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FLAMMABILITY TESTS OF USED

AIRCRAFT INTERIOR MATERIALS

by

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ABSTRACT

Flammability tests specified in Federal Aviation Regulations (FAR's) were conducted on used narrow-and wide-body jet aircraft cabin materials and unregulated airline-furnished items. Some previously certified seat fabrics and cushions exceeded the FAR flammability criteria; however, the carpet samples remained compliant. Loss in flame resistance was more pronounced for polyurethane foam seat cushions than their covers. The foam flammability characteristics were shown to depend on the sample cut taken through the cushion cross section. Some of the pillows, blankets, and headrest covers tested met the latest FAR flammability criteria, although these materials are currently unregulated.

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INTRODUCTION

PURPOSE.

The purpose of this study was to determine the flame retardant characteristics of used commercial transport aircraft interior materials by measuring their flammability using specified Federal Aviation Administration (FAA) test methods and comparing these results with original certification criteria. Of concern is whether cabin materials lose some degree of flame retardance as the result of inservice usage. A secondary purpose was to measure the flammability of unregulated, airline-furnished materials, such as blankets, pillows, and headrest covers, using the flammability test methods specified for regulated interior materials.

BACKGROUND.

Under special conditions to the Federal Aviation Regulations (FAR), materials used in the interior of the three wide-body, jet-type aircraft (DC-10, L-1011 and B-747), which were certificated prior to the most recent regulations, were required to show compliance with these rules (FAR Part 25, Amendment 25-32, effective May 1972 (reference 1)). Basically, wide-body cabin materials must "self extinguish" in a vertical orientation after exposure to a Bunsen burner flame within an allowable burn length and flaming time.

Tests previously performed at the National Aviation Facilities Experimental Center (NAFEC) on samples, primarily fabrics, removed from wide-body aircraft involved in fire, indicated that some materials do not retain their certified flame retardant capabilities after experiencing service usage. The accidents/incidents included: (1) a 707 at Los Angeles International Airport, January 16, 1974 (reference 2) (Although this type aircraft is not required to comply with Amendment 25-32, the materials had been updated by the airline to the latest regulations.); (2) An L-1011 involved in a ramp fire at Boston's Logan Airport, April 20, 1974 (reference 3); and (3) A DC-10 at Los Angeles International Airport, March 1, 1978 (reference 4).

All of the fabric samples tested from these three aircraft failed with varying degrees to meet the May 1972 FAR requirements. For the first two aircraft, which were from the same airline, it was demonstrated the water used during firefighting had leached out the fire retardants. However, subsequent tests on new and used fabrics identical in composition to those used in the accident/incident aircraft demonstrated that those fabrics treated with a topographical fire retardant experienced a degradation in fire resistance, apparently resulting from abrasion of the material from service usage. However, the fabrics from the DC-10 had not been exposed to water or any other type of extinguishing agent, nor experienced any fire damage in the accident.

Other service and maintenance factors may influence the permanency of flame retardant treatments used in cabin materials. For example, Woolley (reference 5) observed from foam mattress tests that a cold-cured flame retardant

polyurethane foam showed a marked deterioration in fire performance after an accelerated aging process. This process involved 60,000 passes with a 225-pound roller and subsequent autoclaving of the foam. Also, one airline has experienced a deterioration of fire retardency in "PFR" nylons dry-cleaned with other materials that have their topographical coatings leached out and deposited on the nylon. This creates a "lattice" which increases the exposure time of nylon to a test flame (The nylon normally melts rapidly and drips away from the flame before ignition can occur.) This phenomenon has been demonstrated in tests at NAFEC using a single asbestos thread sewn into the nylon material to create the "lattice."

An in-house study was initiated to determine if wide-body cabin materials, particularly seat covers and cushions, used by the major airlines (especially those whose materials had not been previously tested at NAFEC) experienced a degradation in fire test performance after service usage. The intent was to determine the magnitude of the problem. Using available resources, it was felt this could best be accomplished by soliciting materials from the major airlines with any information pertaining to, "chemical composition, period of previous service usage, and percentage of usage of each sample." In addition, at the request of Flight Standards Service (FSS), airline-furnished interior items: pillows, blankets, and headrests were solicited to measure their flammability characteristics. The FAA does not regulate the flammability requirements of these materials; however, FSS expressed an interest in a comparison with regulated fabrics and cushions.

Airline response to the request for test samples was mixed. Information on service experience also varied considerably; usually, specific information was either nonexistent or difficult to obtain. Although the letter sent to the airlines specifically requested used, wide-body materials, many of the samples received were from narrow-body aircraft. This necessitated a second request to the airlines for wide-body materials. Although eight airlines were contacted, only three fabrics and four cushions with confirmed usage in wide-body aircraft were received. Additional samples were obtained from four upholstered seat cushions from a wide-body jet undergoing refurbishment. These cushions were purchased by NAFEC for use in the C-133 full-scale cabin fire test project. The only information available on these materials was the labeled manufactured date of the seat.

DISCUSSION

TEST MATERIALS. A description of the materials tested in this study is contained in table 1. Material numbers 301-324 and 327-331 were donated by the airlines, while numbers 332-340d were taken from the seats purchased by NAFEC for full-scale fire tests. Numbers 325 and 326 were from an accident aircraft (reference 4). Service information on donated materials was provided by the airline.

TABLE 1. DESCRIPTION OF MATERIALS

NAFEC CODE NO.	CHEMICAL COMPOSITION	THICKNESS (in)	WEIGHT (oz/yd^2)	CABIN USE	SERVICE INFORMATION
301	70% Nylon, 30% Rayon	0.050	12	Seat Cushion Cover	8 months in service, 60% life
302	70% Nylon, 30% Rayon	0.070	18	Head Rest Cover	3 months in service, 25% life
303	Cold Cured Polyurethane	0.500	23	Seat Cushion	3.5 years in service, 65% life
304	100% Wool	0.125	12	Blanket	2 years in service, 33% life
305	100% Fortrell Polyester Fill	--	--	Pillow	2 years in service, 33% life
306	50% Cotton, 50% Polyester	0.011	4	Pillow Case	2 years in service, 60% life
307	100% Modified Acrylic (Verel)	0.250	61	Carpet	3 months in service, 20% life
308	90% Wool, 10% Nylon	0.045	14	Seat Cushion Cover	Dry cleaned several times, additional expected use, 2 years
309	Polyurethane Foam	0.500	16	Seat Cushion	50% life
310	75% Wool, 25% Nylon	0.200	46	Carpet	Cleaned 2 times in service 18 months
311	Nomex	0.060	8	Blanket	Cleaned several times, 75% life
312	Cotton	0.030	10	Headrest Cover	Cleaned several times, 25% life
313	Vinyl	0.050	23	Headrest Cover	Discarded when soiled
314	Polyester Fiber Fill	--	--	Pillow	Discarded when soiled
315	Cotton	0.012	4	Pillow Case	Laundered several times, 10% worn
316	Unknown	0.011	2	Pillow Case	Discarded after use
317	Wool	0.070	9	Blanket	Cleaning and age unknown
318	100% Verel	0.045	10	Curtain	Cleaning and age unknown

TABLE 1. DESCRIPTION OF MATERIALS (Continued)

NAFEC CODE NO.	CHEMICAL COMPOSITION	THICKNESS (in)	WEIGHT (oz/yd^2)	CABIN USE	SERVICE INFORMATION
319	Polyester Fiber Fill	--	--	Pillow	No Information
320	Unknown	0.009	1.5	Pillow Case	Disposable
321	60% Nylon, 40% Cotton	0.085	16	Seat Cushion Cover	Used--cleaned 6 times, 2 years service, disposable condition
322	Polyurethane Foam	0.500	12	Seat Cushion	No information
323	Unknown	0.275	66	Carpet	New material
324	Wool	0.065	15	Seat Cushion Cover	New material
325	Wool	0.095	24	Seat Cushion Cover	Cleaned 2 times
326	Wool, Nylon	0.075	18	Seat Cushion Cover	Cleaned 1 time
327	90% Wool, 10% Nylon	0.040	14	Seat Cushion Cover	Cleaned several times, 75% worn
328	Polyurethane Foam	0.500	13	Seat Cushion	3 years use, 50% life, Mfd. 5/75
329	Cold-cure Polyurethane Foam	0.500	15	Seat Cushion	Mfd. 6/73
330	70% Nylon, 30% Rayon	0.065	18	Seat Cushion Cover	Dry cleaned at least 1 time
331	Polyurethane Foam	0.500	13	Seat Cushion	Mfd. 1970
332	Unknown	0.085	22	Seat Cushion Cover	No service information
333	Unknown	0.042	13	Seat Cushion Cover	No service information Mfd. 5/71
334	Unknown	0.053	16	Seat Cushion Cover	No service information Mfd. 8/74
335	Unknown	0.057	16	Seat Cushion Cover	No service information Mfd. 7/73

TABLE 1. DESCRIPTION OF MATERIALS (Continued)

NAFEC CODE NO.	CHEMICAL COMPOSITION	THICKNESS (in)	WEIGHT (oz/yd^2)	CABIN USE	SERVICE INFORMATION
336	Unknown	0.053	15	Seat Cushion Cover	No service information, Mfd. 9/75
337	Polyurethane Foam/ Urespray Slipcoat	0.500	12	Seat Cushion	No service information, Mfd. 5/73
338	Polyurethane Foam/ Urespray Slipcoat	0.500	12	Seat Cushion	No service information, Mfd. 10/71
339	Polyurethane Foam/ Urespray Slipcoat	0.500	12	Seat Cushion	No service information, Mfd. 5/73
340	Polyurethane Foam/ Urespray Slipcoat	0.500	12	Seat Cushion	No service information, Mfd. 5/73
340a	Cushion No. 340, No Slipcoat, Specimen Taken .5 to 1 inch From Top	0.500	12	Seat Cushion	Same as No. 340
340b	Cushion No. 340, No Slipcoat, Specimen Taken From Center of Cushion	0.500	12	Seat Cushion	Same as No. 340
340c	Cushion No. 340, Specimen Includes Comfort Portion/ Gluestrip/Floatation Portion	0.500	30	Seat Cushion	Same as No. 340
340d	Cushion No. 340, Floatation Portion Expanded Polyurethane	0.500	27	Seat Cushion	Same as No. 340

TESTS METHODS.

Two test methods, horizontal and vertical, described in appendix F of FAR part 25, Amendment 25-15, effective in October 1967 (reference 6) and part 25, Amendment 25-32, effective May 1972 (reference 1), respectively, were utilized for this study.

VERTICAL METHOD. A more detailed description of the vertical test method than referenced above can be found in American Society for Testing and Materials (ASTM), Standard Method F501-77 (reference 7) or Federal Test Method 5903.2 (reference 8). A 2 3/4-by 12-inch test specimen is positioned vertically in a draft-free chamber and subjected to a Bunsen burner flame on the lower edge for 12 seconds. Following the burner flame exposure, the burn length, flaming time, and time that flaming drops continue to burn on the test chamber floor are recorded.

For the three wide-body jets and any aircraft certificated after May 1972, seat cushions, fabrics, and carpets are required to be tested by this test method. In order to comply with the FAR's, these materials must have a burn length not to exceed 8 inches, the flame must self extinguish within 15 seconds, and any flaming drops may not continue to burn longer than 5 seconds after falling to the test chamber floor.

HORIZONTAL METHOD. The horizontal test method is described in detail in Federal Test Method 5906 (reference 9). A 4 1/2- by 12 1/2-inch specimen is horizontally positioned in a draft-free chamber. A Bunsen burner flame is placed in contact with the open end of the specimen for 15 seconds. The flame front travel is timed for the 10 inches of the specimen after reaching the start point 1 1/2 inches from the ignition edge. The burn rate is determined by dividing the distance (10 inches) by the traverse time.

Prior to May 1972, the FAR's required that seat cushions and fabrics be tested by this method. The burn rate was not allowed to exceed 4 inches per minute.

TEST RESULTS

USED WIDE-BODY SEAT FABRICS AND CUSHIONS.

Results for showing compliance to FAR 25.853b, Amendment 25-32, for 10 upholstery fabrics and 8 polyurethane foam floatation-type seat cushions, known to have been removed from jumbo-jet-type aircraft, are recorded in tables 2 and 3. The reported results are based on an average of three tests for each material. The following is a description of the measurements which were taken. Flame time is the time that the test specimen continued to flame after removal of the 12-second Bunsen burner ignition source. Burn length is the distance from the exposed edge of the test specimen to the farthest evidence of damage, but not including areas sooted, stained, warped, or discolored. Dripping flame time is the time that the melting drops from the specimen continue to burn after falling to the floor of the test chamber.

TABLE 2. FAR 25.853b TEST RESULTS FOR WIDE-BODY UPHOLSTERY FABRICS

NAFEC CODE NO.	VERTICAL FLAME TEST PER FAR 25.853b AMENDMENT 25-32				REASON FOR NOT PASSING		
	FLAME TIME (s)	BURN LENGTH (in.)	DRIPPING FLAME TIME (s)	PASSES FAR 25.853b	FLAME TIME	BURN LENGTH	DRIPPING TIME
301	21.6	3.6	3	No	X		
325	15.1	3.6	0	No	X		
326	37.6	7.9	0	No	X		
327	7.3	4.4	0	Yes			
330	17.6	5.0	0	No	X		
332	1.7	1.5	0	Yes			
333	3.4	3.5	0	Yes			
334	11.2	2.8	0	Yes			
335	9.9	3.6	0	Yes			
336	4.9	2.9	0	Yes			

TABLE 3. FAR 25.853b TEST RESULTS FOR WIDE-BODY URETHANE FOAM SEAT CUSHIONS

NAFEC CODE NO.	VERTICAL FLAME TEST PER FAR 25.853b AMENDMENT 25-32				REASON FOR NOT PASSING		
	FLAME TIME (s)	BURN LENGTH (in.)	DRIPPING FLAME TIME (s)	PASSES FAR 25.853b	FLAME TIME	BURN LENGTH	DRIPPING TIME
303	113	11	73	No	X	X	X
328	1.2	5.1	0	Yes			
329	67.3	9.8	25	No	X	X	X
331	1.7	1.5	0	Yes			
337	62.8	>12	30	No	X	X	X
338	74.9	11.3	58	No	X	X	X
339	65.5	>12	18.3	No	X	X	X
340	57.6	>12	16.3	No	X	X	X
340a	0	4.7	0	Yes			
340b	0	4.5	0	Yes			
340c	106	>12	0	No	X	X	
340d	0	2.6	0	Yes			

Four of the ten upholstery fabrics failed to show compliance to the FAR because of excessive flaming time only. Without the original certification test data, the change in performance of the four materials that failed cannot be determined. However, the present test data by itself indicate that the change in flammability of the fabric in its end-use configuration (as a complete seat cover) is probably undiscernable. This conclusion is based on several factors. First, all four fabrics still "self-extinguished" after removal of the Bunsen burner flame. This implies that a fire would not spread to any significantly greater extent across the surface of the used material than when it was new. Secondly, flame time is probably not as good an indicator of the flammability of a material as is burn length or whether it "self extinguishes" or not. Moreover, the additional flame time above the allowable 15-second limit is insignificant for one material (0.1 second) and relatively small for two of the materials (2.6 and 6.6 seconds). Tests should be performed to determine which vertical test results, if any, translate to a significant increase in seat flammability.

On the basis of the vertical test and the limited variety of materials evaluated during this study, the flammability of urethane foam cushions increases significantly, compared to fabrics, as the result of service use. This is evident in table 3 which indicates that eight of the twelve foam samples do not meet the criteria to which they were originally certified. When failure occurred, all three measurement criteria: flame time, burn length, and dripping flame time were exceeded (except for one foam where dripping time was not exceeded). This is the reason the used foams are considered more flammable than the used fabrics. However, flammability of the foams should not entirely be judged on the pass/failure ratio of table 3. Slipcoat coatings (e.g., Urespray®) and adhesives can cause the foam sample to fail. This was probably the case for numbers 337-339, and was definitely true for number 340. For the latter, different sample cuts were taken through the cushion cross section (340, 340a - 340d); those samples with Urespray or adhesive exposed to the burner flame failed, but those samples without Urespray or adhesive passed (340a, 340b, and 340d). Again, phenomenon involved appears to be the "lattice" effect described earlier for nylon fabrics. Documentation has been received showing this behavior of Urespray-coated foams was brought to the attention of the Western Region during certification testing. They ruled that the cushion satisfied the intent of the FAR which is to test the basic core material. Of the seven uncoated (core only) foam samples tested, only two actually were found not to be compliant with the FAR. Perhaps more than anything, this excercise revealed the risk of reaching erroneous conclusions when there is not complete control over an experiment or access to all pertinent information.

PILLOWS, BLANKETS, AND HEADREST COVERS.

The flammability characteristics of the unregulated, airline-furnished materials were measured with the vertical and horizontal test methods. Table 4 contains the test data and columns indicating whether these materials met the FAR flammability criteria for seat fabrics and cushions set forth in 1967 and 1972.

TABLE 4. TEST RESULTS FOR PILLOWS, BLANKETS, AND HEADREST COVERS

NAFEC CODE NO.	MATERIAL CODE	VERTICAL FLAME TIME (s)	VERTICAL BURN LENGTH (in.)	VERTICAL DRIPPING FLAME TIME (s)	VERTICAL PASS FAR 1972	HORIZONTAL BURN RATE (in./min)	HORIZONTAL PASS FAR 1967
305	P	0.7	1.3	0	Yes	0	Yes
314	P	12.8	4.1	25	No	0	Yes
319	P	20.1	4.3	0	No	0	Yes
306	PC	11.6	>12	0	No	6.0	No
315	PC	17.2	>12	0	No	5.9	No
316	PC	0	6	0	Yes	0	Yes
320	PC	2.3	>12	0	No	7.8	No
304	B	45.4	>12	0	No	0	Yes
311	B	1.0	5.5	0	Yes	0	Yes
317	B	33.9	>12	0	No	0	Yes
302	HC	6.5	5.3	0	Yes	0	Yes
312	HC	40.6	>12	0	No	2.3	Yes
313	HC	0.5	3.5	0	Yes	0	Yes

Material Code: P - Pillow Fill B - Blanket
PC - Pillow Case HC - Headrest Cover

Of the 13 samples tested, five met the latest FAR flammability criteria. There was one compliant sample from each usage category (two compliant headrest covers). The least flammable category was the polyester fill used in pillows. One sample had a very small vertical burn length and flame time. The two samples which did not pass the 1972 FAR criteria were "self extinguishing," although one sample failed because of excessive flaming drippings and the other because of a slightly excessive flame time.

The most flammable materials were the lightweight pillow cases. Of the four tested, three exceeded the old horizontal burn rate requirement of 4 inches per minute established in 1967 (Only one other airline-furnished material propogated a horizontal flame--a headrest cover, number 312.). Surprisingly, there was one pillowcase sample of unknown composition which was compliant with the latest FAR flammability criteria.

One of the three blanket materials, a Nomex, passed the latest FAR flammability criteria. The two blankets which failed were constructed of wool. It is interesting to note that flame retardant treated wool fabrics and carpets are used extensively in cabin interiors and are, of course, compliant with the latest FAR flammability criteria.

Two of the three headrest covers passed the amendment FAR 25-32 flammability criteria. The best material was made of vinyl, which is inherently fire resistant. The material which failed was made of cotton; cotton is generally flammable, as was also evidenced by the cotton pillow cases which also failed the latest flammability regulations.

On the basis of this cursory study of a small number of pillows, blankets, and headrest covers, it is evident that there are materials currently in service usage from each category, and there are readily available fire resistant materials which can be used to make these items that meet the "self-extinguishing" requirements set forth in the latest FAR.

USED CARPETS AND NARROW-BODY FABRICS AND CUSHIONS.

The flammability characteristics of used carpets, apparently from wide-body aircraft, and seat covers and cushions used in narrow-body aircraft were measured with the horizontal and vertical test methods. Table 5 contains the test data and whether these materials met the 1967 and 1972 FAR flammability criteria. All samples met the 1967 regulations.

The three carpet samples were compliant with the latest FAR flammability criteria. It is believed these materials were used in wide-body aircraft (One was unused.). Since carpets may be expected to experience the greatest service abrasion, at least in some particular areas, it was somewhat surprising that the two used samples remained compliant.

TABLE 5. TEST RESULTS FOR USED CARPETS, NARROW-BODY SEAT COVERS, AND CUSHIONS

		VERTICAL				HORIZONTAL	
NAFEC CODE NO.	MATERIAL CODE	FLAME TIME (s)	BURN LENGTH (in.)	DRIPPING FLAME TIME (s)	PASS FAR 1972	BURN RATE (in./min)	PASS FAR 1967
307	C*	1.5	3.1	0	Yes	0	Yes
310	C*	13.3	3.4	0	Yes	0	Yes
323	C*	3.8	2.6	0	Yes	0	Yes
308	F	15.7	6.0	0	No	0	Yes
318	F	3.2	6.5	0	Yes	0	Yes
321	F	69.9	>12	0	No	1.4	Yes
324	F	3.2	3.0	0	Yes	0	Yes
309	SC	59.8	>12	88	No	2.6	Yes
322	SC	52.1	>12	47	No	3.5	Yes

Material Code: C - Carpet
F - Fabric
SC - Seat Cushion

*Carpets reportedly from wide-body aircraft

Three of the fabrics were "self-extinguishing," two of these materials met the latest flammability regulations, and the third material failed by only 0.7 seconds in the flame time requirement. Judging by their chemical composition, it is likely that these materials are used in wide-body aircraft. The fabric which did not "self-extinguish" was a nylon/cotton blend. As noted previously, materials containing large portions of cotton have exhibited poor flammability characteristics during this study.

The two polyurethane foams were very flammable; both samples burned completely in the vertical test. Even the horizontal burn rates were fairly high, although less than the 4 inches per minute requirement of the 1967 FAR's.

SUMMARY OF FINDINGS

The following is a summary of significant findings based on the tests performed during this study:

1. Some wide-body seat fabrics and cushions exceeded the FAR flammability criteria to which they were originally certified after a period of service usage.

2. The degradation in flammability characteristics for used seat cushions is greater than for used seat fabrics.

3. The flammability of seat foam samples is greatly dependent on the sample orientation taken through the cushion cross section (Samples with spray slip coatings or adhesives exposed to the test flame are very flammable.).

4. Some pillows, blankets, and headrest covers which are not regulated by FAA for flammability were compliant with the latest FAR flammability requirements and fire resistant materials are available for their construction.

5. Carpets do not appear to suffer any measureable degradation in flammability characteristics as the result of service usage.

The study to examine the flame-retardant permanency of inservice cabin materials was undertaken under a NAFEC inhouse project 975-420-002, "Flammable Characteristics of Inservice Materials." The work on unregulated airline-furnished materials was included by verbal request from AFS-120. The NAFEC Program Manager is Constantine P. Sarkos. Further information can be obtained from Elden B. Nicholas, ANA-420, (609) 641-8200, extension 3574.

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