DATA REPORT NO. 110

PROPULSION AND FIRE PROTECTION BRANCH, ANA-420

ACTIVITY 920-003-14T

FIRE RESISTANCE, FLAMMABILITY AND SMOKE CHARACTERISTICS OF RAIL TRANSIT CAR BODY STRUCTURAL PANELS

Prepared by

Eldon B. Nicholas

August 1974

Federal Aviation Administration
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

INTRODUCTION

Purpose

To determine the fire resistance, flammability and smoke characteristics of rail transit car body structural panels and materials.

Background

The Boeing Vertol Company of Philadelphia, Pennsylvania, having a contract with the Department of Transportation for the development of transit car interiors, requested that the National Aviation Facilities Experimental Center (NAFEC) conduct fire resistance tests on fabricated assemblies representative of the side construction of a typical transit car body. In addition to the fire resistance tests, flammability and smoke characteristic tests of some of the assembly component were requested.

This work was accomplished through an agreement between the Federal Aviation Administration, NAFEC, and the Boeing Vertol Company, Agreement No. NAFEC 237, Activity No. 920-003-14T. A copy of this agreement is included as attachment 1.

DISCUSSION

Test Methods

The test methods utilized to determine the fire resistance, flammability, smoke and carbon monoxide characteristics of the assemblies and materials provided through the Boeing Vertol Company are described below:

Two-Gallon-per-Hour Kerosene Burner: This method was used to determine the fire and heat penetration resistance of the fabricated assemblies.

The 2-gph kerosene burner consists of a converted oil burner modified to produce a 2000°F flame with a total heat flux of 16 Btu per sq ft per sec and an approximately 6- by 11-inch elliptical flame pattern on the test specimen.

The burner simulates the heat output of a large fuel fire and is normally used in the NAFEC laboratory to test the fire resistance of aircraft fuselage sections. However, since the purpose of this test was to examine the effect of a platform or trash fire on a transit car body exterior, the burner was positioned such that a temperature of approximately 1650°F was recorded on the exterior surface of the panel.

The 2-foot-square panel was bolted or clamped to the open end of a 16-cubic-foot closed rectangular box. A glass window at the opposite end of the box allowed for observation and movies of the panel's interior surface.

Temperatures were measured (1) near the flame exposed surface of the test panel (flame temperature); (2) behind the insulation material; (3) on the interior surface of the test panel (3 thermocouples with spring tension against the surface); and (4) inside the test box, 1½ to 2 inches from the surface of the panel.

In addition to temperature measurements, the test box is equipped with a photometer for measuring the smoke density, utilizing a photocell/light source to measure the percentage of light transmission through a distance of 2 feet.

Radiant Panel: A detailed description of this test method is found in part 14 of the American Society for Testing and Materials (ASTM) standards as E-162-67, titled, "Surface Flammability of Materials Using a Radiant Heat Energy Source."

Basically this test method employs a radiant heat source consisting of a 12-by 18-inch panel operating at a temperature of 1238°F in front of which is placed an inclined 6- by 18-inch specimen. The orientation of the specimen is such that ignition is forced by a pilot flame impinging on the upper edge and the flame front progresses downward.

A factor derived from the rate of progress of the flame front and another relating to the rate of heat liberation by the material are combined to provide a flame spread index (I_s).

NBS Smoke Chamber: This method was utilized to determine the levels of smoke and carbon monoxide generated during combustion of the materials.

The test employs an electrically heated radiant energy source producing an irradiance level of 2.2 Btu per sq sec on the surface of a vertically mounted 3- by 3-inch specimen. In addition to the radiant heat source, a six-tube burner is provided to apply a row of premixed (air-propane) flamelets across the lower edge of the specimen. The materials are tested for two fire exposure conditions, (1) smoldering or nonflaming and (2) flaming, within a closed 18-cubic-foot chamber. A photometer system with a 36-inch-vertical light path measures the continuous decrease in light transmission as smoke accumulates. Results are expressed in terms of specific optical density (D_s), derived from a geometrical factor and the measured optical density (light absorbance).

A more detailed description of the test method and apparatus can be obtained from NBS Technical Note 708, titled, "Laboratory Evaluation of Smoke Density Chamber" or National Fire Protection Association (NFPA) 258-T-1974 tentative "Standard Test Method for Measuring the Smoke Generated by Solid Materials," printed in the 1974 NFPA book of Technical Committee Reports, Volume 1B.

Carbon monoxide was also measured during the smoke test by sampling from the geometric center of the smoke chamber into a Mine Safety Appliance (MSA), Lira Model 303, infrared analyzer. This instrument is capable of continuously measuring CO in a range extending from 0-2000 parts per million (ppm).

Test Results

Two-Gallon-per-Hour Kerosene Burner: Four panels of different construction representative of a typical transit car body side assembly were tested for flame and heat penetration resistance with the 2-gph kerosene burner test apparatus.

Test 1 - Acrylic (Swedlow) composite construction consisting of 0.10-inch fiberglass sheet with 0.10-inch acrylic facing, 0.75-inch aluminum honeycomb core, 0.10-inch fiberglass sheet, 3-inch aluminum channel stiffeners, 2.5-inch aluminum-backed fiberglass insulation, and 0.14-inch fiberglass sheet with 0.10-inch acrylic facing.

Temperatures were recorded at six different locations and are contained in table I. There was no measurable increase in backface temperature after the 10-minute test nor accumulation detected by the photometer.

Observations made during the test showed that blistering of the acrylic material started at about 0.5 minute after the flame was applied and increased in size until 1.25 minutes. Charring of the acrylic material extending outside of the flame pattern was observed at 1.5 minutes. The exposed surface of the panel appeared to be flaming after 3.25 minutes and flaking off at 3.5 minutes. Flashing of the exposed surface was observed at 8.0 minutes, and flaming continued for approximately 1 minute after burner removal.

Test 2 - Balsa core composite consisting of 0.13-inch fiberglass reinforced laminate with 0.13-inch acrylic (Swedlow) facing, 0.75-inch end-grain balsa core and fiberglass reinforced laminate backface. The edges of the panel were sealed with aluminum; however, for this test three holes were drilled in the lower edge of the panel to allow pressure release.

Temperatures are tabulated in table I. The backface temperature only increased 40-60°F by the end of the test.

Observations made during this test were almost identical to test 1. After 10 minutes there was no burn-through and no measurable smoke inside the test box.

Test 3 - Stainless steel construction consisting of a 0.09-inch stainless steel exterior sheet with inside surface coated with red oxide primer and Insulmat, Corten Z stiffeners, aluminum-backed 3-inch fiberglass insulation, and formica-covered 0.125-inch aluminum interior panel.

Temperature data are tabulated in table I. A small increase in backface temperature similar to the previous test was measured. The temperature of the insulation backface reached 360°F at 10 minutes and apparently was high enough to melt the adhesive used for bonding the Formica covering to the aluminum. This was determined by the observation of a heavy dark oily substance dripping from the lower edge of the panel and the strong adhesive odor detected at approximately 3 minutes. Examination of the panel after the test showed some scorching of the insulation. No smoke was detected.

Test 4 - Aluminum construction composed of a 0.125-inch aluminum exterior sheet with red oxide primer inside coating and Insulmat, aluminum stiffeners, 3-inch aluminum-backed fiberglass insulation, and Formica covered 0.125-inch aluminum interior panel.

Temperatures recorded during this test are in table I. Thermal profiles were similar to the two previous tests.

Warping of the aluminum exterior skin caused several of the spot welds which attached the skin to the aluminum stiffeners to pull apart. This allowed heavy smoke to escape from the inside of the panel (probably from the heated primer and insulation). The exposed aluminum began to soften, and melting appeared imminent at the end of the 10-minute test.

Radiant Panel: Three of the materials used in the construction of the panel assemblies were tested on the Radiant Panel.

Material No. 1 - 0.10-inch fiberglass sheet with 0.10-inch acrylic facing (Swedlow). Three specimens of the material were tested. The average flame spread index (I_s) was 74.7 for this material.

Flashing of pyrolysis gases and flaking of the acrylic material were witnessed during this test. Smoke was somewhat acrid and gray in color.

Exhaust stack temperatures recorded during the 15-minute test are listed in table II. To determine the increase in temperature from material combustion, subtract 200°C (180°C radiant panel plus 20°C pilot flame contribution) from the temperature.

Material No. 2 - Formica bonded to 0.125-inch aluminum. Radiant panel tests resulted in an average I_s of 28 for three test specimens.

Snapping and crackling of the of the formica material occurred as the surface of the material blistered. Heavy white smoke was observed emitting from the exposed surface.

Exhaust stack temperatures are shown in table II. The maximum average stack temperature increase was 43°C less than measured for the acrylic/fiberglass laminate.

Material No. 3 - Fiberglass sheet with acrylic (Rohm and Haas) facing.

Only two specimens of this material were tested. Surface burning was rapid, reaching the 15-inch mark by 6 minutes. The average I_s for the two specimens was 192, which was considerably greater than the two previous materials. A heavy black smoke with a very acrid odor was observed.

Exhaust stack temperatures are shown in table II. The temperature rise can be determined as in the previous two tests; however, the initial stack temperature was 10°C lower. The maximum average stack temperature increase was 66°C and 109°C greater than materials 1 and 2, respectively.

NBS Smoke Chamber: Smoke density and carbon monoxide concentrations were measured in the NBS chamber for the same three materials previously tested with the Radiant Panel.

Material No. 1 - 0.10-inch fiberglass sheet with 0.10-inch acrylic (Swedlow) facing. Smoke and CO data are shown in tables III and IV for flaming and smoldering exposure test conditions, respectively. For both exposure conditions, smoke and CO levels were still increasing at the end of the 20-minute tests. The concentration of smoke was comparable for both exposure conditions; however, the flaming CO levels were a factor of 10 or more greater than the smoldering values.

Material No. 2 - Formica bonded to 0.125-inch aluminum. Flaming and smoldering smoke and CO data are in tables V and VI. Smoke reached a peak concentration near the end of the test of D_s = 130 and 102 for flaming and smoldering conditions, respectively. The concentration of CO increased throughout the test and was greater under flaming exposure (1063 ppm vs. 638 ppm at 20 minutes).

Material No. 3 - Fiberglass sheet with acrylic (Rohm and Haas) facing. Only two specimens of this material were tested in the flaming test condition. Results of these tests are contained in table VII. Compared to the Swedlow acrylic/fiberglass laminate, the smoke was two to three times greater and the CO was about the same.

Table VIII contains test results of specimens that because of the lack of available materials only one test could be made. These tests include:

1. Formica material removed from the 0.125-inch aluminum sheet, flaming test condition.

2. Formica material removed from the 0.125-inch aluminum sheet, smoldering test condition.

3. Fiberglass sheet with acrylic (Rohm and Haas) facing, smoldering test condition. Both smoke and CO levels were significantly higher than evidenced with the Swedlow fiberglass/acrylic laminate.

Summary

The four rail transit car body side assemblies when tested for fire resistance and flame penetration utilizing the 2-gph kerosene burner showed no flame penetration of the exterior (exposed) surface after being subjected to the 1650-1750^{o}F flame. There was no recorded smoke accumulation inside the test box and no excessive high temperatures behind the insulation materials or interior surface of the panel. The acrylic (Swedlow) composite construction material had the lowest temperatures both behind the insulation material and on the unexposed surface.

The radiant panel flame spread index for the Swedlow acrylic/ fiberglass laminate was much lower than the similar Rohm and Haas material (I_s = 75 vs. 192). An even lower rating was obtained with the Formica/ aluminum laminate (I_s = 29), which undoubtedly was favorably influenced by the aluminum heat sink effect. Both acrylic/fiberglass laminate are well above the goal of I_s = 25 sometimes set by regulatory bodies and material developers.

The smokiest material tested was the Rohm and Haas acrylic/fiberglass laminate which attained maximum specific optical densities of 425 and 368 under flaming and smoldering conditions, respectively. In comparison, the maximum smoke was in the 100-200 range for both the Swedlow acrylic/ fiberglass and Formica/aluminum laminates.

Carbon monoxide levels were high and comparable for both acrylic/ fiberglass laminates during flaming test conditions. Under smoldering exposure, the CO level decreased substantially (roughly a factor of 10). In contrast, the CO levels for the Formica/aluminum laminate were below the acrylic/fiberglass laminate for flaming but above for smoldering conditions. The concentration of CO increased throughout the test for all materials and exposure conditions.

TABLE I

2 gph Kerosene Burner Flame Penetration Temperature Data

Test 1 Acrylic Composite Construction

Time (min)	Therm #1 Flame Temp. (°F)	Therm. #2 Insulation (°F)	Therm. #3 Unexposed Face Temp. (°F)	Therm #4 Unexposed Face Temp. (°F)	Therm. #5 Unexposed Face Temp. (°F)	Therm #6 Ambient Temp. In Box (°F)
1	1660	100	80	80	80	80
2	1700	100	80	80	80	80
3	1670	100	80	80	80	80
4	1740	100	80	80	80	80
5	1680	100	80	80	80	80
6	1680	110	80	80	80	80
7	1620	120	80	80	80	80
8	1600	120	80	80	80	80
9	1570	120	80	80	80	80
10	1560	120	90	90	80	80

Test 2 Acrylic Composite/Balsa Core

Time (min.)	Therm #1 Flame Temp. (°F)	Therm #2 Insulation (°F)	Therm. #3 Unexposed Face Temp. (°F)	Therm #4 Unexposed Face Temp. (°F)	Therm #5 Unexposed Face Temp. (°F)	Therm #6 Ambient Temp. In Box (°F)
1	1550	(1) N.D.	80	80	80	80
2	1600	N.D.	80	80	80	80
3	1600	N.D.	80	80	80	80
4	1620	N.D.	80	80	80	80
5	1650	N.D.	90	90	80	80
6	1640	N.D.	100	100	100	80
7	1640	N.D.	100	100	110	100
8	1600	N.D.	110	110	120	110
9	1600	N.D.	120	120	130	120
10	1600	N.D.	120	120	140	120

(1) N.D. - No Data Recorded

Test 3 Stainless Steel Construction

Time (min)	Therm #1 Flame Temp. (°F)	Therm #2 Insulation (°F)	Therm #3 Unexposed Face Temp. (°F)	Therm #4 Unexposed Face Temp. (°F)	Therm. #5 Unexposed Face Temp (°F)	Therm. #6 Ambient Temp. In Box °F
1	1480	110	80	80	80	80
2	1480	175	80	80	80	80
3	1560	180	100	100	100	80
4	1580	200	100	100	120	100
5	1660	210	120	120	120	100
6	1700	210	120	120	140	100
7	1700	210	120	120	140	100
8	1710	260	120	120	140	100
9	1700	320	120	120	140	100
10	1700	360	120	120	140	100

Test 4 Aluminum Construction

Time (min)	Therm #1 Flame Temp. (°F)	Therm #2 Insulation (°F)	Therm #3 Unexposed Face Temp. (°F)	Therm #4 Unexposed Face Temp. (°F)	Therm #5 Unexposed Face Temp. (°F)	Therm #6 Ambient Temp. In Box (°F)
1	1560	140	80	80	80	80
2	1540	180	80	80	80	80
3	1600	180	100	100	120	100
4	1600	180	100	100	120	100
5	1600	180	110	110	130	100
6	1600	200	120	120	140	100
7	1600	200	120	120	140	110
8	1600	210	120	120	140	110
9	1620	220	120	120	140	110
10	1600	230	120	120	140	120

TABLE II

RADIANT PANEL TESTS
ASTM-E-162

Fiberglass/Acrylic Facing (Swedlow)					Aluminum/Formica Facing					Fiberglass/Acrylic Facing (Rohm & Haas)			
Time (min)	Test #1 Temperature (°C)	Test #2 Temperature (°C)	Test #3 Temperature (°C)	Avg. Temperature (°C)	Time (min)	Test #1 Temperature (°C)	Test #2 Temperature (°C)	Test #3 Temperature (°C)	Avg. Temperature (°C)	Time (min)	Test #1 Temperature (°C)	Test #2 Temperature (°C)	Avg. Temperature (°C)
0	180	180	180	180	0	180	180	180	180	0	170	170	170
1	190	190	196	192	1	190	190	200	193	1	204	210	207
2	220	224	218	221	2	234	212	244	230	2	276	280	278
3	244	230	238	237	3	224	248	230	234	3	320	322	321
4	274	242	252	256	4	212	246	220	226	4	339	326	333
5	280	260	268	269	5	210	228	212	216	5	330	320	325
6	274	278	280	277	6	210	218	208	212	6	330	314	322
7	266	282	274	274	7	210	210	204	208	7			
8	264	272	274	270	8	204	208	204	205	8			
9	262	270	272	268	9	204	208	204	205	9			
10	258	274	265	266	10	204	208	202	205	10			
11	252	268	264	261	11	200	206	200	202	11			
12	250	262	262	254	12	200	205	200	202	12			
13	248	258	260	255	13	200	205	200	202	13			
14	248	254	260	254	14	200	204	200	201	14			
15	248	250	256	251	15	200	204	200	201	15			
F_s	6.94	4.37	4.42		F_s	4.63	3.03	3.84		F_s	7.02	8.94	
Q	14.11	14.96	13.71		Q	7.31	7.31	8.16		Q	25.16	23.17	
I_s	98	65	61	75	I_s	34	22	31	29	I_s	177	207	192

$I_s = F_s Q$

$F_s = 1 + (1/t_3) + [1/(t_6 - t_3)] + [1/(t_9 - t_6)] + [1/(t_{12} - t_9)] + [1/(t_{15} - t_{12})]$

$t_3 \ldots t_{15}$ corresponds to times in minutes for the flame front to reach 3...15 inches

$Q = 0.1\,(T/\beta)$

0.1 = an arbitrary constant

T = maximum stack temperature rise over that observed with an asbestos-cement board specimen

β = maximum stack temperature rise for unit heat input rate of a calibration burner (constant)

For NAFEC apparatus - Asbestos/cement board temp. rise = 20°C — β = 0.59°C BTU/min. -

TABLE III
SMOKE AND CARBON MONOXIDE – FLAMING
No. 1 FIBERGLASS/ACRYLIC FACING (SWEDLOW)

Time (min)	SMOKE Test #1 %T	Test #1 D_s	Test #2 %T	Test #2 D_s	Test #3 %T	Test #3 D_s	Avg. D_s	CARBON MONOXIDE Test #1 (ppm)	Test #2 (ppm)	Test #3 (ppm)	Avg. (ppm)
1	98	1.15	98	1.15	98	1.15	1.15	56	48	64	56
2	93	4.21	92	4.80	92	4.80	4.60	114	96	96	102
3	83	10.9	84	10.1	83	10.9	10.6	138	123	123	128
4	74	17.5	76	15.9	75	16.7	16.4	214	172	165	183
5	68	22.4	68	22.4	67	23.3	22.7	267	250	267	261
6	62	27.8	62	27.8	57	32.7	29.4	315	325	372	337
7	57	32.7	56	33.7	48	42.7	36.4	402	392	469	421
8	51	39.2	50	40.3	39	54.8	44.8	499	479	550	509
9	45	46.5	42	50.5	32	66.3	54.4	616	571	627	604
10	39	54.8	36	59.4	26	78.4	64.2	796	682	704	727
11	33	65.5	30	70.1	22	88.1	74.2	940	808	773	840
12	28	74.1	24	83.1	18	99.8	85.7	1107	900	856	950
13	23	85.5	20	93.7	15	110	96.4	1292	1019	900	1070
14	20	93.7	16	107	13	119	107	1388	1153	980	1173
15	17	103	13	119	11	128	117	1596	1268	1063	1309
16	15	110	11	128	10	134	124	1760	1364	1130	1418
17	12	123	10	134	9.3	138	131	1920	1434	1198	1517
18	8.2	146	8.6	143	8.3	145	145	1976	1540	1292	1602
19	4.6	179	7.9	148	7.3	152	159	2000	1622	1388	1670
20	2.5	215	6.9	156	6.3	161	177	2000	1730	1460	1730

%T = Percent Light Transmitance
D_s = Specific Optical Density

Specimen No. 1
Initial Weight = 51.9297 gr.
Final weight = 39.5853 gr
Weight Loss = 12.3444 gr
= 23.8 %

Specimen No. 2
Initial Weight = 54.6991
Final Weight = 39.8389
Weight Loss = 14.8602
= 27.2 %

Specimen No. 3
Initial Weight - 55.7352
Final Weight = 45.0943
Weight Loss = 10.6409
= 19.1 %

TABLE IV
SMOKE AND CARBON MONOXIDE ~SMOLDERING
No.1 FIBERGLASS/ACRYLIC FACING (SWEDLOW)

	SMOKE									CARBON MONOXIDE			
	Test #1		Test #2		Test #3					Test #1	Test #2	Test #3	
Time (min)	%T	D_s	%T	D_s	%T	D_s	Avg. D_s			(ppm)	(ppm)	(ppm)	Avg. (ppm)
1	99	0.58	99.5	0.29	99	0.58	0.48			0	0	0	0
2	95	2.95	96	2.34	97	1.72	2.34			0	0	0	0
3	88	7.42	90	6.13	90	6.13	6.56			0	0	0	0
4	78	14.5	80	12.9	80	12.9	13.4			0	0	0	0
5	66	24.2	68	22.4	67	23.3	23.3			6	6	6	6
6	53	36.9	55	34.8	55	34.8	35.5			6	6	9	7
7	42	50.5	43	49.1	44	47.8	49.1			15	15	15	15
8	34	62.8	34	62.8	36	59.4	61.7			22	22	22	22
9	28	74.1	28	74.1	29	72.0	73.4			22	32	27	27
10	23	85.5	23	85.5	23	85.5	85.5			32	40	32	35
11	20	93.7	19	96.7	19	96.7	95.7			48	48	44	47
12	17	103	17	103	16	107	104			56	56	56	56
13	15	110	15	110	14	114	111			60	64	60	61
14	13	119	13	119	12	123	120			80	80	80	80
15	11	128	11	128	10	134	130			96	96	96	96
16	10.5	131	10.5	131	9.1	140	134			105	114	114	111
17	10	134	10	134	8.3	145	138			123	138	130	130
18	8.4	144	8.7	142	7.7	149	145			138	147	138	141
19	7.9	148	8.3	145	7.0	155	149			155	165	165	161
20	7.4	152	8.0	147	6.4	160	153			180	180	180	180

%T = Percent Light Transmitance
D_s = Specific Optical Density

Specimen No. 1
Initial Weight = 59.2079 gr.
Final Weight = 52.8087 gr.
Weight Loss = 6.3992 gr.
= 10.8%

Specimen No. 2
Initial Weight = 58.0583 gr.
Final Weight = 51.4728 gr.
Weight Loss = 6.5855 gr.
= 11.3%

Specimen No. 3
Initial Weight = 47.6676 gr
Final Weight = 39.5211 gr
Weight Loss = 8.1465 gr
= 12.1%

TABLE V

SMOKE AND CARBON MONOXIDE - FLAMING
No. 2 ALUMINUM/FORMICA FACING

	SMOKE							CARBON MONOXIDE			
	Test #1		Test #2		Test #3			Test #1	Test #2	Test #3	
Time (min)	%T	D_s	%T	D_s	%T	D_s	Avg. D_s	(ppm)	(ppm)	(ppm)	Avg. (ppm)
1	73	18.3	83	10.9	77	15.2	14.8	22	22	32	25
2	74	17.5	79	13.7	74	17.5	16.2	56	64	80	67
3	66	24.2	70	20.7	63	26.9	23.9	123	123	138	128
4	57	32.7	61	28.8	55	34.8	32.1	214	197	214	208
5	50	40.3	54	35.8	50	40.3	38.8	297	277	287	287
6	43	49.1	48	42.7	45	46.5	46.1	372	354	363	363
7	38	56.3	41	51.9	40	53.3	53.8	449	430	440	440
8	30	70.1	36	59.4	33	64.5	64.7	540	499	509	516
9	22	88.1	28	74.1	27	76.2	79.5	650	571	594	605
10	18	99.8	21	90.8	21	90.8	93.8	737	650	682	690
11	16	107	18	99.8	17	103	103	820	715	760	766
12	14	114	15	110	14	114	113	892	796	832	840
13	12	123	14	114	13	119	119		868	892	880
14	12	123	13	119	12	123	122		939		
15	11	128	12	123	11	128	126				
16	11	128	12	123	11	128	126	980		920	950
17	11	128	11	128	10	134	130	1019	980	960	986
18	11	128	11	128	10	134	130	1063	1019	1000	1027
19	12	123	11	128	10	128	126	1107	1063	1019	1063
20	13	119	12	123	11	128	123	1130	1107	1063	1100

%T = Percent Light Transmitance
D_s : Specific Optical Density

Specimine No. 1
Initial Weight = 61.0157 gr.
Final Weight = 52.7048 gr
Weight Loss : 8.3109 gr
= 13.6%

Specimen No. 2
Initial Weight = 59.2443 gr.
Final Weight = 51.2349 gr.
Weight Loss : 8.0094 gr.
= 13.5%

Specimen No 3
Initial Weight = 61.0627 gr.
Final Weight = 52.6836 gr
Weight Loss : 8.3791 gr.
= 13.7%

Above Weights include aluminum backing
Approximate Weight of 3 X 3 X 0.125 inch aluminum = 49.4 gr.

TABLE VI

SMOKE AND CARBON MONOXIDE – SMOLDERING
No. 2 ALUMINUM/FORMICA FACING

Time (min)	SMOKE Test #1 %T	Test #1 D_s	Test #2 %T	Test #2 D_s	Test #3 %T	Test #3 D_s	Avg. D_s	CARBON MONOXIDE Test #1 (ppm)	Test #2 (ppm)	Test #3 (ppm)	Avg. (ppm)
1	100	0	100	0	100	0	0	0	0	0	0
2	86	8.79	88	7.42	88	7.42	7.88	6	6	6	6
3	70	20.7	76	15.9	79	13.7	16.8	32	32	22	29
4	45	46.5	56	33.7	62	27.8	36.0	105	72	72	83
5	34	62.8	43	49.1	49	41.5	51.1	165	130	123	139
6	29	72.0	36	59.4	38	56.3	62.6	206	165	180	184
7	26	78.4	31	68.1	33	64.5	70.3	232	189	214	212
8	24	83.1	28	74.1	30	70.1	75.8	258	223	250	244
9	22	88.1	25	80.7	27	76.2	81.7	287	250	267	268
10	21	90.8	23	85.5	25	80.7	85.7	315	297	297	303
11	20	93.7	22	88.1	24	83.1	88.3	334	306	315	318
12	20	93.7	21	90.8	23	85.5	90.0	363	334	345	347
13	20	93.7	20	93.7	23	85.5	91.0	402	382	372	385
14	20	93.7	19	96.7	22	88.1	92.8	440	430	402	424
15	19	96.7	18	99.8	22	88.1	94.9	489	479	440	469
16	19	96.7	17	103	21.5	89.5	96.4	550	519	479	516
17	18.5	98.2	16	107	21	90.8	98.7	594	571	519	561
18	18.5	98.2	15	110	21	90.8	99.7	638	616	550	601
19	18	99.8	14	114	21	90.8	102	671	660	594	642
20	18	99.8	14	114	21	90.8	102	715	693	638	682

%T = Percent Light Transmittance
D_s = Specific Optical Density

Specimen No. 1
Initial Weight = 59.9179 gr.
Final Weight = 55.6389 gr
Weight Loss = 4.2790 gr
= 7.1%

Specimen No. 2
Initial Weight = 60.4142 gr.
Final Weight = 55.7193 gr
Weight Loss = 4.6949 gr
= 7.8%

Specimen No. 3
Initial Weight = 60.3399 gr.
Final Weight = 56.4275 gr
Weight Loss = 3.9124 gr.
= 6.5%

Above weights include aluminum backing
Approximate weight of 3X3X0.125 inch aluminum = 49.4 gr.

TABLE VII

SMOKE AND CARBON MONOXIDE ~ FLAMING
No. 3 FIBERGLASS/ACRYLIC FACING (ROHM and HAAS)

Time (min)	SMOKE Test #1 %T	SMOKE Test #1 D_s	SMOKE Test #2 %T	SMOKE Test #2 D_s	Avg. D_s	CARBON MONOXIDE Test #1 (PPM)	CARBON MONOXIDE Test #2 (PPM)	CARBON MONOXIDE Avg. (PPM)
1	100	0	100	0	0	15	15	15
2	47	43.9	38	56.3	50.1	32	40	36
3	8.8	141	6.0	164	153	147	180	164
4	3.3	199	2.8	208	204	240	240	240
5	3.3	199	2.7	210	205	258	267	263
6	3.8	189	3.2	200	195	287	306	296
7	4.6	179	3.7	192	186	315	345	330
8	5.6	168	3.7	192	180	354	430	392
9	6.4	160	3.5	195	178	411	529	470
10	5.8	166	2.2	222	194	540	660	600
11	3.4	197	1.1	262	230	693	796	745
12	2.0	228	0.54	304	266	832	920	876
13	1.3	253	0.27	344	299	920	1019	970
14	0.65	293	0.13	387	340	1040	1113	1085
15	0.41	320	0.065	427	374	1153	1244	1198
16	0.37	325	0.043	451	388	1268	1340	1304
17	0.20	362	0.032	468	415	1364	1434	1399
18	0.17	371	0.028	478	425	1460	1512	1486
19	0.17	371	0.030	473	422	1568	1596	1582
20	0.18	368	0.032	468	418	1650	1650	1650

%T = Percent Light Transmitance
D_s = Specific Optical Density

Specimen No. 1
Initial Weight = 53.1108 gr.
Final Weight = 31.2855 gr
Weight Loss = 21.8253 gr
= 41.1%

Specimen No. 2
Initial Weight = 46.7641 gr.
Final Weight = 25.5393 gr
Weight Loss = 21.2248 gr
45.4%

TABLE VIII
SMOKE AND CARBON MONOXIDE SPECIAL TESTS

Time (min)	FORMICA ONLY (1) SMOKE %T	FORMICA ONLY (1) SMOKE D_s	FORMICA ONLY (1) CO (ppm)	FORMICA ONLY (2) SMOKE %T	FORMICA ONLY (2) SMOKE D_s	FORMICA ONLY (2) CO (ppm)	FIBERGLASS/ACRYLIC (3) SMOKE %T	FIBERGLASS/ACRYLIC (3) SMOKE D_s	FIBERGLASS/ACRYLIC (3) CO (ppm)
1	63	26.9	22	100	0	0	100	0	0
2	61	28.8	88	80	12.9	15	100	0	0
3	52	38.1	130	54	35.8	123	98	1.15	0
4	33	64.5	250	43	49.1	165	92	4.80	3
5	23	85.5	392	36	59.4	189	77	15.2	6
6	17	103	499	31	68.2	223	62	27.8	14
7	15	110	605	27	76.2	258	58	31.7	18
8	13	119	704	23	85.5	297	34	62.8	27
9	12	123	784	20	93.7	354	24	83.1	40
10	12	123	856	16	107	440	18	99.8	48
11	13	119	903	13	119	529	11	128	56
12	13.5	117	952	11	128	605	7.7	149	72
13	14	114		10	134	660	4.0	152	84
14	15	110		9	140	715	2.5	215	99
15	16	107		9	140	760	1.5	244	123
16	17	103	980	9	140	820	0.9	274	142
17	18	99.8	1000	9	140	892	0.6	298	165
18	19.5	95.1	1019	9	140		0.4	323	189
19	21	90.8	1040	9	140		0.3	342	214
20	22	88.1	1086	9	140	940	0.2	368	250

(1) Formica – Flaming Test Condition
Initial Weight = 11.2407 gr.
Final Weight = 2.6836 gr
Weight Loss = 8.5571 gr = 76.1%

(2) Formica – Smoldering Test Condition
Initial Weight = 11.3081 gr
Final Weight = 5.9047 gr
Weight Loss = 5.4034 gr = 47.8%

(3) Fiberglass/Acrylic (Rohm & Haas) – Smoldering Test Condition
Initial Weight = 49.6903 gr
Final Weight = 40.7026 gr
Weight Loss = 8.9877 gr = 18.1%

ATTACHMENT 1

MEMORANDUM OF AGREEMENT
Between
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

NAFEC 237
(Agreement No.

and

BOEING VERTOL CO.

920-003-14T
(Activity No.)

WHEREAS, the Federal Aviation Administration, hereinafter referred to as the FAA, is in a position to furnish directly or by contract supplies, equipment, and services that are not readily available from commercial sources, and which Boeing Vertol Co., hereinafter referred to as Vertol, has funds available for and has requested, be obtained from the FAA as hereinafter set forth.

WHEREAS, FAA Order 2500.35B, dated July 7, 1972, authorizes the furnishing of supplies, equipment, and services by FAA to Vertol upon a reimbursable basis.

WHEREAS, NAFEC is in a position to furnish directly or by contract, supplies, equipment, and services that are not readily available from commercial sources and which Vertol has requested be obtained from the FAA is hereinafter set forth.

NOW, THEREFORE, the FAA and Vertol mutually agree as follows:

ARTICLE I - Transit Car Sidewall Fire Tests

1. The work to be performed by the FAA will consist of fire tests on transit car sidewall sections. Testing will commence on or about June 10, 1974 (at the earliest date the sections can be fabricated and delivered to NAFEC). The following number of tests will be conducted:

3 2-gph burner
9 radiant panel (ASTM E-162)
18 NBS smoke chamber

Three sidewall configurations, consisting of stainless steel, aluminum and fiberglas outer skins, will be tested to measure resistance against an external fire using the 2-gph burner. The flammability and smoke characteristics of three candidate fiberglas sheets will be determined with the radiant panel (three replicate runs) and NBS smoke chamber (three replicate runs, two exposure conditions). A brief test report will be prepared for the purpose of documenting the test procedures and recording, analyzing, and comparing the data. The report will be issued to the customer 3 weeks after initiation of testing. Such work will be performed at the FAA NAFEC building 203 fire test facility.

2. The FAA will use its best efforts to accomplish the work in accordance with the above general work statement. The FAA will perform this work on a non-interference basis, i.e., subject to necessary schedule arrangements as made by the FAA. In this connection, the FAA will furnish the following supplies, services, and equipment:

a. Test report.

b. 16 mm color motion picture film of 2-gph burner tests.

3. It is agreed that Vertol will:

a. Provide an Agreement Manager, authorized to formalize by an appropriate written amendment any change in the supplies/services later deemed necessary.

b. Provide NAFEC with test specimens in size and configuration compatible with the aforementioned three fire test methods.

ARTICLE II - Payment of FAA Costs

1. Vertol shall reimburse the FAA for all direct and indirect costs incurred by the FAA in performing work under this agreement, including but not limited to labor, supplies, materials and equipment, and outside contractual support. In addition, as reimbursement for overhead services costs Vertol will pay to the FAA a flat rate of 10 percent.

2. Upon revocation or termination of this agreement, for any cause, Vertol will reimburse the FAA for all necessary liquidating expenses.

3. The following are the estimated costs only (charges, however, will be based on actual costs):

10	Engineer man days @ $13.56/hr	=	$1,084.80
7	Engineering Technician man days @ $11.11/hr	=	622.16
1	Photographer man days @ $12.48/hr	=	99.84
	Total		$1,806.80
	Administrative Overhead (10%)	=	180.68
	Total estimated cost		$1,987.48

4. FAA billings will itemize the actual costs for labor, supplies, materials, equipment, and contractual support furnished to Vertol under this agreement. The FAA will utilize its best efforts to accomplish the work within the estimated cost, and will advise Vertol when it is determined that the actual cost will exceed the estimated cost. FAA billing will be rendered periodically, but not less frequently than after the close of each quarter during the FAA's fiscal year.

5. Vertol hereby identifies the office to which FAA bills will be rendered as Mr. William Dunton
P. O. Box 16858
Philadelphia, Pa. 19142
(Mail Stop P41-06).

6. Payment shall be submitted to the Chief, Accounting Division, ANA-20, NAFEC, Atlantic City, New Jersey 08405.

ARTICLE III - Amendment

Any change in supplies, equipment, or services to be furnished under this agreement shall be formalized by an appropriate written amendment to the agreement which shall outline in detail the exact nature of the change. Vertol Agreement Manager, provided in Article 13a, above, will be authorized by Vertol and recognized by FAA to formalize and approve for Vertol all amendments required by Vertol.

ARTICLE IV - Effective Date

1. This agreement supersedes any previous agreements between the parties on the subject matter set forth in Article I, hereof, and is effective when signed by duly authorized representatives.

2. The program may be conducted over a period of approximately 21 calendar days beginning on or about June 10, 1974.

ARTICLE V - Liability

Vertol agrees to hold the FAA harmless against any claim by Vertol, or third person, for personal injury, death, or property damage arising out of work under this agreement. Vertol further agrees to reimburse the FAA for any damage to the FAA's property arising out of work under this agreement.

ARTICLE VI - Date and Publications

Vertol may disseminate and use freely all data resulting from these tests, provided that no such data shall be published or otherwise disclosed by Vertol for product promotion or advertising purposes, that would state or infer FAA endorsement, except as may be authorized in writing by the Director, NAFEC.

ARTICLE VII - Termination

Prior to commencing of work hereunder, this agreement may be terminated at any time by either party with 5 days advance written notice.

The FAA and Vertol agree to the provisions of this agreement as indicated by the signatures of their duly authorized officers.

DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION	VERTOL
By: ______________________	By: ______________________
Title: ______________________	Title: ______________________
Date: ______________________	Date: ______________________