DOT/FAA/CT-83/29

Correlation of Laboratory-Scale Fire Test Methods for Seat Blocking Layer Materials with Large-Scale Test Results

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Final Report

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16. Abstract

An interlaboratory study was conducted to determine the adaptability of various laboratory fire test devices to measure aircraft seat cushion blocking layer effectiveness. Full-scale tests conducted by the FAA have shown blocking layers to be an effective means of delaying aircraft seat cushion fire involvement when exposed to a large external fuel fire. Large-scale tests conducted in the Douglas Aircraft Company Cabin Fire Simulator (CFS) have also shown similar findings. Such findings are fostering development of new candidate materials. However, it is more practical to evaluate these materials in a suitable laboratory test device rather than continuously performing expensive full- or large-scale tests. Several such devices were determined to be satisfactory when operated under specific conditions and when certain parameters are measured. The satisfactory devices are the Ohio State University (OSU) Rate of Heat Release Apparatus operated at 5.0 Watts/centimeter squared, the FAA Standard Two Gallon/Hour Burner operated for a two minute exposure, and the Lockheed Aircraft Company Meeker Burner. For a series of blocking layer material candidates, test measurements obtained with the above devices exhibit comparable rankings with weight loss or percent weight loss from larger scale CFS tests.

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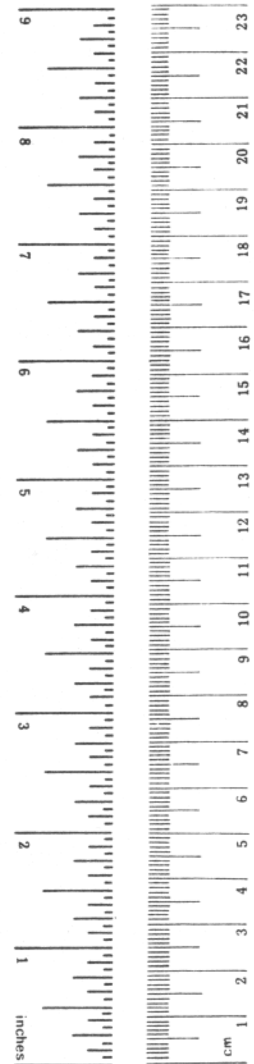
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

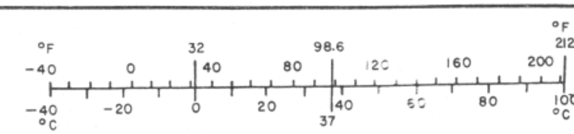
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Full-scale tests conducted by the FAA have shown aircraft seat cushion blocking layers to be an effective means of delaying fire and flame spread during exposure to a large external fuel fire. Similar findings were also made by Douglas Aircraft Company conducting large-scale tests in the Cabin Fire Simulator (CFS).

An interlaboratory study of various test devices was conducted to develop and determine comparability with the full-scale results. The participants in the study were NASA AMES, FAA, Boeing, Lockheed, and Douglas. The participation of the latter three airframe manufacturers was accomplished through an Aerospace Industries Association (AIA) Transport Airworthiness Requirements Committee (TARC) project. The Ohio State University Rate of Heat Release Apparatus (OSU), ASTM E-906 was selected by Boeing, Douglas, and the FAA as the test method best suited for blocking layer evaluation. In addition to the OSU, the FAA pursued as an alternate test method the Standard Two Gallon/Hour Burner. Lockheed chose the Meeker burner and NASA AMES selected a modified NBS smoke chamber. Eleven test materials were selected and distributed to the laboratory participants. They consisted of four types of foam cushioning, three types of foam blocking layer, three types of fabric blocking layer, and a typical upholstery fabric cover. These materials were assembled in eleven different configurations.

Due to the variety of methods and end point measurements employed by the participants of the interlaboratory study and the uncertain relationship between each, it was difficult to meaningfully compare the test results obtained with every device. Instead, it was more desirable to perform a non-parametric study of the relative rankings of the measurements and compare these results with the results from the CFS tests weight loss and percent weight loss data.

As a result of this study, it was concluded that: (1) The Ohio State University Rate of Heat Release Apparatus is a suitable device to measure aircraft seat blocking layer effectiveness. Several test measurement rankings for the OSU operated at a 5.0 W/cm^2 heat flux level showed comparability with larger scale CFS weight loss and percent weight loss rankings, (2) The "Standard" FAA Two Gallon/Hour Burner test is a suitable device to measure aircraft seat blocking layer effectiveness. Of all the laboratory devices, the Two Gallon/Hour Burner most resembled the larger scale CFS tests. Comparability was shown for burner test measurement rankings with CFS percent weight loss ranking, (3) The Lockheed Meeker Burner test is a suitable device to measure aircraft seat blocking layer effectiveness. Two test measurement rankings showed comparability with larger CFS weight loss and percent weight loss rankings and (4) Results from the laboratory study confirm the effectiveness of the aircraft seat blocking layer concept.

INTRODUCTION

PURPOSE.

The purpose of this project was to evaluate the adaptability of existing laboratory test devices to measure aircraft seat cushion fire blocking layer effectiveness. This was accomplished by determining the comparability of data rankings between laboratory test results from a number of organizations with results from larger scale fire tests on a series of candidate blocking layers or improved cushioning materials.

BACKGROUND.

A new concept to limit fire involvement of the urethane foam used in aircraft seat cushions has prompted extensive testing to determine the effectiveness of the many types of seat blocking layers (references 1, 2, and 3). An aircraft seat exposed to large intense radiation from a large fuel fire will contribute to the attainment of flashover conditions within an aircraft cabin. To delay or reduce the intensity of this phenomenon would increase available egress time of passengers. Full-scale tests (reference 1) of a conventional wide-body cabin interior have shown a flashover time of 140 seconds. By contrast, full-scale tests of an interior furnished with seats protected with a blocking layer delayed the onset of flashover by 60 seconds for Vonar™ wrapped cushions and by 43 seconds for Norfab™ wrapped cushions. Results from both simulated in-flight and ramp fire tests show that blocking layers can prevent fires which would become out of control with conventional seats (reference 2). Although full-scale tests are necessary to demonstrate realistic performance of candidate materials, it is more practical to base the evaluation and selection of materials on a laboratory fire test method. Therefore, an interlaboratory study was conducted to evaluate various existing test methods as to their adaptability for such testing. The participants in the study were National Aeronautic and Space Administration (NASA)-AMES, Federal Aviation Administration (FAA), Boeing, Lockheed, and Douglas. The participation of the latter three airframe manufacturers was accomplished through an Aerospace Industries Association (AIA) Transport Airworthiness Requirements Committee (TARC) project (reference 3). The Ohio State University Rate of Heat Release Apparatus (OSU), ASTM E-906 (reference 4), was selected by Boeing, Douglas, and the FAA as the test method best suited for blocking layer evaluation. In addition to the OSU, the FAA pursued as an alternate test method the standard Two Gallon/Hour Burner (reference 5). As the original Lennox Burner was no longer commercially available, it was necessary to find an acceptable replacement. Lockheed chose the Meeker Burner (reference 3) and NASA-AMES selected a modified NBS Smoke Chamber (reference 3). Laboratory results were compared with larger scale tests, which were conducted in the Douglas Cabin Fire Simulator (CFS) (reference 6), to determine comparability of material rankings.

TEST MATERIALS.

Eleven test materials were selected and distributed to the laboratory participants. They consisted of four types of foam cushioning, three types of foam-blocking layer, three types of fabric-blocking layer, and a typical upholstery fabric cover. These materials were assembled in 11 different configurations (table 1). A detailed description of these materials is found in appendix A.

TABLE 1. SEAT CUSHION CONFIGURATIONS FOR FIRE TEST METHODS EVALUATION

CONFIGURATION	DECORATIVE UPHOLSTERY	FIRE-BLOCKING LAYER	FOAM	COMMENTS
1	Wool-Nylon	None	FR Urethane	Baseline
2	" "	Vonar - 3	FR Urethane	Cotton Scrim
3	" "	Vonar - 2	FR Urethane	Cotton Scrim
4	" "	3/8" - LS-200	FR Urethane	
5	" "	Celiox 101	FR Urethane	
6	" "	Norfab 11HT-26-AL	FR Urethane	
7	" "	181 E-Glass	FR Urethane	
8	" "	Vonar - 3	NF Urethane	Cotton Scrim
9	" "	Norfab 11HT-26-AL	NF Urethane	
10	" "	None	LS-200	
11	" "	None	Polyimide	

DISCUSSION

FAA OSU MODIFICATIONS.

The OSU Rate of Heat Release (RHR) was used in a "standard" configuration (figure 1) with the following exceptions:

(1) The sample holder was enlarged to accommodate a thicker sample and the holding rack was accordingly reduced in depth to maintain the proper radiant heat source to sample face distance.

(2) The upper pilot light was exclusively selected because of its similarity to the flashback phenomenon observed in full-scale C-133 tests (reference 1).

(3) A three-channel thermocouple receptacle was mounted in the sample holder rack to facilitate connection of foam backface thermocouples.

Fabric blocking layer samples were fabricated as shown in figure 2. The dimensions of the samples were as follows:

(1) Core foam, 6 inches by 6 inches by 1-inch thick

(2) Foam blocking layer, 8 inches by 8 inches

(3) Fabric blocking layer, 8 inches by 16 inches

In order to reduce the sample thickness, the foam-blocking layers were not wrapped entirely around the core foam (front faces and sides only). The samples were then wrapped in aluminum foil.

A chromel-alumel thermocouple was placed in the sample holder backing board and a 1-inch by 1-inch rear window was cut in the sample to allow the thermocouple to just touch the foam core (figure 3). This provided for the continuous measurement of foam backface temperature. The thermocouple was connected to a digital readout, which was recorded on video tape through a split screen generator along with a camera view of the sample through the observation window in the side of the OSU. A series of tests, using three thermocouples, placed diagonally across the backing board were evaluated. It was determined that one thermocouple located on the center backface of the sample was sufficient in that the outer two thermocouples produced inconsistent results due to heat sink effects of the sample holder. Heat and smoke release rate data were recorded on a Honeywell Strip Chart Recorder, Model 196, with integrator pen feature.

FAA TWO GALLON/HOUR BURNER MODIFICATIONS.

The Lennox Burner used in the original "Standard" burner design is no longer commercially available. An attempt to purchase a Carlin 200 CRD Burner, which was shown to be an appropriate replacement (reference 7), proved futile as it also is being phased out of production. A suitable replacement burner was fabricated by Park Oil Burner, Atlantic City, New Jersey, to the "Standard" burner specification (appendix B). The burner was adjusted to produce a temperature pattern through a horizontal line, a minimum of 1850° F for a distance of not less than 7 inches and at 4 inches from the end of the burner cone (figure 4). This temperature pattern

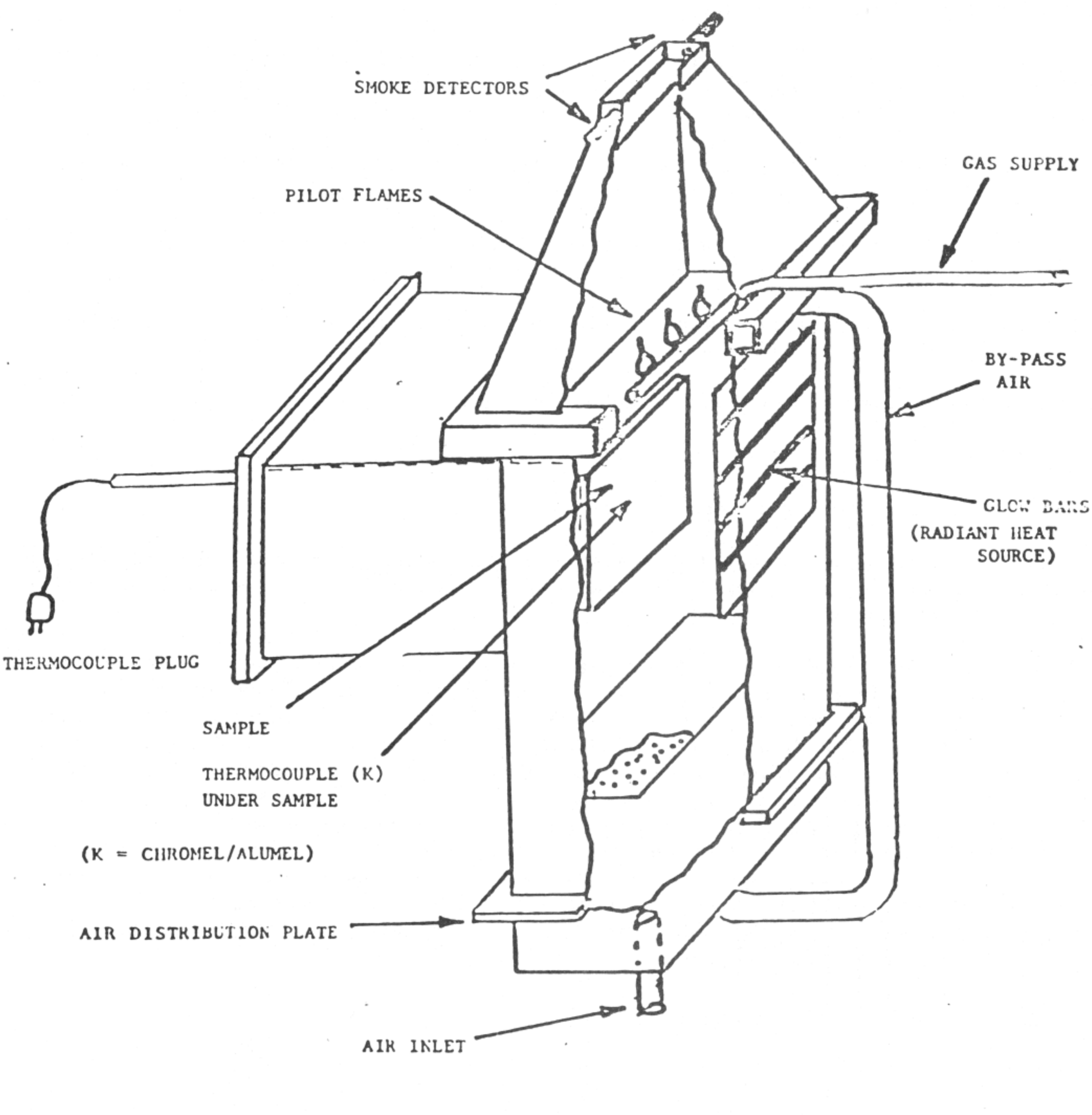


FIGURE 1. FAA OHIO STATE HEAT RELEASE APPARATUS

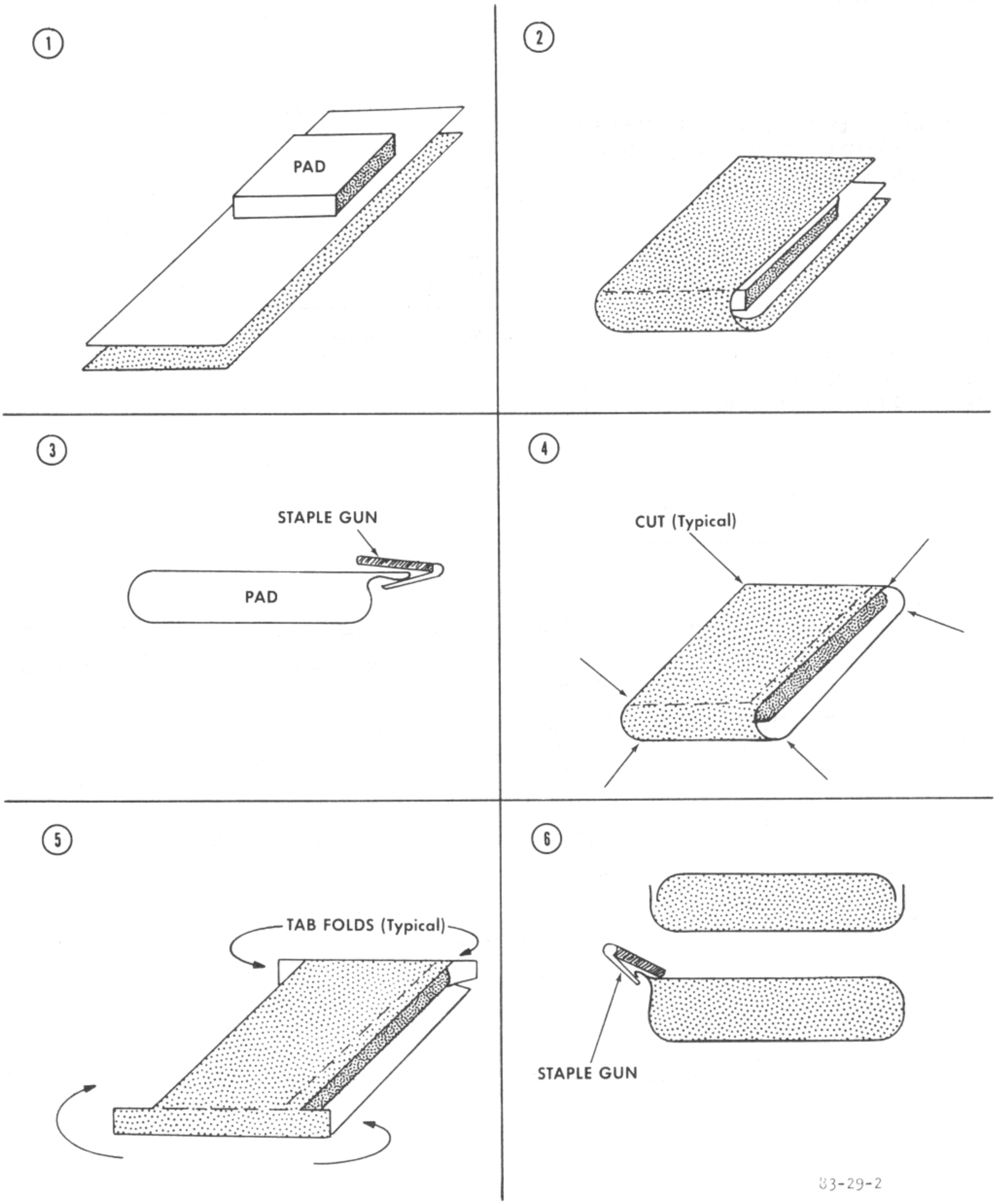


FIGURE 2. SAMPLE FABRICATION PROCEDURE - FAA OSU TEST

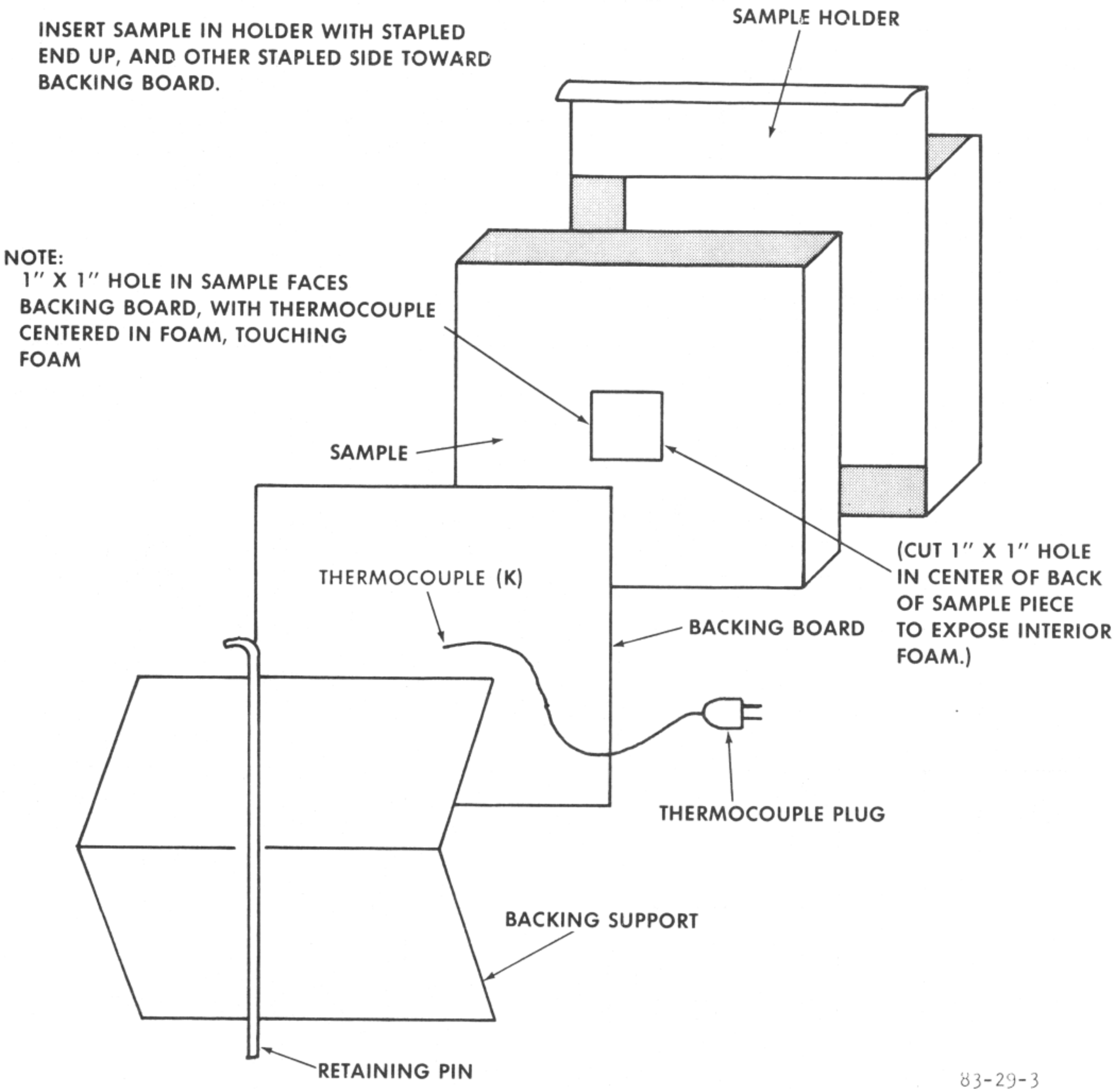


FIGURE 3. FOIL WRAPPED SAMPLE AND SAMPLE HOLDER - FAA OSU TEST

	1	2	3	4	5	6	7	8	9	10	11
63/4"	1582	1569	1525	1424	1433	1694	1699	1665	1681	1649	1269
6"	1649	1721	1717	1813	1868	1887	1804	1743	1740	1726	1394
5"	1658	1966	1933	1980	1962	1957	1924	1933	1863	1712	1428
4"	1582	1840	1896	1905	1910	1910	1915	1924	1813	1609	1269
3"	1402	1690	1735	1762	1744	1717	1781	1730	1547	1359	1057
2"	756	1128	1346	1350	1329	1286	1372	1389	1209	1023	846
1"	515	666	769	760	731	735	820	760	693	606	584
0"	466	528	511	580	545	545	602	558	532	488	515

FIGURE 4. BURNER TEMPERATURE PROFILE - FAA TWO-GALLON/HOUR BURNER

was measured with a thermocouple rake consisting of eleven 1/16-inch, type K, grounded Ceramocouples™ with a nominal 30 American wire gage (AWG)-size conductor, manufactured by the Thermo-Electric Company, mounted on a traverse mechanism 1-inch apart, and remotely controlled to provide 6 3/4 inches of vertical movement. A double seat metal frame was fabricated to which the samples were attached (figure 5). Samples were fabricated with the following dimensions:

1. Seat bottoms, 18 inches by 20 inches by 4 inches thick

2. Seat backs, 17 inches by 25 inches by 2 inches thick

Tests were documented by 16mm movies, 35mm motorized photographs and video tape. Tests were conducted in a well-ventilated room. A series of 1 and 2 minute tests were conducted with the burner flame impinging on the side of the seat bottom cushion (figure 5). The burner was then turned off and the sample allowed to burn until it self-extinguished or became fully consumed. Flame time after the burner was removed and estimated burn length were measured.

Another series of burner tests were conducted with weight loss monitoring, utilizing a Weigh-Tronix, Model WI-110, load platform. Ten of the eleven configurations (fiberglass excluded) were tested with a 2-minute burner exposure. Flame time after burner was removed, estimated burn distance, weight loss, and percent weight loss were calculated for these tests.

In both the OSU and Two Gallon/Hour Burner tests, all aluminized surfaces of fabric-blocking layers faced the outer fabric cover except when Norfab was wrapped over fire retardant urethane foam. Norfab, in this case, is wrapped with the

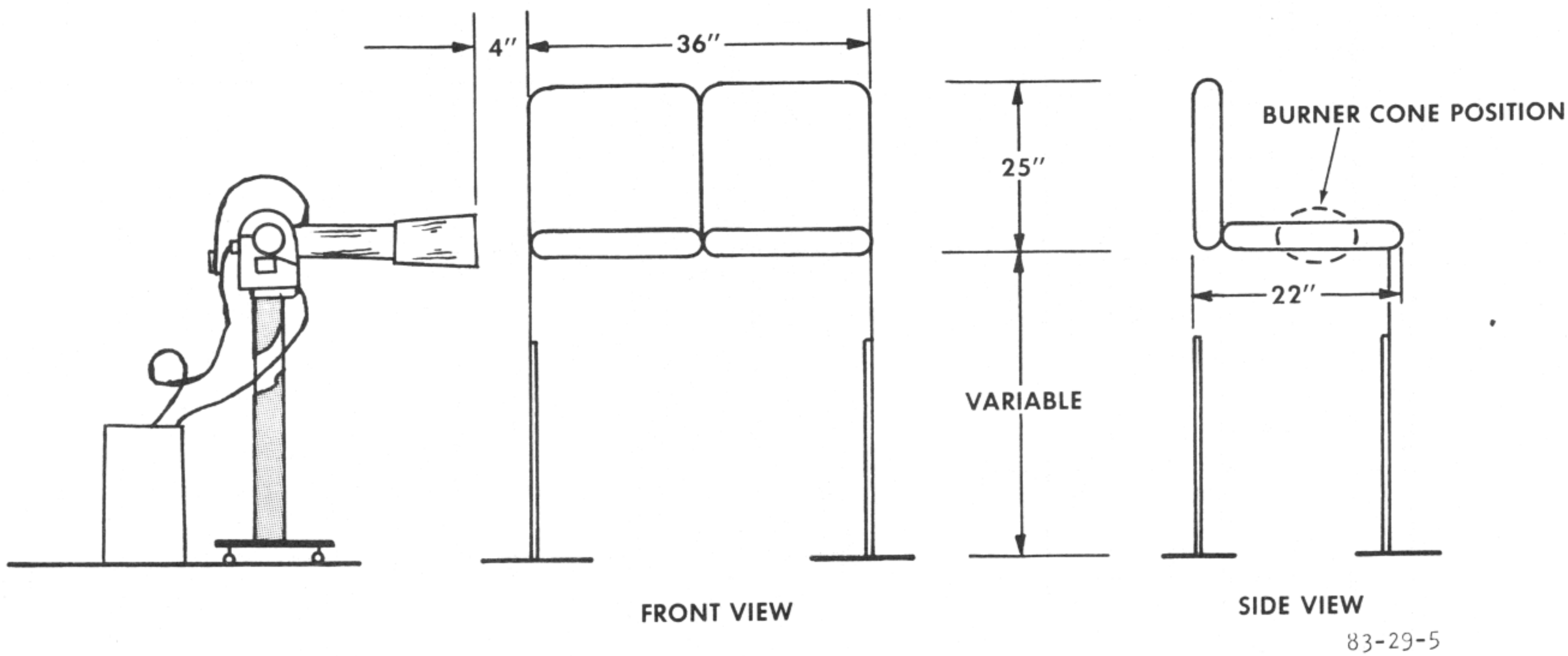


FIGURE 5. FAA TWO GALLON/HOUR BURNER - DOUBLE SEAT METAL FRAME

aluminum surface facing the inner foam cushion to prevent the fire retardant additives released during the foam decomposition process from attacking the Norfab fibers.

A brief description of the laboratory test methods employed by the participants and the larger scale CFS tests is included in appendix C.

TEST RESULTS AND ANALYSIS

FAA OSU tests were conducted in both piloted and nonpiloted modes at 2.5, 5.0, and 7.5 Watts/cm^2 for a total of 132 5-minute tests. The nonpiloted mode refers to exposure to radiant heat only; whereas, the piloted mode refers to exposure to radiant heat and a flaming ignition source. Piloted tests were performed with the standard three-flame burner positioned horizontally above the sample holder. It was decided to use the upper pilot burner system exclusively, since the lower pilot burner produced a highly localized ignition source at the lower edge of the sample, which produced conditions too severe for comparative testing.

Initially, one test of each configuration was performed for each exposure condition. The data were then analyzed and it was determined that the following three exposure conditions gave the most consistent results in terms of sample ignition: 2.5 W/cm^2 nonpiloted, 5.0 W/cm^2 piloted, and 7.5 W/cm^2 piloted. The 2.5 W/cm^2 piloted exposure produced erratic flashdown from the pilot source and resultant ignition of the sample, and appeared to be near the minimum heat flux level for sustained piloted ignition. Some of the samples produced flashdown and some samples did not (table 2). The 2.5 W/cm^2 nonpiloted exposure produced no autoignition. The 5.0 W/cm^2 nonpiloted exposure produced a range of autoignition times making comparison of heat and smoke release rates difficult. The 5.0 W/cm^2 piloted exposure produced consistent flashdown around 12 seconds. The 7.5 W/cm^2 nonpiloted exposure also produced a range of autoignition times making comparison of heat and smoke release rates difficult. The 7.5 W/cm^2 piloted exposure produced a consistent flashdown around 6 seconds. It was concluded that the most consistent exposure conditions would produce the most repeatable results. Therefore, erratic flashdown at 2.5 W/cm^2 piloted exposure and a range of autoignition times for 5.0 and 7.5 W/cm^2 nonpiloted exposures were regarded as good reasons for discarding these conditions.

Cummulative heat and smoke release data at 1, 3, and 5 minutes are presented for 2.5, 5.0, and 7.5 W/cm^2 heat flux levels in tables 3 through 5, respectively. Maximum heat and smoke release rates are also presented.

Figure 6 is a graphical representation of the above parameters. As can be seen in these tables, the data for the three replicate tests at the 5.0 W/cm^2 heat flux level appears to give the best discrimination among the 11 configurations tested. At the 7.5 W/cm^2 heat flux level, the cummulative heat and smoke release data appears to have leveled off at slightly above the 3-minute data, probably because total consumption of the sample occurred near the 3-minute mark. Had there been sufficient material remaining of sample number 1, better discrimination might have been found.

A comparison of the piloted versus nonpiloted heat and smoke release data are presented in tables 6 through 8. Where replicate tests were performed, the average

TABLE 2. TIME TO SAMPLE IGNITION

TIME TO SAMPLE IGNITION (SECONDS)

SAMPLE NO.	HEATING RATE					
	2.5 W/cm2		5.0 W/cm2		7.5 W/cm2	
	N.P.	P.	N.P.	P.	N.P.	P.
1	NI	NI	42	12	11	6
2			138		11	
3			30		14	
4		NI	22		9	
5		39	32		11	
6		33	30		13	
7		71	NI		18	
8		39	25		13	
9		NI	184		15	
10			NI		14	
11	NI	NI	NI	12	9	6

NI=NO IGNITION

TABLE 3. FAA OSU HEAT AND SMOKE RELEASE DATA, 2.5 W/CM^2

HEATING RATE 2.5 W/cm^2

	HEAT						SMOKE				
SAMPLE No.	$Q-J/cm^2$				$Max-J/cm^2-sec$		Ds			$Max-sec^{-1}$	
	1 min	3 min	SD DEV	5 min	dQ/dt	t-sec	1 min	3 min	5 min	dD_s/dt	t-sec
1	13	54	38	109	.68	204	9	49	96	.97	156
2	11	48	28	104	.63	236	8	16	18	.29	44
3	17	66	35	143	.81	258	5	12	12	.26	52
4	12	42	18	101	.81	260	5	10	10	.19	40
5	10	50	42	99	.60	155	7	30	30	.68	72
6	18	70	23	138	.95	227	6	26	26	.46	72
7	21	68	30	136	.99	207	7	19	19	.29	50
8	22	61	30	135	1.07	259	4	11	11	.23	42
9	14	58	19	122	.99	211	8	32	32	.46	56
10	14	52	26	114	.99	259	7	17	17	.32	52
11	27	71	14	143	1.01	261	15	25	25	.71	50

TABLE 4. FAA OSU HEAT AND SMOKE RELEASE DATA, 5.0 W/CM^2

HEATING RATE 5.0 W/cm^2

SAMPLE No.	HEAT						SMOKE				
	$Q-J/cm^2$				$Max-J/cm^2-sec$		Ds			$Max-sec^{-1}$	
	1 min	3 min	SD DEV	5 min	dQ/dt	t-sec	1 min	3 min	5 min	dD_s/dt	t-sec
1	640	1542	110	1901	16.78	44	62	93	93	2.53	24
2	337	761	12	1273	15.16	23	35	117	172	2.40	22
3	341	993	39	1632	15.51	24	33	142	190	2.24	22
4	315	646	81	932	15.09	24	35	69	86	1.36	22
5	381	1055	39	1878	13.75	23	24	49	72	1.13	24
6	393	639	42	1102	14.30	24	37	39	75	1.87	28
7	383	1094	177	1735	14.80	24	20	50	74	.74	30
8	339	695	19	1023	14.95	24	27	82	87	2.01	24
9	356	715	129	1362	14.88	25	29	46	88	1.78	28
10	346	628	38	832	15.30	23	26	28	28	1.23	24
11	410	808	62	1198	17.49	21	14	19	33	1.04	16

TABLE 5. FAA OSU HEAT AND SMOKE RELEASE DATA, 7.5 W/CM^2

HEATING RATE 7.5 W/cm^2

SAMPLE No.	HEAT: Q-J/cm^2 1 min	HEAT: Q-J/cm^2 3 min	HEAT: Q-J/cm^2 SD DEV	HEAT: Q-J/cm^2 5 min	HEAT: Max-J/cm^2-sec dQ/dt	HEAT: Max-J/cm^2-sec t-sec	SMOKE: Ds 1 min	SMOKE: Ds 3 min	SMOKE: Ds 5 min	SMOKE: Max-sec^{-1} dD_s/dt	SMOKE: Max-sec^{-1} t-sec
1	837	1802	356	2042	20.79	48	80	106	106	3.20	18
2	409	1173	183	1880	16.90	15	60	164	209	2.69	16
3	408	1314	26	2036	17.69	18	74	206	263	2.97	16
4	379	967	95	1621	15.44	17	63	152	221	2.21	18
5	433	1632	266	2304	14.66	17	30	94	108	1.54	18
6	450	1247	156	2350	16.28	15	48	126	215	2.33	18
7	427	1487	137	2231	16.28	16	47	95	110	1.13	26
8	405	1040	70	1786	15.93	18	63	159	222	2.53	18
9	422	1349	59	1981	15.58	16	47	124	159	2.72	18
10	416	827	116	1187	17.02	17	61	95	110	2.08	18
11	486	1065	124	1437	21.08	15	22	41	45	1.43	12

TABLE 6. FAA OSU PILOTED VS NONPILOTED TEST RESULTS, 2.5 W/CM^2

HEATING RATE $2.5\ W/cm^2$

		HEAT				SMOKE			
SAMPLE No.		Q-J/cm^2		Max-J/cm^2-sec		Ds		Max-sec^{-1}	
		3 min	5 min	dQ/dt	t-sec	3 min	5 min	dD_s/dt	t-sec
1	NP	19	20	.85	178	56	30	.89	180
	P	54	109	.68	204	49	96	.97	156
2	NP	82	162	1.05	177	2	2	.19	42
	P	48	104	.63	236	16	18	.29	41
3	NP	57	121	.95	232	2	2	.19	42
	P	66	143	.81	252	12	12	.26	52
4	NP	51	108	1.05	261	8	8	.19	36
	P	42	101	.81	260	10	10	.19	40
5	NP	341	391	14.80	48	5	5	.58	48
	P	50	99	.60	155	30	30	.68	72
6	NP	420	472	14.16	45	12	12	.58	48
	P	70	138	.95	227	26	26	.46	72
7	NP	83	143	2.11	76	19	19	.29	60
	P	68	136	.99	207	19	19	.29	50
8	NP	312	389	13.12	50	6	6	.29	54
	P	61	135	1.07	251	11	11	.23	42
9	NP	332	373	13.12	57	8	8	.58	60
	P	58	122	.99	211	32	32	.46	56
10	NP	53	124	1.17	275	5	5	.29	48
	P	52	114	.99	259	17	17	.32	52
11	NP	382	418	13.75	36	11	11	.68	48
	P	71	143	1.01	261	25	25	.71	50

NOTE: NP = Nonpiloted
P = Piloted

TABLE 7. FAA OSU PILOTED VS NONPILOTED TEST RESULTS, 5.0 W/CM^2

HEATING RATE 5.0 W/cm^2

SAMPLE No.		HEAT: Q-J/cm^2 3 min	HEAT: Q-J/cm^2 5 min	HEAT: Max-J/cm^2-sec dQ/dt	HEAT: Max-J/cm^2-sec t-sec	SMOKE: Ds 3 min	SMOKE: Ds 5 min	SMOKE: Max-sec^{-1} dD_s/dt	SMOKE: Max-sec^{-1} t-sec
1	NP	1218	1484	14.80	48	115	121	3.50	42
	P	1542	1901	16.78	44	93	93	2.53	24
2	NP	298	986	8.25	180	138	215	2.33	162
	P	761	1273	15.16	23	117	172	2.40	22
3	NP	823	1511	8.25	201	155	202	1.75	30
	P	993	1632	15.51	24	142	190	2.24	22
4	NP	635	1082	10.99	29	88	114	.78	24
	P	646	932	15.09	24	69	86	1.36	22
5	NP	739	1482	8.25	39	63	106	1.94	30
	P	1055	1878	13.75	23	49	72	1.13	24
6	NP	432	1379	7.83	39	105	178	2.53	42
	P	639	1102	14.30	24	39	75	1.87	28
7	NP	582	1266	7.20	180	106	140	1.91	30
	P	1094	1735	14.80	24	50	74	.74	30
8	NP	541	920	9.30	30	117	145	1.27	126
	P	695	1023	14.95	24	82	87	2.01	24
9	NP	62	637	6.55	300	82	172	1.75	30
	P	715	1362	14.88	25	46	88	1.78	28
10	NP	39	113	1.05	26	47	47	1.94	24
	P	628	832	15.30	23	28	28	1.23	24
11	NP	83	185	1.27	30	95	113	3.35	18
	P	808	1198	17.49	21	19	33	1.04	16

Note: NP = Non-piloted
P = Piloted

TABLE 8. FAA OSU PILOTED VS NONPILOTED TEST RESULTS, 7.5 W/CM^2

HEATING RATE 7.5 W/cm^2

		HEAT				SMOKE			
SAMPLE No.		Q-J/cm^2		Max-J/cm^2-sec		Ds		Max-sec^{-1}	
		3 min	5 min	dQ/dt	t-sec	3 min	5 min	dD_s/dt	t-sec
1	NP	2079	2309	22.21	54	113	113	3.35	24
	P	1802	2042	20.79	48	106	106	3.20	18
2	NP	971	1643	18.40	18	217	306	2.58	18
	P	1173	1880	16.90	15	164	209	2.69	16
3	NP	1199	1929	15.65	19	212	291	2.33	24
	P	1297	2036	17.69	18	206	263	2.97	16
4	NP	951	1591	17.35	15	199	303	1.36	12
	P	967	1621	15.44	17	152	221	2.21	18
5	NP	1665	2044	16.02	15	248	255	1.75	18
	P	1632	2304	14.66	17	94	108	1.54	18
6	NP	1041	2082	16.28	18	137	254	2.53	24
	P	1247	2350	16.28	15	126	215	2.33	18
7	NP	1156	1900	12.90	22	92	137	.97	18
	P	1487	2231	16.28	16	95	110	1.13	26
8	NP	885	1503	17.98	18	107	154	1.36	18
	P	1040	1786	15.93	18	159	222	2.53	18
9	NP	1187	1859	15.45	20	126	156	2.72	18
	P	1349	1981	15.58	16	124	159	2.72	18
10	NP	784	1167	17.13	18	109	137	1.56	18
	P	827	1187	17.02	17	124	110	2.08	18
11	NP	637	966	23.26	16	47	53	1.37	12
	P	1065	1437	21.08	15	41	45	1.43	12

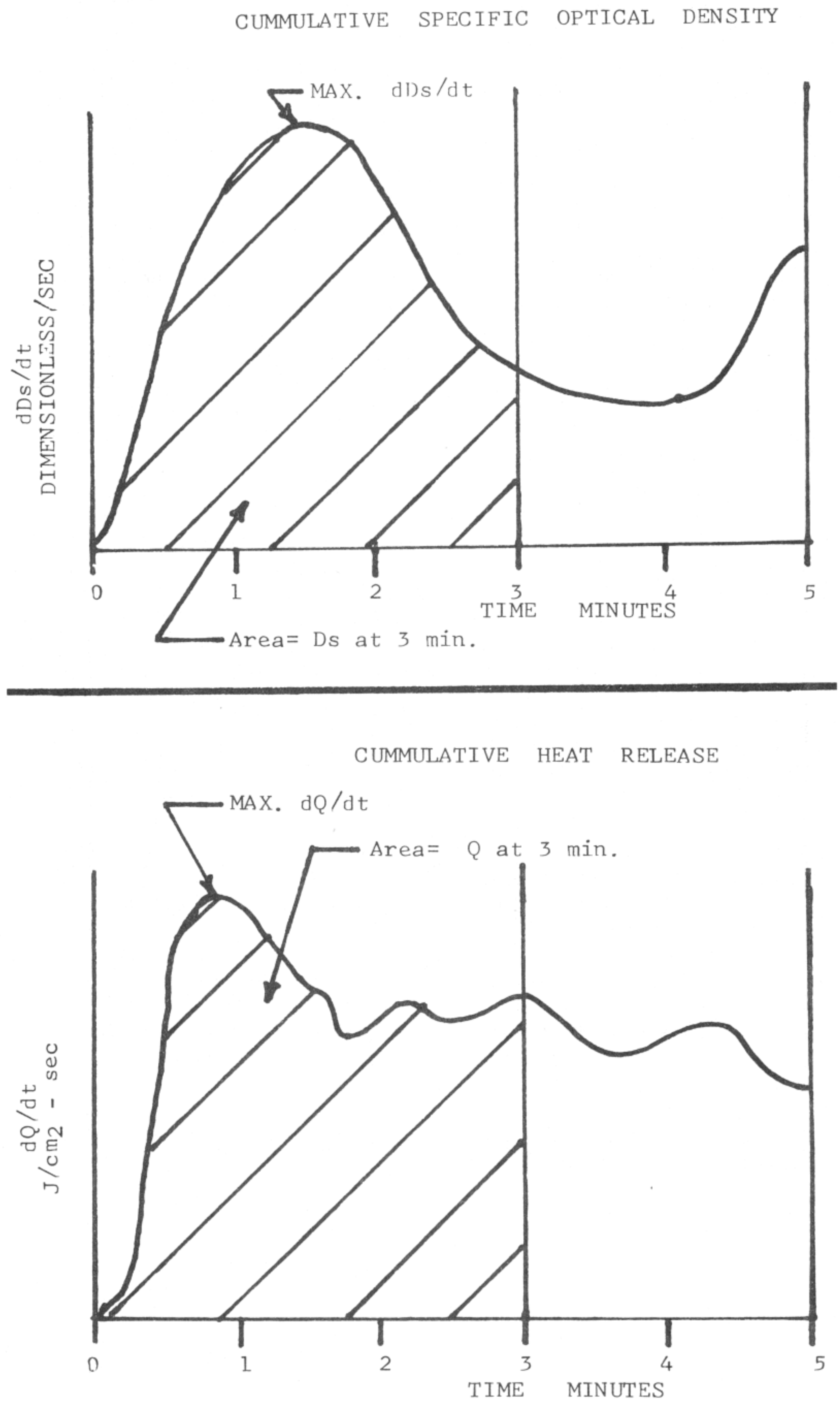


FIGURE 6. PICTORIAL DISPLAY OF OSU PARAMETERS

value is used for comparison. At the 2.5 W/cm^2 heat flux level, the piloted exposure appeared to be a more severe condition, provided flashdown occured. Samples number 5,6,8,9, and 11 displayed significantly higher maximum heat release rates for the piloted case at the 2.5 W/cm^2 exposure. The differences between the 5.0 W/cm^2 piloted versus nonpiloted data are attributed to the range of autoignition times for the nonpiloted exposure (22 to 184 seconds with three samples not igniting at all). At the 7.5 W/cm^2 heat flux level, the differences between the piloted and nonpiloted exposure are less evident. This is due to the early autoignition times (9 to 18 seconds) of all samples tested. Hence, similar results are obtained for both exposure conditions at 7.5 W/cm^2.

Backface differential temperature measurements are presented for the first test at each heat flux exposure condition (figures 7 through 12). At 5.0 W/cm^2, the aluminized fabric and foam blocking layers fall into distinct groups, and the foam-blocking layers had better performance than the aluminized fabrics. Overall, the LS-200 "full" (sample number 10) was the most effective means of reducing the amount of temperature rise over the duration of these 5-minute tests.

Twenty-four Two-Gallon/Hour Burner tests were conducted with actual size seat cushions situated in a double seat metal frame. The end of the burner nozzle was placed 4 inches from the side of the seat bottom cushion (figure 5). Two sets of the following configurations were prepared and tested at 1- and 2-minute exposures: numbers 1,4,5,6,7,10, and 11. The 1-minute exposure was sufficient to discriminate between FR Urethane and blocking layer seats, but was insufficient to discriminate between individual blocking layers. The 2-minute exposure appeared to give better discrimination between individual blocking layers. Another series of 10 sets of the 11 configurations from table 1 (sample number 7 omitted) were prepared and tested for a 2-minute exposure to the burner. Flame time after the burner was removed was recorded and is presented in figure 13. An estimate of the flame spread distance across the bottom cushion adjacent to the burner was made and is presented in figure 14. For this series of tests, continuous weight loss data were recorded. These results are also included in figure 13. The Two-Gallon/Hour Burner tests were more qualitative than quantitative, but produced a clear-cut pass/fail evaluation of the effectiveness of the test materials as shown in figure 15. The photographs shown in figure 15 were taken immediately after the burner was removed at 2 minutes into the tests. Noteworthy, is the dramatic difference of the baseline fire-retarded urethane seat when compared with any of the improved seat cushions. Another advantage of the Two-Gallon/Hour Burner was that the complete cushion assembly could be tested (seams, stitching, etc.) to show actual performance in these critical areas.

The Two-Gallon/Hour Burner test can be likened to a large bunsen burner type of test (FAR 25.853), with approximately the same parameters being measured.

STATISTICAL ANALYSIS OF INTERLABORATORY STUDY.

Due to the variety of methods and end point measurements employed by the participants of the interlaboratory study and the uncertain relationship between each, it is difficult to meaningfully compare the test results obtained with every device. Instead, it is more desirable to perform a non-parametric study of the relative rankings (tables 9 through 12) of the measurements and compare these results with the results from the CFS tests loss and percent weight loss data. This was accomplished through calculation of the correlation coefficient between the parameter ranking of every test condition/measurement and the CFS ranking in terms of weight loss and

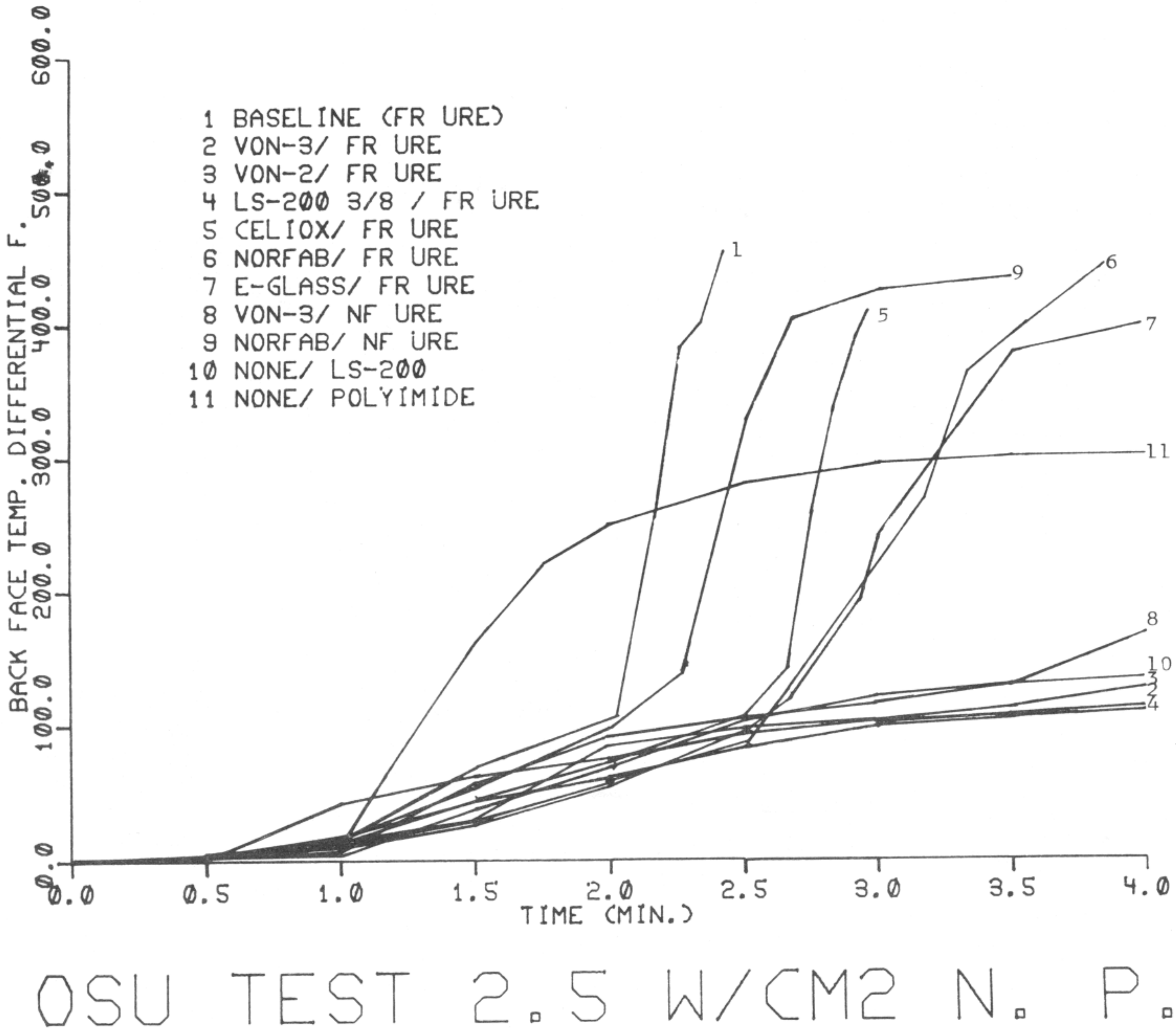


FIGURE 7. BACKFACE TEMPERATURE VS. TIME - FAA OSU 2.5 W/CM^2 - NONPILOTED

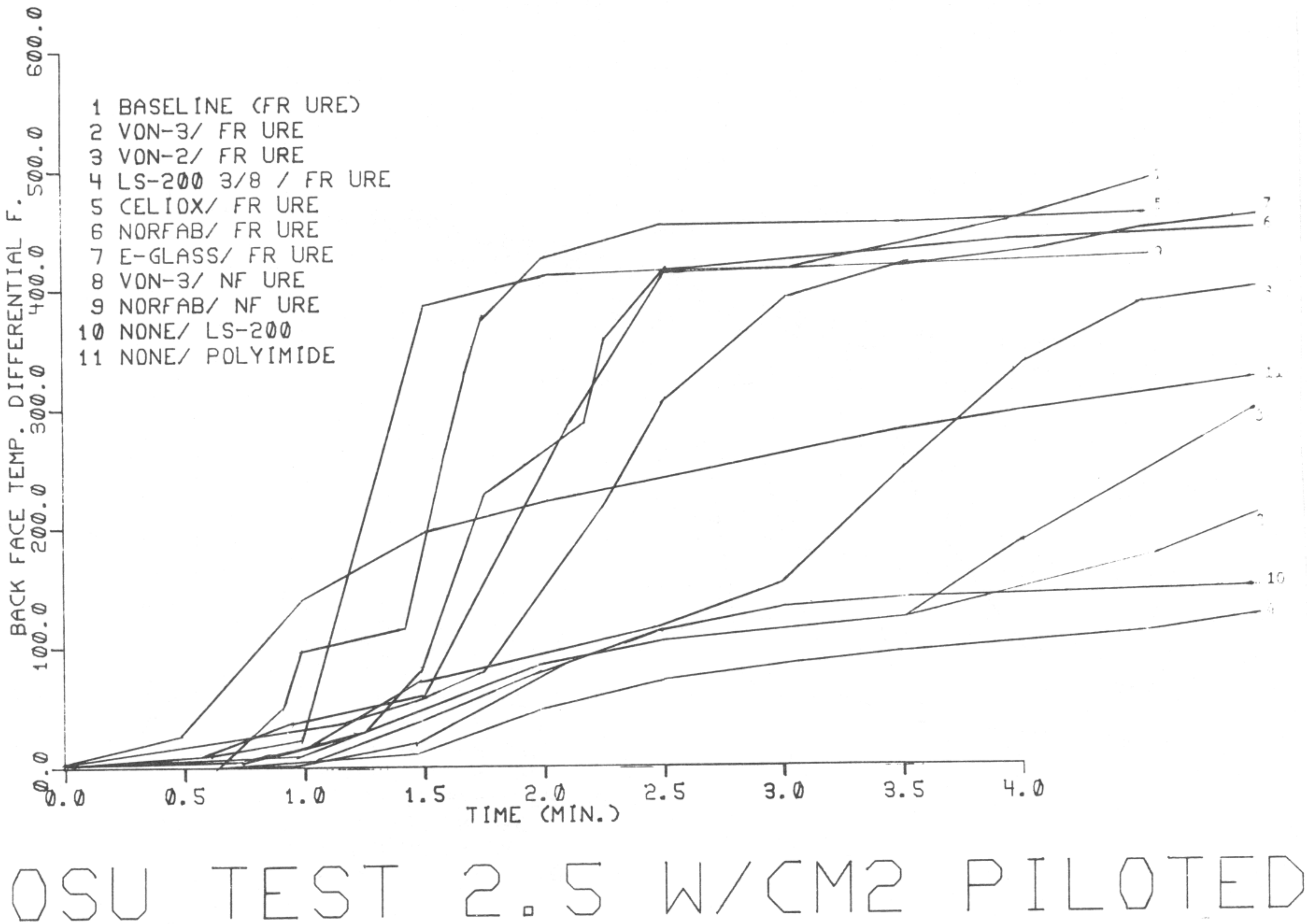


FIGURE 8. BACKFACE TEMPERATURE VS. TIME - FAA OSU 2.5 W/CM^2 - PILOTED

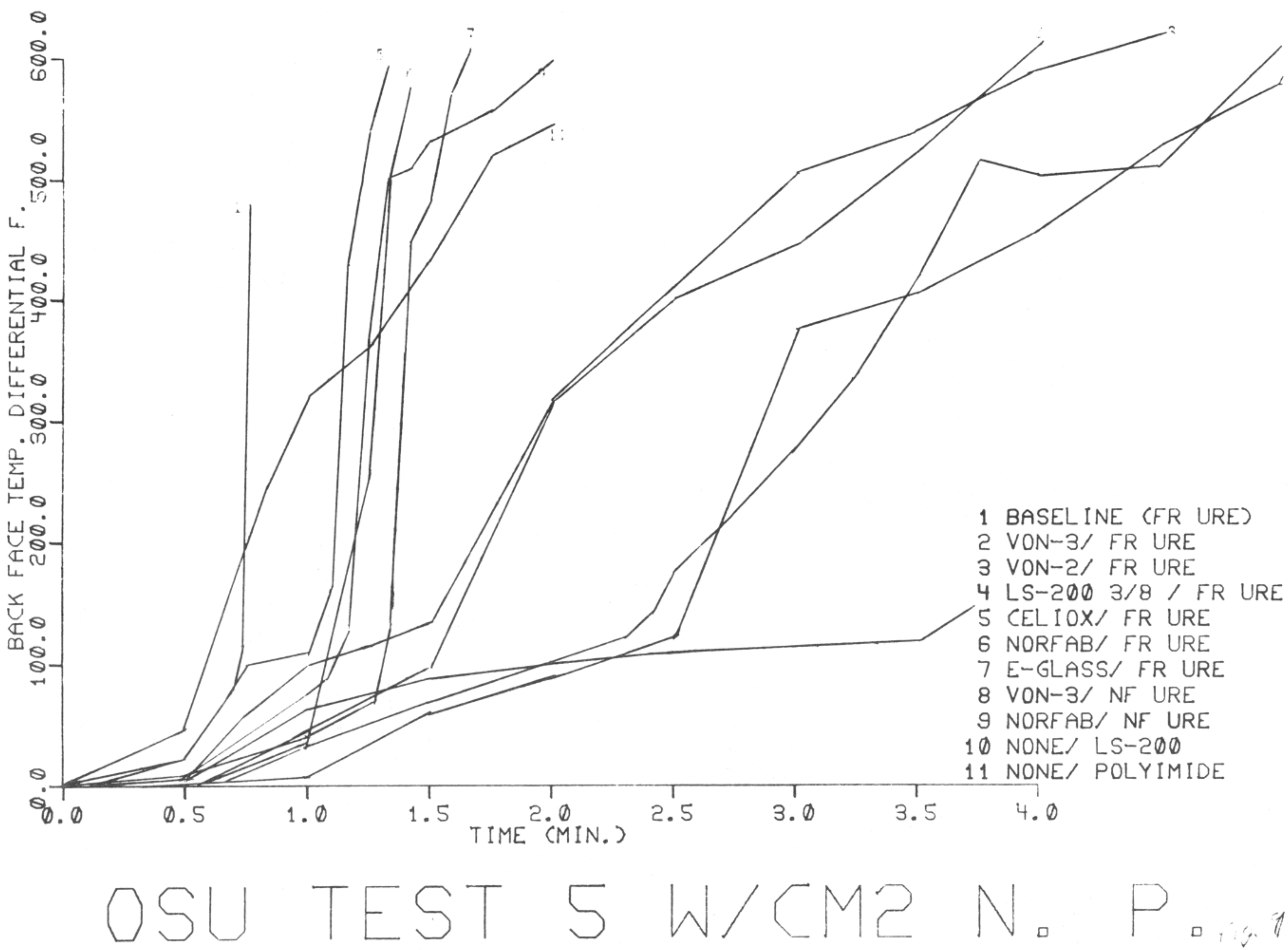


FIGURE 9. BACKFACE TEMPERATURE VS. TIME - FAA OSU 5.0 W/CM^2 - NONPILOTED

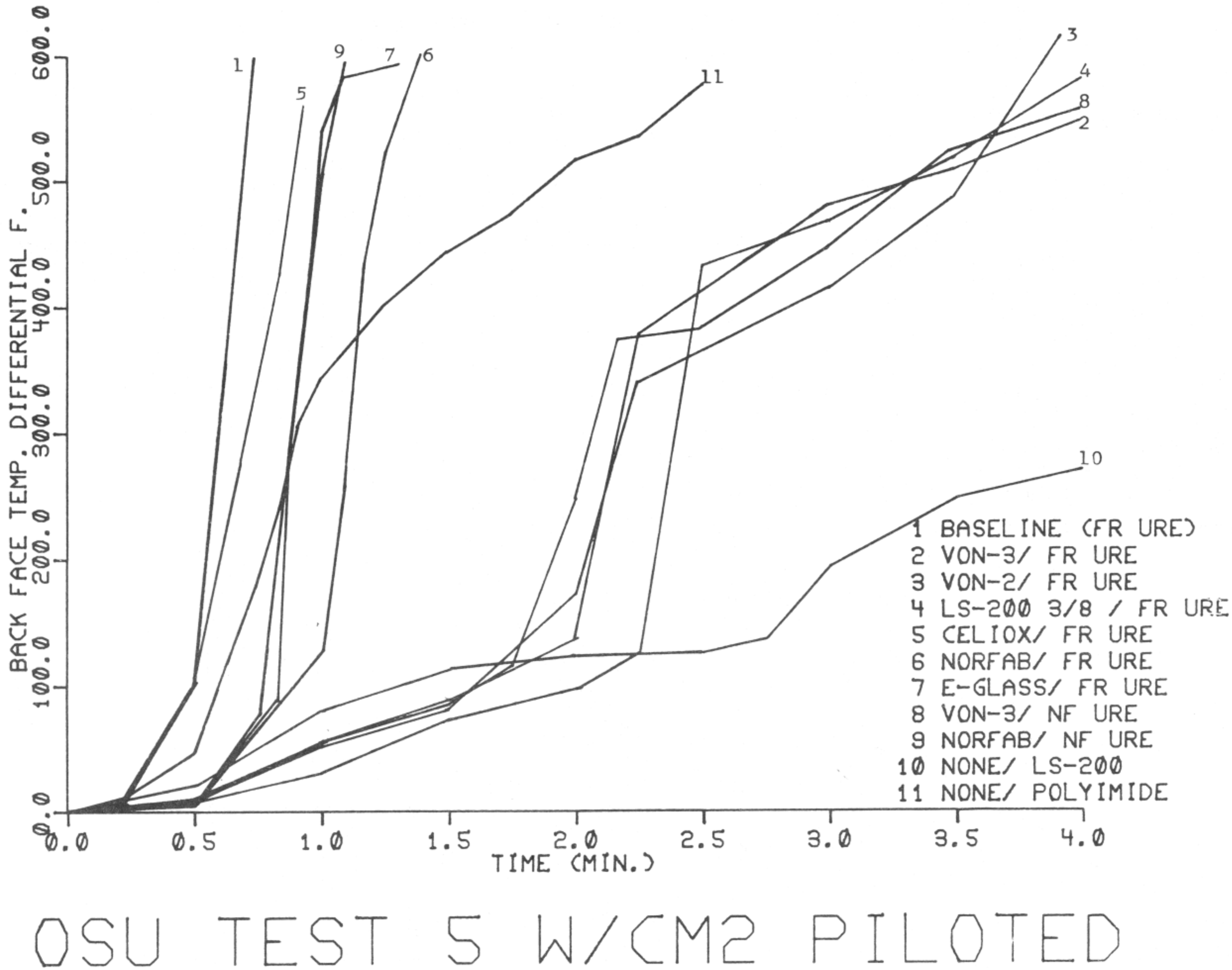


FIGURE 10. BACKFACE TEMPERATURE VS. TIME - FAA OSU 5.0 W/CM^2 - PILOTED

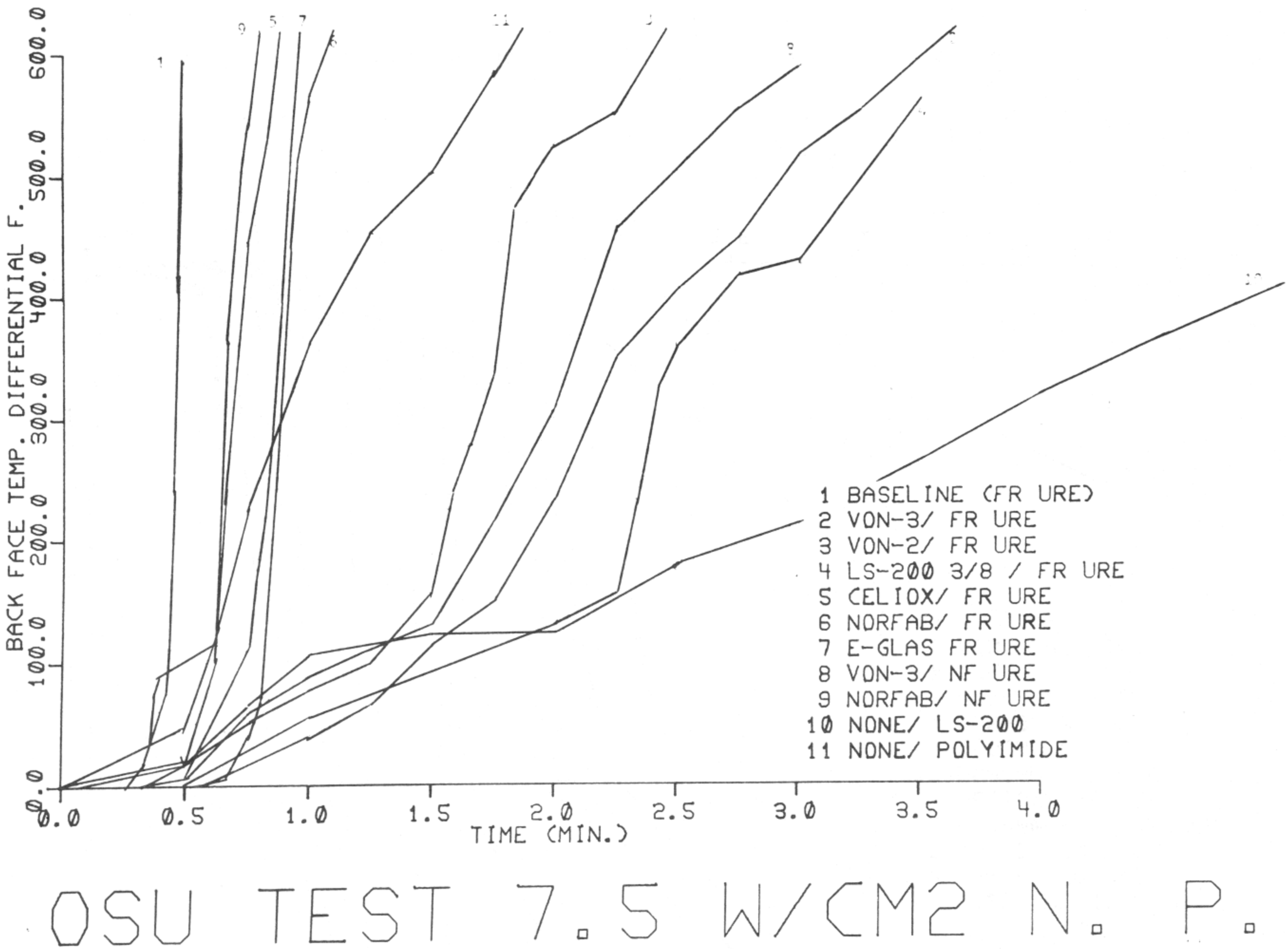


FIGURE 11. BACKFACE TEMPERATURE VS. TIME - FAA OSU 7.5 W/CM^2 - NONPILOTED

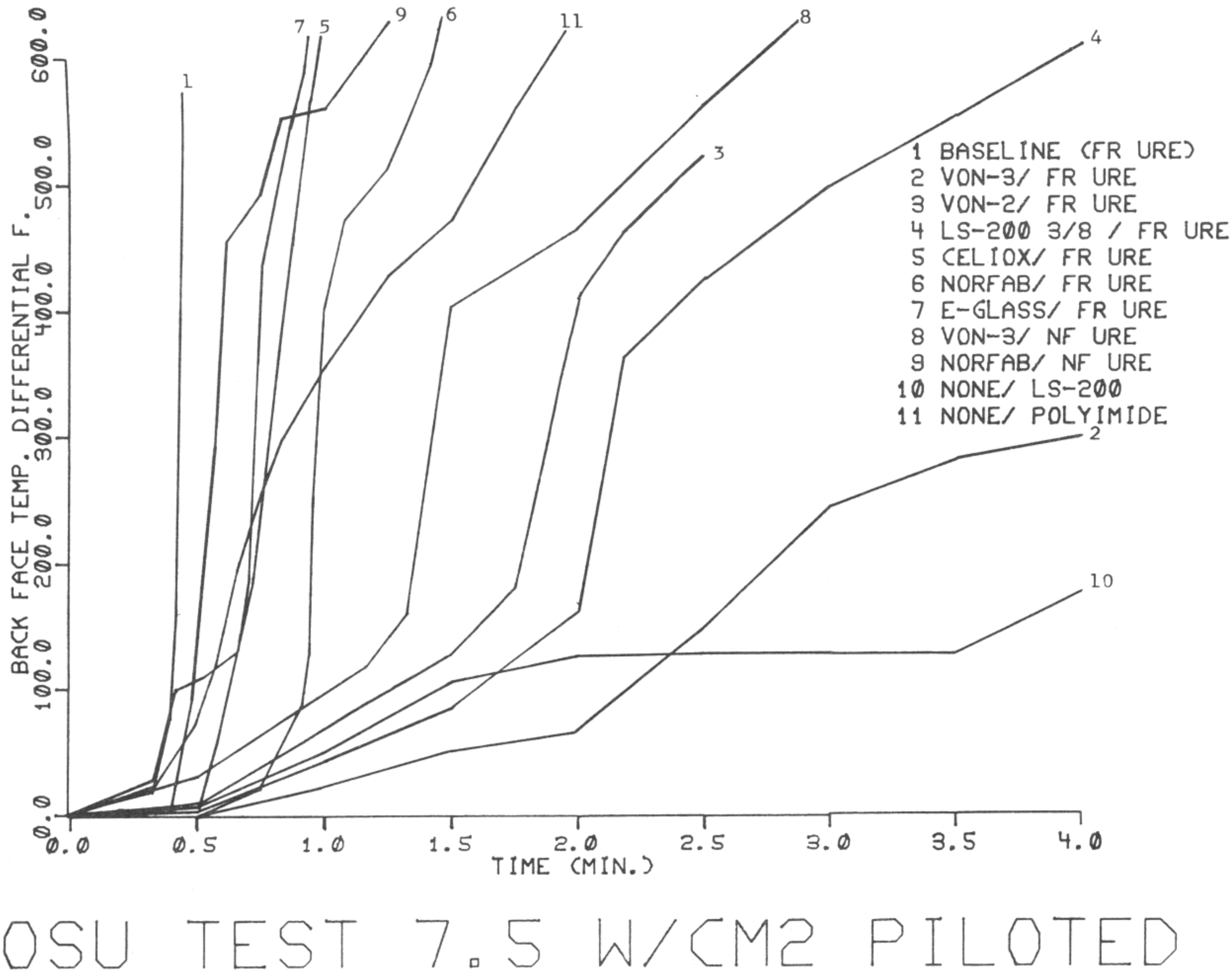


FIGURE 12. BACKFACE TEMPERATURE VS. TIME - FAA OSU 7.5 W/CM^2 - PILOTED

TEST NO.	SAMPLE NO.	WEIGHT (LBS.) INITIAL	FINAL	WEIGHT LOSS Δ LBS.	%	TIME* SEC.
1	10	9.46	9.24	.22	2.33	68
2	6	5.35	5.13	.22	4.11	55
3	5	4.86	-4.54	.32	6.58	102
4	11	2.58	2.30	.28	10.85	19
5	8	5.26	5.04	.22	4.18	50
6	4	5.81	5.31	.50	8.61	180+
7	3	5.43	5.19	.24	4.42	115
8	2	5.78	5.54	.24	4.15	137
9	9	4.86	-4.58	.28	5.76	67
10	1	3.68	1.06	2.62	71.19	0+

*After Burner Removal
Completely consumed @ two minutes

FIGURE 13. SECOND SERIES FAA TWO GALLON/HOUR BURNER — BURN TIME AND WEIGHT LOSS DATA

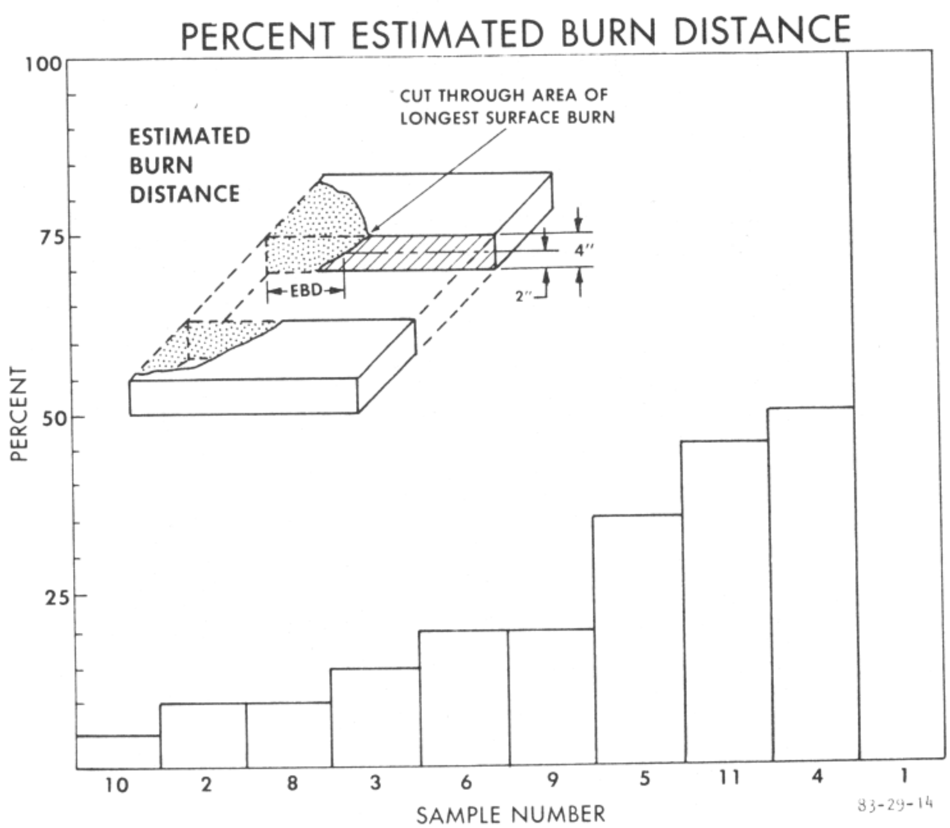
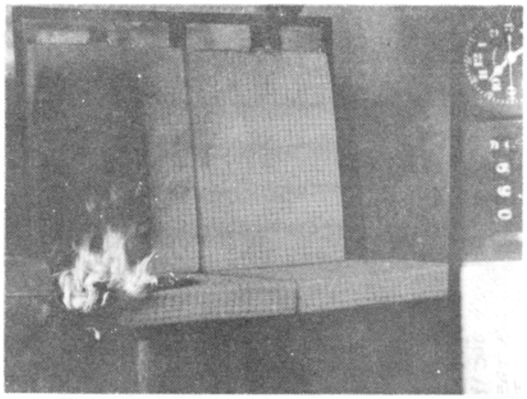
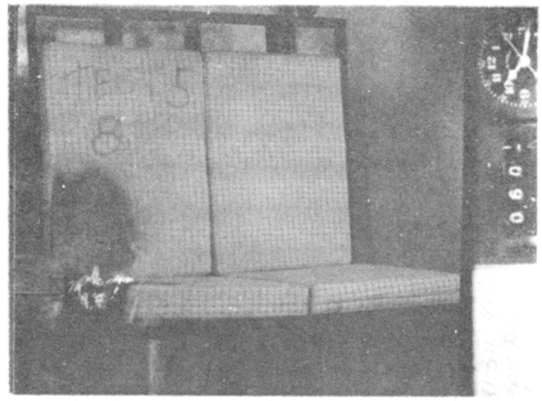


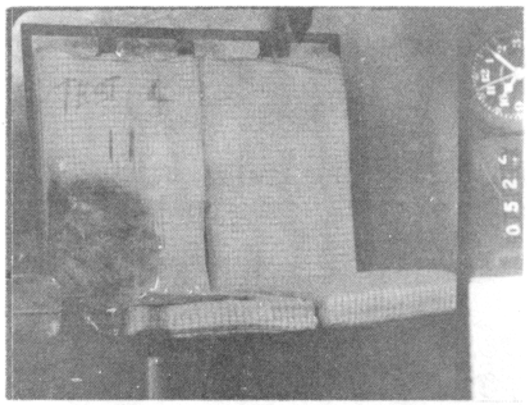
FIGURE 14. SECOND SERIES FAA TWO GALLON/HOUR BURNER - PERCENT ESTIMATED BURN DISTANCE



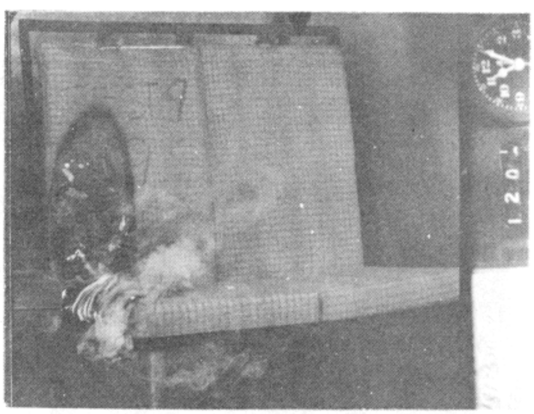
LS-200-3/8/FR



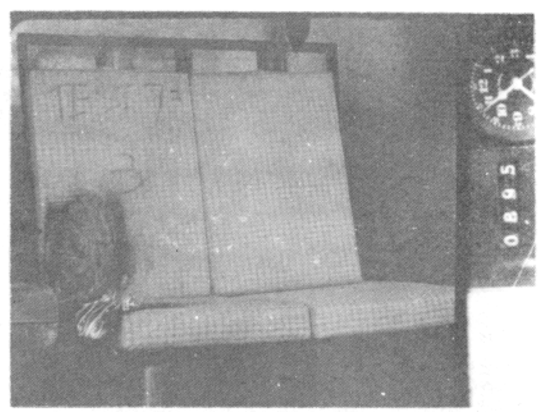
VONAR-3/NF



POLYIMIDE

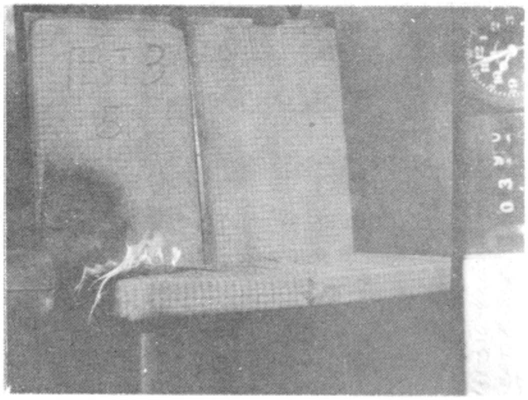


NORFAB/NF

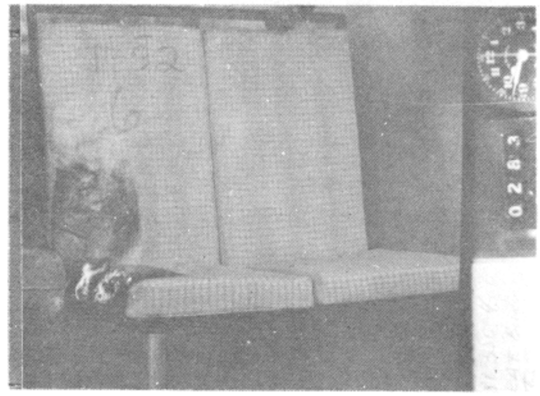


VONAR-2/FR

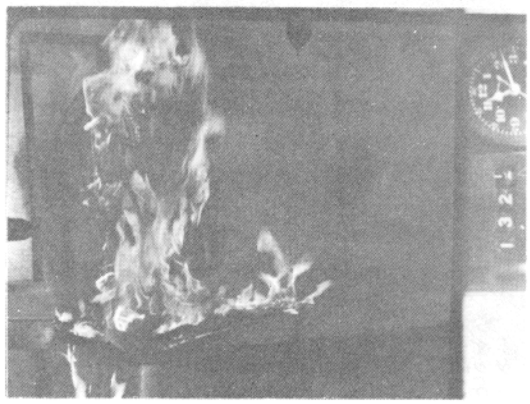
FIGURE 15. SECOND SERIES FAA TWO-GALLON/HOUR BURNER TEST RESULTS COMPARISON - SAMPLES 3, 4, 8, 9, 11, 1, 2, 5, 6, AND 10 (1 of 2 Sheets)



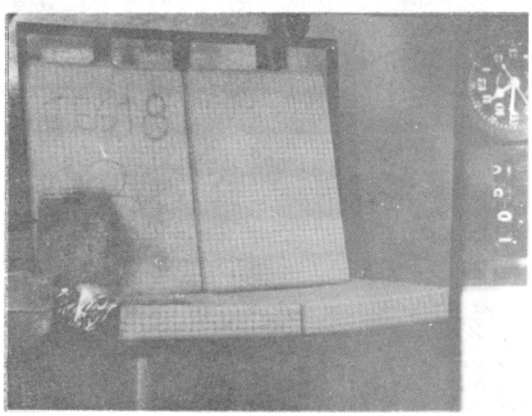
CELIOX/FR



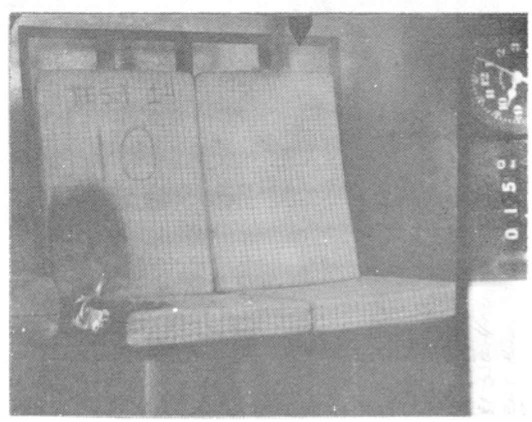
NORFAB/FR



URETHANE/FR



VONAR-3/FR



LS-200 FULL

FIGURE 15. SECOND SERIES FAA TWO-GALLON/HOUR BURNER TEST RESULTS COMPARISON - SAMPLES 3, 4, 8, 9, 11, 1, 2, 5, 6, AND 10 (2 of 2 Sheets)

TABLE 9. FAA OSU RANKING

CFS		2.5 w/cm²					5.0 w/cm²					7.5 w/cm²				
%WL	WL	Heat 1 min	Heat 3 min	Heat 5 min	Max dQ/dt	Back Face Temp	Heat 1 min	Heat 3 min	Heat 5 min	Max dQ/dt	Back Face Temp	Heat 1 min	Heat 3 min	Heat 5 min	Max dQ/dt	Back Face Temp
10	10	5	4	5	5	4	4	10	10	5	10	4	10	10	5	10
6	11	2	2	4	2	2	2	6	4	6	2	8	4	11	4	2
5	6	4	5	2	1	3	8	4	8	9	8	3	8	4	9	4
8	9	1	10	1	4	10	3	8	6	8	4	2	11	8	8	3
11	5	9]	1	10	3	8	10	9	11	4	3	10	2	2	6	8
9	8	10]	9	9	6	11	9	2	2	2	11	9	6	9	2	11
4	4	3	8	8	10	6	5	11	9	10	6	5	3	3	10	6
2	2	6	3	6	9	5	6	3	3	3	9	6	9	1	3	9
3	3	8	6	3	11	9	11	5	5	1	5	11	5	5	1	5
1	1	11	11	11	8	1	1	1	1	11	1	1	1	6	11	1

		SMOKE				SMOKE				SMOKE			
%WL	WL	1 min	3 min	5 min	Max	1 min	3 min	5 min	Max	1 min	3 min	5 min	Max
10	10	8	4	4	4	11	11	10	11	11	11	11	11
6	11	3	8	8	8	5	10	11	5	5	5	1	5
5	6	4	3	3	3	10	6	5	10	9	10	5	10
8	9	6	2	10	2	8	9	6	4	6	1	10	4
11	5	5]	10	2	10	9	5	4	9	2	9	9	6
9	8	10]	11	11	9	3	4	8	6	10	6	2	8
4	4	2	6	6	6	2]	8	9	8	4]	4	6	2
2	2	9	5	5	5	4]	1	1	3	8]	8	4	9
3	3	1	9	9	11	6	2	2	2	3	2	8	3
1	1	11	1	1	1	1	3	3	1	1	3	3	1

Best to worst —— Top to bottom

TABLE 10. BOEING OSU PARAMETER RANKING

	CFS	2.5 w/cm^2				5.0 w/cm^2				7.5 w/cm^2			
%WL	WL	Heat 1.5 min	Heat 3 min	Heat 5 min	Max $\frac{dQ}{dt}$	Heat 1.5 min	Heat 3 min	Heat 5 min	Max $\frac{dQ}{dt}$	Heat 1.5 min	Heat 3 min	Heat 3 min	Max $\frac{dQ}{dt}$
10	10	8	2	10	5	10	10	11	2	10	10	10	6
6	11	2	10	2	6	3	11	10	3	2	11	11	8
5	6	3	8	4	8	4	8	1	5	8	8	8	10
8	9	4	4	11	2	2	2	9	8	4	9	1	2
11	5	6	3	8	9	8	4	8	9	11	1	9	3
9	8	10	11	9	10	11	3	3	10	3	2	2	5
4	4	9	6	3	4	9	9	4	4	6	4	4	9
2	2	11	9	6	1	6	1	2	6	9	3	3	4
3	3	5	5	5	11	5	6	6	1	1	5	5	1
1	1	1	1	1	3	1	5	5	11	5	6	6	11

		SMOKE				SMOKE				SMOKE			
%WL	WL	1.5 min	3 min	5 min	Max	1.5 min	3 min	5 min	Max	1.5 min	3 min	3 min	Max
10	10	2	11	11	11	11	11	11	11	11	11	11	11
6	11	4	1	1	6	2	10	10	10	10	1	1	6
5	6	8	5	5	10	4	1	1	2	1	5	5	10
8	9	11	10	9	9	10	5	5	5	5	10	9	9
11	5	10	9	10	5	8	9	9	8	9	9	10	5
9	8	3	6	6	2	5	4	4	9	6	6	6	2
4	4	2	8	8	8	3	2	2	4	2	8	8	8
2	2	4	3	3	4	1	6	6	3	4	3	3	4
3	3	8	4	4	1	9	8	8	6	8	4	4	1
1	1	3	2	2	3	6	3	3	1	3	2	2	3

Best to worst —— Top to bottom

TABLE 11. NASA MODIFIED NBS CHAMBER AND DOUGLAS OSU PARAMETER RANKING

CFS		THERMAL EFFICIENCY w^3/cm^2			FIGURE OF MERIT			OVERALL RANKING
%WL	WL	2.5	5.0	7.5	2.5	5.0	7.5	
10	10	8]	11	4	8	6	9	8
6	11	4]	8	11	4	5	8	9
5	6	6	3	2	6	9	5	6
8	9	9	6]	8	9	8	2	5
11	5	5	2]	9	5	3	6	4
9	8	10	10	3	3	2	3	3]
4	4	3	4]	5	2	4	4	2]
2	2	2	5]	6				
3	3	11	9]	1				
1	1	1	1	10				

DOUGLAS OSU 2.5 w/cm^2 RANKINGS

		HEAT				SMOKE			
%WL	WL	1.5 min	3 min	5 min	10 min	1.5 min	3 min	5 min	10 min
10	10	2	2	8	8	4	2	2	1
6	11	8	8	2	2	2	4	1	5
5	6	4	4	4	1	8	8	5	9
8	9	9	1	1	9	5	1	8	6
11	5	5	5	9	4	1	5	9	2
9	8	6	9	5	5	9	9	6	4
4	4	1	6	6	6	6	6	4	8
2	2								
3	3								
1	1								

Best to worst — Top to bottom

TABLE 12. LOCKHEED MEEKER BURNER AND FAA TWO GALLON/HOUR BURNER PARAMETER RANKING

%WL	WL	UPHOLSTERY BURN LENGTH	FOAM BURN LENGTH	AFTER FLAME TIME	BURN INTENSITY
10	10	8	10	10	2
6	11	10	4	8	3
5	6	4	2	4	4
8	9	5	8	3	6
11	5	6	3	2	8
9	8	9	11	11	10
4	4	2	5	5	5
2	2	3	6	6	9
3	3	11	9	9	11
1	1	1	1	1	1

FAA TWO GALLON/HOUR BURNER RANKINGS

%WL	WL	Δ WT. LOSS	%WL	AFTER BURN
10	10	10	10	11
6	11	6	6	8
5	6	8	2	6
8	9	3	8	9
11	5	2	3	10
9	8	11	9	5
4	4	9	5	3
2	2	5	4	2
3	3	4	11	4
1	1	1	1	1

Best to worst — Top to bottom

percent weight loss. The correlation coefficient "r" is a measure of the linear relationship between two variables ("x" and "y") for "n" pairs of measurements and is expressed as follows:

$$r = \frac{n \Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

The computational formula for the correlation coefficient known as the Pearson Rank Formula is defined so that "r" will always assume a value from -1 to +1 (reference 8). A value of r=-1 represents perfect negative correlation and a value of r=+1 represents perfect positive correlation. A value of "r" close to zero represents little or no correlation. Hence, the closer a particular ranking is to that of the CFS tests, the closer the "r" value is to +1. It is assumed for purposes of attempted correlation that any test method measurement that did not show sample number 1 as the worst configuration would not be a suitable test method and is therefore not included in the correlation analysis. Tables 13 through 16 include the correlation data from the measurements. Table 17 is drawn from reference 8 and is commonly found in all statistic references. The degree of certainty for the Pearson Correlation calculation is determined by the size or number in the statistical sample population. It can be shown that when sample population is greater, i.e. n=10, a lower "r" value is necessary to show the same degree of certainty. Sample number 7 was omitted from the correlation calculation because it was not tested in the Douglas CFS. A 90-percent degree of certainty is chosen to define comparability between ranked measurements. Table 18 contains the list of rankings showing comparability with the weight loss and percent weight loss data from the CFS tests. Based on the comparability analysis several observations were made. They are (1) A number of test conditions/measurements exhibited comparability with CFS weight loss and percent weight loss rankings. (2) FAA, Boeing, and Lockheed tests exhibited comparability with CFS rankings but NASA and Douglas tests did not. (3) The good correlation with OSU smoke measurements cannot be explained physically. (4) Rankings of OSU tests conducted at 2.5 W/cm^2 did not show comparability with CFS test rankings. (5) The 5.0 W/cm^2 heat flux level seems to be the condition to use for testing blocking layer materials in an OSU.

SUMMARY OF RESULTS

1. Several test measurement rankings from various laboratory devices for the materials tested in the interlaboratory study showed comparability with larger scale CFS weight loss and percent weight loss rankings. These devices were the FAA OSU, the Boeing OSU, the Lockheed Meeker Burner and the FAA Two-Gallon/Hour Burner.

2. For the materials tested, the NASA AMES Modified NBS Smoke Chamber test measurement rankings did not show comparability with larger CFS weight loss or percent weight loss rankings.

3. For the materials tested, the Douglas OSU test measurement rankings did not show comparability with larger CFS weight loss or percent weight loss rankings.

4. No 2.5 W/cm^2 OSU test measurement rankings showed comparability with larger CFS weight loss or percent weight loss rankings.

TABLE 13. FAA OSU - CFS CORRELATION COEFFICIENTS

HEAT	METHOD SMALL SCALE		'r'	METHOD LARGE SCALE
5.0W/CM2	SMOKE	MAX	.782	CFS WEIGHT LOSS
7.5 "	"	"	.733	" " "
7.5 "	"	1MIN	.709	" " "
7.5 "	"	MAX	.709	CFS % WEIGHT LOSS
5.0 "	"	"	.648	" " " "
5.0 "	HEAT	3MIN	.624	" " " "
5.0 "	SMOKE	1MIN	.600	" " " "
5.0 "	HEAT	3MIN	.588	CFS WEIGHT LOSS
5.0 "	"	5MIN	.564	CFS % WEIGHT LOSS
5.0 "	"	"	.552	CFS WEIGHT LOSS
7.5 "	SMOKE	1MIN	.552	CFS % WEIGHT LOSS__________COMPARABILITY^^^^
2.5 "	HEAT	BFT.	.485	" " " "
7.5 "	"	3MIN	.442	CFS WEIGHT LOSS
7.5 "	"	"	.418	CFS % WEIGHT LOSS
5.0 "	"	BFT.	.224	" " " "
5.0 "	"	"	.188	CFS WEIGHT LOSS
7.5 "	"	"	.139	" " "
7.5 "	"	"	.127	CFS % WEIGHT LOSS
2.5 "	SMOKE	5MIN	.067	" " " "
2.5 "	"	MAX	-.006	" " " "
2.5 "	"	3MIN	-.018	" " " "
2.5 "	"	5MIN	-.042	CFS WEIGHT LOSS
2.5 "	HEAT	BFT.	-.115	" " "
2.5 "	SMOKE	3MIN	-.127	" " "
2.5 "	"	MAX	-.188	" " "

Note: BFT = Backside Flame Temperature

TABLE 14. BOEING OSU - CFS CORRELATION COEFFICIENTS

HEAT	METHOD SMALL SCALE		'r'	METHOD LARGE SCALE
5.0W/CM2	SMOKE	MAX	.576	CFS WEIGHT LOSS__________COMPARABILITY^^^^
5.0 "	"	"	.430	CFS % WEIGHT LOSS
2.5 "	HEAT	5MIN	.358	CFS WEIGHT LOSS
2.5 "	"	"	.212	CFS % WEIGHT LOSS
2.5 "	"	3MIN	.139	" " " "
2.5 "	"	"	.103	CFS WEIGHT LOSS
5.0 "	"	1.5MIN	.103	" " "
5.0 "	"	"	.055	CFS % WEIGHT LOSS
2.5 "	"	"	-.030	" " " "
2.5 "	"	"	-.188	CFS WEIGHT LOSS

TABLE 15. NASA NBS CHAMBER-CFS AND DOUGLAS OSU - CFS CORRELATION COEFFICIENTS

HEAT	METHOD SMALL SCALE	NASA 'r'	METHOD LARGE SCALE
2.5W/CM2	THERMAL EFFICIENCY	.467	CFS % WEIGHT LOSS
5.0 "	" "	.333	CFS WEIGHT LOSS
5.0 "	" "	.285	CFS % WEIGHT LOSS
2.5 "	" "	.224	CFS WEIGHT LOSS

HEAT		TIME	DOUGLAS 'r'	METHOD LARGE SCALE
2.5W/CM2	HEAT	1.5MIN	-.143	CFS % WEIGHT LOSS
2.5 "	"	1.5MIN	-.179	CFS WEIGHT LOSS

TABLE 16. LOCKHEED MEEKER BURNER-CFS AND FAA TWO GALLON/HOUR BURNER-CFS CORRELATION COEFFICIENTS

METHOD SMALL SCALE	'r'	METHOD LARGE SCALE
UPHOLSTERY BURN LENGTH	.685	CFS % WEIGHT LOSS
BURN INTENSITY	.612	" " " " ____COMPARABILITY^^^
UPHOLSTERY BURN LENGTH	.406	CFS WEIGHT LOSS
BURN INTENSITY	.370	" " "
AFTERFLAME TIME	.333	" % WEIGHT LOSS
" "	.248	" WEIGHT LOSS
FOAM BURN LENGTH	.224	" % WEIGHT LOSS
" " "	.152	" WEIGHT LOSS

FAA 2 GALLON/HOUR BURNER - CFS CORRELATION COEFFICIENTS

METHOD SMALL SCALE	'r'	METHOD LARGE SCALE
AFTERFLAME TIME	.746	CFS WEIGHT LOSS
" "	.648	" % WEIGHT LOSS
CUSHION WEIGHT LOSS	.552	" " " "
CUSHION % WEIGHT LOSS	.552	" " " " ____COMPARABILITY^^^^

TABLE 17. CORRELATION COEFFICIENT VERSUS SAMPLE SIZE
DEGREE OF CERTAINTY CHART

No. of Samples	80%	90%	95%	99%	99.9%	Degree of Certainty
7 Douglas OSU	.551	.669	.755	.875	.951	
10 FAA OSU Boeing OSU Lockheed Burner NASA Smoke Chamber FAA Burner	.433	.549	.632	.765	.872	Minimum Correlation Coefficient

TABLE 18. LIST OF RANKINGS SHOWING COMPARABILITY WITH CFS WEIGHT LOSS
AND PERCENT WEIGHT LOSS RANKINGS

	OSU		CFS	
FAA	5 w/cm^2	3 Min/H	%WL	WL
	5 w/cm^2	5 Min/H	%WL	WL
	5 w/cm^2	Max/S	%WL	WL
	5 w/cm^2	1 Min/S		WL
	7.5 w/cm^2	Max/S	%WL	WL
	7.5 w/cm^2	1 Min/S	%WL	WL
	2 G/H Burner %WL and WL		%WL	
	After Burn Time		%WL	WL
BOEING	OSU			
	5 w/cm^2			WL
LOOKKHEED	Meeker Burner Uphols. Burn Lth		%WL	
	Burn Intensity		%WL	

5. The Two-Gallon/Hour Burner Test is a laboratory test which exposes actual seat cushions to a large laboratory fire source. Because of its physical characteristics, the Two Gallon/Hour Burner resembles the larger scale CFS tests more closely than the remaining laboratory devices examined.

CONCLUSIONS

1. The Ohio State University Rate of Heat Release Apparatus is a suitable device to measure aircraft seat blocking layer effectiveness. Several test measurement rankings for the OSU operated at a 5.0 W/cm^2 heat flux level showed comparability with larger scale CFS weight loss and percent weight loss rankings.

2. The "Standard" FAA Two-Gallon/Hour Burner test is a suitable device to measure aircraft seat-blocking layer effectiveness. Of all the laboratory devices, the Two-Gallon/Hour Burner most resembled the larger scale CFS tests. Comparability was shown for burner test measurement rankings with CFS percent weight loss ranking.

3. The Lockheed Meeker Burner test is a suitable device to measure aircraft seat blocking layer effectiveness. Two test measurement rankings showed comparability with larger CFS weight loss and percent weight loss rankings.

4. Results from the laboratory study confirm the effectiveness of the aircraft seat-blocking layer concept.

REFERENCES

1. Hill, R. G., et al, Aircraft Seat Fire Blocking Layers; Effectiveness and Benefits Under Various Fire Scenarios, Federal Aviation Administration, report to be published.

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4. Smith, E., Test for Heat and Smoke Release Rates, American Society of Testing and Materials, E-906, Philadelphia, Pa., 1982.

5. Federal Aviation Administration, Flight Standard Service, Power Plant Engineering Report No. 3A (Revised), Standard Fire Test Apparatus and Procedure for Flexible Hose Assemblies, March 1978.

6. Schutter, K. J. and Duskin, F. E., Study for the Optimization of Aircraft Seat Cushion Fire-Blocking Layers - Full Scale - Test Description and Results, Contract NASA 2 - 11095, May 1982.

7. Demaree, J. E., Reevaluation of Burner Characteristics for Fire Resistance Tests, FAA-RD-76-213, January 1977.

8. Walpole, R. E., Elementary Statistical Concepts, Macmillan Publishing Company, Inc., New York, 1976.

APPENDIX A

MATERIAL DESCRIPTION

MATERIAL DESIGNATION	DESCRIPTION	WEIGHT/ DENSITY	SOURCE
Wool/Nylon	R76423 Sun Eclipse, Azure Blue, 78-3880	13.96 OZ/YD^2	Collins & Aikmen P.O. Box 500 Albemarle, NC 28001
LS-200 3/8	Neoprene Foam, 3/8" LS-200	34.0 OZ/YD^2	Toyad Corporation 16 Creole Drive Pittsburgh, Pa 15239
LS-200 Full	Neoprene Foam, LS-200	7.5 LB/FT^3	Toyad Corporation 16 Creole Drive Pittsburgh, Pa 15239
Celiox™ 101	Aluminized Preox™ Fabric, Plain Weave, Neoprene CTD, P/N 1299013, 1100-4	11.53 OZ/YD^2	Gentex Corp. P.O. Box 315 Carbondale, Pa 18407
F.R. Urethane	No. 2043 FR Urethane Foam Fire Retarded	1.87 LB/FT^3	North Carolina Foam P.O. Box 1112 Mt. Airy, NC 27030
Norfab™ 11HT-26-AL	Norfab Fabric, Weave Structure 1x1 Plain, Aluminized on One Side, 25% Nomex™ & 5% Kynol™	11,8 OZ/YD^2	Amatex Corporation 1032 Stonebridge St. Norristown, Pa 19404
Vonar™ 2	Vonar 2, 2/16" with Osnaburg Cotton Scrim	19.97 Oz/YD^2	Chris Craft Industries 1980 East State St. Trenton, NJ 08619
Vonar 3	Vonar 3, 3/16" with Osnaburg Cotton Scrim	27.07 OZ/YD^2	Chris Craft Industries 1980 East State St. Trenton, NJ 08619
Polyimide	Polyimide Foam	1.2 LB/FT^3	International Harvester 2200 Pacific Hwy. P.O. Box 80966 San Diego, CA 92138

N.F. Urethane	Urethane Foam Non-Fire Retarded, Medium Firm, ILD32	1.45 LB/FT^3	Foam Craft, Inc. 11110 Business Cr. Dr. Cerritos, CA 90701
181 E-Glass	181 E-Glass, Satin Weave	22.2 OZ/YD^2	Uniglass Industries Statesville, NC

APPENDIX B

TWO GALLON/HOUR BURNER SPECIFICATIONS

Fuel Flow - 2.0 Gallons/Hour

Motor - 1/4 H.P. 3450 RPM

Blower Wheel - 3.5 x 5.25 Inches

Pump - Single Stage

Tube Extension - 4.125 x 11 Inches

Heat Flux - 10.0 BTU/ft^{2}s. Measured with a Thermogage™ Calorimeter (reference 7)

Heat Transfer to 1/2 Inch Copper Tube - 4750 BTU/hour (reference 5)

The Park Oil Burner used in this study contains a 2.25 gallon/hour 80 degree nozzle operated at a pressure of 85 psig, delivering 2.03 gallons/hour. Air pressure in the air tube, or burner tube, was adjusted to produce 0.17 inches of water.

The Park Oil Burner is a suitable replacement for the Lennox Burner and can be obtained from the following address:

Park Oil Burner Mfg. Co.
N. New York Ave. Absecon Blvd.
Atlantic City, New Jersey 08401

Phone: (609) 344-7709

APPENDIX C

INTERLABORATORY PARTICIPANT DATA

BOEING OSU TESTS.

Boeing used the OSU Apparatus (E-906) with compensator tab for this interlaboratory study. Tests were conducted at 2.5, 5.0 and 7.5 W/cm^2 heat flux levels using three specimens of each configuration (table 1 of the text) for a total of 99 tests. Specimen sizes were 6 by 6 by 1 inch. Only vertical orientation tests were performed. Boeing OSU test data are included in charts C-1 through C-6.

DOUGLAS OSU TESTS.

Douglas also used the OSU Apparatus (E-906) but without compensator tab for this interlaboratory study. Tests were conducted at 2.5 and 5.0 W/cm^2 heat flux levels using three specimens of each of the following configurations: numbers 1, 2, 4, 5, 6, 8, and 9 for a total of 42 tests. Specimen sizes were 10 by 10 by 1 inch. Only vertical orientation tests were performed. Douglas OSU test data are included in charts C-7 through C-10.

DOUGLAS CFS TESTS.

Douglas used their Cabin Fire Simulator (CFS) to test 13 configurations of seat cushion materials under large-scale conditions. Full size seat cushion bottoms and backs were positioned in a double seat metal frame and exposed to a large radiant panel consisting of quartz lamps. Several parameters were measured for these tests, including weight loss of the cushioning material. Douglas CFS weight loss and percent weight loss are included in charts C-11 and C-12.

LOCKHEED MEEKER BURNER TESTS.

Lockheed used a Meeker Burner for this interlaboratory study. Tests were conducted for specimens of each configuration. The Meeker Burner is a more severe version (larger flame) of the Vertical Bunsen Burner test method (F-501) which is specified in FAR 25.853. Burn length and self-extinguish times are the key parameters measured. Lockheed Meeker Burner test data is included in chart C-13.

NASA AMES MODIFIED NBS SMOKE CHAMBER.

NASA AMES used a Modified NBS Smoke Chamber for this interlaboratory study. Tests were conducted at 2.5 and 5.0 W/cm^2 for each material configuration. Weight loss is continuously monitored for the 3 by 3 inch specimens. Thermal efficiency and specific mass injection rate are calculated and a Figure of Merit is determined for each configuration. NASA test data are included in charts C-14 and C-15.

CHART C-1

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - Sec.
1	263.	753.	1235	1898	2107	17.75 17.57	50 90
2	221.	411.	469	622	1133	13.67 5.65	25 270
3	231.	425.	524	955	1895	13.34 8.90	25 275
4	192.	420.	531	787	1241	14.29 4.81	25 300
5	215.	475.	714	1607	1977	12.56 10.81	25 150
6	205.	407.	539	1279	1956	12.32 10.27	25 205
7	243.	467.	638	1546	1983	13.78 11.99	20 155
8	224.	408.	463	745	1274	12.81 5.40	25 205
9	224.	429.	626	1338	1736	13.78 8.38	25 140
10	232.	447.	539	698	929	13.27	25
11	306.	536.	704	1005	1243	17.84	20

CHART C-2

SUMMARY OSU EVALUATION

HEATING RATE: 2.5 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1	20.	95.	122	147	147	2.92 1.23	40 80
2	5.	8.	8	8	59	.59 .75	30 240
3	8.	16.	20	73	203	.86 1.47	30 205
4	5.	9.	10	11	47	.52 .88	30 205
5	6.	23.	52	141	146	1.50 1.14	80 150
6	7.	23.	34	116	154	1.06 1.33	30 120
7	6.	12.	20	88	102	.55 .99	25 150
8	7.	11.	11	33	106	.63 .78	30 175
9	7.	20.	46	117	124	1.24 .87	115 140
10	7.	15.	15	15	16	.67	30
11	7.	10.	13	15	17	.66	25

CHART C-3

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1	499.	1219.	1541	1806	1930	21.59 26.38	10 35
2	355.	562.	733	1513	2326	18.19 12.04	10 150
3	347.	551.	724	1691	2273	18.24 13.32	10 125
4	378.	578.	730	1550	2325	20.55 13.75	10 160
5	390.	773.	1237	2214	2450	17.74 18.45	10 95
6	379.	700.	1192	2161	2446	21.23 18.17	10 110
7	393.	694.	1231	1834	2069	20.24 20.18	10 80
8	347.	567.	742	1419	1991	18.52 8.53	10 120
9	352.	644.	1108	1732	1975	18.73 16.73	15 80
10	354.	557.	712	1104	1546	18.71	10
11	450.	744.	942	1168	1387	26.69	10

CHART C-4

SUMMARY OSU EVALUATION

HEATING RATE: 5.0 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s 30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	MAX dD_s/dt dD_s/dt	Time - sec.
1	71.	122.	130	133	134	3.20 3.47	15 25
2	30.	68.	50	184	215	2.05 2.28	20 150
3	45.	84.	121	274	295	2.67 2.50	20 120
4	26.	43.	51	178	207	1.56 2.51	20 140
5	24.	65.	113	159	161	1.63 2.07	20 60
6	33.	84.	156	212	215	2.51 2.73	20 65
7	21.	51.	104	114	120	1.18 2.07	15 80
8	41.	59.	82	220	244	2.46 2.15	15 110
9	35.	75.	138	167	174	2.20 2.47	20 80
10	41.	68.	80	104	131	2.44	20
11	20.	35.	45	47	48	1.53	15

CHART C-5

SUMMARY OSU EVALUATION

HEATING RATE: 7.5 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: HEAT

CONFIG. NO.	Q - J/cm^2					MAX dQ/dt - W/cm^2	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dQ/dt	Time - sec.
1	617.	1178.	1364	1556	1673	27.00 24.98	7 25
2	357.	524.	681	1618	1859	21.35 15.53	5 130
3	364.	547.	938	1710	1865	22.03 16.73	5 75
4	388.	549.	733	1653	1864	24.53 16.74	5 105
5	442.	1061.	1437	1729	1945	20.41 22.24	5 45
6	351.	682.	1110	1827	2013	15.06 18.91	20 95
7	406.	795.	1308	1654	1748	21.66 19.53	5 75
8	351.	496.	703	1223	1345	20.00 8.75	5 95
9	404.	848.	1215	1506	1700	22.89 18.00	5 55
10	342.	471.	556	718	768	20.82	10
11	954.	677.	773	887	986	31.49	5

CHART C-6

SUMMARY OSU EVALUATION

HEATING RATE: 7.5 W/cm^2

AGENCY: BOEING

CHARACTERISTIC: SMOKE

CONFIG. NO.	D_s					MAX dD_s/dt	
	30 sec.	60 sec.	90 sec.	180 sec.	300 sec.	dD_s/dt	Time - sec.
1	98.	141.	142	143	144	4.75 5.00	15 25
2	66.	121.	192	352	354	3.20 3.66	15 100
3	78.	145.	246	329	331	4.39 4.12	10 80
4	68.	122.	192	340	349	3.13 4.06	10 100
5	45.	129.	149	155	161	1.70 3.61	10 40
6	43.	117.	181	216	216	2.69 2.30	25 90
7	38.	104.	153	158	158	2.94 2.51	40 65
8	71.	132.	220	303	309	3.84 3.30	15 80
9	56.	143.	174	178	182	3.22 3.46	15 40
10	56.	90.	112	168	188	3.31	15
11	36.	56.	58	62	68	2.62	10

CHART C-7

SUMMARY OSU EVALUATION AGENCY: DOUGLAS

HEATING RATE: 2.5 W/cm^2 CHARACTERISTIC: HEAT

SAMPLE No.	Kw-min/m^2				MAX dQ/dt - Kw/m^2	
	90 sec.	180 sec.	300 sec.	600 sec.	dQ/dt	Time - Sec.
1	52	102	134	151	75	57
2	27	33	41	125	37	51
4	31	37	108	192	47	216
5	46	104	155	194	60	87
6	46	126	176	222	70	100
8	30	36	50	112	39	51
9	44	108	147	181	57	100

CHART C-8

SUMMARY OSU EVALUATION AGENCY: DOUGLAS

HEATING RATE: 2.5 W/cm^2 CHARACTERISTIC: SMOKE

SAMPLE No.	SSU/m^2				MAX SMOKE	SSU/m^2-sec.
	90 sec.	180 sec.	300 sec.	600 sec.	SSU/m^2-sec.	Time - sec.
1	11.8	20	22	24	29	48
2	2.3	4.0	19	66	43	340
4	2.2	4.2	64	75	53	210
5	9.3	22	26	28	27	27
6	18	46	51	57	38	85
8	6.5	14.5	46	93	43	288
9	17	33.6	35	37.6	33	79

CHART C-9

SUMMARY OSU EVALUATION AGENCY: DOUGLAS

HEATING RATE: 5.0 W/cm^2 CHARACTERISTIC: HEAT

SAMPLE No.	$Kw\text{-}min/m^2$				MAX dQ/dt - Kw/m^2	
	90 sec.	180 sec.	300 sec.	600 sec.	dQ/dt	Time - Sec.
1	66	113	132	138	77	29
2	48	107	143	179	57	51
4	49	115	162	201	63	117
5	61	118	155	197	68	62
6	82	141	175	202	75	69
8	49	97	133	165	59	22
9	81	127	155	175	72	64

CHART C-10

SUMMARY OSU EVALUATION

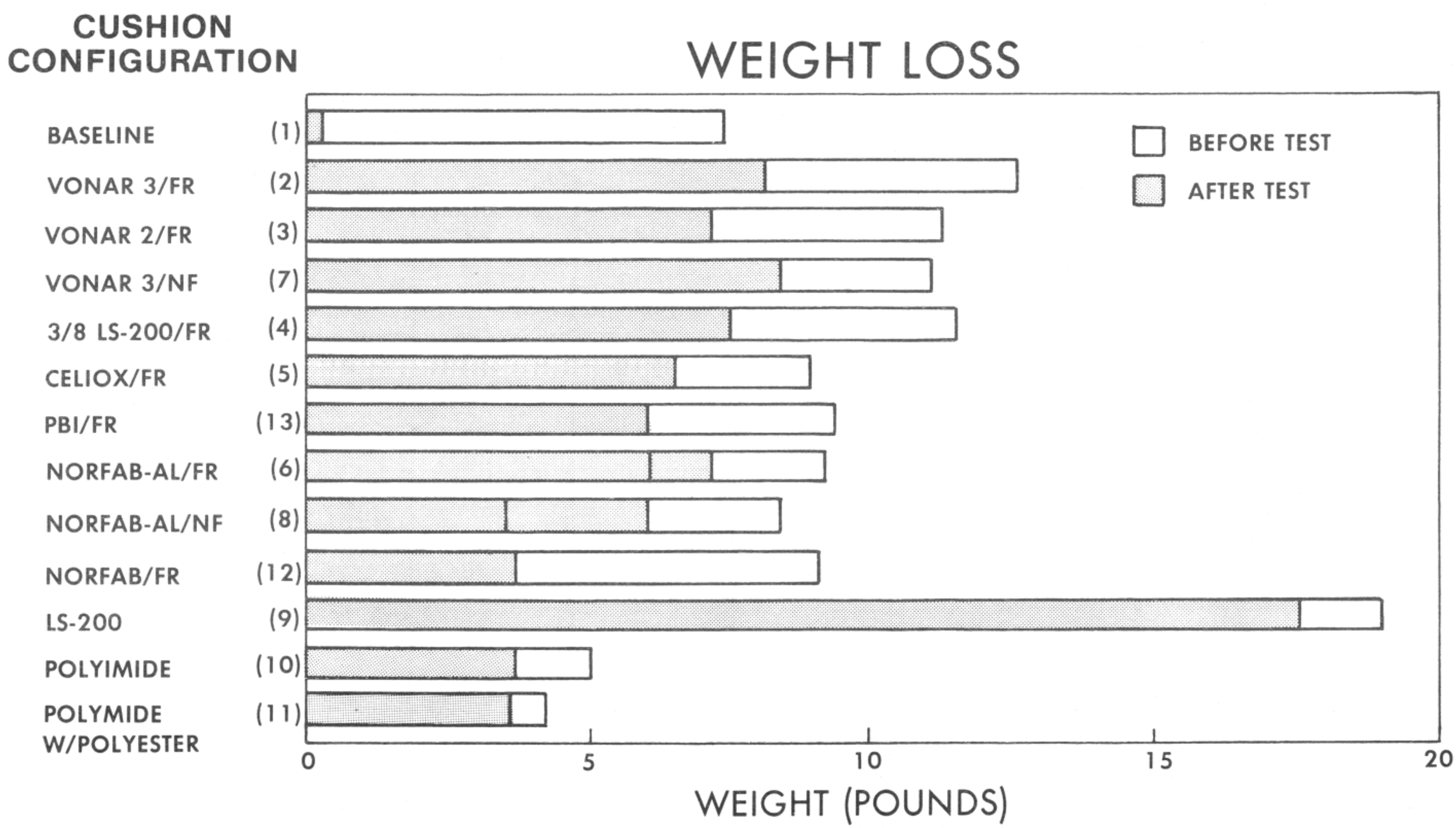
HEATING RATE: 5.0 W/cm^2

AGENCY: DOUGLAS

CHARACTERISTIC: SMOKE

SAMPLE No.	SSU/m^2 90 sec.	180 sec.	300 sec.	600 sec.	MAX SMOKE SSU/m^2-sec.	SSU/m^2-sec. Time - sec.
1	18	25	26	28	46	22
2	24	88	98	101	92	116
4	26	97	109	115	102	113
5	31	43	45	51	43	41
6	49	59	60	64	60	51
8	26	89	103	107	88	118
9	48	55	56	61	67	25

CHART C-11



CUSHION CONFIGURATION
WEIGHT LOSS
BASELINE (1)
VONAR 3/FR (2)
VONAR 2/FR (3)
VONAR 3/NF (7)
3/8 LS-200/FR (4)
CELIOX/FR (5)
PBI/FR (13)
NORFAB-AL/FR (6)
NORFAB-AL/NF (8)
NORFAB/FR (12)
LS-200 (9)
POLYIMIDE (10)
POLYMIDE W/POLYESTER (11)
BEFORE TEST
AFTER TEST
0
5
10
15
20
WEIGHT (POUNDS)

CHART C-12

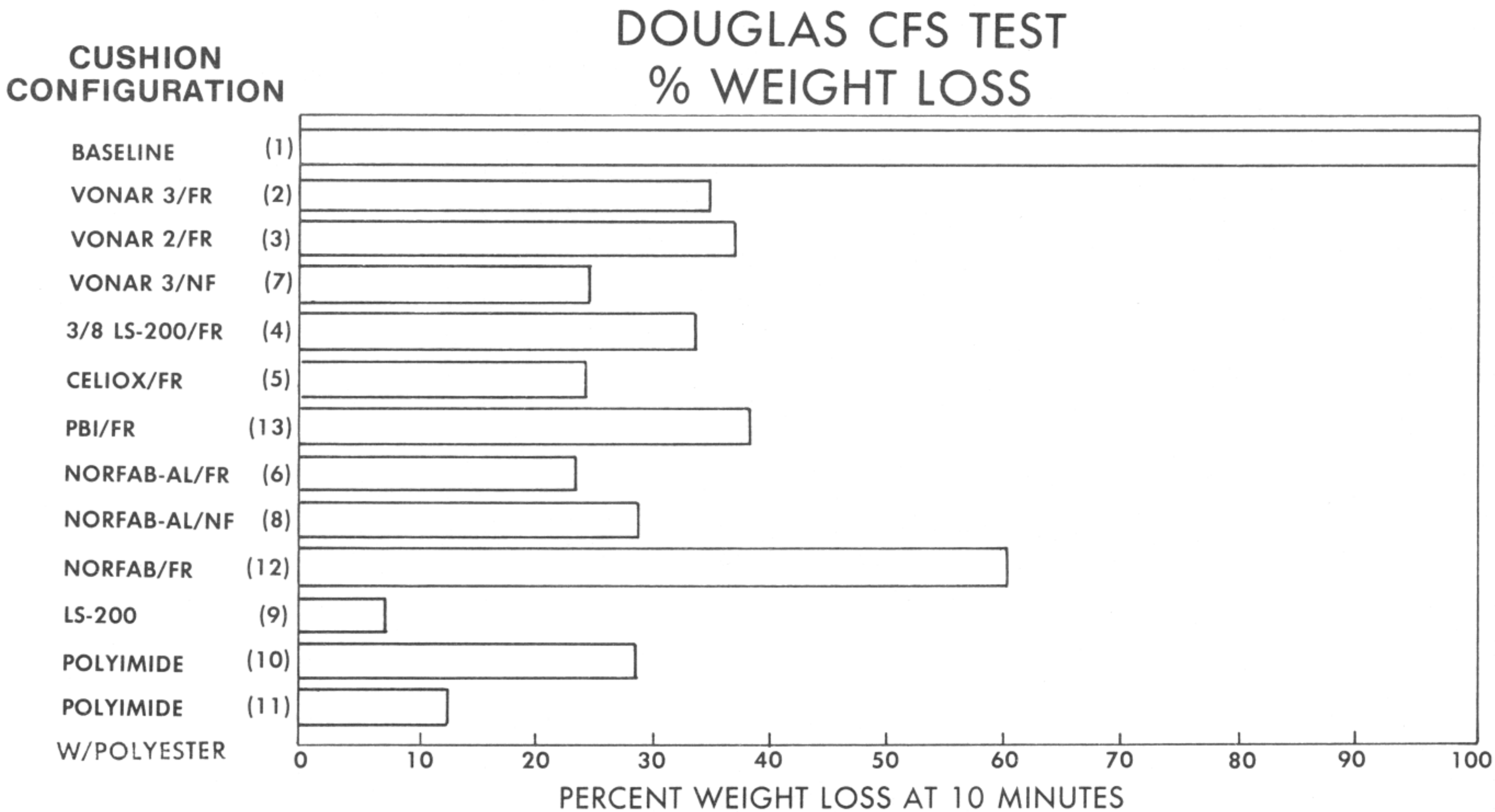

DOUGLAS CFS TEST
% WEIGHT LOSS
CUSHION
CONFIGURATION
BASELINE (1)
VONAR 3/FR (2)
VONAR 2/FR (3)
VONAR 3/NF (7)
3/8 LS-200/FR (4)
CELIOX/FR (5)
PBI/FR (13)
NORFAB-AL/FR (6)
NORFAB-AL/NF (8)
NORFAB/FR (12)
LS-200 (9)
POLYIMIDE (10)
POLYIMIDE (11)
W/POLYESTER
0
10
20
30
40
50
60
70
80
90
100
PERCENT WEIGHT LOSS AT 10 MINUTES

CHART C-13

Lockheed-California Company

FLAME TEST RESULTS AVERAGE

NO.	CONFIGURATION	BURN INTENSITY	BURN LENGTH, INCHES UPHOLSTERY	FOAM	AFTER FLAME (SECONDS)
1	BASE	5	9 3/4	5 3/4	60+
2	VONAR 3	2	5 1/4	1/8	0-2
3	VONAR 2	2	5 1/4	5/16	0
4	LS-200	2	4 1/2	1/8	0
5	CELIOX	3	4 3/4	1	2
6	NORFAB	2	4 3/4	1 1/4	3
7	181 E GLASS	2	4 3/4	1 1/8	3
8	VONAR 3, NF	2	4 1/4	1/4	0
9	NORFAB, NF	3	5	1 1/4	0-6
10	LS-200 FOAM	2	4 1/2	1/8	0
11	POLYIMIDE	4	7	1/2	0-2

BURN INTENSITY 1 = GOOD, 5 = POOR

CHART C-14

Round Robin Sample No.	NASA No.	Description of Sample	Specific Mass Injection Rate $\dot{M} = 10^{-5} \frac{g}{cm^2\ sec.}$			Thermal Effic. $\varepsilon = \dot{q}/\dot{m} = 10^4 \frac{Wsec}{g}$			Relative Thermal Effic. ε_R, $\varepsilon_R = \frac{\varepsilon}{\varepsilon_0} \times 100$		
			2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2	2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2	2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2
1	367	W/N, FR Urethane	13	61	76	1.9	0.8	0.98	32	42	36
2	17	W/N, Von. 3, F.R. Urethane	4.1	27	28	6.0	1.9	2.7	100	100	100
3	11	W/N, Von. 2, F.R. Urethane	4.0	21	50	6.3	2.3	1.5	105	121	56
4	143	W/N, LS 200, F.R. Urethane	0	29	14.8	N/A	1.7	5.1	N/A	89	188
5	373	W/N, 1100-4, F.R. Urethane	3.3	29	59	7.7	1.7	1.3	128	89	48

CHART C-15

Round Robin Sample No.	NASA No.	Description Of Sample	Specific Mass Injection Rate $\dot{M} = 10^{-5} \frac{g}{cm^2\ sec.}$			Thermal Effic. $\varepsilon = \dot{q}/\dot{m} = \frac{10^4 Wsec}{g}$			Relative Thermal Effic. ε_R $\varepsilon_R = \frac{\varepsilon}{\varepsilon_o} \times 100$ VONAR 3		
			2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2	2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2	2.5 W/cm^2	5.0 W/cm^2	7.5 W/cm^2
6	376	W/N, 11HT, FR Urethane	2.7	31	66	9.4	1.9	1.1	155	100	41
7	377	W/N, 181, FR Urethane	4.0	25	85	6.3	2.0	0.9	105	105	32
8	15	W/N, Von. 2, NF Urethane	0	17	29	N/A	2.8	2.5	N/A	147	92.5
9	375	W/N, 11HT, NF Urethane	6.9	28	36	7.9	1.7	2.0	131	89.4	74
10	400	W/N, LS200	3.9	22.9	17.3	6.4	1.8	04.3	107	90	15.1
11	289	W/N, PI	10.8	6.8	1.5	2.4	7.4	4.9	40	389	181