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20. Abstract (continued)

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flame exposure at 2.2 cal/cm²/sec have all been measured. Thirty-six single-layer fabrics and fabric assemblies have been used in the investigation ranging in weight from 3 to 25 oz/sq yd. Fabric materials tested include cotton, wool, modacrylic, Nomex, Kevlar, PAN, corespun semi-carbon/Kevlar, coated fabrics and various blends. (U)

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FOREWORD

The work described herein was done under Contract No. N00140-82-C-BD00 for the Navy Clothing and Textile Research Facility, Natick, Massachusetts and follows a similar investigation of the heat protective capability of Navy Shipboard Work Clothing carried out under Contract N00140-81-C-BA83 and reported in Technical Report 148, October 1982. The Technical Representative of the Contracting Officer was Mr. Zelig Kupferman. The work at Albany International Research Co. was under the general supervision of Norman J. Abbott, Associate Director, and was planned and directed by Meredith M. Schoppee, Senior Research Mathematician. Judith M. Welsford, Research Assistant, performed the laboratory measurements and assisted with interpretation of the test results.

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I. INTRODUCTION

As a continuation of the work performed under an earlier contract for which the heat protective capability of Navy Shipboard work clothing was determined at various exposure conditions, the investigation described in this report is concerned with the resistance to high heat fluxes of various outerwear garments. The materials of which the outerwear garments tested are composed includes: cotton and cotton blends, wool and wool blends; Nomex, Kevlar, Nomex/Kevlar blends and a semi-carbon/Kevlar corespun construction; coated fabrics; a PAN fabric; and assemblies of various of these materials with insulating and heat-resistant liners. The 36 fabrics and assemblies tested ranged in weight from 3 to 25 oz/sq yd.

The same methods of investigation were employed as in the earlier work and consisted of: determination of strength retention and time-to-ignition during bilateral irradiation of single-layer fabrics to fluxes of 1.1 cal/cm²/sec for exposure times ranging from a few seconds to a minute or two; measurement of heat transfer to an underlying surface as the result of unilateral exposure of the single-layer fabrics and fabric assemblies to a radiant heat source up to 1.25 cal/cm²/sec, in one case, and to a directly impinging flame at 2.2 cal/cm²/sec in another.

Test equipment, test methods and exposure conditions are described briefly in this report; a more complete description of each is contained in U. S. Navy Clothing and Textile Research Facility Technical Report No. 148 to which frequent reference will be made. Test results for the various fabrics represented by the outerwear garments are given in detail herein accompanied by discussion of the results in the same context as for evaluation of the protective capability of shipboard work clothing in the earlier report.

II. FABRICS INVESTIGATED

A description of each of the fabrics and fabric assemblies in the current test series is contained in Table 1. The entries are grouped by weight in the following categories: cotton and rayon blends; wool blends; Nomex and Kevlar blends; coated fabrics; and fabric assemblies. A 100% acrylic knit and a PAN (polyacrylonitrile) fabric are also included.

The tensile properties of the single-layer fabrics measured in the warp direction are given in Table 2. These properties of the woven fabrics were determined from 1.0-inch wide raveled strips which were tested at a crosshead speed of 20.0 inches/minute using a 13.5 inch gauge length in order to conform with the test conditions employed during exposure to radiant heat. Cut strips, 1.0-inch wide, of the knit fabrics were tested and in some cases the gauge length was reduced to accommodate their greater elongation to rupture.

(Text continued on page 5.)

Table 1. Fabric Description

Fabric No.	Fiber Content	Fabric Description	Weight (oz/yd ²)	Thickness (inch)		Color	Intended Use
				0.035 psi	0.63 psi		
Single-Layer Fabrics:							
36	100% cotton	waffle knit	13.3	0.120	0.090	white	cold-weather underwear
38	100% cotton	sateen	10.3	0.037	0.028	white	coveralls for explosives handlers
70	80/20 PFR rayon/polyester	twill	8.6	0.022	0.018	blue	flame resistant fabric
71	80/20 PFR rayon/Nomex	knit	8.5	0.059	0.041	purple	identification jersey pullover
10	rayon warp, cotton fill	4/1 twill	8.2	0.026	0.018	royal blue	identification vest, flight deck clothing
34	80/20 PFR rayon/Nomex	plain weave	7.0	0.020	0.012	blue	coverall, battle dress
44	100% cotton	twill	6.6	0.028	0.019	yellow	radiation protective coverall
50	100% cotton	oxford	6.4	0.024	0.016	olive green	wind-resistant, hot-weather coat
37	100% cotton	jersey knit	5.1	0.037	0.025	royal blue	flight deck identification garment
48	100% cotton	jersey knit	4.3	0.035	0.025	white	anti-flash hood
21	100% wool	3/1 crowfoot	15.7	0.079	0.064	navy	wool melton for peacoat
63	70/30 wool/modacrylic	knit	12.8	0.122	0.094	olive green	heavyweight sweater overgarment
23	100% wool	knit	12.3	0.132	0.097	olive drab	sweater
46	100% wool (mothproof treated)	knit	11.6	0.096	0.071	navy	sweater
62	70/30 wool/modacrylic	knit	11.5	0.098	0.074	navy	lightweight sweater (body sweater)
28	90/10 wool/nylon	flannel	8.2	0.071	0.056	olive green	cold weather shirt
25	55/45 polyester/wool	plain weave	6.6	0.020	0.018	navy	trousers
45	100% acrylic	knit	9.7	0.106	0.080	navy	women's sweater
78	Amatex 16HT65 Series 900 corespun semi-carbon/Kevlar	herringbone twill	15.4	0.063	0.052	yellow/black	flame resistant fabric
75	100% Kevlar	twill	8.3	0.051	0.025	yellow	standard fabric in proximity clothing
47	100% Nomex	knit	8.1	0.027	0.024	olive drab	flyer's coveralls
74	50/50 Nomex/Kevlar	twill	6.0	0.029	0.022	yellow	experimental
73	95/5 Nomex/Kevlar	cloque	5.3	0.024	0.018	olive green	outershell for ship-board clothing
17	95/5 Nomex/Kevlar	plain weave	4.6	0.019	0.015	olive green	shirt, pants

Table 1. Fabric Description (cont)

Fabric No.	Fiber Content	Fabric Description	Weight (oz/yd ²)	Thickness (inch)		Color	Intended Use
				0.035 psi	0.63 psi		
39	nylon	double butyl coated	12.5	0.016	0.013	grey	coverall for toxicological agent protection
5	cotton, resin-modified	butyl coated	10.5	0.020	0.014	black	coverall for rocket fuel handlers
32	nylon	neoprene coated	7.7	0.016	0.011	green	outer shell for cold-weather jacket
18	nylon	polyurethane coated	3.1	0.009	0.006	olive green	poncho
72	(PAN) polyacrylonitrile	herringbone twill	15.6	0.053	0.042	black	high heat resistant fabric
Fabric Assemblies:							
40	polyester outer shell; 100% wool liner	polyurethane coated twill	12.0	0.053	0.042	black	lightweight raincoat with lining
1A	polyester batt, nylon fabric	quilted batt, 1.1 oz rip-stop fabric both sides	4.6	0.098	0.043	olive green	poncho liner blanket
1	polyurethane coated nylon + 1A above	coated fabric outer shell, quilted liner 1A above	7.7	0.107	0.049	olive green	poncho with liner blanket
13	50/50 cotton/nylon fluoro-carbon treated outer shell; 100% nylon liner	sateen; knit fleece	20.0	0.185	0.145	olive green	cold weather jacket with insulating liner
2A	50/50 cotton/polyester outer shell; 100% nylon liner	poplin; knit fleece	12.5	0.094	0.068	navy	utility jacket with insulating liner
55	50/50 cotton/nylon fluoro-carbon treated outer shell (same as #13); 100% cotton liner; polyester batt-nylon fabric	sateen oxford quilted batt	22.0	0.335	0.212	olive green	continuous cold weather jacket
21A	100% wool outer shell 100% nylon liner	3/1 crowfoot knit fleece	24.9	0.213	0.159	black	overcoat
58	nylon/acrylic outer shell carbon impregnated liner	twill	10.7	0.055	0.042	green/gray	chemical protective suit

Table 2. Tensile Properties of Single Layer Outerwear Fabrics in the Warp Direction

Fabric No.	Fiber Content	Weight (oz/yd ²)	Modulus (lbs/inch width/ unit strain)	Rupture Elongation (%)	Rupture Load (lbs/inch width)
<u>Single-Layer Fabrics:</u>					
36	100% cotton	13.3	240	95	70
38	100% cotton	10.3	2250	9	122
70	80/20 PFR rayon/polyester	8.6	700	17	83
71	80/20 PFR rayon/polyester	8.5	430	74	54
10	rayon warp cotton fill	8.2	2760	18	222
34	80/20 PFR rayon/Nomex	7.0	790	19	107
44	100% cotton	6.6	2350	15	148
50	100% cotton	6.4	1890	14	118
37	100% cotton	5.1	170	37	19
48	100% cotton	4.3	150	59	25
21	100% wool	15.7	290	35	56
63	70/30 wool/ modacrylic	12.8	80	125	41
23	100% wool	12.3	110	93	28
46	100% wool (mothproof treated)	11.6	100	84	35
62	70/30 wool/ modacrylic	11.5	90	102	36
28	90/10 wool/ nylon	8.2	200	30	35
25	55/45 poly- ester/wool	6.6	440	38	92
45	100% acrylic	9.7	90	113	35
78	semi carbon/Kevlar	15.4	2170	21	205
75	100% Kevlar	8.3	8450	15	439
47	100% Nomex	8.1	600	44	152
74	50/50 Nomex/Kevlar	6.0	4750	14	202
73	95/5 Nomex/Kevlar	5.3	2090	17	129
17	95/5 Nomex/Kevlar	4.6	900	30	115
39	nylon	12.5	790	26	173
5	cotton, resin- modified	10.5	1300	12	72
32	nylon	7.7	840	17	158
18	nylon	3.1	350	28	67
72	PAN	15.6	3010	12	163

III. EXPOSURE TO BILATERAL RADIANT HEAT

A. Test Procedure

The tensile strength retention and tensile modulus of 20 of the 28 single-layer fabrics in the test group were measured during short-term exposure to five levels of bilateral radiant heat ranging from 0.2 to 0.8 cal/cm²/sec and corresponding to equilibrium temperatures from 270°C to 560°C. Some of the knit fabrics in the series could not be tested in this manner because of their excessively high elongation-to-failure which exceeded the capacity of the test equipment. The high levels of bilateral heat flux were supplied by two, facing quartz heater panels shown in Figures 1 and 2 and described in detail in TR 148, Section IIIA. At the start of a test, the heater surfaces, already at equilibrium temperature, are pulled along a track to surround the test specimen which is clamped in an Instron tensile test machine. The onset of exposure is virtually instantaneous, the duration of exposure is precisely known, and subsequent mechanical stressing is performed quickly so that information on fabric tensile properties can be generated during the period of rapid temperature rise as well as after thermal equilibrium has been reached. Tests were run at total exposure times ranging from a few seconds to one minute. A testing speed of 20 inches/minute was employed with a 1.0 inch wide test specimen at a gauge length of 13.5 inches.

The quartz heater panels used to investigate retention of tensile properties under this contract were newly installed. Replacement of the set employed for the work reported in TR 148 was necessary because constant use had caused a considerable decrease in thermal output as a function of temperature. The thermal characteristics of the new heater panels are compared in Table 3 and Figure 3 with the output of the old panels. Although the heat flux emitted at a given temperature is higher with the new panels than with the old, the equilibrium temperature attained by exposed specimens at a given heater temperature should be unaffected; however, the rate at which that temperature is attained will be greater with the new panels. As a result, the rate of change of tensile properties during the initial period of rapid temperature change may be somewhat increased.

Measurements were made with the new heater panels of the tensile properties of a 95/5 Nomex/Kevlar fabric which had been characterized with the old heater panels; previous data for this fabric (#17) was reported in TR 148 (see Figures 33a and b). A comparison of the results obtained with both old and new panels at 270°C, 350°C and 400°C is shown in Figure 4 where tensile strength and modulus changes are plotted. There is obviously very good agreement between results obtained with the two heater systems.

A complete discussion of the thermal environment created by the facing quartz heaters and its interaction with exposed fabric specimens is contained in TR 148, Section IIIA.

(Text continued on page 10.)

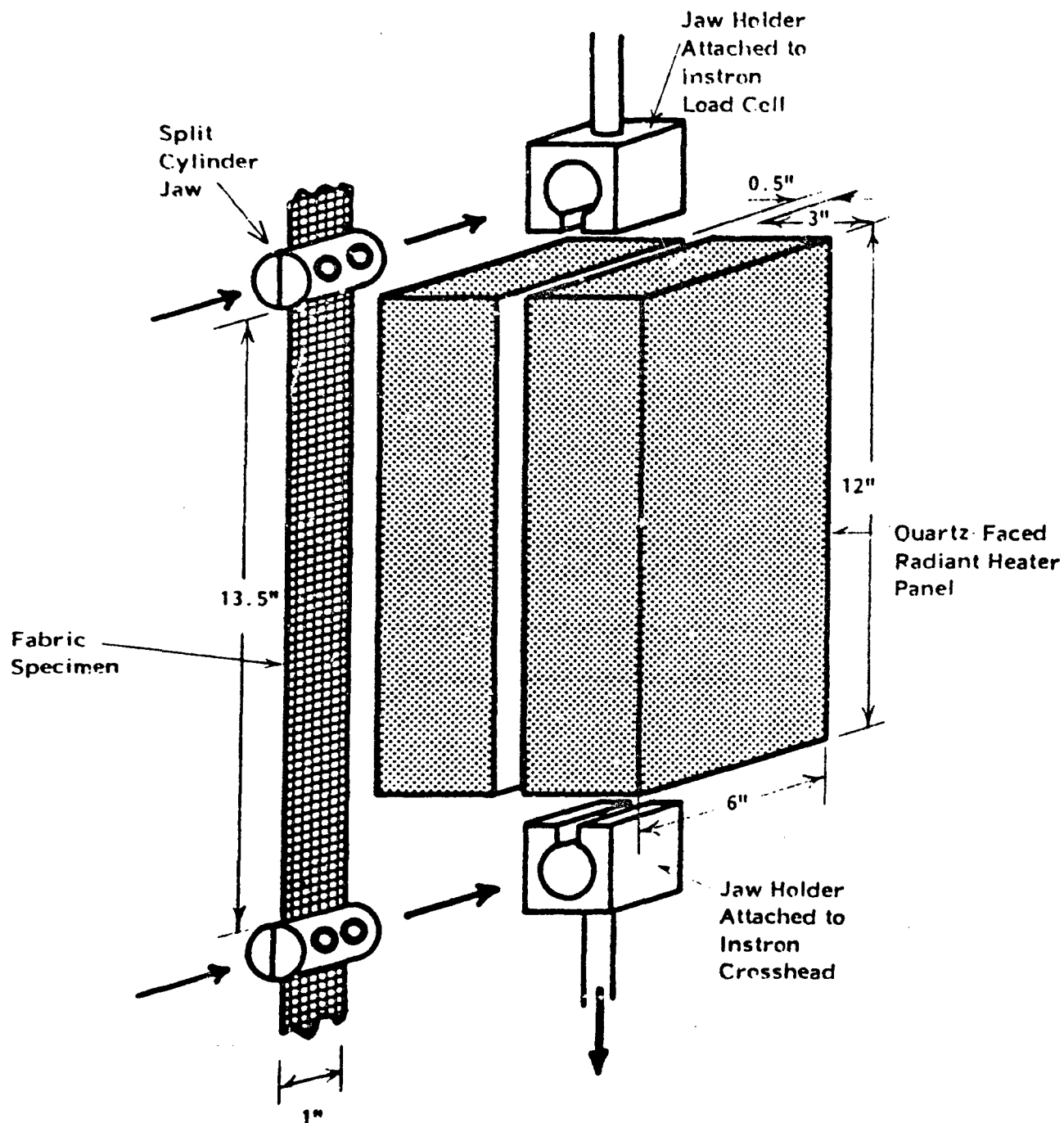


Figure 1. Test Configuration for Exposure of Fabric Specimen to Bilateral Radiant Heat

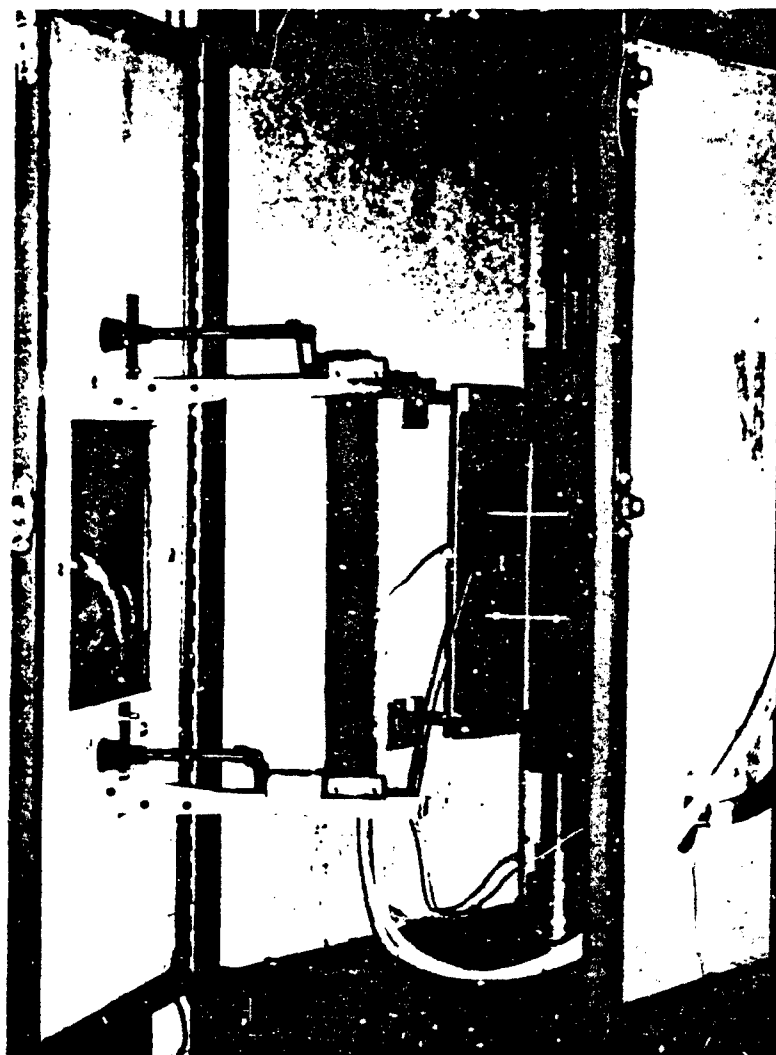


Figure 2. Quartz-Faced Radiant Heater Panels and Fabric Specimen in Test Chamber

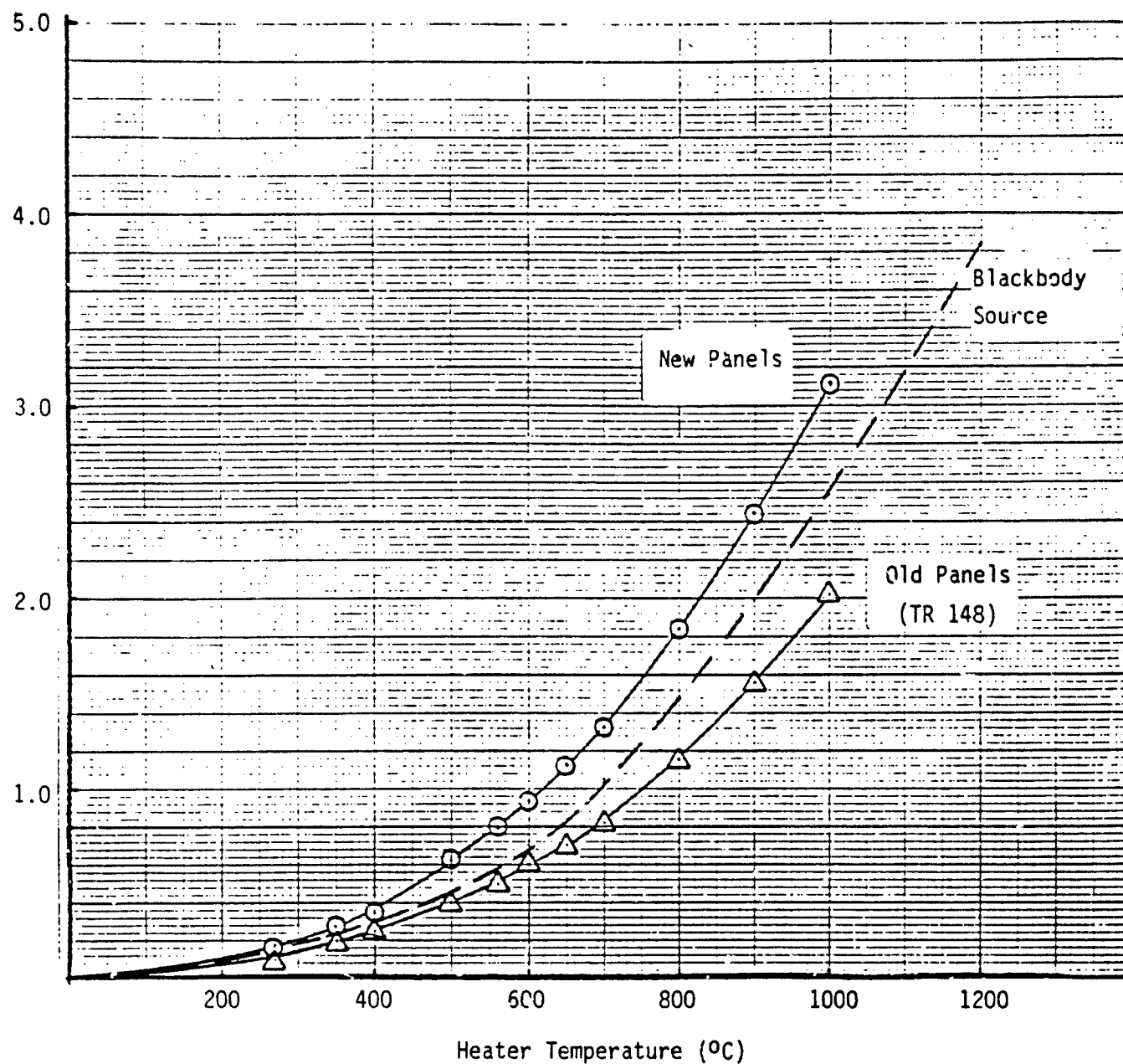
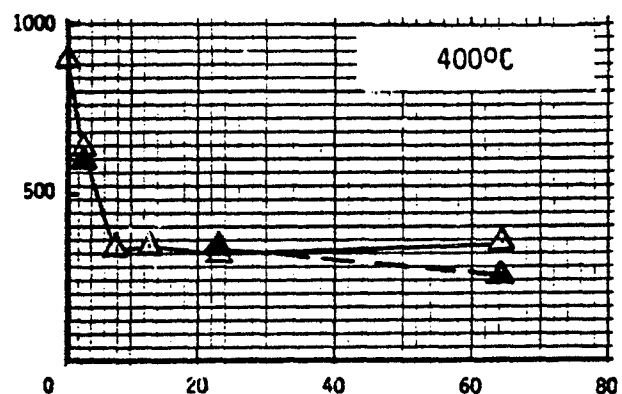
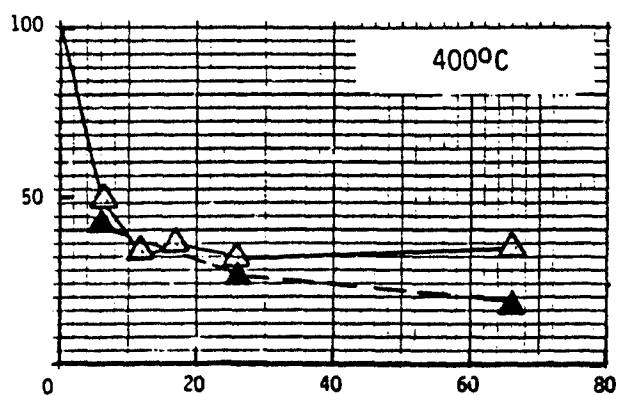
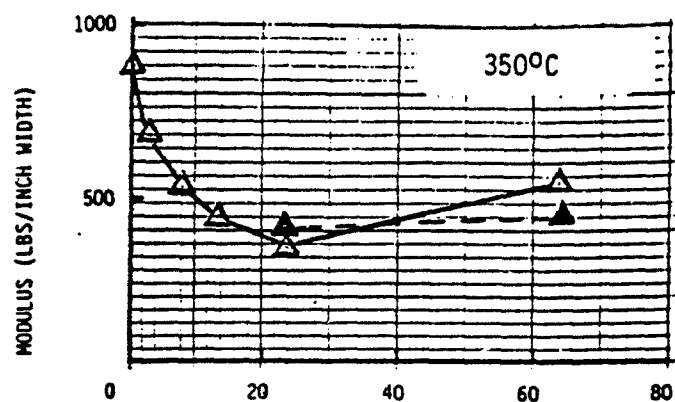
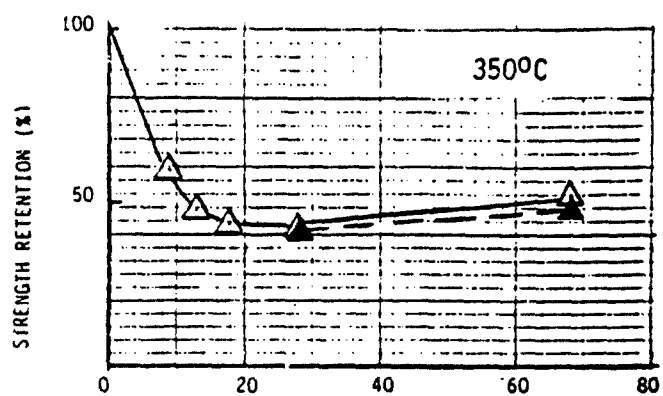
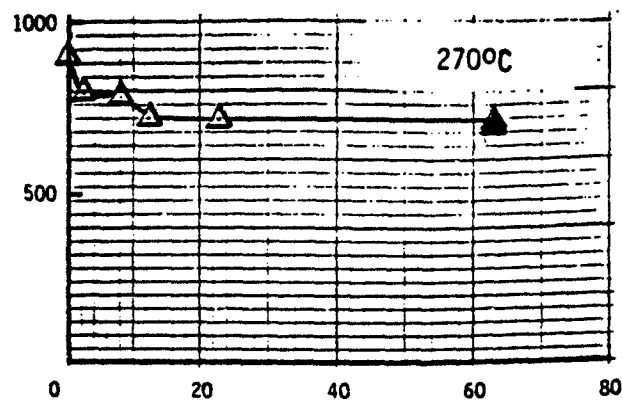
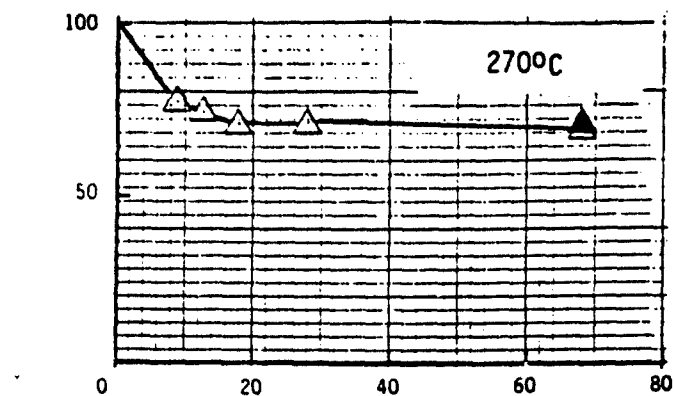


Figure 3. Initial Bilateral Radiant Heat Flux Absorbed by Fabric Specimen



△ old heaters

▲ new heaters

Figure 4. Strength Retention and Modulus of Control Fabric #17 (95/5 Nomex/Kevlar, 4.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

Table 3. Thermal Output of New Quartz-faced Heater Panels

Heater Temperature (°C)	Radiant Heat Flux (cal/cm ² /sec)	
	New Panels (1983)	Old Panels (1982)
270	0.2	0.1
350	0.3	0.2
400	0.35	0.25
500	0.6	0.4
560	0.8	0.5
600	0.9	0.6
650	1.1	0.7

B. Single-Layer Fabric Tensile Properties During Exposure to Bilateral Radiant Heat

The tensile strength retention and modulus of 23 single-layer fabrics were measured during bilateral exposure to radiant heat at the following exposure conditions:

270°C (0.2 cal/cm²/sec);
 350°C (0.3 cal/cm²/sec);
 400°C (0.35 cal/cm²/sec);
 500°C (0.6 cal/cm²/sec); and
 560°C (0.8 cal/cm²/sec).

These temperatures were chosen to correspond with the heater temperatures used in the earlier work described in TR 148. Measurements were made after five different exposure times, where appropriate, ranging from a few seconds to one minute.

The average values of fabric strength expressed as a percentage of original strength for various times of exposure at each heat flux condition are plotted in Figures 5a through 24b, respectively; individual test results are documented in Appendix Table 1. Similarly, average values of fabric modulus are plotted in Figures 5b through 24b and individual values are listed in Appendix Table 1. The values of strength retention are given at total exposure time to rupture: this time includes both the dwell time prior to the start of crosshead motion and the time required to rupture the specimen after the onset of loading.

The modulus is a measure of the stiffness of the fabric in tension since it is essentially the ratio between the applied load and the resulting elongation in the linear region of the load-elongation diagram after uncrimping of the fabric structure has taken place. The modulus values given represent the maximum slope of the load-elongation curves in the units lbs per inch width of fabric per unit strain (see Appendix Figure 1 for an example of this calculation). These values are somewhat in error, however, because a portion of the specimen length is located outside of the high-temperature region between the facing heater panels. The true modulus of the specimen during exposure is related to the ratio of the modulus measured directly from the Instron load-elongation diagram to the original modulus at ambient tempera-

(Text continued on page 51.)

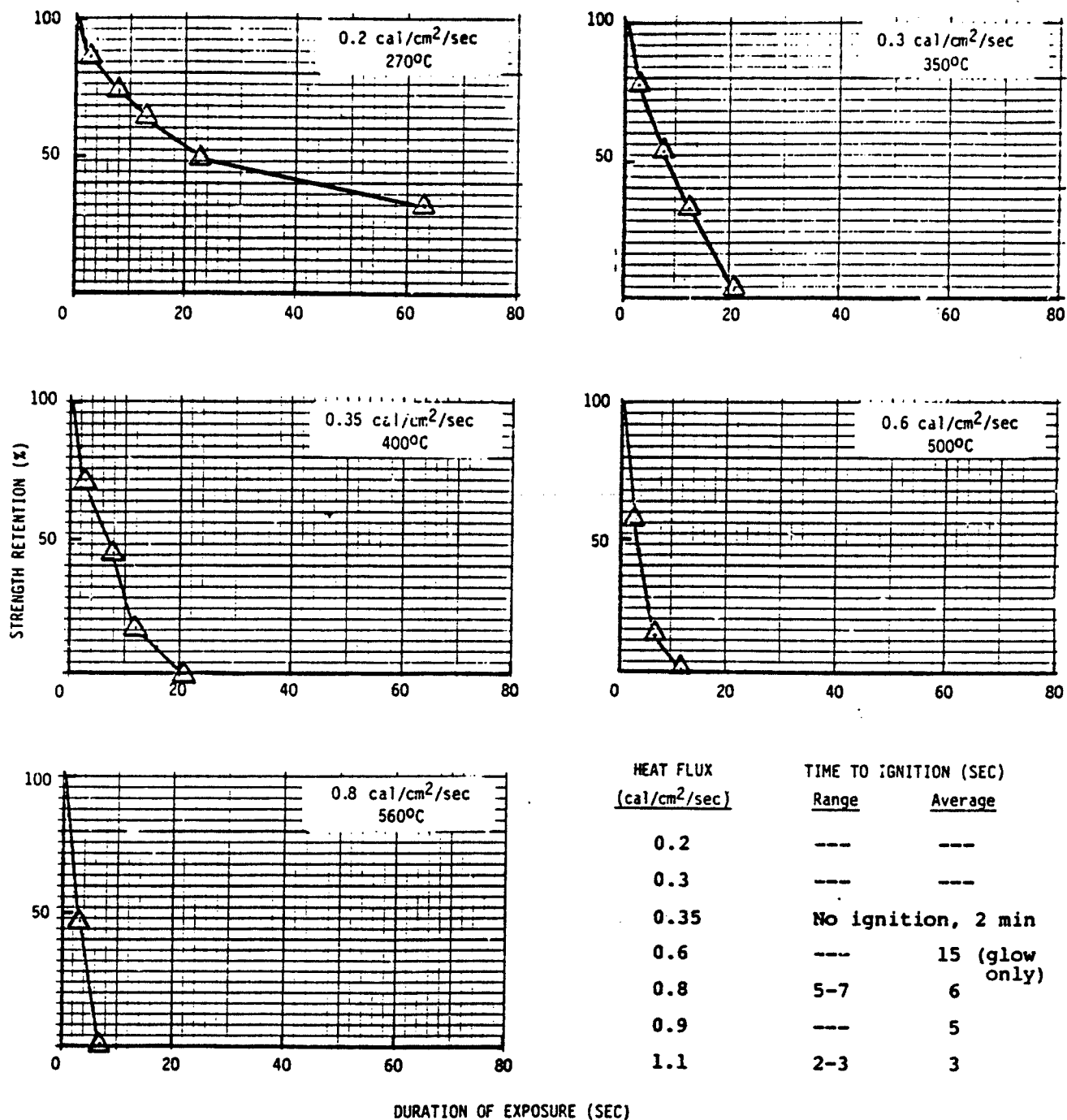


Figure 5a. Strength Retention of Fabric #38 (100% cotton, 10.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

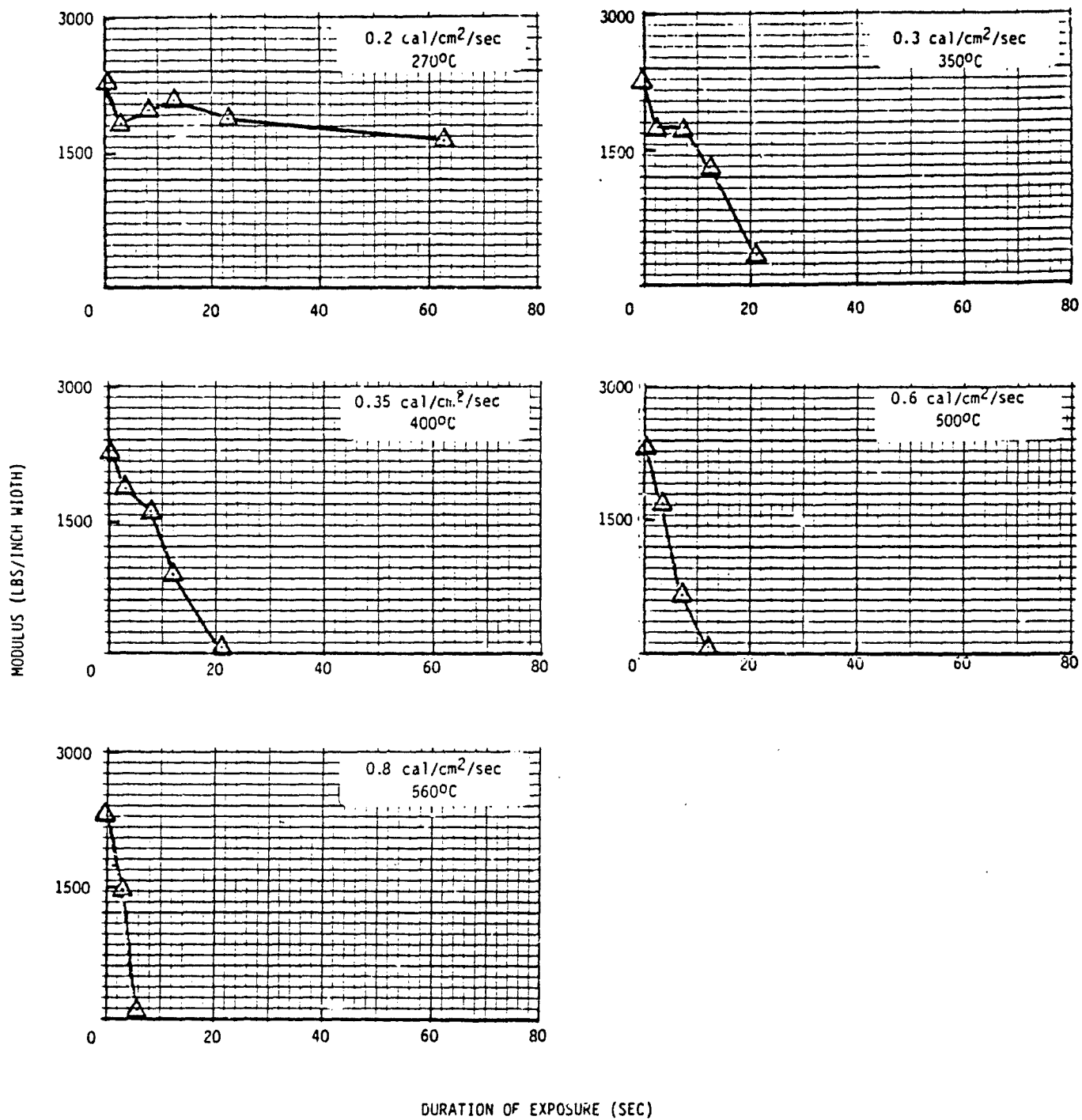


Figure 5b. Modulus of Fabric #38 (100% cotton, 10.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

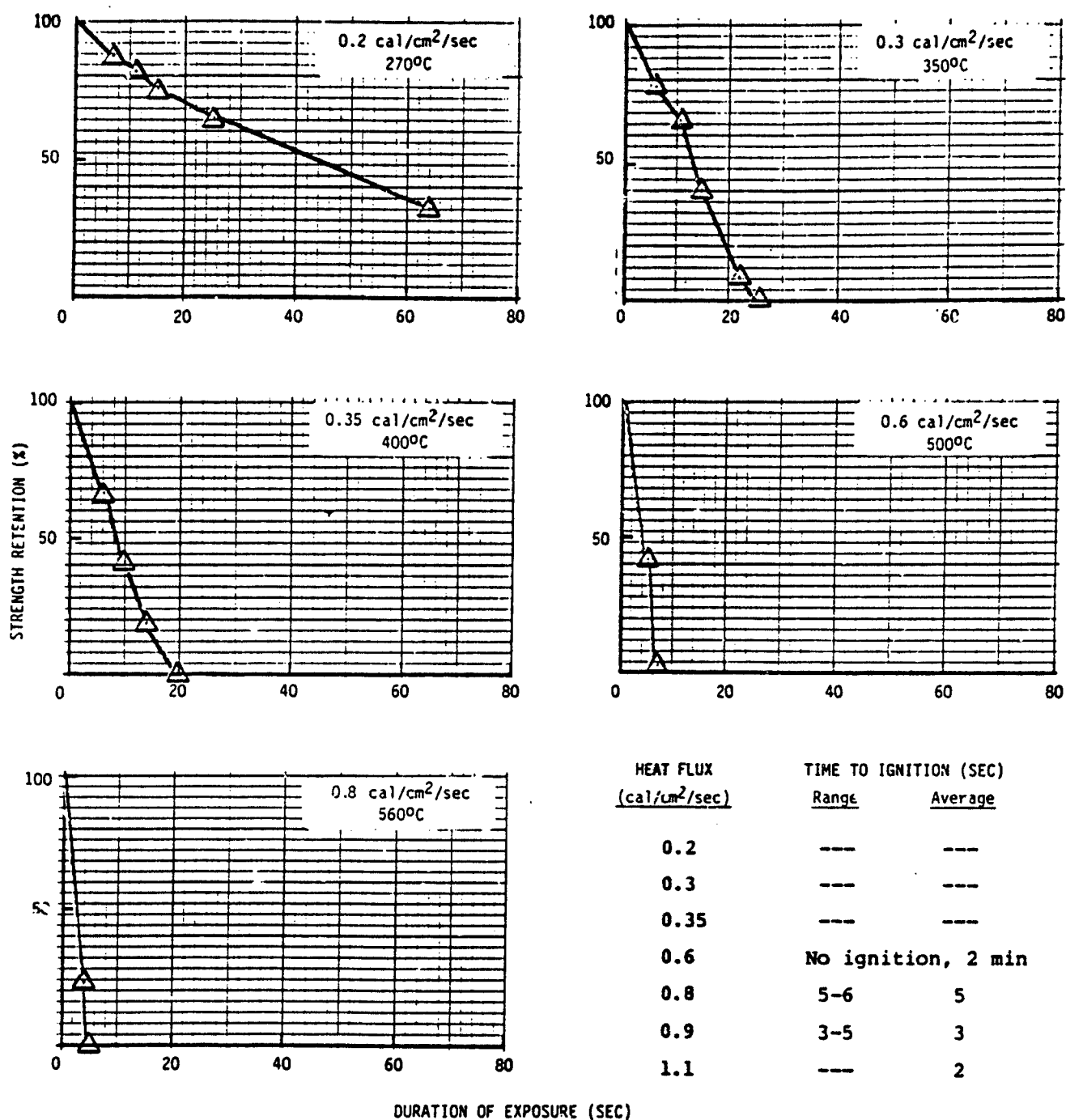
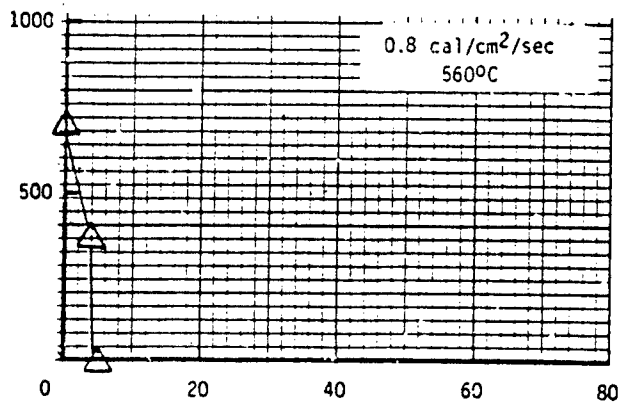
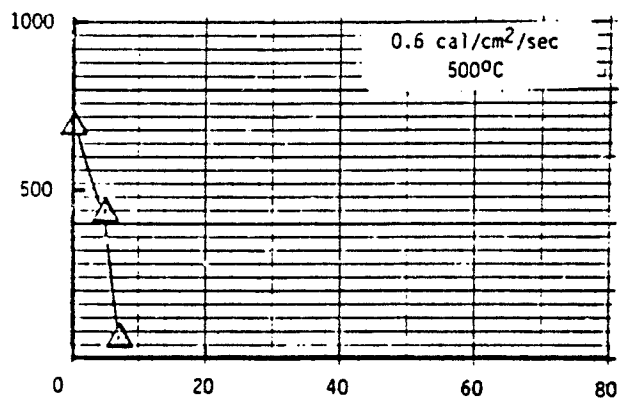
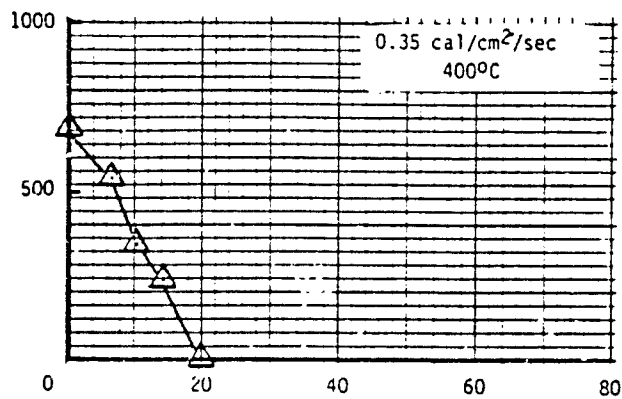
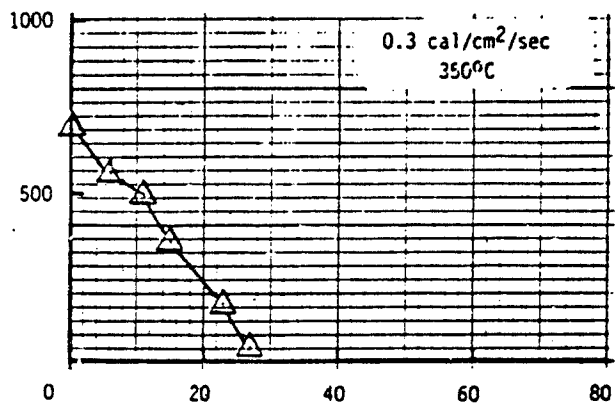
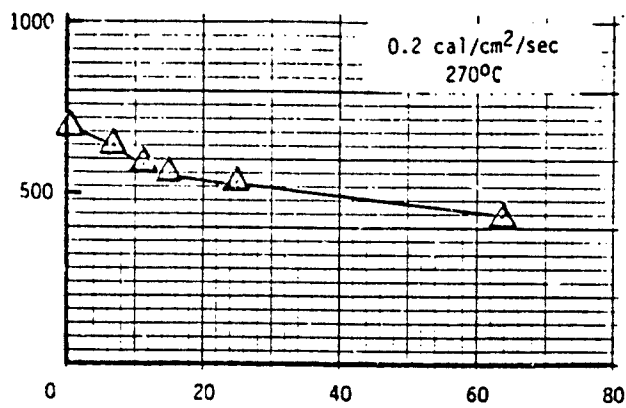


Figure 6a. Strength Retention of Fabric #70 (80/20 PFR rayon/polyester, 8.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



DURATION OF EXPOSURE (SEC)

Figure 6b. Modulus of Fabric #70 (80/20 PFR rayon/polyester, 8.6 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat

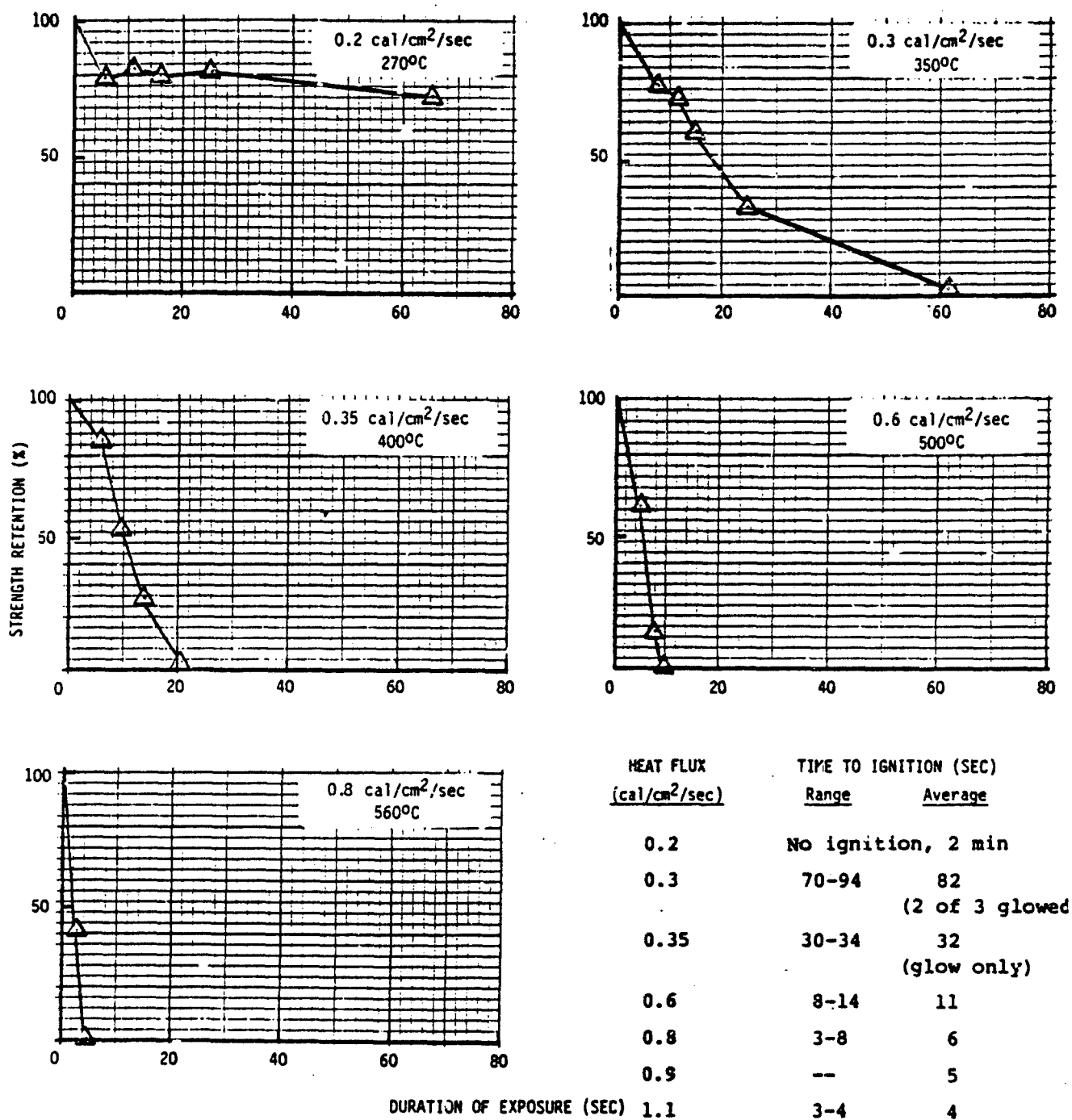


Figure 7a. Strength Retention of Fabric #10 (rayon warp/cotton fill, 8.2 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

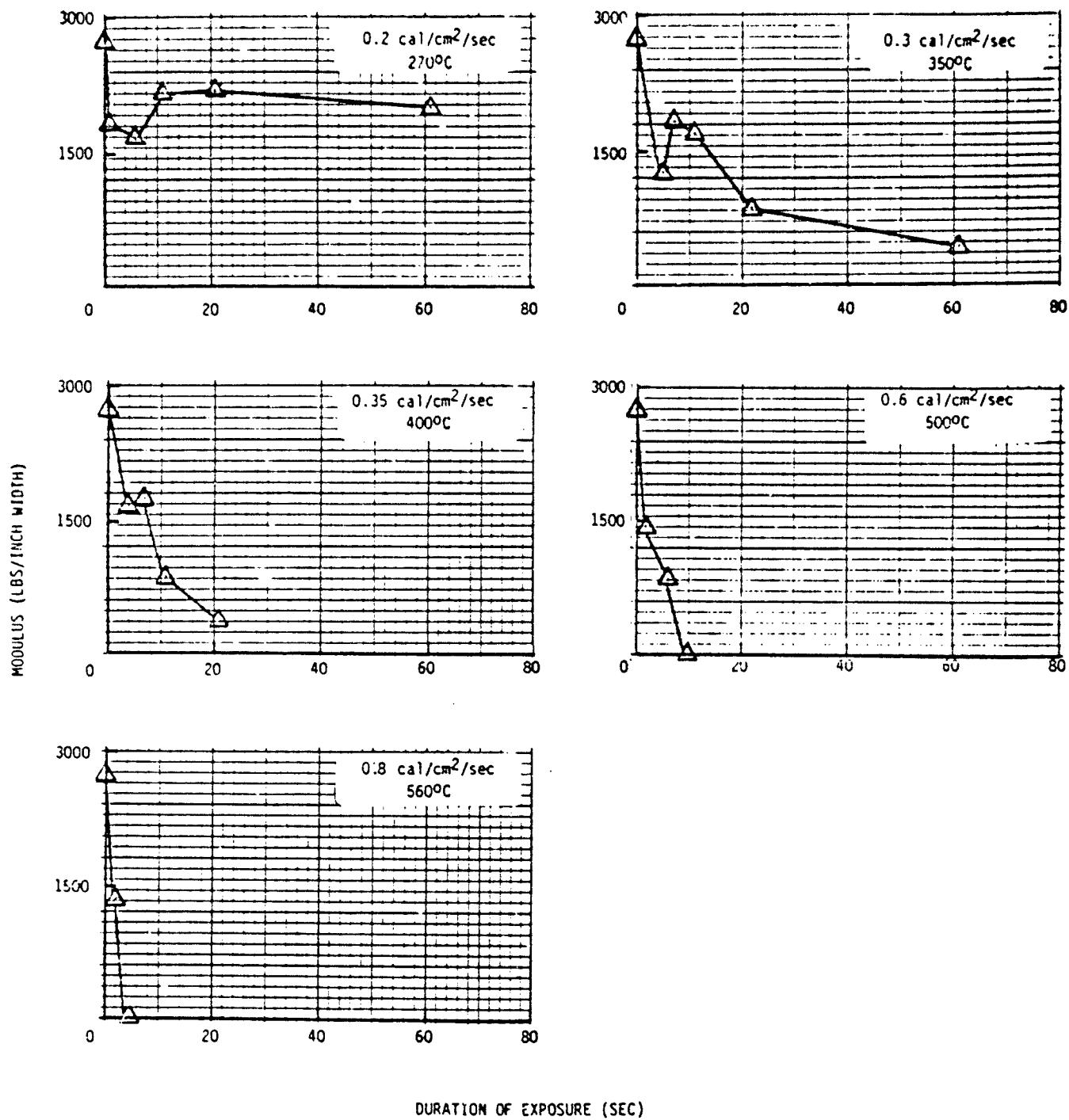


Figure 7b. Modulus of Fabric #10 (rayon warp/cotton fill, 8.2 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

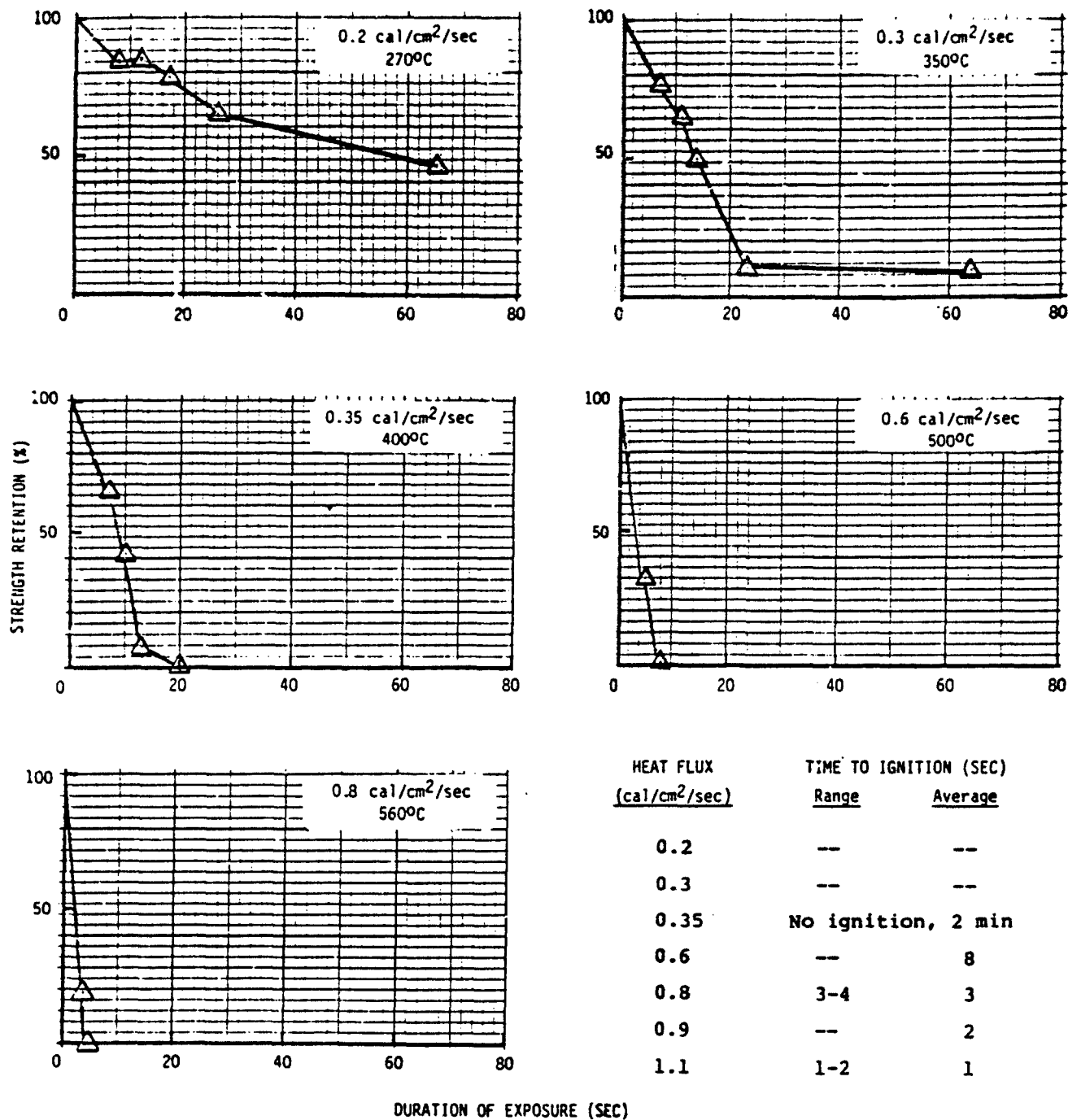


Figure 8a. Strength Retention of Fabric #34 (80/20 PFR rayon/Nomex, 7.0 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

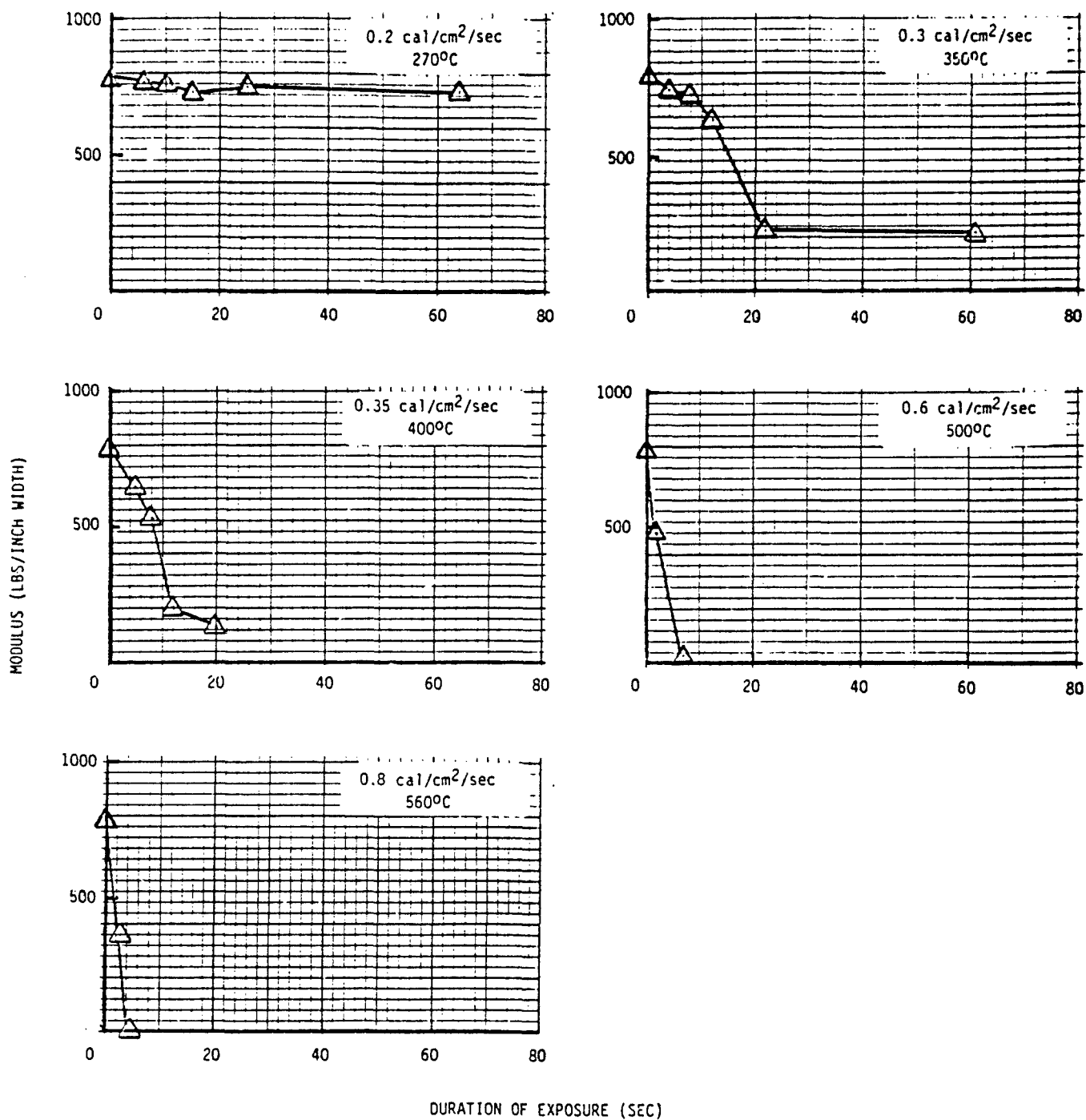


Figure 8b. Modulus of Fabric #34 (80/20 PFR rayon/Nomex, 7.0 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat

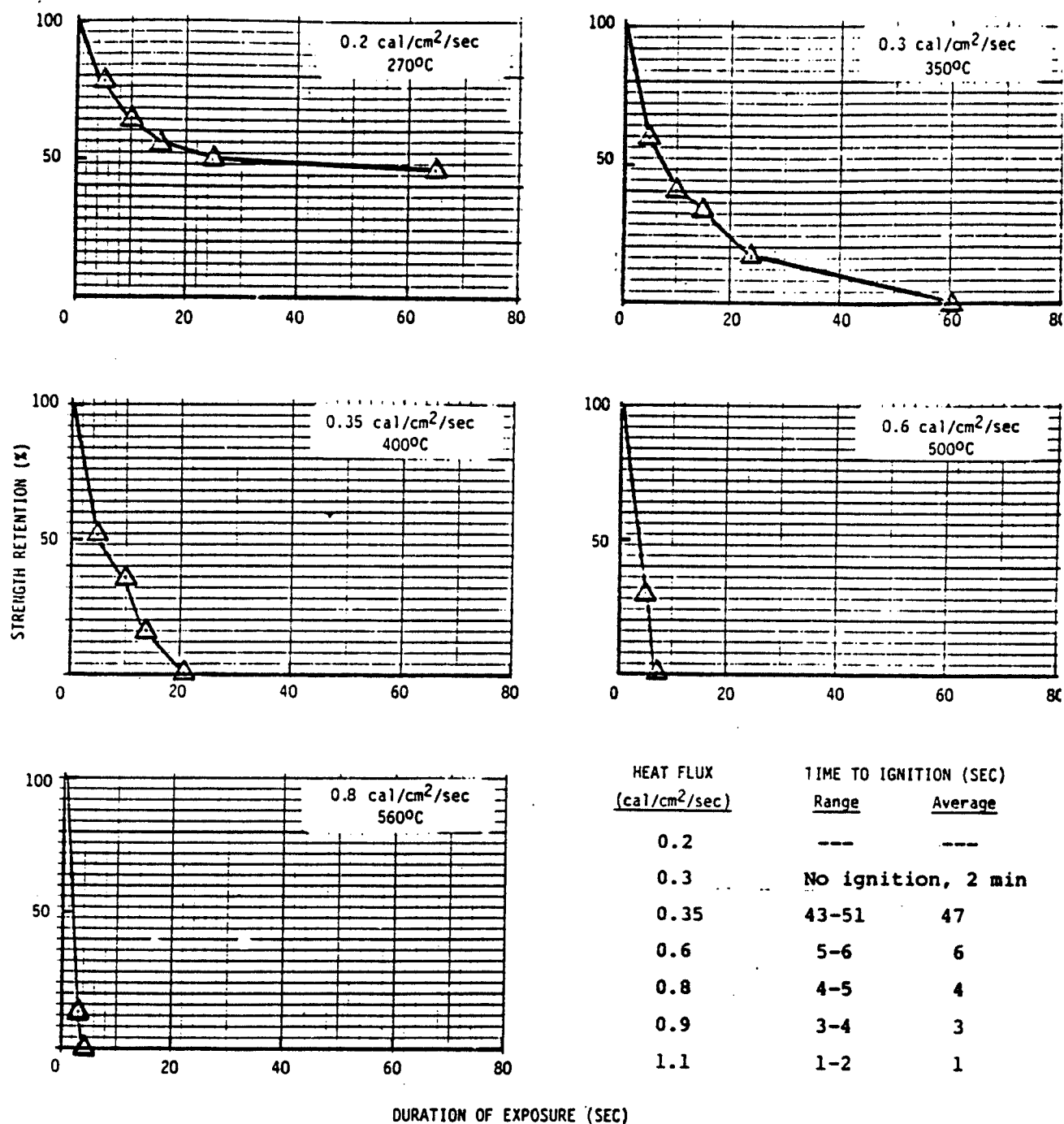


Figure 9a. Strength Retention of Fabric #44 (100% cotton, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

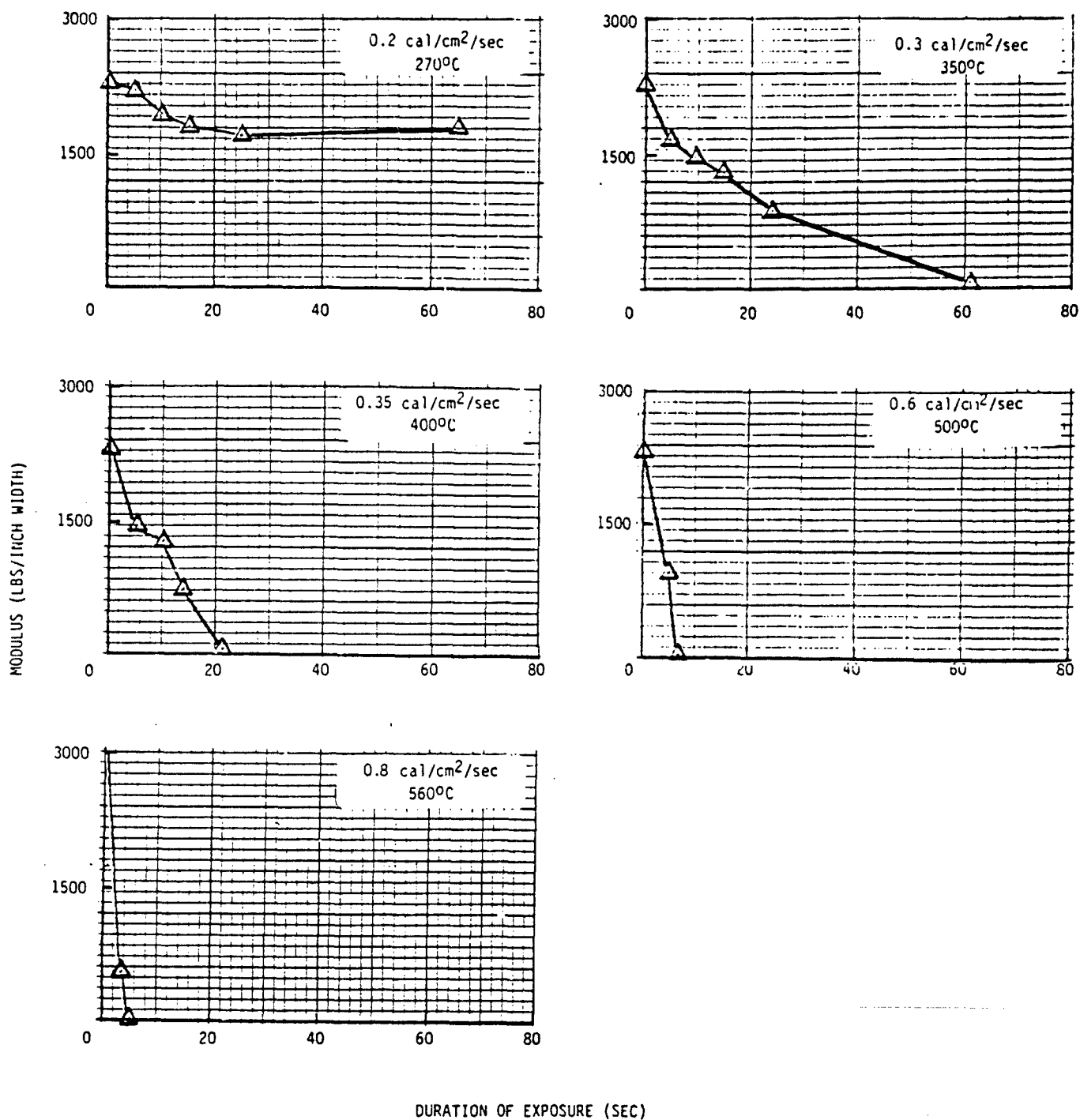


Figure 9b. Modulus of Fabric #44 (100% cotton, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

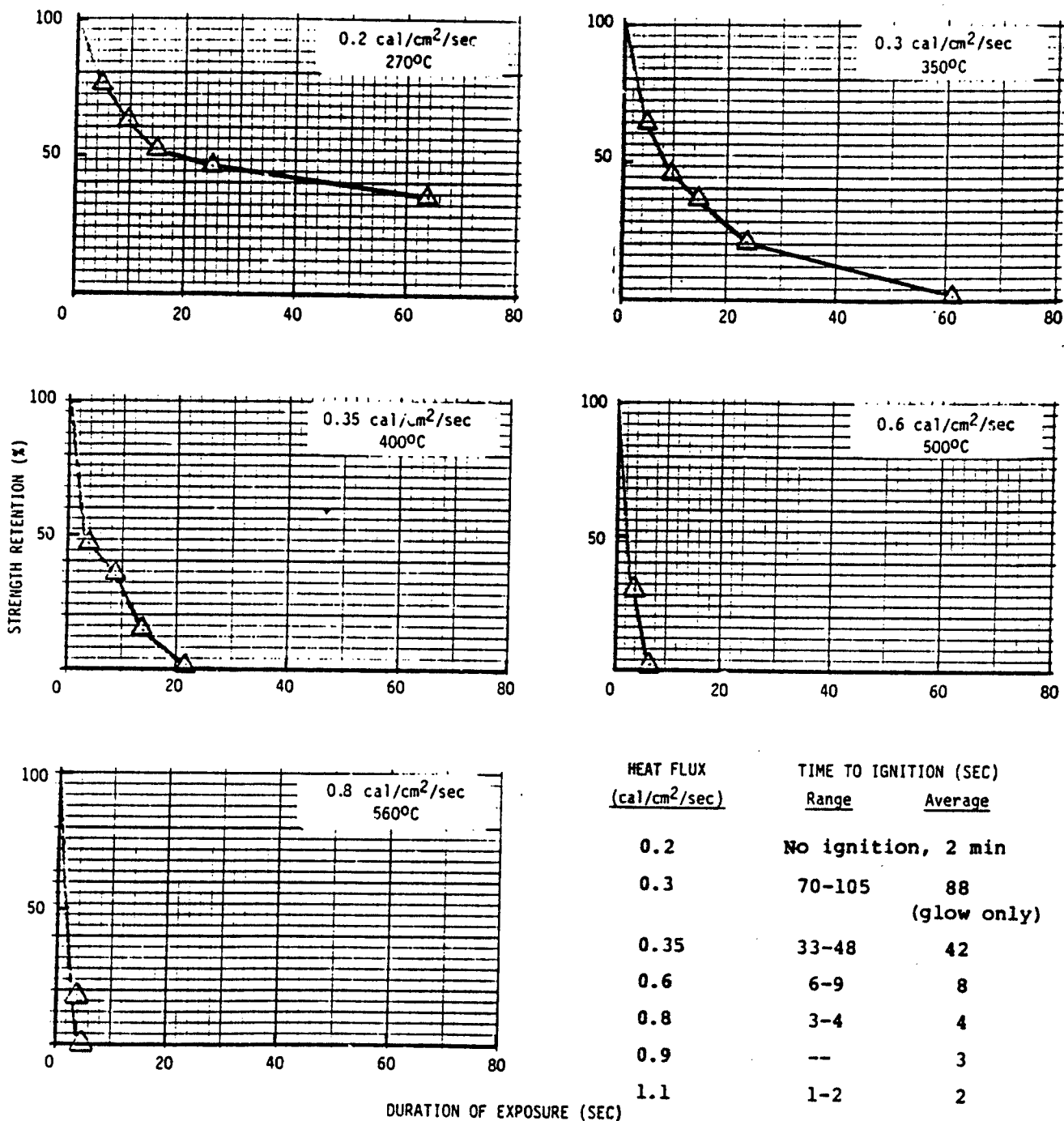


Figure 10a. Strength Retention of Fabric #50 (100% cotton, 6.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

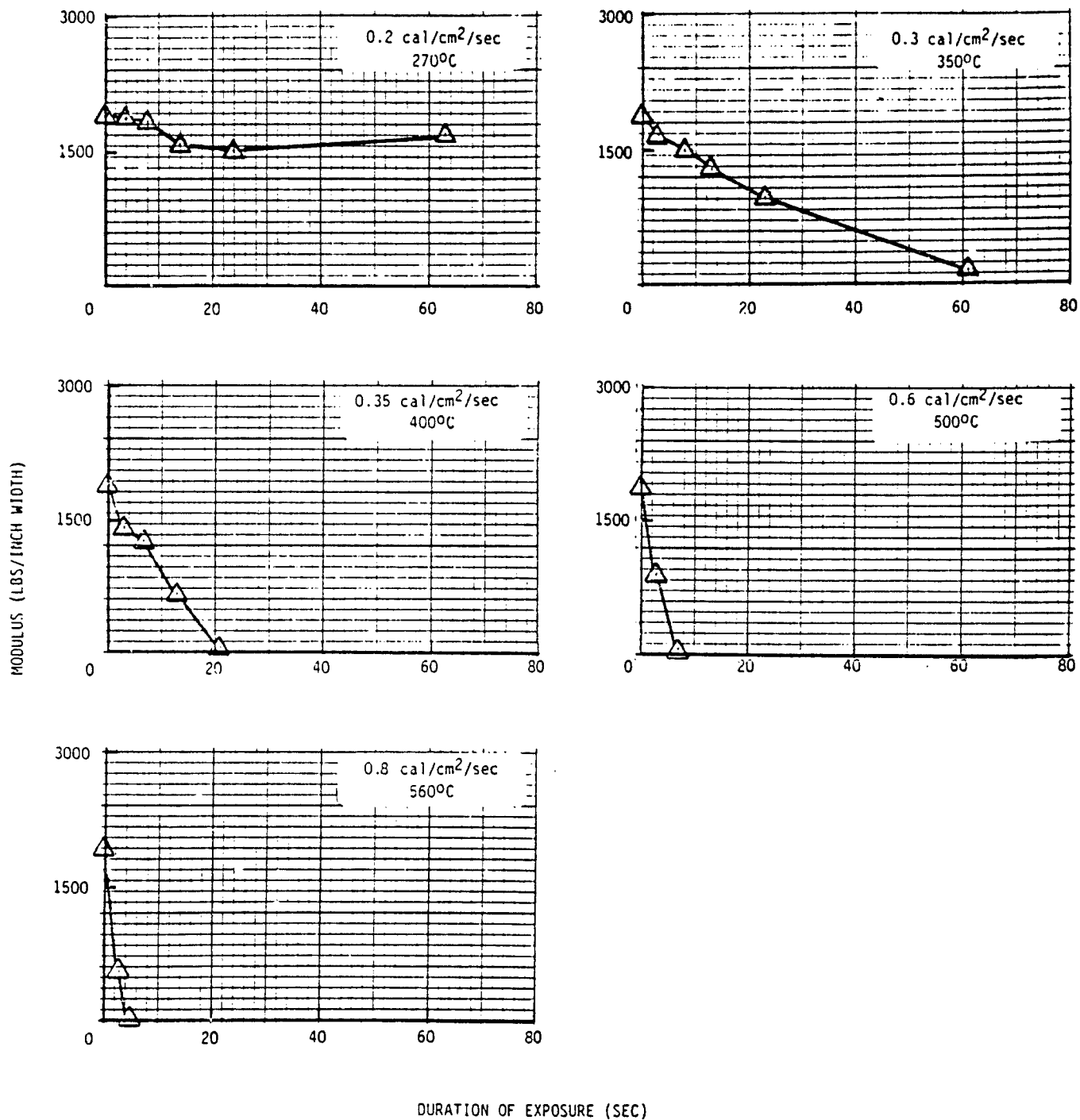


Figure 10b. Modulus of Fabric #50 (100% cotton, 6.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

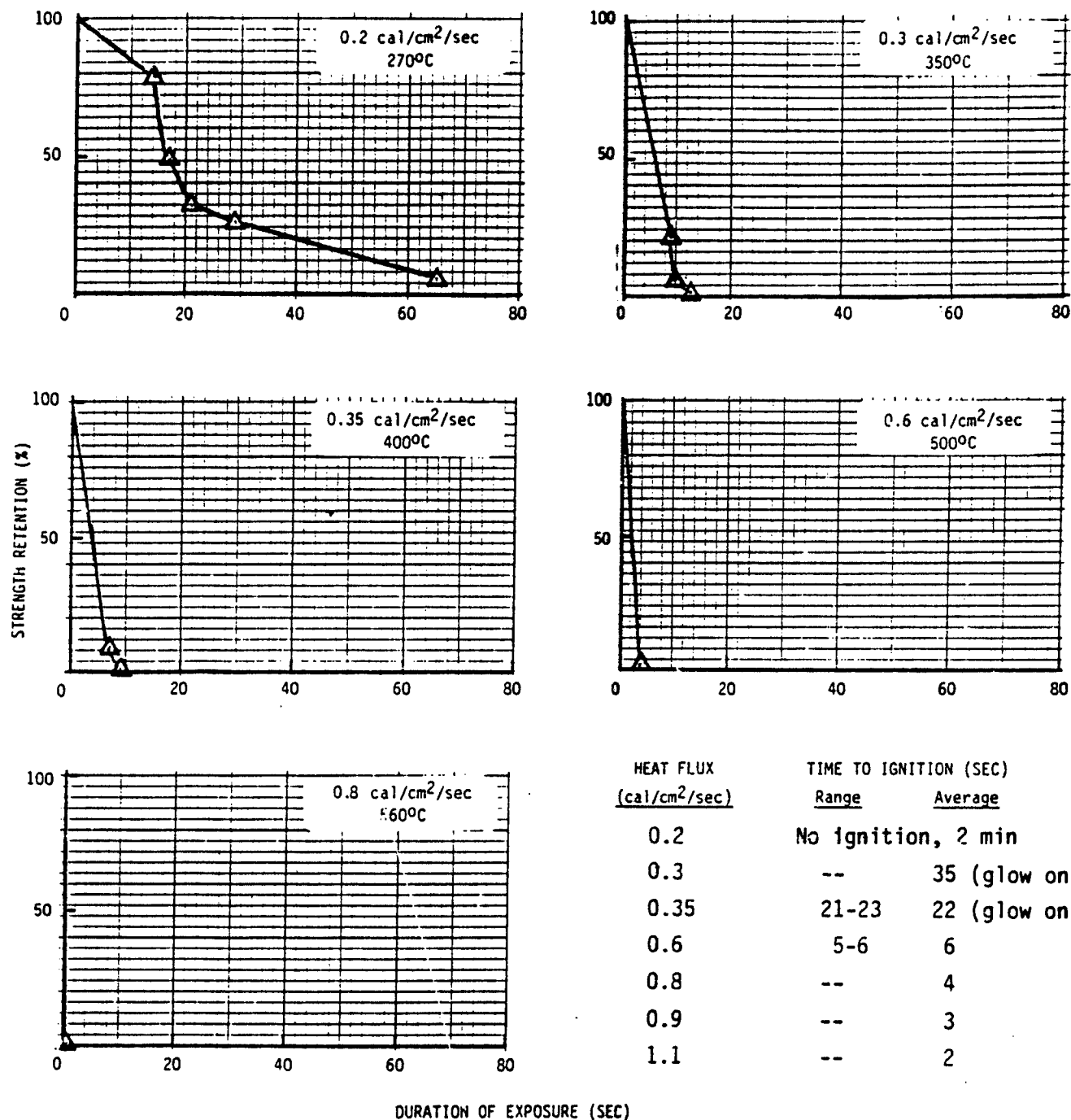


Figure 11a. Strength Retention of Fabric #37 (100% cotton, 5.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

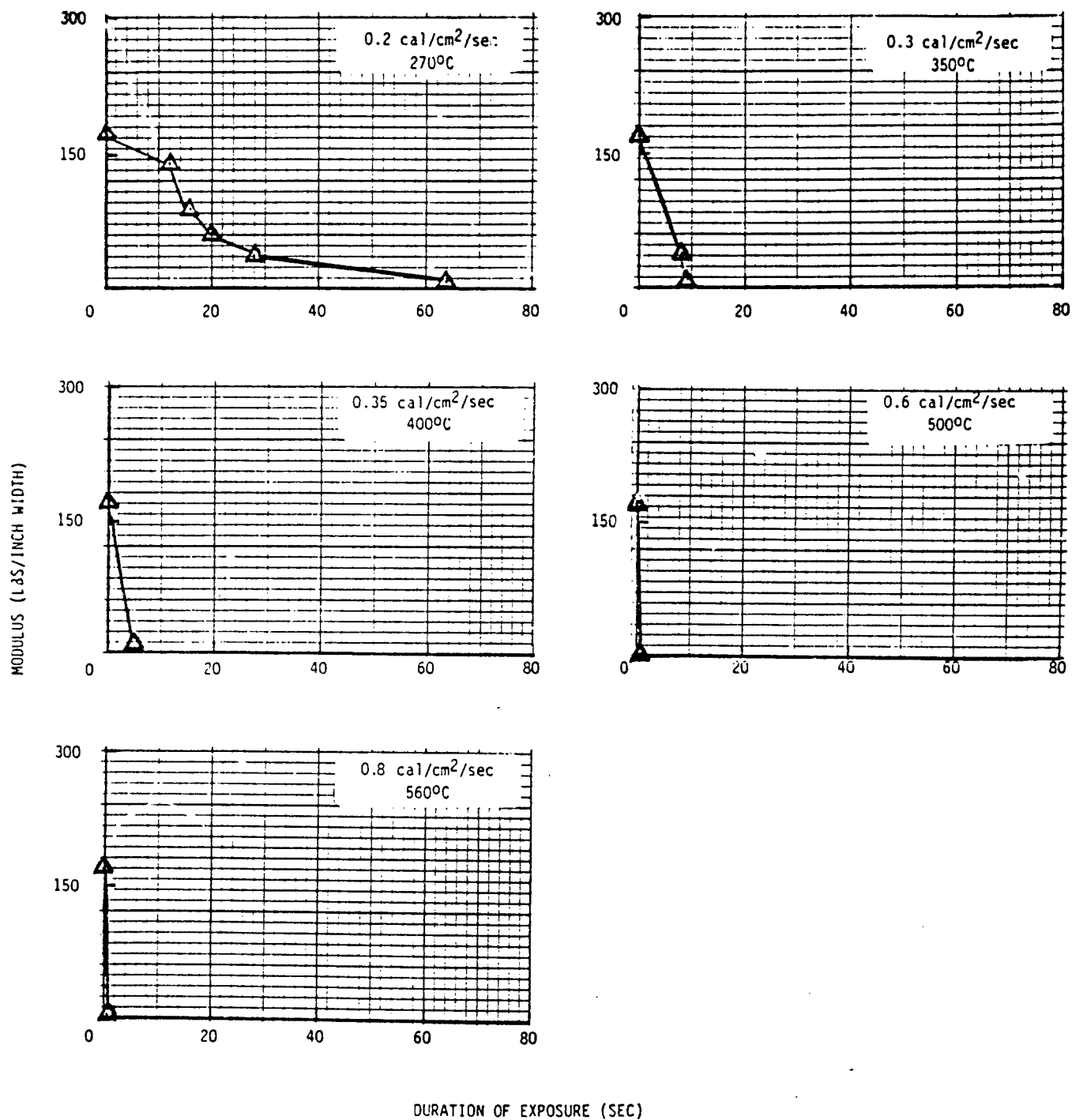


Figure 11b. Modulus of Fabric #37 (100% cotton, 5.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

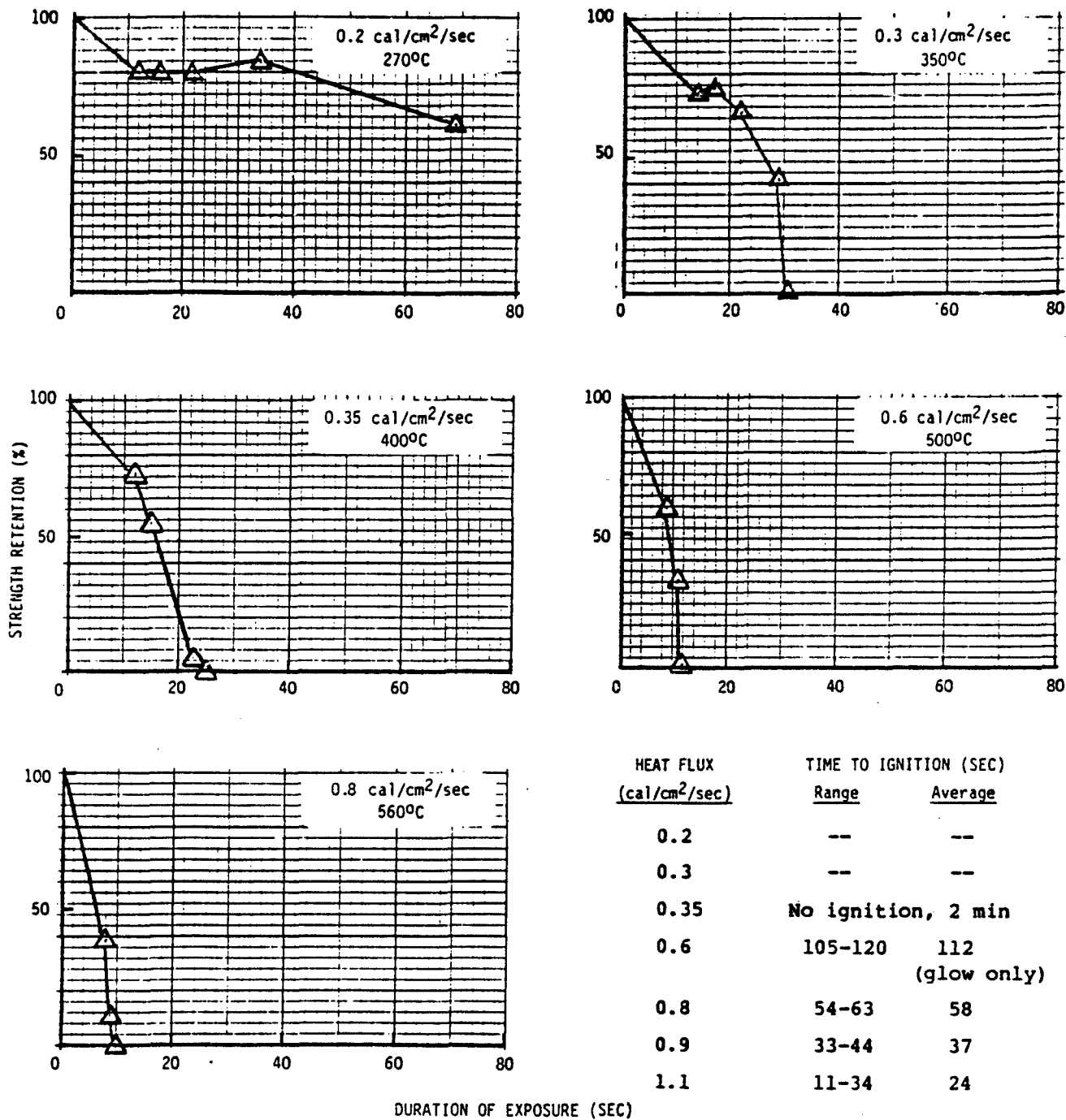


Figure 12a. Strength Retention of Fabric #21 (100% wool, 15.7 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

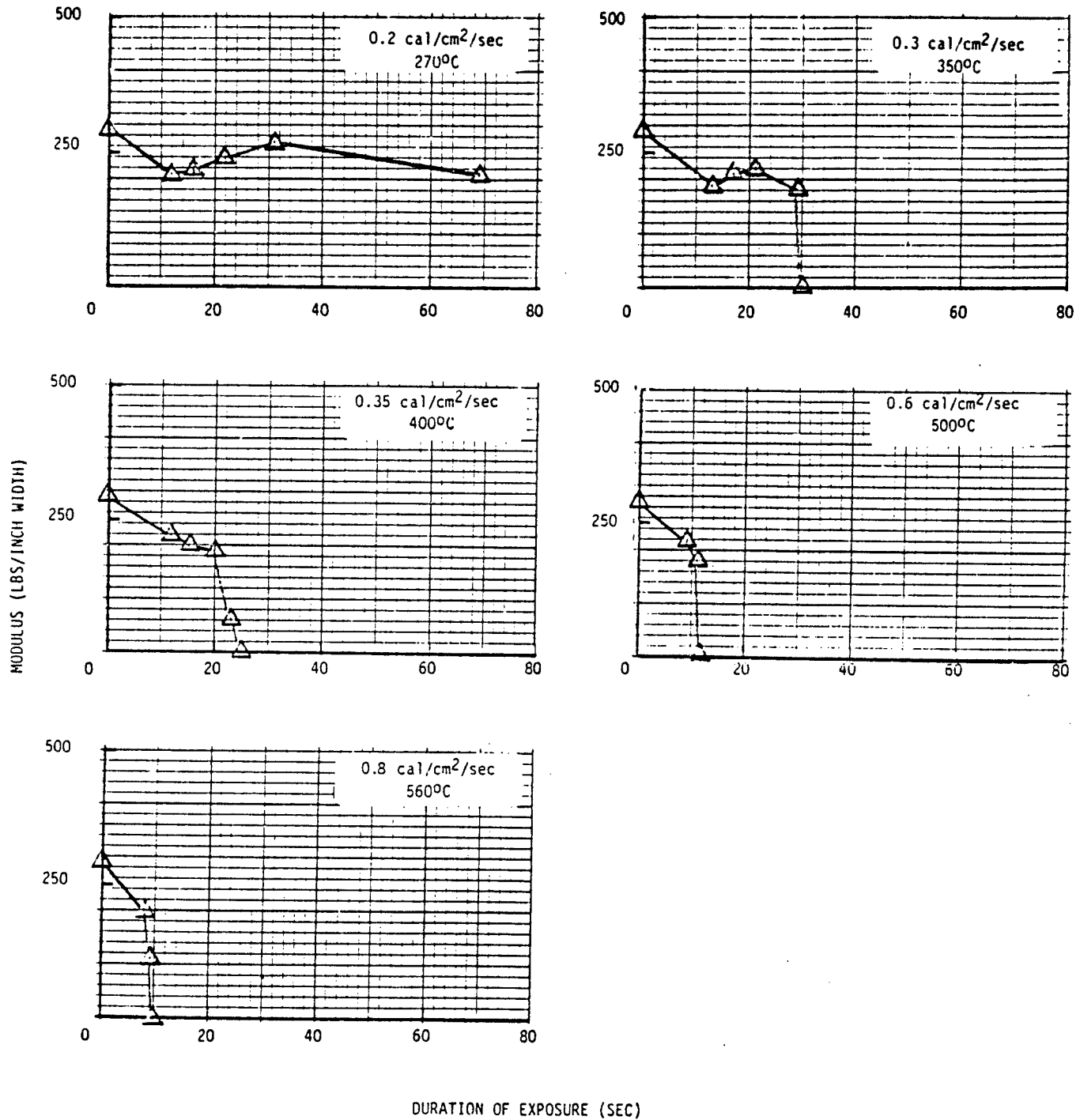


Figure 12b. Modulus of Fabric #21 (100% wool, 15.7 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

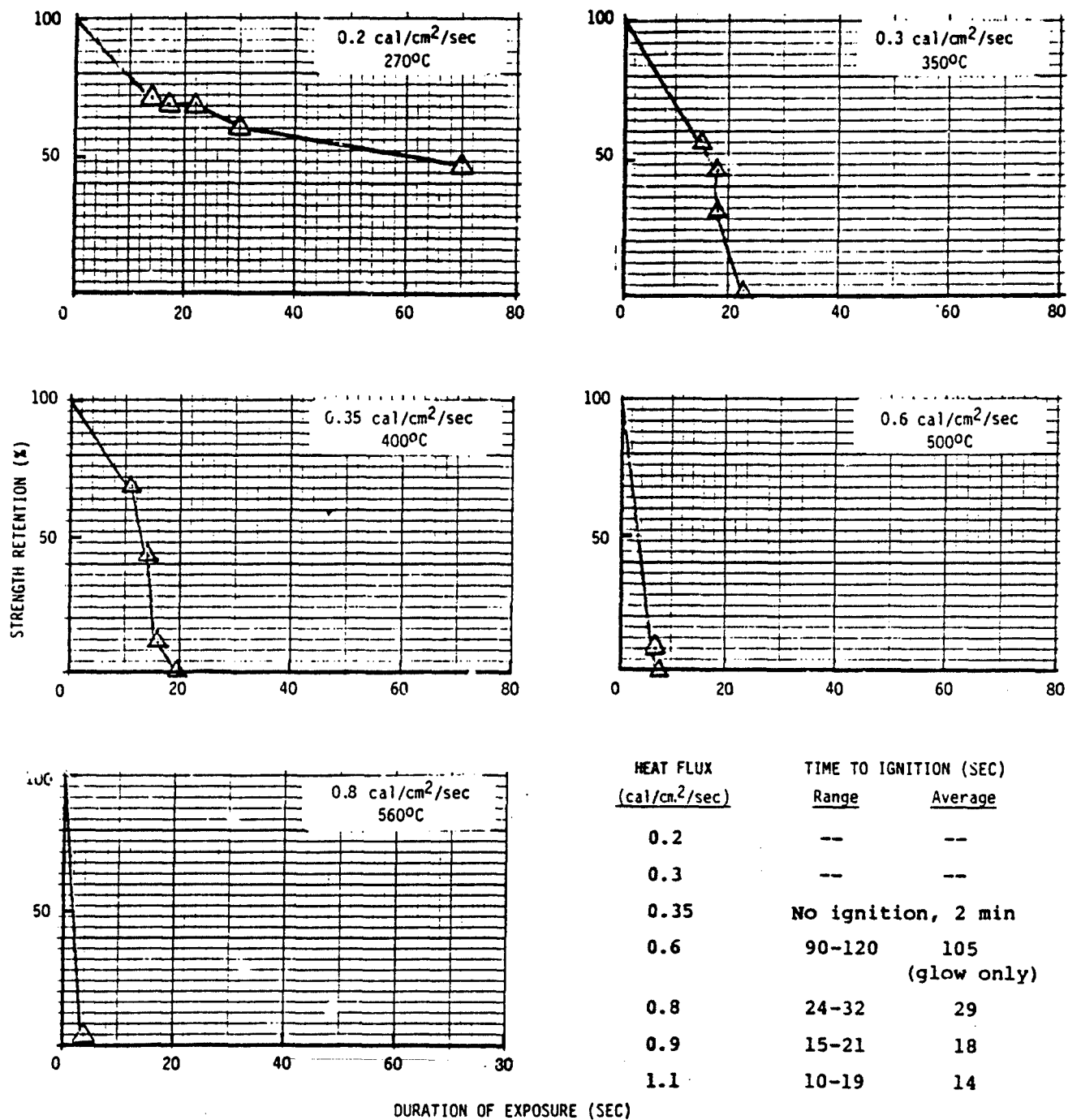


Figure 13a. Strength Retention of Fabric #28 (90/10 wool/nylon, 8.2 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat

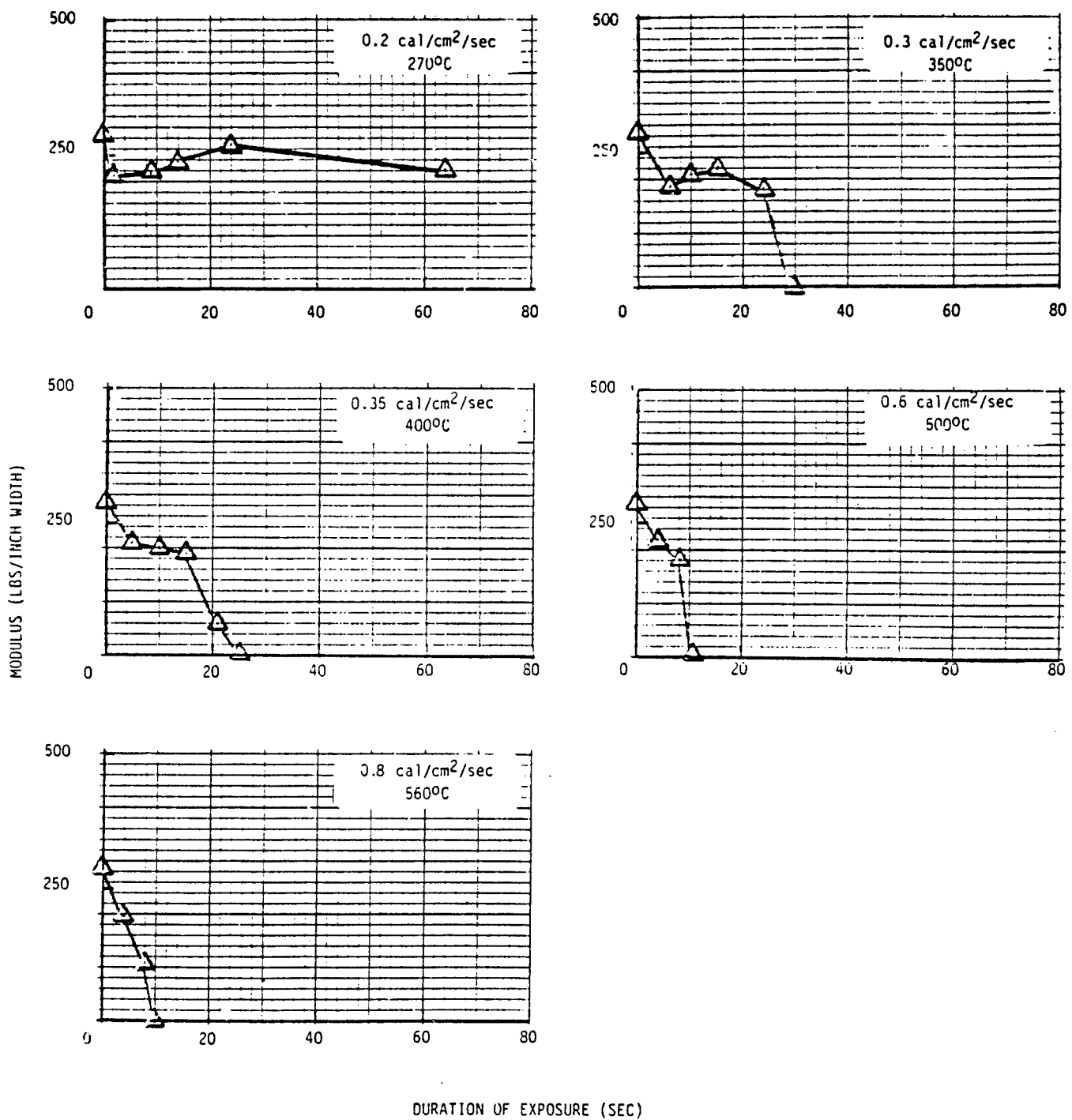


Figure 13b. Modulus of Fabric #28 (90/10 wool/nylon, 8.2 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

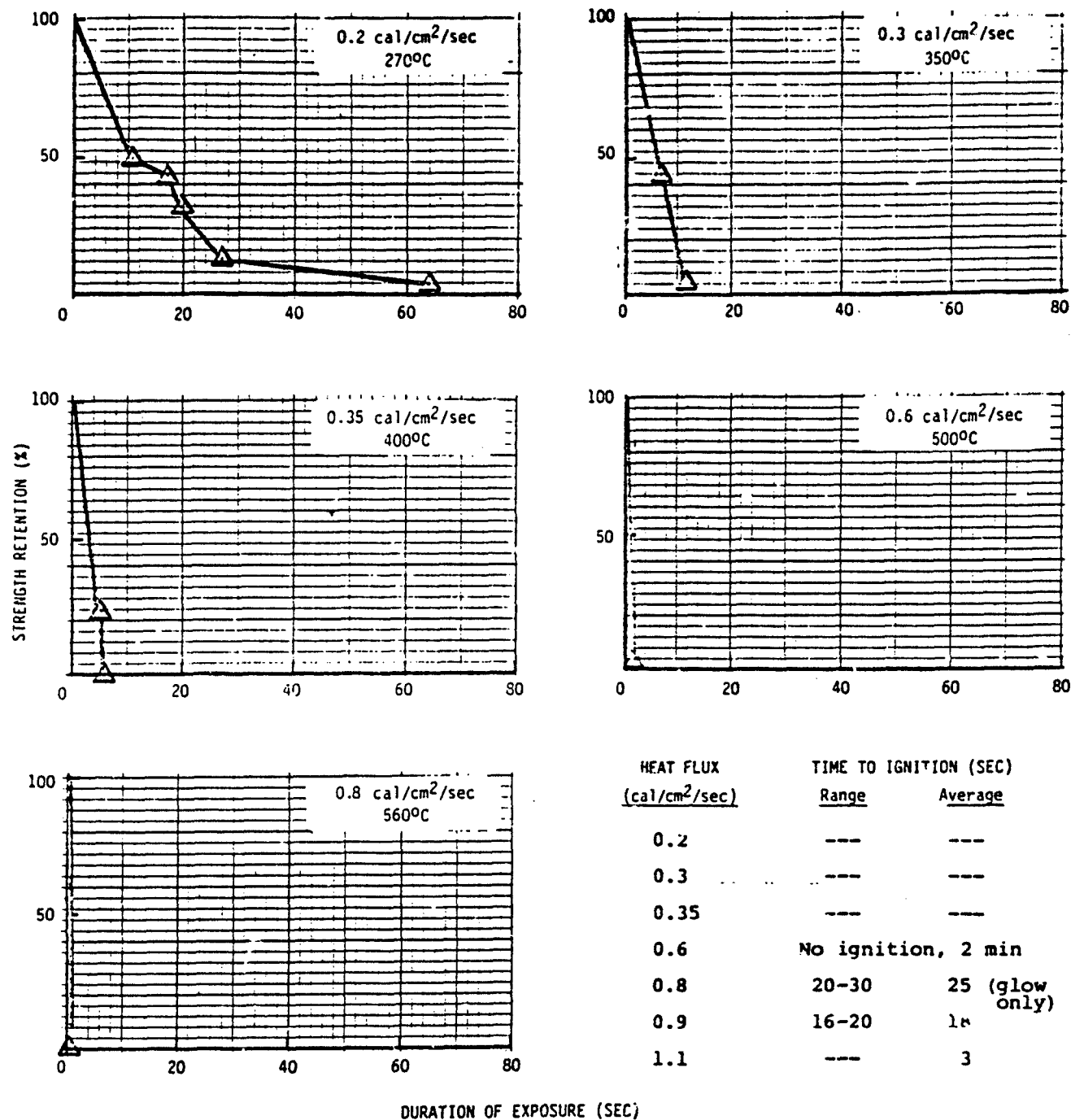


Figure 14a. Strength Retention of Fabric #25 (55/45 polyester/wool, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

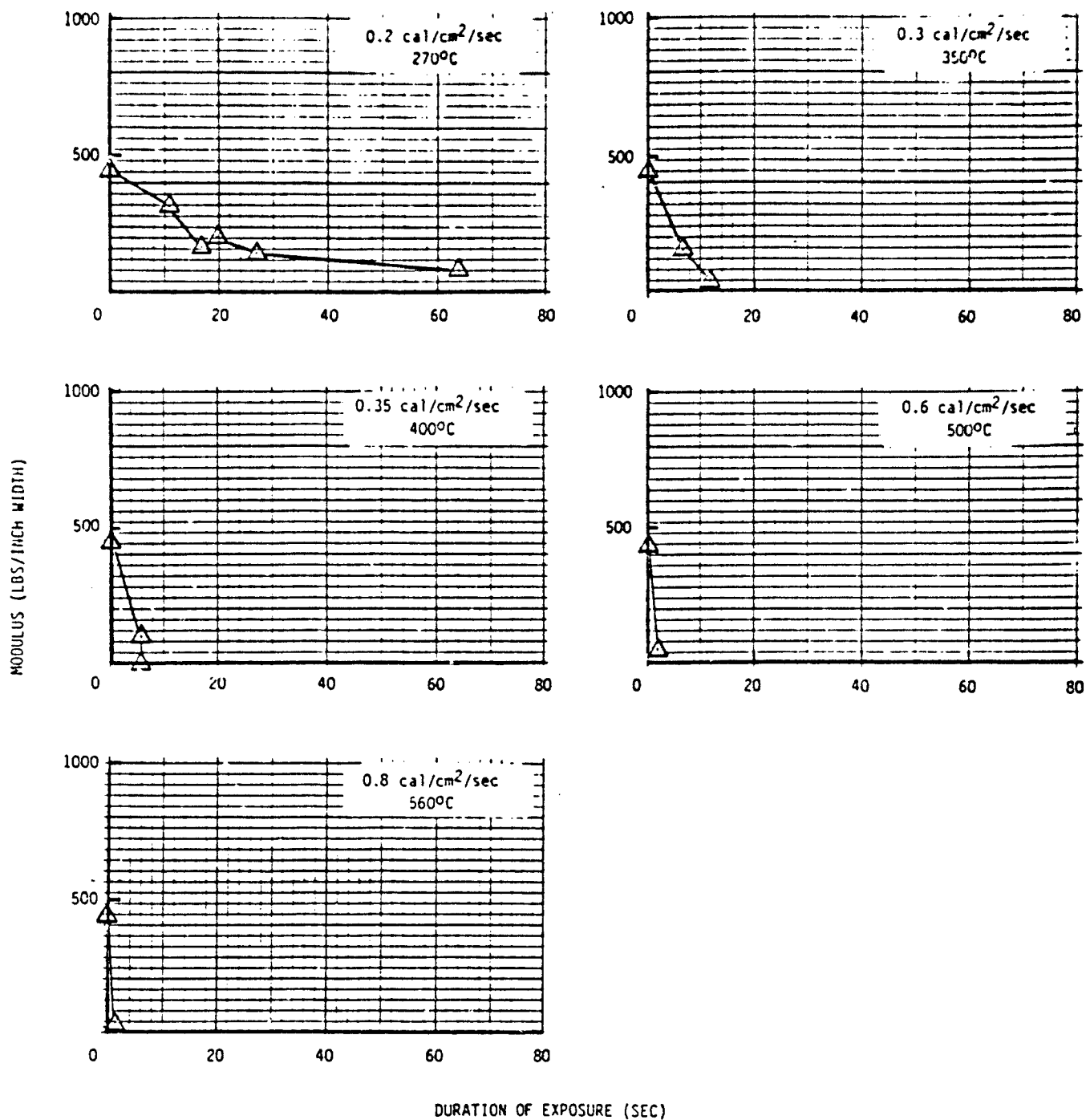


Figure 14b. Modulus of Fabric #25 (55/45 polyester/wool, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

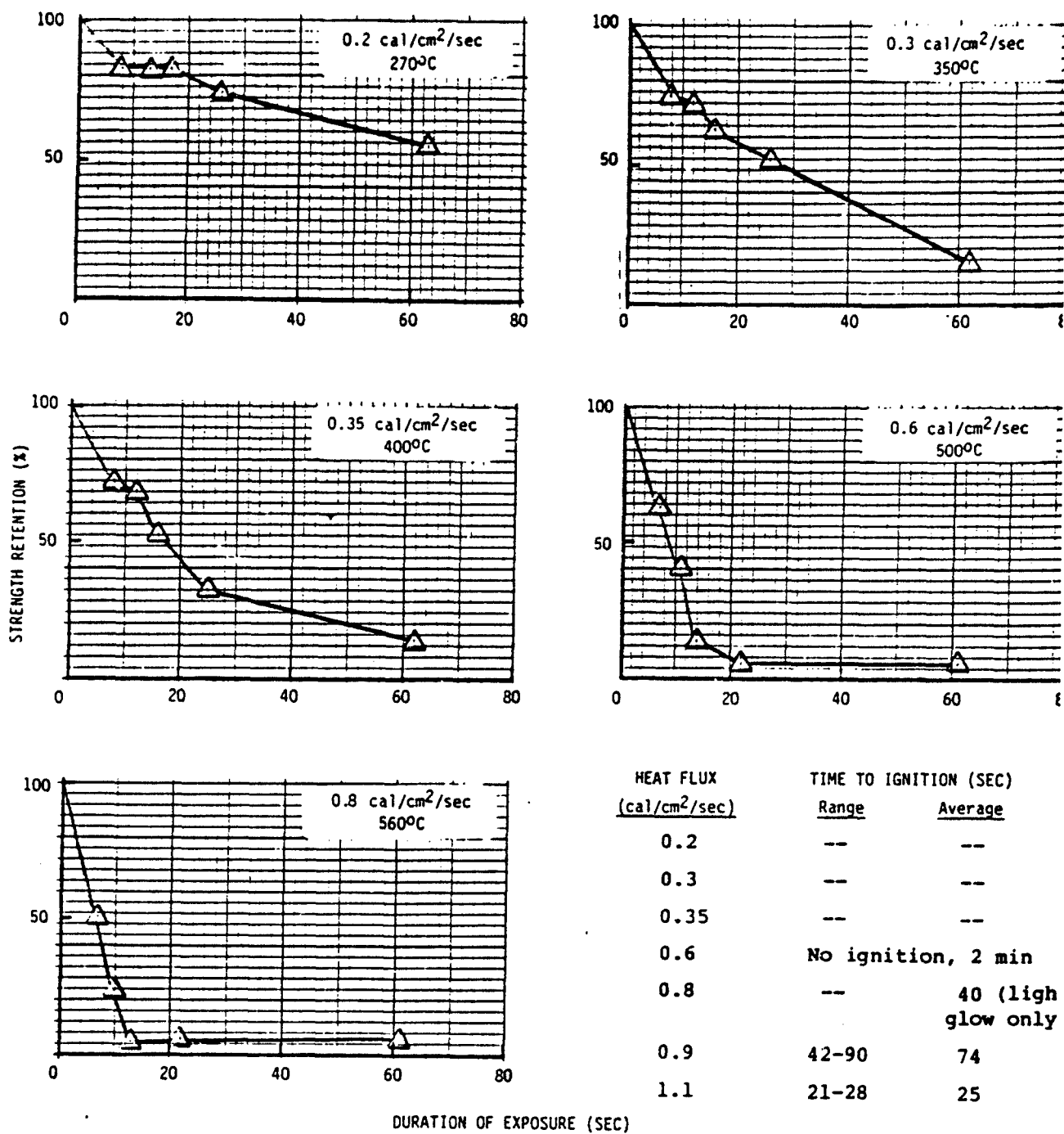


Figure 15a. Strength Retention of Fabric #78 (core spun, semi-carbon Kevlar, 15.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

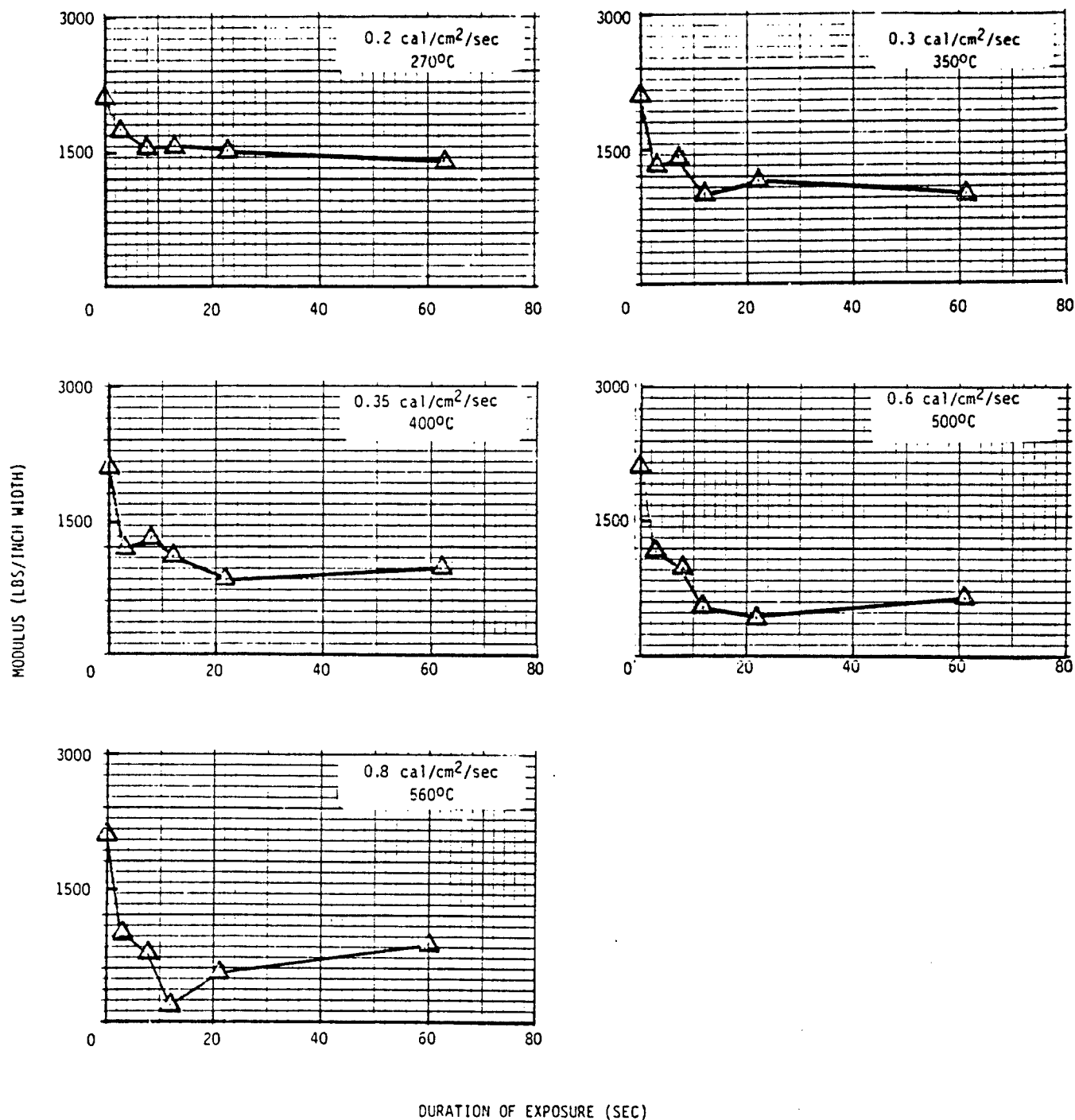


Figure 15b. Modulus of Fabric #78 (core spun, semi-carbon Kevlar, 15.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

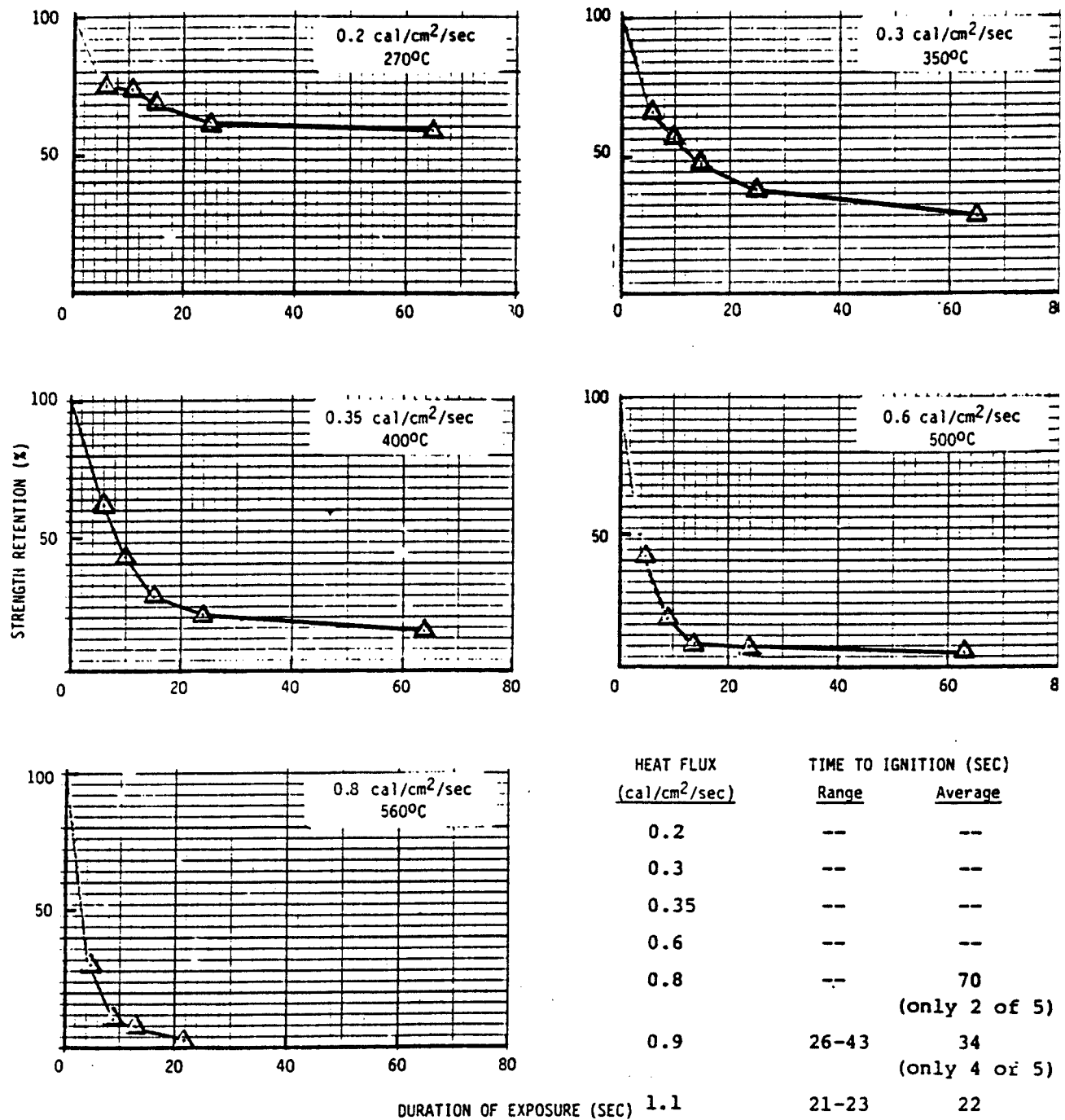
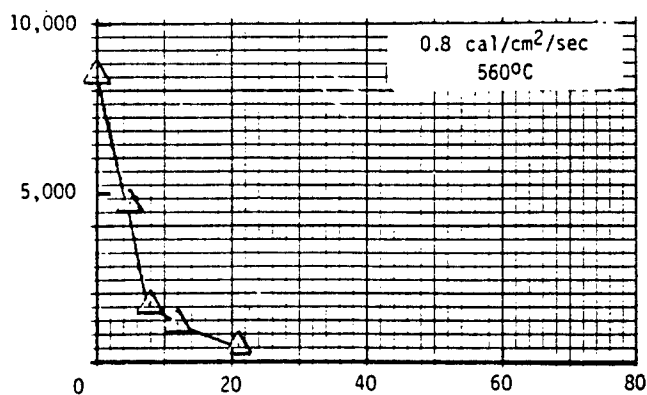
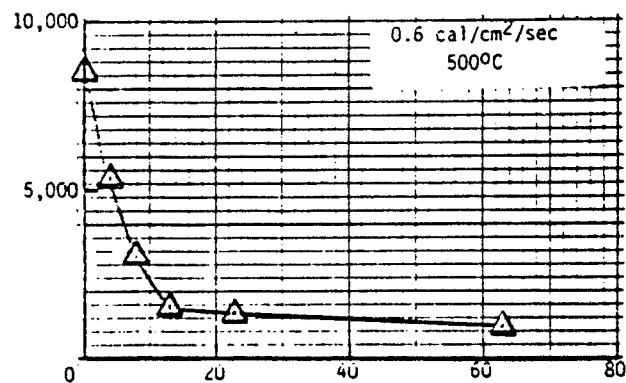
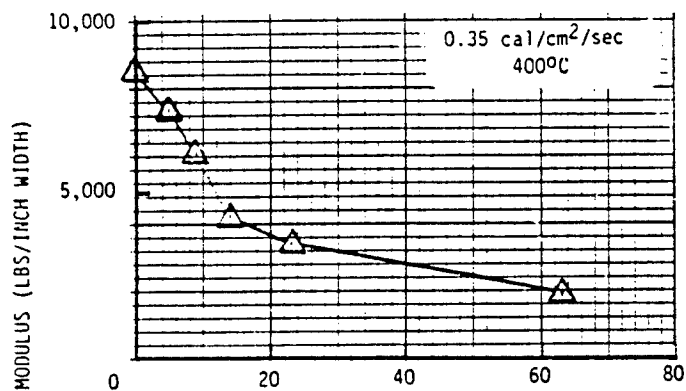
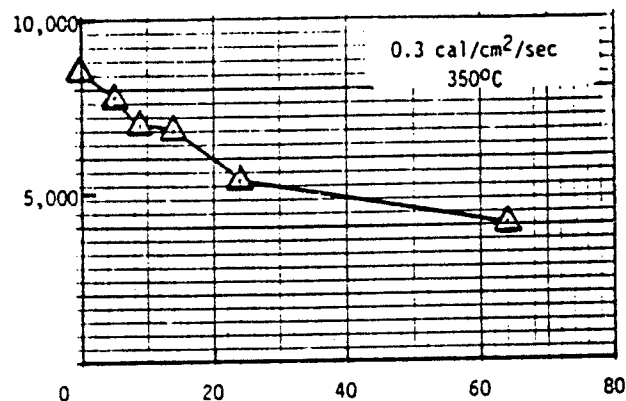
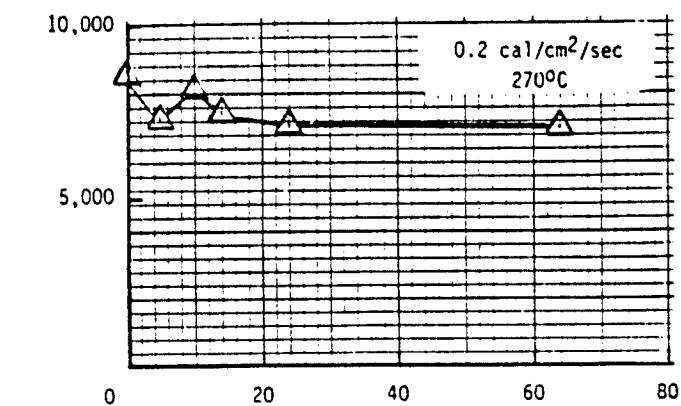
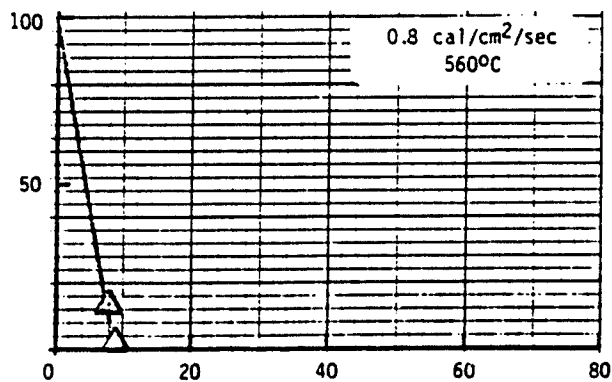
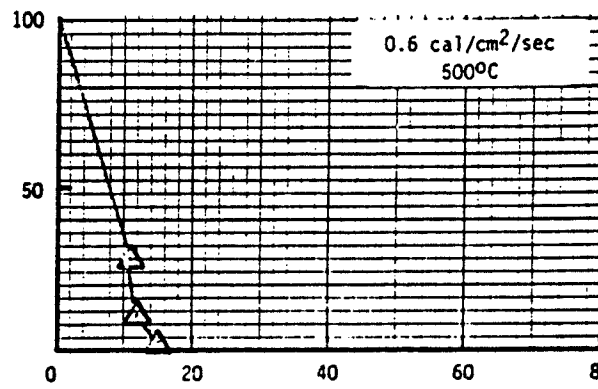
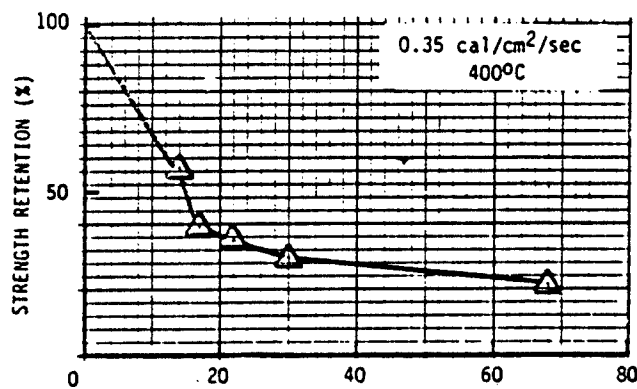
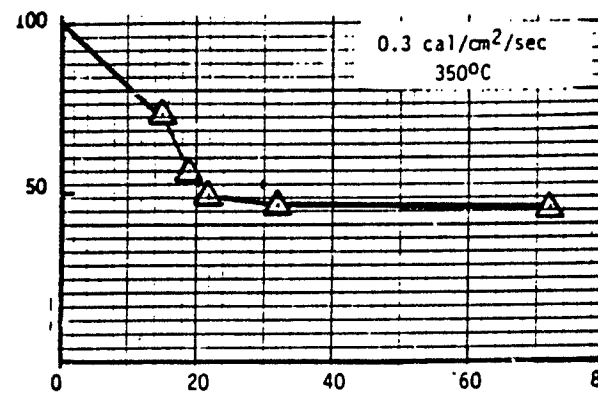
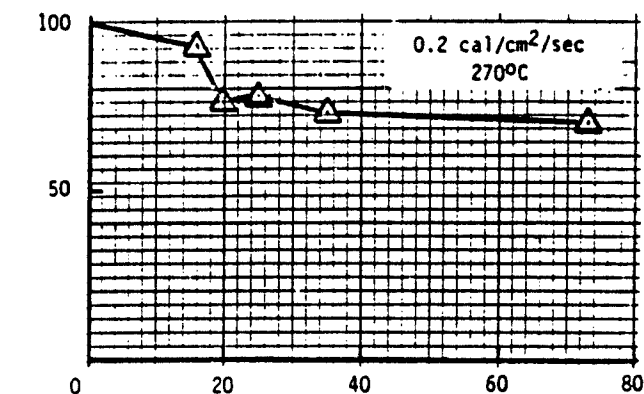


Figure 16a. Strength Retention of Fabric #75 (100% Kevlar, 8.3 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat



DURATION OF EXPOSURE (SEC)

Figure 16b. Modulus of Fabric #75 (100% Kevlar, 8.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC)	
	Range	Average
0.2	--	--
0.3	--	--
0.35	--	--
0.6	No ignition 2 min	
0.8	melted,	10-13
0.9	85-95	90
1.1	43-44	44

DURATION OF EXPOSURE (SEC)

Figure 17a. Strength Retention of Fabric #47 (100% Nomex, 8.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

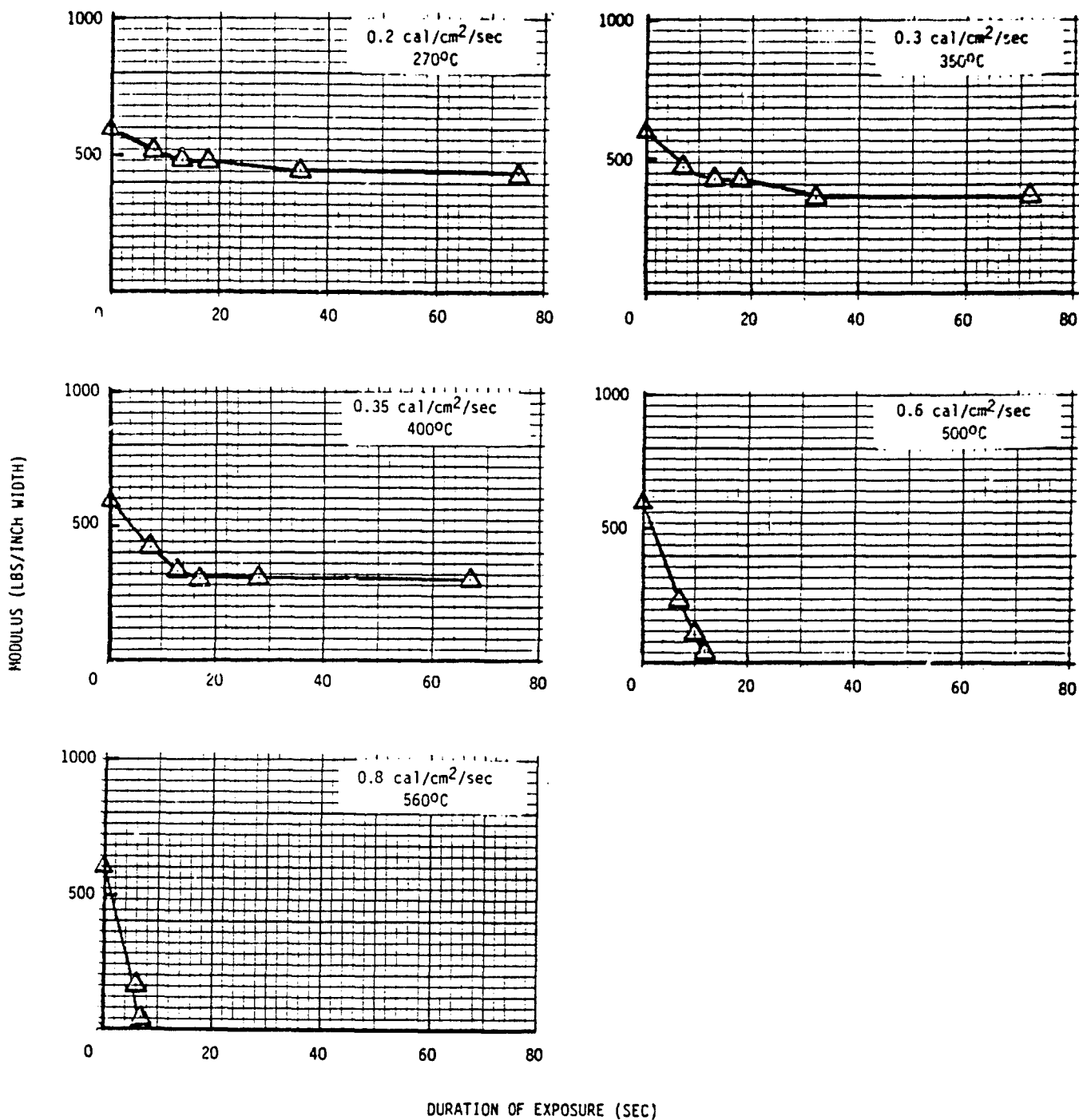


Figure 17b. Modulus of Fabric #47 (100% Nomex, 8.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

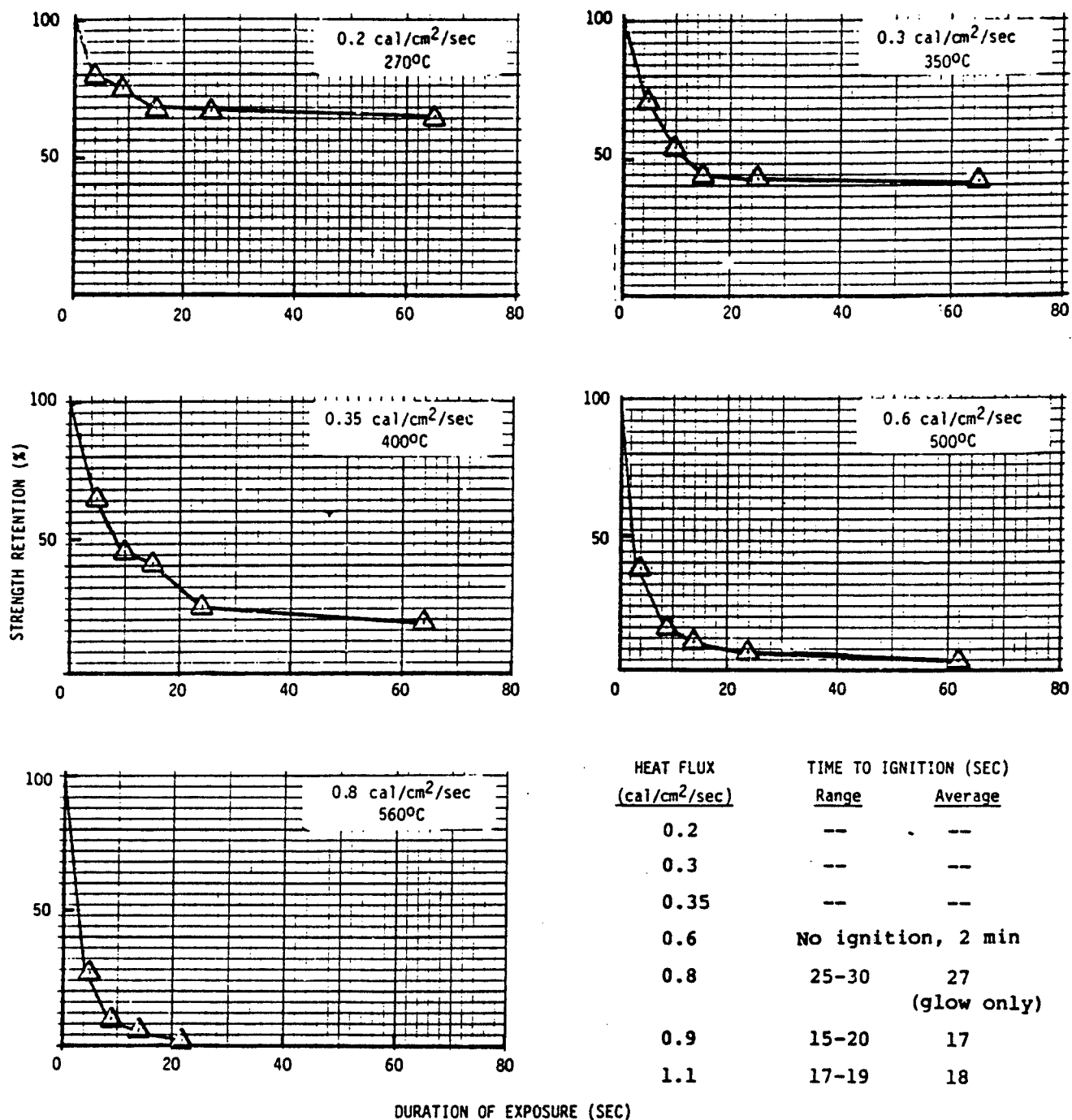


Figure 18a. Strength Retention of Fabric #74 (50/50 Nomex/Kevlar, 6.0 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

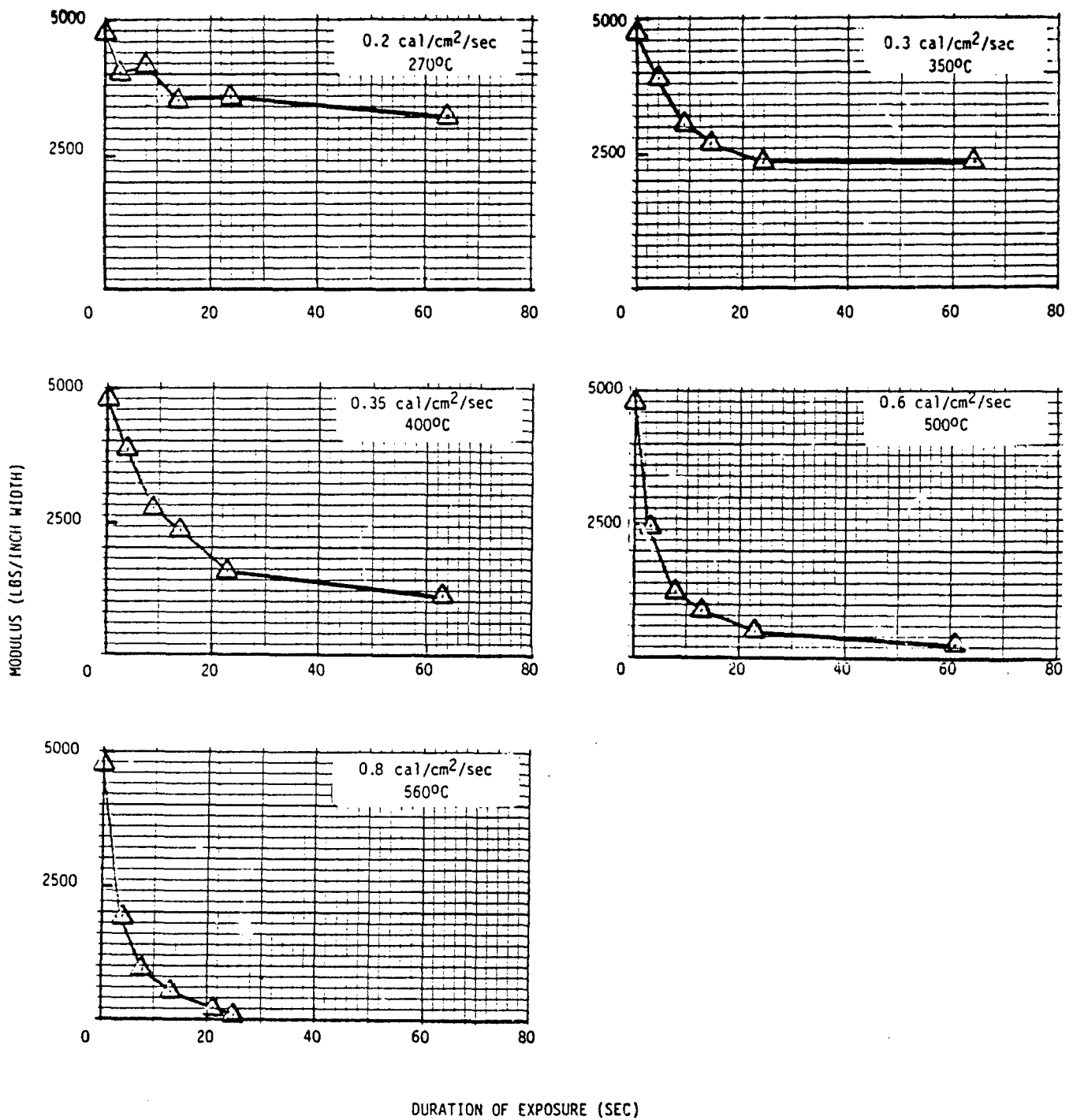


Figure 18b. Modulus of Fabric #74 (50/50 Nomex/Kevlar, 6.0 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat

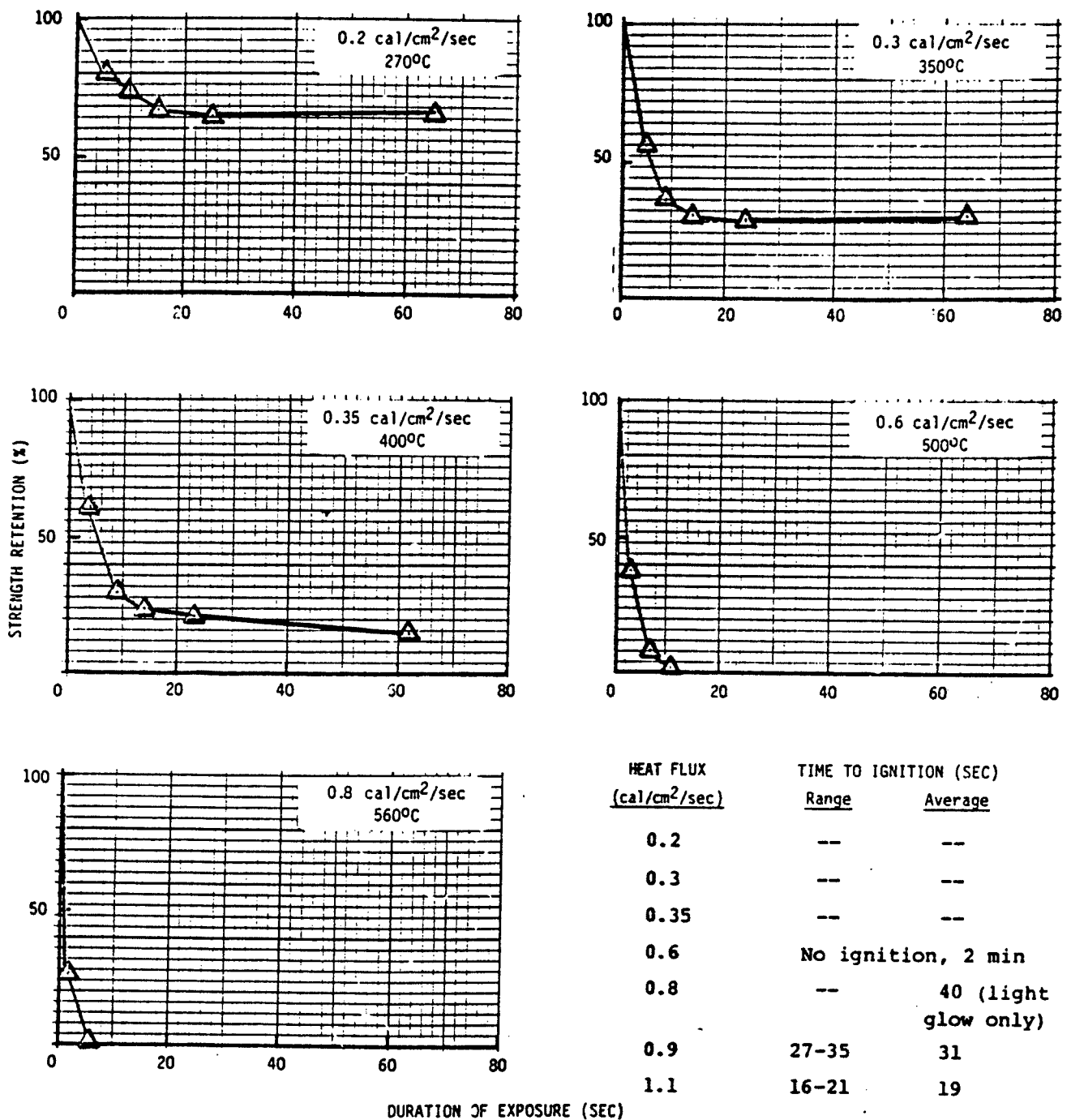


Figure 19a. Strength Retention of Fabric #73 (95/5 Nomex/Kevlar, 5.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

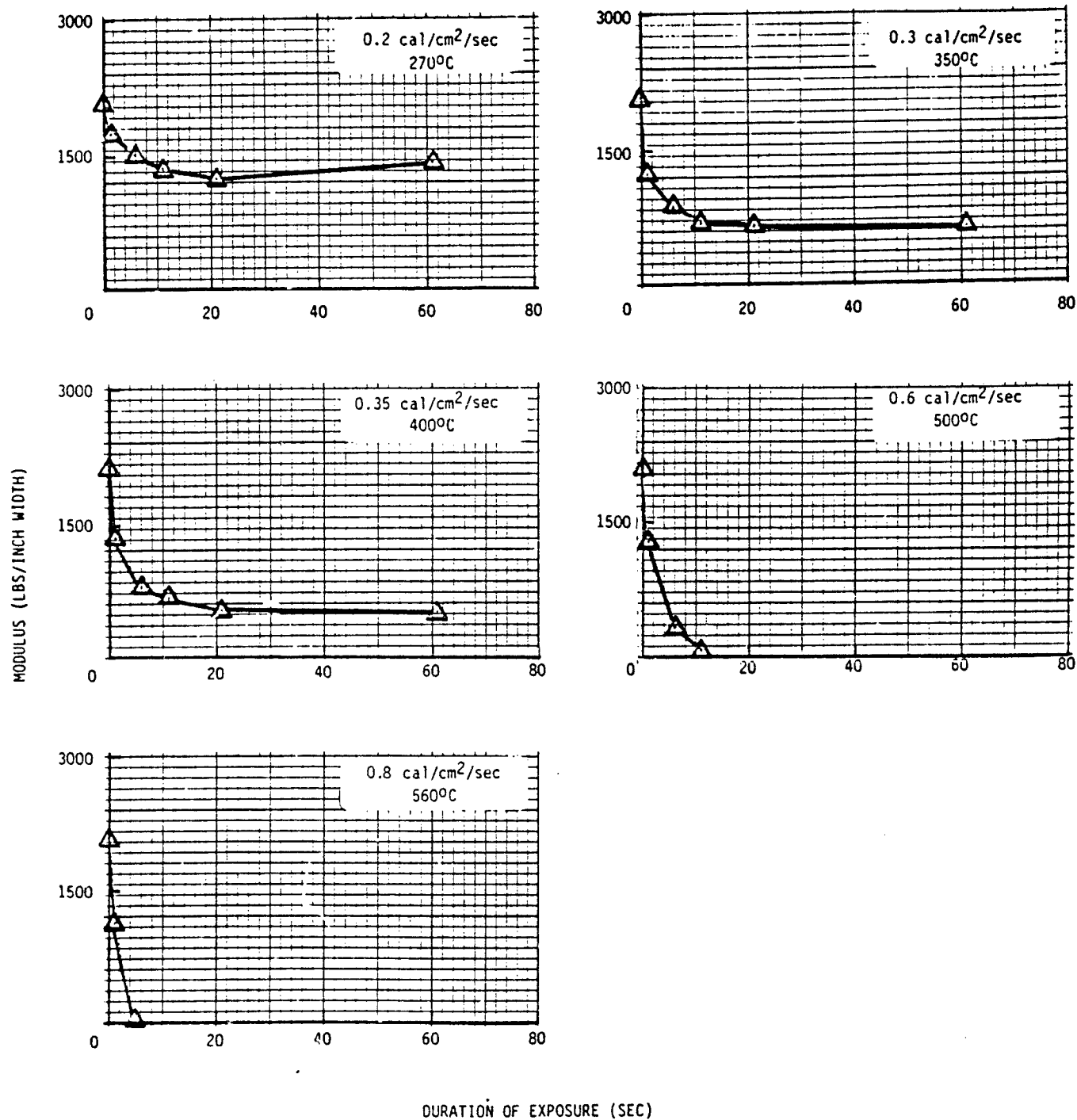


Figure 19b. Modulus of Fabric #73 (95/5 Nomex/Kevlar, 5.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

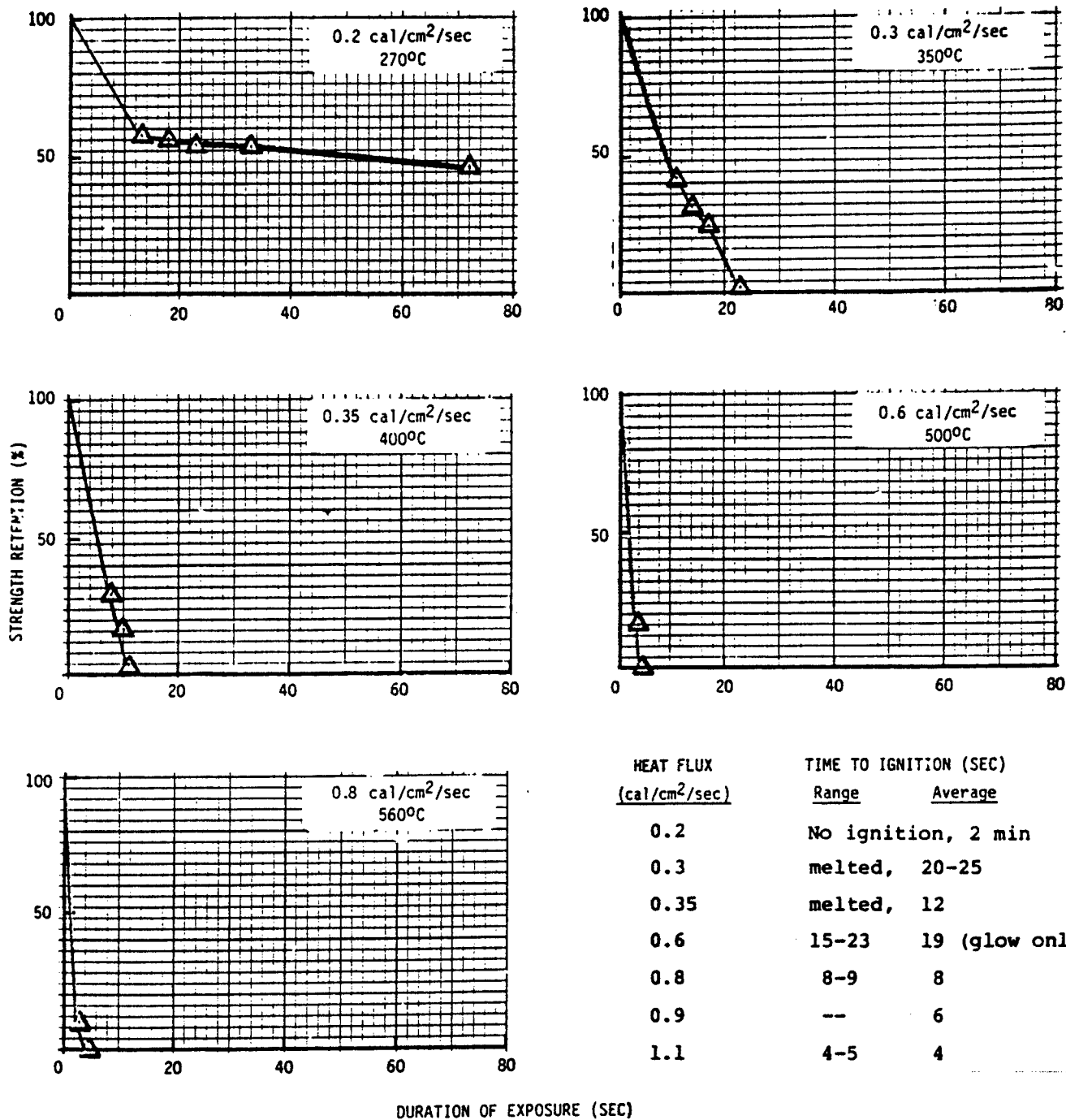


Figure 20a. Strength Retention of Fabric #39 (nylon, butyl coated, 12.5 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

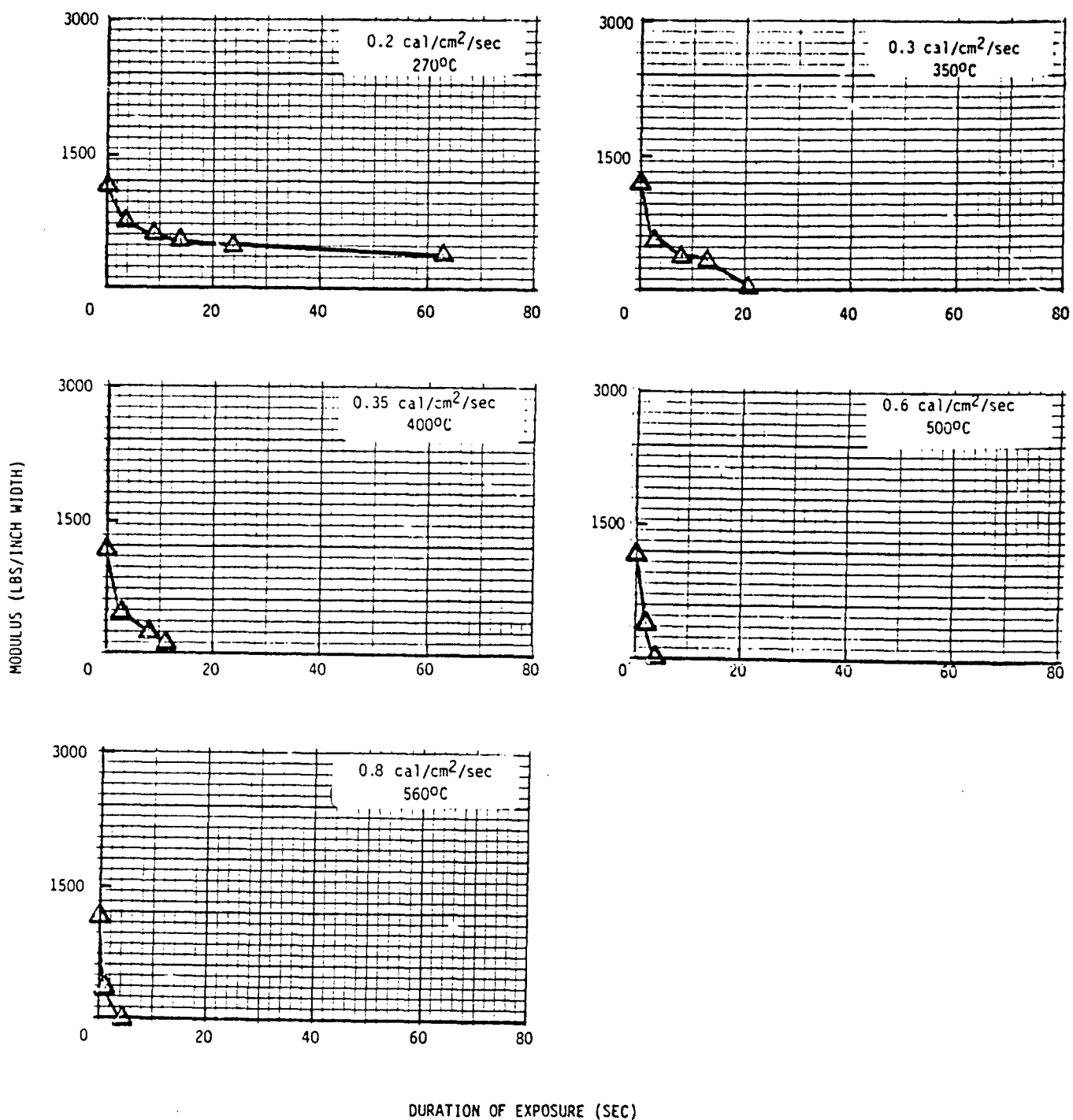


Figure 20b. Modulus of Fabric #39 (nylon, butyl coated, 12.5 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat

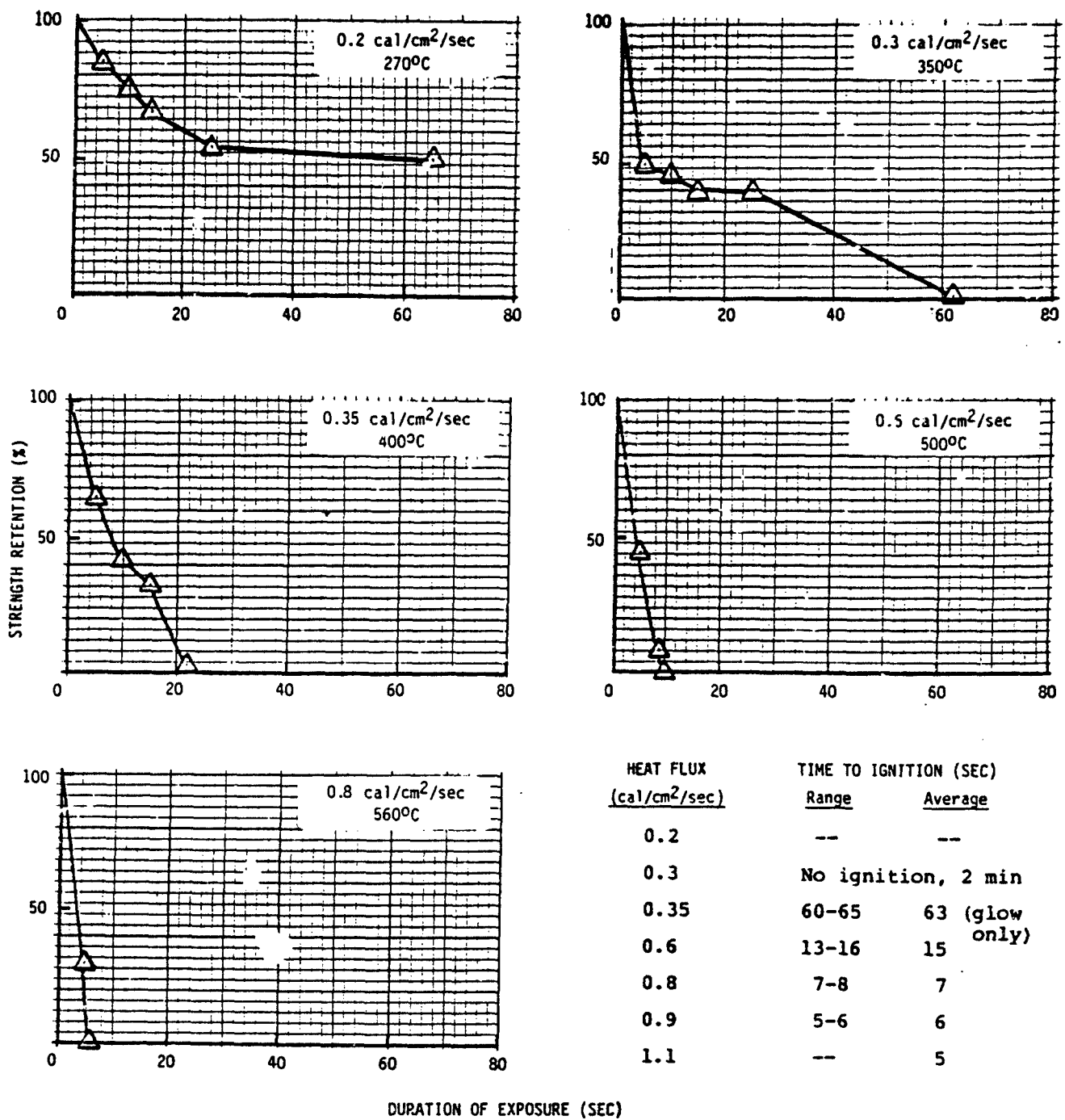


Figure 21a. Strength Retention of Fabric #5 (cotton, resin modified, butyl coated, 10.5 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

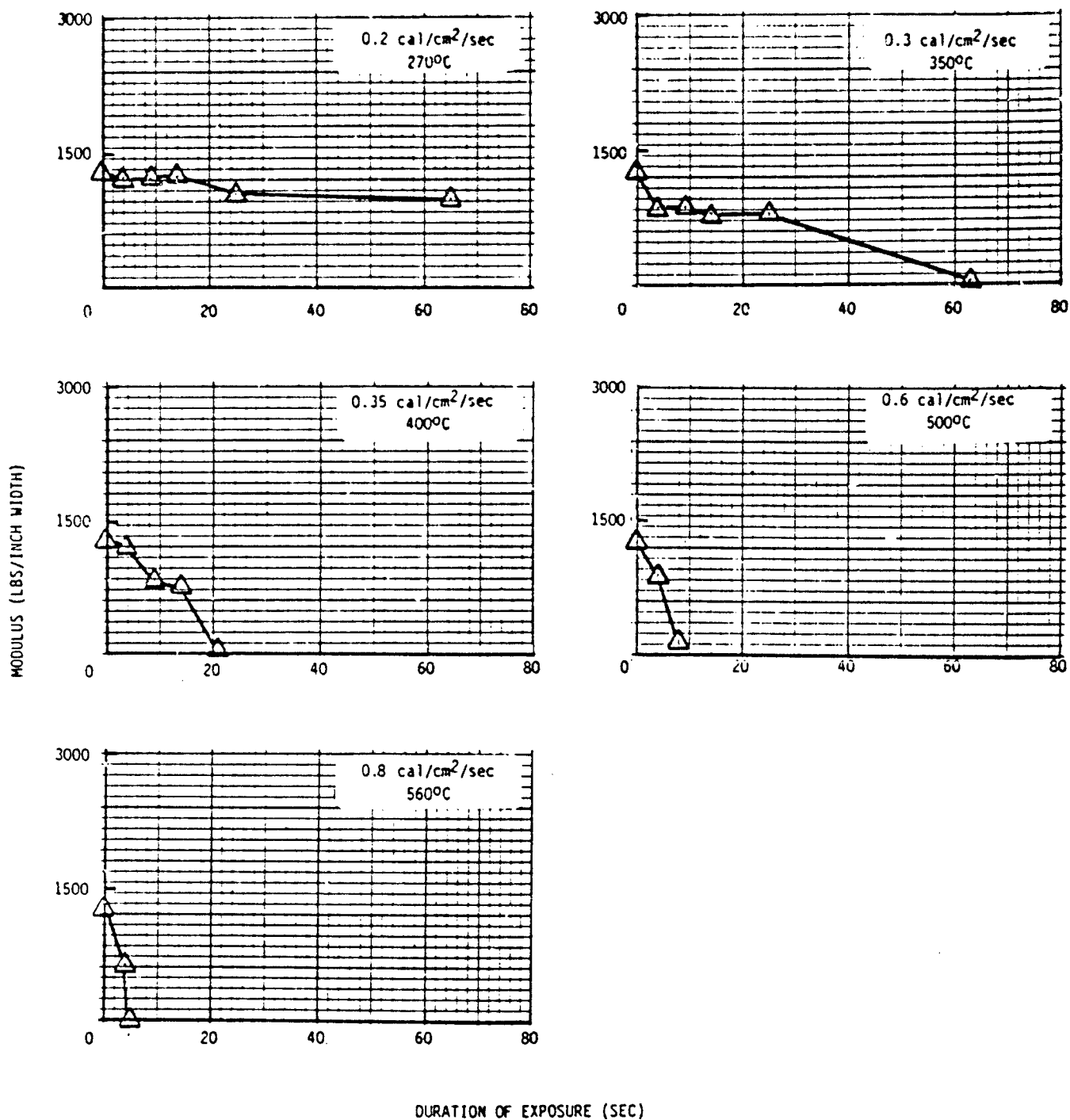
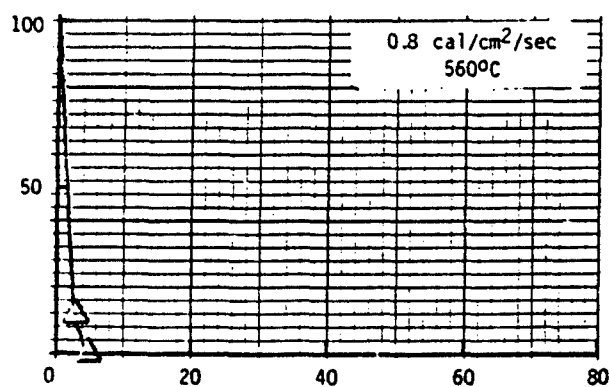
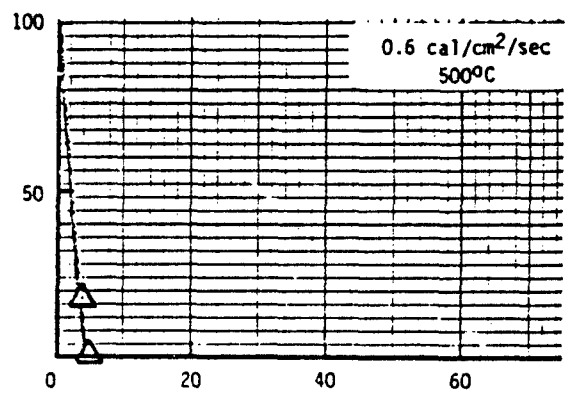
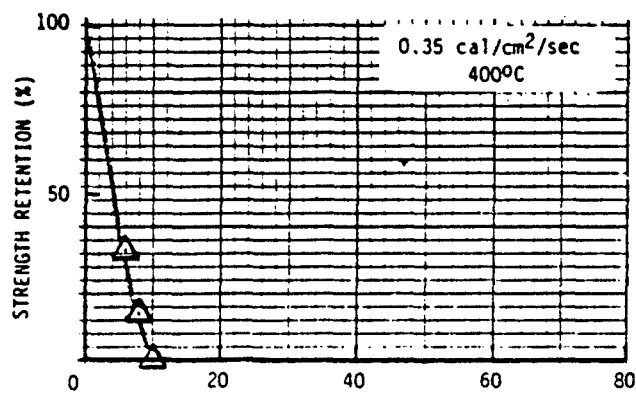
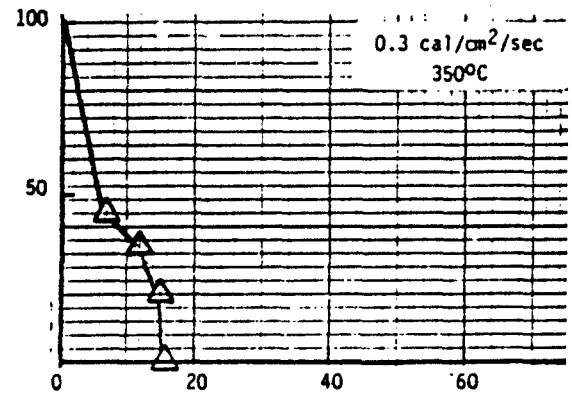
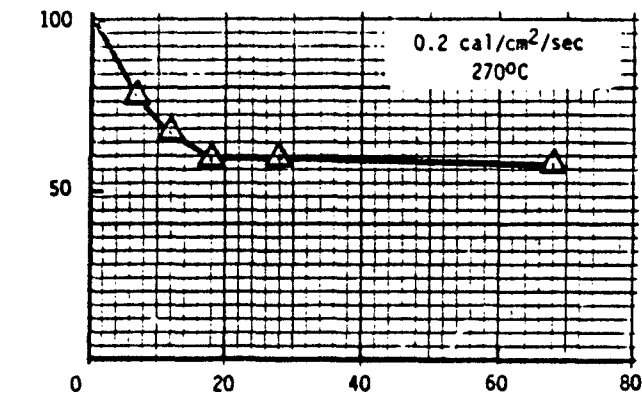


Figure 21b. Modulus of Fabric #5 (cotton, resin modified, butyl coated, 10.5 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm ² /sec)	TIME TO IGNITION (SEC)	
	Range	Average
0.2	No ignition, 2 min	
0.3	melted,	15
0.35	melted,	10
0.6	melted,	5
0.8	10-12	11
0.9	8-9	8
1.1	4-5	4

DURATION OF EXPOSURE (SEC)

Figure 22a. Strength Retention of Fabric #32 (nylon, neoprene coated, 7.7 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

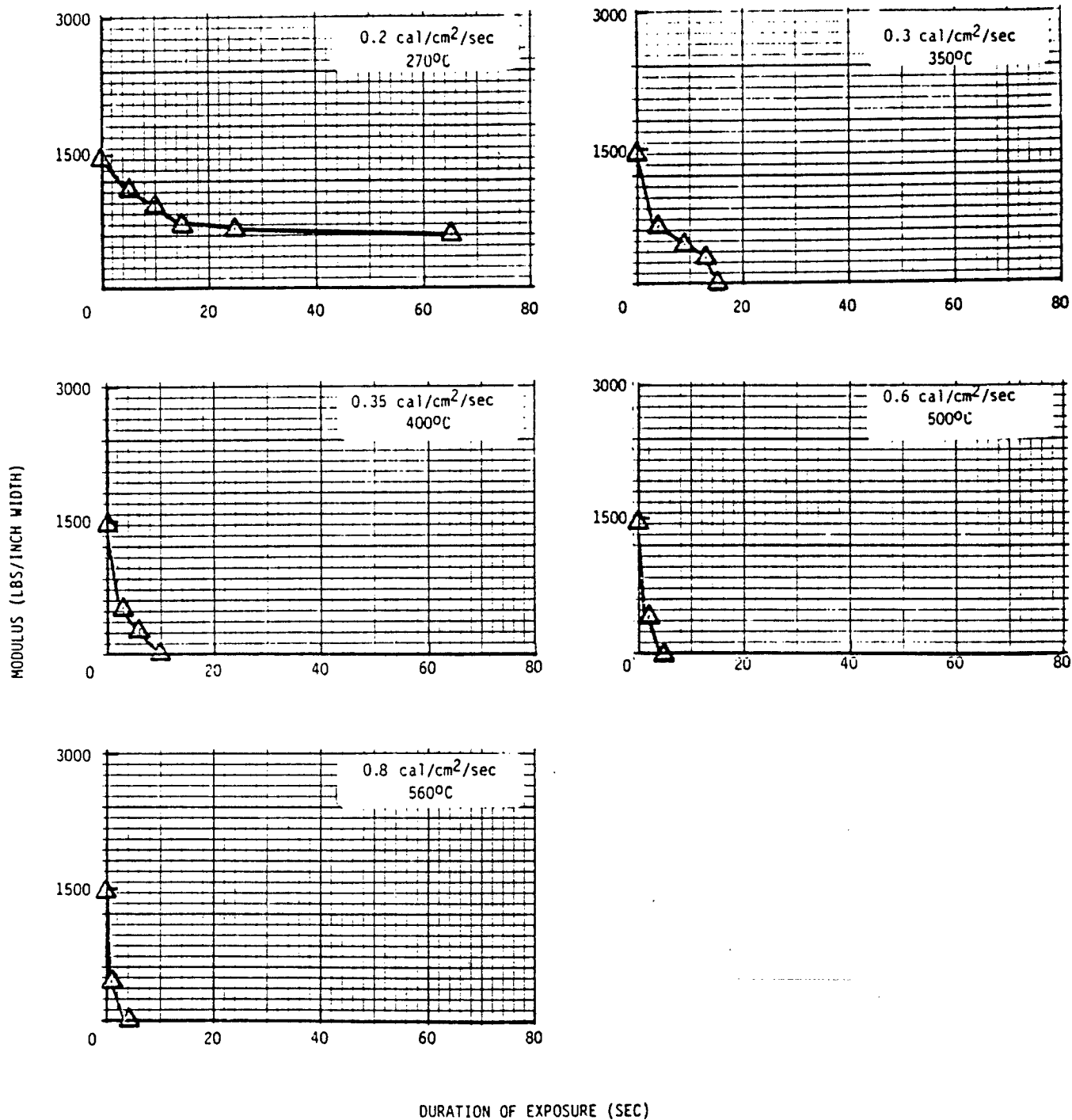
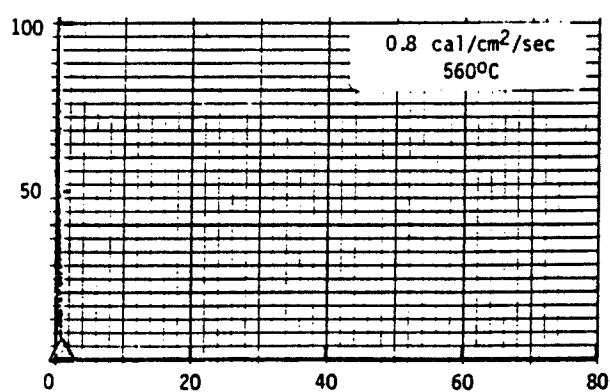
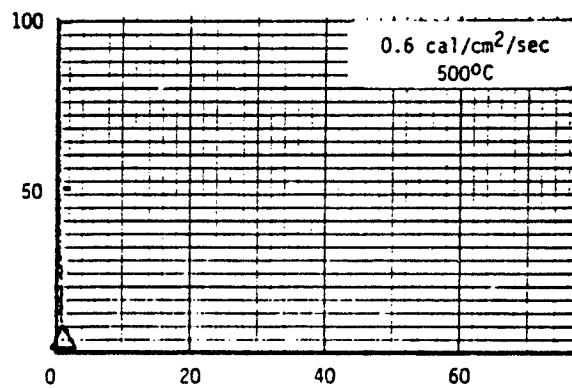
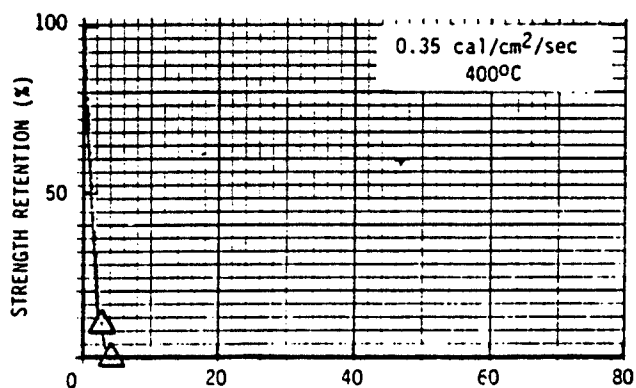
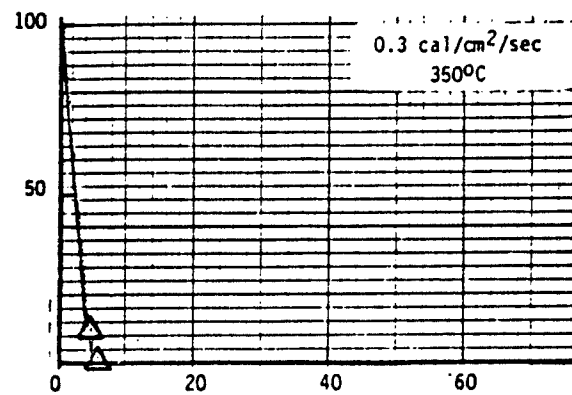
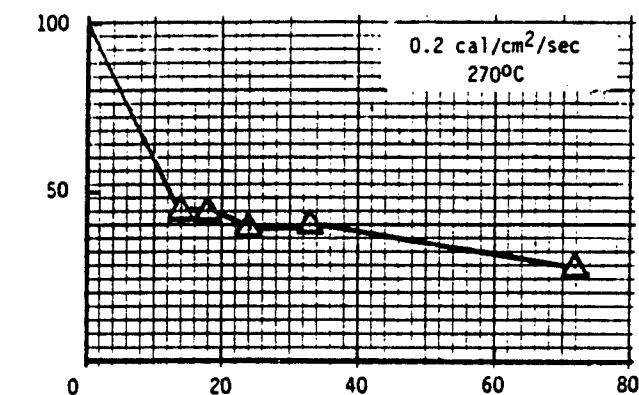


Figure 22b. Modulus of Fabric #32 (nylon, neoprene coated, 7.7 oz/sq yd)
During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm ² /sec)	TIME TO IGNITION (SEC)	
	Range	Average
0.2	melted,	40
0.3	melted,	10
0.35	melted,	5
0.6	melted,	4
0.8	melted,	2
0.9	melted,	2
1.1	2-4	3

(only 2 of 3)

DURATION OF EXPOSURE (SEC)

Figure 23a. Strength Retention of Fabric #18 (nylon, polyurethane coated, 3.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

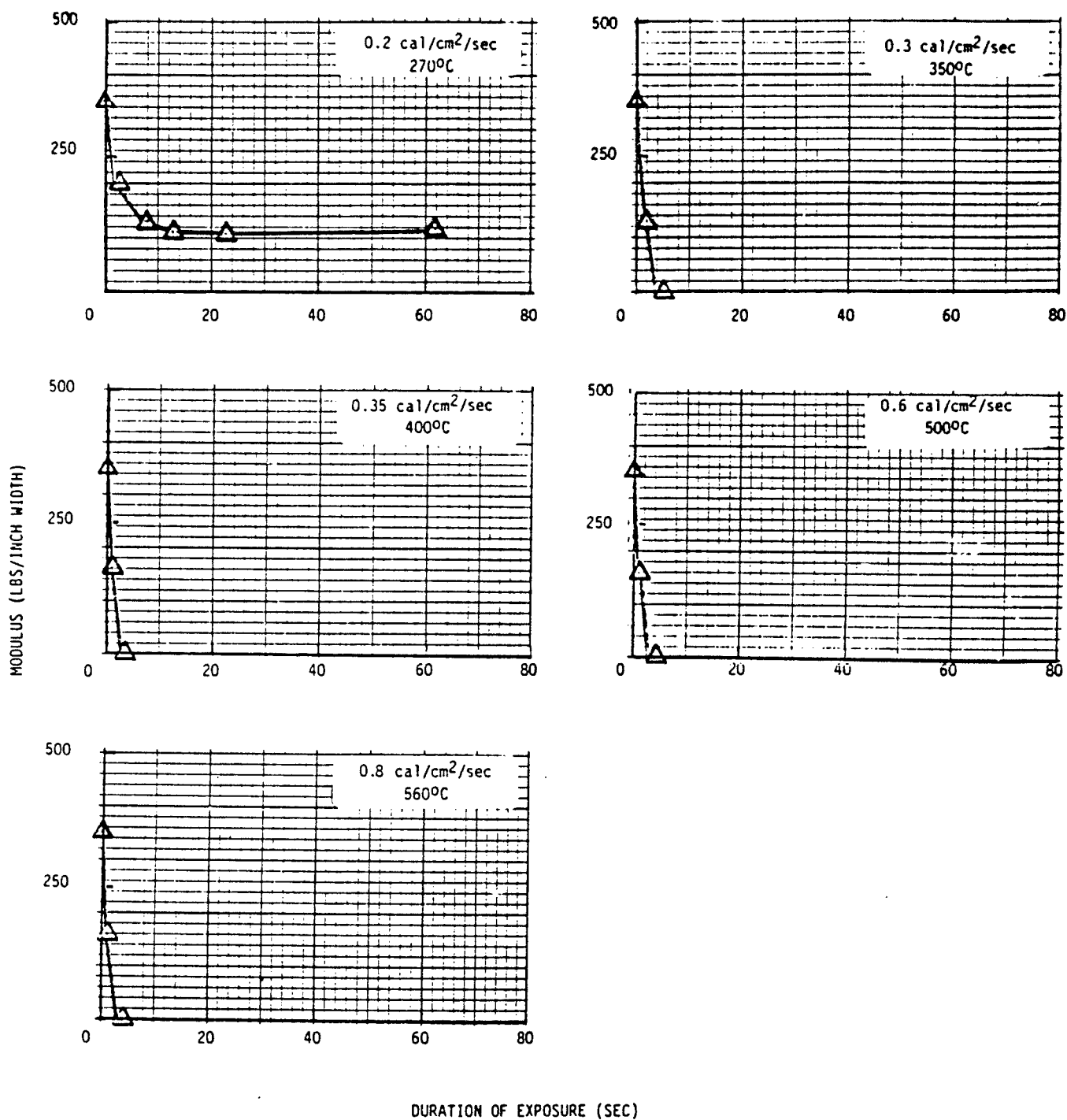
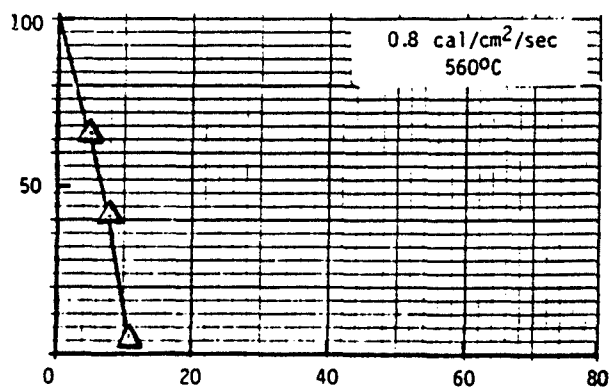
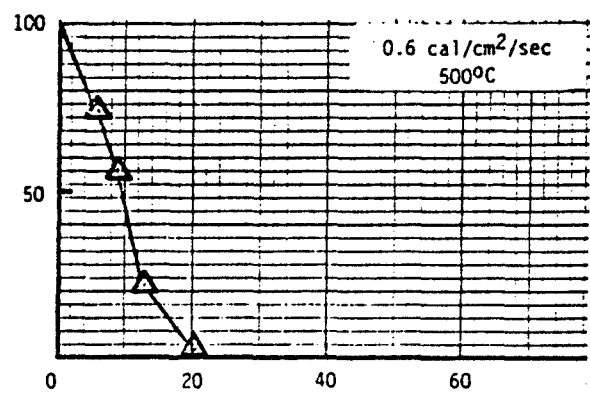
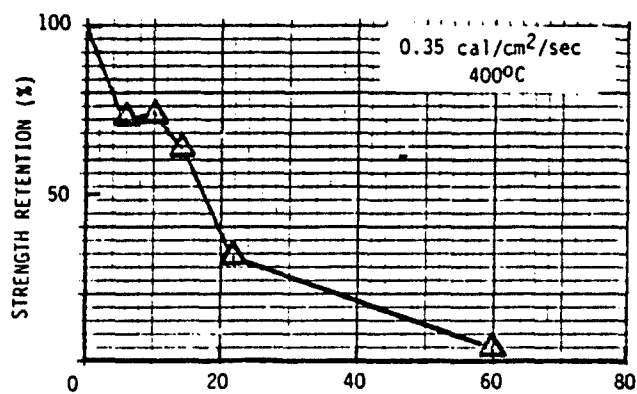
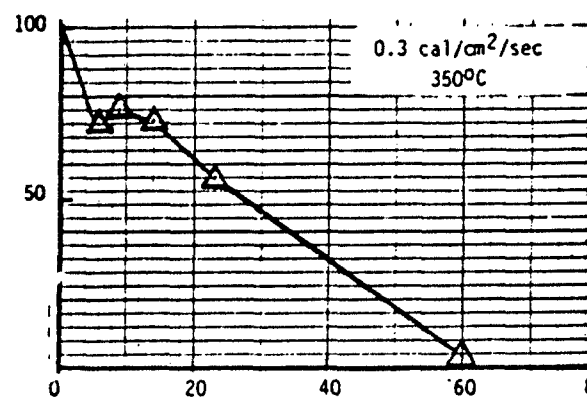
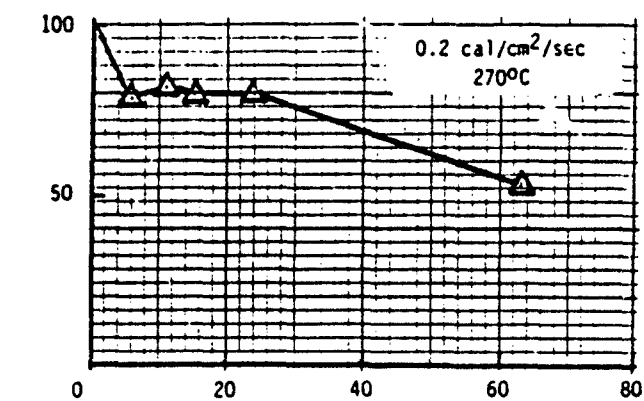


Figure 23b. Modulus of Fabric #18 (nylon, polyurethane coated, 3.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC)	
	Range	Average
0.2	--	--
0.3	--	--
0.35	--	--
0.6	No ignition, 2 min	
0.8	30-35	33 (ligh glow only
0.9	30-35	33 (ligh glow only
1.1	24-40	32

DURATION OF EXPOSURE (SEC)

Figure 24a. Strength Retention of Fabric #72 (PAN, 15.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

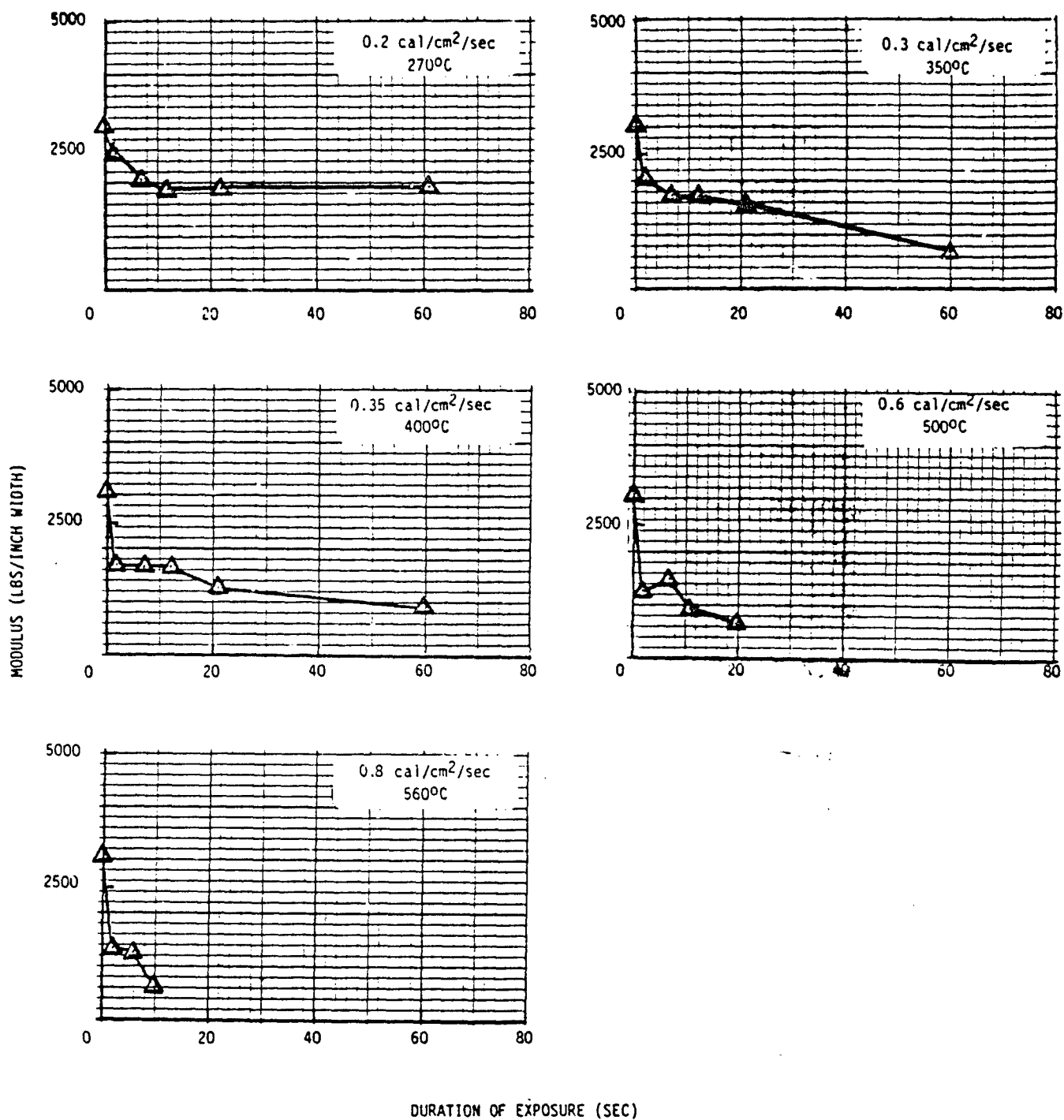


Figure 24b. Modulus of Fabric #72 (PAN, 15.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

ture. For example, if the measured modulus during exposure is one half of the original modulus, the true modulus may be as low as 85% of the measured value; similarly, if the measured modulus is one tenth of the original level, the actual modulus may be only 76% of the measured value. Notwithstanding this error, the approximate modulus, as measured, can be a valuable indicator of the occurrence of physical and chemical changes within the material with increasing temperature.

As seen in Figures 5a through 24a, at the lower heat intensities, many of the materials exhibit a rapid decrease in strength during the initial few seconds of exposure followed by a more gradual decrease until ultimately an equilibrium level of strength is attained. This is the type of behavior that would be expected for materials whose strength depends more or less linearly on temperature because of the rate at which the temperature of a typical specimen would increase during the course of exposure (see TR 148, Figures 17, 35 and 36). However, some exceptions to the general shape of the strength loss vs. time curve were observed; most notably, fabrics #21 and 28, heavy fabrics with a high wool content, PAN fabric #72, and semi-carbon/Kevlar fabric #78, show delays or reversals in the initial downward trend of strength loss vs. time. These delays for the wool probably result partly from the vaporization of large amounts of sorbed water and partly from the rigidifying effect of drying on the protein molecule. Some additional carbonization during exposure of the PAN fabric, and to a smaller extent, the semi-carbon/Kevlar fabric may serve to delay strength changes in these materials.

At heater temperatures of 500°C and above, all of the fabrics in the test group except the heavy PAN fabric #72, the heavy wool fabric #21 and the group of heavier fabrics containing Kevlar or Nomex, #78, 75, 47 and 74 lose all strength within a few seconds after the start of exposure. However, since the rate of strength loss is strongly dependent on temperature and the temperature achieved after a given period of exposure depends directly on fabric weight per unit area, the behavior of the various fabrics as materials is best compared on a weight normalized basis. Accordingly, bar graphs were prepared comparing time-to-90% strength loss at different heat levels for each of the fabrics tested normalized to a 6.0 oz/sq yd fabric weight (chosen so that comparisons could be easily made with the similar data presentation in TR 148, Figures 37 through 42). These graphs are given in Figures 25 through 27. The weight normalization is performed by altering the time scale of the strength retention graphs by a factor equal to 6 oz/sq yd divided by the actual weight of the fabric tested. For example, for 10.3 oz/sq yd fabric #38, a strength loss of 90% occurs after approximately 8 seconds of exposure at 500°C (see Figure 5a); to estimate the time to 90% strength loss for a similar 6.0 oz/sq yd fabric under the same exposure conditions the following calculation applies:

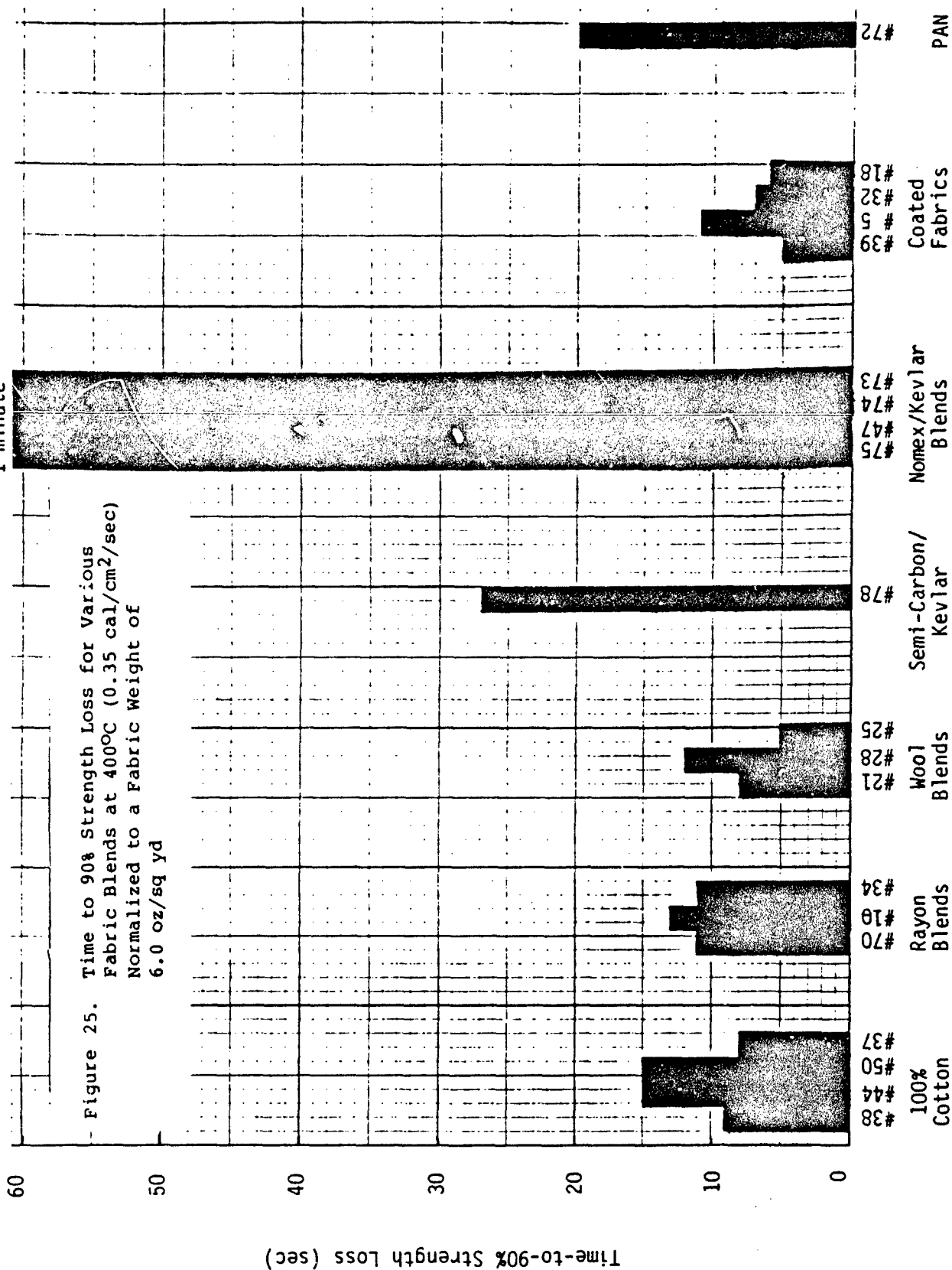
$$8 \text{ seconds} \times \frac{6.0 \text{ oz/sq yd}}{10.3 \text{ oz/sq yd}} = 5 \text{ seconds.}$$

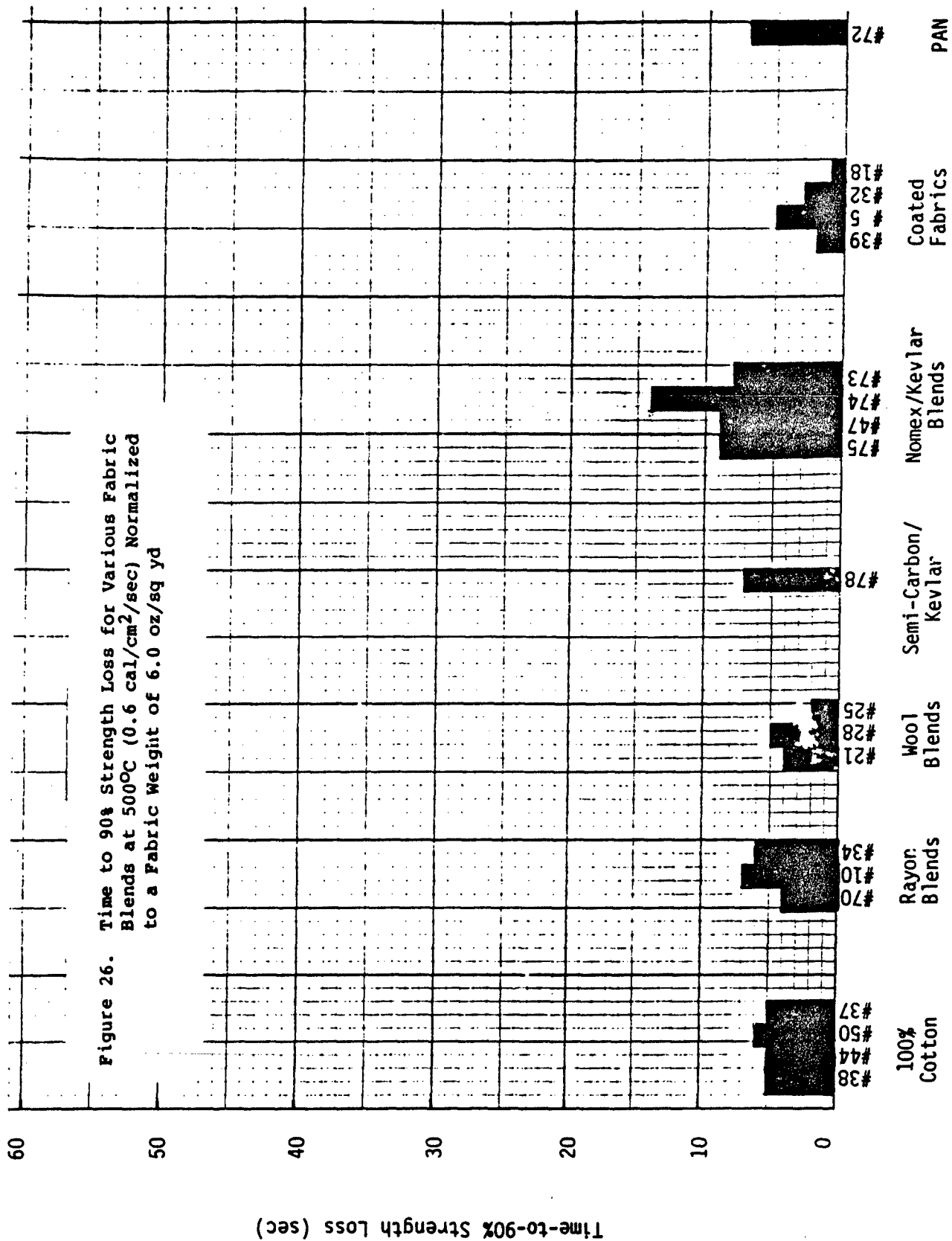
Similarly, for 5.3 oz/sq yd fabric #73, the strength falls to 10% of its original level at about 7 seconds when exposed at 500°C (see Figure 19a); therefore, a 6.0 oz/sq yd fabric of this type would be expected to lose 90% of its strength in $7 \times (6.0/5.3) = 8$ seconds. Thus, the time scale for fabrics heavier than 6 oz/sq yd is lengthened and that for lighter fabrics, shortened. Because of the time-adjusted and interpolated nature of the data presented in Figures 25 through 27, the values should be considered as approximate and differences less than about 4 seconds between materials should probably not be regarded as significant.

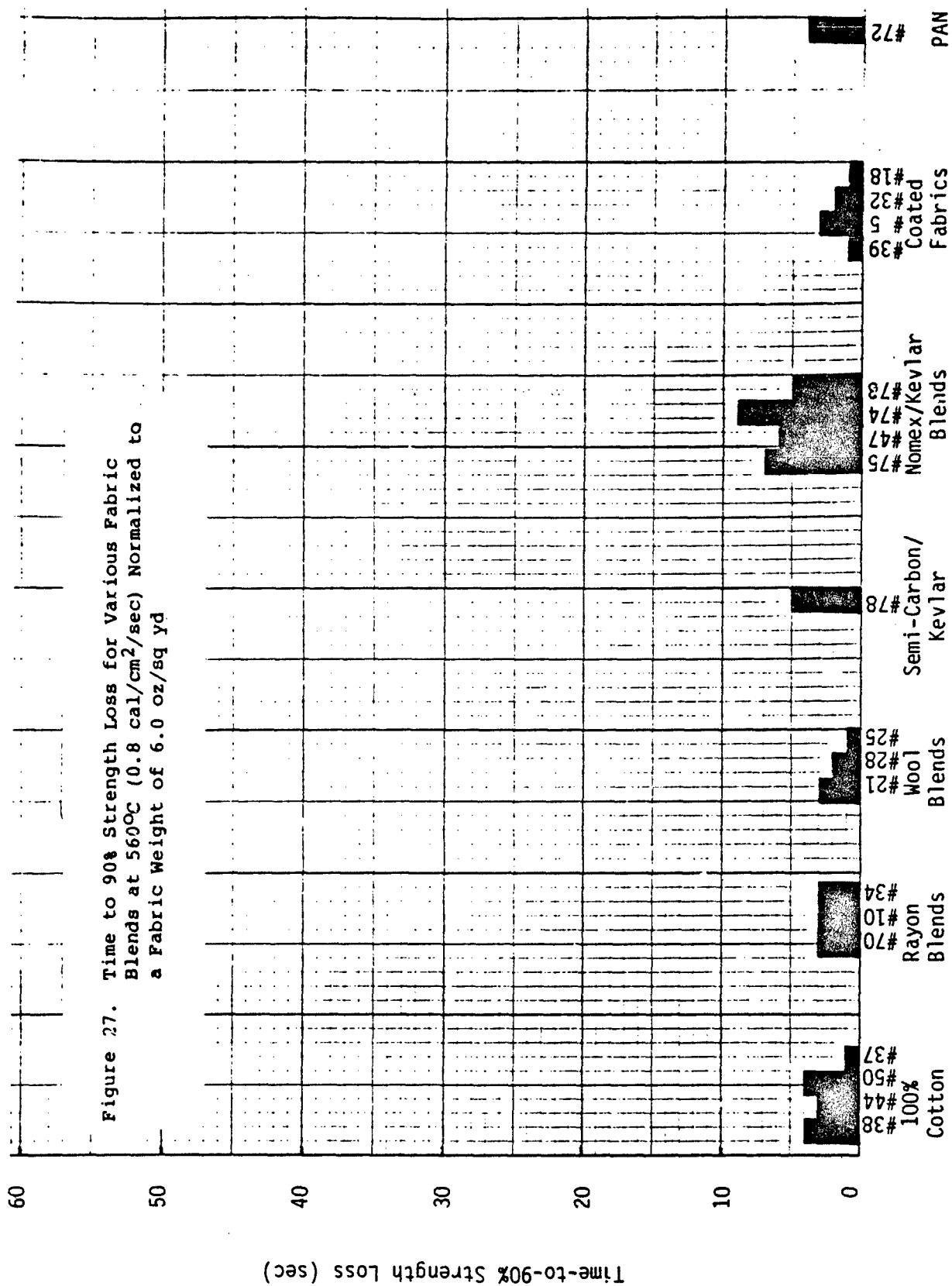
(Text continued on page 55.)

more than
1 minute

Figure 25. Time to 90% Strength Loss for Various Fabric Blends at 400°C (0.35 cal/cm²/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd







At a heat flux of $0.35 \text{ cal/cm}^2/\text{sec}$ and heater temperature of 400°C (Figure 25), the Nomex/Kevlar blends are clearly superior to the other materials. More than a minute of exposure time at this condition would be required to reduce the strength of a 6 oz fabric to 10% of its original value. The semi-carbon/Kevlar fabric #78 and PAN fabric #72 also retain some strength for significantly longer periods of time at this flux than the cotton, rayon, and wool blends or the coated fabrics when compared at the same weight.

At higher flux levels and heater temperatures (Figures 26 and 27) the Nomex and Kevlar materials on a weight normalized basis continue to show marginally better performance than the other materials; the 50/50 blend of Nomex and Kevlar #74 performs particularly well in this group.

If we compare the behavior of the fabrics at their actual weights as in Figures 5 through 24, it is clear that the heavy (15 oz/sq yd) fabrics #78 semi-carbon/Kevlar and #72 PAN retain some useful strength for the longest period of time at the most severe exposure condition at which strength retention was measured (560°C , $0.8 \text{ cal/cm}^2/\text{sec}$). Some strength remains for both of these fabrics to 10-12 seconds at this exposure condition. The combination of more heat-resistant material and greater weight provides greater protection from radiant heat.

C. Ease of Ignition

The average times required for the single-layer fabrics in the test series to ignite spontaneously during exposure to bilateral radiant heat at various levels are summarized in the Table 4; individual test results are collected in Appendix Table 2. Such data should be used only to compare the ignition properties of the various fabrics when measured under the same test conditions and may not relate well to ignition behavior determined under other circumstances since ignition is a path-dependent event affected by mode and rate of heating, specimen size and position, rate of air flow, oxygen availability and the criteria used to determine the onset of ignition. In the present case, the point of ignition was taken as the first appearance of a flame; in some cases a glow preceded or occurred instead of a flame and this is noted in the Appendix Table 2; the level of smoke generation and the incidence of melting are also noted in the Appendix table.

As with comparisons of strength retention, the times-to-ignition of the various fabrics have been normalized to a fabric weight of 6 oz/sq yd and presented in histogram form in Figures 28 through 30. On a material behavior basis it is again evident that the Nomex and Kevlar fabrics and those fabrics with a high carbon content resist ignition better than those fabrics consisting of cellulose, thermoplastic polymers or blends of these components. The tightly woven wool fabrics tested, including those blended with nylon or polyester, also exhibit good resistance to ignition. The knit wool fabric #23, however, resists exposure no better than the wool/modacrylic blends #63 and #62, each of which melt apart within a few seconds at fluxes above $0.6 \text{ cal/cm}^2/\text{sec}$. Fabric #46, also a knit wool but one which has been mothproofed requires a longer exposure time to ignite than the other fabrics in the wool group. Since differences in finishing history and types of dyes and other chemicals used to process these materials are not known, the differences in behavior observed between knit wool fabrics #23 and #46 cannot be explained.

(Text continued on page 60.)

Table 4. Time to Ignition of Various Fabrics During Exposure to Bilateral Radiant Heat

Fabric No.	Fiber Content	Weight (oz./yd ²)	Average Time-to-Ignition (seconds)				
			0.35 (400°C)	0.6 (500°C)	0.8 (560°C)	0.9 (600°C)	1.1 cal/cm ² /sec (650°C)
36	100% cotton	13.3	50 (glow)	19	10	6	4
38	100% cotton	10.3	--	15 (glow)	6	5	3
70	80/20 PFR rayon/polyester	8.6	--	--	5	3	2
71	80/20 PFR rayon/Nomex	8.5	--	8	5	4	3
10	rayon/cotton	8.2	32 (glow)	11	6	5	4
34	80/20 PFR rayon/Nomex	7.0	--	8	3	2	1
44	100% cotton	6.6	47	6	4	3	1
50	100% cotton	6.4	42	8	4	3	2
37	100% cotton	5.1	22 (glow)	6	4	3	2
48	100% cotton	4.3	32	13	8	6	4
21	100% wool	15.7	--	112 (glow)	58	37	24
63	70/30 wool/modacrylic	12.8	--	<-----	melts	----->	----->
23	100% wool	12.3	--	<-----	melts	----->	----->
46	100% wool (mothproofed)	11.6	--	77	54	45	37
62	70/30 wool/modacrylic	11.5	--	67 (glow)	<-----	melts	----->
28	90/10 wool/nylon	8.2	--	105 (glow)	29	18	14
25	55/45 polyester/wool	6.6	--	--	25 (glow)	18	3
45	100% acrylic	9.7	<-----	melts	----->	----->	----->
78	semi-carbon/Kevlar	15.4	--	--	40 (glow)	74	25
75	100% Kevlar	8.3	--	--	70	34	22
47	100% Nomex	8.1	--	--	--	90	44
74	50/50 Nomex/Kevlar	6.0	--	--	27 (glow)	17 (glow)	18
73	95/5 Nomex/Kevlar	5.3	--	--	40 (glow)	31	19
39	butyl-coated nylon	12.5	melts	19 (glow)	8	6	4
5	butyl-coated cotton	10.5	63 (glow)	15	7	6	5
32	neoprene coated nylon	7.7	<-----	melts	11	8	4
18	polyurethane-coated nylon	3.1	<-----	melts	----->	----->	----->
72	PAN	15.6	--	--	33 (glow)	33 (glow)	32

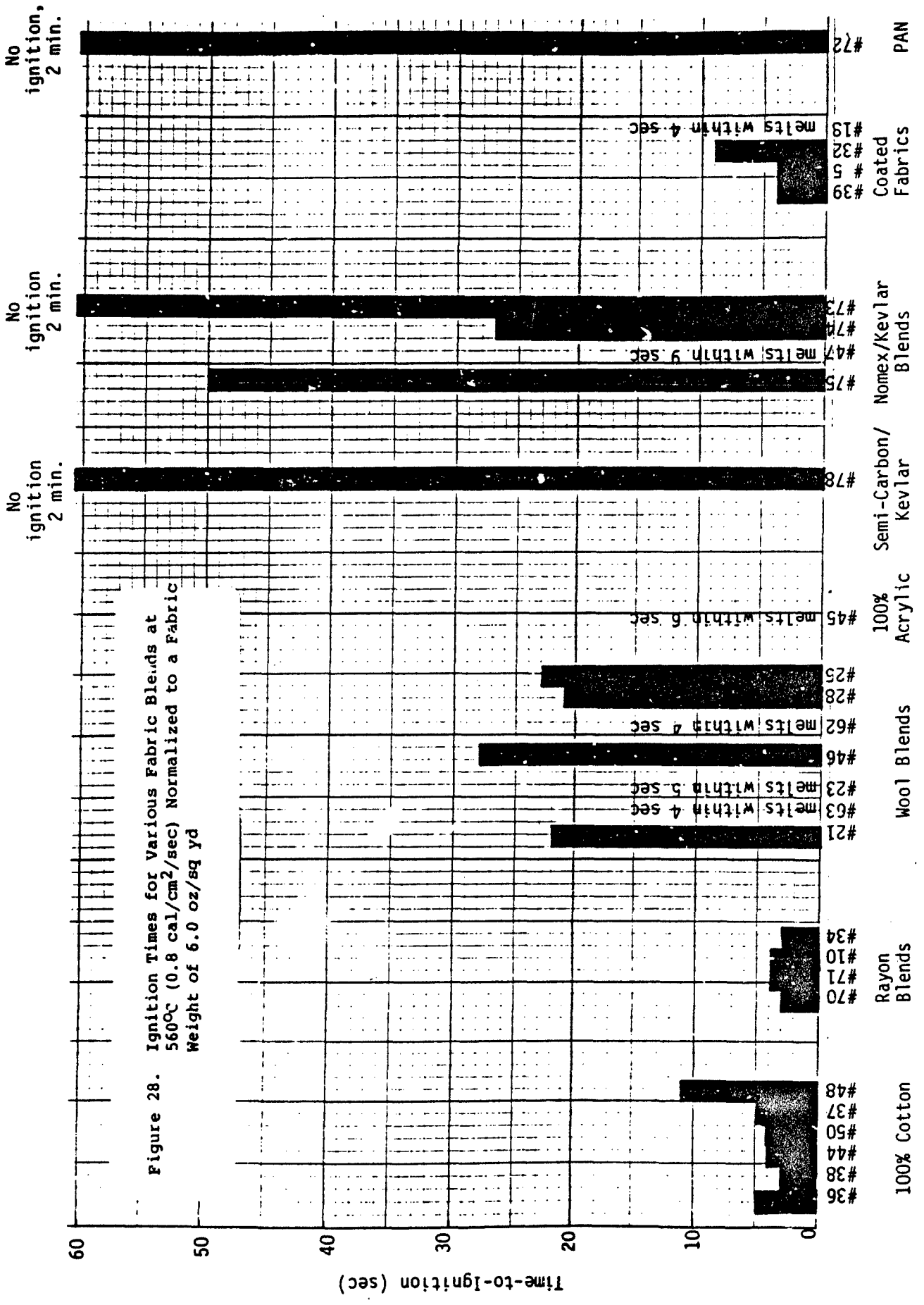
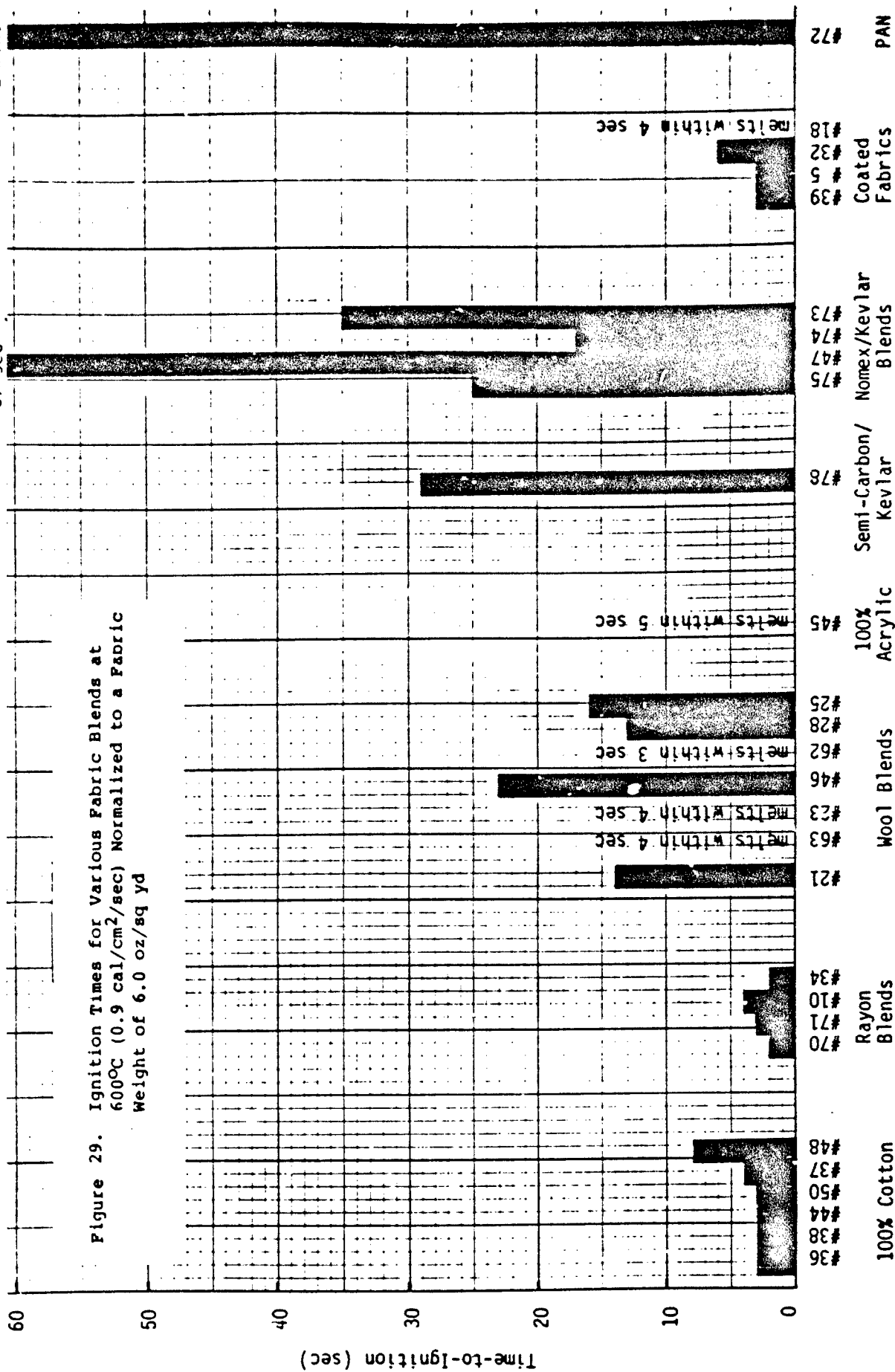
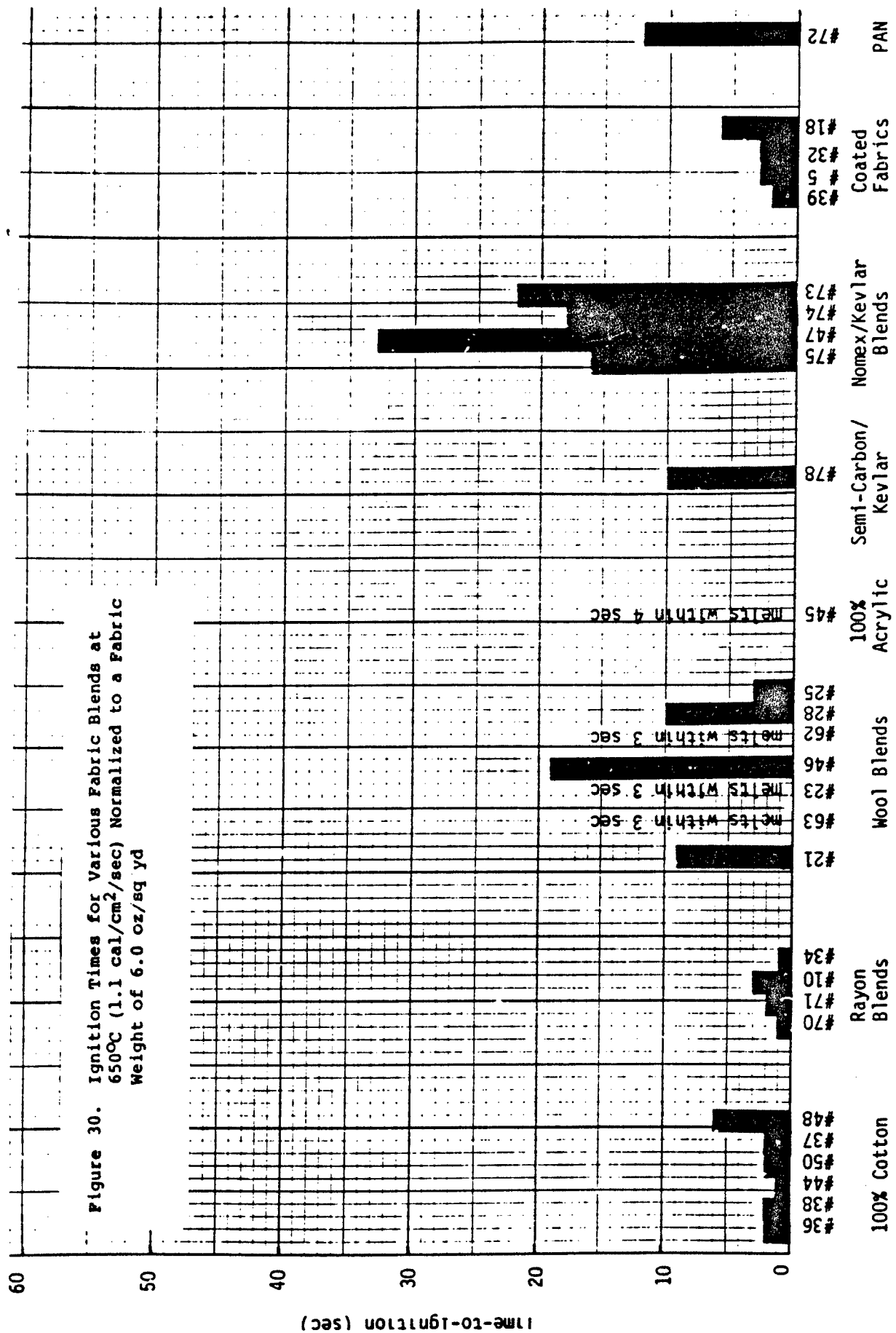


Figure 29. Ignition Times for Various Fabric Blends at 600°C (0.9 cal/cm²/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

Ignition at 67 sec
No ignition, 2 min.





If the resistance to ignition of the various fabrics are compared directly without normalizing for fabric weight, it is evident from Table 4 that the heavy, 100% wool fabric #21, semi-carbon/Kevlar fabric #78, and PAN fabric #72 have the greatest resistance to ignition by radiant heat of the materials in the test group.

IV. RADIANT HEAT TRANSFER

In order to assess the extent of protection to the skin provided by the various work clothing fabrics and fabric assemblies from the direct penetration of radiant heat, measurements were made of the amount of heat transferred from unilaterally irradiated fabric strips to an underlying surface. For this measurement a single quartz heater panel and a water-cooled copper calorimeter were employed as illustrated in Figure 31. The calorimeter is embedded flush with the surface of a black transite board on which the fabric test strip is mounted. At the start of exposure the preheated panel, mounted on a track, is quickly pulled into place facing the fabric strip. The voltage output of the calorimeter, proportional to impinging heat flux, is recorded continuously for the next 60 seconds. If ignition occurs during this time, the panel is pushed away while the calorimeter continues to monitor the heat flux from the burning fabric. Incident heat flux is determined separately with no fabric specimen in place. The total heat flux transferred from the fabric to the surface of the calorimeter is expressed as a percentage of the heat flux incident on the surface of the fabric at the start of exposure.

Fabric response was determined at three unilateral heat flux levels: 0.4, 0.75 and 1.25 cal/cm²/sec corresponding to heater temperatures of 650°C, 800°C, and 1000°C respectively. Table 5 contains a summary of the heat transfer and ignition behavior of the 36 fabrics and fabric assemblies tested; individual pieces of data for three specimens of each fabric are reported in Appendix Table 3.

Because of the diversity of fabric types and assemblies tested, there were no "typical" traces of the calorimeter output, although there were, in general, two distinct peaks during the course of exposure. In general, an initial peak in heat transfer was followed by a more gradual rise to a steady level or, if ignition occurred, it was followed by a sharper and more intense peak as the burning fabric itself gave off considerable quantities of heat. The response tended to be somewhat variable within the group of three replicate specimens of each fabric or assembly type tested at each condition depending on the extent of specimen shrinking and curling away from the calorimeter. However, the data in Table 5 represents a reasonable estimate of the worst case conditions.

None of the fabrics ignited during exposures at 0.4 cal/cm²/sec; some of the fabrics ignited during the 60-second exposure at 0.75 cal/cm²/sec; all single layer fabrics except the PAN fabric #72 and the 100% Kevlar fabric #75 ignited or were destroyed within 60 seconds at 1.25 cal/cm²/sec. The Kevlar fabric #75 was glowing at the end of exposure at the highest flux level but the PAN fabric #72 although smoking showed no signs of ignition. The outer shell of each of the fabric assemblies also ignited at the highest flux, with the entire assemblies of #1A, 2A and 21A igniting.

(Text continued on page 64.)

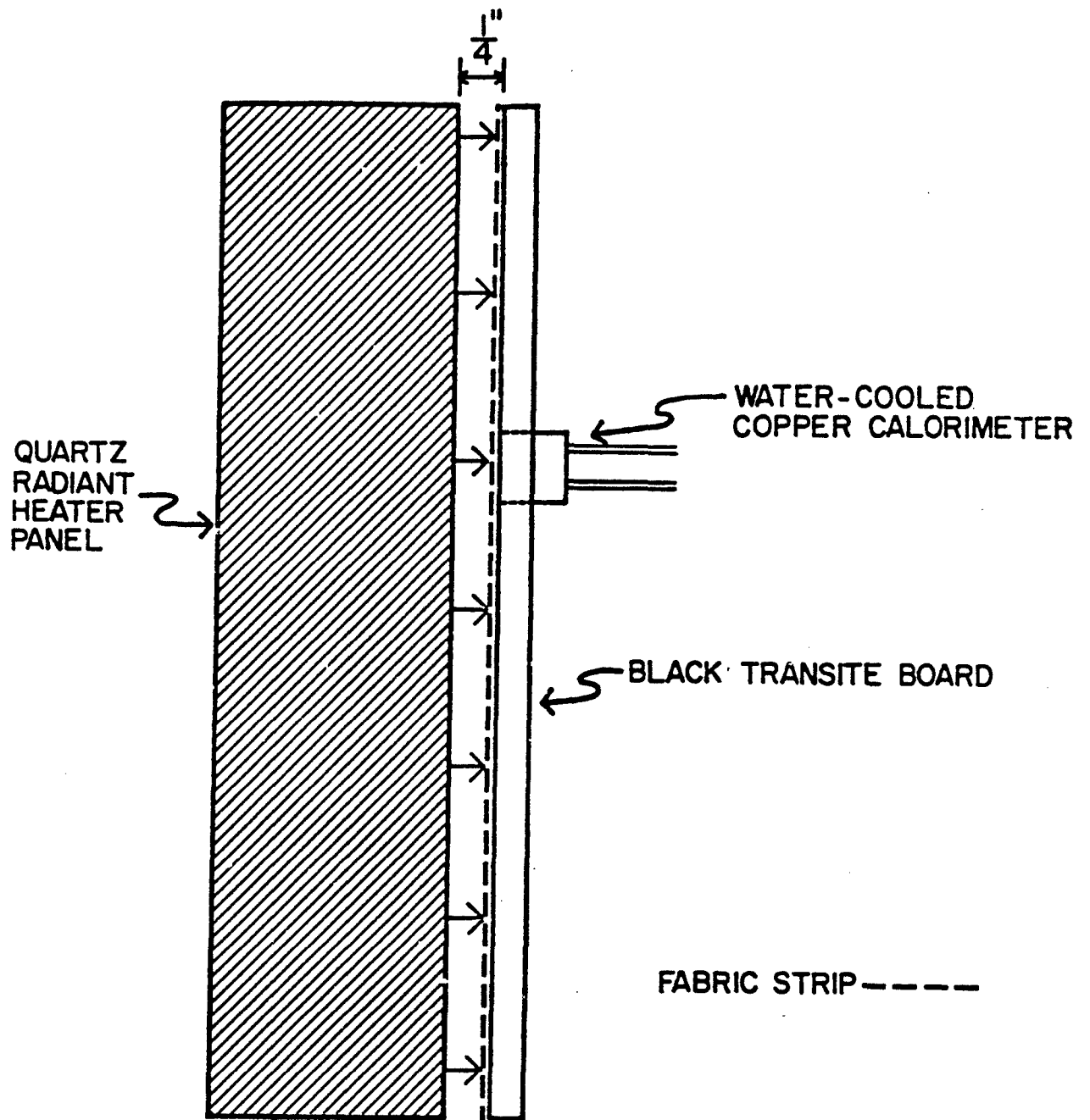


Figure 31. Test Configuration for Radiant Heat Transfer Measurements

Table 5

Summary of Heat Transfer Values to an Underlying Surface from Fabric Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Fiber Content	Weight (oz/sq yd)	Maximum Heat Transfer in First 10 Seconds of Exposure (%)			Time to Ignition (seconds)		Maximum Heat Transfer in 60 Seconds (%)		
			0.40 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec	0.4 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec
Single-Layer Fabrics:										
36	100% cotton	13.3	55	35	30	16-18	6-7	80	50	30
38	100% cotton	10.3	50	40	80	--	7-8	65	120	80
70	80/20 PFR rayon/polyester	8.6	50	135	80	melted	5	135	135	80
71	80/20 PFR rayon/Nomex	8.5	50	95	50	10 (only 1 of 3)	4	120	110	50
10	rayon warp cotton fill	8.2	40	50	50	15 (only 2 of 3)	5	60	140	60
34	80/20 PFR rayon/Nomex	7.0	50	40	80	--	5	70	125	80
44	100% cotton	6.6	55	50	55	15-29	4-7	75	80	55
50	100% cotton	6.4	50	55	50	8-23	4-5	75	90	50
37	100% cotton	5.1	60	80	60	6-8	3	75	80	60
48	100% cotton	4.3	50	60	50	7-8	3	220	60	50
21	100% wool	15.7	65	50	30	--	15-60	75	50	60
63	70/30 wool/modacrylic	12.8	40	35	85	--	--	140	120	100
23	100% wool	12.3	55	125	110	melted (only 1 of 3)	30	120	100	130
46	100% wool (moth-proof treated)	11.6	50	60	65	--	18-30	70	80	65
62	70/30 wool/modacrylic	11.5	75	95	100	--	--	150	120	100
28	90/10 wool/nylon	8.2	40	35	33	--	12-23	60	115	105
25	55/45 polyester/wool	6.6	65	40	120	melted	5-7	160	150	120
45	100% acrylic	9.7	30	20	135	17-24 (only 2 of 3)	8-11	100	160	140
78	Amatex 16HT65 Series 900	15.4	55	45	35	-- (only 2 of 3)	60	60	60	60
75	100% Kevlar	8.3	40	35	30	--	--	60	60	80
47	100% Nomex	8.1	45	40	50	--	30-45	70	60	120
74	50/50 Nomex/Kevlar	6.0	50	35	40	--	23-45	65	65	75
73	95/5 Nomex/Kevlar	5.3	45	35	40	--	45-54	70	55	70

Table 5 (cont)

Summary of Heat Transfer Values to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Fiber Content	Weight (oz/sq yd)	Maximum Heat Transfer in First 10 Seconds of Exposure (t)			Time to Ignition (seconds)		Maximum Heat Transfer in 60 Seconds (t)		
			0.40 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec	0.4 cal/cm ² /sec	0.75 cal/cm ² /sec	1.25 cal/cm ² /sec
Single-Layer Fabrics: (cont)										
39	nylon; double butyl coated	12.5	60	30	120	--	5-13	120	140	120
5	cotton, resin modified; butyl coated	10.5	60	40	90	26 (only 1 of 3)	5-6	70	100	90
32	nylon; neoprene coated	7.7	65	55	110	--	4-5	170	75	110
18	nylon; polyurethane coated	3.1	70	100	80	melted	2	100	100	80
72	polyacrylonitrile (PAN)	15.6	60	30	50	--	--	75	80	50
Fabric Assemblies:										
40	polyester outer shell, wool liner	12.0	55	45	55	--	6-13 (outer shell only)	120	100	55
1A	polyester batt, nylon fabric	4.6	30	100	115	melted	2	120	100	115
1	18 + 1A above	7.7	40	40	30	melted	2-3 (1A only)	100	100	30
13	50/50 cotton/nylon fluoro-carbon treated outer shell; 100% nylon liner	20.0	30	35	20	melted	3-8 (outer shell only)	110	195	20
2A	50/50 cotton/polyester outer shell; 100% nylon liner	12.5	20	40	30	10-11	30-32	60	40	50
55	50/50 cotton/nylon fluoro-carbon treated outer shell; 100% cotton liner; polyester batt-nylon fabric insulation	22.0	45	45	30	17-40	2-4	125	100	50
21A	100% wool outer shell; 100% nylon liner	24.9	55	40	30	--	15-28	55	90	30
58	nylon/acrylic outer shell; carbon impregnated liner	10.7	45	85	50	--	4 (outer shell only)	130	100	50

In several cases at each of the incident heat flux levels, the calorimeter located behind the fabric specimen sensed a transmitted heat flux that was equal to or greater than the incident flux. Exothermic reactions occurring within the heated fabric associated with melting, smoke generation and ignition can result in significant amounts of energy transmitted to underlying surfaces.

Among the group of single-layer fabrics with a cellulosic component, ignition or the attainment of maximum heat transfer occurs, in general, at shorter times for the lighter weight fabrics. Those fabrics in this group containing PFR rayon were no better in retarding heat transfer than similar all-cotton fabrics; fabric #70 with a polyester component exhibited particularly high heat transfer rates at short exposure times that were associated with melting.

The modacrylic/wool blends, #63 and 62, tended to split apart during exposure in some cases allowing the heat source to impinge directly on the calorimeter. Although the 100% acrylic fabric remained intact, it did ignite readily at the two higher flux levels with attendant high levels of heat transfer. The 100% wool fabrics #21, 23 and 46 ignited at the highest flux only.

Of the uncoated single-layer fabric types, the Kevlar, Nomex and carbon-containing fabrics exhibited the longest times to ignition and the most consistently low heat transfer rates.

The coated fabrics, #39, 5, 32 and 18, ignited readily at the highest flux and transmitted considerable heat either because the fabric failed by melting or because the coating material was exothermic. Although the outer layer of most of the thicker assemblies ignited during exposure at the highest flux, transmitted heat levels to the underlying calorimeter were lower after 60 seconds than with most of the thinner, single-layer fabrics tested.

The heat flux sensed at surfaces located behind covering fabric layers depends little on fabric construction, whether knit or woven, more on weight and thickness, but mostly on the material type and the ease with which exothermic reactions are induced by increased temperature within the material.

V. FLAME IMPINGEMENT HEAT TRANSFER

A. Test Device and Test Procedure

The flame-impingement test device used to measure the heat flow through the various fabrics and fabric assemblies when exposed to the heat of a flame consists of a Meker burner flame source, a specimen holder which includes a skin-simulant sensor, and a shuttering system for controlling the initiation and timing of exposure of the specimen to the flame. A diagram of the device is given in Figure 32, and photographs are presented in Figure 33. A specimen mounted in its holder and the skin-simulated mounted behind it are shown in Figure 34.

(Text continued on page 68.)

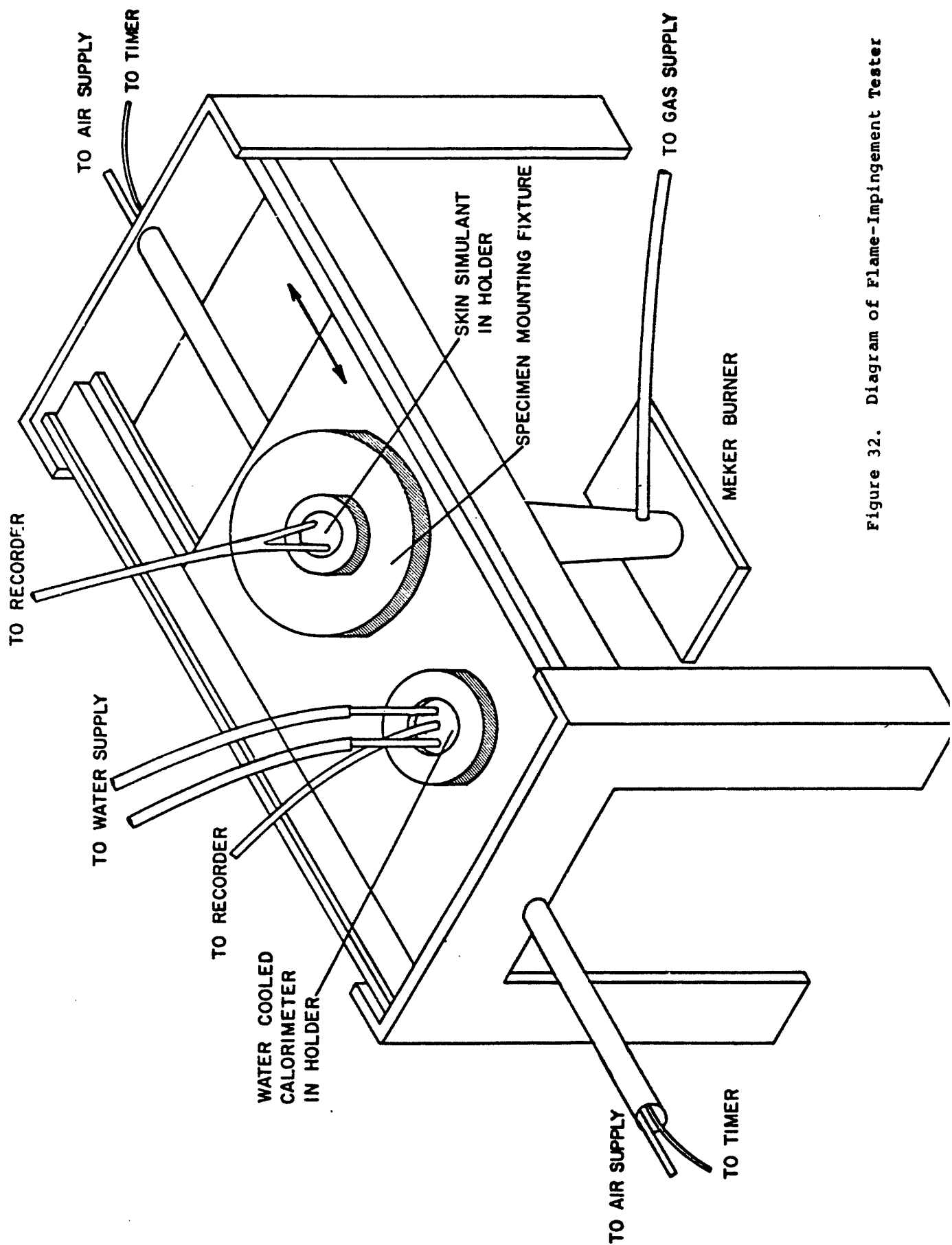
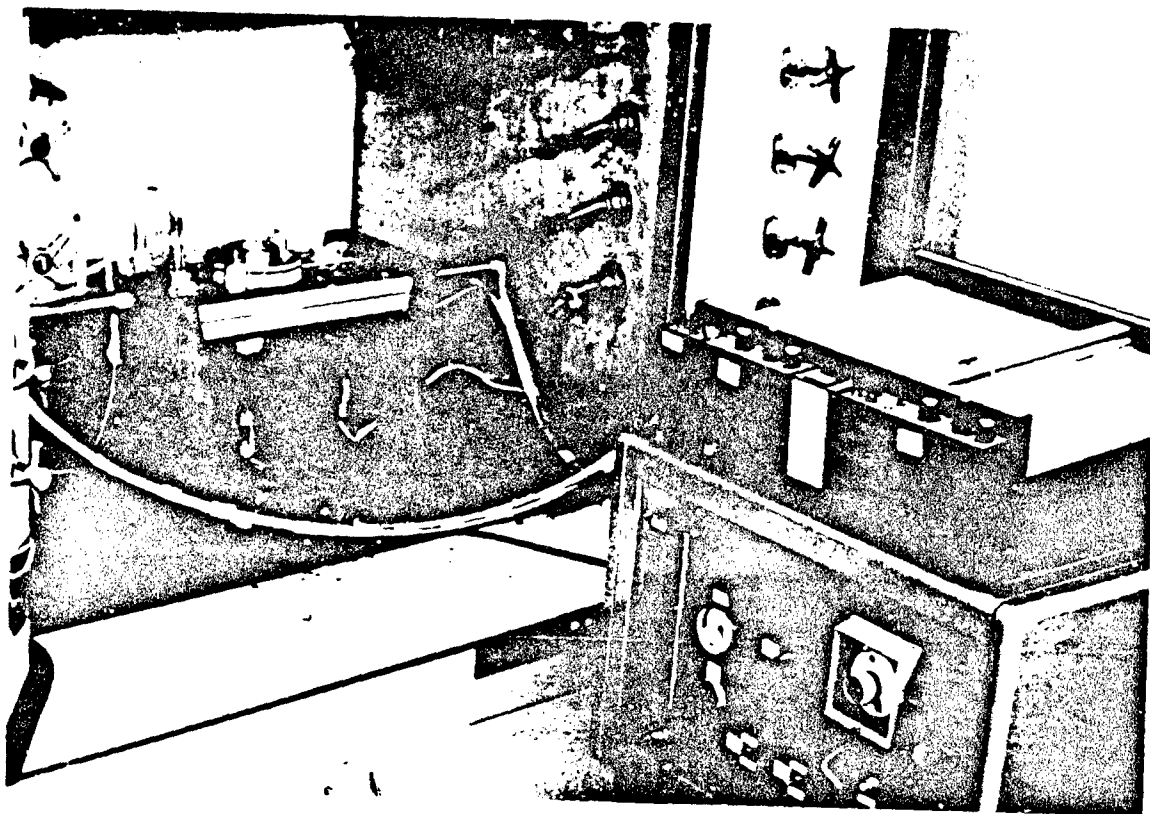
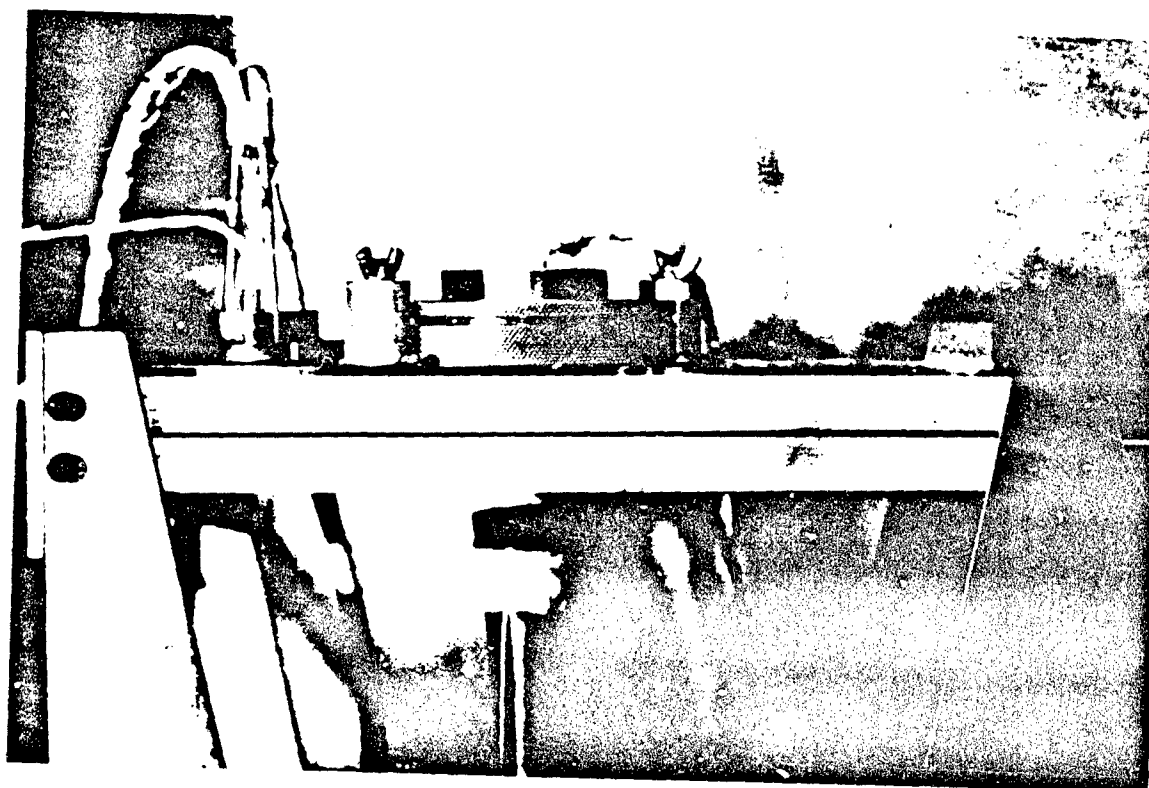


Figure 32. Diagram of Flame-Impingement Tester

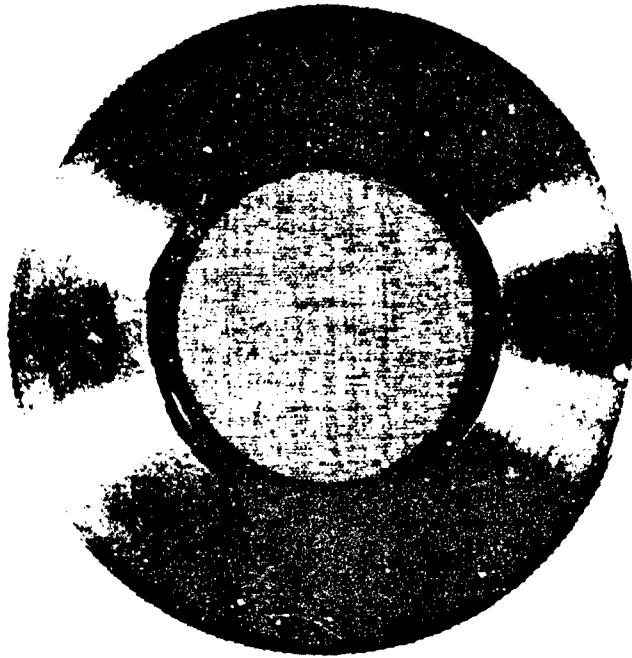


(a)

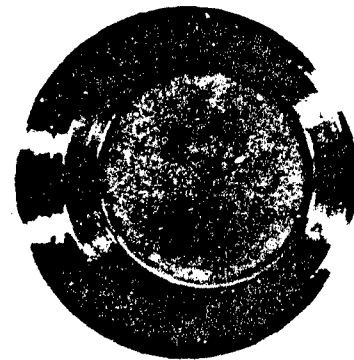


(b)

Figure 33. Flame Impingement Tester: (a) Tester, Control Panel, Recorder
(b) Close-Up of Specimen Mounting Block Over Burner



Specimen in Place



Skin Simulant in Holder

Figure 34. Assembled Specimen Mounting Fixture
and Skin-Simulant Holder

The Meker burner, located 2.1 inches from the surface of the fabric during a test, causes a vertical propane flame calibrated to a total heat flux of 2.2 ± 0.1 cal/cm²/sec to impinge perpendicularly on the surface of a horizontally mounted test specimen. This level of heat flux was chosen to conform to the value of heat flux generally accepted as average for a large fueled fire. The flame is calibrated frequently by means of a water-cooled calorimeter and adjusted by altering the rate of gas flow at maximum air intake. During calibration the surface of the calorimeter is positioned in the flame at the same distance from the burner as is the fabric specimen during a test.

Prior to exposure a fabric swatch measuring about 4 inches in diameter is mounted in the specimen holder which is designed to provide uniform and reproducible clamping pressure; the skin-simulant sensor is placed behind it in intimate contact with it. The skin simulant is a special formulation of resins designed to duplicate the optical and conductive properties of real skin. A fine-wire thermocouple is embedded 500 μ below the surface.

During a test, the quick motion of the shuttering and carriage-control system allows precise timing of the exposure (within milliseconds) so that a square-wave heat pulse is experienced by the fabric specimen. Exposures of 3- and 6-seconds duration were carried out for each of the fabrics and fabric assemblies in the test series with the skin simulant in direct contact with the fabric specimen, a worst-case situation.

Typical skin-simulant temperature response curves illustrate the rapid temperature rise during the period of actual flame-impingement, the attainment of maximum temperature a few seconds after cessation of exposure and the more gradual decrease of temperature as cooling proceeds (see TR 148, Figure 54).

Ignition of fabric specimens does not commonly occur during the flame-impingement test even though the outer surface of the fabric undoubtedly reaches temperatures sufficient to cause ignition. Specimens decompose, char and become ash but actual flaming of the specimen itself does not occur. This behavior has been observed even when the specimen is not backed up by a skin simulant. The nature of the decomposition that occurs during direct, intimate exposure of fabric specimens to a flame seems to be quite different than that which occurs during irradiation only. In the previous section it was seen that exothermic reactions induced in the fabrics during exposure to a radiant heat source almost completely dominate the heat transfer situation. During the flame-impingement tests, the heat transfer gives all appearances of being completely conductive, or dependent only on level of heat source, with no evidence of exothermic reactions developing with the material despite the extremely high heat flux level. The principal difference between the two modes of exposure is probably the abundance of oxygen available to the heating specimen during radiation with the quartz heater panels and the lack of it as the specimen is surrounded by flame during flame-impingement.

B. Test Results

The results of the measurements of heat transfer through the various single layer fabrics and assemblies are reported in Table 6. Temperature rise in the skin simulant at flame cut-off times of 3- and 6-seconds are given along with the maximum temperature achieved in the 3- and 6-second exposure respectively. Three replicate tests were made with each fabric at each condition; good agreement among replicates is generally the case.

The correlation between thickness of the specimen and the maximum temperature rise observed is shown in Figure 35(a) and (b) for the 3- and 6-second exposure respectively. Those fabrics which melted, or split-apart during the test exposing the skin-simulant directly to the flame are excluded from these graphs. Not surprisingly, these graphs show that thicker assemblies are more effective in protecting against conductive heat transfer. The nature of the non-linear relationship between temperature rise and thickness depicted in the figures makes it possible to suggest a thickness level above which improvement is marginal; this value seems to be about 0.15 inches for the conditions employed in the flame-impingement test.

On the basis of the point spread in Figure 35 only the PAN fabric #72 and assembly #40 with a polyester outer shell and a 100% wool liner stand out as offering better protection than expected on the basis of thickness. Energy absorbed during melting of the polyester outer layer combined with the structural stability of the wool liner is undoubtedly responsible for the better-than-average performance of fabric assembly #40.

The PAN fabric #72 retards heat transfer significantly better than the semi-carbon Kevlar fabric #78 of approximately the same weight and thickness while fabric assembly #58 with a carbon impregnated liner is a particularly poor performer. Neither fabric #72, fabric #78, nor the carbon-impregnated liner of assembly #58 were altered in appearance after flame exposure. Both the PAN fabric and the Kevlar fabric show evidence of high heat absorption in the strength retention and modulus curves given previously, but in the absence of specific information about the thermal properties of the three carbon-containing fabrics, it is difficult to postulate reasons for their very different response to flame exposure.

C. Burn Injury Potential

As described in the previous report TR 148, there is no exact or wholly satisfactory method of predicting burn injury potential from skin-simulant temperature rise data. Because of the uncertainties inherent in the method used in TR 148 to obtain estimate of burn injury index, only very broad approximations were attempted for the fabrics in the current test series. These approximations, which are given with the temperature rise data in Table 6, were obtained using Figure 62 of TR 148. In this figure, the burn injury index of each of the fabrics tested in Phase I is plotted against temperature rise after 3-seconds of exposure to the flame. A best fit regression line was calculated for this previous group of data and used in conjunction with the measured values of temperature rise at 3-seconds given in Table 6 to estimate burn injury index for the current test series.

(Text continued on page 75.)

Table 6. Temperature Rise in Skin Simulant Covered by Single Layer of Fabric During Flame Impingement
(heat flux, 2.2 cal/cm²/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm ³)	Thickness (inch)	Temperature Rise (°C)			Maximum Temperature Rise (°C)			Approx. Burn Injury Index
					at 3-sec	at 5-sec	3-second exposure	6-second exposure	6-second exposure		
										0.035 psi	
Single Layer Fabrics:											
36	100% cotton	13.3	0.20	0.090	5.4	10.6	9.6	15.2			
					5.1	11.0	8.7	15.2			
					5.4	12.3	9.3	16.5			
				Avg. 5.3	11.3		9.2	15.6			<0.1
38	100% cotton	10.3	0.49	0.028	15.4	42.0	22.5	47.0			
					16.8	36.8	22.6	47.2			
					16.7	40.6	23.6	45.4			
				Avg. 16.3	39.8		22.9	46.5			>1000
70	80/20 PPR rayon/polyester	8.6	0.64	0.022	25.4	53.0	31.4	57.2			
					29.2	49.0	34.2	65.0			
					29.2	48.6	34.4	56.6			
				Avg. 27.9	50.2		33.3	59.6			
71	80/20 PPR rayon/polyester	8.5	0.28	0.059	12.0	34.0	14.2	40.6			
					13.2	33.6	16.1	41.2			
					16.0	36.4	17.7	42.4			90
				Avg. 13.7	34.7		16.2	41.4			
10	Rayon warp cotton fill	8.2	0.61	0.026	16.0	42.0	19.0	48.8			
					20.4	41.6	26.4	49.0			
					18.4	38.4	26.0	46.2			
				Avg. 18.3	40.7		23.8	48.0			>1000
34	80/20 PPR rayon/Momex	7.0	0.78	0.020	26.5	50.0	32.5	52.8			
					25.0	52.4	32.8	54.0			
					28.5	52.8	36.8	55.6			
				Avg. 26.7	51.7		34.0	54.1			
44	100% cotton	6.6	0.46	0.028	21.2	46.0	28.6	53.2			
					23.0	42.4	30.2	50.0			
					24.0	42.6	31.5	50.6			
				Avg. 22.7	43.7		30.1	51.3			
50	100% cotton	6.4	0.53	0.024	24.0	50.4	30.2	55.4			
					24.0	46.4	29.0	53.0			
					24.4	49.6	30.0	55.4			
				Avg. 24.1	48.8		29.7	54.6			
37	100% cotton	5.1	0.27	0.037	15.5	38.6	25.9	41.5			
					16.3	41.2	24.1	44.3			
					20.2	40.0	27.0	43.4			
				Avg. 17.3	39.9		25.7	43.1			>1000
48	100% cotton	4.3	.23	0.035	20.5	43.2	28.5	45.6			
					21.3	44.0	29.0	47.0			
					20.8	42.2	28.5	44.6			
				Avg. 20.9	43.1		28.7	45.7			

*Estimated from temperature rise at 3-seconds during 3-second exposure.

Table 6. Temperature Rise in Skin Simulant Covered by Single Layer of Fabric During Flame Impingement (con.)
(heat flux, 2.2 cal/cm²/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm ³)	Thickness (inch)	Temperature Rise (°C)		Maximum Temperature Rise (°C)		Approx. Burn Injury Index*
					at 3-sec	at 6-sec	3-second exposure	6-second exposure	
21	100% wool	15.7	0.33	0.079	0.064	6.9	23.2	14.4	24.8
						7.7	22.8	15.3	24.1
						9.3	22.1	15.0	23.8
					Avg. 8.0	22.7	14.6	24.7	0.1
63	70/30 wool/modacrylic	12.8	0.18	0.122	0.094	13.1	41.0	15.3	45.0
						9.8	58.6	13.6	62.8
						12.2	58.6	14.3	61.0
					Avg. 11.7	52.7	14.4	56.3	10
23	100% wool	12.3	0.17	0.132	0.097	12.5	19.7	14.7	21.0
						9.1	28.2	12.3	32.7
						9.0	26.0	12.8	29.2
					Avg. 10.2	24.6	13.3	27.6	1
46	100% wool (moth proof treated)	11.6	0.16	0.096	0.071	11.0	21.2	14.3	23.5
						11.9	23.8	14.9	25.3
						11.5	22.5	15.0	22.6
					Avg. 11.5	22.5	14.7	23.8	6
62	70/30 wool/modacrylic	11.5	0.21	0.098	0.074	10.8	42.8	18.1	46.8
						10.1	54.2	9.9	54.2
						20.0	65.2	27.8	65.2
					Avg. 13.6	54.1	21.9	55.4	80
28	90/10 wool/nylon	8.2	0.20	0.071	0.056	11.9	22.0	16.6	23.8
						13.1	22.8	16.2	24.0
						12.0	23.5	16.1	25.7
					Avg. 12.3	22.8	16.3	24.5	20
25	55/45 polyester/wool	6.6	0.49	0.020	0.018	26.6	37.6	30.2	42.2
						24.0	38.0	27.9	69.6
						24.6	38.2	29.3	59.0
					Avg. 25.1	37.9	29.1	56.9	-
45	100% acrylic	9.7	0.16	0.105	0.080	23.5	88.4	25.1	94.2
						17.5	85.0	22.3	93.8
						14.8	69.6	20.5	75.4
					Avg. 18.6	81.0	22.7	87.8	-
78	Corespun semi-carbon Kevlar	15.4	0.40	0.063	0.052	15.0	26.4	18.7	31.6
						13.5	26.0	18.3	32.6
						14.5	26.0	18.6	32.8
					Avg. 14.3	26.1	18.5	32.3	200
75	100% Kevlar	8.3	0.44	0.031	0.025	21.0	46.8	25.5	51.6
						23.0	54.0	27.3	57.0
						19.2	50.2	25.5	53.8
					Avg. 21.1	50.3	26.1	57.1	-

*Estimated from temperature rise at 3-seconds during 3-second exposure.

Table 6. Temperature Rise in Skin Simulant Covered by Single Layer of Fabric During Flame Impingement (cont)
(heat flux, 2.2 cal/cm²/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm ³)	Thickness (inch)	Temperature Rise (°C)		Maximum Temperature Rise (°C)		Approx. Burn Injury Index*
					at 3-sec	at 6-sec	3-second exposure	6-second exposure	
47	100% Nomex	8.1	0.45	0.027	0.024	28.0	58.8	37.9	64.2
						30.0	56.4	37.0	61.0
						30.7	58.6	38.6	62.6
				Avg.	29.6		57.9	37.9	62.6
74	50/50 Nomex/Kevlar	6.0	0.36	0.029	0.022	27.4	61.8	33.5	68.4
						29.1	64.0	33.7	70.0
						26.1	61.0	32.5	65.2
				Avg.	27.5		62.3	33.2	67.9
73	95/5 Nomex/Kevlar	5.3	0.29	0.024	0.018	30.0	60.0	40.8	66.2
						29.6	63.0	37.0	68.0
						34.6	63.0	37.2	68.4
				Avg.	31.4		62.0	38.3	67.5
39	Nylon, double butyl coated	12.5	--	0.016	0.013	38.0	64.4	52.6	64.8
						38.4	62.0	46.8	62.8
						32.6	51.2	51.4	54.2
				Avg.	36.3		59.9	50.3	62.3
5	Cotton, resin modified, butyl coated	10.5	--	0.020	0.014	31.1	54.8	43.6	62.0
						28.6	54.0	45.2	60.8
						27.0	54.0	44.4	61.4
				Avg.	27.2		54.3	44.3	61.4
32	Nylon, neoprene coated	7.7	--	0.016	0.011	32.8	35.0	35.7	38.8
						32.0	35.6	32.0	37.4
						29.8	34.6	31.6	38.8
				Avg.	31.5		35.7	33.1	38.1
18	Nylon, polyurethane coated	3.1	--	0.009	0.006	71.5	118.5	74.0	121.8
						40.0	120.5	42.0	126.5
						54.0	126.0	59.2	130.2
				Avg.	55.2		121.7	58.4	126.0
72	PAN, polyacrylonitrile	15.6	0.50	0.053	0.042	5.2	19.5	10.3	26.2
						6.8	22.6	11.7	31.1
						7.9	21.0	13.8	30.9
				Avg.	6.6		21.0	11.9	29.1
									>0.1
Fabric Assemblies:									
40	Polyester outer shell, 100% wool liner	12.0	--	0.053	0.045	8.2	21.8	12.5	26.7
						7.5	20.0	13.0	24.8
						5.7	20.0	10.9	24.3
				Avg.	7.1		20.6	12.1	25.3
1A	Polyester batt, nylon fabric	4.6	--	0.098	0.043	52.4	112.5	54.4	116.5
						55.0	100.0	56.8	113.5
						60.0	110.0	62.4	117.9
				Avg.	55.8		107.5	57.9	114.3

*Estimated from temperature rise at 3-seconds during 3-second exposure.

Table 6. Temperature Rise in Skin Simulant Covered by Single Layer of Fabric During Flame Impingement (cont)
(heat flux, 2.2 cal/cm²/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm ³)	Thickness (inch)	Temperature Rise (°C)			Approx. Burn Injury Index*
					at 3-sec	at 6-sec	Maximum Temperature Rise at 3-second exposure	
1	818 and 1A	7.7	--	0.107	0.049	10.5	79.8	79.8
						13.0	81.2	81.2
						9.0	64.4	64.4
				Avg. 10.8		75.1	75.1	3
13	50/50 cotton/nylon fluorocarbon treated outer shell; 100% nylon liner	20.0	--	0.185	0.145	1.2	6.2	12.6
						1.2	6.6	13.0
						1.0	6.3	12.5
				Avg. 1.1		6.4	7.3	12.7
2A	50/50 cotton/polyester outer shell; 100% nylon liner	12.5	--	0.094	0.068	4.5	20.8	31.6
						4.7	22.2	29.0
						4.6	24.6	30.0
				Avg. 4.6		23.5	19.9	30.2
55	50/50 cotton/nylon fluorocarbon treated outer; 100% cotton liner; polyester batt nylon fabric	22.0	--	0.335	0.213	2.3	7.3	9.8
						2.5	9.0	11.7
						3.0	9.7	12.5
				Avg. 2.6		8.7	7.8	11.3
21A	100% wool outer shell; 100% nylon liner	24.9	--	0.213	0.159	0.8	8.3	12.8
						0.9	7.5	12.8
						0.8	8.9	13.4
				Avg. 0.8		8.2	7.6	13.0
58	Nylon/acrylic outer shell; carbon impregnated liner	10.7	--	0.055	0.042	20.5	42.8	49.4
						21.0	46.4	50.6
						23.0	46.4	48.4
				Avg. 21.5		45.2	31.3	49.5

*Estimated from temperature rise at 3-seconds during 3-second exposure.

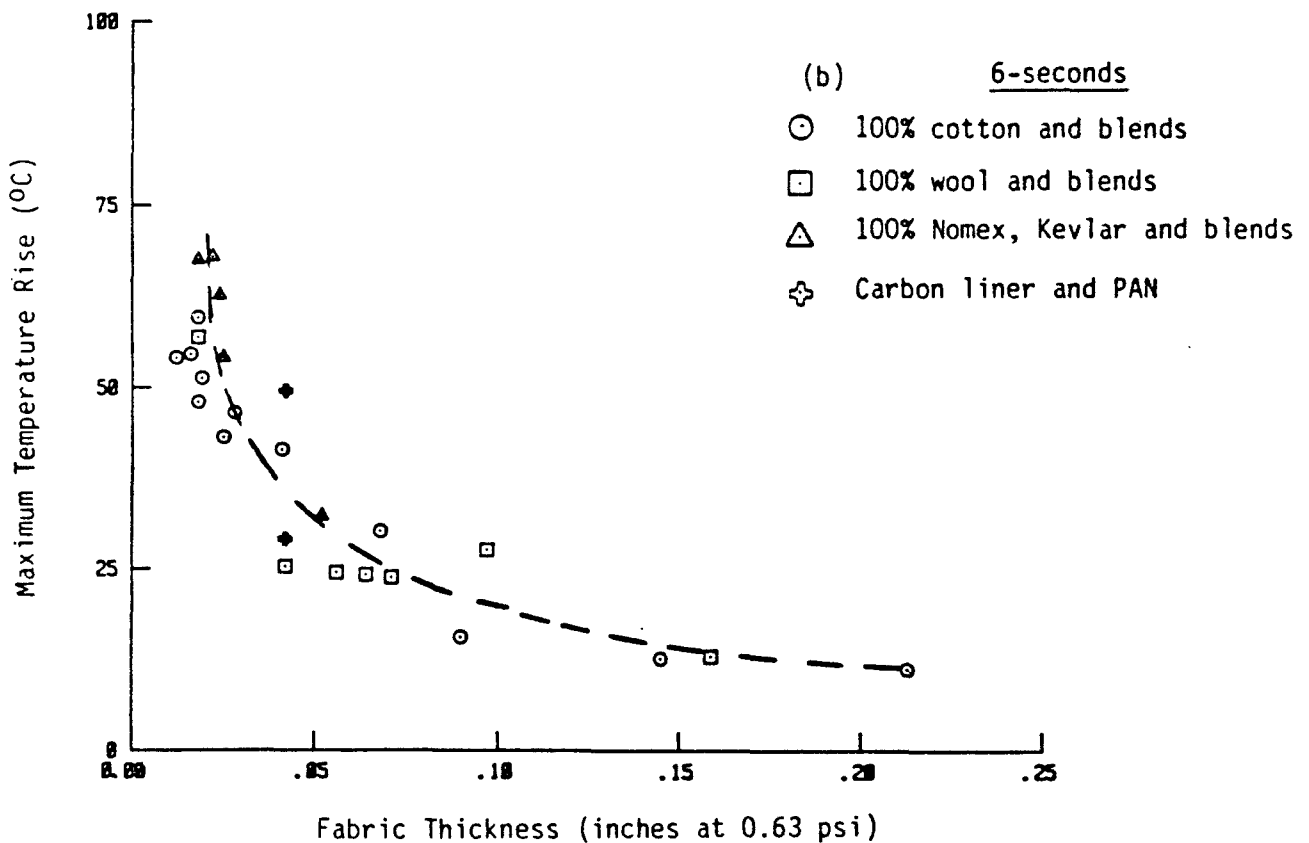
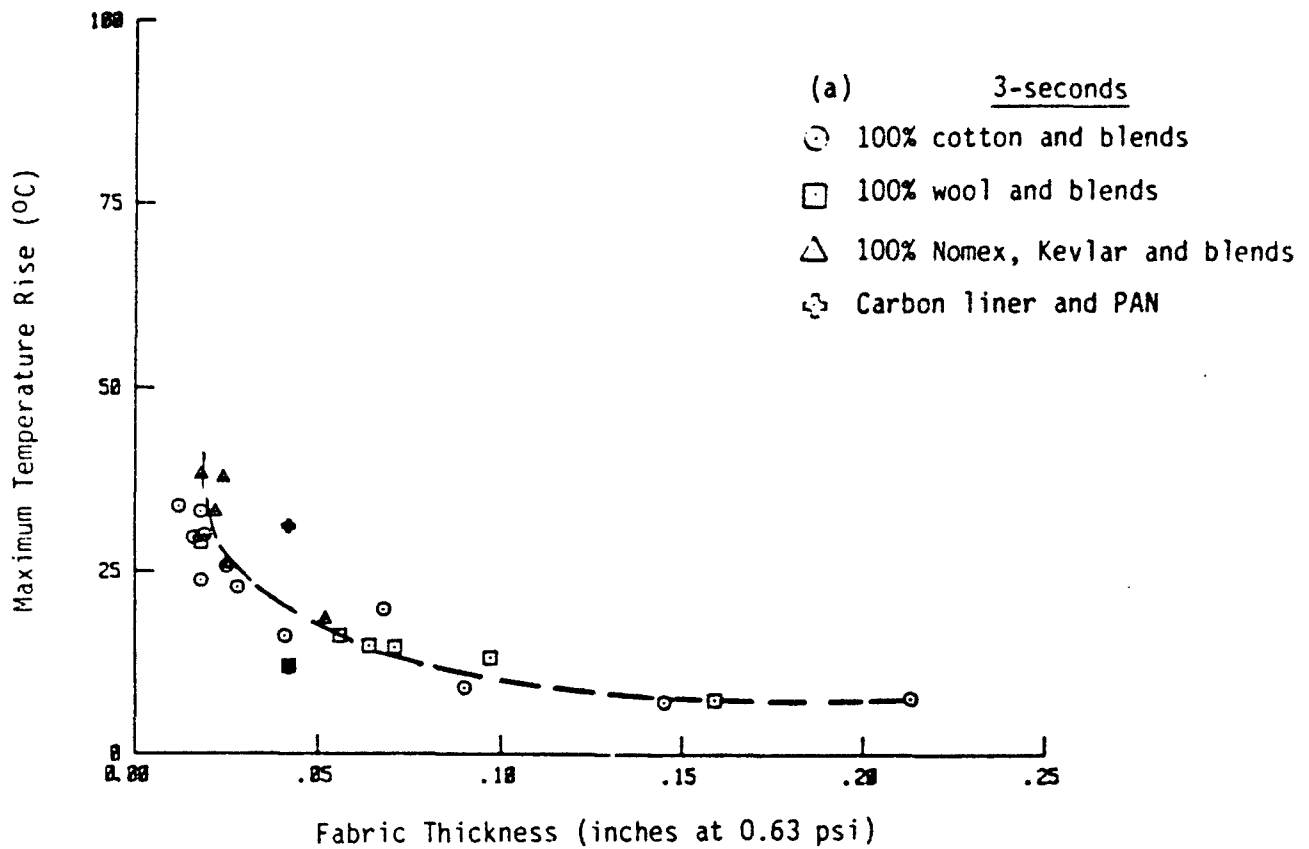


Figure 35. Variations of Maximum Temperature Rise of Single Layers and Fabric Assemblies with Fabric Thickness

VI. SUMMARY AND CONCLUSIONS

Measurements of strength loss and ease of ignition during bilateral irradiation to $1.1 \text{ cal/cm}^2/\text{sec}$ of various fabrics used in Navy shipboard outer garments have shown that the Nomex/Kevlar materials and those containing a carbon component (PAN, semi-carbon/Kevlar) retain strength and resist ignition longer for their weight than other fabrics in the test series including those composed of cellulose (cotton, rayon), wool or wool blends, or coated thermoplastic fabrics. Fabrics high in wool content may or may not resist ignition well depending on their finishing history, but generally lose strength more rapidly than cotton or rayon fabrics of the same weight. Those fabrics that consist primarily of a thermoplastic fraction melt readily even in combination with rubber coating materials.

During unilateral irradiation to $1.25 \text{ cal/cm}^2/\text{sec}$ the Nomex/Kevlar blends and PAN fabric tested consistently exhibited low heat transfer rates to an inner surface and resisted ignition for longer times than other fabrics in the series. Transfer of heat during one-sided radiation of fabrics in air with ample oxygen available during heating is governed principally by the nature of the chemical reactions induced in the material. Exothermic reactions, even considerably prior to ignition, can generate sufficient heat in irradiated materials that the amount of heat transferred to an inner surface exceeds the heat flux incident on the outer surface. Fabric geometry has little effect on heat transfer under these conditions.

During direct impingement by a gas flame at $2.2 \text{ cal/cm}^2/\text{sec}$, heat transfer is primarily conductive and depends principally on fabric thickness and material type. The lack of oxygen in the immediate vicinity of the flame prevents additional generation of heat within the exposed fabric from chemical reactions. A PAN fabric and a polyester outer shell with a wool liner performed better than expected for their thickness under these conditions.

As concluded, during the previous investigation, it can again be stated on the basis of the comparisons of fabric behavior contained herein that thicker, heavier fabrics composed of the more heat-resistant materials offer better protection to high impinging heat fluxes. Such fabrics can provide precious additional seconds for escape from the vicinity of a fire before their strength is lost and ignition occurs.

VII. REFERENCES

- Schoppee, M.M. et al, "The Transient Thermomechanical Response of Protective Fabrics to Radiant Heat," AFML-TR-77-72, May 1977.
- Stanton, R.M., Schulman, S., "Thermal Response of Woven and Knitted Fabrics in JP-4 Fuel Fire Environment," AFML-TR-75-64, October 1975.
- Morse, H.L. et al, "Analysis of the Thermal Response of Protective Fabrics," AFML-TR-73-17, January 1973.
- Quintierre, J., "Radiation Characteristics of Fire-Fighters' Coat Fabrics," Fire Technology, 153-161, May 1974.
- Sparrow, E.M., and Cess, R.D., Radiation Heat Transfer, Brooks/Cole Publishing Co., 1966.
- Singham, J.R., "Tables of Emissivity of Surfaces," Inter. J. Heat Mass Transfer, 1962.
- Gubareff, G.G., et al, "Thermal Radiation Properties Survey," Hoeneywell Research Center, 1960.
- Polymer Handbook, Brandup, J., Immengut, E.H. Ed., Wiley Interscience, 1975.
- Schoppee, M.M., "Comparative Performance of T456 Nomex and PBI Fabrics at Extreme Heat Levels," Report under U. S. Gov't No. DAAK60-79-M-2475, October 1979.
- Stoll, A.M., Chianta, M.A., Munroe, L.R., "Flame-Contact Studies," J. Heat Transfer, ASME Series C, Vol. 86, 449-456 (1964).
- Maggio, R.C., "A Molded Skin Simulant Material with Thermal and Optical Constants Approximating Those of Human Skin," Naval Material Laboratory, NS 081-001, August 1956.
- Derksen, W.L., deLhery, G.P., Monahan, T.I., "Thermal and Optical Properties of the NML Skin Simulant," Naval Material Laboratory, SF-001-05-11, January 1960.
- Monitz, A.R., Henniques, F.C., "Studies of Thermal Injury II: The Relative Importance of Time and Surface Temperature in the Causation of Cutaneous Burns," Amer. J. Pathol., Vol. 23, 695-719, 1947.
- Derksen, W.L., Monahan, T.I., deLhery, G.P., "The Temperature Associated with Radiant Energy Skin Burns," Chap. 16, Temperature: Its Measurement and Control in Science and Industry, Part 3, Biology and Medicine, Herzfeld, C.M., Ed., Reinhold Publishing Corporation (1961).
- Stoll, A.M., Chianta, M.A., "Method and Rating System for Evaluation of Thermal Protection," Aerospace Medicine, 1232-1238, November 1969.

VII. REFERENCES (cont)

Stoll, A.M., Chianta, M.A., "Heat Transfer through Fabrics as Related to Thermal Injury," Trans. New York Academy of Sciences, Vol. 33, No. 7, 649-670, November 1971.

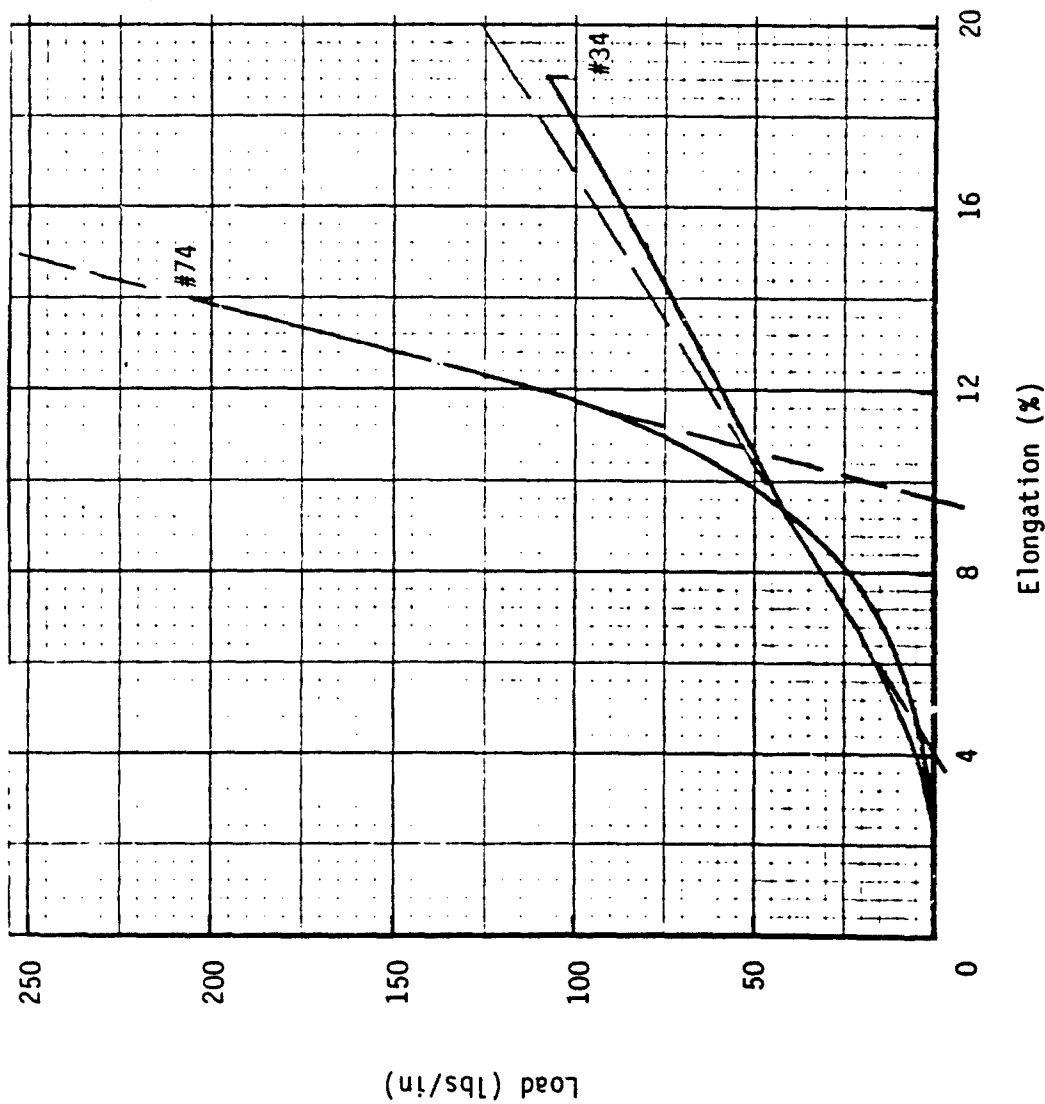
Stoll, A.M., "Thermal Properties of Human Skin Related to Nondestructive Measurement of Epidermal Thickness," J. of Investigative Dermatology, Vol. 69, 328-332, September 1977.

Griffith, M.V., Horton, G.K., "The Transient Flow of Heat through a Two-Layer Wall," Proc. Phys. Soc., London, Vol. 58, 1946.

Conduction of Heat in Solids, Carslaw, H.S., Jaeger, J.C., Oxford at the Clarendon Press, p. 75, 1959.

Textile Fabric Flammability, Backer, S. et al, MIT Press, 1976.

Freeston, W.D., Jr. et al, "Flammability and Heat Transfer Characteristics of PBI Fabric," AFML-TR-70-267, January 1971.



Fabric #34:

$$\text{slope} = \frac{126 \text{ lb/inch width}}{(0.200-0.040) \text{ strain units}}$$

$$= \frac{788 \text{ lb/inch width}}{1 \text{ strain unit}}$$

$$\text{modulus} = 788 \text{ lb/inch width/unit strain}$$

Fabric #74:

$$\text{slope} = \frac{250 \text{ lb/inch width}}{(0.149-0.096) \text{ strain units}}$$

$$= \frac{4720 \text{ lb/inch width}}{1 \text{ strain unit}}$$

$$\text{modulus} = 4720 \text{ lb/inch width) unit strain}$$

Appendix Figure 1. Calculation of Modulus from Maximum Slope of Load-Elongation Diagram

Appendix Table 1

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #38 100% cotton 10.3 oz/sq yd	0.2	270	0	3	Avg. 2290	122	100
					1900	114	
					1840	108	
					1710	96	
					Avg. 1820	106	87
			5	8	1960	98	
					2030	90	
					2080	89	
					Avg. 2020	92	75
			10	13	2160	76	
					2130	78	
					2080	82	
					Avg. 2120	79	65
			20	23	1850	60	
					2080	60	
					1930	62	
					Avg. 1952	61	50
			60	63	1710	40	
					1710	43	
					1610	40	
					Avg. 1680	41	34
	0.3	350	0	3	1930	95	
					1780	93	
					1780	97	
					Avg. 1830	95	78
			5	8	1890	68	
					1840	66	
					1740	66	
					Avg. 1820	67	55
			10	13	1130	30	
					1470	44	
					1410	41	
					1420	46	
					1480	45	
					Avg. 1380	41	34
			20	21	420	5	
					350	5	
					390	5	
					Avg. 390	5	4
	0.15	400	0	3	1840	86	
					1850	87	
					1890	91	
					Avg. 1860	88	72
			5	8	1670	54	
					1650	54	
					1520	57	
					Avg. 1610	55	45
			10	12	900	21	
					830	17	
					960	26	
					Avg. 900	21	17
			20	21	60	<1	
					70	<1	
					70	<1	
					Avg. 70	<1	<1

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	A Rupture			
Fabric #38 (cont)	0.6	500	0	3	1690	73	57
					1650	69	
					1730	69	
			5	7	Avg. 1690	70	
					500	10	
					690	20	
	0.8	560	10	12	750	16	13
					640	13	
					720	19	
			10	12	Avg. 660	16	
					40	1	
					40	1	
Fabric #70 80/20 PFR rayon/polyester 8.6 oz/sq yd	0.2	270	0	3	1470	54	48
					1480	59	
					1500	60	
			5	6	Avg. 1480	58	
					150	2	
					40	1	
	0.3	350	0	6	210	3	88
					Avg. 130	2	
					700	83	
			5	11	610	74	
					680	73	
					630	73	
	0.4	430	10	15	Avg. 640	73	82
					590	70	
					600	68	
			10	15	560	67	
					Avg. 590	68	
					560	63	
	0.5	510	20	25	560	63	76
					560	62	
					Avg. 560	63	
			20	25	530	52	
					560	57	
					520	57	
	0.6	590	60	64	Avg. 540	55	66
					430	21	
					450	26	
			60	64	380	16	
					460	35	
					480	41	
Fabric #70 80/20 PFR rayon/polyester 8.6 oz/sq yd	0.7	670	0	6	Avg. 440	28	34
					560	64	
					550	65	
			5	11	560	67	
					560	65	
					510	53	
	0.8	750	0	6	530	56	65
					460	53	
					Avg. 500	54	
			5	11	510	53	
					530	56	
					460	53	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #70 (cont)	0.3	350	10	15	350	32	41
					360	35	
					370	35	
			20	23	Avg. 360	34	10
					200	9	
					130	5	
			25	27	190	9	2
					Avg. 180	8	
					91	4	
	0.35	400	0	6	32	1	67
					34	1	
					Avg. 52	2	
			5	10	550	55	40
					540	58	
					550	58	
			10	14	Avg. 550	57	18
					330	31	
					380	34	
	0.6	500	0	5	350	34	41
					Avg. 350	33	
			5	7	240	17	3
					170	9	
					240	15	
			0	4	270	15	24
					260	19	
					Avg. 240	15	
			5	—	70	3	0
					80	3	
					Avg. 70	3	
	0.8	560	0	—	350	18	0
					370	21	
					390	21	
			5	—	Avg. 370	20	0
					350	18	
					370	21	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)			
			At Start	At Rupture						
Fabric #10 rayon warp cotton fill 8.2 oz/sq yd	0.2	270	--	--	Avg. 2760	222	100			
					1770	153				
					1730	175				
			0	6	1800	190				
					1810	176				
					1950	170				
					Avg. 1810	173	78			
			5	11	1910	166				
					1030	168				
					1920	183				
			10	16	1890	187				
					1900	187				
					Avg. 1730	182	82			
			20	25	2000	178				
					2240	170				
					2180	180				
			60	65	Avg. 2140	176	79			
	0.3	350			1930	155				
					2230	192				
					2180	163				
		5	11	2200	191					
				2310	192					
				Avg. 2170	179	81				
		10	14	1840	157					
				2110	161					
				2090	160					
		20	24	Avg. 2013	159	72				
				0.3	350			1230	172	
								1250	171	
		1330	183							
		60	61		1240	164				
					1320	167				
	Avg. 1270				171	77				
	5	11	1850		171					
			1880		170					
			1790		160					
	10	14	1850		154					
			1720		157					
			Avg. 1820		162	73				
	20	24	1670		129					
			2050		146					
			1880		148					
	60	61	1510		124					
			1500		132					
			Avg. 1720		136	61				
	20	24	900		77					
			790		80					
			820		66					
	60	61	930		66					
			900		70					
			Avg. 870		72	32				
	20	24	430		6					
			340		5					
			570		6					
	60	61	Avg. 450		6	3				

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)					
			At Start	At Rupture								
Fabric #10 (cont)	0.35	400	0	6	1630	197						
					1580	189						
					1730	179						
			Avg.	1650	188	85						
			5	10	1770	123						
					1710	117						
					1800	117						
			Avg.	1760	118	53						
			10	14	830	53						
					910	64						
					920	61						
			Avg.	890	59	27						
	20	21	420	6								
			340	5								
			390	6								
	Avg.	380	6	3								
	0.6	500	0	5	1530	131						
					1480	136						
					1410	138						
			Avg.	1480	135	61						
			5	8	860	32						
					820	28						
					870	33						
			Avg.	850	31	14						
10			—	Avg.	0	0	0					
				0.8	560	0	3	1270	83			
								1410	93			
1380			93									
Avg.	1350	90	41									
5	—	Avg.	—			0	0					
		Fabric #34	—			20	—	—	Avg.	790	107	100
7.0 oz/sq yd	0.2	270	0			8	770	87				
							800	93				
Avg.	750	91	84									
	770	90										
	5	12				770	91					
770			92									
750			89									
Avg.	760	91	85									
10	17	710	76									
		720	84									
		780	88									
Avg.	740	83	77									
20	26	760	72									
		790	69									
		720	66									
Avg.	750	69	64									
60	65	690	39									
		760	51									
		770	58									
Avg.	740	49	46									

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #34 (cont)	0.3	350	0	7	750	82	
					730	80	
					740	82	
			Avg. 740		81	76	
			5	11	750		65
					720		71
					690		69
			Avg. 720		68	64	
			10	14	610		48
					630		51
					640		56
			Avg. 630		52	49	
			20	23	250		12
					140		8
					290		14
			Avg. 230		11	10	
			60	64	230		10
					210		10
					230		10
			Avg. 220		10	9	
	0.35	400	0	7	640		70
					560		70
					670		70
			Avg. 650		70	65	
			5	10	540		43
					550		45
					500		41
			Avg. 530		43	40	
			10	13	220		8
					220		10
170					6		
Avg. 200			8		7		
20			20	170		1	
				130		1	
				110		1	
Avg. 130				1	1		
0.6	500	0	5	510		35	
				480		37	
				450		29	
		Avg. 480		34	32		
		5	8	10		1	
				40		1	
				50		2	
		Avg. 40		1	1		
0.8	560	0	4	400		21	
				350		19	
				330		19	
		Avg. 360		20	19		
		5	--	Avg. ----		0	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #44 100% cotton 3.2 oz/sq yd	0.2	270	—	—	Avg. 2350	148	100
			0	5	2180	117	
					2250	115	
					2310	117	
					Avg. 2250	116	78
			5	10	2030	91	
					2000	98	
					2077	96	
					Avg. 2040	95	64
			10	15	1820	82	
					1820	85	
					1920	83	
					Avg. 1850	83	56
			20	25	1890	78	
					1710	74	
					1710	74	
					Avg. 1770	76	51
			60	65	1710	70	
					1720	69	
					1840	70	
					Avg. 1960	70	47
	0.3	350	0	5	1770	98	
					1380	74	
			5	10	1800	94	
					1590	85	
					2050	95	
					Avg. 1720	89	60
			10	15	1340	51	
					1260	52	
					1390	53	
					Avg. 1330	52	35
			20	24	990	24	
					760	21	
					1190	39	
					750	18	
			60	61	890	26	
					Avg. 920	26	18
					80	2	
					100	2	
					140	2	
					Avg. 110	2	1

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)			
			At Start	At Rupture						
Fabric #44 (cont)	0.35	400	0	5	1750	87				
					1280	67				
					1160	57				
					1670	85				
							1500	78	51	
			Avg.	1470	75					
			5	10	1310	54				
					1150	47				
					1410	54				
					Avg.	1290	52			
			10	14	770	21				
					810	25				
					770	22				
					Avg.	760	23			
			20	21	70	1				
					70	2				
					80	2				
					Avg.	70	2			
	0.6	500	0	5	830	43				
					1230	53				
					850	39				
					Avg.	970	45			
			5	7	100	1				
					60	2				
		20	2							
Avg.	60	2	<1							
0.8	560	0	4	260	10					
				780	33					
				730	26					
				500	19					
				580	19					
		Avg.	560	21	14					
		5	--	Avg.	--	--	0			
		Fabric #50 100% cotton 6.4 oz/sq yd	---	20	--	--	Avg.	1890	118	100
0.2	270	0	5	2080	100					
				1800	90					
				1760	90					
				Avg.	1880	90				
		5	10	1990	82					
				1740	70					
				1740	69					
				Avg.	1820	74				
		10	15	1540	59					
				1710	62					
				1540	61					
				Avg.	1600	61				

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #50 (cont)	0.3	350	20	25	1480	52	46
					1550	55	
					1530	54	
					Avg. 1520	54	45
			60	64	1800	58	
					1610	49	
					1690	51	
					Avg. 1700	53	64
			0	5	1700	77	
					1660	72	
					1690	75	
					Avg. 1680	75	45
			5	10	1700	54	
					1660	50	
					1690	56	
					Avg. 1680	53	36
			10	15	1160	40	
					1310	39	
					1380	48	
					Avg. 1290	42	21
			20	24	900	23	
					990	25	
					1040	26	
					Avg. 980	25	3
			60	62	190	3	
					170	6	
					190	4	
					Avg. 180	4	47
	0.35	400	0	4	1390	57	
					1470	57	
					1390	55	
					Avg. 1420	56	36
			5	9	1290	43	
					1260	42	
					1230	40	
					Avg. 1260	42	14
			10	14	710	19	
					550	13	
					770	18	
					Avg. 680	17	1
			20	22	90	2	
					80	1	
					50	1	
					Avg. 70	1	30
	0.6	500	0	4	990	33	
					900	39	
					810	32	
					Avg. 900	35	2
			5	7	110	3	
					80	2	
					40	2	
					Avg. 80	2	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #50 (cont)	0.8	560	0	4	500	18	18
					640	22	
					570	23	
					Avg. 570	21	
Fabric #37 100% cotton 5.1 oz/sq yd	0.2	270	5	--	Avg. ---	0	0
					Avg. 170	19	100
					120	13	79
					150	17	
					150	15	
					Avg. 140	15	
			10	21	90	8	49
					110	11	
					80	9	
					Avg. 90	9	
			20	28	60	6	32
					50	6	
					70	7	
					Avg. 60	6	
			60	65	30	4	26
					50	6	
					40	4	
					Avg. 40	5	
			10	13	20	2	5
					10	1	
					10	1	
					Avg. 10	1	
	0.3	350	0	9	50	4	22
					30	4	
					50	4	
					Avg. 40	4	
			5	10	10	1	6
					10	1	
					10	1	
					Avg. 10	1	
			10	13	---	>0.5	2
					---	>0.5	
					---	>0.5	
					Avg. ---	>0.5	
	0.35	400	0	7	20	2	9
					20	2	
					20	2	
					Avg. 20	2	
			5	9	---	>0.5	1
					---	>0.5	
					---	>0.5	
					Avg. ---	>0.5	
	0.6	500	0	4	---	>0.5	1
					---	>0.5	
					---	>0.5	
					Avg. ---	>0.5	
	0.8	560	0	0	Avg. 0	0	0

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #21 100% wool 15.7 oz/sq yd	0.2	270	—	—	Avg. 290	56	100
					200	46	
					190	43	
			0	12	240	45	
					Avg. 210	45	80
			5	16	220	46	
					210	44	
					220	46	
					Avg. 220	45	80
			10	22	240	45	
					230	43	
					230	46	
					Avg. 230	45	80
			20	31	270	47	
					270	48	
					260	47	
					Avg. 270	47	84
			60	69	220	35	
					230	35	
					190	31	
					Avg. 210	34	61
	0.3	350	0	14	220	42	
					180	40	
					170	42	
					Avg. 190	42	73
			5	17	200	42	
					220	45	
					200	39	
					Avg. 210	42	75
			10	22	220	39	
					210	33	
					220	39	
					Avg. 220	37	66
			20	29	150	18	
					170	21	
					210	27	
					200	26	
					180	22	
					Avg. 180	23	41
			30	31	---	<1	
					---	<1	
					---	<1	
					Avg. ---	<1	<1

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)	
			At Start	At Rupture				
Fabric #21 (cont)	0.35	400	0	12	210	45		
					190	41		
					<u>210</u>	<u>38</u>		
			Avg.		<u>210</u>	<u>41</u>	73	
			5	15	190	30		
					200	29		
					<u>210</u>	<u>34</u>		
			Avg.		<u>200</u>	<u>31</u>	15	
			10	20	210	30		
					190	29		
					<u>180</u>	<u>34</u>		
			Avg.		<u>190</u>	<u>31</u>	48	
			20	23	50	2		
					65	3		
					<u>65</u>	<u>3</u>		
			Avg.		<u>60</u>	<u>3</u>	5	
			25	--	Avg.	--	0	0
			0.6	500	0	9	230	35
	210	33						
	<u>210</u>	<u>31</u>						
	Avg.				<u>220</u>	<u>33</u>	59	
	5	11			180	18		
					180	18		
					<u>180</u>	<u>17</u>		
Avg.		<u>180</u>			<u>18</u>	32		
10	12	---			<1			
		---			1			
		---			<u><1</u>			
Avg.		---			<1	<1		
0.8	560	0			8	210	23	
						200	23	
						<u>190</u>	<u>21</u>	
		Avg.				<u>200</u>	<u>22</u>	39
		5	9	100	6			
				120	7			
				<u>110</u>	<u>6</u>			
		Avg.		<u>110</u>	<u>6</u>	11		
		10	--	Avg.	---	0	0	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)		
			At Start	At Rupture					
Fabric #28 90/10 wool/nylon 8.2 oz/sq yd	0.2	270	---	---	Avg. 200	35	100		
			0	14	90	22			
					90	29			
					<u>100</u>	<u>24</u>			
			Avg. 90	25	71				
			5	17	120	22			
					130	24			
					<u>90</u>	<u>27</u>			
			Avg. 110	24	69				
			10	22	130	21			
					130	24			
					<u>150</u>	<u>28</u>			
			Avg. 140	24	69				
			20	30	120	20			
					120	22			
					<u>120</u>	<u>20</u>			
			Avg. 120	21	60				
			60	70	90	15			
	100	15							
	<u>100</u>	<u>18</u>							
	Avg. 100	16	46						
	0.3	350	0	15	80	19			
					110	21			
					<u>80</u>	<u>19</u>			
			Avg. 90	20	57				
			5	18	70	15			
					100	16			
					<u>90</u>	<u>17</u>			
			Avg. 90	16	46				
			10	18	90	10			
					90	9			
					<u>100</u>	<u>14</u>			
			Avg. 90	11	31				
			20	23	40	<1			
					50	1			
					<u>50</u>	<u>1</u>			
			Avg. 50	1	2				
			0.35	400	0	11	140	23	
							160	25	
	<u>140</u>	<u>25</u>							
	Avg. 150	24			69				
	5	14			120	15			
					120	13			
					<u>120</u>	<u>16</u>			
	Avg. 120	15			43				
	10	16			60	4			
					70	5			
					<u>60</u>	<u>4</u>			
	Avg. 60	4			11				
	20	---			Avg. 0	0	0		

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #28 (cont)	0.6	500	0	7	40	3	
					30	3	
					<u>40</u>	<u>3</u>	
					Avg. 40	3	8
	0.8	560	0	4	20	1	
					20	2	
					<u>20</u>	<u>1</u>	
					Avg. 20	1	4
Fabric #25 55/45 polyester/wool 6.6 oz/sq yd	---	20	--	--	Avg. 440	92	100
	0.2	270	0	11	250	48	
					360	48	
					<u>320</u>	<u>48</u>	
					Avg. 310	48	52
			5	17	190	38	
					200	44	
					<u>190</u>	<u>41</u>	
					Avg. 170	41	45
			10	20	190	22	
					166	19	
					210	40	
					220	31	
					<u>216</u>	<u>36</u>	
					Avg. 200	30	33
			20	27	140	12	
					120	11	
					<u>170</u>	<u>16</u>	
					Avg. 150	13	14
			60	64	100	6	
					90	5	
					<u>90</u>	<u>5</u>	
					Avg. 90	5	5
	0.3	350	0	7	130	16	
					170	20	
					<u>140</u>	<u>17</u>	
					Avg. 150	19	45
			5	12	50	3	
					40	3	
					<u>40</u>	<u>3</u>	
					Avg. 40	3	7
	0.35	400	0	6	110	12	
					90	8	
					<u>120</u>	<u>11</u>	
					Avg. 110	10	24
			5	--	Avg. 0	0	0

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #25 (cont)	0.6	500	0	2	70	69	6
					70	67	
					60	60	
	0.8	560	0	2	Avg. 70	65	1
					40	1	
					40	1	
Fabric #78 core spun, semi- carbon Kevlar 15.4 oz/sq yd	0.2	270	0	8	Avg. 40	1	83
					40	1	
					40	1	
					Avg. 2170	205	
					1720	168	
					1770	169	
					1740	174	
					Avg. 1740	170	
					1610	171	
					1500	171	
					1510	172	
					Avg. 1570	171	
					1540	170	
					1600	169	
					1620	170	
					Avg. 1590	170	
					1520	139	
					1540	159	
					1610	156	
					Avg. 1560	151	
					1480	110	
					1440	111	
					1330	109	
					Avg. 1420	112	
	0.3	350	0	8	1340	153	75
					1370	152	
					1290	154	
					Avg. 1350	153	
					1440	148	
					1450	155	
					1380	140	
					Avg. 1430	148	
					1260	125	
					1390	136	
					1420	136	
					Avg. 1030	130	
					1130	101	
					1110	104	
					1200	102	
					Avg. 1150	106	
					960	39	
					1010	26	
					1080	27	
					Avg. 1020	31	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)		
			At Start	At Rupture					
Fabric #78 (cont)	0.35	400	0	8	1210	148			
					1180	148			
					<u>1190</u>	<u>148</u>			
			Avg.		1190	148	72		
			5	12	1270	135			
					1260	139			
					<u>1320</u>	<u>143</u>			
			Avg.		1290	139	68		
			10	16	1060	100			
					1070	100			
					<u>1240</u>	<u>119</u>			
			Avg.		1120	106	52		
			20	25	870	63			
					840	63			
					<u>890</u>	<u>69</u>			
			Avg.		870	65	32		
			60	62	990	29			
					960	28			
					<u>1010</u>	<u>28</u>			
			Avg.		990	28	14		
			0.6	500	0	7	1160	133	
							1240	136	
							<u>1170</u>	<u>120</u>	
					Avg.		1190	130	63
	5	11			980	78			
					1110	87			
					<u>930</u>	<u>78</u>			
	Avg.				1003	81	40		
	10	14			500	25			
					560	33			
					<u>480</u>	<u>25</u>			
	Avg.				510	28	14		
	20	22			420	11			
					460	12			
					<u>440</u>	<u>13</u>			
	Avg.				440	12	6		
	60	61			660	13			
					650	11			
					<u>640</u>	<u>13</u>			
	Avg.				650	12	6		
	0.8	560			0	7	1080	96	
							1040	106	
							<u>1100</u>	<u>110</u>	
					Avg.		1070	104	51
			5	10	740	51			
					710	49			
					<u>740</u>	<u>47</u>			
			Avg.		730	49	24		
10			13	200	10				
				170	8				
				<u>240</u>	<u>13</u>				
Avg.				200	10	5			

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)					
			At Start	At Rupture								
Fabric #78 (cont)			20	22	560	13	6					
					540	12						
					<u>560</u>	<u>12</u>						
			Avg.	560	12							
			60	61	940	12						
					890	14						
					<u>820</u>	<u>12</u>						
			Avg.	880	13							
			Fabric #75 100% Kevlar 8.3 oz/rq yd	0.2	270	0		6	Avg.	8450	439	100
									7670	350	75	
7670	340											
<u>6310</u>	<u>300</u>											
Avg.	7220	330										
5	11	8770					320					
		7180					320					
		<u>8770</u>					<u>340</u>					
Avg.	8240	330					74					
10	15	6820					283					
		8130					294					
		<u>7590</u>					<u>318</u>					
Avg.	7490	298					68					
20	25	6310					254					
		7760					265					
		<u>7420</u>					<u>275</u>					
Avg.	7160	266					61					
60	65	7500					244					
		6740					263					
		<u>6960</u>					<u>270</u>					
Avg.	7070	260					59					
0.3	350	0					6		8230	285		
									7760	304		
									<u>7420</u>	<u>280</u>		
Avg.	7800	291					63					
5	18	6030					236					
		7180					255					
		<u>7670</u>		<u>257</u>								
Avg.	6960	249		57								
10	15	6890		205								
		6750		206								
		<u>6960</u>		<u>203</u>								
Avg.	6870	205		47								
20	25	5630		156								
		5320		150								
		<u>5670</u>		<u>188</u>								
Avg.	5370	165		38								
60	65	3690		118								
		4090		125								
		<u>4290</u>		<u>129</u>								
Avg.	4020	124		28								

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #75 (cont)	0.35	400	0	6	7580	277	
					7370	268	
					7360	271	
			Avg. 7440		272	62	
			5	10	5920		192
					6430		182
					6190		191
			Avg. 6180		183	43	
			10	15	4290		126
					4360		127
					4150		127
			Avg. 4270		125	28	
			20	24	3380		93
					3510		92
					3420		96
			Avg. 3430		94	21	
			60	64	1850		58
					2050		57
					2080		57
			Avg. 1990		57	13	
	0.6	500	0	5	5770		190
					5110		177
					5190		186
			Avg. 5360		184	42	
			5	9	3180		84
					2780		80
					3380		79
			Avg. 3110		81	18	
			10	14	1590		40
					1390		37
					1650		41
			Avg. 1540		39	9	
			20	24	1230		34
					1440		38
					1380		38
			Avg. 1350		37	8	
60			63	1090	26		
				940	25		
				820	25		
Avg. 970				25	6		
0.8	560	0	5	4820		123	
				4430		136	
				4910		137	
		Avg. 4720		132	30		
		5	9	1860		45	
				1550		44	
				1710		45	
		Avg. 1710		45	10		
		10	13	1040		34	
				1130		33	
				1180		35	
		Avg. 1120		34	8		
		20	22	460		12	
				520		15	
				530		17	
		Avg. 500		15	3		

Appendix Table 1 (cont)

**Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During
Exposure to Various Bilateral Radiant Heat Flux Levels**

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #47 100% Nomex 8.1 oz/sq yd	0.2	270	0	16	Avg. 600	152	100
					500	172	
					540	130	
					520	125	
					Avg. 520	142	93
			5	20	480	116	
					460	108	
					500	124	
					Avg. 480	116	76
			10	25	500	122	
					460	113	
					490	122	
					Avg. 480	113	78
			20	35	460	115	
					430	108	
					450	112	
					Avg. 450	112	73
			60	75	430	104	
					450	109	
					440	106	
					Avg. 440	106	70
	0.3	350	0	15	460	111	
					480	107	
					480	114	
					Avg. 470	111	73
			5	19	390	80	
					430	86	
					430	91	
					Avg. 420	86	57
			10	22	400	71	
					390	71	
					380	79	
					Avg. 390	74	49
			20	32	340	72	
					350	66	
					360	72	
					Avg. 350	70	46
			60	72	370	70	
					360	66	
					360	70	
					Avg. 360	69	45
	0.35	400	0	14	400	80	
					420	84	
					430	91	
					Avg. 410	86	57
			5	17	350	65	
					330	60	
					320	55	
					Avg. 330	60	39
			10	22	300	53	
					310	58	
					310	48	
					Avg. 310	53	35

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)			
			At Start	At Rupture						
Fabric #47 (cont)	0.6	500	20	30	290	43				
					330	43				
					310	50				
			Avg.		310	45	30			
			60	68	310	31				
					320	37				
					270	28				
			Avg.		300	32	21			
			0	11	250	39				
					230	43				
					240	43				
			Avg.		240	42	28			
			5	12	130	12				
					170	19				
					150	16				
			Avg.		110	16	11			
			10	15	60	6				
					50	5				
					40	4				
Avg.	50	5	3							
0	8	160		23						
		160		21						
		160		19						
Avg.		160	21	14						
5	9	50	5							
		40	4							
		50	4							
Avg.		50	4	3						
Fabric #74 50/50 Nomex/Kevlar 6.0 oz/sq yd	0.2	270	—		—	Avg.	4750	202	100	
						0	4	4170		164
								3920		158
			3970	162						
			Avg.	4020	161	80				
			5	9	4190		151			
					4410		150			
					4040		154			
			Avg.		4220	152	75			
			10	15	3500	137				
					3180	133				
					4030	144				
			Avg.		3570	138	68			
			20	25	3750	133				
					3550	134				
					3600	139				
			Avg.		3630	135	67			
			60	65	3290	136				
					3070	129				
3380	129									
Avg.	3250	131	65							

Appendix Table 1 (cont)

**Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During
Exposure to Various Bilateral Radiant Heat Flux Levels**

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #74 (cont)	0.3	350	0	5	3990	144	
					3800	144	
					3910	140	
			Avg. 3900		143	71	
			5	10	3000		108
					3140		110
					3000		108
			Avg. 3050		109	54	
			10	15	2970		86
					2430		89
					2700		91
			Avg. 2700		89	44	
			20	25	2330		89
					2330		81
					2500		87
			Avg. 2390		86	43	
			60	65	2350		84
					2410		84
					2290		84
			Avg. 2350		84	42	
			3800	132			
			3860	132			
			Avg. 3840	132	65		
			5	10		2700	85
	2650	93					
	2900	91					
	Avg. 2750	90	45				
	10	15		2600	78		
				2050	79		
				2390	88		
	Avg. 2340		82	41			
	20	24	1530		46		
			1530		49		
			1690		54		
	Avg. 1590		50	25			
	60	64	1140		39		
			1100		38		
			1110		38		
	Avg. 1120		38	19			
	2430	78					
	2480	72					
	Avg. 2480	76	38				
	5	9		1090	29		
				1220	32		
				1440	35		
	Avg. 1250		32	16			
	10	14	940		23		
			930		23		
840			21				
Avg. 900	22		11				

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #74 (cont)	0.8	561	20	24	560	15	7
					520	13	
					510	15	
					Avg. 530	14	
			60	62	290	10	4
					290	9	
					240	7	
					Avg. 270	9	
			0	5	1990	53	27
					1890	53	
					1890	55	
					Avg. 1950	54	
			5	9	990	19	10
					980	22	
					850	22	
					Avg. 940	21	
			10	14	590	14	6
					520	13	
					510	13	
					Avg. 540	13	
			20	22	190	4	2
					210	5	
					220	5	
					Avg. 210	5	
			25	25	80	1	<1
					90	1	
					70	1	
					Avg. 80	1	
Fabric #73 95/5 Nomex/Kevlar 5.3 oz/sq yd	---	20	--	--	Avg. 2090	129	100
	0.2	270	0	6	1780	102	81
					1790	104	
					1780	106	
					Avg. 1780	104	
			5	10	1580	95	74
					1530	101	
					1430	91	
					Avg. 1510	96	
			10	15	1320	85	67
					1380	87	
					1320	89	
					Avg. 1340	87	
			20	25	1220	84	65
					1270	82	
					1240	87	
					Avg. 1240	84	
			60	65	1390	86	67
					1380	84	
					1530	87	
					Avg. 1430	86	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #73 (cont)	0.3	350	0	5	1200	69	
					1230	71	
					1290	76	
			Avg. 1240		72	56	
			5	9	890		47
					870		48
					840		47
			Avg. 870		47	36	
			10	14	640		34
					760		42
					720		43
			Avg. 700		40	31	
			20	24	640		36
					690		39
					720		39
			Avg. 670		38	29	
			60	64	640		41
					590		37
					660		41
			Avg. 630		40	31	
	0.35	400	0	4	1420		78
					1420		80
					1320		78
			Avg. 1390		79	61	
			5	9	840		40
					700		36
					850		41
			Avg. 800		39	30	
			10	14	600		28
					700		30
					700		34
			Avg. 660		31	24	
			20	23	480		22
					530		28
					570		30
			Avg. 530		27	21	
			60	62	440		19
					440		19
					520		20
			Avg. 470		19	15	
	0.6	500	0	3	1260		53
					1290		48
					130		46
			Avg. 1300		49	38	
			5	7	370		10
					370		9
					420		11
			Avg. 380		10	8	
			10	11	70		2
					90		2
					90		2
			Avg. 80		2	2	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #73 (cont)	0.8	560	0	2	1110 1140 <u>1090</u> Avg. 1110	35 37 <u>34</u> 35	27
			5	6	40 50 <u>50</u> Avg. 50	2 2 <u>2</u> 2	
			—	—	Avg. 1120	173	
			0	13	720 720 <u>730</u> Avg. 730	97 101 <u>101</u> 100	
			5	18	590 580 <u>630</u> Avg. 600	97 96 <u>96</u> 96	
			10	23	530 540 <u>540</u> Avg. 540	94 95 <u>96</u> 95	
Fabric #39 nylon, butyl coated 12.5 oz/sq yd	0.2	270	0	13	720 720 <u>730</u> Avg. 730	97 101 <u>101</u> 100	58
			5	18	590 580 <u>630</u> Avg. 600	97 96 <u>96</u> 96	
			10	23	530 540 <u>540</u> Avg. 540	94 95 <u>96</u> 95	
			20	32	500 480 <u>490</u> Avg. 490	91 89 <u>98</u> 93	
			60	72	400 420 <u>490</u> Avg. 400	81 79 <u>79</u> 79	
			0	12	570 580 <u>590</u> Avg. 560	71 72 <u>74</u> 73	
			5	14	410 400 <u>400</u> Avg. 400	53 57 <u>57</u> 56	
			10	17	350 340 <u>380</u> Avg. 360	42 41 <u>50</u> 44	
			20	23	40 40 <u>70</u> Avg. 50	3 3 <u>6</u> 4	
			0	8	470 480 <u>490</u> Avg. 480	50 54 <u>53</u> 52	
			5	10	290 260 <u>290</u> Avg. 280	32 28 <u>29</u> 30	
			0	8	470 480 <u>490</u> Avg. 480	50 54 <u>53</u> 52	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #39 (cont)	0.6	500	10	11	140 120 --- 150 140 Avg. 140	9 7 4 7 8 7	4
			15	15	Avg. 0	0	0
			0	4	300 370 400 Avg. 360	26 26 32 28	16
			5	5	Avg. 0	0	0
			0	3	300 360 300 Avg. 320	17 20 13 17	10
			5	5	Avg. 0	0	0
Fabric #5 cotton, resin modified, butyl coated 10.5 oz/sq yd	0.2	270	---	---	Avg. 1300	72	100
			0	5	1300 1260 1090 Avg. 1220	68 58 57 61	85
			5	10	1270 1260 1140 Avg. 1230	60 53 49 54	75
			10	14	1310 1180 1230 Avg. 1241	54 45 46 48	67
			20	25	1060 1130 1020 Avg. 1070	42 42 34 39	34
			60	65	1050 1040 940 Avg. 1010	35 40 32 36	50
	0.3	350	0	5	760 840 920 Avg. 840	30 39 39 36	50
			5	10	770 850 920 Avg. 850	32 36 32 33	46
			10	15	790 750 840 Avg. 790	30 28 28 29	40

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #5 (cont)	0.35	400	20	25	790	27	40
					810	27	
					850	32	
					Avg. 820	29	
			60	62	50	1	1
					60	1	
					30	1	
					Avg. 50	1	
			0	5	1160	50	65
					1210	43	
					1220	49	
					Avg. 1200	47	
	0.6	500	5	10	750	27	42
					910	31	
					880	33	
					Avg. 850	30	
			10	15	700	23	33
					820	24	
					800	25	
					Avg. 780	24	
			20	22	90	1	3
					40	1	
					100	3	
					Avg. 80	2	
			0	5	1020	36	46
					890	30	
					820	33	
					Avg. 910	33	
	0.8	560	5	9	290	8	8
					130	5	
					160	6	
					Avg. 190	6	
			10	10	0	0	0
			0	5	680	23	
					610	22	
					610	21	
					Avg. 630	22	
			5	5	0	0	0
					Avg. 0	0	
Fabric #32 nylon, neoprene coated 7.7 oz/sq yd	---	20	--	--	Avg. 1440	158	100
	0.2	270	0	7	1050	120	78
					1130	125	
					1130	125	
					Avg. 1100	123	
			5	12	930	110	67
					990	110	
					850	99	
					Avg. 920	110	
			10	18	750	83	59
					790	102	
					750	94	
					Avg. 760	93	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #32 (cont)	0.3	350	20	28	680 740 670 Avg. 700	95 94 93 94	59
			0	7	630 640 640 Avg. 340	70 68 70 59	44
			5	12	480 400 400 Avg. 430	62 50 52 55	35
			10	15	310 340 300 Avg. 310	31 34 31 32	20
			15	15	Avg. 0	0	0
			0	6	490 440 570 Avg. 500	48 48 61 52	33
	0.6	500	5	8	270 300 290 Avg. 290	20 25 21 22	14
			10	10	Avg. 0	0	0
			0	4	380 430 400 Avg. 400	25 32 29 29	18
			5	5	Avg. 0	0	0
			0	3	450 440 460 Avg. 450	20 18 20 19	12
			5	5	Avg. 0	0	0
Fabric #18 nylon, poly- urethane coated 3.1 oz/sq yd	---	20	---	---	Avg. 350	67	100
	0.2	270	0	14	210 190 210 Avg. 200	30 29 31 30	45
			5	18	130 120 130 Avg. 130	39 31 30 30	45

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabric During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #18 (cont)	0.3	350	10	24	90	23	39
					120	29	
					120	28	
					Avg. 110	26	
			20	33	90	22	40
					120	30	
					100	28	
					Avg. 110	27	
			60	72	120	28	28
					130	30	
					130	28	
					90	4	
	0.35	400	0	5	120	7	10
					120	7	
					140	8	
					Avg. 130	7	
			5	6	---	1	2
					---	2	
					---	1	
					Avg. ---	1	
			0	3	150	7	10
					150	6	
					170	7	
					Avg. 160	7	
	0.6	500	5	5	0	0	0
					0	0	
					0	0	
					0	0	
			0	1	170	3	5
					160	3	
					160	3	
					Avg. 160	3	
	0.8	560	0	1	160	3	3
					160	2	
					160	2	
					Avg. 160	2	
Fabric #72 PAN 15.6 oz/sq yd	0.2	270	---	---	Avg. 3010	163	100
					2410	127	
					2500	130	
					2780	138	
			0	6	Avg. 2570	128	79
					2130	131	
					2000	136	
					2130	131	
			5	11	Avg. 2080	133	82
					1900	129	
					1860	121	
					1900	139	
	0.2	270	10	15	Avg. 1890	130	80
					1840	121	
					1970	131	
					1901	137	
			20	24	Avg. 1900	130	80
					1840	121	
					1970	131	
					1901	137	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #72 (cont)	0.3	350	60	63	1920	84	53
					1930	91	
					1930	87	
					Avg. 1930	87	
			0	6	1990	113	71
					2050	121	
					2000	113	
					Avg. 2010	116	
			5	9	1710	126	77
					1710	126	
					1840	123	
					Avg. 1750	125	
			10	14	1840	125	73
					1780	118	
					1550	115	
					Avg. 1720	119	
			20	23	1570	95	56
					1610	94	
					1580	88	
					Avg. 1590	92	
	0.35	400	60	60	600	6	4
					1000	8	
					600	6	
					Avg. 730	7	
			0	6	1780	113	71
					1590	113	
					1670	123	
					Avg. 1680	116	
			5	10	1630	120	74
					1840	128	
					1563	115	
					Avg. 1679	121	
			10	14	1610	108	64
					1710	103	
					1640	100	
					Avg. 1650	105	
			20	22	1890	55	31
					1040	43	
					1210	50	
					Avg. 1380	50	
			60	60	1190	8	4
					800	6	
					790	6	
					Avg. 930	7	

Appendix Table 1 (cont)

Tensile Properties in the Warp Direction of Navy Shipboard Work Clothing Fabrics During Exposure to Various Bilateral Radiant Heat Flux Levels

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Exposure Time (sec)		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
			At Start	At Rupture			
Fabric #72 (cont)	0.6	590	0	6	1350	125	
					1310	118	
					1410	120	
			Avg.	1360	121	74	
			5	9	1500	90	
					1510	95	
					1550	90	
			Avg.	1520	92	56	
			10	13	950	33	
					900	39	
					950	35	
			Avg.	930	36	22	
	20	20	680	4			
			650	3			
			650	4			
	Avg.	660	4	2			
	0.8	560	0	5	1340	103	
					1380	108	
					1330	109	
			Avg.	1350	107	66	
			5	8	1270	68	
					1290	68	
					1270	65	
			Avg.	1280	67	41	
10			11	610	8		
				590	8		
				620	11		
Avg.			610	9	6		
15	15	470	3				
		440	3				
		350	2				
Avg.	420	3	2				

Appendix Table 2

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #36 100% cotton 13.3 oz/sq yd	0.2	270	No ignition, 2 min	Light smoke at 45 seconds
	0.3	350	<u>Glow Only</u>	Medium smoke at 55 seconds
			90	
			75	
			85	
			Avg. 83	
	0.35	400	<u>Glow Only</u>	Heavy smoke at 35 seconds
			50	
			50	
			50	
			Avg. 50	
	0.6	500	17	Heavy smoke at 18 seconds
			21	
			18	
			Avg. 19	
	0.8	560	9	Medium smoke at 8 seconds
			10	
			11	
			Avg. 10	
	0.9	600	6	Light smoke at 5 seconds
			6	
			6	
			Avg. 6	
	1.1	650	4	Light smoke at 3 seconds
			4	
			4	
			Avg. 4	
Fabric #38 100% cotton 10.3 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Medium smoke at 30 seconds
	0.35	400	No ignition, 2 min	Medium smoke at 15 seconds
	0.6	500	Glow, 15 seconds	Heavy smoke at 5 seconds
	0.8	560	5	Light smoke at 45 seconds
			5	
			7	
			Avg. 6	
	0.9	600	5	Medium smoke at 4 seconds
			5	
			5	
			Avg. 5	
	1.1	650	2	Heavy smoke at ignition
			3	
			2	
			Avg. 3	

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #70 80/20 PPR rayon/polyester 8.6 oz/sq yd	0.3	350	No ignition, 2 min	Medium smoke at 30 seconds
	0.35	400	No ignition, 2 min	Medium smoke at 20 seconds
	0.6	500	No ignition, 2 min	Heavy smoke at 6-9 seconds
	0.8	560	6 6 5 5 Avg.	Medium smoke at 4 seconds
	0.9	600	4 3 5 3 3 3 Avg.	Medium smoke at 2-3 seconds
	1.1	650	2 2 2 2 Avg.	Heavy smoke at ignition
	0.2	270	No ignition, 2 min	Light smoke at 60 seconds
	0.3	350	No ignition, 2 min	Heavy smoke at 20 seconds
	0.35	400	No ignition, 2 min	Heavy smoke at 15 seconds
	0.6	500	7 8 8 8 Avg.	Heavy smoke at 6 seconds
Fabric #71 80/20 PPR rayon/ Nomex 8.5 oz/sq yd	0.8	560	5 6 5 5 Avg.	Light smoke at 4 seconds
	0.9	600	4 4 4 4 Avg.	Light smoke at 3 seconds
	1.1	650	3 3 3 3 Avg.	No smoke generation

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #10 rayon warp cotton fill 8.2 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	Glow	Light-medium smoke at 60-90 seconds
			94	
			70	
			Avg. 82	
	0.35	400	Glow	Medium-heavy smoke at 20-25 seconds
			34	
			30	
			Avg. 32	
	0.6	500	9 14	Heavy smoke at 7-10 seconds
			10 8	
			Avg. 11	
	0.8	560	8 6	Light smoke at 5 seconds
			8 6	
			Avg. 6	
	0.9	600	5	Light smoke at 4 seconds
			5	
			Avg. 5	
	1.1	650	4	Light smoke at 3 seconds
			4	
			Avg. 4	
Fabric #34 80/20 PFR rayon/Momex 7.0 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Medium-heavy smoke at 20 seconds
	0.35	400	No ignition, 2 min	Heavy smoke at 13 seconds
	0.5	500	8	Heavy smoke at 7 seconds
			8	
			Avg. 8	
	0.8	560	4	Medium-heavy smoke at 2 seconds
			3	
			Avg. 3	
	0.9	600	2	Light smoke at 1 second
			2	
			2	
	1.1	650	1	Light smoke at <1 second
			2	
			Avg. 1	

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #37 100% cotton 5.1 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	<u>Glow Only</u>	Medium smoke at 10 seconds
			35	
			35	
			<u>35</u>	
			35	
	0.35	400	<u>Glow Only</u>	Medium to heavy at 10 seconds
			21	
			23	
			<u>23</u>	
			Avg. 22	
	0.6	500	6	Medium smoke at 4 seconds
			6	
			<u>5</u>	
			Avg. 6	
	0.8	560	4	Light smoke at 3 seconds
			4	
			<u>4</u>	
			Avg. 4	
	0.9	600	3	Light smoke at 2 seconds
			3	
			<u>3</u>	
			Avg. 3	
	1.1	650	2	Light smoke at 1 second
			2	
			<u>2</u>	
			Avg. 2	
Fabric #48 100% cotton 4.3 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	81	Light smoke at 10 seconds
			--	
			90 (glow only)	
			Avg. 81	
	0.35	400	30	Medium to heavy smoke at 25 seconds
			33	
			<u>35</u> (glow only)	
			Avg. 32	
	0.6	500	13	Medium smoke at 12 seconds
			14	
			<u>13</u>	
			Avg. 13	
	0.8	560	7	Light smoke at 7 seconds
			9	
			<u>8</u>	
			Avg. 8	
	0.9	600	6	Light smoke at 5 seconds
			7	
			<u>6</u>	
			Avg. 6	
	1.1	650	5	Light smoke at 3 seconds
			3	
			<u>5</u>	
			Avg. 4	

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #21 100% wool 15.7 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Medium smoke; slight intumescent char at 60-70 seconds
	0.35	400	No ignition, 2 min	Medium-heavy smoke, intumescent char at 35 seconds
	0.6	500	<u>Glow</u> 105 110 120 Avg. 112	Heavy smoke; intumescent char at 15-20 seconds
	0.8	560	<u>Glow with small flame</u> 60 54 63 Avg. 58	Heavy smoke, intumescent char at 15 seconds
	0.9	600	33 44 35 Avg. 37	Heavy smoke, intumescent char at 9-12 seconds
	1.1	650	34 14 11 31 33 Avg. 24	Heavy smoke; intumescent char at 7-10 seconds
Fabric #63 70/30 wool/modacrylic 12.8 oz/sq yd	0.2	270	No ignition, 2 min	Medium smoke, slight melting at 80 seconds
	0.3	350	No ignition, 2 min	Medium smoke at 55 seconds
	0.35	400	No ignition, 2 min	Heavy smoke, slight melting at 30 seconds
	0.6	500	Melts apart at 13	Medium smoke at 12 seconds
	0.8	560	Melts apart at 9	Light smoke at 5 seconds
	0.9	600	Melts apart at 8	Medium smoke at 2 seconds
	1.1	650	Melts apart at 6	Heavy smoke at 6 seconds
Fabric #23 100% wool 12.3 oz/sq yd	0.2	270	No ignition, 2 min	Light smoke at 40 seconds
	0.3	350	No ignition, 2 min	Medium smoke, intumescent char 45-50 seconds
	0.35	400	No ignition, 2 min	Heavy smoke at 35, intumescent char at 40 seconds
	0.6	500	Melts apart at 13	Heavy smoke at 6-9 seconds
	0.8	560	Melts apart at 10	Light smoke at 4 seconds
	0.9	600	Melts apart at 8	Heavy smoke at 1 second
	1.1	650	Melts apart at 6	Heavy smoke at 1 second

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #46	0.2	270	No ignition, 2 min	No smoke generation
100% wool	0.3	350	No ignition, 2 min	Medium smoke at 70, light intumescent char at 75 seconds
(mothproof-treated)	0.35	400	No ignition, 2 min	Heavy smoke, intumescent char at 45-50 seconds
11.6 oz/sq yd	0.6	500	82 70 80 Avg. 77	Heavy smoke, intumescent char at 20 seconds
	0.8	560	53 58 51 Avg. 54	Heavy smoke, intumescent char at 15 seconds
	0.9	600	47 44 45 Avg. 45	Heavy smoke, intumescent char at 13 seconds
	1.1	650	43 36 30 Avg. 37	Heavy smoke, intumescent char at 9 seconds
Fabric #62	0.2	270	No ignition, 2 min	Medium smoke, slight melting at 110 seconds
70/30 wool/modacrylic	0.3	350	No ignition, 2 min	Heavy smoke at 45 seconds
11.5 oz/sq yd	0.35	400	No ignition, 2 min	Heavy smoke, slight melting at 20 seconds
	0.6	500	Glcw Only 55 70 75 Avg. 67	Heavy smoke, melting at 10 seconds
	0.8	560	Melts apart at 7	Medium smoke at 2 seconds
	0.9	600	Melts apart at 6	Medium smoke at 2 seconds
	1.1	650	Melts apart at 5	Heavy smoke at 4 seconds

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #28 90/10 wool/nylon 8.2 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Light-medium smoke slight intumescent char at 45 seconds
	0.35	400	No ignition, 2 min	Medium-heavy smoke, intumescent char, slight melting at 20-25 seconds
	0.6	500	<u>Glow</u> 90 120 <u>105</u> Avg. 105	Heavy smoke, intumescent char at 10 seconds
	0.8	560	<u>Glow</u> <u>Small Flame</u> 25 30 21 24 <u>25</u> <u>32</u> Avg. 24 29	Heavy smoke, intumescent char at 10 seconds
	0.9	600	21 18 <u>15</u> Avg. 18	Heavy smoke, intumescent char at 8 seconds
	1.1	650	19 12 <u>10</u> Avg. 14	Heavy smoke, intumescent char at 6 seconds
	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	No smoke generation
	0.35	400	No ignition, 2 min	Heavy smoke, melting at 15 seconds
Fabric #25 55/45 polyester/wool 6.6 oz/sq yd	0.6	500	No ignition, 2 min	Heavy smoke, melting at 8-10 seconds
	0.8	560	<u>Glow</u> 25 30 <u>20</u> Avg. 25	Heavy smoke, melting at 4 seconds
	0.9	600	17 20 <u>16</u> Avg. 18	Heavy smoke, melting at 6-9 seconds
	1.1	650	3 3 <u>3</u> Avg. 3	Medium smoke at 2-3 seconds

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)		Smoke Generation
Fabric #45 100% acrylic 9.7 oz/sq yd	0.2	270	No ignition, 2 min		No smoke generation
	0.3	350	Melts apart at 70		Medium smoke at 60
	0.35	400	Melts apart at 45		Medium smoke at 35
	0.6	500	Melts apart at 12		Light smoke at 10 seconds
	0.8	560	Melts apart at 9		Light smoke at 8
	0.9	600	Melts apart at 8		Light smoke at 7 seconds
	1.1	650	Melts apart at 7		Light smoke at 6 seconds
Fabric #78 corespun, semi- carbon Kevlar 15.4 oz/sq yd	0.2	270	No ignition, 2 min		No smoke generation
	0.3	350	No ignition, 2 min		Light smoke at 25 seconds
	0.35	400	No ignition, 2 min		Light smoke at 20 seconds
	0.6	500	No ignition, 2 min		Light smoke at 15 seconds
	0.8	560	Light Glow Only, 40		Light smoke at 10 seconds
	0.9	600	Light Glow	Small Flame	Light smoke at 8 seconds
			30	90	
			30	42	
			30	82	
			30	75	
			30	80	
			Avg. 30	74	
	1.1	650	25		Light to medium smoke at 8 seconds
			28		
			21		
			Avg. 25		
Fabric #75 100% Kevlar 8.3 oz/sq yd	0.2	270	No ignition, 2 min		No smoke generation
	0.3	350	No ignition, 2 min		No smoke generation
	0.35	400	No ignition, 2 min		No smoke generation
	0.6	500	No ignition, 2 min		No smoke generation
	0.8	560	Glow	Flame	Medium smoke at 35-45 seconds
			40	70	
			50	70	
			50	—	
			40	—	
			40	—	
			Avg. 40	70	
	0.9	600	Glow	Flame	Medium smoke at 15 seconds
			20	43	
			20	—	
			25	36	
			20	32	
			20	26	
			Avg. 21	34	
	1.1	650	23		Medium-heavy smoke at 12 seconds
			22		
			21		
			Avg. 22		

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #47 100% Nomex 8.1 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	No smoke generation
	0.35	400	No ignition, 2 min	Light smoke at 17 seconds
	0.6	500	No ignition, 2 min	Medium smoke at 10 seconds
	0.8	560	Melts, 10-13	Medium smoke at 7 seconds
	0.9	600	<u>Glow</u> <u>Small Flame</u> 65 85 75 95 70 90 Avg. 65 90	Medium smoke at 5 seconds, melts at 10
	1.1	650	43 45 45 Avg. 44	Medium smoke at 4 seconds, melts at 7
Fabric #74 50/50 Nomex/Kevlar 6.0 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	No smoke generation
	0.35	400	No ignition, 2 min	No smoke generation
	0.6	500	No ignition, 2 min	Light smoke at 15 seconds
	0.8	560	<u>Glow</u> 30 25 25 Avg. 27	Medium smoke at 8 seconds
	0.9	600	<u>Glow</u> 20 15 15 Avg. 17	Medium smoke at 7 seconds
	1.1	650	19 19 17 Avg. 18	Medium-heavy smoke at 7 seconds
Fabric #73 95/5 Nomex/Kevlar 5.3 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Light smoke at 15 seconds
	0.35	400	No ignition, 2 min	Medium smoke at 15 seconds
	0.6	500	No ignition, 2 min	Medium smoke at 7 seconds
	0.8	560	Light Glow, 40	Medium smoke at 5 seconds
	0.9	600	<u>Glow</u> <u>Small Flame</u> 13 30 20 35 18 27 Avg. 17 31	Medium to heavy smoke at 3-5 seconds
	1.1	650	16 19 21 Avg. 19	Heavy smoke at 4 seconds

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #39 nylon, butyl coated 12.5 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	Melts, 20-25	Light smoke at 10 seconds
	0.35	400	Melts, 12	Light smoke at 8 seconds, blisters at 10
	0.6	500	<u>Glow Only</u> 23 15 18 Avg. 19	Melts at 5, light smoke and blistering at 8 seconds
	0.8	560	9 8 8 Avg. 8	Blisters at 4, light smoke and melting at 7 seconds
	0.9	600	6 6 5 Avg. 6	Light smoke at 5 seconds
	1.1	650	4 5 4 Avg. 4	Light smoke at 3 seconds
Fabric #5 cotton, resin modified, butyl coated, 10.5 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Light smoke at 15 seconds
	0.35	400	<u>Glow Only</u> 65 63 60 Avg. 63	Medium smoke, coating melts exposing base fabric at 25 seconds
	0.6	500	13 16 16 Avg. 15	Medium smoke, coating melts at 8 seconds
	0.8	560	7 8 7 Avg. 7	Medium smoke at 5 seconds
	0.9	600	6 6 5 Avg. 6	Light smoke at 5 seconds
	1.1	650	5 5 5 Avg. 5	Light smoke at 3 seconds

Appendix Table 2 (cont)

Time to Ignition for Navy Shipboard Work Clothing Fabrics Exposed to Bilateral Radiant Heat

Fabric Description	Radiant Heat Flux (cal/cm ² /sec)	Heater Temp (°C)	Time to Ignition (seconds)		Smoke Generation	
Fabric #32 nylon, neoprene coated 7.7 oz/sq yd	0.2	270	No ignition, 2 min		No smoke generation	
	0.3	350	Melts, 15		Light smoke at 10 seconds	
	0.35	400	Melts, 10		Light smoke at 10 seconds	
	0.6	500	Melts, 5		Medium-heavy smoke at 5 seconds	
	0.8	560	10 12 <u>11</u> Avg. 11		Medium smoke, melts at 4 seconds	
	0.9	600	8 9 <u>8</u> Avg. 8		Medium smoke, melts at 4 seconds	
	1.1	650	5 4 <u>4</u> Avg. 4		Medium smoke at 4 seconds	
	Fabric #18 nylon, polyurethane coated 3.1 oz/sq yd	0.2	270	Melts slightly, 40		No smoke generation
		0.3	350	Melts, 10		Light smoke at 5 seconds
		0.35	400	Melts, 5		No smoke generation
		0.6	500	Melts, 4		No smoke generation
0.8		560	Melts, 2		No smoke generation	
0.9		600	Melts, 2		No smoke generation	
1.1		650	2 2 <u>4</u> Avg. 3		No smoke generation, melts at 1 second	
Fabric #72 PAN 15.6 oz/sq yd		0.2	270	No ignition, 2 min		No smoke generation
	0.3	350	No ignition, 2 min		Light smoke at 25 seconds	
	0.35	400	No ignition, 2 min		Light smoke at 15 seconds	
	0.6	500	No ignition, 2 min		Medium to heavy smoke at 10 seconds	
	0.8	560	Light glow, 30-35		Heavy smoke at 10 seconds	
	0.9	600	Light glow, 30-35		Medium smoke at 7 seconds	
	1.1	650	Light Glow <u>18</u> 18 <u>18</u> Avg. 18	Small Flame <u>24</u> 32 <u>40</u> 32	Medium smoke at 5 seconds	

Appendix Table 3

Heat Transfer to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description	
<u>Single-Layer Fabrics:</u>									
36 100% cotton 13.3 oz/sq yd	0.40	5	5	6	33	38	55	Initial peak	
		40	40	45	64	79	76	Medium smoke	
		54	54	52	81	83	86	Heat transfer stabilizes	
	0.75	4	4	4	34	34	32	Initial peak	
		18	17	16	48	49	39	Ignition	
	1.25	7	6	6	26	28	25	Ignition	
	38 100% cotton 10.3 oz/sq yd	0.40	3	3	3	33	50	31	Initial peak
			25	25	25	60	60	50	Light smoke
			45	48	45	67	64	57	Heat transfer stabilizes
0.75		2	2	2	40	38	37	Initial peak	
		15	14	12	118	116	119	Medium smoke	
		25	20	20	77	87	80	Heat transfer stabilizes	
1.25		4	2	2	31	29	30	Initial peak	
		7	8	8	68	80	82	Ignition	
70 80/20 PFR rayon/ polyester 8.6 oz/sq yd		0.40	3	3	3	44	50	48	Initial peak
	25		23	25	135	111	108	Melting	
	45		40	40	61	61	68	Heat transfer stabilizes	
	0.75	3	2	2	34	42	27	Initial peak	
		13	11	10	114	135	129	Melting, heavy smoke	
		25	30	40	63	75	80	Heat transfer stabilizes	
	1.25	2	2	2	32	30	34	Initial peak	
		5	5	5	73	76	79	Ignition	
	71 80/20 PFR rayon/ Nomex 8.5 oz/sq yd	0.40	4	4	4	45	53	53	Initial peak
25			25	25	87	108	117	Light smoke	
45			45	40	64	65	75	Heat transfer stabilizes	
0.75		3	3	2	53	52	49	Initial peak	
		13	11	9	114	93	96	Heavy smoke	
		—	—	10	—	—	96	Ignition	
1.25		30	25	—	71	61	—	Heat transfer stabilizes	
		2	2	2	33	34	33	Initial peak	
0.40		4	4	4	50	47	42	Ignition, heavy smoke	
	10 rayon warp/ cotton fill 9.2 oz/sq yd	0.40	4	4	3	40	40	38	Initial peak
35			35	30	62	60	52	Heat transfer stabilizes	
2			2	2	43	45	48	Initial peak	
0.75		15	—	15	70	—	85	Ignition with medium smoke	
		19	27	26	86	140	140	Maximum heat transfer	
1.25		2	2	2	38	29	31	Initial peak	
		5	5	5	51	34	31	Ignition, heavy smoke	
		17	5	25	60	34	46	Maximum heat transfer	

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Single-Layer Fabrics: (cont)								
34 80/20 PFR rayon/Nomex 7.0 oz/sq yd	0.40	3	3	3	50	52	52	Initial peak
		35	30	30	71	69	71	Heat transfer stabilizes
	0.75	3	3	3	40	40	40	Initial peak
		14	13	12	123	127	125	Heavy smoke
		30	20	15	65	66	71	Heat transfer stabilizes
	1.25	2	2	2	38	41	41	Initial peak
5		5	5	73	73	78	Ignition	
44 100% cotton 6.6 oz/sq yd	0.40	2	2	2	50	55	52	Initial peak
		30	25	27	69	74	74	Heat transfer stabilizes
	0.75	3	2	2	43	41	48	Initial peak
		29	15	15	78	68	70	Ignition
	1.25	2	2	2	34	27	26	Initial peak
		7	6	4	55	53	32	Ignition
50 100% cotton 5.1 oz/sq yd	0.40	2	2	2	50	48	50	Initial peak
		30	25	25	74	67	74	Heat transfer stabilizes
	0.75	2	2	2	53	42	40	Initial peak
		8	23	23	61	88	80	Ignition
	1.25	2	2	2	31	28	31	Initial peak
		4	4	5	45	41	49	Ignition
37 100% cotton 5.1 oz/sq yd	0.40	2	2	2	57	50	48	Initial peak
		15	17	20	76	67	74	Light smoke
		40	40	35	69	74	69	Heat transfer stabilizes
	0.75	2	2	2	40	41	42	Initial peak
		8	7	6	82	75	77	Ignition
	1.25	2	2	2	34	28	32	Initial peak
	3	3	3	51	57	63	Ignition	
48 100% cotton 4.3 oz/sq yd	0.40	4	1	2	29	36	50	Initial peak
		15	17	18	57	69	55	Light smoke
		60	43	55	105	217	110	Maximum heat transfer
	0.75	2	2	2	49	35	46	Initial peak
		7	8	8	54	36	62	Ignition
		29	27	8	56	45	62	Maximum heat transfer
1.25	3	3	3	52	47	37	Ignition	
21 100% wool 15.7 oz/sq yd	0.40	6	7	6	57	64	43	Initial peak
		30	23	25	48	55	48	Light smoke
		40	45	37	67	74	62	Heavy smoke, intumesces
	0.75	5	4	5	40	44	52	Initial peak
		20	17	30	43	52	37	Heavy smoke, intumesces
		25	25	50	29	30	40	Heat transfer stabilizes
	1.25	5	5	5	31	33	33	Initial peak
		13	13	15	18	21	51	Heavy smoke, intumesces
		60	15	20	57	21	28	Ignition

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to
Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description	
Single-Layer Fabrics: (cont)									
63 70/30 wool/ modacrylic 12.8 oz/sq yd	0.40	5	4	4	37	32	32	Initial peak	
		30	28	27	107	90	85	Heavy smoke	
		37	38	40	124	122	137	Maximum heat transfer	
	0.75	3	4	5	23	36	36	Initial peak	
		15	15	15	73	91	82	Heavy smoke	
		20	18	—	100	100	—	Fabric split	
	1.25	—	—	20	—	—	121	Maximum heat transfer	
		2	2	2	16	22	37	Initial peak	
		8	8	7	72	80	86	Heavy smoke	
	15	10	15	100	100	100	Fabric split		
	23 100% wool 12.3 oz/sq yd	0.40	6	7	4	51	56	29	Initial peak
			34	34	24	85	110	110	Heavy smoke
43			50	50	59	100	122	Heat transfer stabilizes	
0.75		3	4	3	96	52	126	Melts, heavy smoke	
		20	13	10	100	100	100	Fabric destroyed	
		3	3	2	27	30	43	Initial peak	
1.25		10	12	10	107	105	102	Melts, heavy smoke	
		15	—	12	100	—	100	Fabric destroyed	
		—	30	—	—	127	—	Ignition	
46 100% wool (moth-proof treated) 11.6 oz/sq yd		0.40	8	5	6	27	51	39	Initial peak
			20	25	30	24	46	49	Medium smoke, intumesces
			45	42	43	45	73	59	Maximum heat transfer
	0.75	5	4	4	58	57	62	Initial peak	
		12	10	10	33	48	36	Medium smoke	
		—	20	25	—	30	41	Heat transfer stabilizes	
	1.25	43	—	—	79	—	—	Maximum heat transfer	
		2	2	2	43	42	66	Initial peak, heavy smoke	
		10	15	10	33	66	49	Intumesces	
	23	30	18	49	64	52	Ignition		
	62 70/30 wool/ modacrylic 11.5 oz/sq yd	0.40	4	3	5	61	73	46	Initial peak
			20	17	25	93	76	117	Heavy smoke
38			35	—	85	68	—	Heat transfer stabilizes	
0.75		—	—	34	—	—	146	Maximum heat transfer	
		4	5	5	27	41	26	Initial peak	
		15	15	17	96	122	100	Heavy smoke	
1.25		20	30	20	100	100	100	Heat transfer stabilizes	
		3	3	3	21	24	21	Initial peak	
		8	8	7	94	87	84	Heavy smoke	
11		10	10	100	100	100	Fabric split		
28 90/10 wool/nylon 8.2 oz/sq yd		0.40	5	4	5	33	36	38	Initial peak
			30	35	30	45	60	54	Medium-heavy smoke
	45		45	45	54	60	52	Heat transfer stabilizes	
	0.75	4	4	4	37	36	32	Initial peak	
		15	15	15	45	41	54	Heavy smoke, intumesces	
		30	30	30	108	116	93	Maximum heat transfer	
	1.25	35	35	35	80	100	100	Heat transfer stabilizes	
		3	3	4	35	34	32	Initial peak	
		10	12	12	24	29	30	Heavy smoke, intumesces	
	12	18	23	44	50	106	Ignition		

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (B)			Fabric Event Description	
<u>Single-Layer Fabrics: (cont)</u>									
25 55/45 polyester/wool 6.6 oz/sq yd	0.40	3	2	3	45	33	48	Initial peak	
		30	25	25	119	160	102	Heavy smoke	
		40	30	40	112	114	67	Heat transfer stabilizes	
	0.75	2	2	3	41	37	38	Initial peak	
		11	15	15	72	146	109	Melts, heavy smoke	
		45	30	20	130	110	109	Heat transfer stabilizes	
	1.25	2	2	2	31	29	30	Initial peak	
		7	5	7	119	119	114	Ignition, heavy smoke	
	45 100% acrylic 9.7 oz/sq yd	0.40	10	5	8	29	27	24	Initial peak
35			45	37	110	90	100	Heavy smoke	
40			50	40	100	100	100	Fabric destroyed	
0.75		3	4	5	12	13	13	Initial peak	
		24	17	--	130	159	--	Ignition, heavy smoke	
		--	--	25	--	--	115	Heat transfer stabilizes	
1.25		2	2	2	13	14	16	Initial peak	
		11	8	11	135	137	120	Ignition, heavy smoke	
78 Amatex 16HT65 Corespun semi-carbon Kevlar FR 15.3 oz/sq yd		0.40	5	5	5	47	54	49	Initial peak
	45		40	45	63	65	62	Heat transfer stabilizes	
	0.75	4	4	4	47	37	41	Initial peak	
		30	30	30	60	61	61	Heat transfer stabilizes	
	1.25	4	3	3	31	36	32	Initial peak	
		25	30	20	58	56	49	Heat transfer stabilizes	
		--	60	60	--	56	49	Ignition	
	75 100% Kevlar 8.3 oz/sq yd	0.40	5	5	6	37	37	40	Initial peak
			35	30	30	60	53	58	Heat transfer stabilizes
0.75		4	3	4	34	37	32	Initial peak	
		30	30	30	59	61	56	Heat transfer stabilizes	
1.25		3	3	3	29	25	27	Initial peak	
		20	20	20	62	60	62	Heat transfer stabilizes	
		60	60	60	65	67	81	Fabric glowing	
47 100% Nomex 8.1 oz/sq yd		0.40	4	3	3	45	40	38	Initial curve
			20	20	25	69	71	60	Heat transfer stabilizes
	0.75	3	2	3	38	39	33	Initial peak	
		25	20	30	58	58	57	Heat transfer stabilizes	
	1.25	2	2	2	28	29	29	Initial peak	
		20	45	22	123	100	122	Maximum heat transfer	
		40	45	30	115	100	82	Ignition	
	74 50/50 Nomex/Kevlar 6.0 oz/sq yd	0.40	3	3	3	41	41	50	Initial peak
			25	20	30	57	55	65	Heat transfer stabilizes
0.75		2	2	2	36	33	34	Initial peak	
		25	30	25	62	65	60	Heat transfer stabilizes	
1.25		2	2	2	31	32	32	Initial peak	
		45	37	23	76	69	67	Ignition	

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to
Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant heat Transfer (%)			Fabric Event Description
Single-Layer Fabrics: (cont)								
73 95/5 Nomex/Kevlar 5.3 oz/sq yd	0.40	3	2	3	39	45	43	Initial peak
		25	20	25	59	63	67	Heat transfer stabilizes
	0.75	3	2	2	32	36	29	Initial peak
		20	20	20	50	54	51	Heat transfer stabilizes
	1.25	2	2	2	28	28	29	Initial peak
		15	13	15	53	58	53	Second peak
		45	54	45	69	65	65	Ignition
39 nylon - double butyl coated 12.5 oz/sq yd	0.40	7	10	12	52	62	57	Initial curve
		30	23	25	86	86	67	Melts
		44	45	35	98	88	117	Heat transfer stabilizes
	0.75	8	7	6	31	31	26	Initial peak
		15	16	16	81	132	140	Medium smoke
		25	20	30	100	114	118	Fabric destroyed
	1.25	3	4	4	17	30	22	Initial peak
		8	13	5	122	55	79	Ignition
5 cotton, resin modified butyl coated 10.5 oz/sq yd	0.40	3	3	4	33	57	38	Initial peak
		25	35	25	62	67	67	Heat transfer stabilizes
	0.75	4	4	4	41	44	35	Initial peak
		20	15	19	69	71	99	Medium smoke
		26	--	--	81	--	--	Ignition
	1.25	--	30	30	--	60	62	Heat transfer stabilizes
32 nylon, neoprene coated 7.7 oz/sq yd	0.40	15	8	8	48	64	67	Initial peak
		40	37	40	79	79	119	Medium smoke
		45	45	50	81	74	169	Heat transfer stabilizes
	0.75	6	3	6	28	23	27	Initial peak
		15	14	12	71	59	76	Medium smoke
		20	20	20	60	65	65	Heat transfer stabilizes
	1.25	5	4	5	109	53	33	Ignition
18 nylon, polyurethane coated 3.1 oz/sq yd	0.40	5	8	8	71	71	67	Initial peak
		15	20	16	100	100	100	Fabric melted
	0.75	2	2	2	33	36	41	Initial curve
		3	3	3	100	100	100	Melted
	1.25	2	2	2	82	71	78	Ignition
72 Polyacrylonitrile (PAN) 15.6 oz/sq yd	0.40	3	4	4	59	50	47	Initial peak
		45	50	40	73	73	59	Heat transfer stabilizes
	0.75	4	3	3	28	21	22	Initial peak
		28	25	25	77	81	76	Second peak
		45	35	40	64	67	63	Heat transfer stabilizes
	1.25	2	2	2	35	37	21	Initial peak
		10	11	12	52	53	52	Medium smoke
		45	25	40	70	60	75	Heat transfer stabilizes

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
<u>Fabric Assemblies:</u>								
4J polyester shell, wool liner 12.0 oz/sq yd	0.40	5	6	7	54	58	49	Outer shell melted
		34	32	35	73	65	69	Medium smoke
		--	50	--	--	116	--	Maximum heat transfer
		50	--	45	58	--	55	Heat transfer stabilizes
	0.75	4	4	4	43	43	47	Outer shell melted
		15	15	14	51	55	84	Heavy smoke, liner intumesces
		40	30	25	97	77	94	Maximum heat transfer
		45	35	35	60	60	70	Heat transfer stabilizes
	1.25	2	2	2	45	34	45	Outer shell melted
		6	6	13	45	54	45	Heavy smoke, intumesing, outer shell ignited
1A polyester batt, nylon fabric 4.6 oz/sq yd	0.40	5	2	4	23	18	28	Initial peak
		15	--	--	125	--	--	Assembly melts
		--	15	22	--	115	95	Heat transfer stabilizes
	0.75	4	4	4	29	26	27	Assembly melts, medium smoke
		7	6	7	100	100	100	Fabric destroyed
	1.25	2	2	2	115	70	50	Ignition
1 polyurethane coated nylon and 1A above	0.40	3	4	3	18	20	23	Initial peak
		15	16	17	60	38	53	Second peak
		20	--	--	100	--	--	Assembly melts
		20	40	45	100	80	63	Heat transfer stabilizes
	0.75	10	10	10	40	27	23	Assembly melts, medium smoke
		23	13	15	86	77	97	Heat transfer stabilizes
	1.25	3	3	2	28	25	25	Ignition of 1A only
13 50/50 cotton/nylon fluorocarbon treated outer shell; 100% nylon liner 20.0 oz/sq yd	0.40	7	10	10	20	32	29	Initial peak
		40	35	35	41	55	41	Medium smoke
		40	36	52	41	107	88	Maximum heat transfer
	0.75	10	10	10	25	33	30	Medium smoke
		17	16	20	24	23	26	Heavy smoke
		20	30	35	93	30	193	Assembly melts
	1.25	--	3	3	--	11	12	Initial peak
		3	7	8	8	21	19	Ignition of outer shell only
2A 50/50 cotton/poly- ester outer shell; 100% nylon liner 12.5 oz/sq yd	0.40	6	5	4	18	13	15	Initial peak
		35	30	30	53	43	55	Light smoke
		50	45	40	58	48	53	Heat transfer stabilizes
	0.75	3	3	4	20	14	15	Initial peak
		10	11	10	41	39	39	Assembly ignition
	1.25	5	4	5	27	21	29	Assembly ignition
		32	30	30	52	46	30	Maximum heat transfer
		Curing ignition						

Appendix Table 3 (cont)

Heat Transfer to an Underlying Surface from Fabrics Exposed to Various Unilateral Radiant Heat Flux Levels

Fabric No.	Incident Radiant Heat Flux (cal/cm ² /sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Fabric Assemblies: (cont)								
55	0.40	5	5	5	32	37	45	Initial
50/50 cotton/nylon		30	32	33	44	58	55	Medium smoke
fluorocarbon treated		60	60	60	77	124	124	Maximum heat transfer
outer shell								
(same as #13);	0.75	4	4	4	24	44	37	Initial peak, medium smoke
100% cotton liner;		17	25	40	60	87	99	Maximum transfer during
polyester batt/								ignition
nylon fabric								
22.0 oz/sq yd	1.25	2	3	4	17	27	26	Ignition
		20	3	4	49	27	26	Maximum transfer during
								ignition
21L	0.40	7	7	6	39	46	54	Initial peak
100% wool outer		30	25	30	37	39	32	Heavy smoke
shell; 100% nylon		55	55	50	49	46	51	Heat transfer stabilizes
liner								
24.9 oz/sq yd	0.75	6	7	7	41	42	36	Initial peak
		15	15	15	25	29	28	Heavy smoke, intumesces
		33	45	35	91	48	69	Maximum heat transfer
	1.25	5	4	5	28	26	28	Initial peak
		13	13	13	13	13	12	Heavy smoke, intumesces
		15	28	22	25	25	13	Assembly ignition
58	0.40	6	4	7	35	45	43	Initial peak
nylon/acrylic outer		18	20	18	100	113	128	Medium smoke
shell; carbon im-		30	50	35	100	78	98	Heat transfer stabilizes
pregnated liner								
10.7 oz/sq yd	0.75	4	4	4	31	31	41	Initial peak
		8	8	8	88	86	85	Outer shell melts, medium
								smoke
		20	20	25	97	98	86	Maximum heat transfer
		45	40	35	70	70	69	Heat transfer stabilizes
	1.25	2	2	2	32	28	25	Initial peak
		4	4	4	50	52	32	Ignition, outer shell
								only