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Fire Resistivity and Toxicity Studies of Candidate Aircraft Passenger Seat Materials

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ABSTRACT

This paper describes fire resistivity studies of a wide range of candidate nonmetallic materials for the construction of improved fire resistant aircraft passenger seats. These materials were evaluated on the basis of FAA airworthiness burn and smoke generation tests, colorfastness, limiting oxygen index (LOI), and animal toxicity tests. Physical, mechanical, and aesthetic properties were also included in the evaluations.

Candidate seat materials that have significantly improved thermal response to various thermal loads corresponding to reasonable fire threats as they relate to in-flight fire situations, are identified.

INTRODUCTION

The major interior on-board fire threat potential in commercial passenger aircraft is the nonmetallic components in the passenger seats. The major components of aircraft passenger seats are the polymeric cushioning material and, to a lesser degree, the textile fabric covering; together they represent a large quantity of potentially combustible material. Each aircraft passenger seat consists of about 5.9 kg of nonmetallic material, the major component being the seat cushion.

Modern day wide-body passenger jet aircraft have from 275 to 500 passenger seats. The selection of the nonmetallic components for the construction of the seats requires a careful consideration of the thermal characteristics of each seat component. The modern aircraft passenger seat provides many functions other than those of the seats used in earlier aircraft (Figure 1). Early passenger seats were of tubular frame construction with little styling and were essentially designed to meet the load requirements of 4.5 g. Figure 1 is typical of the passenger seats used in the DC 3 and DC 4. The modern aircraft passenger seat (Figure 2) is optimally engineered for comfort and convenience, is compact and well suited for close-pitch, high-density operation, is lightweight, and of rugged construction. The seat frame is of tubular aluminum construction, sheet-metal floor and track-mounted. The nylon bottom support, which gives comfort and life to the flotation bottom cushion, has the advantage of ruggedness and minimum maintenance.

The nonmetallic components of the seat represent some 5.9 kg (13 lb) of material whose thermal characteristics must be critically ascertained. Over half of the seat's weight in nonmetallics is due to the polymeric foam cushioning material. The polymeric foam cushion must meet requirements such as:

(1) resilience, (2) low total heat release, and (3) low toxicity and smoke generation. The fabric covering is usually the first part of the seat exposed to a fire and must (1) be resistant to ignition, (2) have low flame spread, and (3) be low in smoke and toxic gas generation. In addition, the fabric must wear well and be fade resistant. Aircraft passenger seats are generally airline furnished and are purchased from aircraft seat manufacturers. As a result, there is a wide range of material options.

It was realized in this study that many materials, when subjected to laboratory-scale tests, can pass the guideline criteria of flammability, smoke production, and toxicity, but fail when subjected to full-scale testing. This study represents one phase of a materials study in the development of improved fire resistant aircraft passenger seats [1,2]. Full-scale testing of actual aircraft seats in a simulated aircraft fuselage will complement this developmental program.

EXPERIMENTAL METHODS

Experimental analyses presented in this study were conducted at McDonnell-Douglas Corp., Long Beach, Calif., under contract NAS2-9337. Screening tests (Figure 3) were selected based on reasonable fire threat levels in order to identify the types of properties related to in-flight fire situations. Materials were classified on the basis of anticipated end use in seat design and construction. Materials were categorized as: (1) decorative fabric coverings, (2) fireblocking layers, and (3) cushioning layers. Classification of materials was made based on screening and performance test data as well as on other criteria such as raw material availability, available thickness, and manufacturing limitations.

All materials (Table 1) were first screened in accordance with current FAA burn requirements. The combination of screening tests used (Table 2) represents significantly higher fire resistance performance criteria than current laboratory test standards imposed on aircraft seat materials. A modified version of the FAA airworthiness burn test (FAR 25.8536) took into consideration materials that melt or drip; such melting or dripping effectively removes the sample from contact with the flame, thus reducing the exposure time. The vertical burn test (equivalent to DNIS 1511 and FTMS 191 No. 5903) is a standard 12-sec vertical burn test which was modified only as to how the sample was secured. Each specimen was clamped in such a manner that the back surface was in direct contact over the entire surface with a single layer of MIL-C-9084 glass fiber cloth. This permitted an exposure area of a minimum of 50 cm by 30.5 cm. The direction of the specimen corresponding to the most critical burn rate was parallel to the 30.5 cm direction. Foam samples 3.8 cm thick were utilized in these tests. Materials for these tests had fire retardant additives which provided increased flammability resistance and were subjected to an additional test for permanence of the retardant when aged at 74° C for 72 hr and then retested or subjected to FAA burn test (FAR 25.853(b)). The two materials showing the greatest change were then tested for smoke per NBS Technical Note 708 to determine any effect of aging on smoke generation. No testing for persistence after laundering or dry cleaning was done. The results of the screening tests were reported in Tables 3, 4, and 5 and fire retardant additive persistence tests are reported in Table 6.

Candidate materials were tested for weight loss by standard procedures of thermal gravimetric analysis. Data were obtained using a DuPont Instruments Division Thermal Analyzer. Samples (5-15 mg) were introduced into the sample

dish and pyrolyzed at a heating rate of 20° C/min in dry air at a flow rate of 75 ml/min. Rates of weight loss versus temperature were recorded. Samples were pyrolyzed in this manner until no further weight change was detected (Figures 4-6).

Performance tests used to assess the mechanical and physical properties of candidate materials are presented in Table 7. These tests were performed by the material suppliers and results were submitted with the samples. Performance test criteria were selected in order to ensure that materials passing these requirements would be equal to or better than current seat materials.

EVALUATION OF PRODUCTS OF COMBUSTION

The equipment used for evaluating the pyrolysis and combustion products generated by candidate seat materials was essentially a modification of the apparatus employed in a study by Gaume [3]. It consisted of a test chamber made of rectangular glass and had a plexiglass lid. The exercise wheel and drive mechanism, electrical power leads, radiation heat shield, gas sampling, and thermocouple tube feed-through lines (Figure 7) were attached to the plexiglass lid. The chamber was sealed with a silicone rubber gasket and the lid secured with clamps.

Each test subject (mouse) was held in place inside the exercise wheel with a transparent plexiglass disc. A modification was found to be necessary because the test subject tended to ride the hardware screen lid previously used in the free-turning wheel tests.

A final assembly is shown in Figure 8. Power leads from a 110 V a.c. variac transformer wired in series with an a.c. ammeter and in parallel with a voltmeter were connected to the external leads on the chamber lid. A

variable-speed controlled electric motor drive was attached to the exercise wheel vertical friction drive just prior to a test.

Swiss albino male mice of the Webster strain weighing 25-37 g were used for most of the tests. Several initial tests were conducted with mice of mixed breed and unknown strain.

In the range of 1-2 g, material samples were weighed within ±0.1 mg. The tare weight of the heating coil and pyrolysis tube was recorded for each run so that the quantity of material pyrolyzed into the 5.3-liter free volume of the chamber was calculated after the conclusion of each test run, to determine the efficiency and repeatability of the pyrolysis.

The toxic endpoints selected for these tests were time to incapacitation T_i and time to death T_d. With rare exceptions, T_i was determined to a precision of about one revolution of the exercise wheel (10 sec), and T_d was determined on the basis of time to cessation of breathing.

Measurements of internal temperature and oxygen residual associated with thermal decomposition of the samples indicated maximum temperatures of 30°-40° C and oxygen levels above 15%. Therefore, hyperthermia and anoxia were not significant factors in animal mortality, but probably contributed marginally to the T_i determination. Pryor et al. [4] reported 4-hr lethal temperatures of 49° C (120° F) and an oxygen concentration of 7.5% for mice. Swiss albino male mice, however, have shown less resistance to temperature, averaging 77 min survival time at 40° C (104° F) as reported by Maul et al. [5].

The test was terminated at the end of a 30-min test period if the animal subject survived. These animals were not used in additional testing. Detailed post-test observations and pathological examinations were not made on surviving animals. Within the scope of the 30-min acute exposure procedure, the

recorded data were limited to the T_i and T_d determinations as measures of short-term survivability, rather than a determination of LC_{50} of LD_{50}, which require more testing.

Each animal was acclimated to the powered wheel for a short period (2 min) with air circulating through the chamber prior to a run. The air supply was shut down, and an electronic timer started at the same time the power was applied to the pyrolysis tube heating coil. Input energy was adjusted to 5.3 A which provided a heating profile of about 300°-400° C per minute inside the pyrolysis tube, depending on the quantity and packing density of sample, sample thermal conductivity, decomposition temperature, heat capacity, and orientation. The pyrolysis phase was limited to 200 sec; the temperature inside the pyrolysis tube exceeded 800° C at that time.

Examination of sample residues and weight measurements indicated that practically complete decomposition occurred in the 200-sec heating interval for most materials, as shown by the char yield [6].

RESULTS AND DISCUSSION

Thirty-nine candidate materials (Table 1) for use in the construction of improved fire resistant aircraft passenger seats were screened (Figure 3) in this study. Due to the number of candidate materials and the developmental nature of this study it was necessary to designate baseline materials. The baseline materials screened are representative of materials currently in use on aircraft. The baseline fabric consisted of 90% wool and 10% nylon that had a density of 457 g/m^2; the baseline cushioning material was a fire retardant treated urethane foam with a density of 0.03 g/cm^3.

The decorative fabric covering is generally the first component of the seat to be subjected to the heat flux from a fire. The decorative fabric covering must be appealing to the eye and must meet a wide variety of requirements such as colorfastness, resistance to ignition, low flame spread, and good wearability. Due to these requirements it was necessary to establish mandatory criteria in comparing the various materials and their suitability for utilization in specified components of seat construction (for example decorative fabric or cushioning foam). The first level of importance in considering candidate materials for decorative fabric covering applications is (1) colorfastness, (2) color availability, (3) FAA burn and smoke tests, (4) resistance to ignition, and (5) low flame spread. Heat release was not considered to be of first level of importance due to the small mass of fabric distributed in the seat.

On the basis of the mandatory requirements listed in Table 6, the following materials were eliminated as unsuitable for use as decorative fabric materials due to fading: (1) 100% cotton double knit (sample No. 102) (this fabric also showed poor abrasion resistance in performance testing; (2) the drapery fabric 100% nomex (sample No. 103); and (3) kynol-nomex blend (sample No. 105). The nylon backed with neoprene vonar No. 3 (sample No. 106) did not meet the FAA burn test criteria (FAR-25.853(b)) and the urethane coated nylon fabric was at low tear strength and was not available in a sufficient number of colors. Subsequently they were eliminated for consideration as decorative fabric materials.

The fabric samples that met the mandatory requirements for application as decorative fabric coverings (Table 3) were: (1) the baseline fabric (sample No. 104) which is a wool/nylon blended fabric; (2) a fire retardant treated

nylon (sample No. 100); and (3) kermel/wool blend (sample No. 101, Table 1). The toxicity of these materials on a comparative basis (Table 3 and Figure 9) was lower than that of the baseline material. These three fabric materials are currently in use as upholstery materials in aircraft passenger seating. It is of interest to note that nomex, which is not colorfast but is aesthetically appealing is utilized in airline seat upholstery.

The fire blocking layer is a new aircraft seat design concept (Figure 10) and is designed primarily to function as a thermal barrier; it is not, however, intended to compensate for cushioning materials that do not meet fire resistivity levels set forth in the screening test criteria of this study. A fire blocking layer would accomplish the following: (1) insulate, to delay the involvement of foam cushion in the fire situation, (2) provide mechanical enhancement of the tear strength of the foam cushion, and (3) provide a smooth sliding surface which facilitates the ease of removal or installation of the decorative fabric cover. To be considered for fire blocking applications, a material must pass the Pill ignition test in which the fabric must demonstrate a resistance to flame spread and a slow rate of heat release.

All candidate materials for fire blocking applications passed the FAA burn and smoke requirements. These materials showed good resistance to flame spread and passed the ignition test.

Polybenzimidazole materials (fabric and batting Nos. 204 and 205) and a proprietary material known as Black Batting (No. 206) showed excessive shrinkage and produced highly toxic gases upon pyrolysis, as evidenced in our animal toxicity studies (Figure 11 and Table 4). In the case of polybenzimidazole (PBI) we attribute the shrinkage problem and toxicity to the nature of the sample; namely, the PBI fibers were natural and unstabilized rather than acid

stabilized. The supplier of the PBI material is expected to supply acid-stabilized PBI material in the near future for evaluation in another study. Because of its proprietary nature, not much is known about the Black Batting material; however, the material produces a highly potent toxic gas upon pyrolysis, as evidenced in our animal toxicity studies (Figure 11 and Table 4), it was therefore dropped from the program. The kynol batting material (on polyester scrim needle punch) sample No. 203 (Table 1) proved the best all-around fabric in both screening and performance testing (Table 7).

In general, the kynol fabrics show a longer time to subject incapacitation than any of the synthetic fabrics, based on animal toxicity studies (Table 4).

The neoprene interliner called vonar No. 3 [7] performed well in the screening tests and in the animal toxicity studies, but in the area of smoke generation there is room for improvement.

Of the 11 candidate materials for fire-blocking-layer applications, three were suitable. The other materials will be dropped from the program. The three materials that met the requirements for a fire blocking layer material (Table 4 and Figure 9) were: (1) kynol batting sample No. 203, (2) neoprene interliner (vonar No. 3) sample No. 210, and (3) nomex III, sample No. 214. These materials are recommended for utilization in the third phase of this study which will involve the construction and full-scale testing of prototype passenger seats. The next study phase will involve continued testing to ascertain and identify the contribution of the fire-blocking layer to the enhancement of the fire resistivity (flame penetration, insulation, etc.) of the seat.

Cushioning materials make up over half the weight of nonmetallics in an aircraft passenger seat. From the standpoint of flammability, polymeric foam materials present quite a challenge. The enhancement of fire resistivity of polymeric foams is a problem because of their rather large surface area for the potential initiation of combustion. Resistance to ignition was the primary mandatory requirement for aircraft seat cushioning material candidates (Table 8). Heat release rate, development, and toxicity are of the first level of importance due to the amount of cushioning material used in aircraft passenger seats.

Of the nine cushioning materials, only four met dimensional criteria of being available in thicknesses from 7.6 cm (3 in.) to 10.2 cm (4 in.). They were the urethane baseline foam (No. 306), glass fiberblock foam (No. 300), HL neoprene foam (No. 307), and neoprene foam called Koylon Firm Foam (No. 308). The neoprene foam (No. 308) was dropped from the program due to smoke generation levels that exceeded the recommended limits of FAR 25.853(b) (Table 5). The other cushioning materials, although not available in the required thicknesses, could possibly be built to greater thicknesses by plying them or by using them in multilayer cushion constructions. Of all the cushioning materials tested, the glass fiberblock tested far above the baseline urethane foam and the other cushioning layer candidate materials. The glass fiberblock material did not ignite at all in the Pill test ASTM D 2859 and had the lowest NBS smoke generation value (Table 5). The HL neoprene foam (No. 307) was the next best cushioning material but there is room for improvement in the area of smoke production. HL neoprene was also low in toxicity (Figure 12).

A rather heavy flexible urethane foam (0.2 g/cm^3, sample No. 302) and a neoprene foam (sample No. 308) were dropped from the program because they

failed the recommended limits for smoke generation (Table 5). The silicone foam (Nos. 304 and 305) and the HL neoprene foam tested to FAA burn and smoke requirements; their only disadvantage is their density. The low toxicity values of the silicone foam's pyrolysis products in our animal toxicity studies (Table 5 and Figure 9) justify further study of these materials. The polyphosphazene APN foam (No. 307) was quite toxic in terms of time to incapacitation in our animal toxicity studies (Figure 10) and appeared weak mechanically; the sample was dropped from further consideration in this study.

Table 8 lists the candidate materials that met all the mandatory requirements for utilization in various aircraft seat components.

CONCLUSIONS

This study has attempted to critically ascertain the thermal response characteristics or fire resistivity of each component of an aircraft passenger seat. A data base has been constructed for a wide range of candidate fire resistant seat materials from which material selections have been made for incorporation in the next phase of this developmental program.

The criteria established in this program were in some cases at a higher level than standard tests. The modified burn test for materials that melt or drip, and by so doing are removed from the flame, and the Pill test for cushioning or foam materials, represent a higher seat material standard than current FAA requirements. The baseline fabric and foam in current use were entirely consumed during the modified burn test. The modified burn test more closely represents a combined material (fabric on foam) and is more in accord with an actual fire situation.

Some of the materials tested were still in the developmental state and the possibility exists that their thermal characteristics can be improved by making minor modifications in their formation. New materials that are being developed which are advantageous to the development of improved fire resistant aircraft passenger seats and meet the time constraints (commercial availability by 1980) will continue to be evaluated in the next phase of this program.

REFERENCES

1. L. L. Fewell, D. A. Kourtides, R. W. Rosser, and J. A. Parker: Conference on the Development of Fire Resistant Aircraft Passenger Seats, NASA TM X-73,144, August 1976.
2. Edward L. Trabold: Study to Develop Improved Fire Resistant Aircraft Passenger Seat Materials, Phase I. NASA CR-152056. Prepared under contract NAS2-9337, July 1977.
3. J. G. Gaume, P. Barter, and H. J. Rostami: Experimental Results on Time of Useful Function After Exposure to Mixtures of Serious Contaminants, Aerospace Medicine 42N09 987-99, September 1971.
4. A. J. Pryor, D. E. Johnson, and N. N. Jackson: Hazards of Smoke and Toxicology in Urban Fires, Combustion Toxicology, Vol. 2, No. 1, February 1975, pp. 64-112.
5. T. W. Maul, W. E. Walden, and D. A. Hoy: Effect of Heat on Swiss Albino Male Mice, NASA Grant NSG 2087, August 1975.
6. D. W. Van Krevelen: Some Basic Aspects of Flame Resistance of Polymeric Materials, Polymer. Vol. 16, August 1975, pp. 615-620.
7. J. R. Galloway, C. Anolick, C. W. Stewart, R. T. McSweeney, and P. R. Johnson: Flammability of Neoprene Cushioning Foam and the Neoprene Interliner System in Seating. Paper Presented at National Fire Protection Association Meeting, May 1976.

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2. Edward L. Trabold: Study to Develop Improved Fire Resistant Aircraft Passenger Seat Materials, Phase I. NASA CR-152056. Prepared under contract NAS2-9337, July 1977.
3. J. G. Gaume, P. Barter, and H. J. Rostami: Experimental Results on Time of Useful Function After Exposure to Mixtures of Serious Contaminants, Aerospace Medicine 42N09 987-99, September 1971.
4. A. J. Pryor, D. E. Johnson, and N. N. Jackson: Hazards of Smoke and Toxicology in Urban Fires, Combustion Toxicology, Vol. 2, No. 1, February 1975, pp. 64-112.
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6. D. W. Van Krevelen: Some Basic Aspects of Flame Resistance of Polymeric Materials, Polymer. Vol. 16, August 1975, pp. 615-620.
7. J. R. Galloway, C. Anolick, C. W. Stewart, R. T. McSweeney, and P. R. Johnson: Flammability of Neoprene Cushioning Foam and the Neoprene Interliner System in Seating. Paper Presented at National Fire Protection Association Meeting, May 1976.

Table 1. Candidate Aircraft Seat Materials Tested.

SAMPLE NO.	SAMPLE FORM	GENERIC TYPE	MATERIAL DESCRIPTION	DENSITY
100	FABRIC	AMIDE	100% NYLON, FIRE RETARD-ANT TREATED	389 g/m^2
101	FABRIC	AMIDE-IMIDE/WOOL BLEND	52.5% KERMEL/47.5% WOOL	290 g/m^2
102	FABRIC	COTTON	100% COTTON DOUBLE KNIT	335 g/m^2
103	DRAPERY FABRIC	ARAMID	100% NOMEX DENSITY	311 g/m^2
104	FABRIC	WOOL/AMIDE	BASELINE FABRIC 90% WOOL/ 10% NYLON	457 g/m^2
105	FABRIC	NOVOLOID/ ARAMID	50% KYNOL/50% NOMEX	319 g/m^2
106	FABRIC FOAM	AMIDE/ CHLOROPRENE	NYLON GOLD WITH VONAR #3 FOAM BACKING	1367 g/m^2
107	ELASTOMER ON FABRIC	URETHANE/ AMIDE	URETHANE ELASTOMER COATED ON NYLON FABRIC	385 g/m^2
200	FABRIC	NOVOLOID	100% KYNOL FABRIC (TWILL WEAVE)	244 g/m^2
201	FABRIC	NOVOLOID/ ARAMID	70% KYNOL/30% NOMEX (PERMANENT PRESS FINISHED)	200 g/m^2
202	FABRIC	NOVOLOID/ ARAMID	70% KYNOL/30% NOMEX (PERMANENT PRESS FINISHED)	159 g/m^2
203	FABRIC (NEEDLE PUNCH)	NOVOLOID (WITH SCRIM)	100% KYNOL BATTING ON POLYESTER SCRIM NEEDLE PUNCH	213 g/m^2
204	FABRIC	IMIDAZOLE	POLYBENZIMIDAZOLE FABRIC NATURAL AND UNSTABILIZED ZXI TWILL	273 g/m^2
205	BATTING	IMIDAZOLE	PBI (POLYBENZIMIDAZOLE) BATTING NATURAL UNSTA-BILIZED FROM STAPLE	118.7 g/m^2

Table 1. Continued.

SAMPLE NO.	SAMPLE FORM	GENERIC TYPE	MATERIAL DESCRIPTION	DENSITY
206	BATTING	IMIDAZOLE	BLACK COLORED BATTING (PROPRIETARY IN NATURE)	142.4 g/m^2
207	BATTING	NOVOLOID FIBER BATTING	REMAY SPUN BONDED POLYESTER FABRIC NEEDLED WITH 100% KYNOL FIBER	95 g/m^2
208	FOAM	POLYCHLOROPRENE	0.156 cm THICK NEOPRENE FOAM WITH COTTON SCRIM	42.5 g/cm^3
209	FOAM	POLYCHLOROPRENE	0.317 cm THICK NEOPRENE FOAM WITH COTTON SCRIM	723 g/cm^3
210	FOAM	POLYCHLOROPRENE	0.475 cm THICK NEOPRENE FOAM WITH COTTON SCRIM	954 g/cm^3
212	FABRIC		DURETTE UPHOLSTERY FABRIC	322 g/m^2
213	ELASTASTOMER	SILICONE	SILICONE RUBBER	2516 g/m^2
214	FABRIC	ARAMID	NOMEX III FABRIC	254 g/m^2
215	FABRIC	AMIDE-IMIDE	KERMEL FABRIC	250 g/m^2
216	BATTING		DURETTE BATTING	---
300	FOAM	GLASS	GLASS FIBER BLOCK CUSHION EDGE GRAIN BLOCKING OF GLASS FIBERS	0.03-0.06 g/cm^3
301	INORGANIC FOAM	POLY-PHOSPHAZENE	APN PHOSPHAZENE OPEN CELL FOAM	0.14 g/cm^3
302	FOAM	URETHANE	POLYURETHANE FOAM, FLEXIBLE	0.20 g/cm^3
303	ELASTOMER	SILICONE	SILICONE RUBBER SPONGE	0.15 g/cm^3
304	ELASTOMER	SILICONE	SILICONE RUBBER SPONGE (NIOSITES)	0.19 g/cm^3
305	ELASTOMER	SILICONE	SILICONE RUBBER SPONGE	0.21 g/cm^3
306	FOAM	URETHANE	BASELINE FOAM MATERIAL, POLYURETHANE FOAM, FIRE-RETARDANT TREATED	0.03 g/cm^3

Table 1. Concluded.

SAMPLE NO.	SAMPLE FORM	GENERIC TYPE	MATERIAL DESCRIPTION	DENSITY
307	FOAM	POLYCHLORO-PRENE	NEOPRENE FOAM	0.12 g/cm^3
308	FOAM	POLYCHLORO-PRENE	NEOPRENE FOAM	0.14 g/cm^3

Table 2. Test Screening Methods.

FABRIC SAMPLES	
MATERIAL PROPERTY	TEST METHOD
WEIGHT	METHOD 5041 - FEDERAL TEST METHOD STANDARD NO. 191 TEXTILE TEST METHODS
BURN	FAR 25.853* FAR 25.853*
NBS SMOKE	NBS TECHNICAL NOTE NO. 708**
LOI	ASTM D2863-70
TGA	HEATING RATE - 20° C/min IN AIR
FOAM SAMPLES	
MATERIAL PROPERTY	TEST METHOD
DENSITY	ASTM 1564 SUFFIX W
BURN	FAR 25.853 FAR 25.853 MODIFIED
NBS SMOKE	NBS TECH NOTE NO. 708
IGNITION	ASTM D2859
LOI	ASTM D2863-70
TGA	HEATING RATE - 20° C/min IN AIR

*FEDERAL AVIATION REGULATIONS PART 25 AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES.

**NBS TECHNICAL NOTE NO. 708; TEST METHOD FOR MEASURING THE SMOKE GENERATION CHARACTERISTICS OF SOLID MATERIALS.

Table 3. Decorative Fabric Cover - Comparisons.

REQUIREMENT	TEST METHOD	MATERIALS							
		BASELINE FABRIC (104)		FABRIC (100)		KERMEL BLEND (101)		100% COTTON DOUBLEKNIT (102)	
COLOR:	AVAILABILITY WIDE RANGE	YES		YES		YES		YES	
COLORFASTNESS	FTMS NO. 191	20SFH	40SFH	20SHF	40SHF	20SFH	40SFH	20SFH	40SFH
- LIGHT	*METHOD 5660	EXC	EXC	EXC	EXC	EXC	GOOD	FAIR	FAIR
- CROCKING	*METHOD 5651(B)	---	---	---	---	---	---	---	---
NBS SMOKE: (AGED AND NONAGED SPECIMENS)	NBS TECH NOTE 708 NONFLAMING, D_m 90 sec	28		4		21		40	
	4 min	73		12		38		41	
	FLAMING, D_m 90 sec	64		10		21		8	
	4 min	127		33		37		13	
FLAMMABILITY: BURN TEST FAR 25.853	BURN TIME	1	1	3	6	0	0	0	
	BURN LENGTH	2.3	2.6	2.8	2.8	4.5	5.0	4.5	
	DRIP	ND	ND	1	1	ND	ND	ND	
WEAR: ABRASION	*METHOD 5306 NO. 8 COTTON ASTM 1175 DUCK ABRADER	---		---		---		POOR 750cy 100 g CS-10 WHEEL	
TEAR	*METHOD 5132 k_g	>6.4	4.8	>6.4	>6.4	4.0	3.1	>6.4	>6.4
	lb								
IGNITION: PILL TEST	ASTM D 2859	NO BURN CHAR IN AREA OF PILL ON FOAM		SLIGHT BURNING OF FABRIC 1.9 cm DIAM ON FOAM		NO BURN CHAR IN AREA OF PILL ON FOAM		---	
TOXICITY: NORMALIZED DATA PER GRAM OF MATERIAL; 25-g MOUSE	AV T_i Min	0.83		2.89		1.40		---	
	AV T_d Min	2.59		4.00		3.13			

*FEDERAL TEST METHOD STANDARD NO. 191, TEXTILE TEST METHODS.

Table 3. Concluded.

REQUIREMENT	TEST METHOD	MATERIALS							
		BASELINE FABRIC (103)		FABRIC (105)		KERMEL BLEND (107)		COATED NYLON (106)	
COLOR:	AVAILABILITY, WIDE RANGE	NO		YES		NO		DISCONTINUED	
COLORFASTNESS	FTMS NO. 191	20SFH	40SFH	20SFH	40SFH	20SFH	40SFH	20SFH	40SFH
- LIGHT	*METHOD 5660	POOR	POOR	POOR	POOR	GOOD	GOOD	GOOD	GOOD
- CROCKING	*METHOD 5651(B)	---	---	---	---	---	---	---	---
NBS SMOKE: (AGED AND NONAGED SPECIMENS)	NBS TECH NOTE 708 NONFLAMING, D_m 90 sec	2		2		12		---	
	4 min	3		6		43		---	
	FLAMING, D_m 90 sec	6		11		30		---	
	4 min	12		19		46		---	
FLAMMABILITY:	BURN TIME	0	0	0	0	0	0	282**	
BURN TEST	BURN LENGTH	2.8	2.6	2.3	2.5	4.9	4.6	10.3**	
FAR 25.853	DRIP	ND	ND	ND	ND	1	0	ND	
WEAR: ABRASION	*METHOD 5306 NO. 8 COTTON ASTM 1175 DUCK ABRADER	---		---		---		---	
TEAR	*METHOD 5132	22 k cycles							
	kg	>6.4	>6.4	>6.4	>6.4	2.5	3.2	>6.4	>6.4
	lb								
IGNITION: PILL TEST	ASTM D	NO BURN CHAR IN AREA OF PILL ON FOAM		NO BURN CHAR IN AREA OF PILL 1.27 cm DIAM ON FOAM		NO BURN CHAR IN AREA OF PILL 2.54 cm ON FOAM		---	
TOXICITY: NORMALIZED DATA PER GRAM OF MATERIAL; 25-g MOUSE	AV T_i min	0.82		1.74		1.83		---	
	AV T_d min	2.54		5.54		3.45			

**FAILED REQUIREMENTS.

Table 4. Fire Blocking Layers - Comparisons.

REQUIREMENT	TEST METHOD	MATERIALS					
		BLACK BATTING (206)	"FLAMEOUT" KYNOL ON REMAY (207)	VONAR NO. 1 NEOPRENE FOAM (208)	VONAR NO. 2 NEOPRENE FOAM (209)	VONAR NO. 3 NEOPRENE FOAM (210)	DURETTE UPHOLSTERY (212)
IGNITION	PILL TEST ASTM D 2559	0.8 IN CHAR AREA AROUND PILL ON FOAM	NO BURN CHAR IN AREA OF PILL	---	---	NO BURN CHAR IN PILL AREA	NO BURN 10.2 cm DIAM CHAR
BURN TEST	FAR 25.853						
	BURN TIME	0 0	0 0	0 0	0 0	0 0	0 0
	BURN LENGTH	1.7 1.9	2.3 2.3	2.6 2.2	2.0 1.6	1.7 1.6	1.3 1.3
	DRIP	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
NBS SMOKE (AGED AND NONAGED SPECIMENS)	NBS NOTE 708 NONFLAMING,						
	D_m 90 sec	0	2	22	30	40	0
	4 min	2	8	34	57	98	3
TGA BASED ON WEIGHT LOSS/m^2	FLAMING,						
	D_m 90 sec	1	3	30	45	70	8
	4 min	0	3	43	78	136	15
	PARAGRAPH 3.3	139 g	95 g	---	---	591.5 g	148.1 g
FLAME SPREAD AT 5.0 W/cm^2	PARAGRAPH 3.5.3 mm/sec	ND	---	FLASH VERT	---	0.9	4
TOXICITY NORMALIZED DATA PER GRAM; 25-g MOUSE	PARAGRAPH 3.5.2						
	AV T_i min	0.20	2.59	10.54	---	10.99	0.71
	AV T_d min	0.31	4.40	21.05	---	LIVED	1.27
WEAR	FTMS NO. 191 METHOD 5132						
TEAR	k_g	1.01 0.91	1.19 1.09	---	---	---	>6.4 >6.4
	lb	2.24 2.01	2.61 2.41				

Table 4. Continued.

REQUIREMENT	TEST METHOD	MATERIALS					
		BLACK BATTING (206)	"FLAMEOUT" KYNOL ON REMAY (207)	VONAR NO. 1 NEOPRENE FOAM (208)	VONAR NO. 2 NEOPRENE FOAM (209)	VONAR NO. 3 NEOPRENE FOAM (210)	DURETTE UPHOLSTERY (212)
IGNITION	PILL TEST ASTM D 2559	0.8 IN CHAR AREA AROUND PILL ON FOAM	NO BURN CHAR IN AREA OF PILL	---	---	NO BURN CHAR IN PILL AREA	NO BURN 10.2 cm DIAM CHAR
BURN TEST	FAR 25.853						
	BURN TIME	0 0	0 0	0 0	0 0	0 0	0 0
	BURN LENGTH	1.7 1.9	2.3 2.3	2.6 2.2	2.0 1.6	1.7 1.6	1.3 1.3
	DRIP	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
NBS SMOKE (AGED AND NONAGED SPECIMENS)	NBS NOTE 708 NONFLAMING,						
	D_m 90 sec	0	2	22	30	40	0
	4 min	2	8	34	57	98	3
TGA BASED ON WEIGHT LOSS/m^2	FLAMING,						
	D_m 90 sec	1	3	30	45	70	8
	4 min	0	3	43	78	136	15
	PARAGRAPH 3.3	139 g	95 g	---	---	591.5 g	148.1 g
FLAME SPREAD AT 5.0 W/cm^2	PARAGRAPH 3.5.3 mm/sec	ND	---	FLASH VERT	---	0.9	4
TOXICITY NORMALIZED DATA PER GRAM; 25-g MOUSE	PARAGRAPH 3.5.2						
	AV T_i min	0.20	2.59	10.54	---	10.99	0.71
	AV T_d min	0.31	4.40	21.05	---	LIVED	1.27
WEAR	FTMS NO. 191 METHOD 5132						
TEAR	k_g	1.01 0.91	1.19 1.09	---	---	---	>6.4 >6.4
	lb	2.24 2.01	2.61 2.41				

Table 4. Concluded.

REQUIREMENT	TEST METHOD	MATERIALS				
		SILICONE ELASTOMER (213)	NOMEX III (214)	KERMEL FABRIC (215)	DURETTE BATTING 400-11 (216)	DURETTE DUCK 400-6 (217)
IGNITION	PILL TEST ASTM D 2559	NO BURN CHAR IN AREA OF PILL	NO BURN 40.6 cm DIAM CHAR IN AREA OF PILL	---	---	---
BURN TEST	FAR 25.853(b)					
	BURN TIME	0 0	2 0	1 2	0 0	
	BURN LENGTH	0.1 0.1	2.7 2.7	2.2 2.4	0.6 0.7	---
	DRIP	ND ND	ND ND	ND ND	ND ND	
NBS SMOKE (AGED AND NONAGED SPECIMENS)	NBS NOTE 708					
	NONFLAMING, D_m 90 sec	0	1	3	0	---
	4 min	11	5	10	1	
TGA	FLAMING, D_m 90 sec	7	8	6	6	---
BASED ON WEIGHT LOSS/m^2	4 min	26	16	16	11	
	PARAGRAPH 3.3	377.4 g	68.6 g			
FLAME SPREAD 5.0 W/cm^2	PARAGRAPH 3.5.3 mm/sec	---	>6	>6	NONE	FLASH 7.5
TOXICITY NORMALIZED DATA PER GRAM; 25-g MOUSE	PARAGRAPH 3.5.2					
	AV T_i min	---	0.98	1.5	0.80	0.75
	AV T_d min	---	2.63	2.29	1.46	1.75
WEAR TEAR	FTMS NO. 191 k_g		5.4 3.3	4.4 6.2	---	---
	METHOD 5132 lb		11.8 7.2			

Table 5. Cushioning Layers - Comparisons.

REQUIREMENT	TEST METHOD	MATERIAL				
		URETHANE BASELINE (306)	GLASS FIBER BLOCK (300)	APN PHOSPHAZENE (301)	HYPOL FOAM (302)	SILICONE FOAM (303)
BURN TEST	FAR 25.853					
WARP	BURN TIME	1	0	0		3
	BURN LENGTH	2.8	0.1	0.8	---	0.9
	DRIP BURN TIME	ND	ND	ND		ND
FILL	BURN TIME	---	---	---	---	---
	BURN LENGTH					
	DRIP BURN TIME					
NBS SMOKE	NBS TECH. NOTE 708					
	FLAMING 90 sec	27	4	43		31
	4 min	37	6	89		67
	NONFLAMING 90 sec	51	5	14	---	47
	4 min	134	8	113		163
TGA BASED ON WEIGHT LOSS PER 0.28 m^3 (1 ft^3)		1.68 kg	0.20 kg-0.41 kg	2.30 kg	---	1.83 kg
TOXICITY ANIMAL TOXICITY PER 3.5.2	AV T_i min	1.95	---	2.9	---	6.74
	AV T_d min	3.18	---	26.6	---	7.69
INDENTATION LOAD	ASTM 1564 METHOD A	10.2 cm (4.0 in.)	12.1 cm (4.75 in.)			
	25%	195.7-222.4 N (44.5 lb)	41.9 N (9.41 lb)	---	155.7 N (35 lb)	---
DEFLECTION (ILD)	SECT 19-26 65%		252.6 N (56.8 lb)		889.6 N (200 lb)	
COMPRESSION SET	ASTM 1564 SECT 12-18	AT 80% = 5% AT 90% = 10%	---	---	32%	---

Table 5. Continued.

REQUIREMENT	TEST METHOD	MATERIAL				
		URETHANE BASELINE (306)	GLASS FIBER BLOCK (300)	APN PHOSPHAZENE (301)	HYPOL FOAM (302)	SILICONE FOAM (303)
BURN TEST	FAR 25.853b					
WARP	BURN TIME	1	0	0	---	3
	BURN LENGTH	2.8	0.1	0.8		0.9
	DRIP BURN TIME	ND	ND	ND		ND
FILL	BURN TIME	---	---	---	---	---
	BURN LENGTH					
	DRIP BURN TIME					
NBS SMOKE	NBS TECH. NOTE 708					
	FLAMING 90 sec	27	4	43		31
	4 min	37	6	89	---	67
	NONFLAMING 90 sec	51	5	14		47
	4 min	134	8	113		163
TGA BASED ON WEIGHT LOSS PER 0.028 m^3 (1 ft^3)		1.68 kg	0.20 kg-0.41 kg	2.30 kg	---	1.83 kg
TOXICITY ANIMAL TOXICITY PER 3.5.2	AV T_i min	1.95	---	2.9	---	6.74
	AV T_d min	3.18	---	26.6	---	7.69
INDENTATION LOAD	ASTM 1564 METHOD A	10.2 cm (4.0 in.)	12.1 cm (4.71 in.)			
	25%	195.7-222.4 N	41.9 N (9.41 lb)	---	155.7 N (35 lb)	---
DEFLECTION (ILD)	SECT 19-26 65%	(40-50 lb)	252.6 N (56.8 lb)		889.6 N (200 lb)	
COMPRESSION SET	ASTM 1564 SECT 12-18	AT 80% = 5% AT 90% = 10%		---	32%	---

Table 5. Concluded.

REQUIREMENT	TEST METHOD	MATERIAL			
		SILICONE FOAM (304)	SILICONE FOAM (305)	NEOPRENE FOAM (307)	KOYLON FIRM FOAM (308)
BURN TEST	FAR 25.853b				
WARP	BURN TIME	0	90	0	0
	BURN LENGTH	1.5	0.8	1.0	1.2
	DRIP BURN TIME	ND	ND	ND	ND
FILL	BURN TIME	---	---	---	0
	BURN LENGTH				1.4
	DRIP BURN TIME				ND
NBS SMOKE	NBS TECH. NOTE 708				
	FLAMING				
	90 sec	51	54	84	122
	4 min	115	100	165	231*
	NONFLAMING				
	90 sec	42	2	45	107
	4 min	113	17	115	222*
TGA BASED ON WEIGHT LOSS PER 0.028 m^3 (1 ft^3)		2.69 kg	3.12 kg	2.04 kg	---
TOXICITY ANIMAL TOXICITY PER 3.5.2					
	AV T_i min	6.81	4.77	13.13	2.58
	AV T_d min	8.34	6.0	23.61	9.06
INDENTATION LOAD	ASTM 1564 METHOD A	1334.4 N (300 lb)	1334.4 N (300 lb)	6.4 cm (2.5 in.)	---
	25%	12232.0 N	9563.2 N	164.6 N (37 lb)	
DEFLECTION (ILD)	SECT 19-26 65%	(2750 lb)	(2150 lb)	725.0 N (163 lb)	
COMPRESSION SET	ASTM 1564 SECT 12-18	at 50%-30%			---

*FAILED REQUIREMENT.