
14	B	0	Full	Closed	
15	B	0	Full	1/2	
16	B	0	Full	Open	Tentative upon Test No. 15 results
17	B	0	1/2	Closed	
18	B	2800	Full	Closed	
19	B	2800	Full	1/2	Tentative upon Test No. 18 results

TABLE 1. COMPARTMENTATION FIRE TESTS (Continued)

Test No.	Partition Configuration	Flow Rate (cu ft per min)	Curtain		Remarks
			Length	Opening	
20	B	2800	Full	Open	Tentative upon Test No. 19 results
21	B	2800	1/2	Closed	Tentative upon Test No. 18 results
22	B	1500	Full	Closed	
23	B	1500	Full	1/2	Tentative upon Test No. 22 results
24	B	1500	Full	Open	Tentative upon Test No. 23 results
25	B	1500	1/2	Closed	Tentative upon Test No. 22 results
26	C-1	0	-	-	
27	C-1	2800	-	-	Tentative upon Test No. 26 results
28	C-1	1500	-	-	Tentative upon Test No. 27 results
29	C-2	0	-	-	Tentative upon Test No. 26 results
30	C-2	2800	-	-	Tentative upon Test No. 29 results
31	C-2	1500	-	-	Tentative upon Test No. 30 results
32	C-3	0	-	-	Tentative upon Test No. 29 results
33	C-3	2800	-	-	Tentative upon Test No. 32 results
34	C-3	1500	-	-	Tentative upon Test No. 33 results
35	None	0	-	-	
36	None	2800	-	-	
37	None	1500	-	-	