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Propulsion Section, NA-542
TECHNICAL INFORMATION SHEET NO. 15
Flammability Characteristics of Boeing Aircraft Interior Materials
Project No. 510-001-11X
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Summary:

A recent survivable crash landing of a Boeing 727 transport airplane resulted in heavy loss of life to passengers from exposure to fire and combustion products within the cabin. As a result of extensive fire damage sustained by the cabin interior materials, attention has been directed to possible deficiencies in the flame/fire resistance of the materials as an important factor affecting the safety of passengers attempting evacuation. A test program was initiated to satisfy inquiries on the flammability, smoke and toxic characteristics of the cabin materials presumably involved in the Salt Lake City crash of November 1965. Smoke and toxic data was obtained separately and concurrently with the cooperation of the Bureau of Standards and is contained in a separate report.

Conclusions:

All of the cabin materials tested, with the possible exception of only one which was borderline, passed the present FAA requirements for a burn rate of four inches per minute or less. Materials differed widely in their degree of flame resistance as shown by the test data with many of the materials being self-extinguishing in both the horizontal and vertical positions. The vertical burn and radiant panel test methods provided means for determining flammability of materials by a more severe criteria. Materials with a low flame spread-index number generally show a high degree of flame resistance as in the Bunsen burner exposure tests. Many of the materials show a tendency to flash fire when subjected to radiant heating in the presence of a flame.

Procedures:

Tests were conducted on the materials in accordance with the procedures and utilizing the apparatus specified for the particular specified standard laboratory test method. Three test methods were employed:

1. Method 5906 (Federal Specification CCC-T-191b and FSS Release 453):

Ignition time, flaming time, burn length and burn rate were measured for each of the materials suspended horizontally over a 1 1/2-inch Bunsen burner flame for an indefinite time.

2. Method 5902 (Federal Specification CCC-T-191b):

Ignition time, flaming time, burn and char length and burn rate were measured for each of the materials suspended vertically directly above a 1 1/2-inch Bunsen burner flame for a period of 12 seconds only.

3. Method NBS Radiant Panel (Interim Federal Standard 00136b):

Ignition time, burn length, burn rate, heat factor, flame-spread factor, flame-spread index and smoke factor were measured for each of the materials suspended at an angle of 45° in front of a 12" x 18" size radiant panel heated to a temperature of 1238°F.

The materials tested were obtained directly from a major commercial airline. A list and a description of the materials as furnished by the supplier are contained in Table I.

TABLE I
Boeing 727 Materials

No.	Description	Thickness (in.)	Weight (lbs/sq. yd.)	Manufacturer
1	Wool Curtain	0.035	0.69	E. F. Timme Co.
2	Verel Curtain	0.030	0.60	Orinoka Mills
3	Verel/Wool Curtain	0.055	0.86	E. F. Timme Co.
4	Wool Upholstery	0.050	0.82	E. F. Timme Co.
5	Naugahyde Fabric	0.030	0.76	U.S. Rubber Co.
6	Expanded Vinyl	0.045	1.61	Columbus Coated Co.
7	Acrilan Carpet with Curon	0.325	3.84	Gulistan
8	Herculon Carpet	0.100	1.93	E. F. Timme
9	Royalite Flex. ABS	0.046	2.91	U.S. Rubber Co.
10	Boltaron Rigid ABS	0.045	2.35	General Tire Co.

TABLE I (Continued)
Boeing 727 Materials

No.	Description	Thickness (in.)	Weight (lbs/sq. yd)	Manufacturer
11	Cycolac Rigid ABS	0.080	4.12	Marbon Chem. Co.
12	Kydex	0.080	5.04	Rohm & Haas
13	Polyplastix ABS/Mylar	0.030	1.65	Polyplastix Co.
14	Polyplastix Vinyl/Mylar	0.020	1.27	Polyplastix Co.
15	Polyether Urethane Cushion	0.500	0.86	General Tire Co.

Note: No. 4 material appears to be incorrectly labeled since it readily melts when burned.

Results:

Flammability data on the cabin interior materials submitted for tests are given in Tables II, III and IV.

The degree of flame resistance of the materials when ignited in the horizontal position is shown in Table II.

TABLE II
Flammability by Test Method 5906 (FSS Release 453) - Horizontal Position

Material No.	Ignition Time (min.)	Total Flaming Time (min.)	Total Burn Length (in.)	Burn Rate (in./min)	Remarks
1	0.07	1.03	2.0	1.0	Light smoke.
1	0.06	1.50	3.0	1.5	
1	0.08	0.80	1.4	I	
Average	0.07	1.11	2.1		
2	0.01	0.28	0.5	I	
2	0.01	0.25	0.5	I	
2	0.02	0.25	0.4	I	
Average	0.01	0.26	0.5	I	

TABLE II (Continued) *

Flammability by Test Method 5906 (FSS Release 453) - Horizontal Position

Material No.	Ignition Time (min.)	Total Flaming Time (min.)	Total Burn Length (in.)	Burn Rate (in./min)	Remarks
3	0.10	0.40	0.6	I	
3	0.10	0.40	0.5	I	
3	0.20	0.38	0.5	I	
Average	0.13	0.40	0.5	I	
4	0.03	0.31	0.5	I	Melts. Incorrectly
4	0.04	0.27	0.5	I	labeled - Not wool
4	0.05	0.32	0.8	I	
Average	0.04	0.30	0.6	I	
5	0.05	1.01	1.6	0.5	Some flashing. Lt. smoke
5	0.07	0.80	1.5	I	Some flashing. Lt. smoke
5	0.05	0.76	1.5	I	
Average	0.06	0.86	1.5		
6	0.20	0.80	1.3	I	Some flashing. Moderate
6	0.10	1.00	0.9	I	smoke.
6	0.10	0.50	1.8	1.3	
Average	0.13	0.76	1.0		
7	0.04	15.56	X	0.8	Padding intensifies
7	0.09	17.11	X	0.7	burning. Heavy black
7	0.08	12.90	X	0.9	smoke
Average	0.07	15.19	X	0.8	
8	0.17	9.4	X	1.2	Melts and drips burning
8	0.18	11.2	X	1.0	droplets.
8	0.15	10.3	X	1.1	
Average	0.16	10.3	X	1.1	
9	0.05	1.70	0.9	I	Light black smoke and
9	0.06	1.73	1.0	I	soot.
9	0.06	1.00	1.0	I	
Average	0.06	1.48	1.0	I	

TABLE II (Continued) *
Flammability by Test Method 5906 (FSS Release 453) - Horizontal Position

Material No.	Ignition Time (min.)	Total Flaming Time (min.)	Total Burn Length (in.)	Burn Rate (in./min.)	Remarks
10	0.08	3.30	X	4.1	Melts and drips
10	0.10	3.57	X	3.8	burning droplets.
10	0.08	3.75	X	4.3	Heavy smoke and soot.
Average	0.09	3.54	X	4.1	
11	0.06	5.18	X	2.1	Melts and drips
11	0.09	5.07	X	2.2	burning droplets.
11	0.09	5.82	X	2.2	High flames. Very heavy
Average	0.08	5.39	X	2.2	smoke and soot.
12	0.12	1.25	0.5	I	
12	0.12	1.31	0.5	I	
12	0.08	2.62	0.5	I	
Average	0.10	1.63	0.5	I	
13	0.12	0.84	0.7	I	
13	0.02	0.93	0.7	I	
13	0.02	0.91	0.7	I	
Average	0.05	0.90	0.7	I	
14	0.01	0.86	0.5	I	Lt. smoke. Glow time
14	0.03	0.72	0.5	I	1.57 min.
14	0.05	0.70	0.5	I	Lt. smoke. Glow time
Average	0.03	0.76	0.5	I	1.85 min.
15	0.01	1.21	X	10.0	Burns rapidly. Lt. smoke.
15	0.01	1.34	X	10.5	
15	0.01	1.61	X	6.6	
Average	0.01	1.39	X	9.0	

* FSS Release 453 specifies a burn rate of four inches per minute or less.

Note: (1) I - designates that material was self-extinguishing within 1 1/2 inches burn length (i.e. zero (0) burn rate).

(2) X- designates that material was not self-extinguishing since it burned completely (12 inches).

(3) Materials No. 9 and 13 designated as ABS plastics produced HCL gas in separate tests.

TABLE III

Flammability by Test Method 5902 - Vertical Position

Material No.	Ignition Time (min.)	Flaming Time (Measured After 12 sec. Burner Removal) (min.)	Total Burn Length (in.)	Char Length (in.)	Burn Rate (12 sec. Burner Time Included) 0-12 in. (in./min)	Burn Rate (12 sec. Burner Time Included) 12 in. (in./min)	Remarks
1	0.05	0.83	X	12.0	X	12.2	
1	0.08	0.84	X	12.0	X	12.4	
1	0.07	1.21	X	12.0	X	8.7	
Average	0.07	0.96	X	12.0	X	11.1	
2	0.04	0.00	1.8	0.5	11.2	I	Glowing time - 0.04 min.
2	0.04	0.00	1.7	1.0	10.6	I	Light smoke.
2	0.04	0.00	1.4	0.5	8.8	I	Shrinks from flame.
Average	0.04	0.00	1.6	0.7	10.2	I	
3	0.10	0.75	X	12.0	X	14.1	
3	0.10	0.75	X	12.0	X	14.1	
3	0.05	1.01	X	12.0	X	10.4	
Average	0.08	0.84	X	12.0	X	12.9	
4	0.05	0.55	5.1	5.1	7.3	I	Melts and drips burning
4	0.05	0.48	5.1	5.1	8.1	I	droplets.
4	0.05	0.66	6.2	6.2	7.7	I	Incorrectly labeled -
Average	0.05	0.56	5.5	5.5	7.7	I	Not Wool
5	0.10	0.09	3.1	2.5	16.3	I	
5	0.10	0.14	2.0	1.5	8.3	I	
5	0.10	0.13	2.6	2.0	11.3	I	
Average	0.10	0.12	2.6	2.0	12.0	I	

TABLE III (Continued)

Flammability by Test Method 5902 - Vertical Position

Material No.	Ignition Time (min.)	Flaming Time (Measured After 12 sec. Burner Removal) (min.)	Total Burn Length (in.)	Char Length (in.)	Burn Rate (12 sec. Burner Time Included) 0-12 in. (in./min)	Burn Rate (12 sec. Burner Time Included) 12 in. (in./min)	Remarks
6	0.10	0.35	6.8	5.7	10.5	I	High flames - heavy smoke - gases produced small explosion to extinguish flaming. Backing the more flammable of the two surfaces.
6	0.10	0.42	8.1	5.0	15.5	I	
6	0.10	0.47	5.1	3.1	9.0	I	
Average	0.10	0.48	6.7	4.6	11.7	I	
7	0.20	4.95	X	12.0	X	2.4	High flames. Very heavy smoke.
7	0.20	5.45	X	12.0	X	2.2	
7	0.10	4.68	X	12.0	X	2.5	
Average	0.16	5.03	X	12.0	X	2.4	
8	0.10	4.85	X	12.0	X	2.4	
8	0.02	3.39	X	12.0	X	3.5	Glow time - 5.20 min.
8	0.02	3.39	X	12.0	X	3.5	Glow time - 5.56 min.
Average	0.05	3.84	X	12.0	X	3.1	
9	0.07	0.00	1.1	0.6	8.5	I	Glow time - 0.05 min.
9	0.05	0.00	1.1	0.5	7.3	I	Some flashing.
9	0.02	0.08	1.2	0.8	4.6	I	
Average	0.05		1.1	0.6	6.8	I	

TABLE III (Continued)

Flammability by Test Method 5902 - Vertical Position

Material No.	Ignition Time (min.)	Flaming Time (Measured after 12 sec. Burner Removal) (min.)	Total Burn Length (in.)	Char Length (in.)	Burn Rate (12 sec. Burner Time Included) 0-12 in. (in./min)	Burn Rate (12 sec. Burner Time Included) 12 in. (in./min)	Remarks
10	0.08	1.99	X	12.0	X	5.8	Melts & drips burning droplets. Very heavy smoke and soot.
10	0.08	1.05	X	12.0	X	10.3	
10	0.05	2.88	X	12.0	X	4.0	
Average	0.07	2.00	X	12.0	X	6.7	
11	0.05	1.42	X	12.0	X	7.7	Melts and drips burning droplets. Very heavy smoke.
11	0.05	1.19	X	12.0	X	9.0	
11	0.05	1.83	X	12.0	X	6.0	
Average	0.05	1.48	X	12.0	X	7.6	
12	0.02	0.00	2.1	1.2	11.6	I	Light smoke. Material softens like rubber.
12	0.02	0.00	0.6	0.2	3.3	I	
12	0.04	0.02	0.3	0.1	12.5	I	
Average	0.03	0.01	1.0	0.5	9.1	I	
13	0.02	0.62	4.2	2.1	5.3	I	Moderate smoke & soot. Some flashing.
13	0.02	1.38	6.6	5.5	4.2	I	
13	0.02	1.89	6.6	5.5	3.1	I	
Average	0.02	1.30	5.8	4.4	4.2	I	

TABLE III (Continued)

Flammability by Test Method 5902 - Vertical Position

Material No.	Ignition Time (min.)	Flaming Time Measured After 12 sec. Burner Removal (min.)	Total Burn Length (in.)	Char Length (in.)	Burn Rate (12 sec. Burner Time Included) 0-12 in. (in./min)	Burn Rate (12 sec. Burner Time Included) 12 in. (in./min)	Remarks
14	0.02	0.00	2.8	1.1	15.6	I	Light smoke.
14	0.02	0.00	2.2	1.1	12.2	I	
14	0.02	0.02	2.8	1.6	14.0	I	
Average	0.02	0.01	2.6	1.3	14.0	I	
15	0.01	0.10	X	12.0	X	41	Burns extremely rapidly.
15	0.01	0.07	X	12.0	X	43	Light smoke. Sample
Average	0.01	0.09	X	12.0		42	approx. 1/2 thick.

Notes: I - designates that material was self-extinguishing within 12 inches burn length.
X - designates that material was not self-extinguishing since it burned completely (12 inches).

TABLE IV

Flammability by NBS Radiant Panel

Material No.	Ignition Time (min.)	Burn Length (in.)	Burn Rate (Initial 3-inch length (in./min)	Smoke Factor (mg.)	Heat Factor (°C)	Flame Spread (F_s)	Flame Spread Index (I_s)	Coefficient of Variation (%)	Remarks
1	0.18	X	9.6	0.7	63	20.2	222		
1	0.15	X	9.0	0.9	63	20.3	224		
Average	0.17		9.3	0.8	63	20.3	223	0.5	
2	0.41	0	0	0.4	5	1.00	1		Some flashing.
2	0.41	6-9	7.3		11	8.70	17		
Average	0.41			0.4	8	4.85	9	88	
3	0.17	6-9	7.3	0.4	37	10.2	66		Some flashing. Melts.
3	0.08	9-12	7.5		46	19.6	157		
3	0.09	9-12	5.6		52	22.7	207		
Average	0.11		6.8		45	17.5	143	41	
4	0.18	12-15	3.8	0.4	13	9.05	21		Melts and drips.
4	0.18	12-15	4.0		10	11.3	20		
4	0.18	9-12	4.9		4	7.92	6		
Average	0.18		4.2		9	9.43	16	7	
5	0.07	12-15	11.5	1.3	75	35.4	464		Severe flashing.
5	0.09	X	3.2		55	29.4	283		
5	0.09	X	2.8		47	20.6	170		
Average	0.08		5.8		59	28.5	306	37	

TABLE IV (Continued)

Flammability by NBS Radiant Panel

Material No.	Ignition Time (min.)	Burn Length (in.)	Burn Rate (Initial 3-inch length (in./min)	Smoke Factor (mg.)	Heat Factor (°C)	Flame Spread (F_s)	Flame Spread Index (I_s)	Coefficient of Variation (%)	Remarks
6	0.05	12-15	12.0	1.2	69	20.4	247		Some flashing.
6	0.08	X	14.2		63	30.2	333		
6	0.08	X	13.6		56	28.0	275		
Average	0.07		13.3		63	26.2	285	12	
7	0.09	X	3.9	0.3	183	12.3	395		Pad flashes.
7	0.10	X	3.9		147	10.2	267		
7	0.11	X	4.0		121	10.4	219		
Average	0.10	X	3.9		150	11.0	294	25	
8	0.25	X	4.5	0.4	127	11.8	261		
9	0.10	9-12	2.6	0.3	51	15.9	142		Some flashing.
9	0.20	9-12	5.1	0.7	37	7.03	96		
9	0.11	12-15	2.7	0.3	47	11.4	94		
Average	0.14		3.1	0.4	45	11.4	113	42	
10	0.15	X	4.2	0.7	111	8.05	156		Melts and drips. Very heavy black smoke and soot.
10	0.10	X	5.2		85	15.1	225		
10	0.09	X	5.0		91	15.8	252		
Average	0.11	X	4.8		96	13.0	211	19	

TABLE IV (Continued)

Flammability by NBS Radiant Panel

Material No.	Ignition Time (min.)	Burn Length (in.)	Burn Rate (Initial 3-inch length) (in./min)	Smoke Factor (mg.)	Heat Factor (°C)	Flame Spread (F_s)	Flame Spread Index (I_s)	Coefficient of Variation (%)	Remarks
11	0.28	X	4.7	0.6	66	19.8	229		Melts and drips
11	0.11	X	4.2	0.7	183	11.7	374		burning d: plets.
11	0.24	X	4.7		189	10.1	334		Very heavy black
Average	0.21	X	4.5	0.6	146	13.9	312	20	smoke and soot.
12	0.14	6-9	0.5	0.3	25	2.29	10		
12	0.14	9-12	0.6	0.5	33	3.45	20		Some flashing.
12	0.10	9-12	0.9	0.3	45	2.41	19		
Average	0.13	9-12	0.7	0.4	31	2.72	16	4.5	
14	0.08	3-6	2.0	0.4	1	4.54	1		
14	0.09	3-6	2.4	0.5	1	3.66	1		
14	0.08	3-6	2.2	0.5	1	3.59	1		
Average	0.08	3-6	2.2	0.5	1	3.93	1	0.0	

Notes: (1) X - designates that material was not self-extinguishing since it burned completely (15 inches).

(2) Materials No. 13 and 15 were not tested because of sample shortage. Material No. 15 consisting of 1-inch thick Polvether Urethane foam tested earlier (Report ADS-3) showed a flame-spread index of 864.

The data in Table II for horizontal flammability show that the Wool/Verel fabrics used in the upholstery and curtains are self-extinguishing with a burn length of 1.5 inches or less (i.e. zero burn rate). The vinyl coated cotton fabric (Naugahyde) also showed a similar high degree of flame resistance. The two carpet materials burned completely in this test and thus were not self-extinguishing. However, their burn rates were only about one inch per minute compared to the four inch per minute maximum allowable burn rate. The remainder of the materials except for the polyether urethane pad consisted of semi-rigid plastics. These showed a high degree of flame resistance with the notable exception of two materials (No. 10 and 11). The most flammable material tested was Boltaron ABS (No. 10) which constituted a borderline failure with an average burn rate of 4.1 inches per minute. Polyether urethane material is not required to meet the requirements of flame resistance. With a burn rate of about ten inches per minute, this material meets the flash resistance requirements of 20 inches per minute or less burn rate.

The data in Table III for vertical flammability show that only the Verel fabric (No. 2) and the Naugahyde fabric (No. 5) were self-extinguishing among the five fabrics tested. Wool fabric (No. 1) as has been noted elsewhere (Report ADS-44) is not self-extinguishing by this test method. Of the fifteen materials tested, eight materials were self-extinguishing in the vertical position as compared to ten materials in the horizontal position. A very wide range in flame resistance of the semi-rigid plastics is apparent from the test data. Royalite (No. 9), Kydex (No. 12) and Polyplastix Vinyl/Mylar (No. 14) were outstanding among the plastics as was Verel among the fabrics in their superior flame resistance.

The degree of flame resistance of the materials when subjected to the heat of a radiant panel is shown in Table IV. The data show that materials that are difficult to burn in the Bunsen burner flame tests have generally low flame-spread index numbers. The majority of the materials show what would be generally considered a rather high flame-spread index number which exceeds 200 (Red oak - 100). Only four materials had a desirable index of 50 or less. These consisted of the Verel fabric (No. 2), Kydex (No. 12) and Polyplastix Vinyl/Mylar (No. 14) which were outstanding by this test method as similarly by the other two test methods. Most of the materials tested exhibited a tendency for flames to flash across the specimen surface exposed to radiant heat. Heavy black smoke was noted with the more flammable materials.