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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The heat protective capabilities of a variety of fabrics used in Navy Shipboard outerwear garments have been characterized in several ways. Fabric tensile strength retention during short-term exposure to bilateral radiant heat at fluxes to 0.8 cal/cm²/sec, time-to-ignition at bilateral radiant fluxes to 1.1 cal/cm²/sec, and the level of heat transferred to an underlying surface as the result of unilateral radiation to 1.25 cal/cm²/sec and

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20. Abstract (continued)

flame exposure at 2.2 cal/cm^2/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)

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/cm^2/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/cm^2/sec, in one case, and to a directly impinging flame at 2.2 cal/cm^2/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) 0.035 psi	Thickness (inch) 0.63 psi	Color	Intended Use
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	0.031	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 shipboard 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) 0.035 psi	0.63 psi	Color	Intended Use
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) poly-acrylonitrile	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 fluorocarbon 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 fluorocarbon treated outer shell (same as #13); 100% cotton liner; polyester batt-nylon fabric	sateen; oxford; quilted batt	22.0	0.335	0.213	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)
Single-Layer Fabrics:					
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/cm^2/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.)

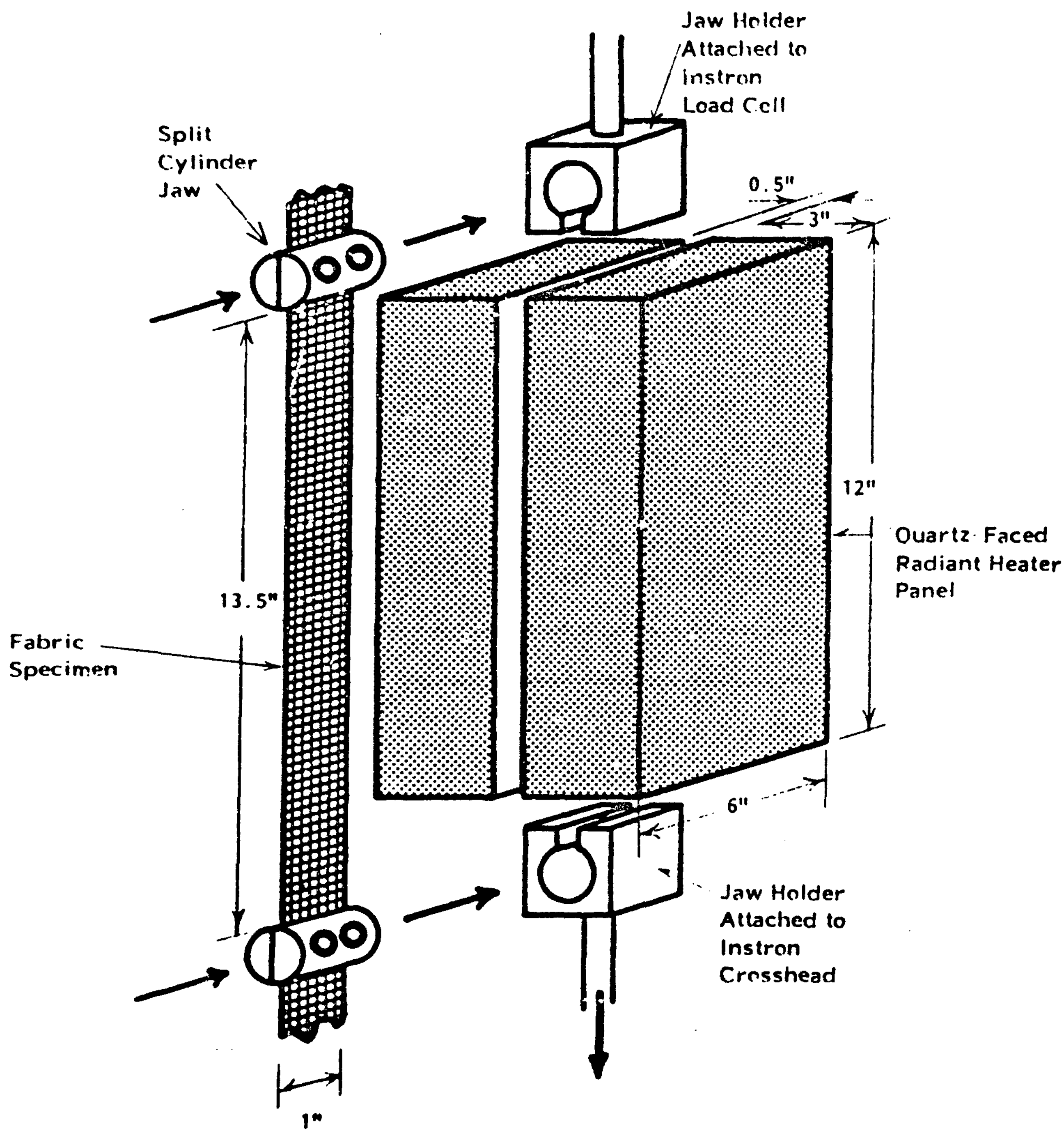


Figure 1. Test Configuration for Exposure of Fabric Specimen to Bilateral Radiant Heat

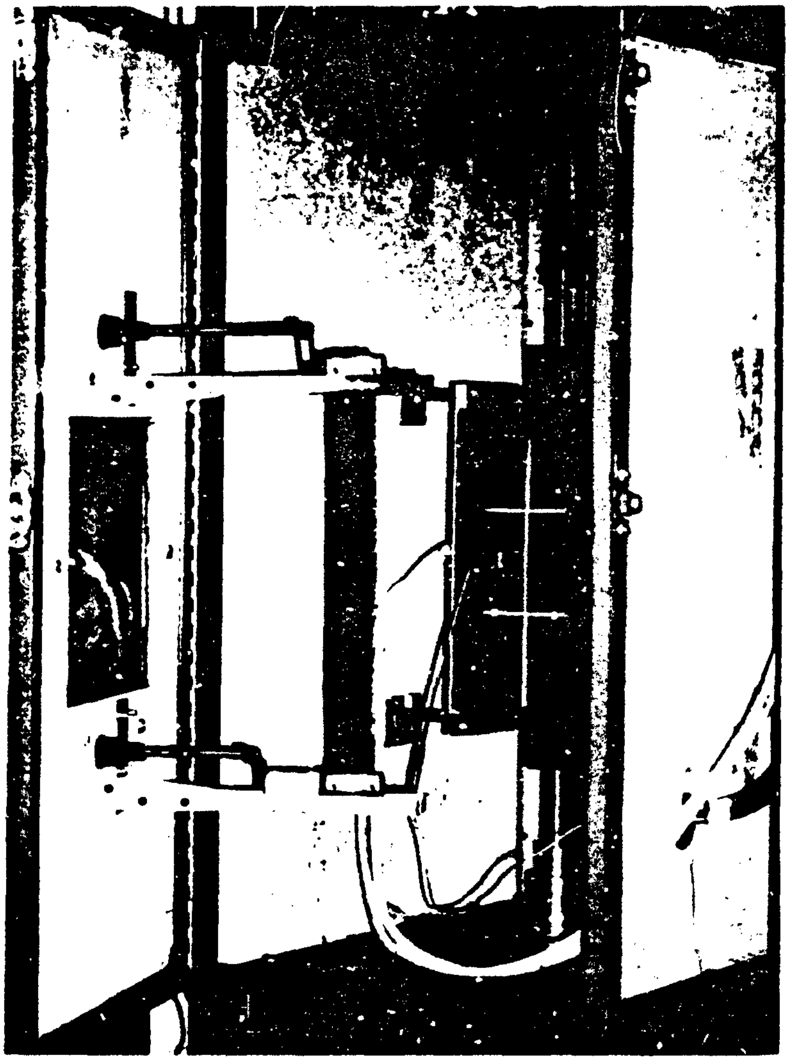


Figure 2. Quartz-Faced Radiant Heater Panels and Fabric Specimen in Test Chamber

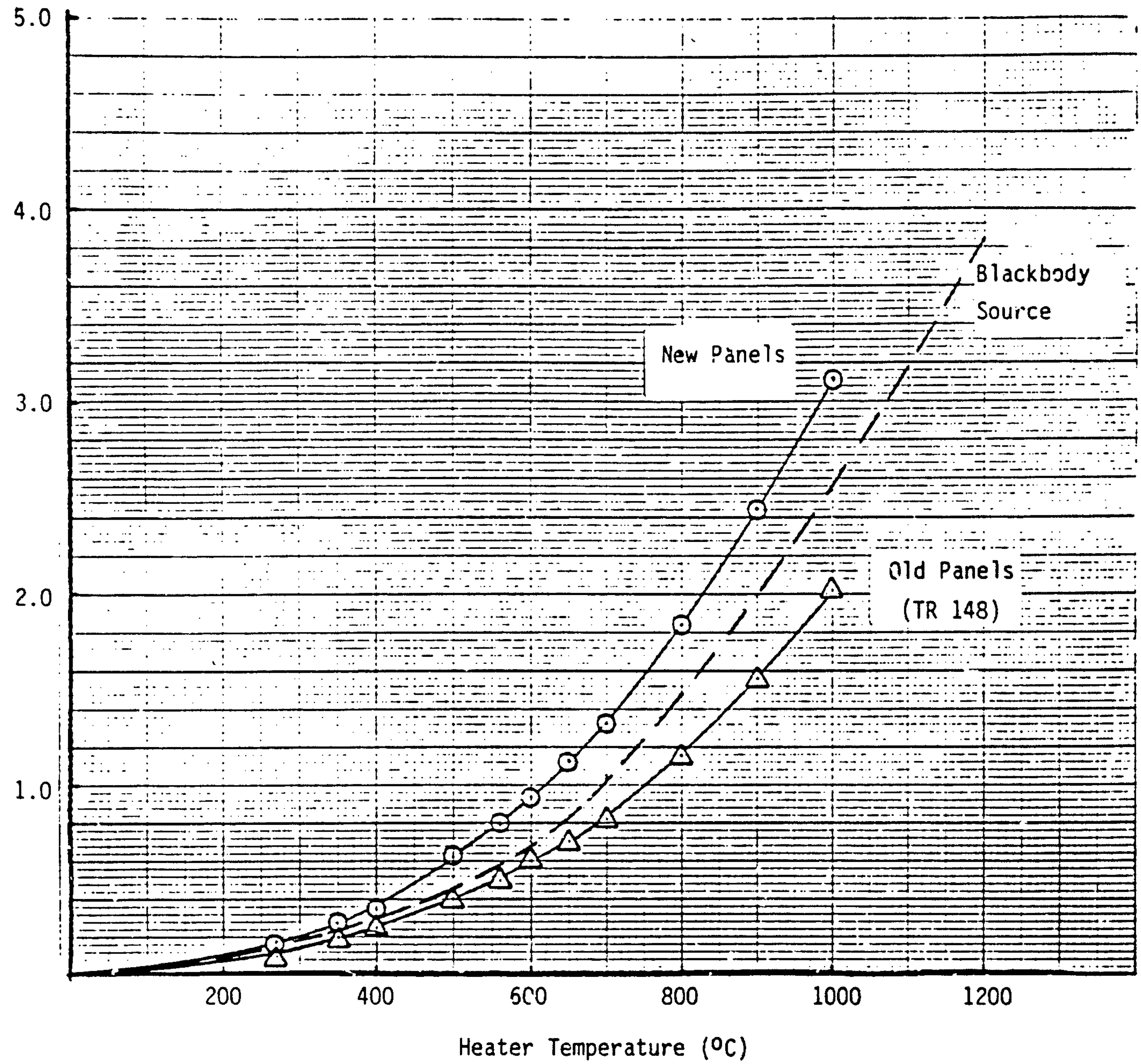


Figure 3. Initial Bilateral Radiant Heat Flux Absorbed by Fabric Specimen

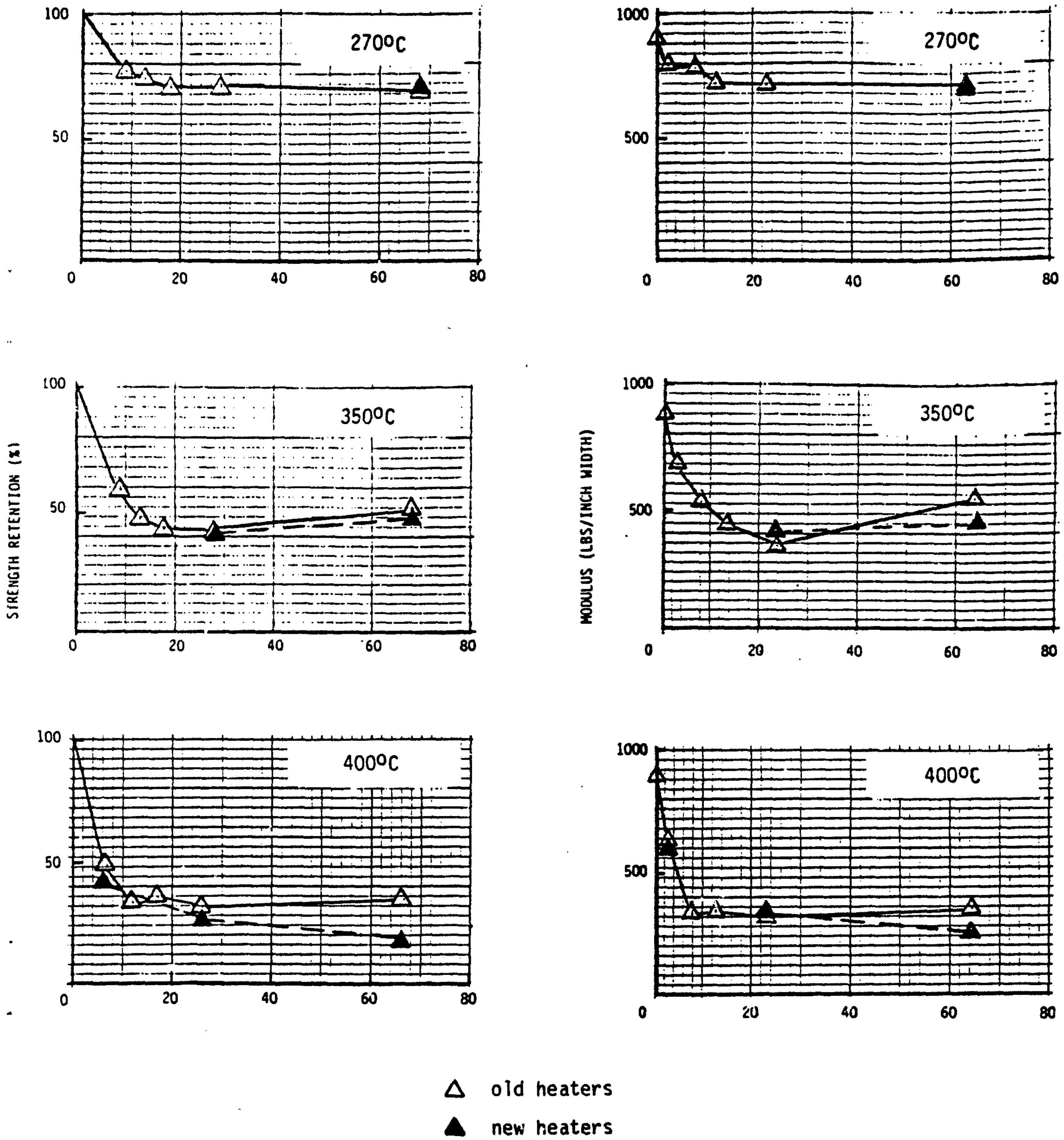


Figure 4. Strength Retention and Modulus of Control Fabric #17 (95/5 Nomex/Kevlar, 4.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

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:

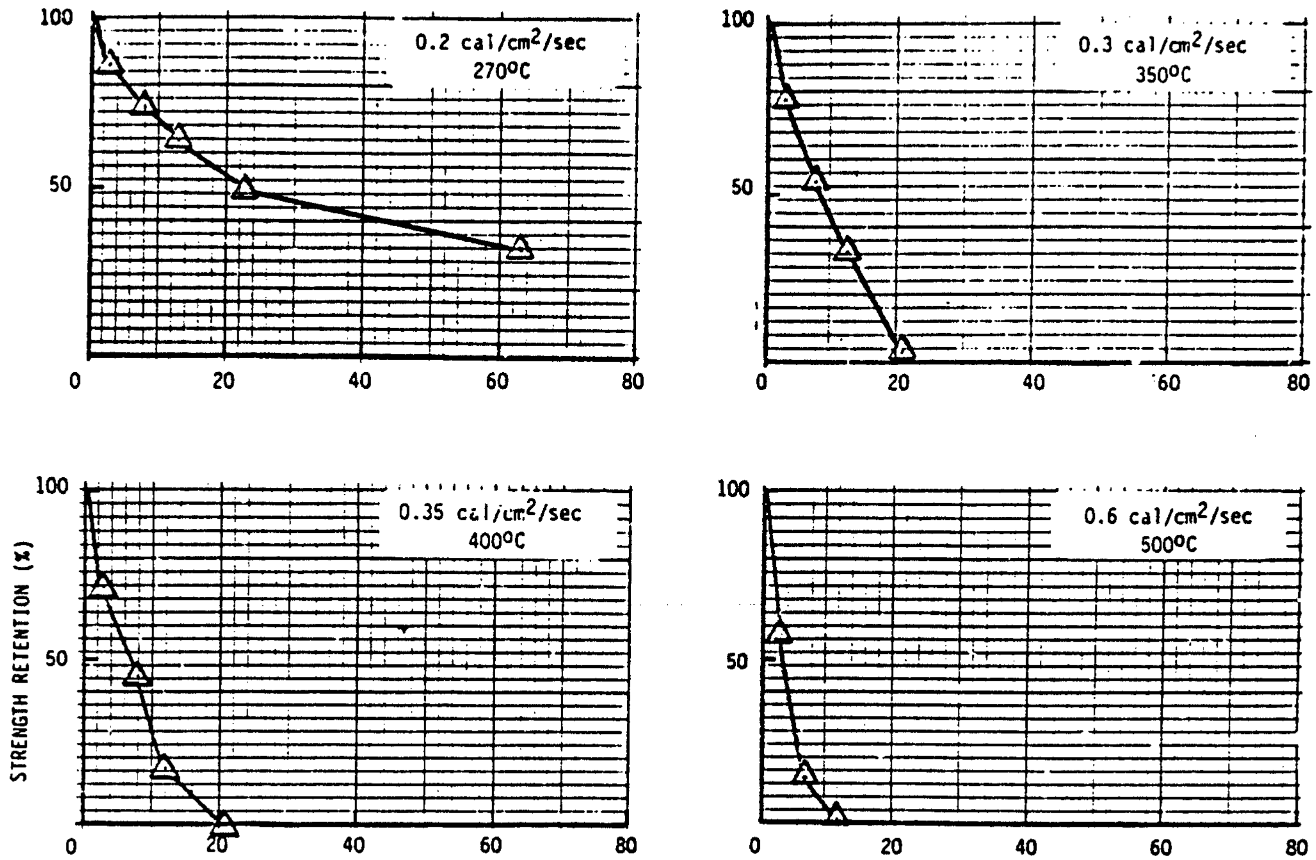
270°C (0.2 $cal/cm^2/sec$);
350°C (0.3 $cal/cm^2/sec$);
400°C (0.35 $cal/cm^2/sec$);
500°C (0.6 $cal/cm^2/sec$); and
560°C (0.8 $cal/cm^2/sec$).

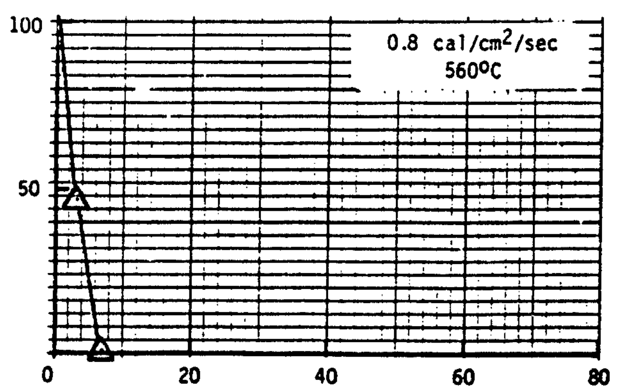
These temperatures were chosen to correspond with the heater temperatures used in the earlier work described in TR 148. Measurements were made after five different exposure times, where appropriate, ranging from a few seconds to one minute.

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.)





HEAT FLUX (cal/cm^2/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	---	---
0.3	---	---
0.35	No ignition, 2 min	
0.6	---	15 (glow only)
0.8	5-7	6
0.9	---	5
1.1	2-3	3

DURATION OF EXPOSURE (SEC)

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

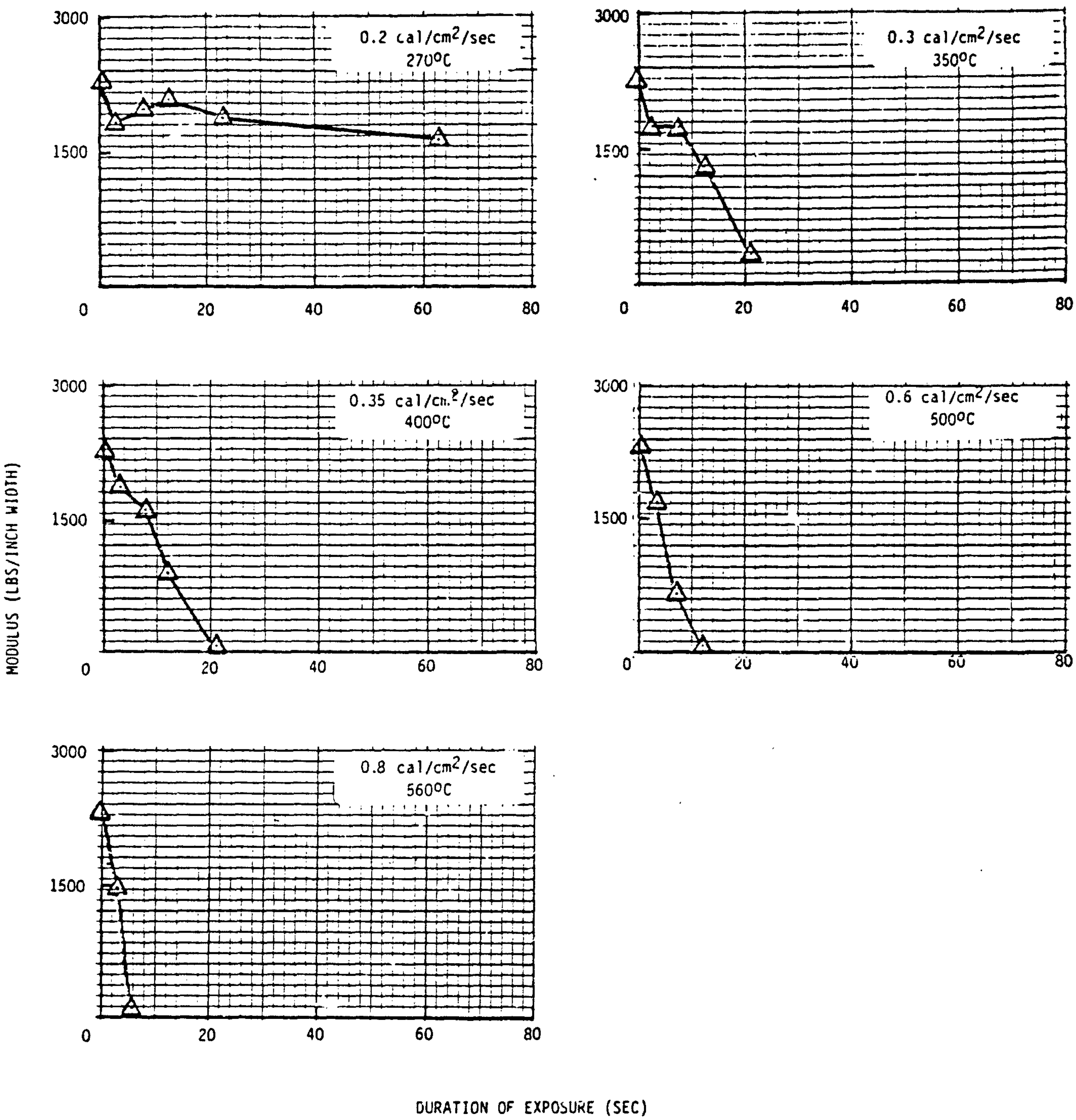
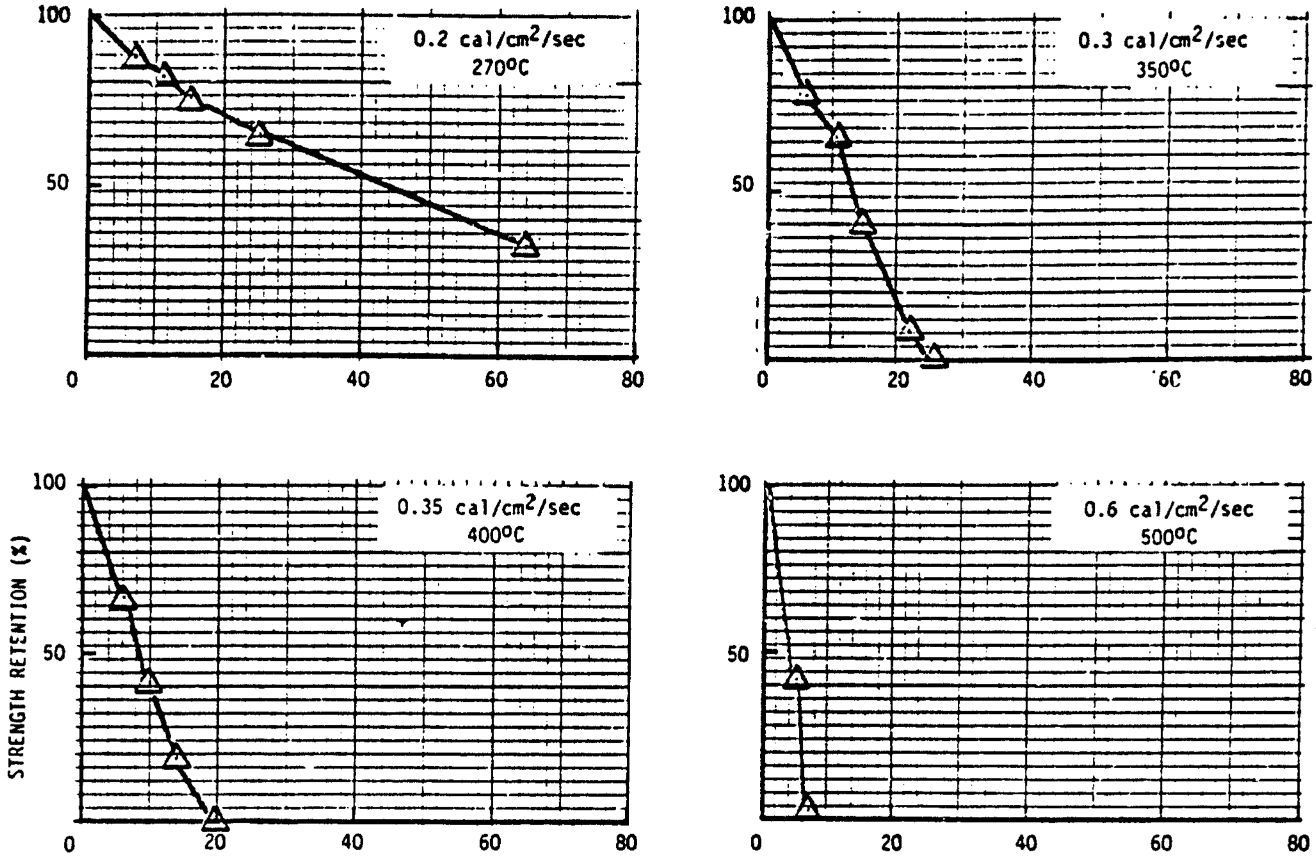
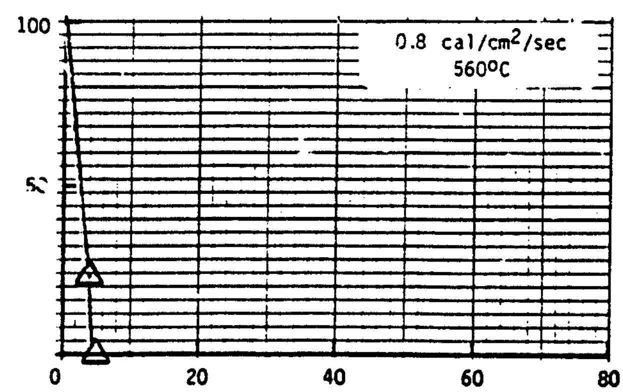


Figure 5b. Modulus of Fabric #38 (100% cotton, 10.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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	5-6	5
0.9	3-5	3
1.1	---	2

DURATION OF EXPOSURE (SEC)

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

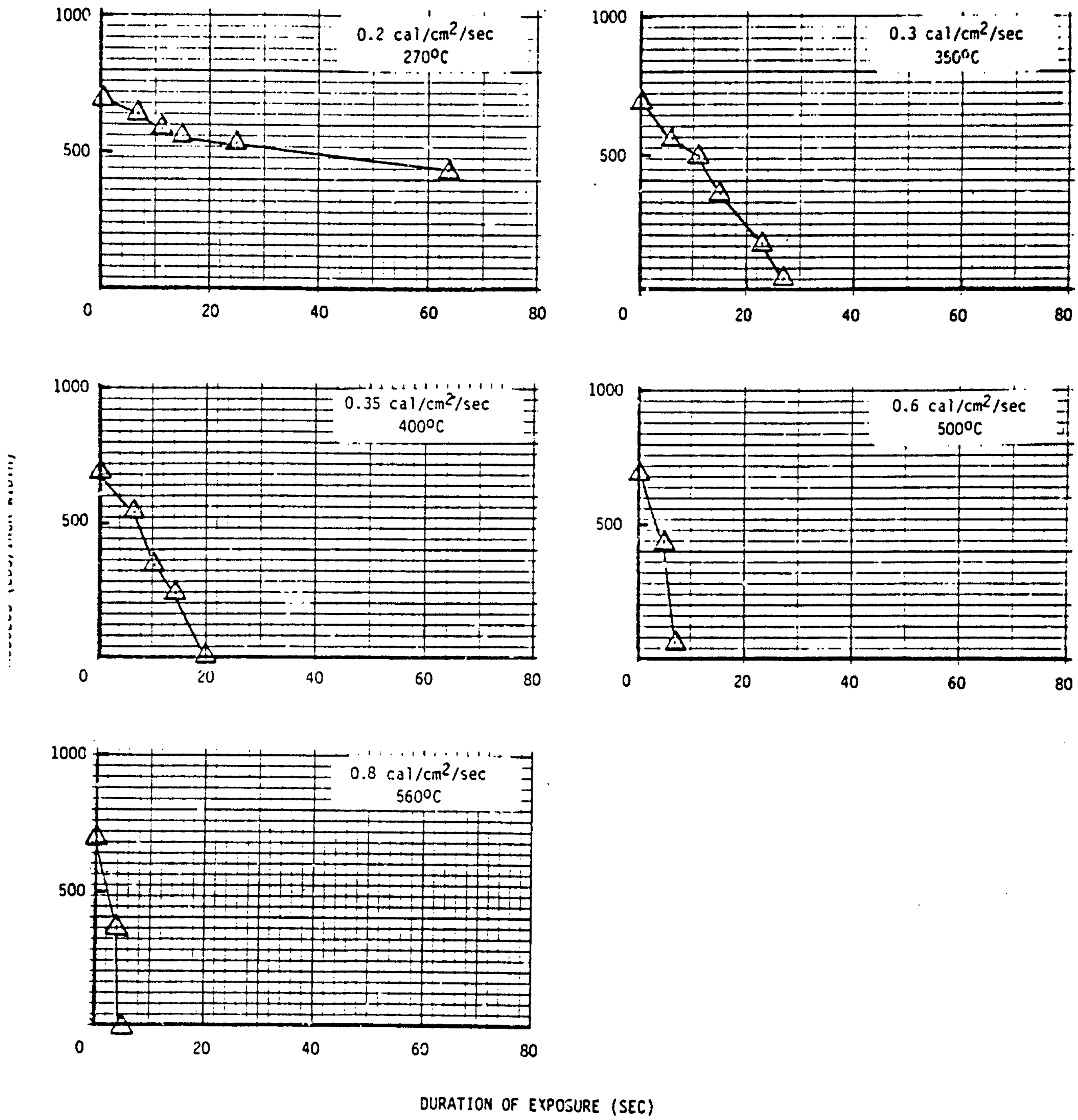
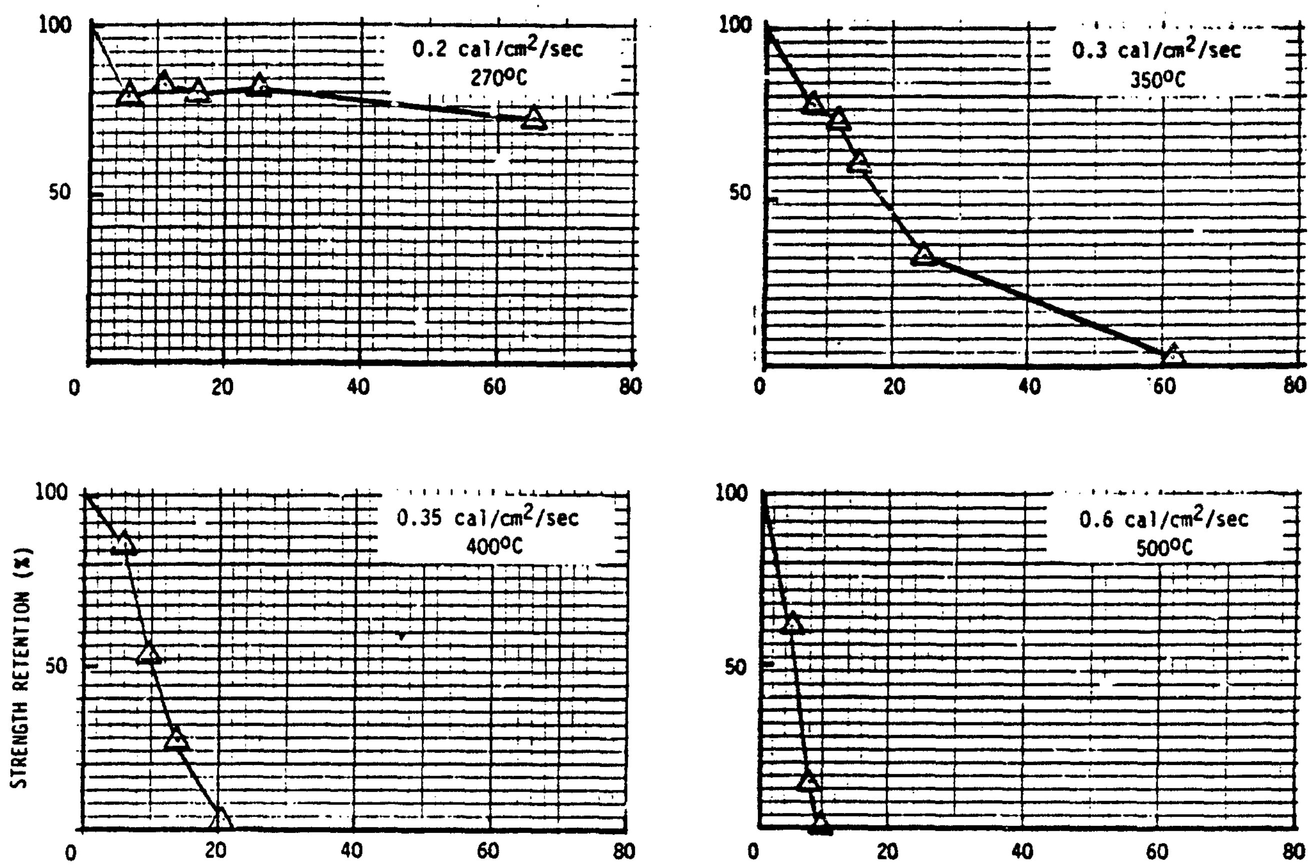
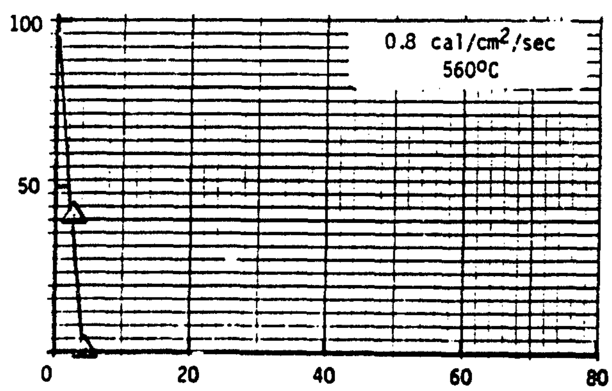


Figure 6b. Modulus of Fabric #70 (80/20 PFR rayon/polyester, 8.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	No ignition, 2 min	
0.3	70-94	82 (2 of 3 glowed
0.35	30-34	32 (glow only)
0.6	8-14	11
0.8	3-8	6
0.9	--	5
1.1	3-4	4

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

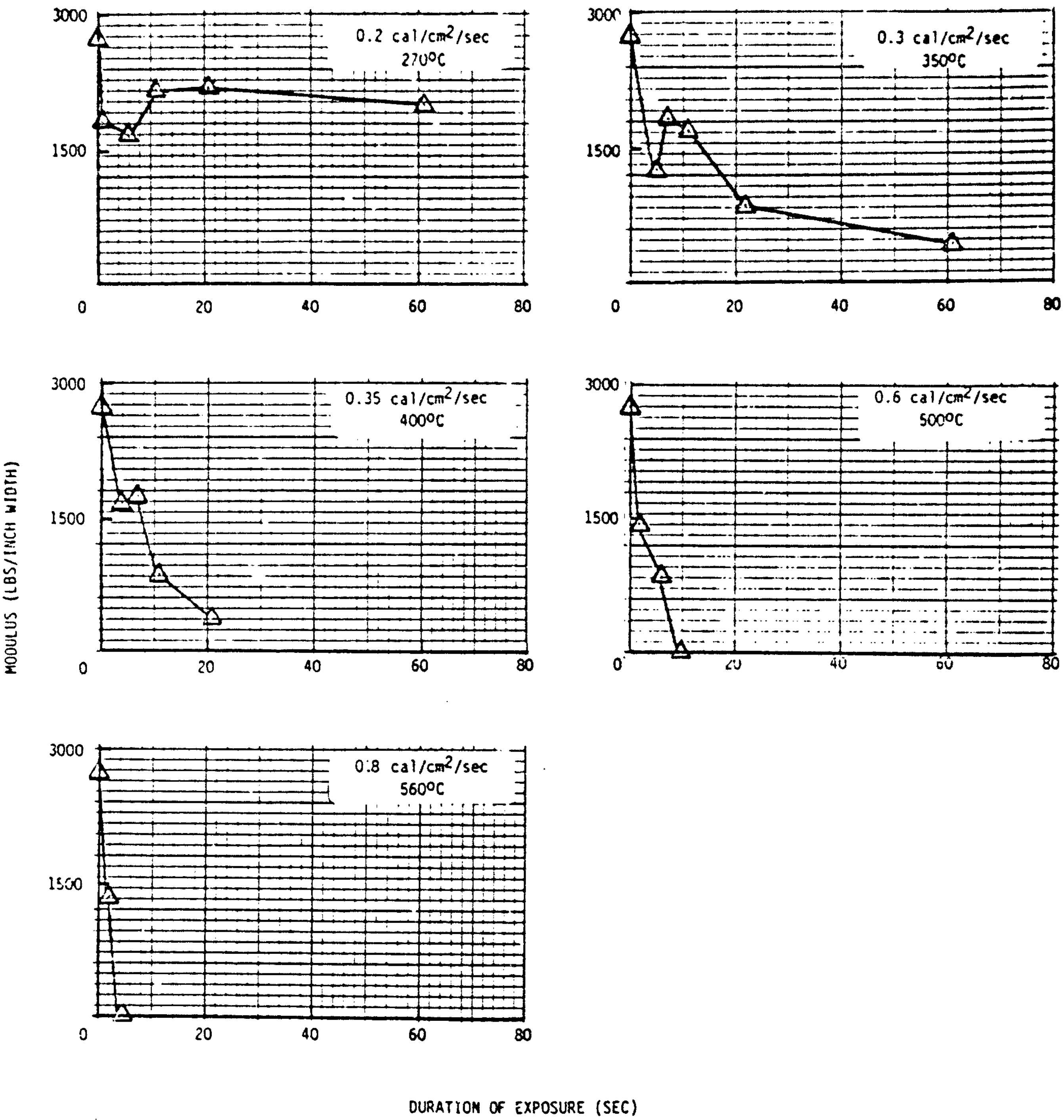
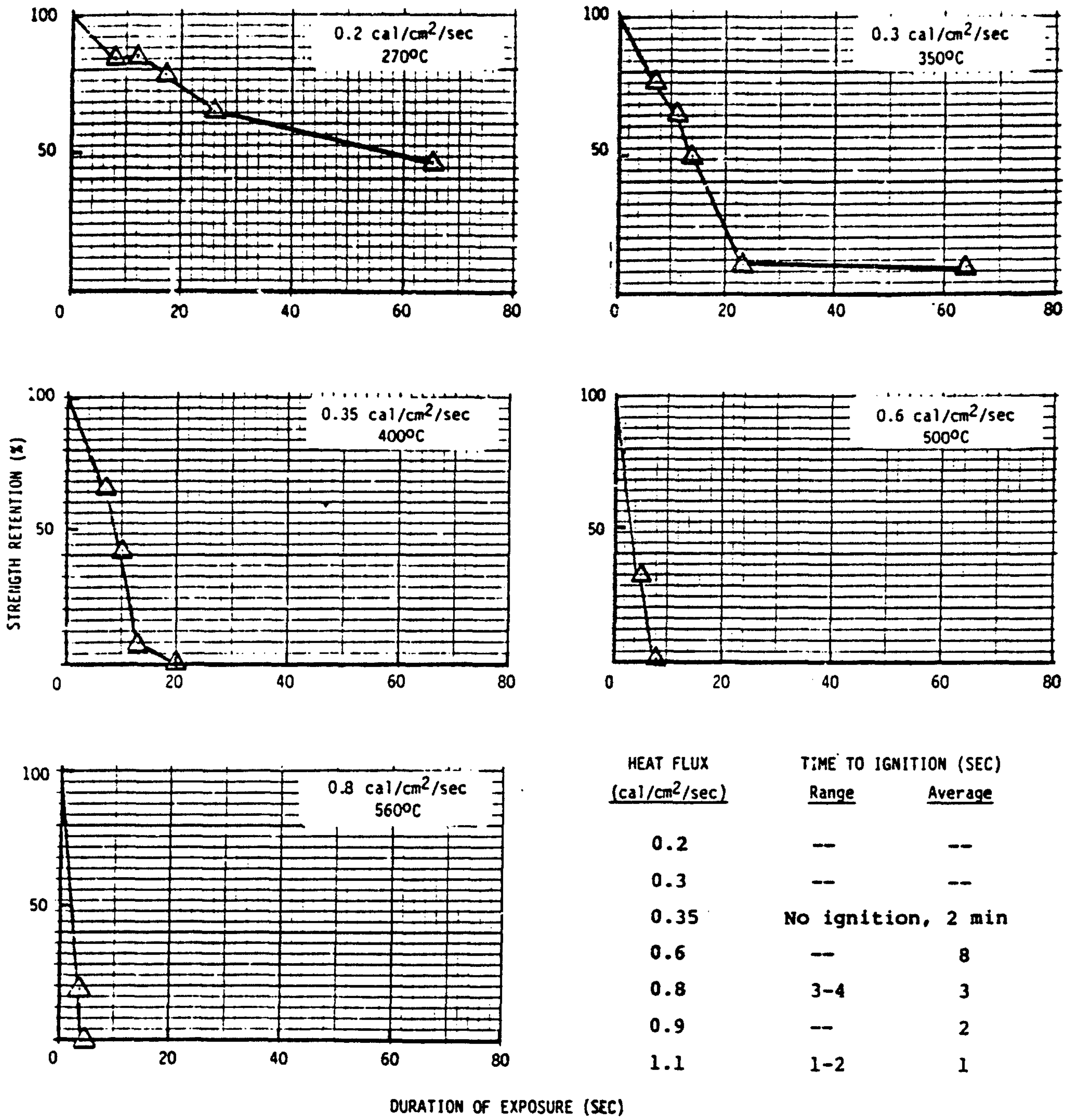


Figure 7b. Modulus of Fabric #10 (rayon warp/cotton fill, 8.2 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	--	--
0.3	--	--
0.35	No ignition, 2 min	
0.6	--	8
0.8	3-4	3
0.9	--	2
1.1	1-2	1

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

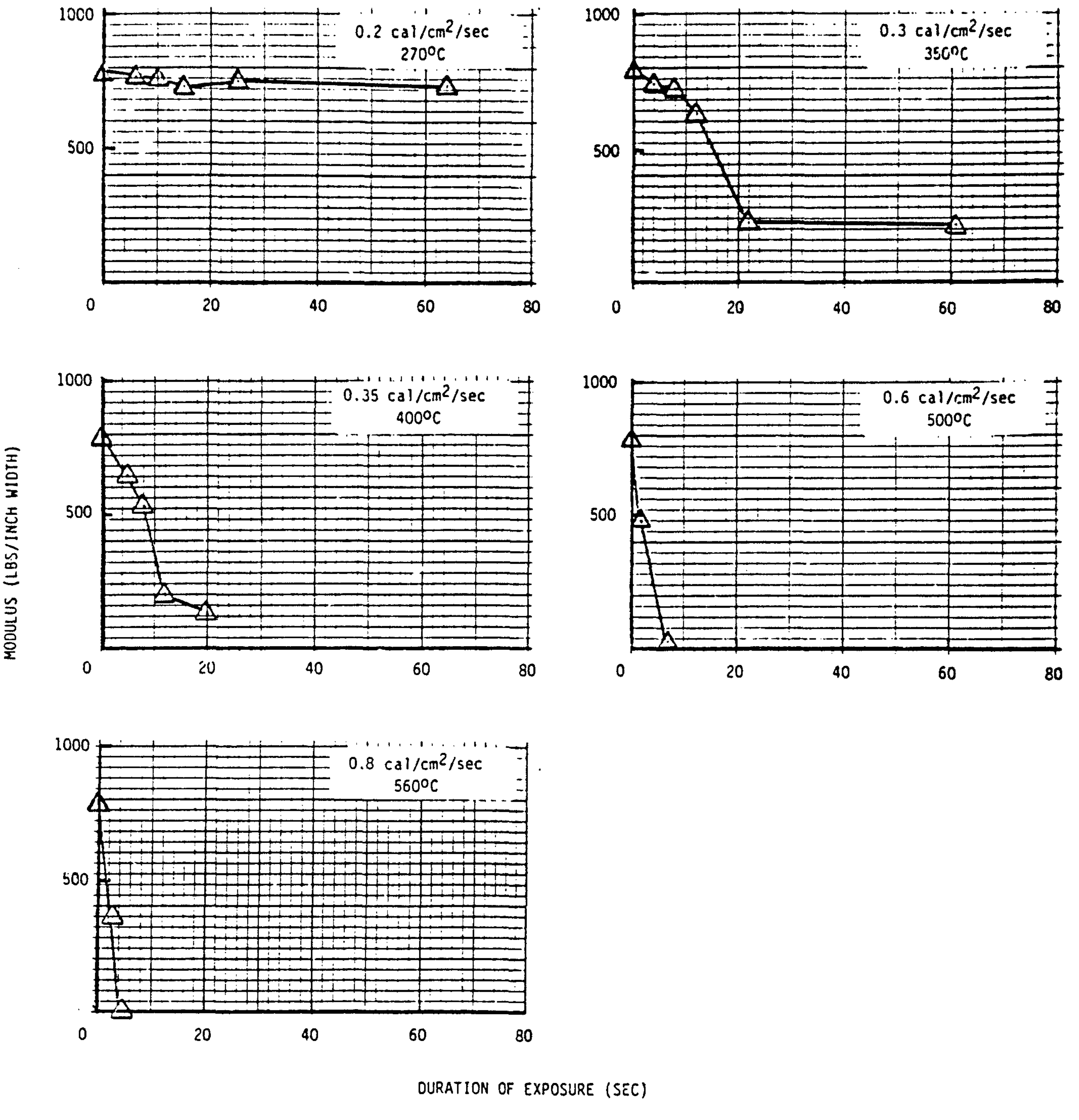
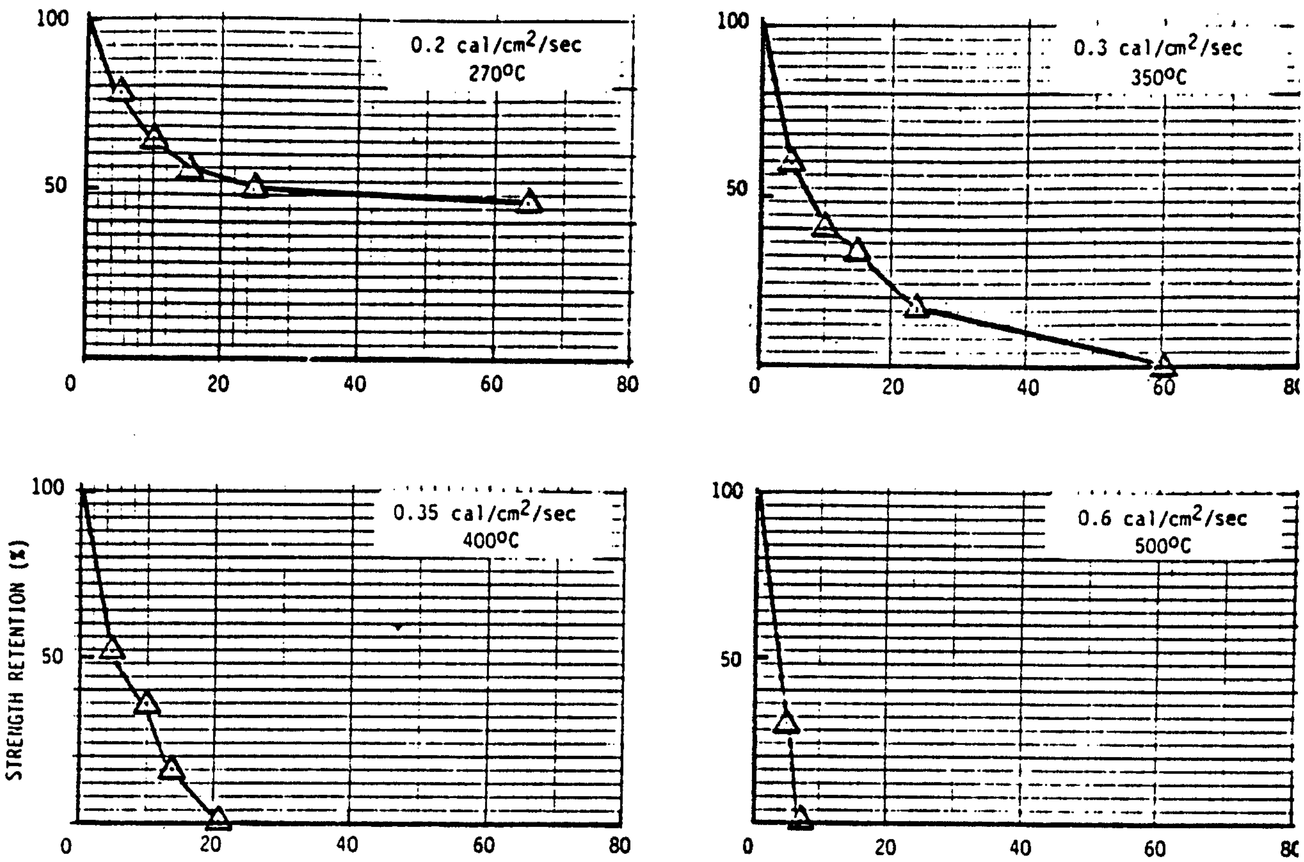
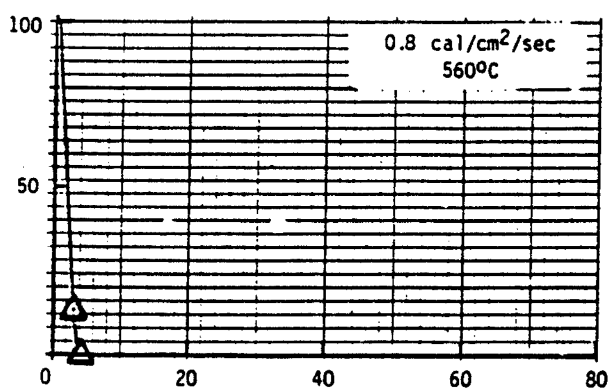


Figure 8b. Modulus of Fabric #34 (80/20 PFR rayon/Nomex, 7.0 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	---	---
0.3	No ignition, 2 min	
0.35	43-51	47
0.6	5-6	6
0.8	4-5	4
0.9	3-4	3
1.1	1-2	1

DURATION OF EXPOSURE (SEC)

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

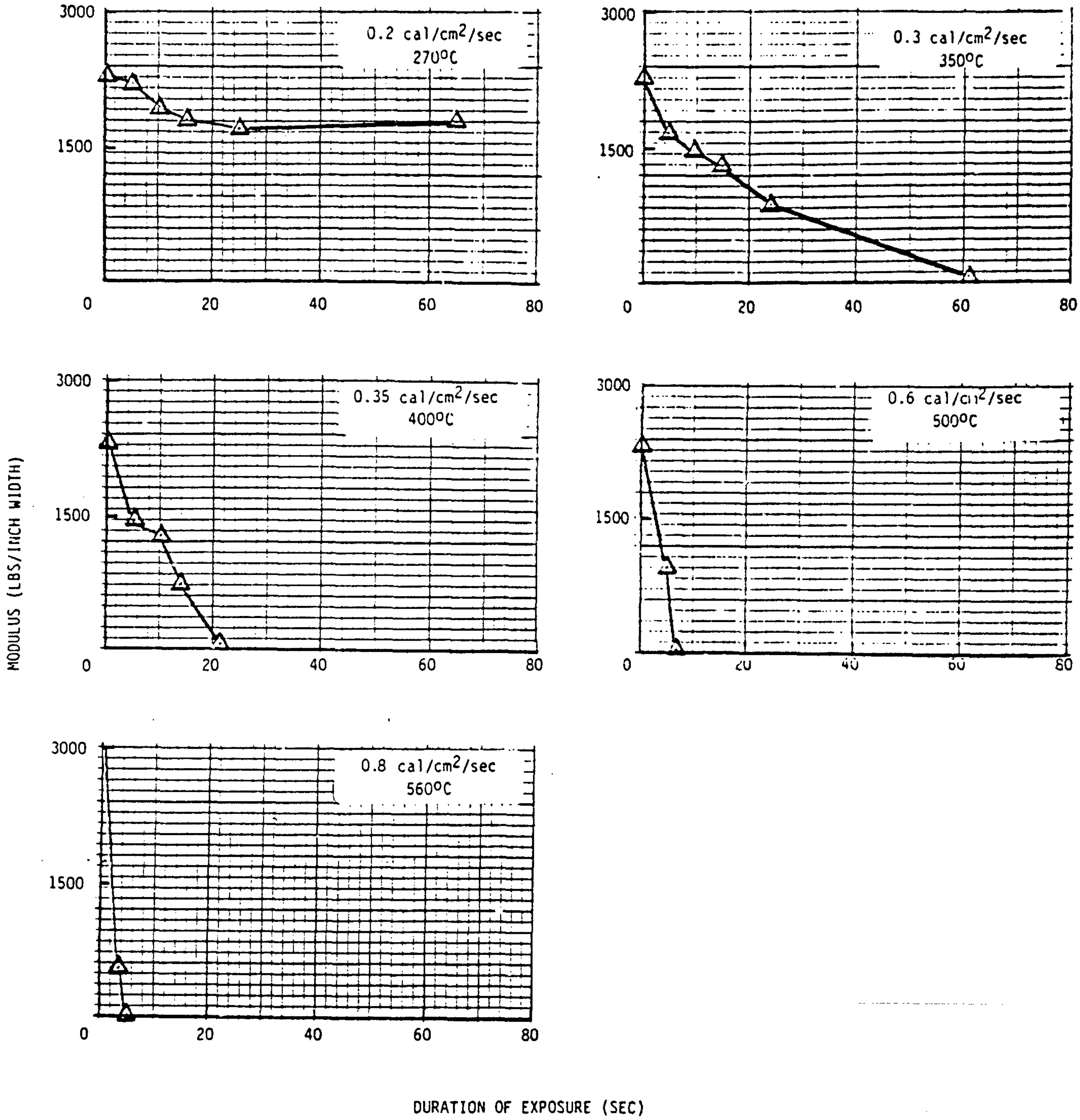
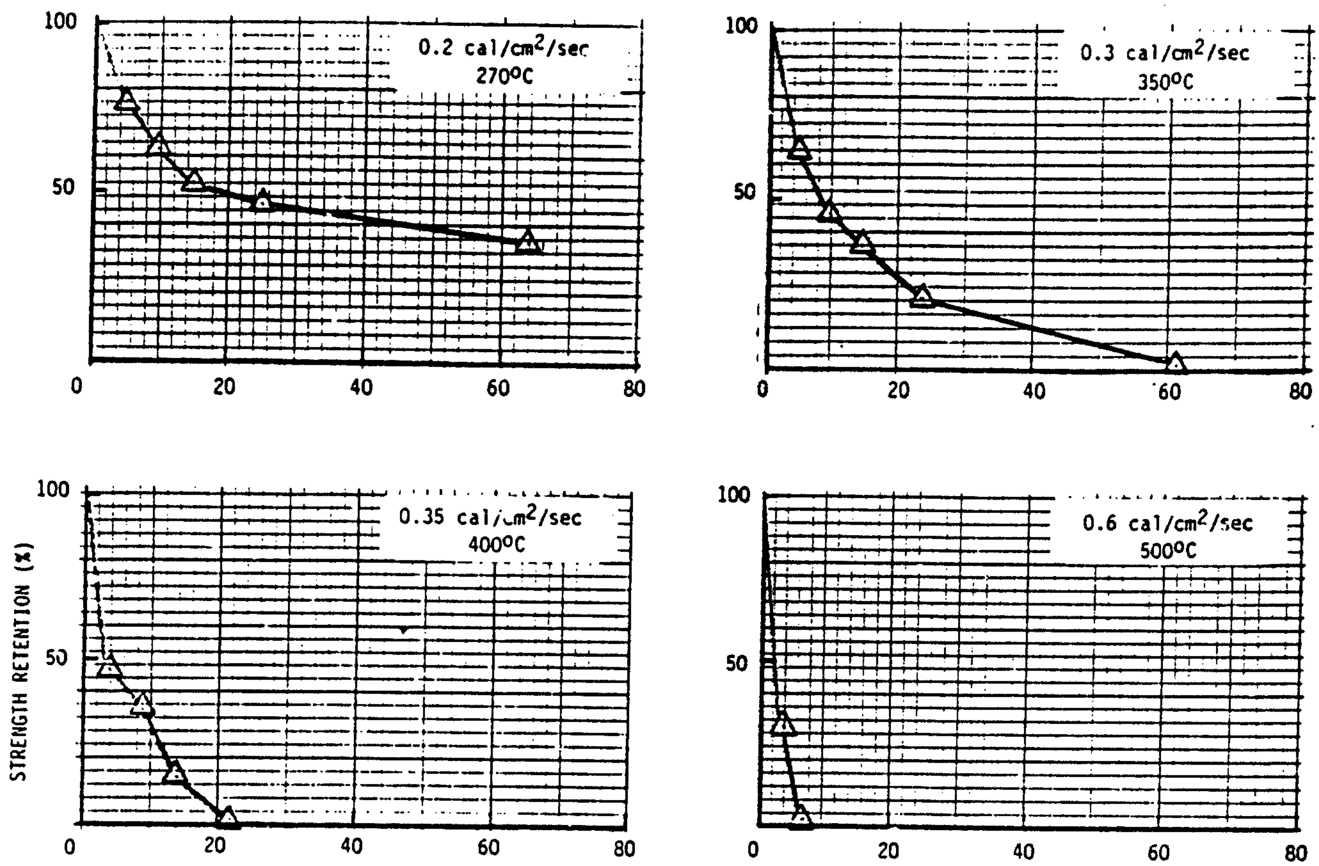
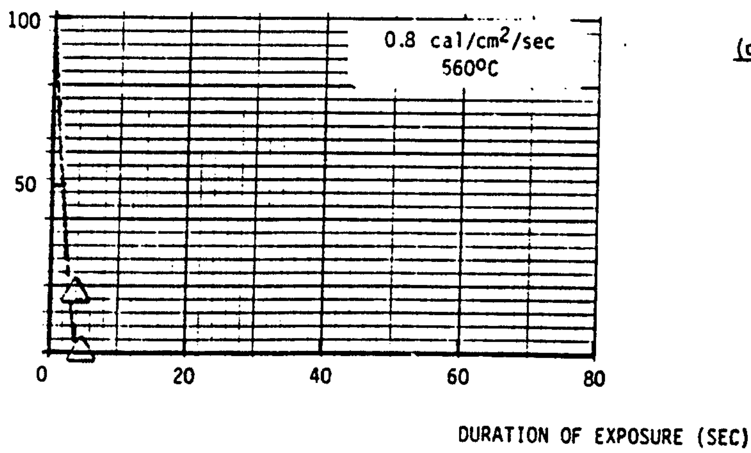


Figure 9b. Modulus of Fabric #44 (100% cotton, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX ($cal/cm^2/sec$)	TIME TO IGNITION (SEC) Range	Average
0.2	No ignition, 2 min	
0.3	70-105	88 (glow only)
0.35	33-48	42
0.6	6-9	8
0.8	3-4	4
0.9	--	3
1.1	1-2	2

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

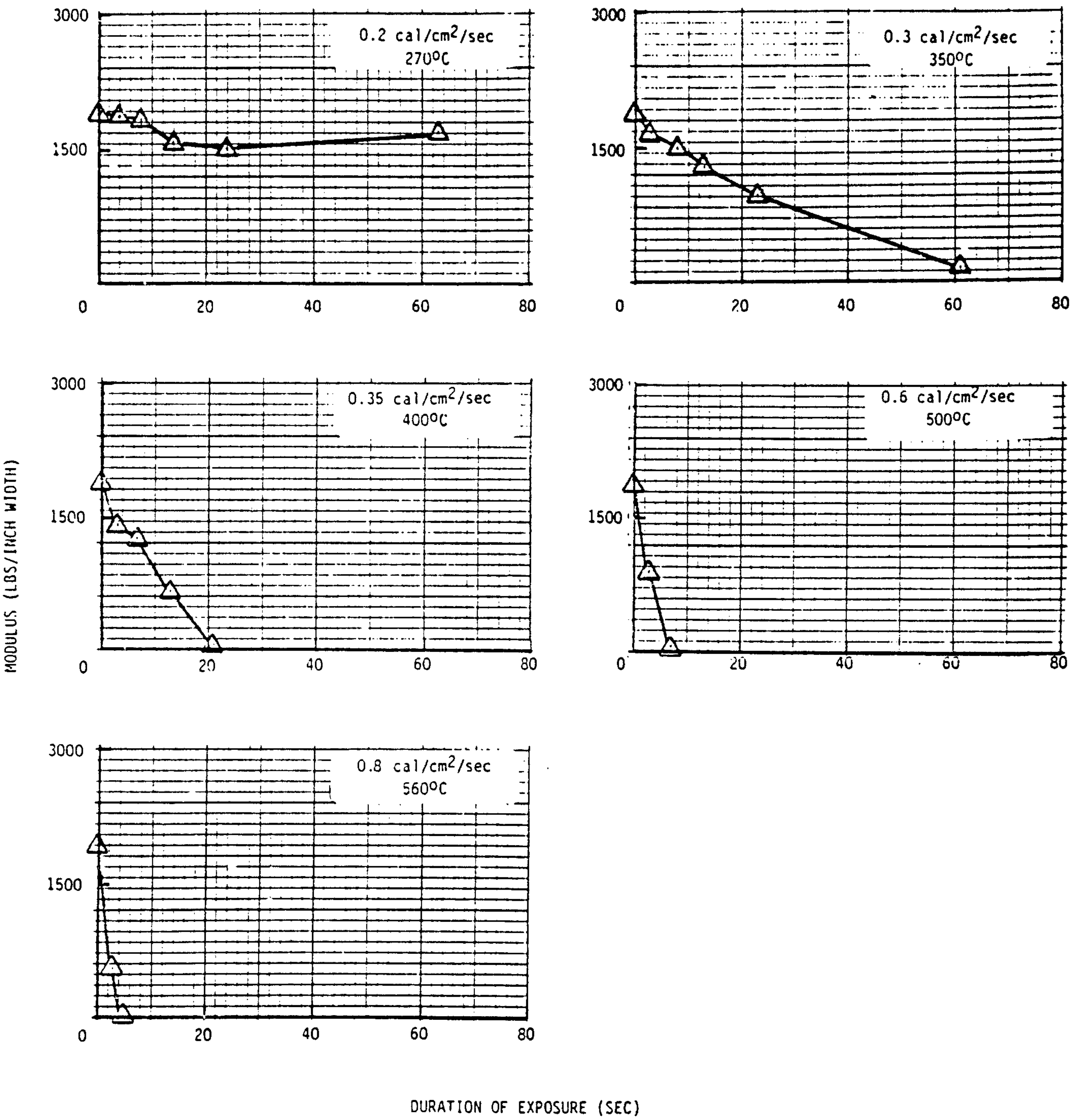
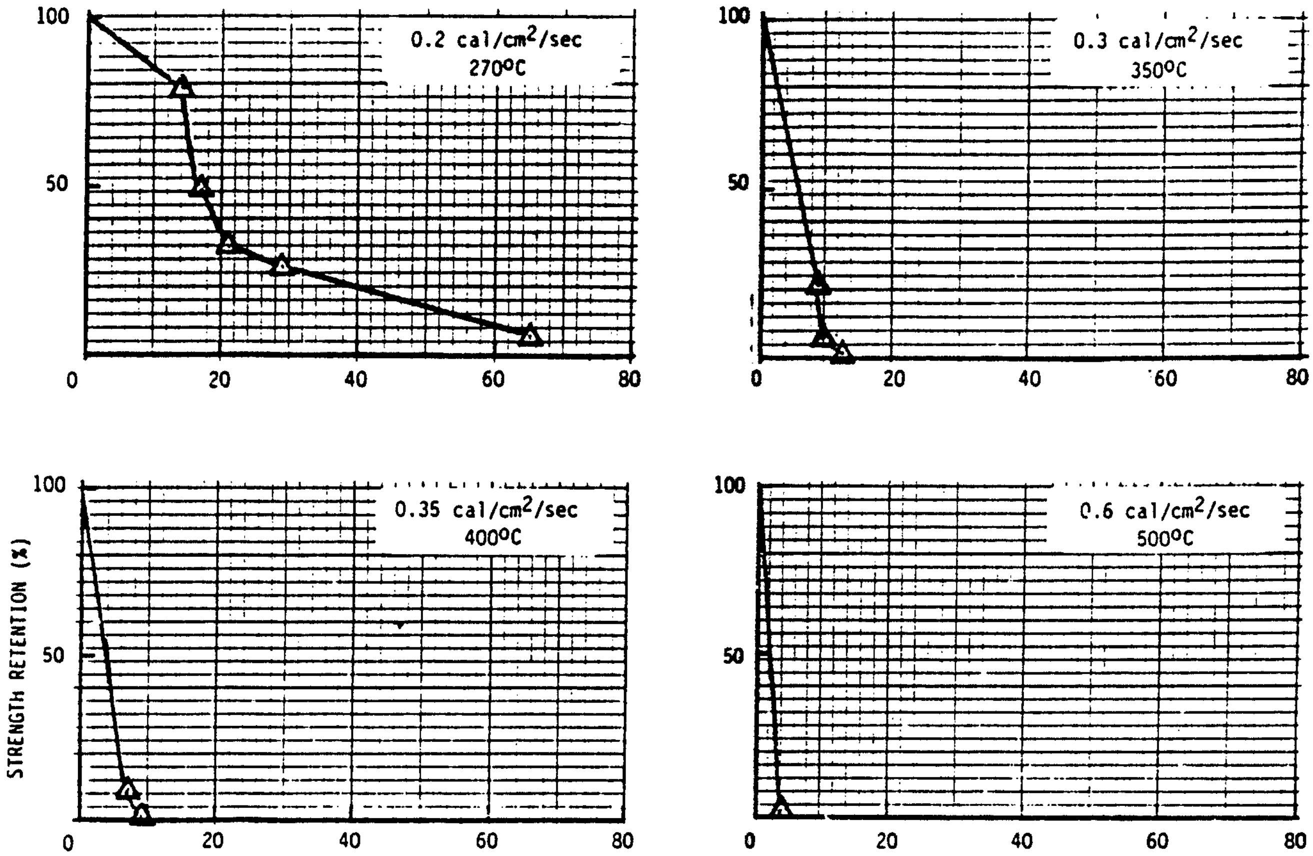
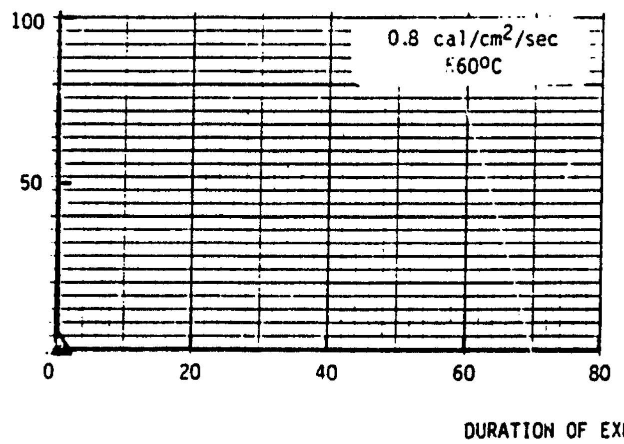


Figure 10b. Modulus of Fabric #50 (100% cotton, 6.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm^2/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	No ignition, 2 min	
0.3	--	35 (glow on
0.35	21-23	22 (glow on
0.6	5-6	6
0.8	--	4
0.9	--	3
1.1	--	2

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

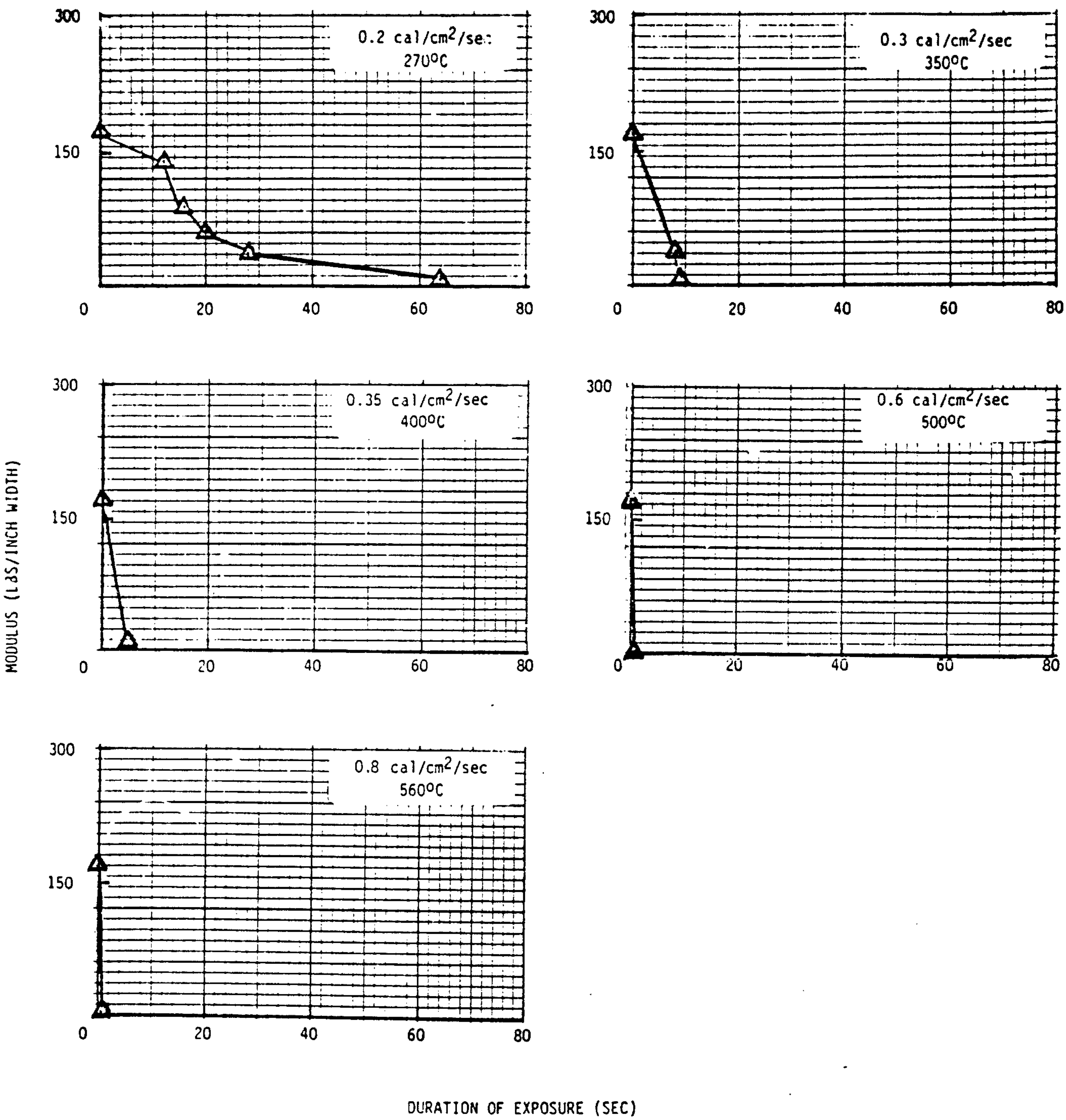
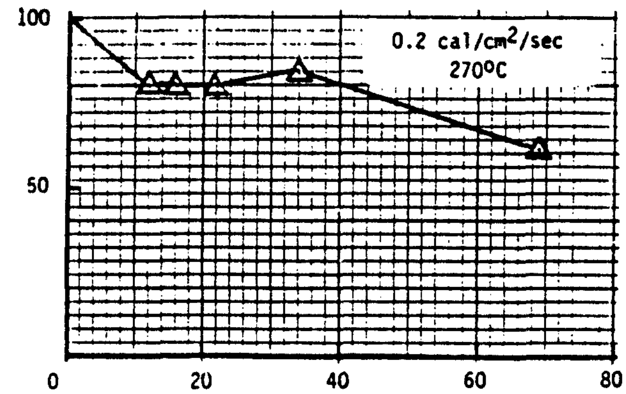
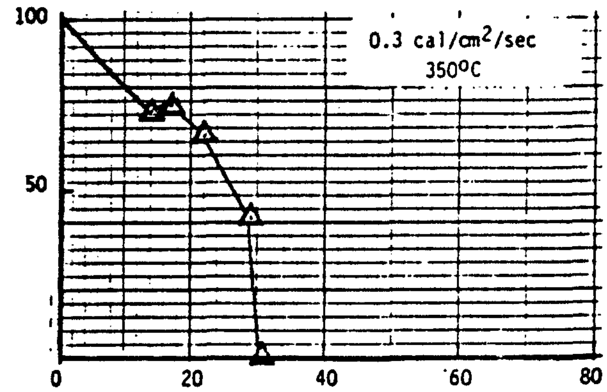
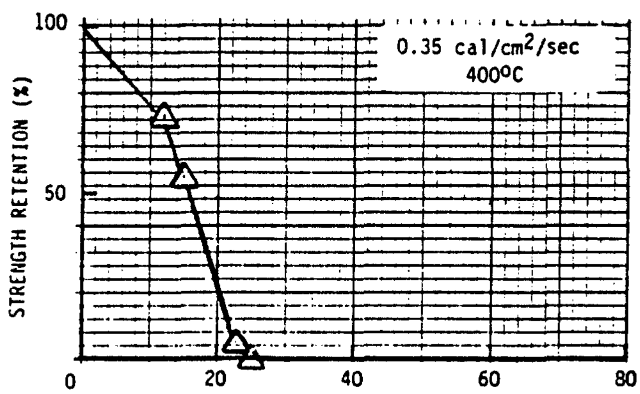
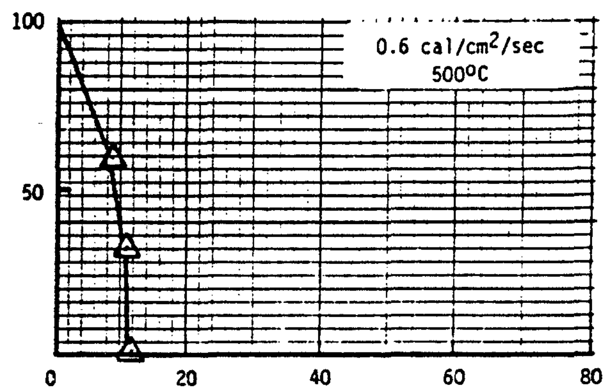


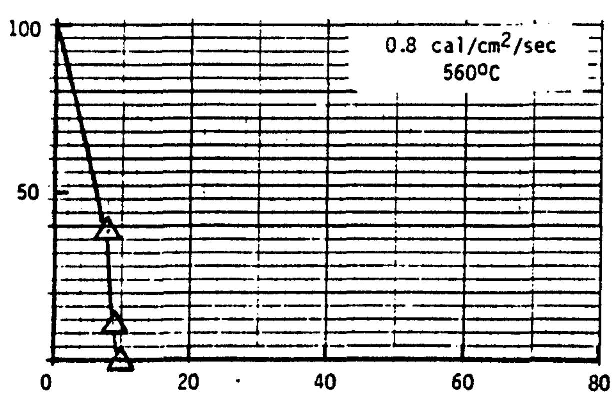
Figure 11b. Modulus of Fabric #37 (100% cotton, 5.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat











HEAT FLUX ($cal/cm^2/sec$)	TIME TO IGNITION (SEC) Range	Average
0.2	--	--
0.3	--	--
0.35	No ignition, 2 min	
0.6	105-120	112 (glow only)
0.8	54-63	58
0.9	33-44	37
1.1	11-34	24

DURATION OF EXPOSURE (SEC)

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

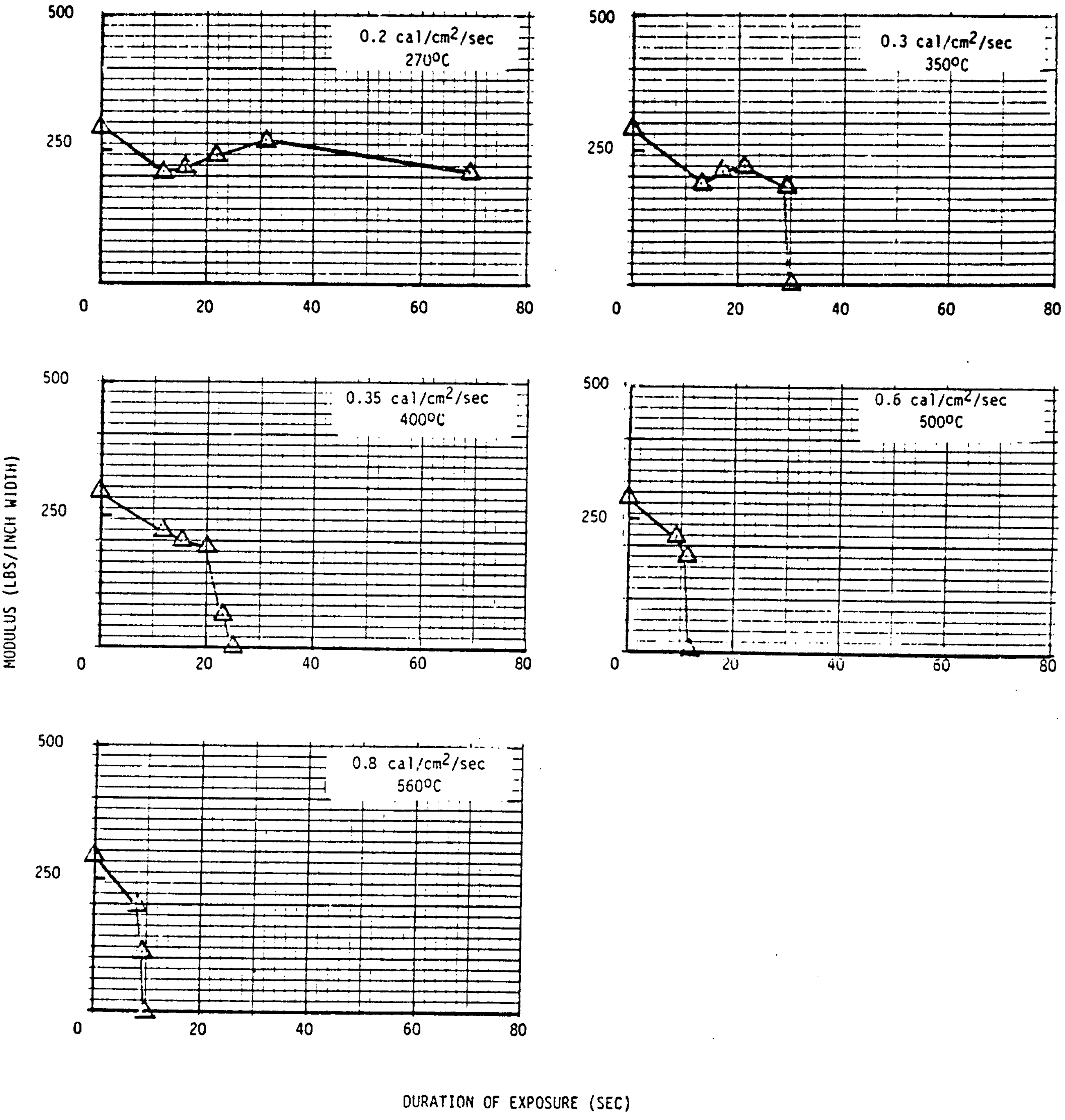
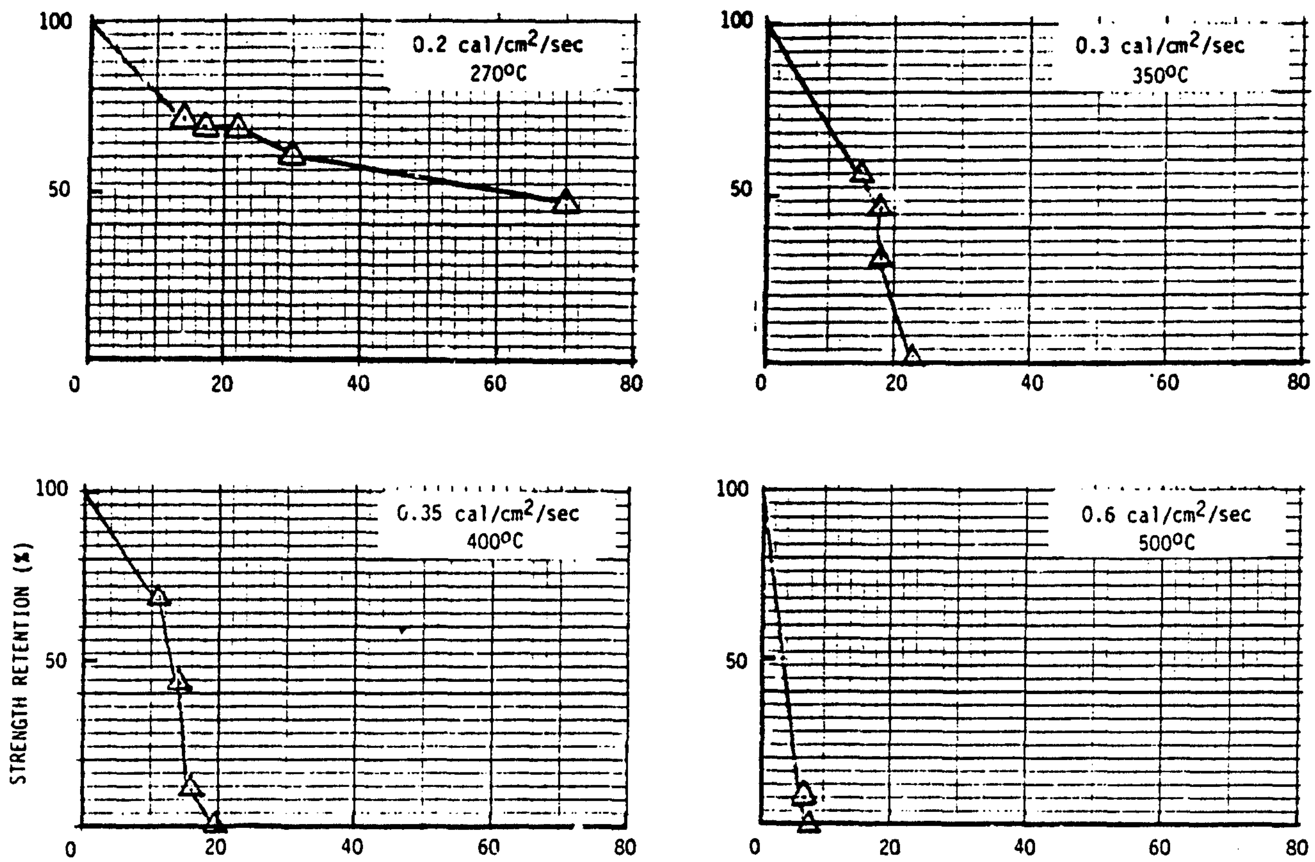
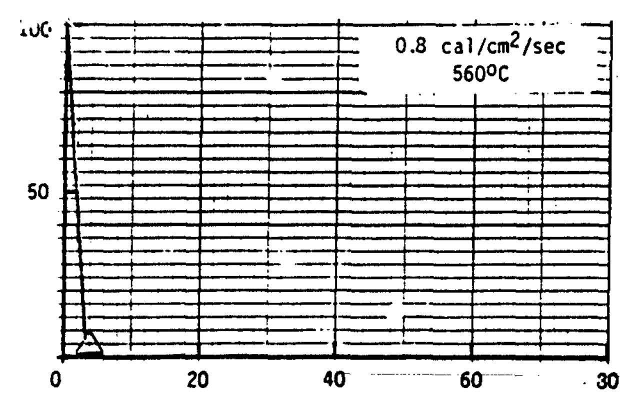


Figure 12b. Modulus of Fabric #21 (100% wool, 15.7 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm.²/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	--	--
0.3	--	--
0.35	No ignition, 2 min	
0.6	90-120	105 (glow only)
0.8	24-32	29
0.9	15-21	18
1.1	10-19	14

DURATION OF EXPOSURE (SEC)

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

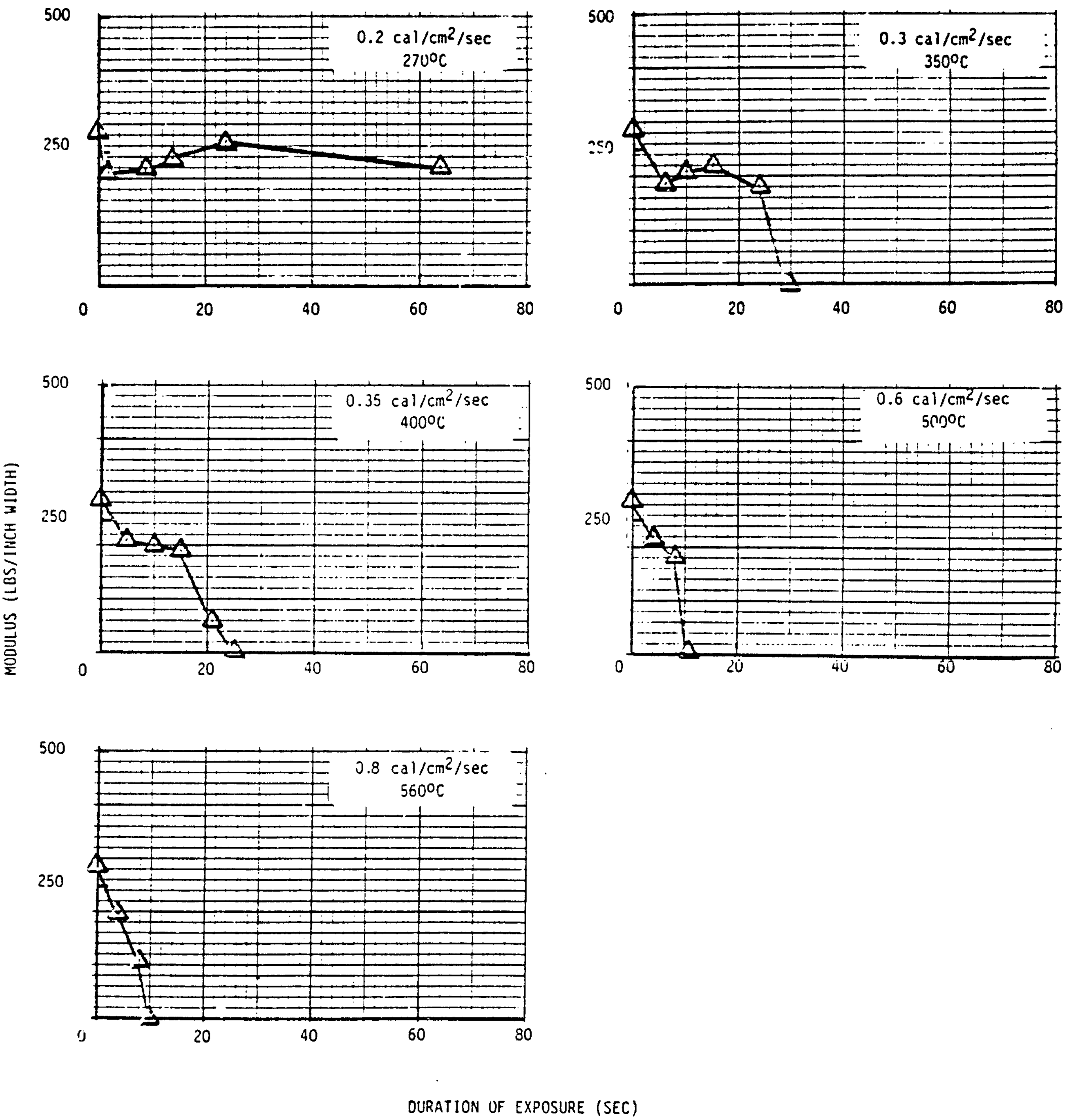
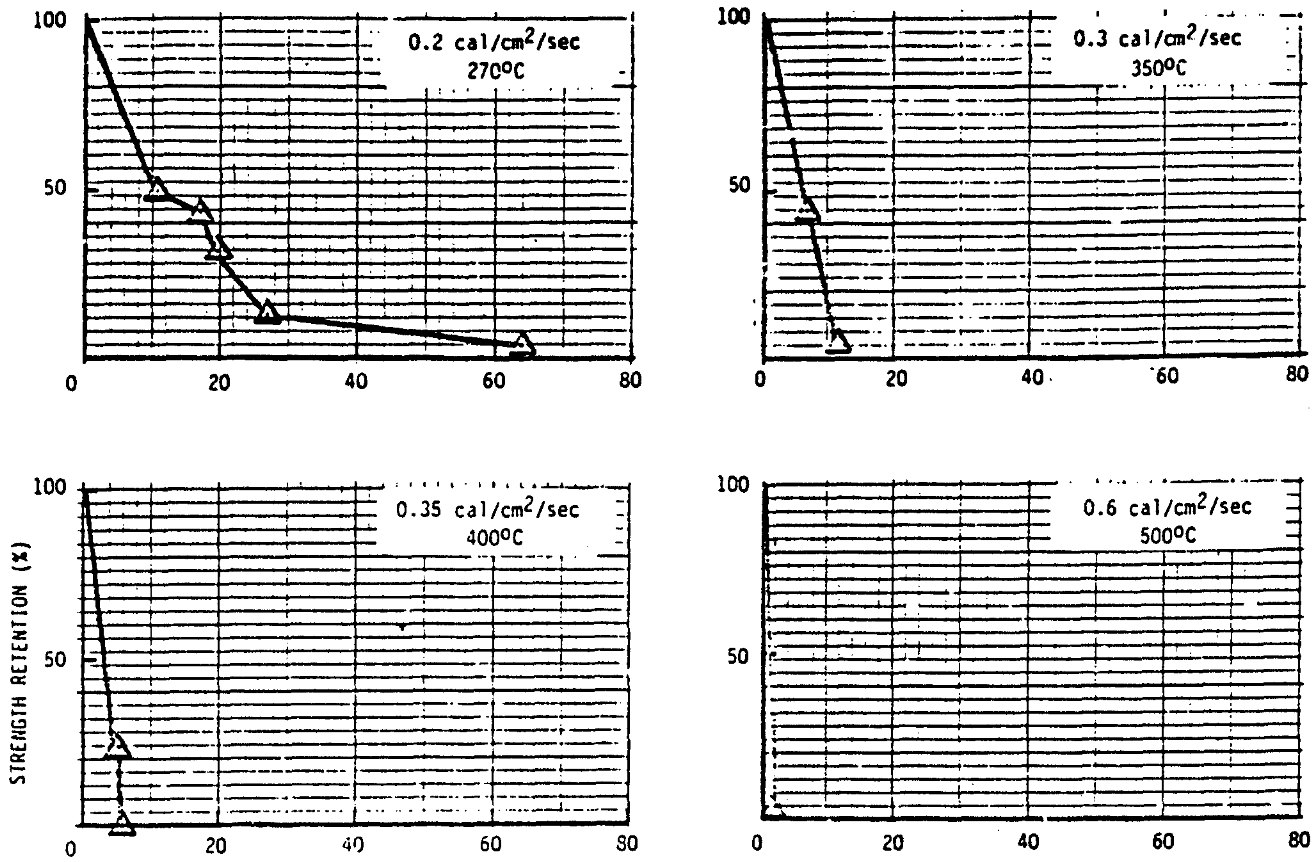
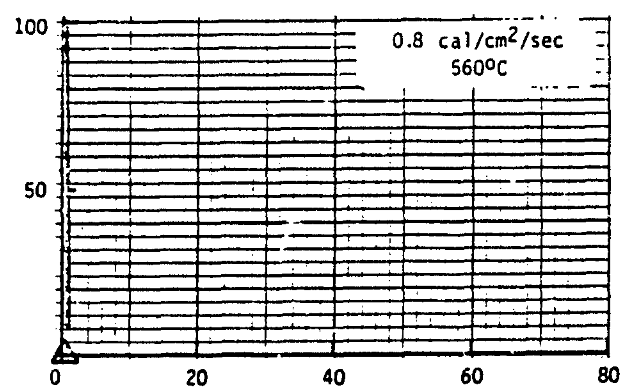


Figure 13b. Modulus of Fabric #28 (90/10 wool/nylon, 8.2 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm^2/sec)	TIME TO IGNITION (SEC) Range	TIME TO IGNITION (SEC) Average
0.2	---	---
0.3	---	---
0.35	---	---
0.6	No ignition, 2 min	
0.8	20-30	25 (glow only)
0.9	16-20	18
1.1	---	3

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

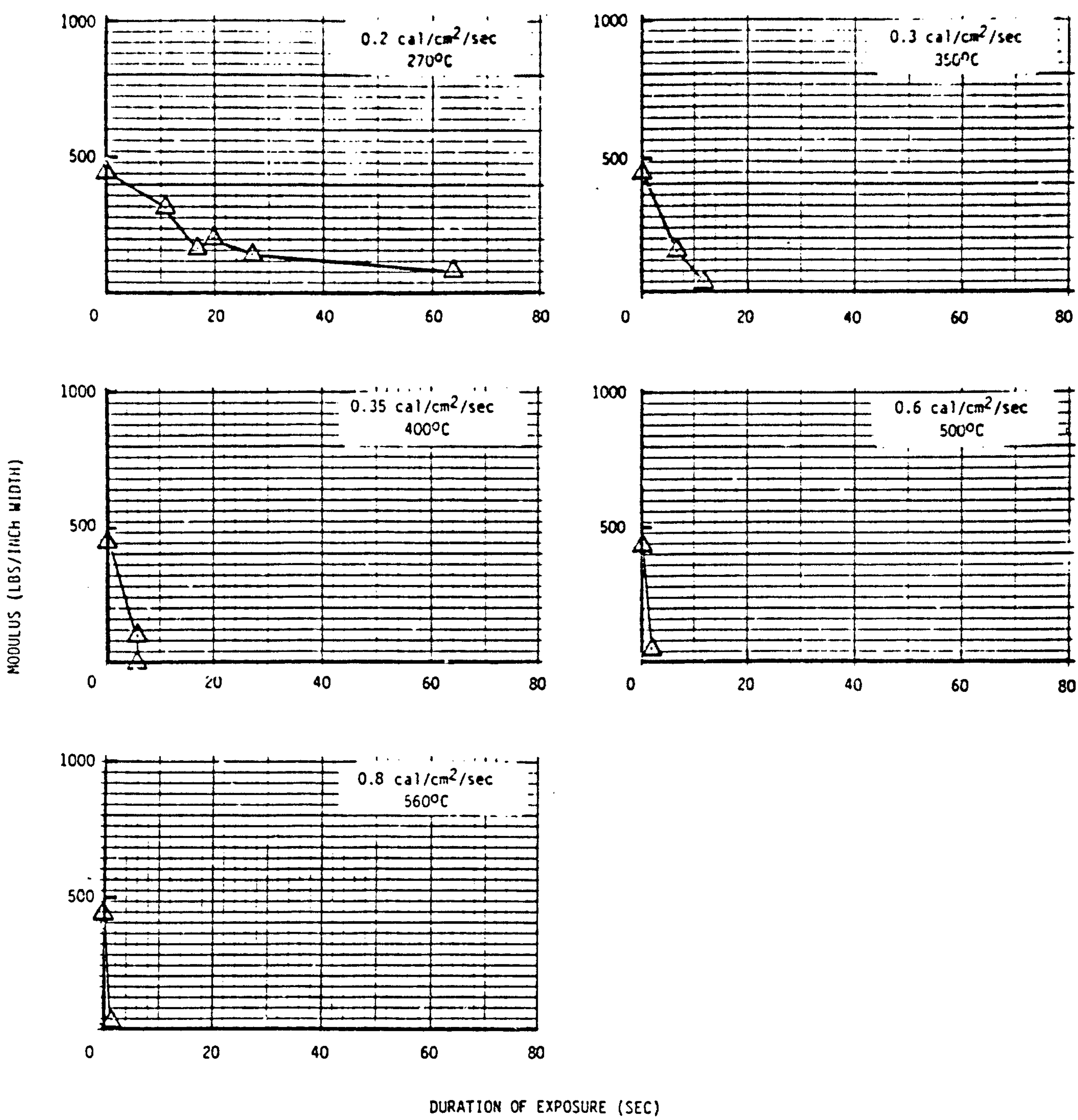
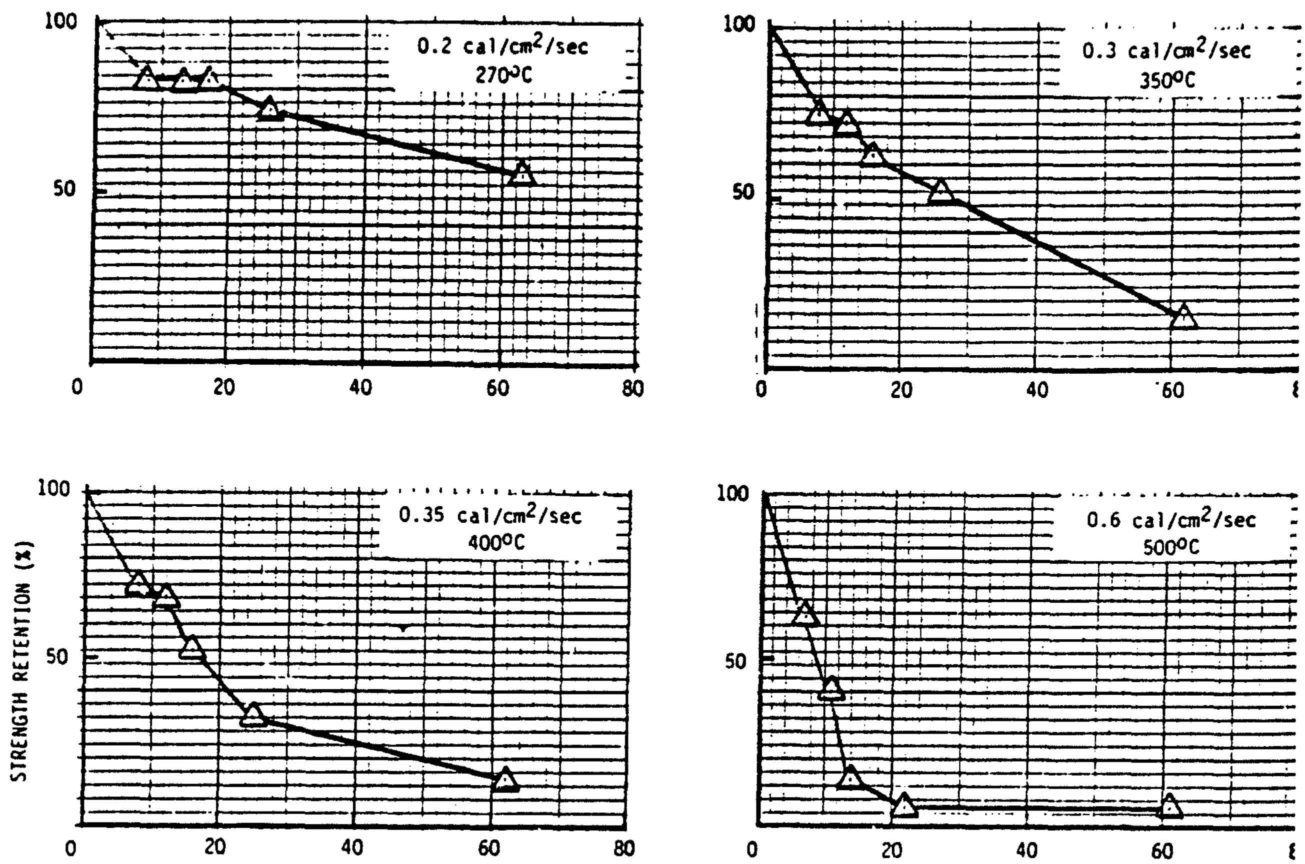
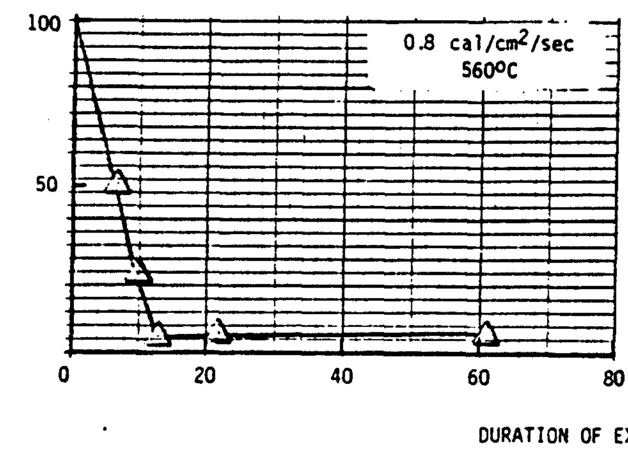


Figure 14b. Modulus of Fabric #25 (55/45 polyester/wool, 6.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX ($cal/cm^2/sec$)	TIME TO IGNITION (SEC) Range	Average
0.2	--	--
0.3	--	--
0.35	--	--
0.6	No ignition, 2 min	
0.8	--	40 (ligh glow only
0.9	42-90	74
1.1	21-28	25

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

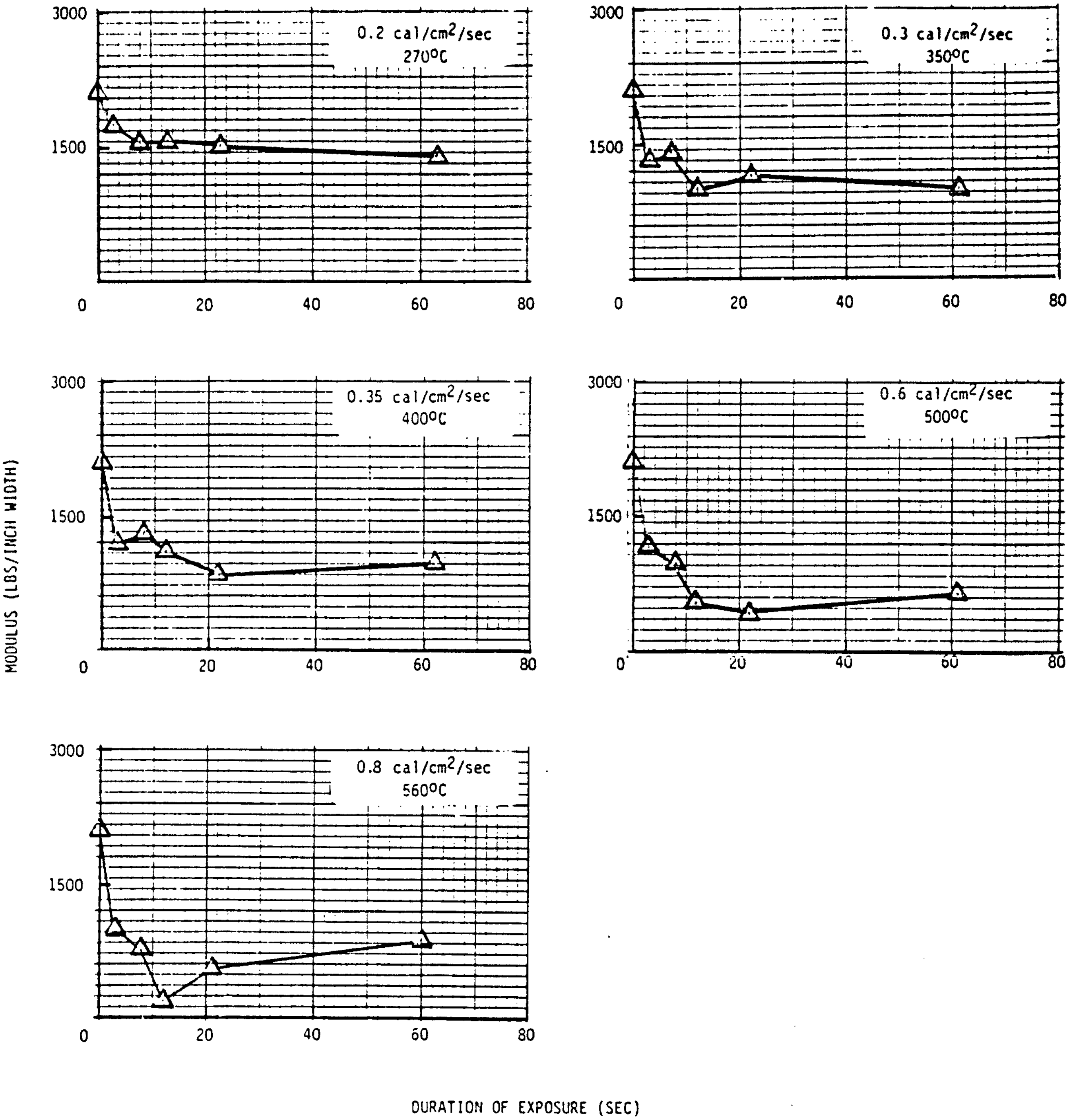
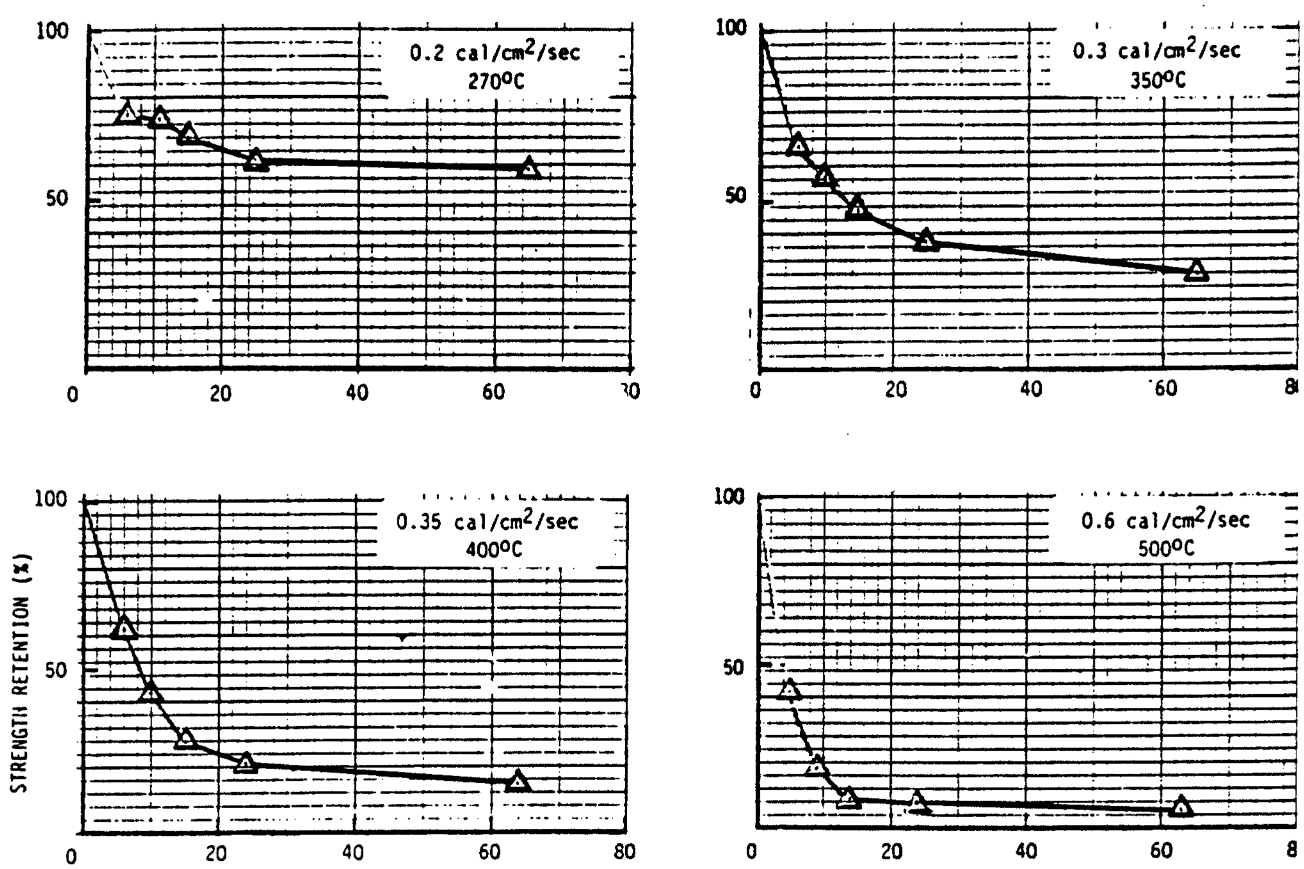
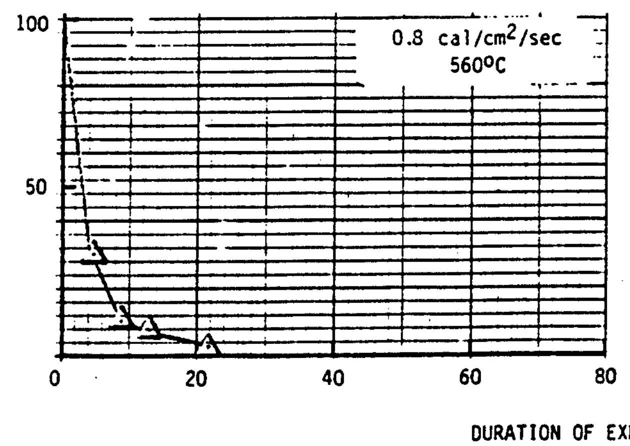


Figure 15b. Modulus of Fabric #78 (core spun, semi-carbon Kevlar, 15.4 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX ($cal/cm^2/sec$)	TIME TO IGNITION (SEC) Range	TIME TO IGNITION (SEC) Average
0.2	--	--
0.3	--	--
0.35	--	--
0.6	--	--
0.8	--	70 (only 2 of 5)
0.9	26-43	34 (only 4 of 5)
1.1	21-23	22

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

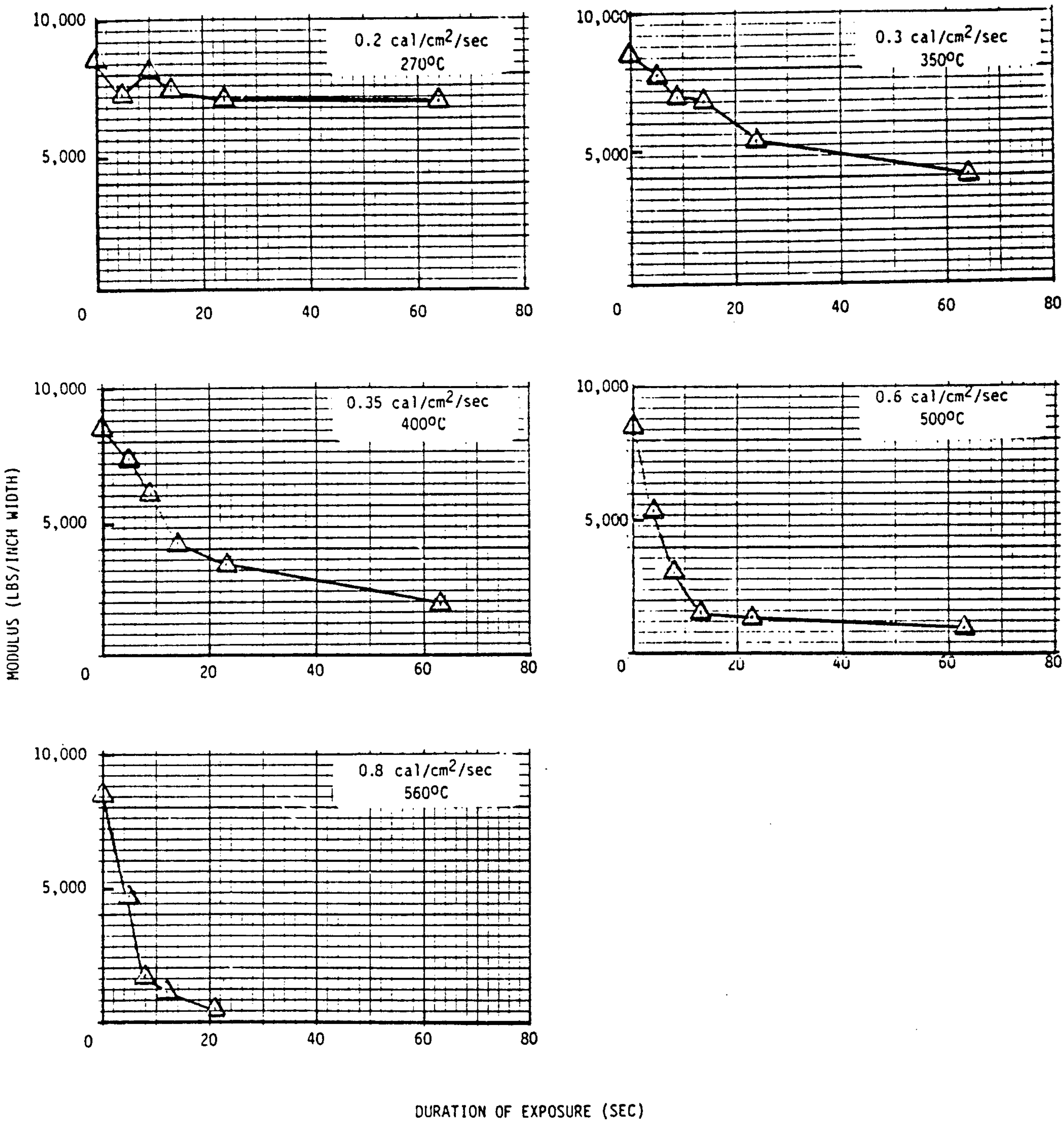
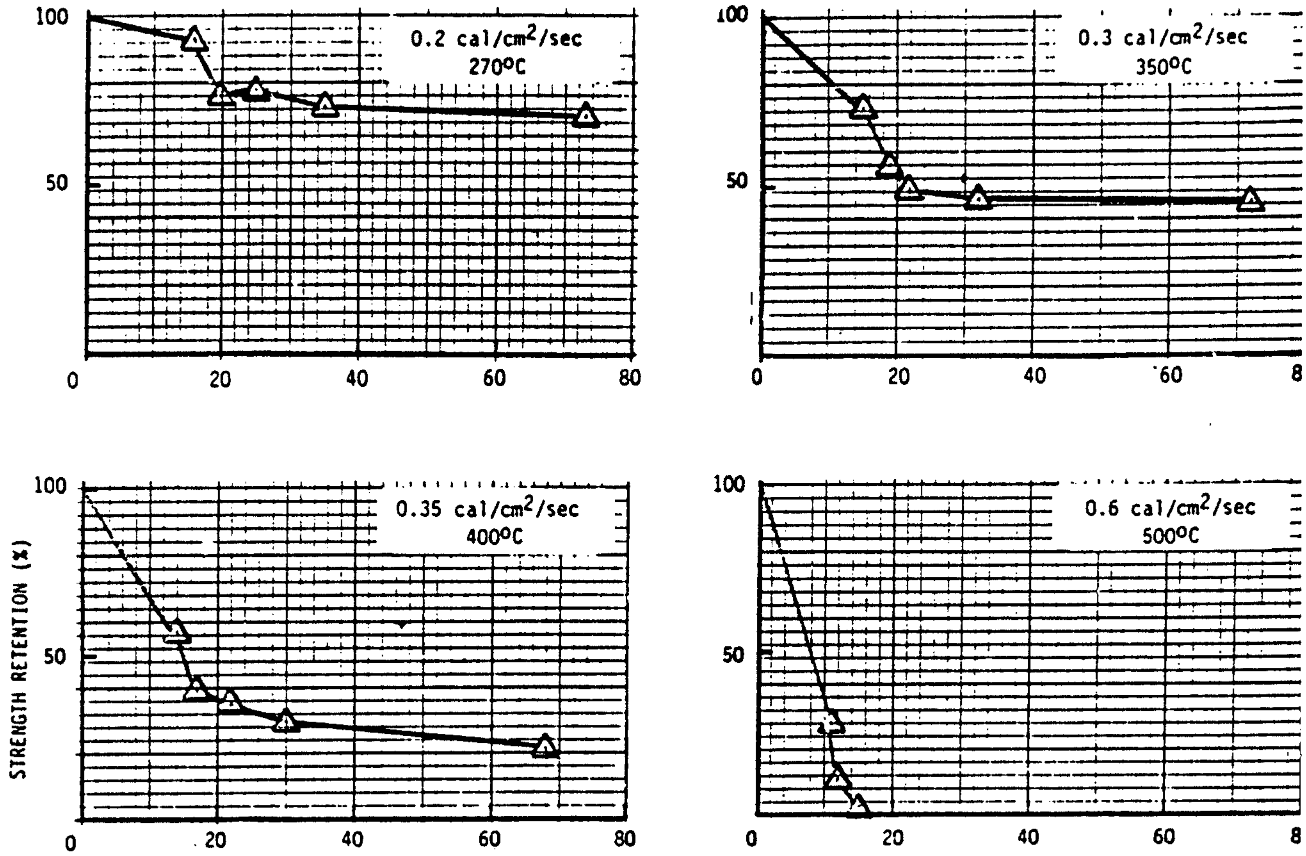
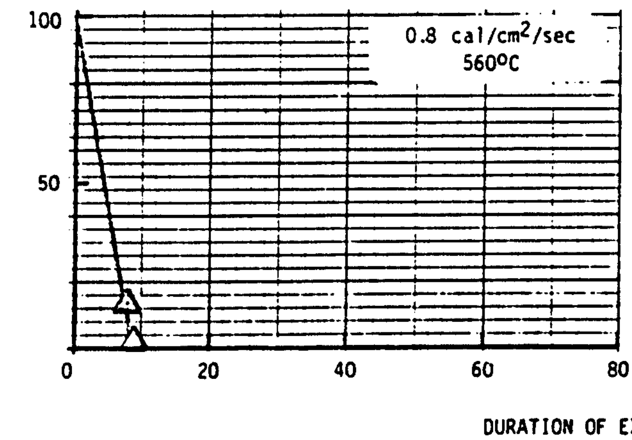


Figure 16b. Modulus of Fabric #75 (100% Kevlar, 8.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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

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

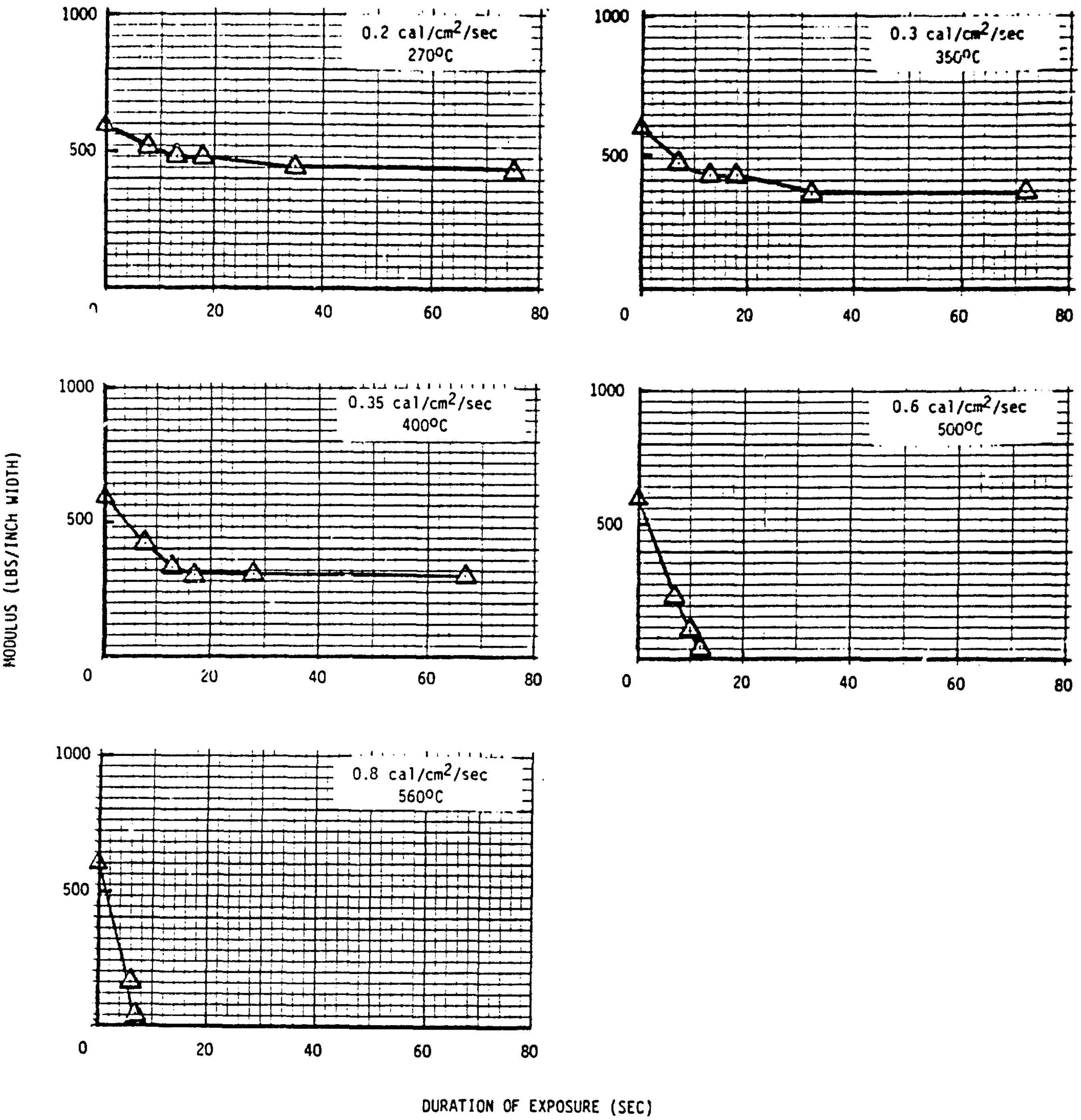
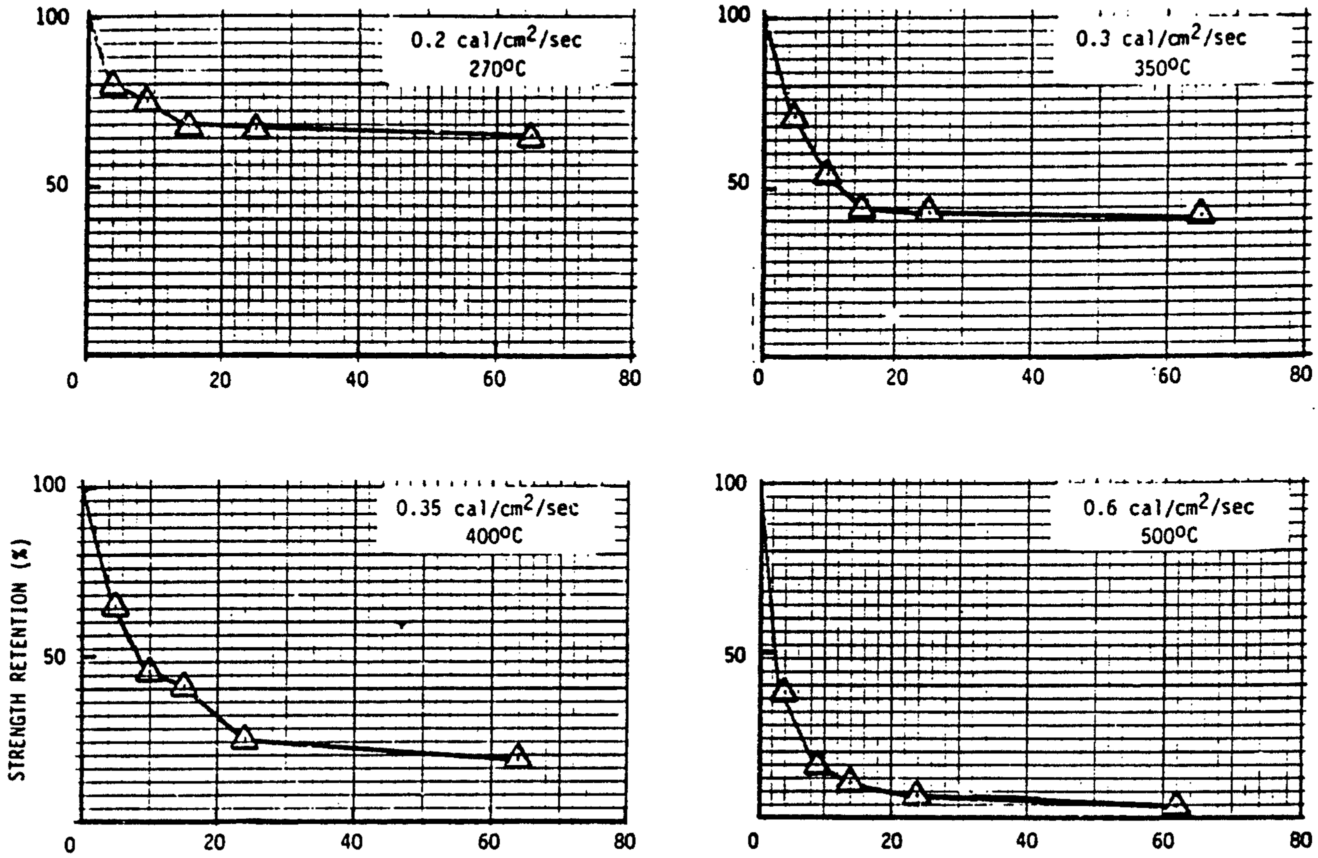
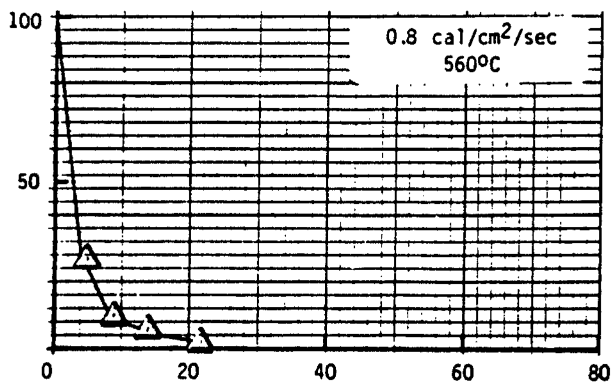


Figure 17b. Modulus of Fabric #47 (100% Nomex, 8.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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	25-30	27 (glow only)
0.9	15-20	17
1.1	17-19	18

DURATION OF EXPOSURE (SEC)

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

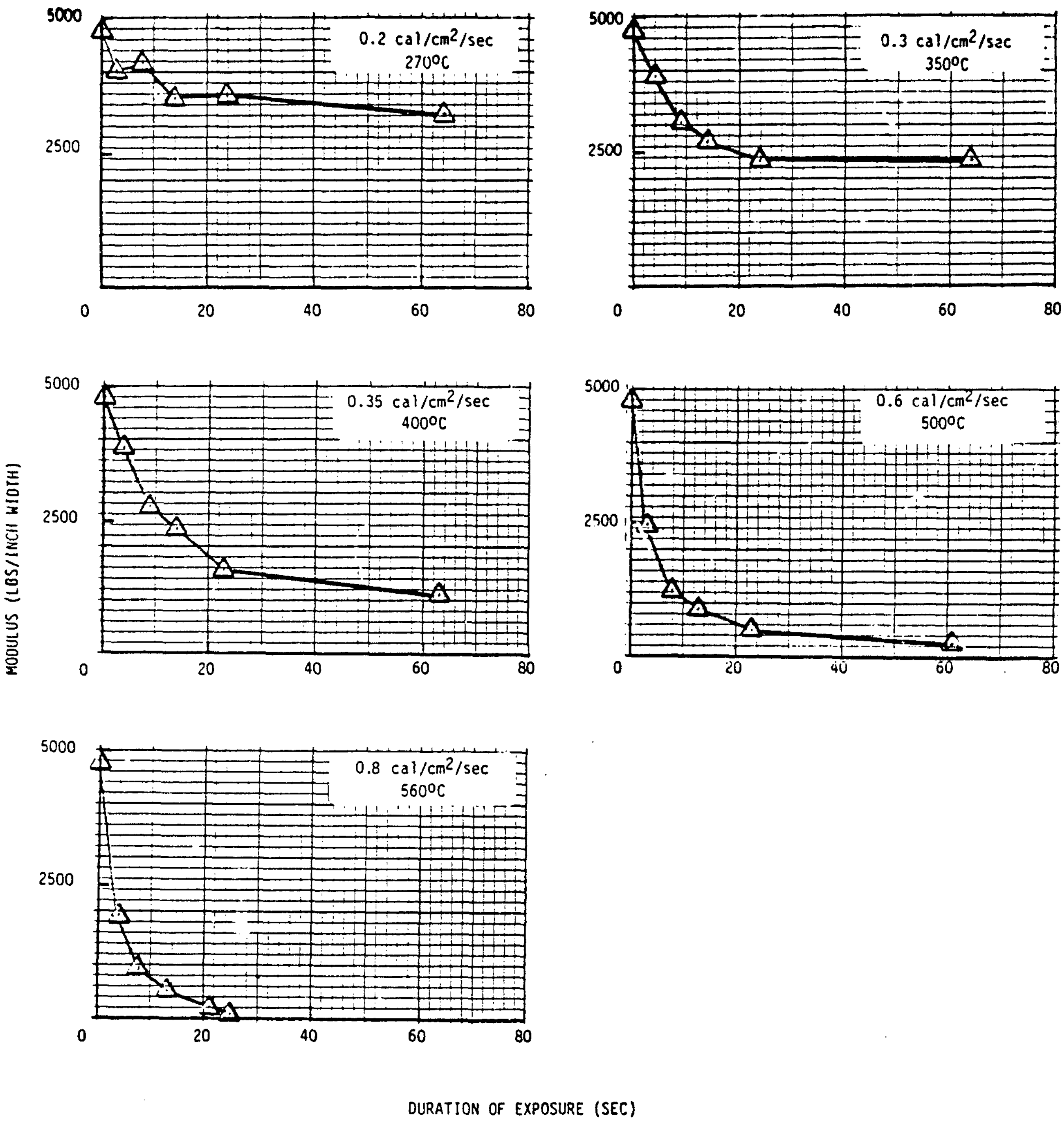
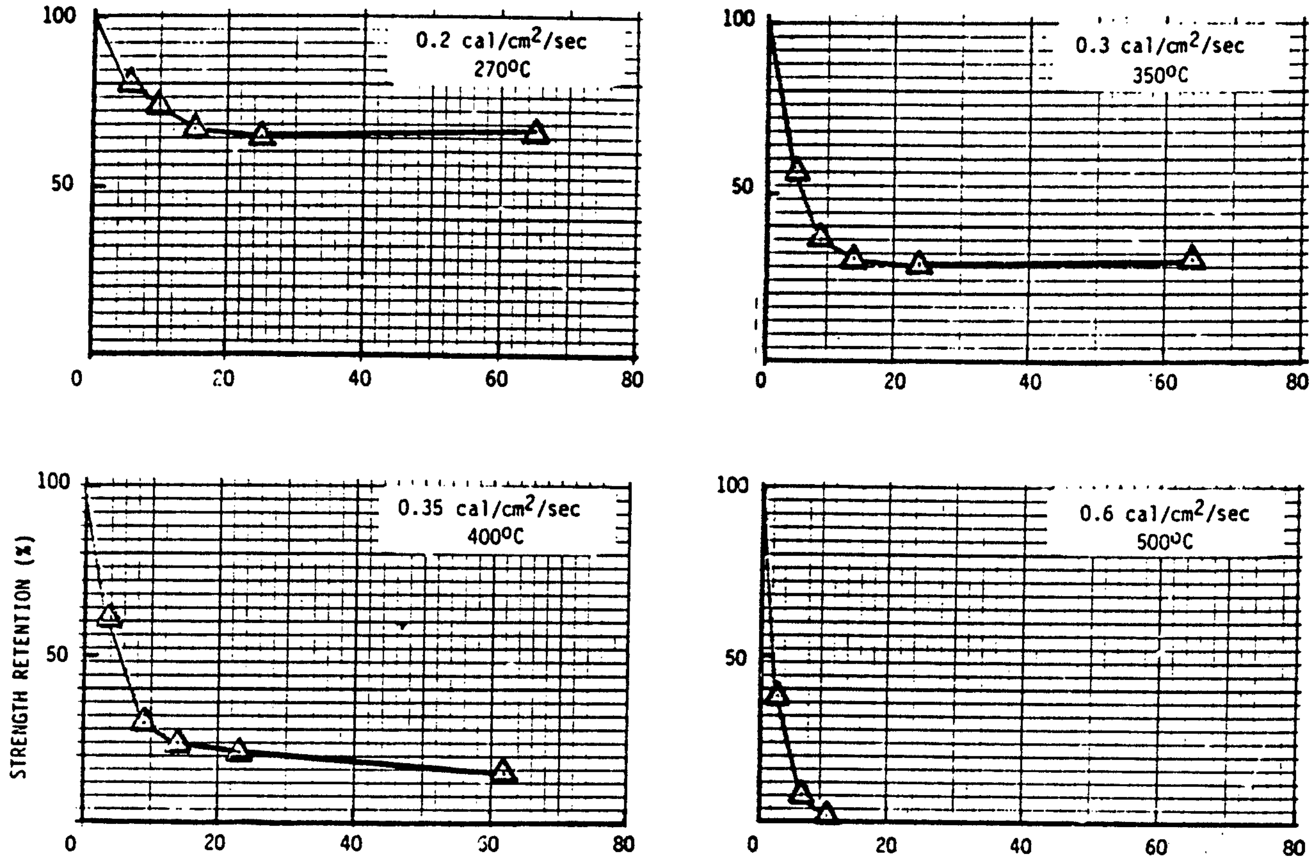
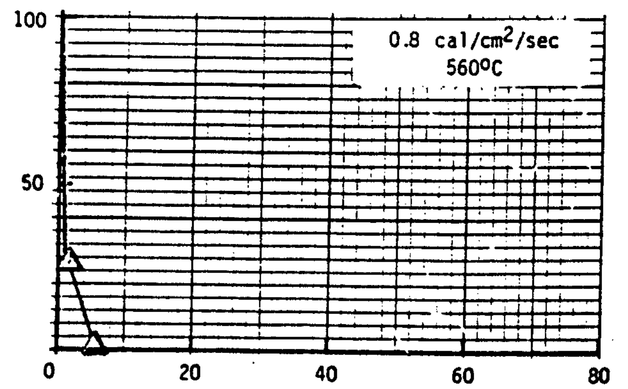


Figure 18b. Modulus of Fabric #74 (50/50 Nomex/Kevlar, 6.0 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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	--	40 (light glow only)
0.9	27-35	31
1.1	16-21	19

DURATION OF EXPOSURE (SEC)

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

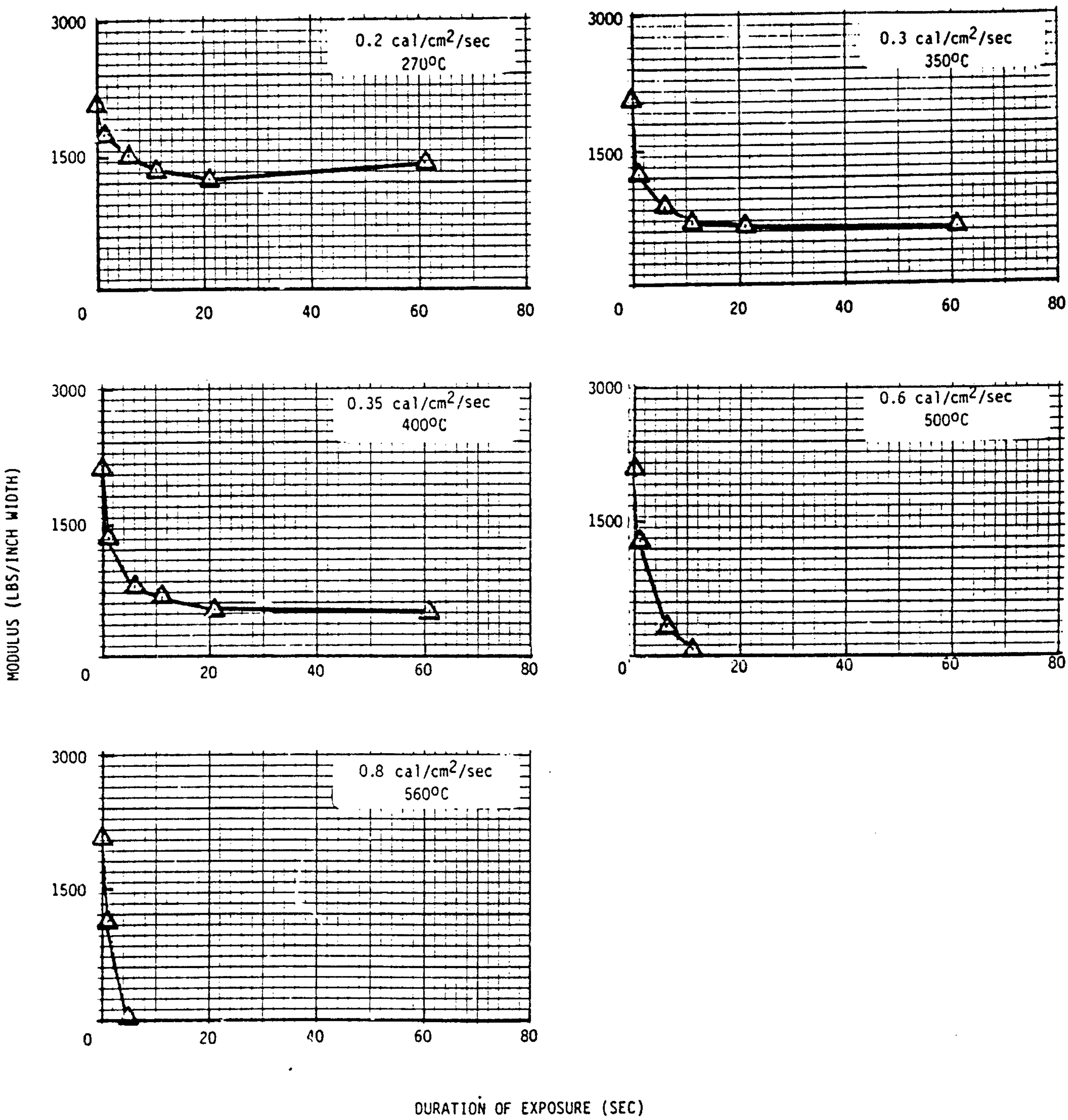
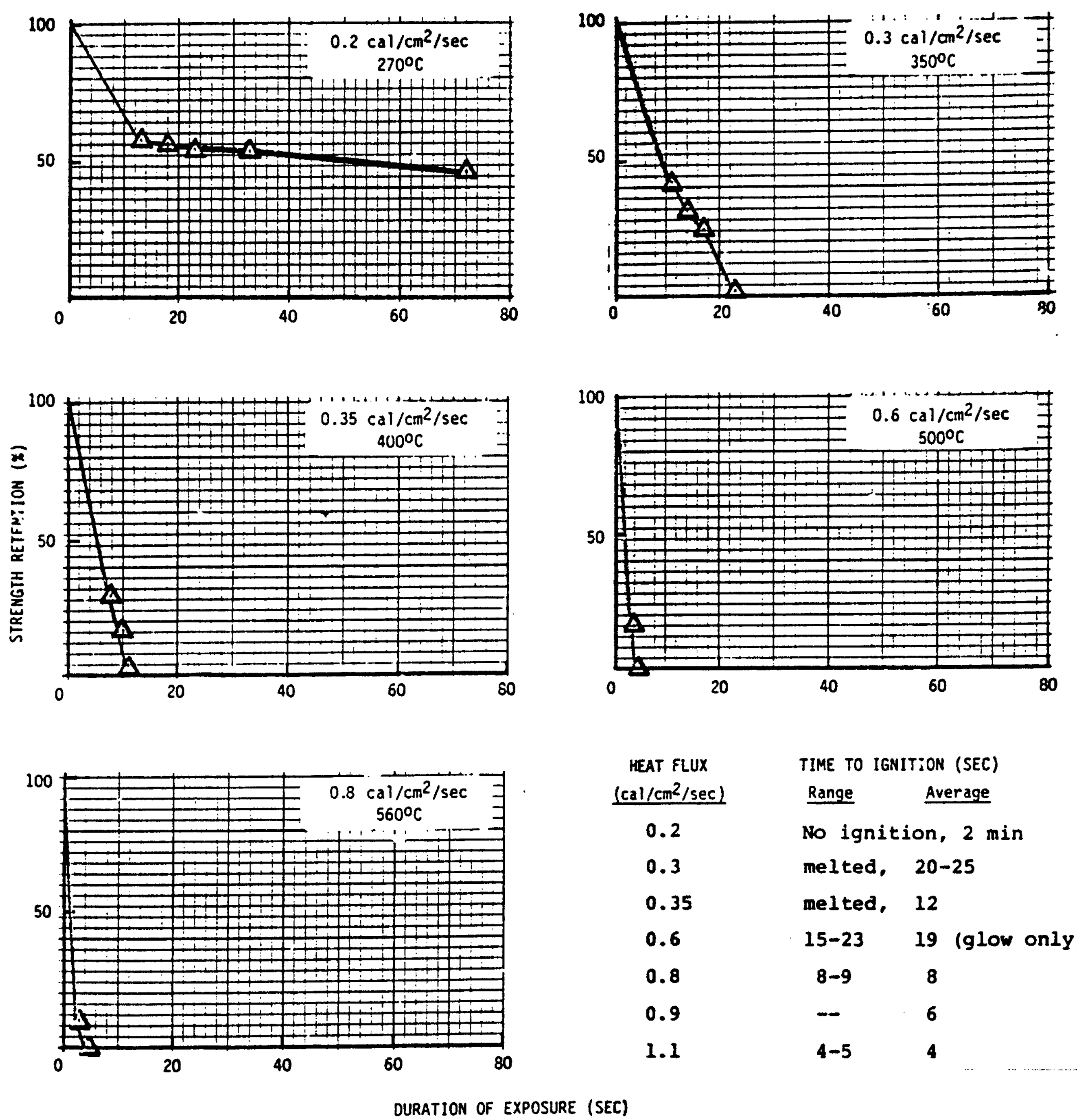


Figure 19b. Modulus of Fabric #73 (95/5 Nomex/Kevlar, 5.3 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm^2/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	No ignition, 2 min	
0.3	melted,	20-25
0.35	melted,	12
0.6	15-23	19 (glow only)
0.8	8-9	8
0.9	--	6
1.1	4-5	4

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

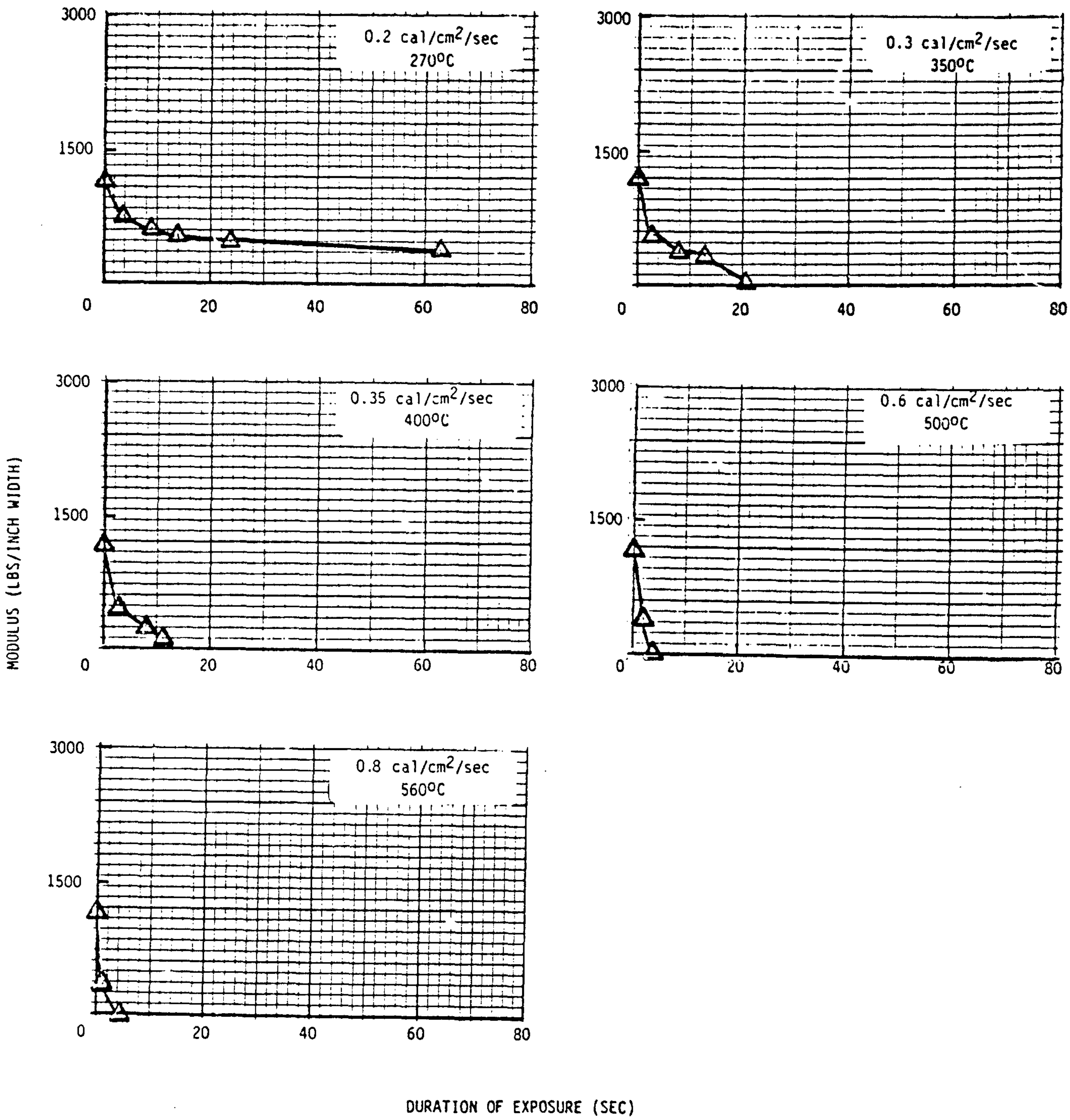
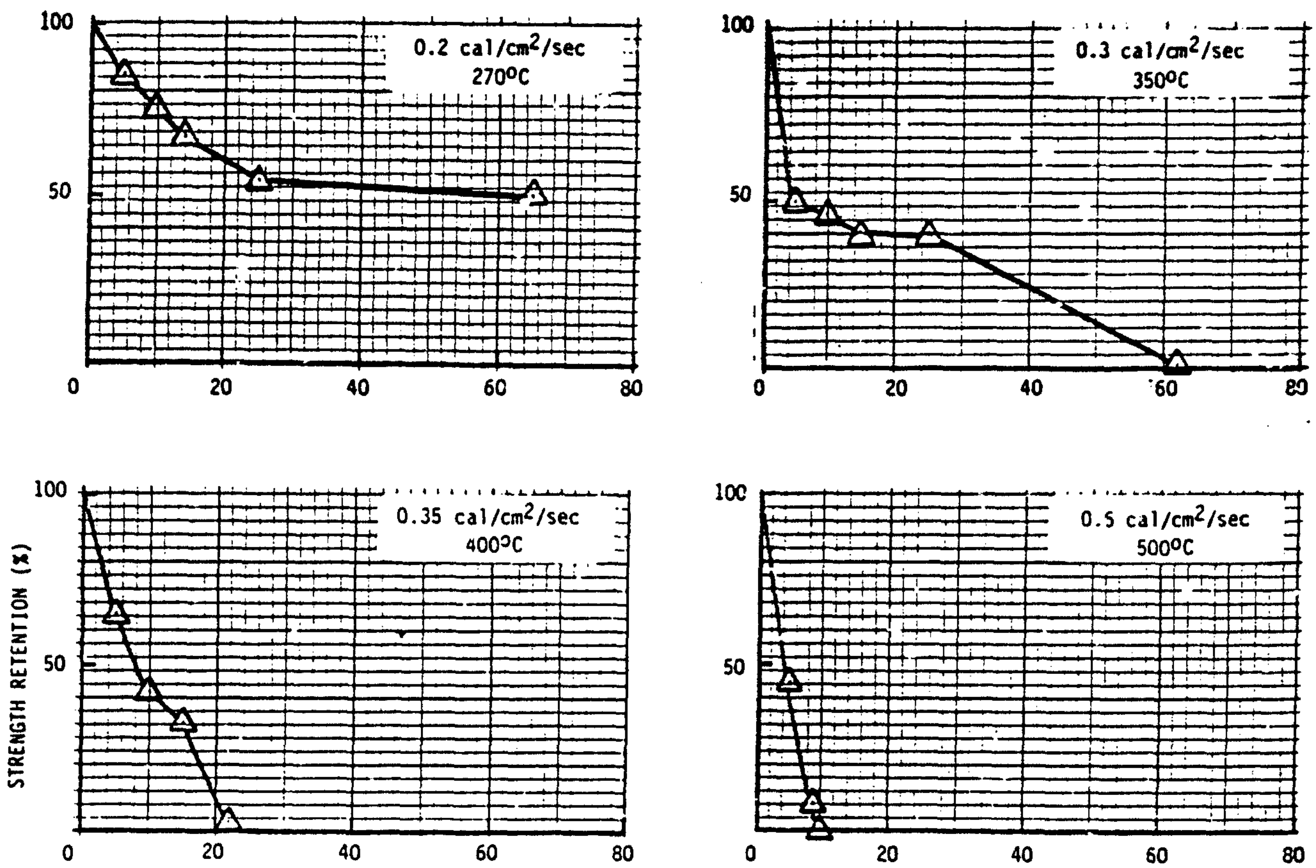
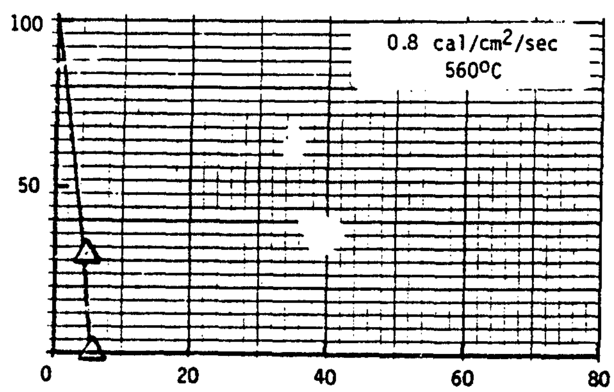


Figure 20b. Modulus of Fabric #39 (nylon, butyl coated, 12.5 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





HEAT FLUX (cal/cm²/sec)	TIME TO IGNITION (SEC) Range	Average
0.2	--	--
0.3	No ignition, 2 min	
0.35	60-65	63 (glow only)
0.6	13-16	15
0.8	7-8	7
0.9	5-6	6
1.1	--	5

DURATION OF EXPOSURE (SEC)

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

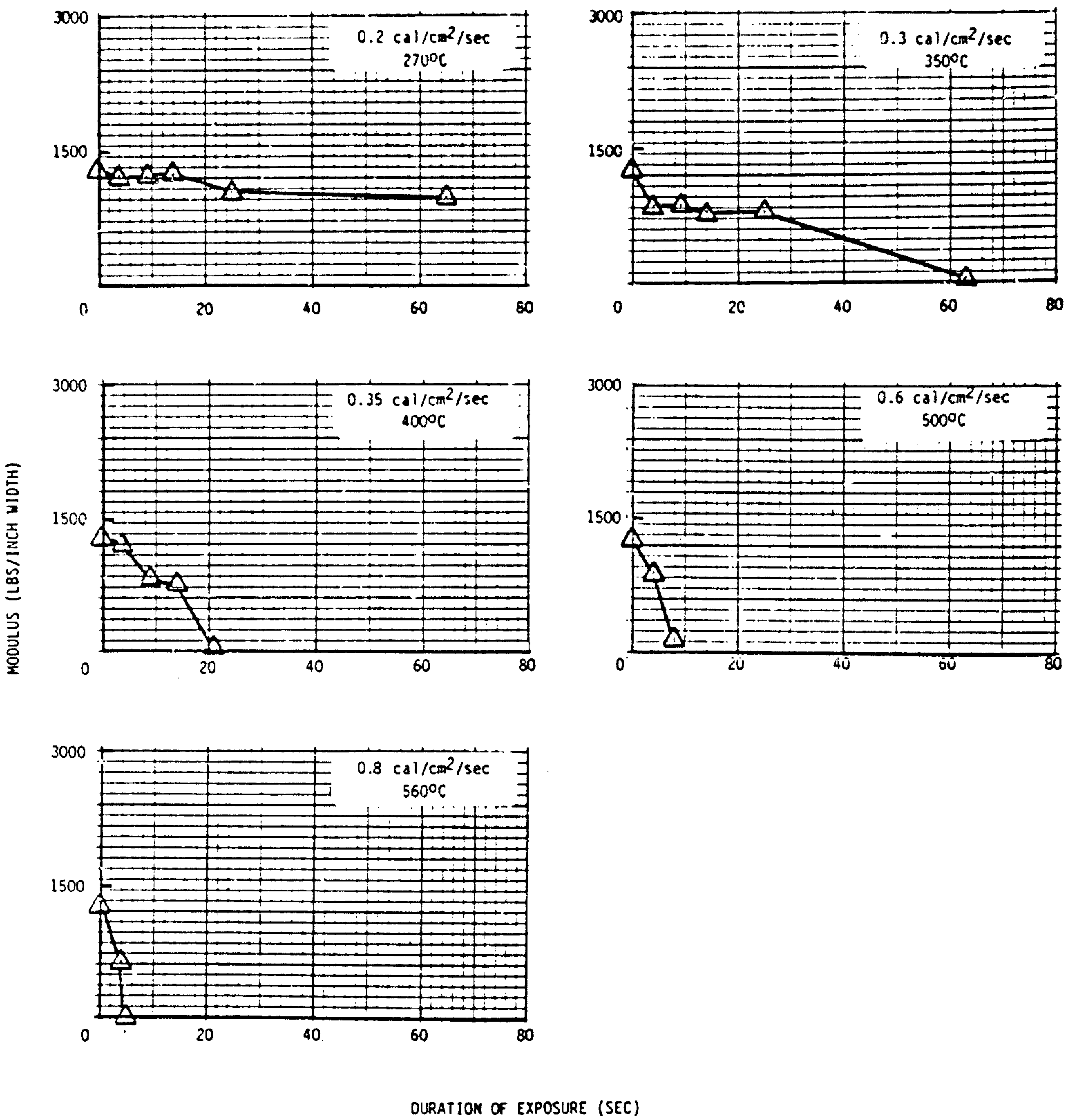
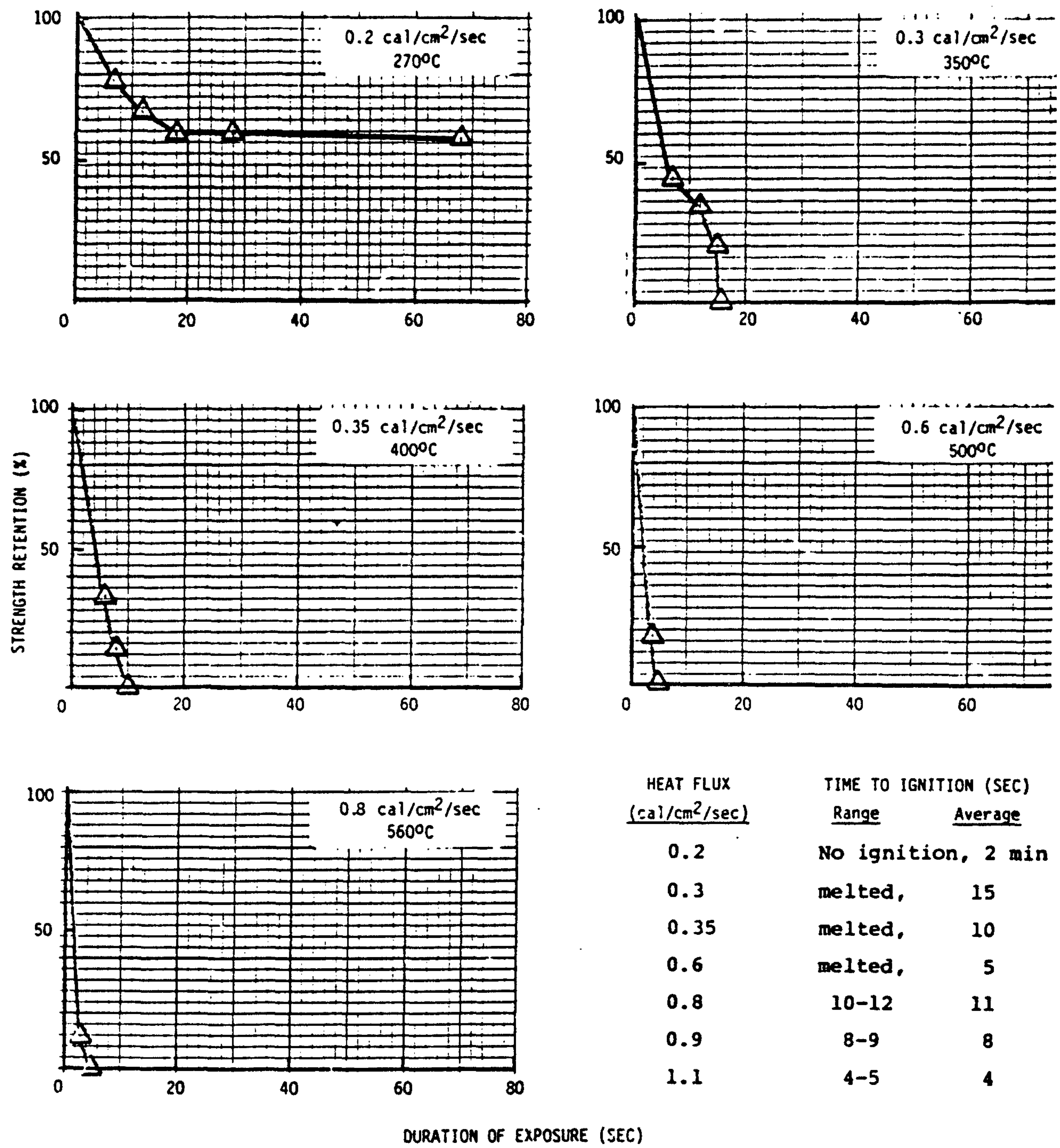


Figure 21b. Modulus of Fabric #5 (cotton, resin modified, butyl coated, 10.5 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat



HEAT FLUX (cal/cm²/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

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

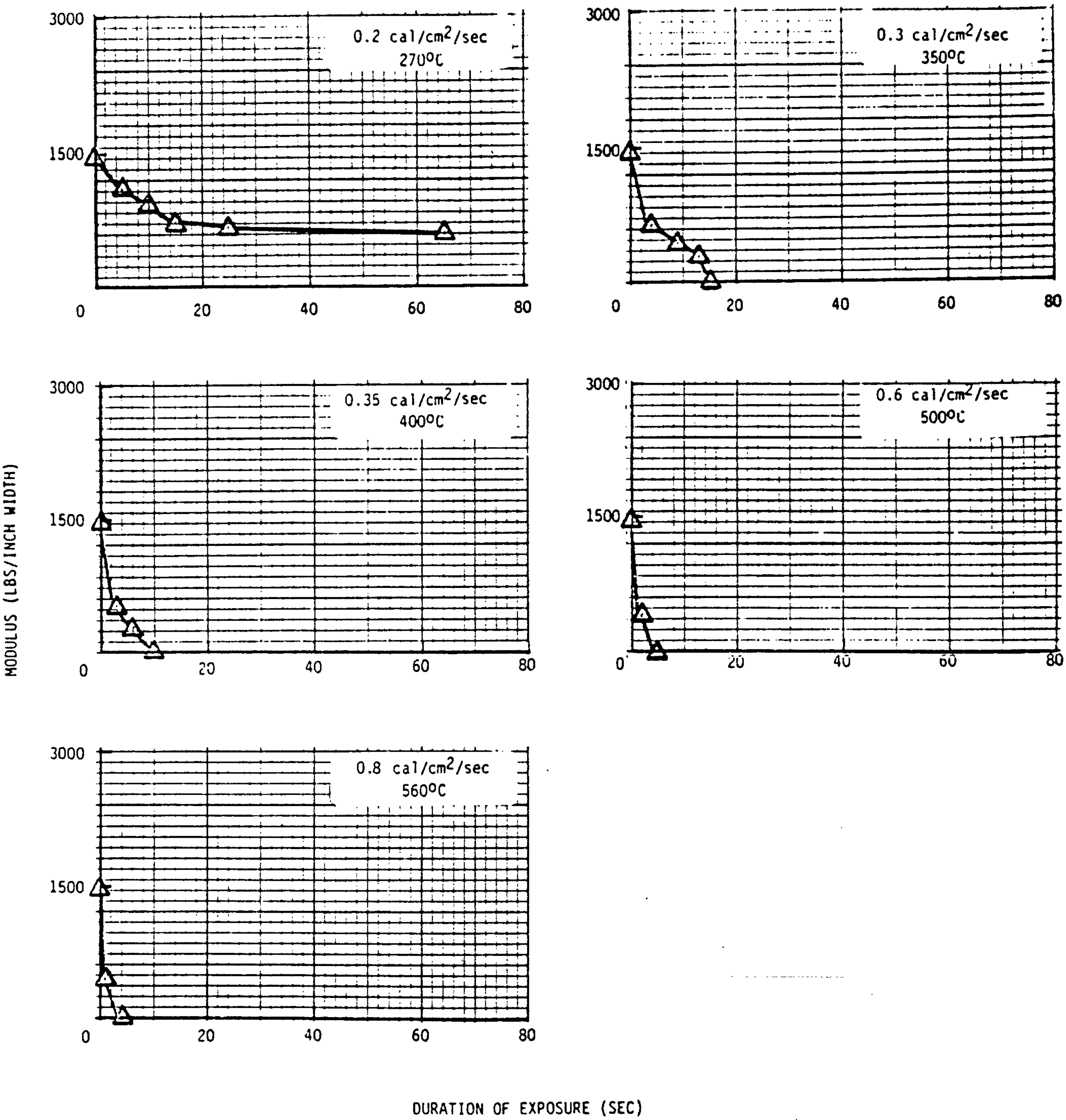
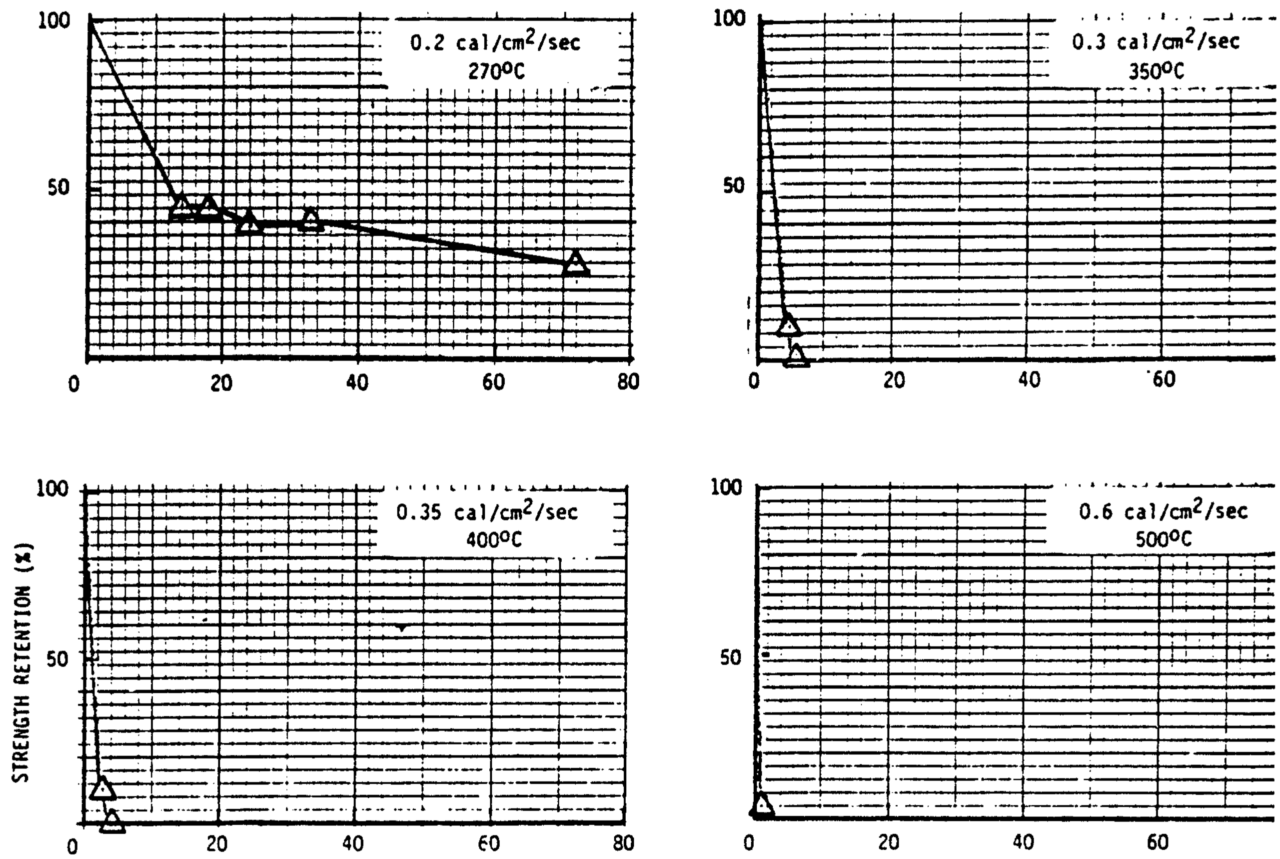
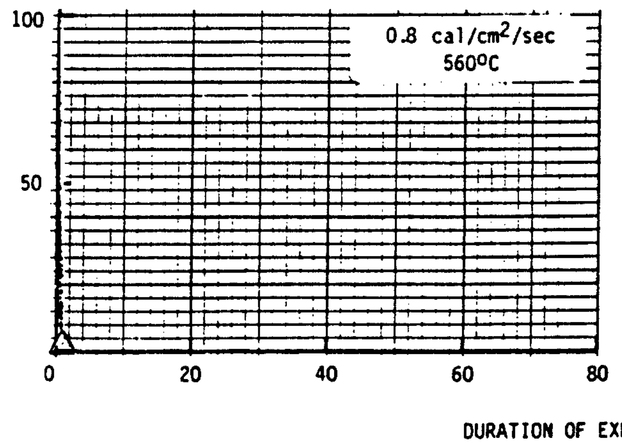


Figure 22b. Modulus of Fabric #32 (nylon, neoprene coated, 7.7 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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 :

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

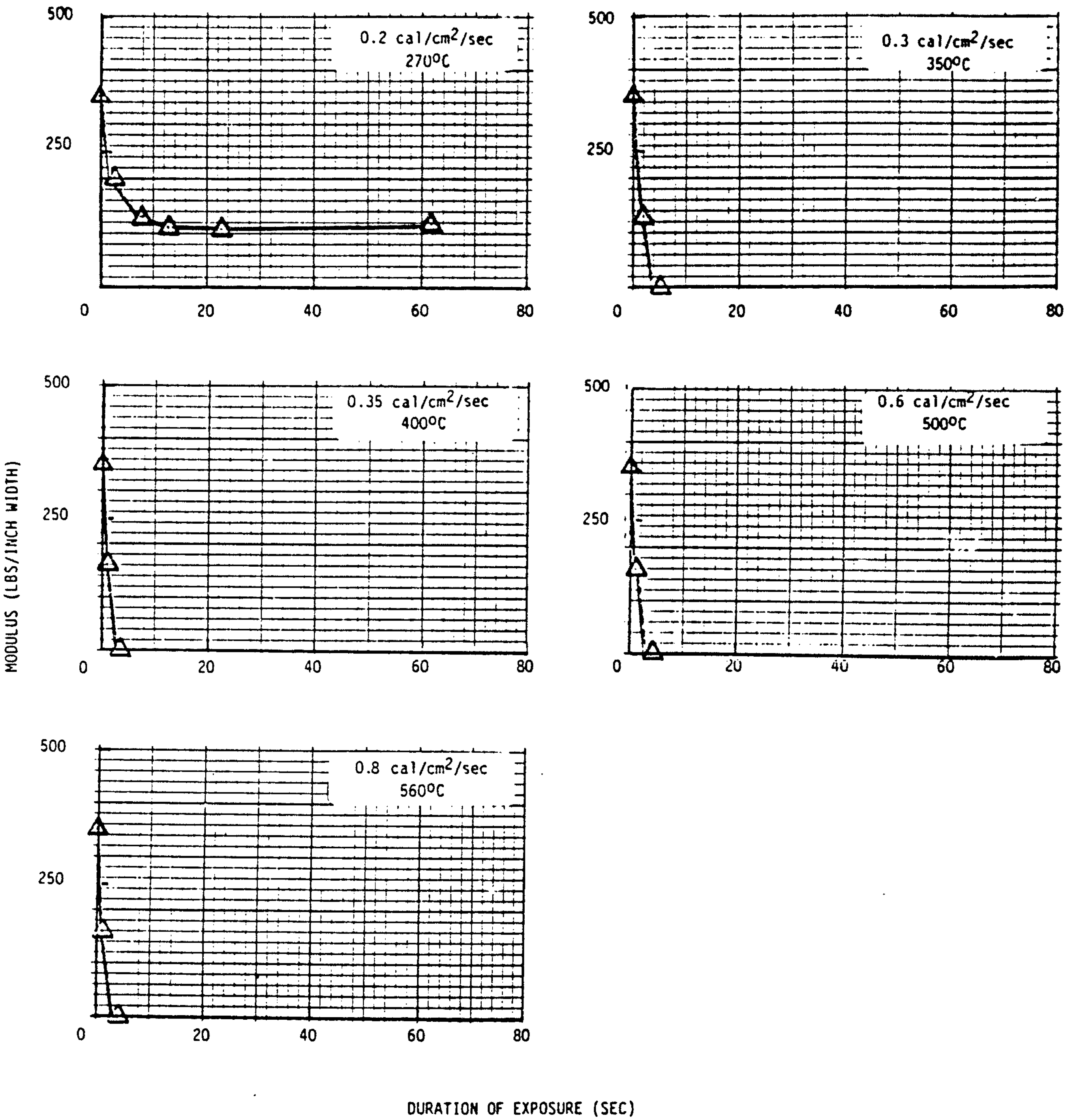
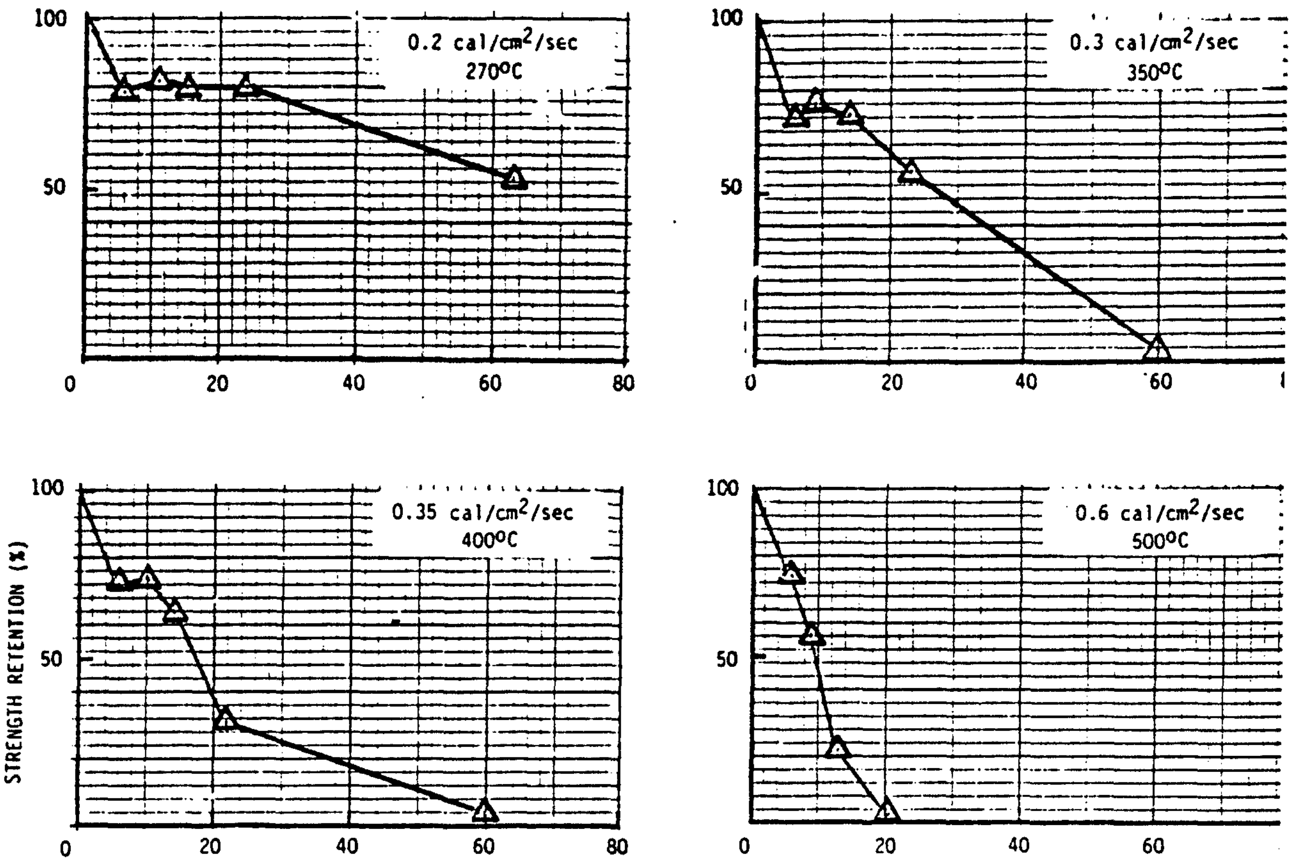
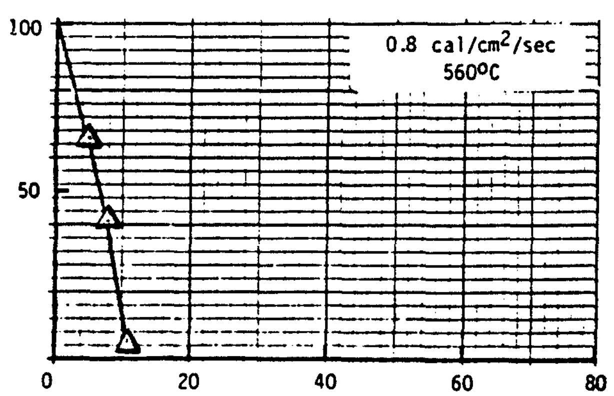


Figure 23b. Modulus of Fabric #18 (nylon, polyurethane coated, 3.1 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat





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

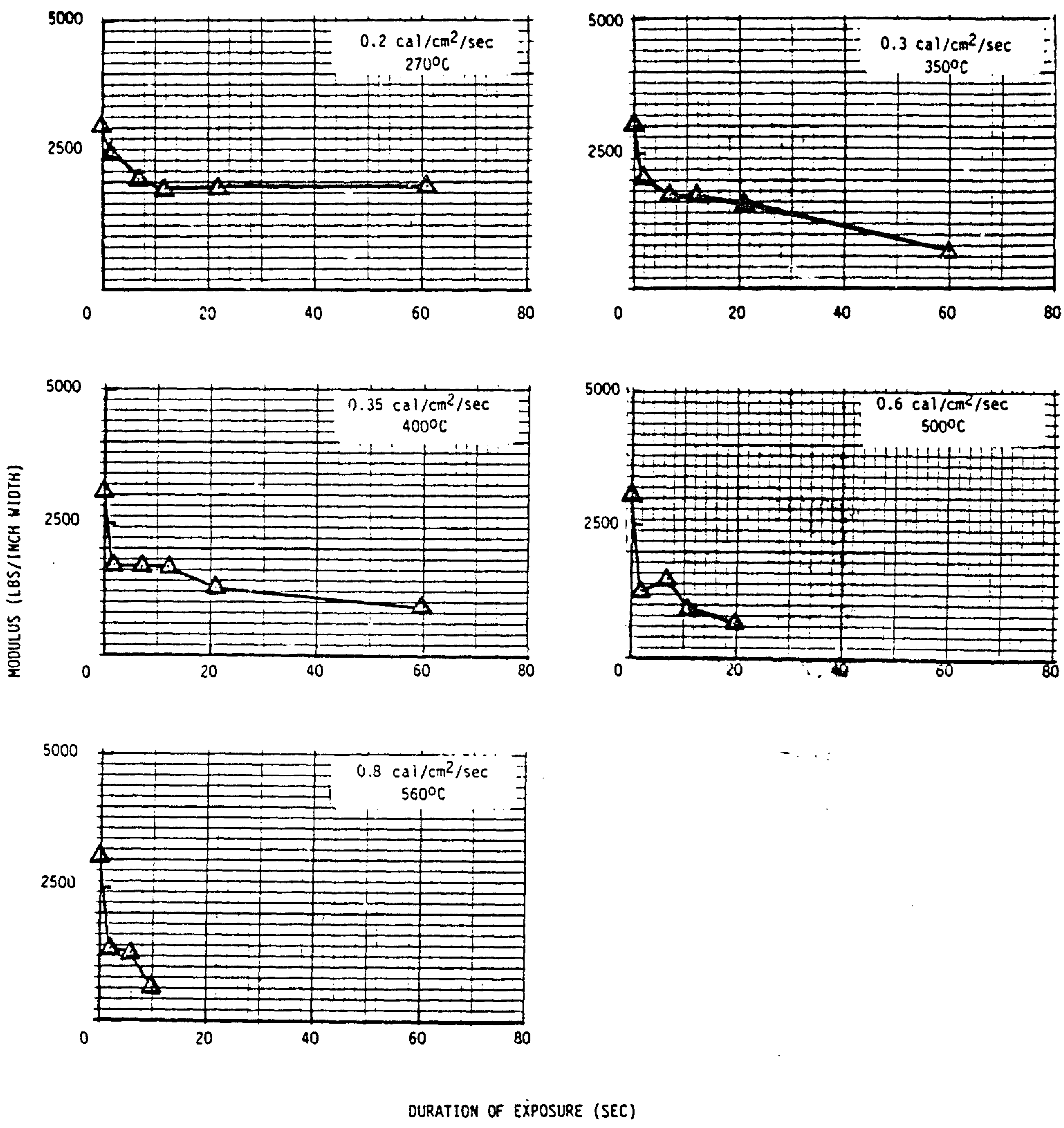


Figure 24b. Modulus of Fabric #72 (PAN, 15.6 oz/sq yd) During Exposure to Various Levels of Bilateral Radiant Heat

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 7x(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.)

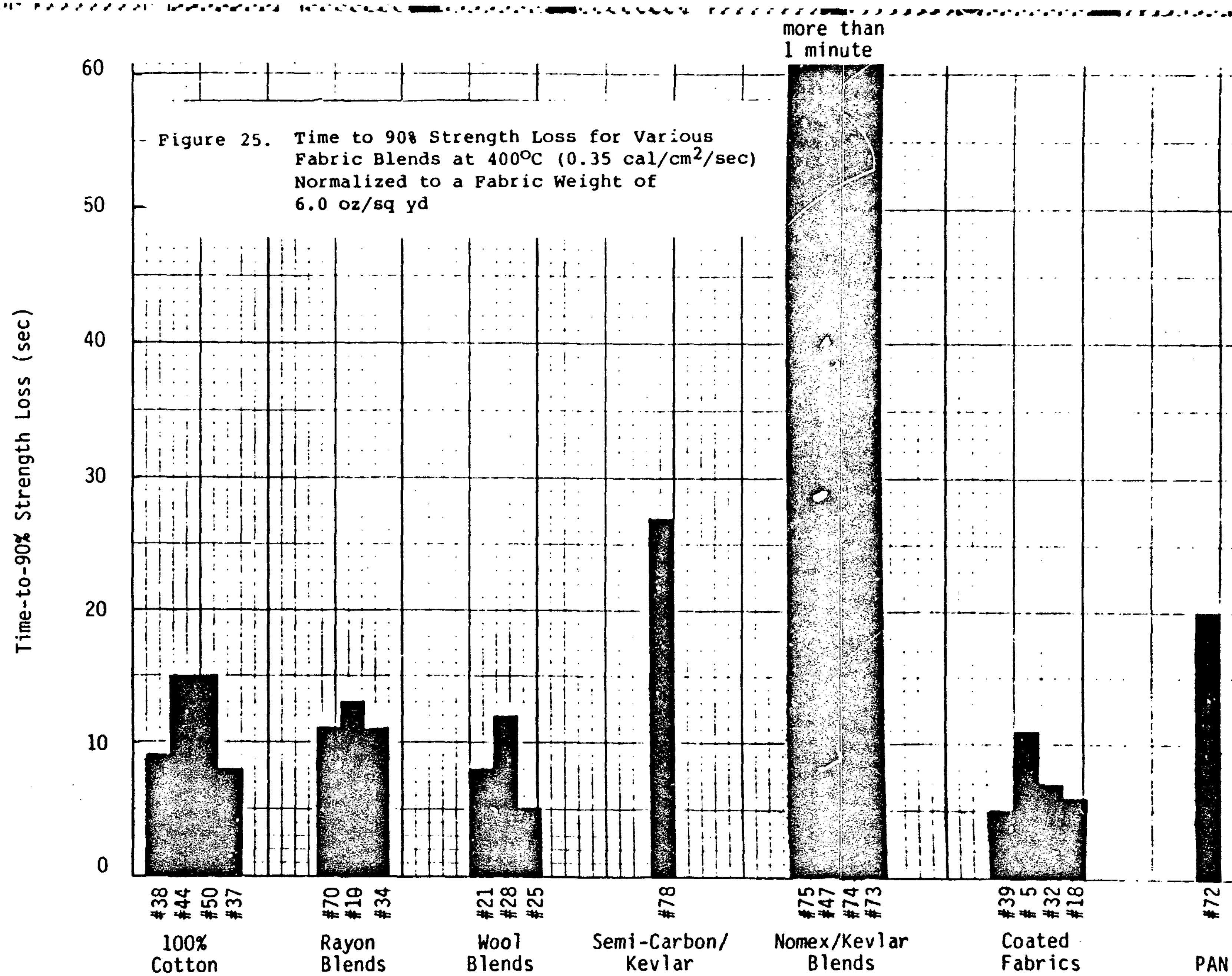


Figure 25. Time to 90% Strength Loss for Various Fabric Blends at 400°C (0.35 cal/cm^2/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

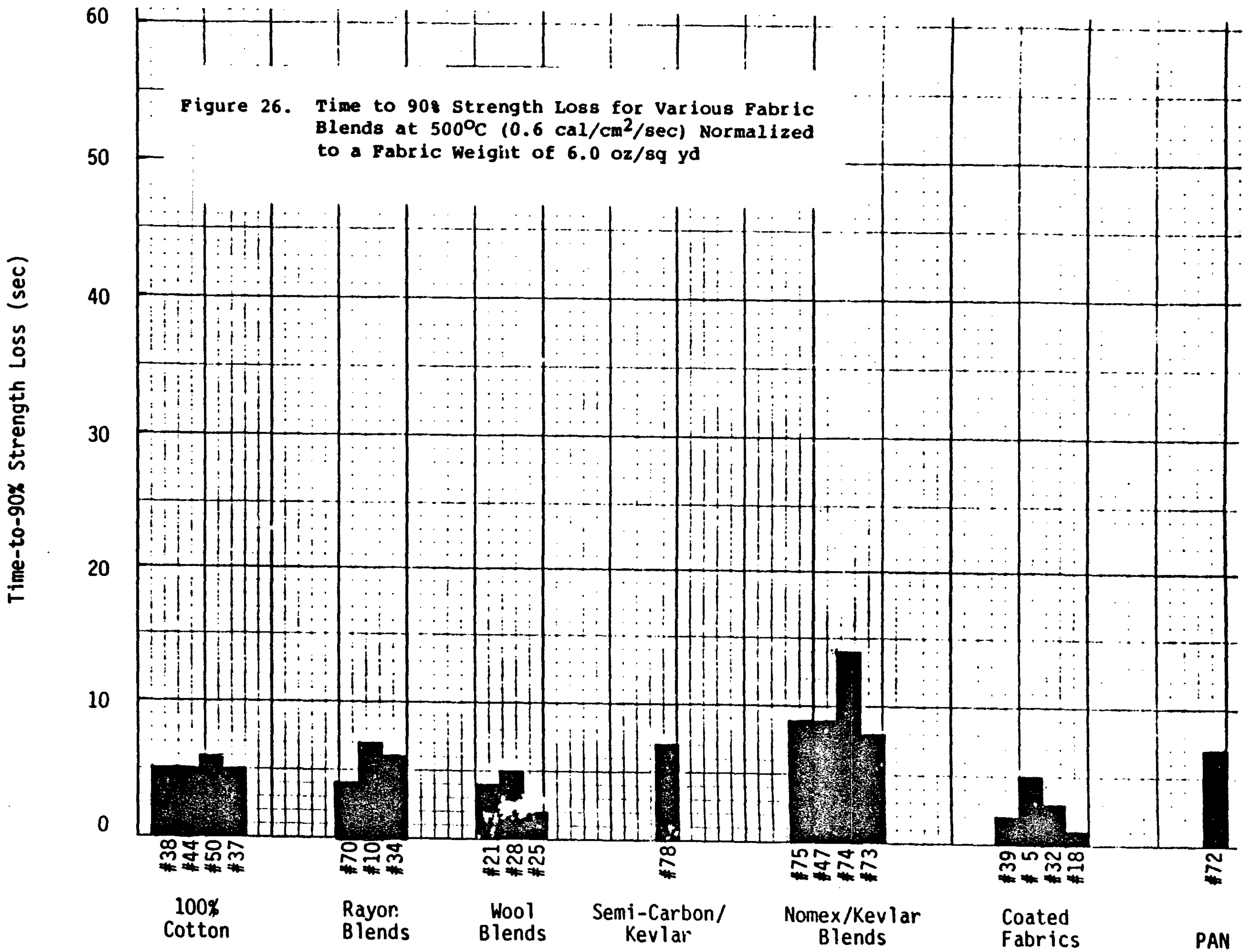


Figure 26. Time to 90% Strength Loss for Various Fabric Blends at 500°C (0.6 cal/cm²/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

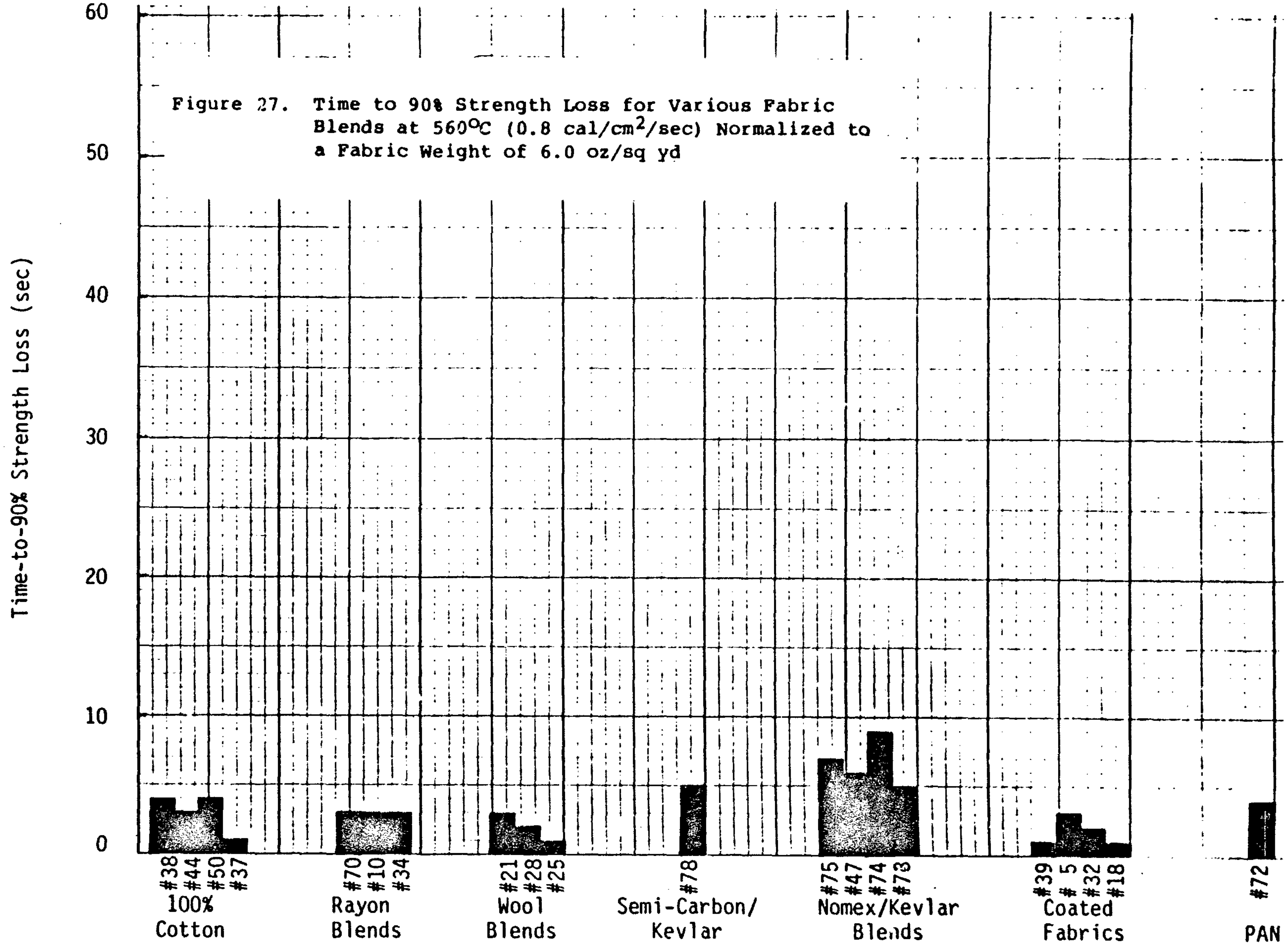


Figure 27. Time to 90% Strength Loss for Various Fabric Blends at 560°C (0.8 cal/cm^2/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

At a heat flux of 0.35 cal/cm^2/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 cal/cm^2/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 cal/cm^2/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/yd²)	Average Time-to-Ignition (seconds) 0.35 (400°C)	0.6 (500°C)	0.8 (560°C)	0.9 (600°C)	1.1 (650°C) cal/cm²/sec
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	——	——>	3
72	PAN	15.6	--	--	33 (glow)	33 (glow)	32

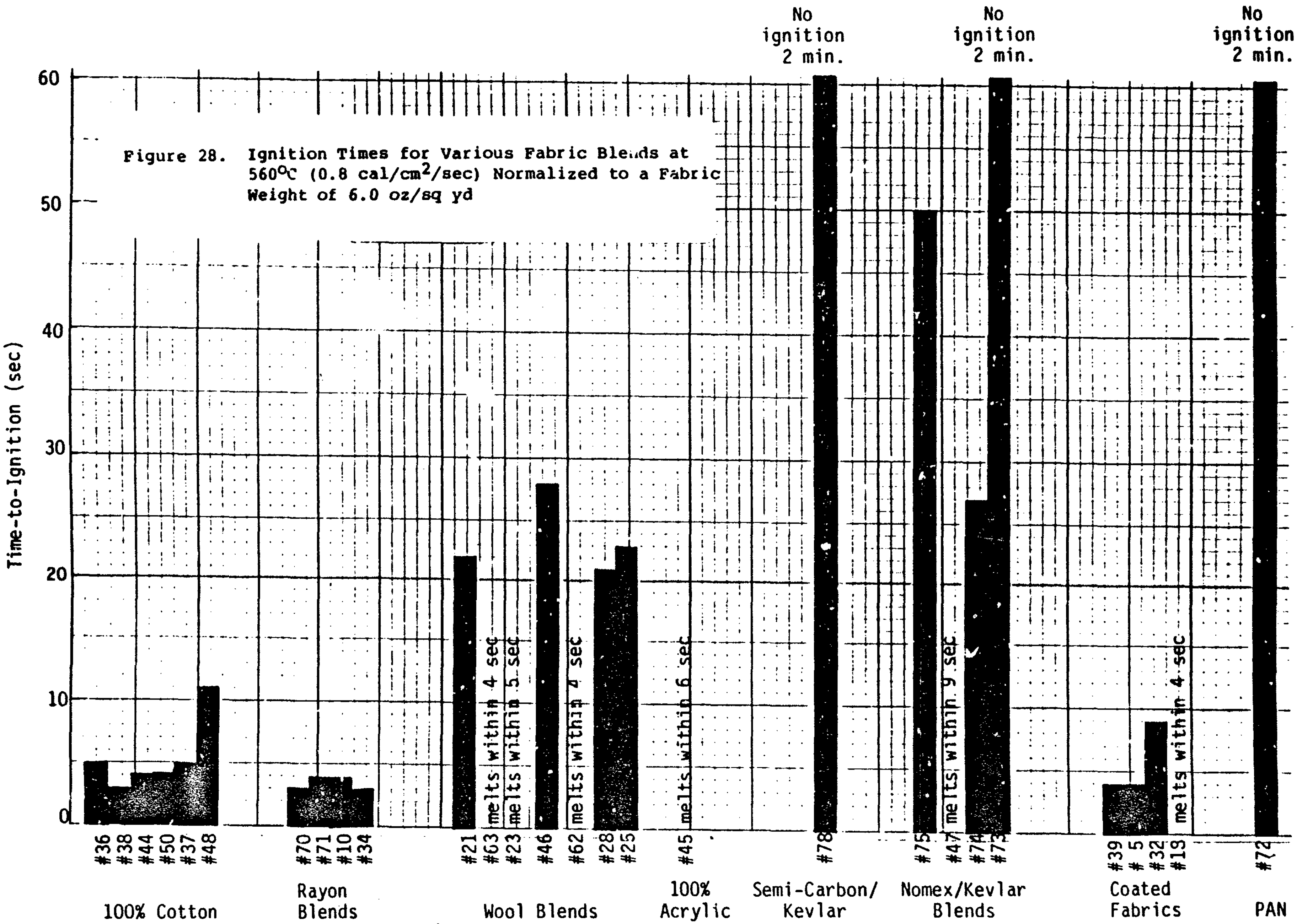


Figure 28. Ignition Times for Various Fabric Blends at 560°C (0.8 cal/cm^2/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

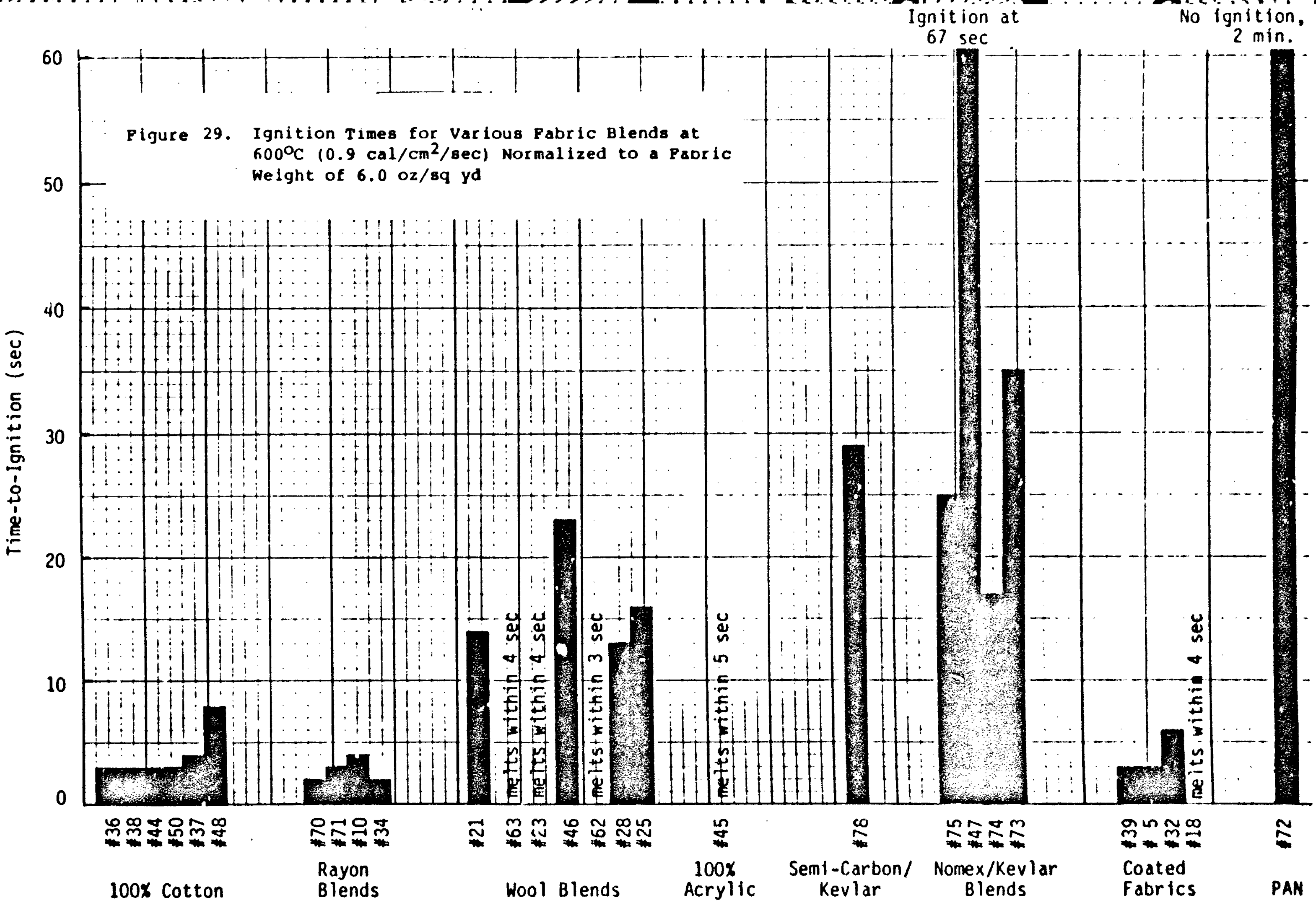


Figure 29. Ignition Times for Various Fabric Blends at 600°C (0.9 cal/cm²/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

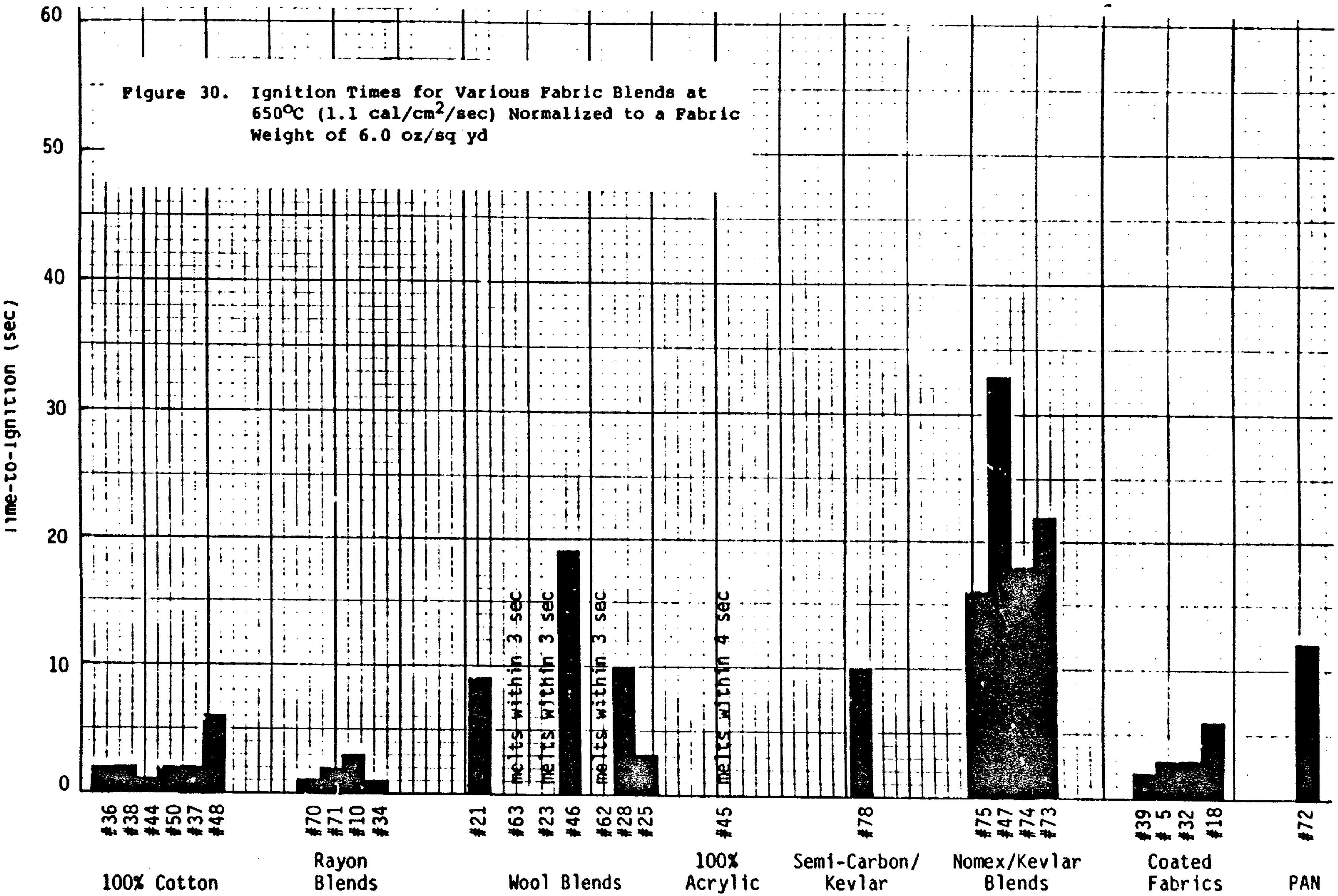


Figure 30. Ignition Times for Various Fabric Blends at 650°C (1.1 cal/cm²/sec) Normalized to a Fabric Weight of 6.0 oz/sq yd

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 unilateraly 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/cm^2/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/cm^2/sec; some of the fabrics ignited during the 60-second exposure at 0.75 cal/cm^2/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/cm^2/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.)

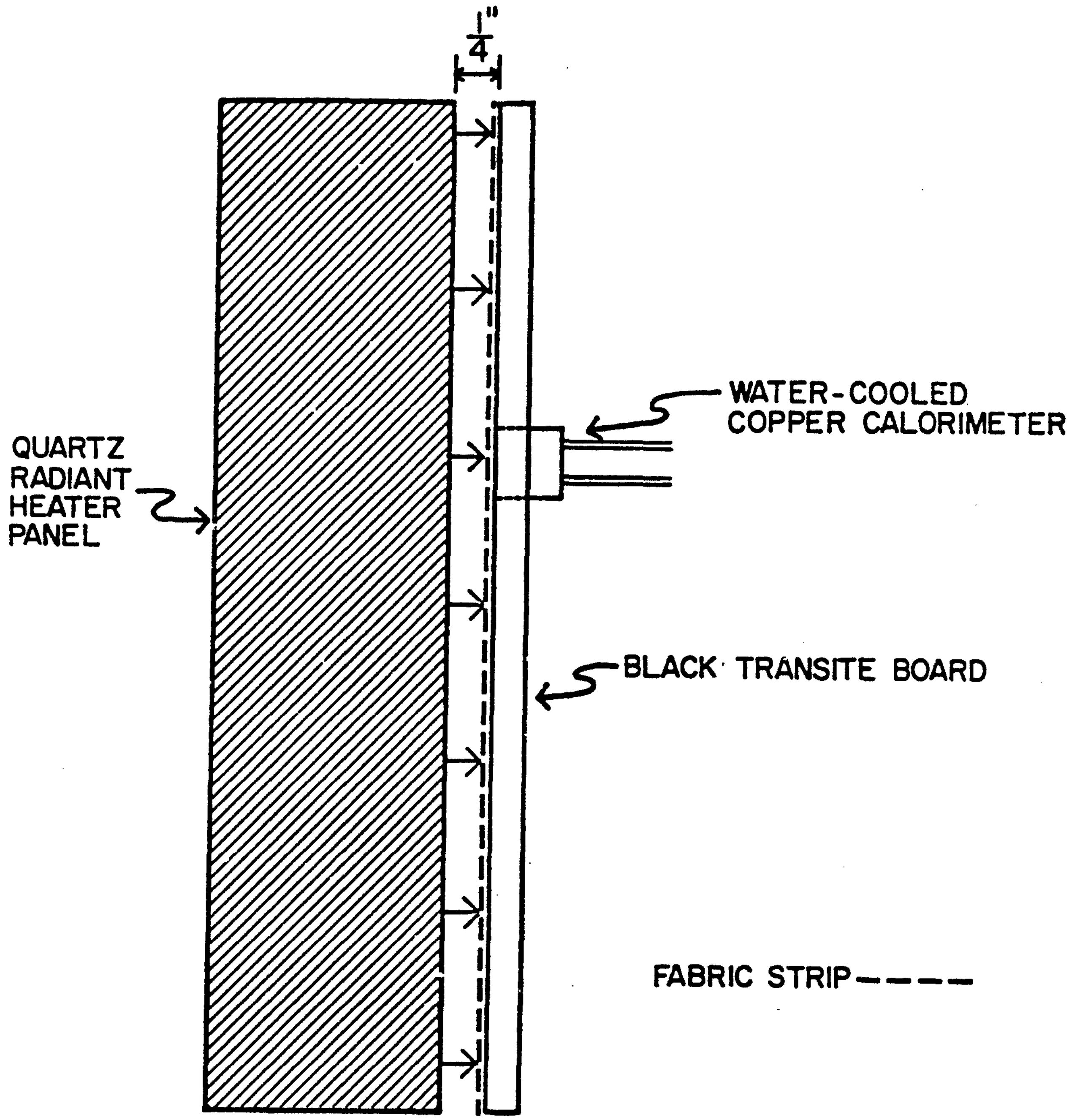


Figure 31. Test Configuration for Radiant Heat Transfer Measurements

Table 5

Summary of Heat Transfer Values to an Underlying Surface from 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 (%) 0.40 cal/cm²/sec	0.75 cal/cm²/sec	1.25 cal/cm²/sec	Time to Ignition (seconds) 0.75 cal/cm²/sec	1.25 cal/cm²/sec	Maximum Heat Transfer in 60 Seconds (%) 0.4 cal/cm²/sec	0.75 cal/cm²/sec	1.25 cal/cm²/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	30 (only 1 of 3)	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	—	60 (only 2 of 3)	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 (%)			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 c cm^2/s
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 fluorocarbon 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 fluorocarbon 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.)

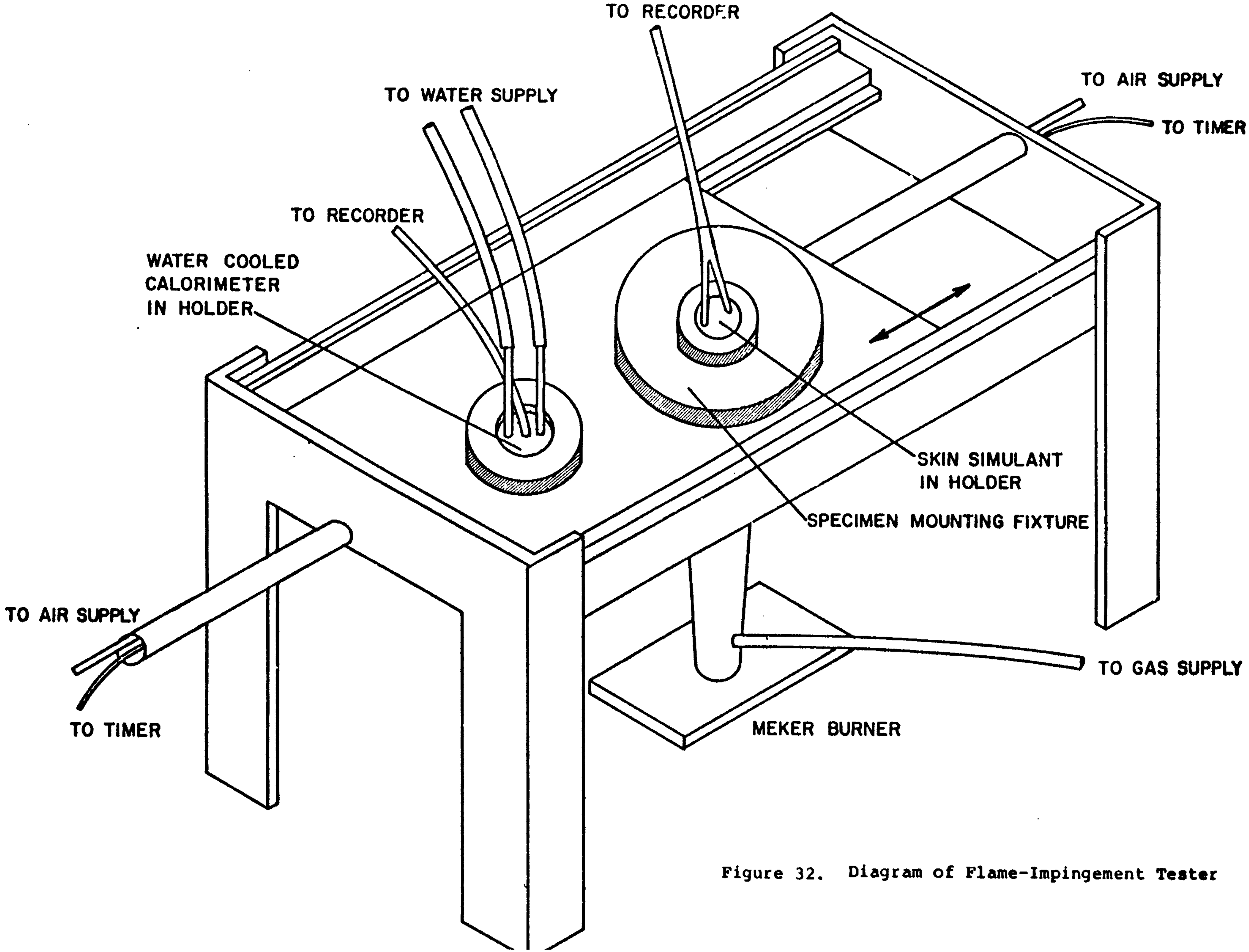
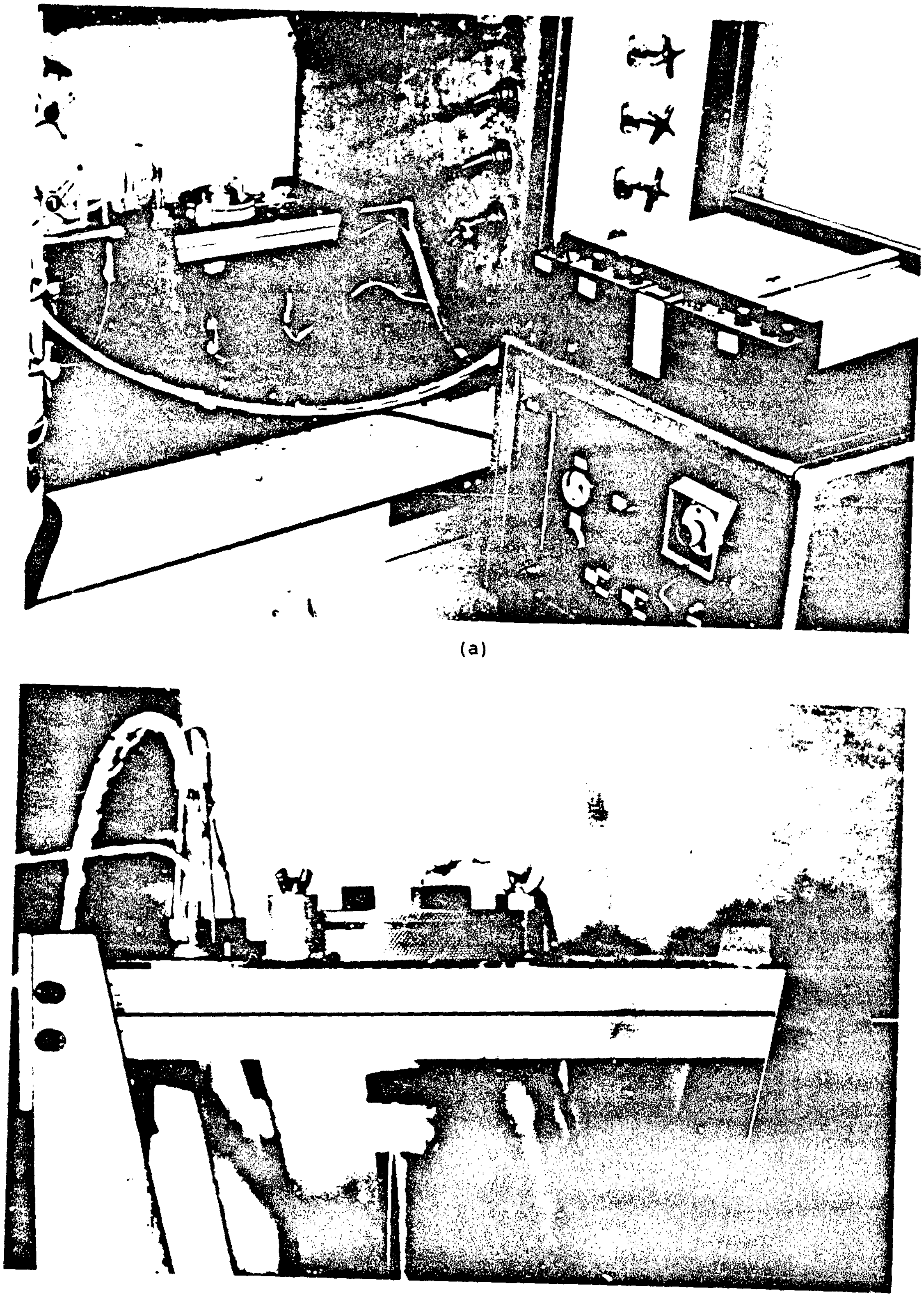


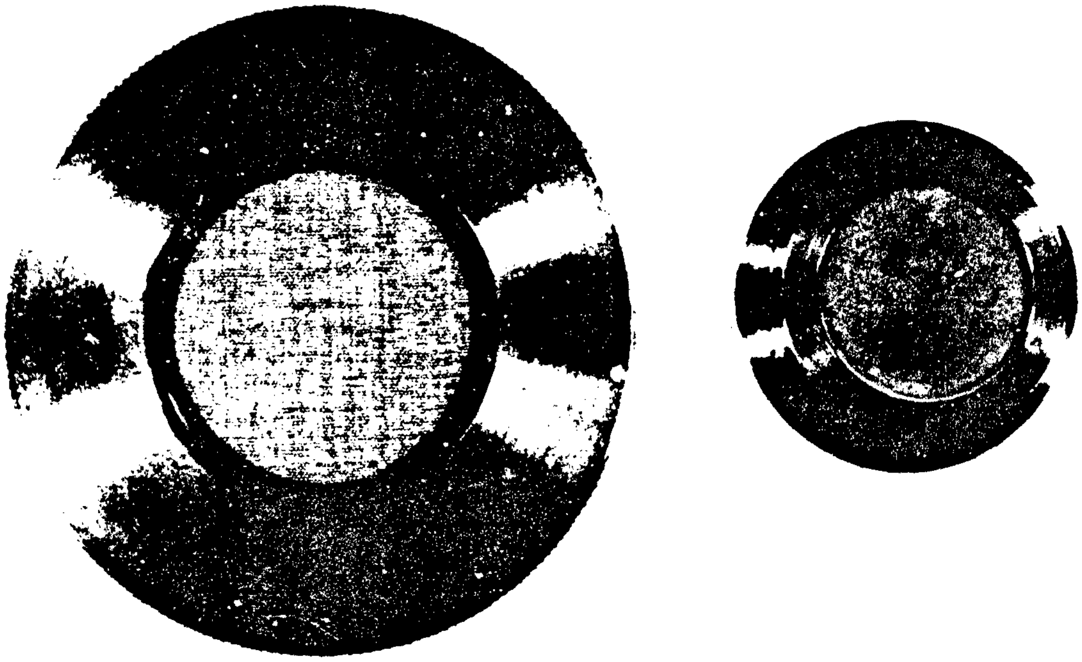
Figure 32. Diagram of Flame-Impingement Tester



(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 $\pm$ 0.1 cal/cm^2/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 500μ 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/cm³)	Thickness (inch) 0.035 psi	Thickness (inch) 0.63 psi	Temperature Rise (°C) at 3-sec	Temperature Rise (°C) at 6-sec	Maximum Temperature Rise (°C) 3-second exposure	Maximum Temperature Rise (°C) 6-second exposure	Approx. Burn Injury Index*
Single Layer Fabrics:										
36	100% cotton	13.3	0.20	0.120	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	0.037	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 PFR rayon/polyester	8.6	0.64	0.022	0.018	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 PFR rayon/polyester	8.5	0.28	0.059	0.041	12.0	34.0	14.2	40.6	
						13.2	33.6	16.1	41.[illegible]	
						16.0	36.4	17.7	42.4	
					Avg.	13.7	34.7	16.2	41.4	90
10	Rayon warp cotton fill	8.2	0.61	0.026	0.018	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 PFR rayon/Nomex	7.0	0.78	0.020	0.012	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	0.019	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	0.016	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	0.025	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	0.025	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 (cont.)
(heat flux, 2.2 cal/cm²/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm³)	Thickness (inch) 0.035 psi	Thickness (inch) 0.63 psi		Temperature Rise (°C) at 3-sec	Temperature Rise (°C) at 6-sec	Maximum Temperature Rise (°C) 3-second exposure		Maximum Temperature Rise (°C) 6-second exposure	Approx. Burn Injury Index*
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	14.9		24.2	0.1
63	70/30 wool/ modacrylic	12.8	0.18	0.122	0.094		13.1	41.0	15.3	split open	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	split open	46.8	
							10.1	54.2	19.9		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	0.106	0.080		23.5	88.4	25.1	split open	94.2	
							17.5	85.0	22.3		93.8	
							14.8	69.6	20.5		75.4	
						Avg.	18.6	81.0	[illegible]		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	
							19.3	50.2	25.5		53.8	
						Avg.	21.1	50.3	26.1		[illegible]	∞

*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/cm^2/sec)

Fabric No.	Fiber Content	Weight (oz/sq yd)	Density (g/cm^3)	Thickness (inch) 0.035 psi	Thickness (inch) 0.63 psi	Temperature Rise (°C) at 3-sec	Temperature Rise (°C) at 6-sec	Maximum Temperature Rise (°C) 3-second exposure		Maximum Temperature Rise (°C) 6-second exposure	Approx. Burn Injury Index*
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	43.8		62.0	
						28.6	54.0	45.2		60.8	
						27.0	54.0	44.4		61.4	
					Avg.	27.2	54.3	44.5		61.4	-
32	Nylon, neoprene coated	7.7	--	0.016	0.011	32.8	35.0	35.7		38.0	
						32.0	35.6	32.0		37.4	
						29.8	36.6	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	fabric melted during exposure	121.0	
						40.0	120.5	42.0		126.5	
						54.0	126.0	59.2		130.5	
					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		30.0	
					Avg.	6.6	21.0	11.9		29.1	>0.1
Fabric Assemblies:											
40	Polyester outer shell; 100% wool liner	12.0	--	0.053	0.042	8.2	21.8	12.5	outer shell melted	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	>0.1
1A	Polyester batt, nylon fabric	4.6	--	0.098	0.043	52.4	112.5	54.4	assembly melted	116.5	
						55.0	100.0	56.8		113.5	
						60.0	110.0	62.4		113.0	
					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) 0.035 psi	Thickness (inch) 0.63 psi	Temperature Rise (°C) at 3-sec	Temperature Rise (°C) at 6-sec	Maximum Temperature Rise (°C) 3-second exposure		Maximum Temperature Rise (°C) 6-second exposure	Approx. Burn Injury Index*
1	818 and 1A	7.7	--	0.107	0.049	10.5	79.8	16.4	assembly	79.8	
						13.0	81.2	15.4	melted	81.2	
						9.0	64.4	13.2	(6 sec)	64.4	
					Avg.	10.8	75.1	15.0		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	7.4		12.6	
						1.2	6.6	7.3		13.0	
						1.0	6.3	7.2		12.5	
					Avg.	1.1	6.4	7.3		12.7	<0.1
2A	50/50 cotton/ polyester outer shell; 100% nylon liner	12.5	--	0.094	0.068	4.5	20.8	20.0		31.6	
						4.7	22.2	19.7		29.0	
						4.6	24.6	20.1		30.0	
					Avg.	4.6	22.5	19.9		30.2	<0.1
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	7.1		9.8	
						2.5	9.0	8.4		11.7	
						3.0	9.7	8.0		12.5	
					Avg.	2.6	8.7	7.8		11.3	<0.1
21A	100% wool outer shell; 100% nylon liner	24.9	--	0.213	0.159	0.8	8.3	7.9		12.8	
						0.9	7.5	7.6		12.8	
						0.8	8.9	7.3		13.4	
					Avg.	0.8	8.2	7.6		13.0	<0.1
58	Nylon/acrylic outer shell; carbon impregnated liner	10.7	--	0.055	0.042	20.5	42.8	31.8	outer shell	49.4	
						21.0	46.4	29.4	melted	50.6	
						23.0	46.4	32.8		48.4	
					Avg.	21.5	45.2	31.3		49.5	∞

*Estimated from temperature rise <u>at</u> 3-seconds during 3-second exposure.

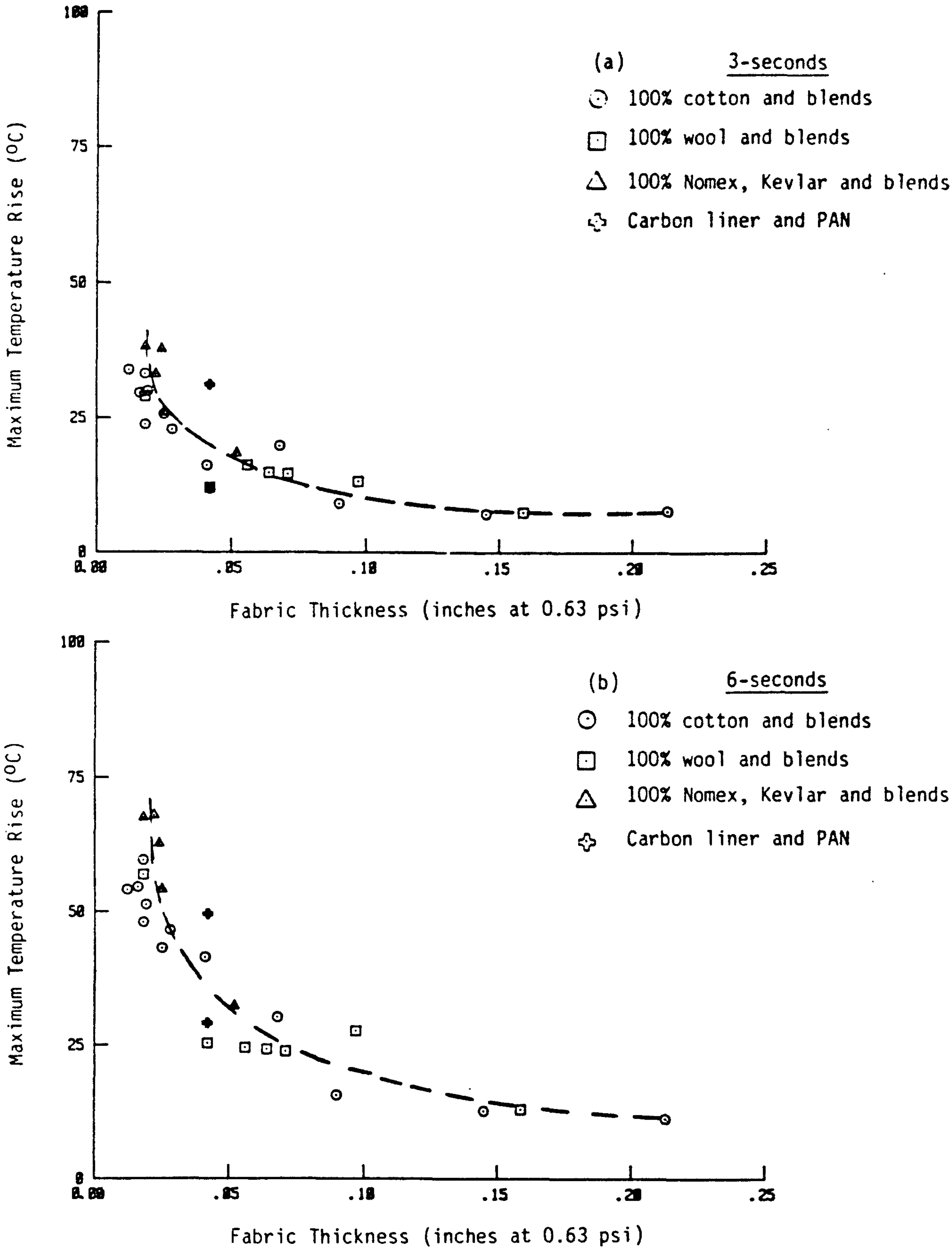


Figure 35. Variations of Maximum Temperature Rise of Single Layers and Fabric Assemblies with Fabric Thickness

VI. SUMMARY AND CONCLUSIONS

Measurements of strength loss and ease of ignition during bilateral irradiation to 1.1 cal/cm^2/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 cal/cm^2/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 cal/cm^2/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.

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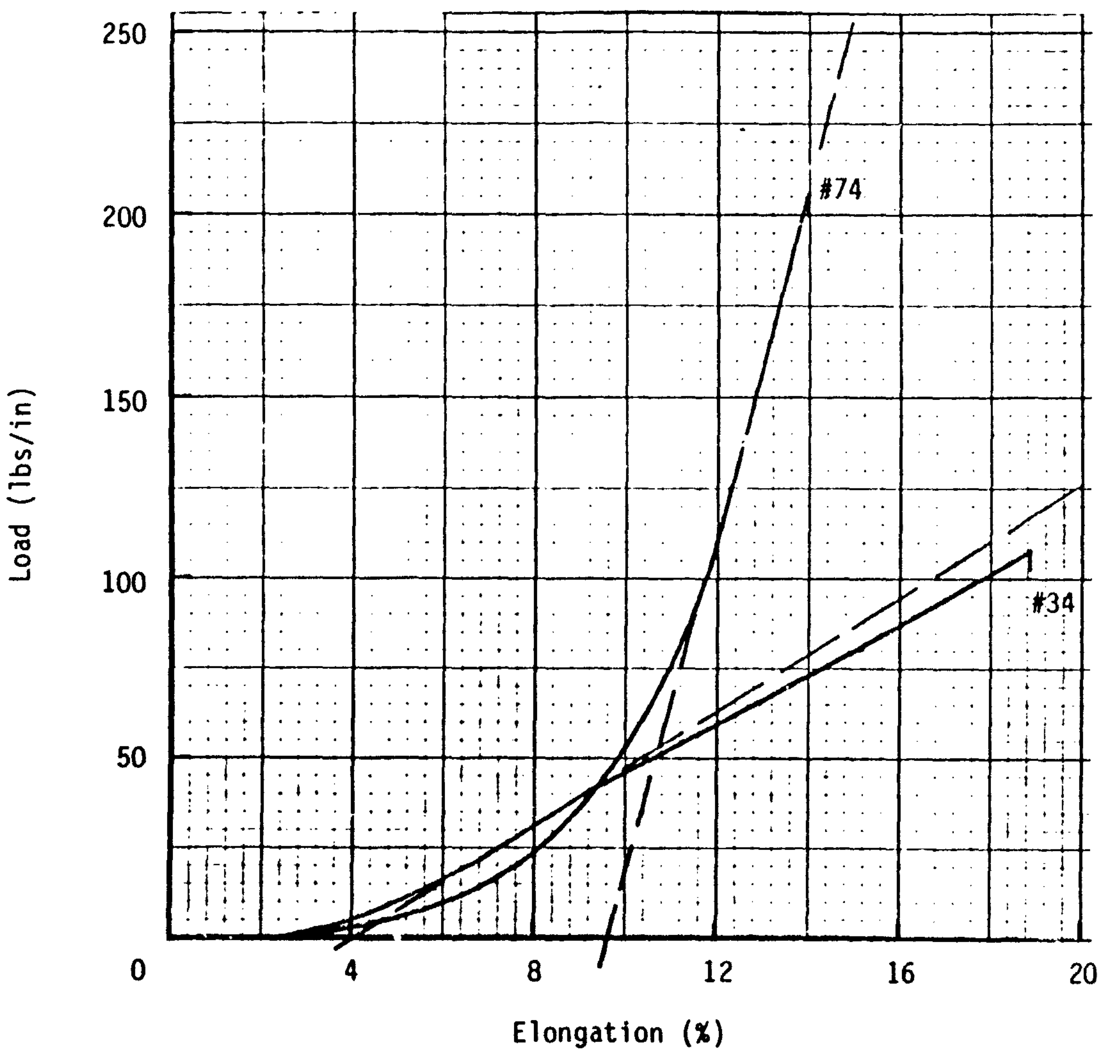

Fabric #34:

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

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

modulus = 788 lb/inch width/unit strain

Fabric #74:

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

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

modulus = 4720 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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #38	---	20	--	--	Avg. 2290	122	100
100% cotton							
10.3 oz/sq yd	0.2	270	0	3	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
	0.35	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #38 (cont)	0.6	500	0	3		1690	73	
						1650	69	
						1730	69	
					Avg.	1690	70	57
			5	7		500	10	
						690	20	
						750	16	
						640	13	
						720	19	
					Avg.	660	16	13
			10	12		40	1	
						40	1	
						40	2	
					Avg.	40	1	1
	0.8	560	0	3		1470	54	
						1480	59	
						1500	60	
					Avg.	1480	58	48
			5	6		150	2	
						40	1	
						210	3	
					Avg.	130	2	2
Fabric #70	---	20	--	--	Avg.	700	83	100
80/20 PFR								
rayon/polyester	0.2	270	0	7		610	74	
8.6 oz/sq yd						680	73	
						630	73	
					Avg.	640	73	88
			5	11		590	70	
						600	68	
						560	67	
					Avg.	590	68	82
			10	15		560	63	
						560	63	
						560	62	
					Avg.	560	63	76
			20	25		530	52	
						560	57	
						520	57	
					Avg.	540	55	66
			60	64		430	21	
						450	26	
						380	16	
						460	35	
						480	41	
					Avg.	440	28	34
	0.3	350	0	6		560	64	
						550	65	
						560	67	
						560	65	78
			5	11		510	53	
						530	56	
						460	53	
					Avg.	500	54	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #70 (cont)	0.3	350	10	15		350	32	
						360	35	
						370	35	
					Avg.	360	34	41
			20	23		200	9	
						130	5	
						190	9	
					Avg.	180	8	10
			25	27		91	4	
						32	1	
						34	1	
					Avg.	52	2	2
	0.35	400	0	6		550	55	
						540	58	
						550	58	
					Avg.	550	57	67
			5	10		330	31	
						380	34	
						350	34	
					Avg.	350	33	40
			10	14		240	17	
						170	9	
						240	15	
						270	15	
						260	19	
					Avg.	240	15	18
			20	—	Avg.	0	0	0
	0.6	500	0	5		430	33	
						470	39	
						420	30	
					Avg.	440	34	41
			5	7		70	3	
						80	3	
						60	3	
					Avg.	70	3	3
	0.8	560	0	4		350	18	
						370	21	
						390	21	
					Avg.	370	20	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 (^oC)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #10	---	20	--	--	Avg. 2760	222	100
rayon warp							
cotton fill	0.2	270	0	6	1770	153	
8.2 oz/sq yd					1730	175	
					1800	190	
					1810	176	
					1950	170	
					Avg. 1810	173	78
			5	11	1910	166	
					1030	168	
					1920	183	
					1890	187	
					1900	187	
					Avg. 1730	182	82
			10	16	2000	178	
					2240	170	
					2180	180	
					Avg. 2140	176	79
			20	25	1930	155	
					2230	192	
					2180	163	
					2200	191	
					2310	192	
					Avg. 2170	179	81
			60	65	1840	157	
					2110	161	
					2090	160	
					Avg. 2013	159	72
	0.3	350	0	7	1230	172	
					1250	171	
					1330	183	
					1240	164	
					1320	167	
					Avg. 1270	171	77
			5	11	1850	171	
					1880	170	
					1790	160	
					1850	154	
					1720	157	
					Avg. 1820	162	73
			10	14	1670	129	
					2050	146	
					1880	148	
					1510	124	
					1500	132	
					Avg. 1720	136	61
			20	24	900	77	
					790	80	
					820	66	
					930	66	
					900	70	
					Avg. 870	72	32
			60	61	430	6	
					340	5	
					573	6	
					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 (^oC)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
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 80/20 PFR rayon/Nomex 7.0 oz/sq yd	---	20	--	--	Avg. 790	107	100
	0.2	270	0	8	770	87	
					800	93	
					750	91	
					Avg. 770	90	84
			5	12	770	91	
					770	92	
					750	89	
					Avg. 760	91	85
			10	17	710	76	
					720	84	
					780	88	
					Avg. 740	83	7[illegible]
			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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
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	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 (^oC)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #44 100% cotton 3.2 oz/sq yd	---	20	--	--	Avg.	2350	148	100
	0.2	270	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	
						1800	94	
						1590	85	
						2050	95	
					Avg.	1720	89	60
			5	10		1550	64	
						1470	58	
						1500	64	
					Avg.	1510	62	42
			10	15		1340	51	
						1260	52	
						1390	53	
					Avg.	1330	52	35
			20	24		990	24	
						760	21	
						1190	39	
						750	18	
						890	26	
					Avg.	920	26	18
			60	61		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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #44 (cont)	0.35	400	0	5		1750	87	
						1280	67	
						1160	57	
						1670	85	
						1500	78	
					Avg.	1470	75	51
			5	10		1310	54	
						1150	47	
						1410	54	
					Avg.	1290	52	35
			10	14		770	21	
						810	25	
						770	22	
					Avg.	7[illegible]0	23	16
			20	21		70	1	
						70	2	
						80	2	
					Avg.	70	2	1
	0.6	500	0	5		830	43	
						1230	53	
						850	39	
					Avg.	970	45	30
			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	76
			5	10		1990	82	
						1740	70	
						1740	69	
					Avg.	1820	74	63
			10	15		1540	59	
						1710	62	
						1540	61	
					Avg.	1600	61	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) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #50 (cont)			20	25		1480	52	
						1550	55	
						1530	54	
					Avg.	1520	54	46
			60	64		1800	58	
						1610	49	
						1690	51	
					Avg.	1700	53	45
	0.3	350	0	5		1700	77	
						1660	72	
						1690	75	
					Avg.	1680	75	64
			5	10		1700	54	
						1660	50	
						1690	56	
					Avg.	1680	53	45
			10	15		1160	40	
						1310	39	
						1380	48	
					Avg.	1290	42	36
			20	24		900	23	
						990	25	
						1040	26	
					Avg.	980	25	21
			60	62		190	3	
						170	6	
						190	4	
					Avg.	180	4	3
	0.35	400	0	4		1390	57	
						1470	57	
						1390	55	
					Avg.	1420	56	47
			5	9		1290	43	
						1260	42	
						1230	40	
					Avg.	1260	42	36
			10	14		710	19	
						550	13	
						770	18	
					Avg.	680	17	14
			20	22		90	2	
						80	1	
						50	1	
					Avg.	70	1	1
	0.6	500	0	4		990	33	
						900	39	
						810	32	
					Avg.	900	35	30
			5	7		110	3	
						80	2	
						40	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #50 (cont)	0.8	560	0	4		500	18	
						640	22	
						570	23	
					Avg.	570	21	18
			5	--	Avg.	---	0	0
Fabric #37 100% cotton 5.1 oz/sq yd	---	20	--	--	Avg.	170	19	100
	0.2	270	0	14		120	13	
						150	17	
						150	15	
					Avg.	140	15	79
			5	17		90	8	
						110	11	
						80	9	
					Avg.	90	9	49
			10	21		60	6	
						50	6	
						70	7	
					Avg.	60	6	32
			20	28		30	4	
						50	6	
						40	4	
					Avg.	40	5	26
			60	65		20	2	
						10	1	
						10	1	
					Avg.	10	1	5
	0.3	350	0	9		50	4	
						30	4	
						50	4	
					Avg.	40	4	22
			5	10		10	1	
						10	1	
						10	1	
					Avg.	10	1	6
			10	13		---	>0.5	
						---	>0.5	
						---	>0.5	
					Avg.	---	>0.5	2
	0.35	400	0	7		20	2	
						20	2	
						20	2	
					Avg.	20	2	9
			5	9		---	>0.5	
						---	>0.5	
						---	>0.5	
					Avg.	---	>0.5	1
	0.6	500	0	4		---	>0.5	
						---	>0.5	
						---	>0.5	
					Avg.	---	>0.5	1
	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #21	---	20	--	--	Avg. 290	56	100
100% wool							
15.7 oz/sq yd	0.2	270	0	12	200	46	
					190	43	
					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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #21 (cont)	0.35	400	0	12		210	45	
						190	41	
						210	38	
					Avg.	210	41	73
			5	15		190	30	
						200	29	
						210	34	
					Avg.	200	31	[illegible]5
			10	20		210	30	
						190	29	
						180	34	
					Avg.	190	31	48
			20	23		50	2	
						65	3	
						65	3	
					Avg.	60	3	5
			25	--	Avg.	--	0	0
	0.6	500	0	9		230	35	
						210	33	
						210	31	
					Avg.	220	33	59
			5	11		180	18	
						180	18	
						180	17	
					Avg.	180	18	32
			10	12		---	<1	
						---	1	
						---	<1	
					Avg.	---	<1	<1
	0.8	560	0	8		210	23	
						200	23	
						190	21	
					Avg.	200	22	39
			5	9		100	6	
						120	7	
						110	6	
					Avg.	110	6	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #28 90/10 wool/nylon	---	20	--	--	Avg.	200	35	100
8.2 oz/sq yd	0.2	270	0	14		90	22	
						90	29	
						100	24	
					Avg.	90	25	71
			5	17		120	22	
						130	24	
						90	27	
					Avg.	110	24	69
			10	22		130	21	
						130	24	
						150	28	
					Avg.	140	24	69
			20	30		120	20	
						120	22	
						120	20	
					Avg.	120	21	60
			60	70		90	15	
						100	15	
						100	18	
					Avg.	100	16	46
	0.3	350	0	15		80	19	
						110	21	
						80	19	
					Avg.	90	20	57
			5	18		70	15	
						100	16	
						90	17	
					Avg.	90	16	46
			10	18		90	10	
						90	9	
						100	14	
					Avg.	90	11	31
			20	23		40	<1	
						50	1	
						50	1	
					Avg.	50	1	2
	0.35	400	0	11		140	23	
						160	25	
						140	25	
					Avg.	150	24	69
			5	14		120	15	
						120	13	
						120	16	
					Avg.	120	15	43
			10	16		60	4	
						70	5	
						60	4	
					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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #28 (cont)	0.6	500	0	7		40	3	
						30	3	
						40	3	
					Avg.	40	3	8
			5	--	Avg.	0	0	0
	0.8	560	0	4		20	1	
						20	2	
						20	1	
					Avg.	20	1	4
Fabric #25	---	20	--	--	Avg.	440	92	100
55/45 polyester/wool								
6.6 oz/sq yd	0.2	270	0	11		250	48	
						360	48	
						320	48	
					Avg.	310	48	52
			5	17		190	39	
						200	44	
						190	41	
					Avg.	170	41	45
			10	20		190	22	
						166	19	
						210	40	
						220	31	
						210	36	
					Avg.	200	30	33
			20	27		140	12	
						120	11	
						170	16	
					Avg.	150	13	14
			60	64		100	6	
						90	5	
						90	5	
					Avg.	90	5	5
	0.3	350	0	7		130	16	
						170	20	
						140	17	
					Avg.	150	19	45
			5	12		50	3	
						40	3	
						40	3	
					Avg.	40	3	7
	0.35	400	0	6		110	12	
						90	8	
						120	11	
					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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #25 (cont)	0.6	500	0	2	70	69	
					70	67	
					60	60	
					Avg. 70	65	6
	0.8	560	0	2	40	1	
					40	1	
					40	1	
					Avg. 40	1	1
Fabric #78 core spun, semi-carbon Kevlar 15.4 oz/sq yd	---	20	--	--	Avg. 2170	205	100
	0.2	270	0	8	1720	168	
					1770	169	
					1740	174	
					Avg. 1740	170	83
			5	13	1610	171	
					1500	171	
					1510	172	
					Avg. 1570	171	83
			10	17	1540	170	
					1600	169	
					1620	170	
					Avg. 1590	170	83
			20	26	1520	139	
					1540	159	
					1610	156	
					Avg. 1560	151	74
			60	65	1480	110	
					1440	11[illegible]	
					1320	109	
					Avg. 1420	112	55
	0.3	350	0	8	1340	153	
					1370	152	
					1290	154	
					Avg. 1330	153	75
			5	12	1440	148	
					1450	155	
					1380	140	
					Avg. 1430	148	72
			10	16	1260	125	
					1390	136	
					1420	136	
					Avg. 1030	130	63
			20	26	1130	101	
					1110	104	
					1200	102	
					Avg. 1150	106	52
			60	62	960	39	
					1010	26	
					1080	27	
					Avg. 1020	31	15

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #78 (cont)	0.35	400	0	8		1210	148	
						1180	148	
						1190	148	
					Avg.	1190	148	72
			5	12		1270	135	
						1260	139	
						1320	143	
					Avg.	1290	139	68
			10	16		1060	100	
						1070	100	
						1240	119	
					Avg.	1120	106	52
			20	25		870	63	
						840	63	
						890	69	
					Avg.	870	65	32
			60	62		990	29	
						960	28	
						1010	28	
					Avg.	990	28	14
	0.6	500	0	7		1160	133	
						1240	136	
						1170	120	
					Avg.	1190	130	63
			5	11		980	78	
						1110	87	
						930	78	
					Avg.	1000	81	40
			10	14		500	25	
						560	33	
						480	25	
					Avg.	510	28	14
			20	22		420	11	
						460	12	
						440	13	
					Avg.	440	12	6
			60	61		660	13	
						650	11	
						640	13	
					Avg.	650	12	6
	0.8	560	0	7		1080	96	
						1040	106	
						1100	110	
					Avg.	1070	104	51
			5	10		740	51	
						710	49	
						740	47	
					Avg.	730	49	24
			10	13		200	10	
						170	8	
						240	13	
					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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #78 (cont)			20	22	560	13	
					540	12	
					560	12	
					Avg. 560	12	6
			60	61	940	12	
					890	14	
					820	12	
					Avg. 880	13	6
Fabric #75 100% Kevlar	---	20	--	--	Avg. 8450	439	100
8.3 oz/sq yd	0.2	270	0	6	7670	350	
					7670	340	
					6310	300	
					Avg. 7220	330	75
			5	11	8770	320	
					7180	320	
					8770	340	
					Avg. 8240	330	74
			10	15	6820	283	
					8130	294	
					7500	318	
					Avg. 7490	298	68
			20	25	6310	254	
					7760	265	
					7420	275	
					Avg. 7160	266	61
			60	65	7500	244	
					6740	263	
					6960	270	
					Avg. 7070	260	59
	0.3	350	0	6	8230	285	
					7760	304	
					7420	280	
					Avg. 7800	291	63
			5	10	6030	236	
					7180	255	
					7670	257	
					Avg. 6960	249	57
			10	15	6890	205	
					6750	206	
					6960	203	
					Avg. 6870	205	47
			20	25	5630	156	
					5320	150	
					5670	188	
					Avg. 5370	165	38
			60	65	3690	118	
					4090	125	
					4290	129	
					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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
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	120	
						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	
						880	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #47 100% Nomex	---	20	---	---	Avg.	600	152	100
8.1 oz/sq yd	0.2	270	0	16		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	119	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #47 (cont)			20	30		290	43	
						330	43	
						310	50	
					Avg.	310	45	30
			60	68		310	31	
						320	37	
						270	28	
					Avg.	300	32	21
	0.6	500	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	560	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	---	20	—	--	Avg.	4750	202	100
	0.2	270	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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
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
	0.35	400	0	5		3860	132	
						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
	0.6	500	0	4		2530	77	
						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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #74 (cont)			20	24	560	15	
					520	13	
					510	15	
					Avg. 530	14	7
			60	62	290	10	
					290	9	
					240	7	
					Avg. 270	9	4
	0.8	5[illegible]	0	5	1990	53	
					1890	53	
					1890	55	
					Avg. 1950	54	27
			5	9	990	19	
					980	22	
					850	22	
					Avg. 940	21	10
			10	14	590	14	
					520	13	
					510	13	
					Avg. 540	13	6
			20	22	190	4	
					210	5	
					220	5	
					Avg. 210	5	2
			25	25	80	1	
					90	1	
					70	1	
					Avg. 80	1	<1
Fabric #73 95/5 Nomex/Kevlar	---	20	--	---	Avg. 2090	129	100
5.3 oz/sq yd	0.2	270	0	6	1780	102	
					1790	104	
					1780	106	
					Avg. 1780	104	81
			5	10	1580	95	
					1530	101	
					1430	91	
					Avg. 1510	96	74
			10	15	1320	85	
					1380	87	
					1320	89	
					Avg. 1340	87	67
			20	25	1220	84	
					1270	82	
					1240	87	
					Avg. 1240	84	65
			60	65	1390	86	
					1380	84	
					1530	87	
					Avg. 1430	86	67

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
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	
					700	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	
					[illegible]30	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) At Start	Exposure Time (sec) At Rupture	Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #73 (cont)	0.8	560	0	2	1110	35	
					1140	37	
					1090	34	
					Avg. 1110	35	27
			5	6	40	2	
					50	2	
					50	2	
					Avg. 50	2	2
Fabric #39 nylon, butyl coated 12.5 oz/sq yd	---	20	--	--	Avg. 1120	173	100
	0.2	270	0	13	720	97	
					720	101	
					730	101	
					Avg. 730	100	58
			5	18	590	97	
					580	96	
					630	96	
					Avg. 600	96	56
			10	23	530	94	
					540	95	
					540	96	
					Avg. 540	95	55
			20	32	500	91	
					480	89	
					490	98	
					Avg. 490	93	54
			60	72	400	81	
					420	79	
					490	79	
					Avg. 400	79	46
	0.3	350	0	12	570	71	
					580	72	
					590	74	
					Avg. 560	73	42
			5	14	410	53	
					400	57	
					400	57	
					Avg. 400	56	32
			10	17	350	42	
					340	41	
					380	50	
					Avg. 360	44	25
			20	23	40	3	
					40	3	
					70	6	
					Avg. 50	4	2
	0.35	400	0	8	470	50	
					480	54	
					490	53	
					Avg. 480	52	30
			5	10	290	32	
					260	28	
					290	29	
					Avg. 280	30	17

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #39 (cont)			10	11		140	9	
						120	7	
						---	4	
						150	7	
						140	8	
					Avg.	140	7	4
			15	15	Avg.	0	0	0
	0.6	500	0	4		300	26	
						370	26	
						400	32	
					Avg.	360	28	16
			5	5	Avg.	0	0	0
	0.8	560	0	3		300	17	
						360	20	
						300	13	
					Avg.	320	17	10
			5	5	Avg.	0	0	0
Fabric #5 cotton, resin modified, butyl coated 10.5 oz/sq yd	---	20	---	---	Avg.	1300	72	100
	0.2	270	0	5		1300	68	
						1260	58	
						1090	57	
					Avg.	1220	61	85
			5	10		1270	60	
						1260	53	
						1140	49	
					Avg.	1230	54	75
			10	14		1310	54	
						1180	45	
						1230	46	
					Avg.	1241	48	67
			20	25		1060	42	
						1130	42	
						1020	34	
					Avg.	1070	39	34
			60	65		1050	35	
						1040	40	
						940	32	
					Avg.	1010	36	50
	0.3	350	0	5		760	30	
						840	39	
						920	39	
					Avg.	840	36	50
			5	10		770	32	
						850	36	
						920	32	
					Avg.	850	33	46
			10	15		790	30	
						750	28	
						840	28	
					Avg.	790	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) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #5 (cont)			20	25		790	27	
						810	27	
						850	32	
					Avg.	820	29	40
			60	62		50	1	
						60	1	
						30	1	
					Avg.	50	1	1
	0.35	400	0	5		1160	50	
						1210	43	
						1220	49	
					Avg.	1200	47	65
			5	10		750	27	
						910	31	
						880	33	
					Avg.	850	30	42
			10	15		700	23	
						820	24	
						800	25	
					Avg.	780	24	33
			20	22		90	1	
						40	1	
						100	3	
					Avg.	80	2	3
	0.6	500	0	5		1020	36	
						890	30	
						820	33	
					Avg.	910	33	46
			5	9		290	8	
						130	5	
						160	6	
					Avg.	190	6	8
			10	10	Avg.	0	0	0
	0.8	560	0	5		680	23	
						610	22	
						610	21	
					Avg.	630	22	31
			5	5	Avg.	0	0	0
Fabric #32 nylon, neoprene coated 7.7 oz/sq yd	---	20	--	--	Avg.	1440	158	100
	0.2	270	0	7		1050	120	
						1130	125	
						1130	125	
					Avg.	1100	123	78
			5	12		930	110	
						990	110	
						850	99	
					Avg.	920	110	67
			10	18		750	83	
						790	102	
						750	94	
					Avg.	760	93	59

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #32 (cont)			20	28		680	95	
						740	94	
						670	93	
					Avg.	700	94	59
	0.3	350	0	7		630	70	
						640	68	
						640	70	
					Avg.	340	59	44
			5	12		480	62	
						400	50	
						400	52	
					Avg.	430	55	35
			10	15		310	31	
						340	34	
						300	31	
					Avg.	310	32	20
			15	15	Avg.	0	0	0
	0.35	400	0	6		490	48	
						440	48	
						570	61	
					Avg.	500	52	33
			5	8		270	20	
						300	25	
						290	21	
					Avg.	290	22	14
			10	10	Avg.	0	0	0
	0.6	500	0	4		380	25	
						430	32	
						400	29	
					Avg.	400	29	18
			5	5	Avg.	0	0	0
	0.8	560	0	3		450	20	
						440	18	
						460	20	
					Avg.	450	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	30	
						190	29	
						210	31	
					Avg.	200	30	45
			5	18		130	29	
						120	31	
						130	30	
					Avg.	130	30	45

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #18 (cont)			10	24		90	23	
						120	29	
						120	28	
					Avg.	110	26	39
			20	33		90	22	
						120	30	
						100	28	
					Avg.	110	27	40
			60	72		120	28	
						130	30	
						130	28	
						90	4) melted	
						120	7)	
					Avg.	120	19	28
	0.3	350	0	5		140	7	
						120	7	
						140	8	
					Avg.	130	7	10
			5	6		---	1	
						---	2	
						---	1	
					Avg.	---	1	2
	0.35	400	0	3		150	7	
						150	6	
						170	7	
					Avg.	160	7	10
			5	5	Avg.	0	0	0
	0.6	500	0	1		170	3	
						160	3	
						160	3	
					Avg.	160	3	5
	0.8	560	0	1		160	3	
						160	2	
						160	2	
					Avg.	160	2	3
Fabric #72	---	20	--	--	Avg.	3010	163	100
PAN								
15.6 oz/sq yd	0.2	270	0	6		2410	127	
						2500	130	
						2780	138	
					Avg.	2570	128	79
			5	11		2130	131	
						2000	136	
						2130	131	
					Avg.	2080	133	82
			10	15		1900	129	
						1860	121	
						1900	139	
					Avg.	1890	130	80
			20	24		1840	121	
						1970	131	
						1901	137	
					Avg.	1900	130	80

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/ unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #72 (cont)			60	63		1920	84	
						1930	91	
						1930	87	
					Avg.	1930	87	53
	0.3	350	0	6		1990	113	
						2050	121	
						2000	113	
					Avg.	2010	116	71
			5	9		1710	126	
						1710	126	
						1840	123	
					Avg.	1750	125	77
			10	14		1840	125	
						1780	118	
						1550	115	
					Avg.	1720	119	73
			20	23		1570	95	
						1610	94	
						1580	88	
					Avg.	1590	92	56
			60	60		600	6	
						1000	8	
						600	6	
					Avg.	730	7	4
	0.35	400	0	6		1780	113	
						1590	113	
						1670	123	
					Avg.	1680	116	71
			5	10		1630	120	
						1840	128	
						1563	115	
					Avg.	1679	121	74
			10	14		1610	108	
						1710	103	
						1640	100	
					Avg.	1650	105	64
			20	22		1890	55	
						1040	45	
						1210	50	
					Avg.	1380	50	31
			60	60		1190	8	
						800	6	
						790	6	
					Avg.	930	7	4

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/cm²/sec)	Heater Temp (°C)	Exposure Time (sec) At Start	Exposure Time (sec) At Rupture		Modulus (lbs/inch width/unit strain)	Rupture Load (lbs/inch width)	Strength Retention (%)
Fabric #72 (cont)	0.6	500	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	Glow Only 90 75 85 Avg. 83	Medium smoke at 55 seconds
	0.35	400	Glow Only 50 50 50 Avg. 50	Heavy smoke at 35 seconds
	0.6	500	17 21 18 Avg. 19	Heavy smoke at 18 seconds
	0.8	560	9 10 11 Avg. 10	Medium smoke at 8 seconds
	0.9	600	6 6 6 Avg. 6	Light smoke at 5 seconds
	1.1	650	4 4 4 Avg. 4	Light smoke at 3 seconds
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 5 7 Avg. 6	Light smoke at 45 seconds
	0.9	600	5 5 5 Avg. 5	Medium smoke at 4 seconds
	1.1	650	2 3 3 Avg. 3	Heavy smoke at ignition

Appendix Table 2 (cont)

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

Fabric Description	Radiant Heat Flux (cal/cm²/sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #70 80/20 PFR 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	Medium smoke at 4 seconds
			6	
			5	
			Avg. 5	
	0.9	600	4	Medium smoke at 2-3 seconds
			3	
			5	
			3	
			3	
			Avg. 3	
	1.1	650	2	Heavy smoke at ignition
			2	
			2	
			Avg. 2	
Fabric #71 80/20 PFR rayon/ Nomex 8.5 oz/sq yd	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	Heavy smoke at 6 seconds
			9	
			8	
			Avg. 8	
	0.8	560	5	Light smoke at 4 seconds
			6	
			5	
			Avg. 5	
	0.9	600	4	Light smoke at 3 seconds
			4	
			4	
			Avg. 4	
	1.1	650	3	No smoke generation
			3	
			3	
			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/cm²/sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #10 rayon warp	0.2	270	No ignition, 2 min	No smoke generation
cotton fill 8.2 oz/sq yd	0.3	350	Glow -- 94 70 Avg. 82	Light-medium smoke at 60-90 seconds
	0.35	400	Glow 34 30 30 Avg. 32	Medium-heavy smoke at 20-25 seconds
	0.6	500	9 14 10 8 14 Avg. 11	Heavy smoke at 7-10 seconds
	0.8	560	8 6 8 6 3 Avg. 6	Light smoke at 5 seconds
	0.9	600	5 5 5 Avg. 5	Light smoke at 4 seconds
	1.1	650	4 4 3 Avg. 4	Light smoke at 3 seconds
Fabric #34 80/20 PFR rayon/Nomex	0.2	270	No ignition, 2 min	No smoke generation
7.0 oz/sq yd	0.3	350	No ignition, 2 min	Medium-heavy smoke at 20 seconds
	0.35	400	No ignition, 3 min	Heavy smoke at 13 seconds
	0.[illegible]	500	8 8 8 Avg. 8	Heavy smoke at 7 seconds
	0.8	560	4 3 3 Avg. 3	Medium-heavy smoke at 2 seconds
	0.9	600	2 2 2 2	Light smoke at 1 second
	1.1	650	1 2 1 Avg. 1	Light 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/cm²/sec)	Heater Temp (°C)	Time to Ignition (seconds)	Smoke Generation
Fabric #37	0.2	270	No ignition, 2 min	No smoke generation
100% cotton				
5.1 oz/sq yd	0.3	350	Glow Only	Medium smoke at 10 seconds
			35	
			35	
			35	
			35	
	0.35	400	Glow Only	Medium to heavy at 10 seconds
			21	
			23	
			23	
			Avg. 22	
	0.6	500	6	Medium smoke at 4 seconds
			6	
			5	
			Avg. 6	
	0.8	560	4	Light smoke at 3 seconds
			4	
			4	
			Avg. 4	
	0.9	600	3	Light smoke at 2 seconds
			3	
			3	
			Avg. 3	
	1.1	650	2	Light smoke at 1 second
			2	
			2	
			Avg. 2	
Fabric #48	0.2	270	No ignition, 2 min	No smoke generation
100% cotton				
4.3 oz/sq yd	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	
			35 (glow only)	
			Avg. 32	
	0.6	500	13	Medium smoke at 12 seconds
			14	
			13	
			Avg. 13	
	0.8	560	7	Light smoke at 7 seconds
			9	
			8	
			Avg. 8	
	0.9	600	6	Light smoke at 5 seconds
			7	
			6	
			Avg. 6	
	1.1	650	5	Light smoke at 3 seconds
			3	
			5	
			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/cm²/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	Glow 105 110 120 Avg. 112	Heavy smoke; intumescent char at 15-20 seconds
	0.8	560	Glow with small flame 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 #46 100% wool (mothproof-treated) 11.6 oz/sq yd	0.2	270	No ignition, 2 min	No smoke generation
	0.3	350	No ignition, 2 min	Medium smoke at 70, light intumescent char at 75 seconds
	0.35	400	No ignition, 2 min	Heavy smoke, intumescent char at 45-50 seconds
	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 70/30 wool/modacrylic 11.5 oz/sq yd	0.2	270	No ignition, 2 min	Medium smoke, slight melting at 110 seconds
	0.3	350	No ignition, 2 min	Heavy smoke at 45 seconds
	0.35	400	No ignition, 2 min	Heavy smoke, slight melting at 20 seconds
	0.6	500	Glow 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/cm²/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	Glow 90 120 105 Avg. 105	Heavy smoke, intumescent char at 10 seconds
	0.8	560	Glow / Small Flame 25 / 30 21 / 24 25 / 32 Avg. 24 / 29	Heavy smoke, intumescent char at 10 seconds
	0.9	600	21 18 15 Avg. 18	Heavy smoke, intumescent char at 8 seconds
	1.1	650	19 12 10 Avg. 14	Heavy smoke, intumescent char at 6 seconds
Fabric #25 55/45 polyester/wool 6.6 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	Heavy smoke, melting at 15 seconds
	0.6	500	No ignition, 2 min	Heavy smoke, melting at 8-10 seconds
	0.8	560	Glow 25 30 20 Avg. 25	Heavy smoke, melting at 4 seconds
	0.9	600	17 20 16 Avg. 18	Heavy smoke, melting at 6-9 seconds
	1.1	650	3 3 3 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 30 / 90 30 / 42 30 / 82 30 / 75 30 / 80 Avg. 30 / 74	Light smoke at 8 seconds
	1.1	650	25 28 21 Avg. 25	Light to medium smoke at 8 seconds
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 40 / 70 50 / 70 50 / — 40 / — 40 / — Avg. 40 / 70	Medium smoke at 35-45 seconds
	0.9	600	Glow / Flame 20 / 43 20 / — 25 / 36 20 / 32 20 / 26 Avg. 21 / 34	Medium smoke at 15 seconds
	1.1	650	23 22 21 Avg. 22	Medium-heavy smoke at 12 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/cm²/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	Glow	Small Flame	Medium smoke at 5 seconds, melts at 10
			65	85	
			75	95	
			70	90	
			Avg. 65	90	
	1.1	650	43		Medium smoke at 4 seconds, melts at 7
			45		
			45		
			Avg. 44		
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	Glow		Medium smoke at 8 seconds
			30		
			25		
			25		
			Avg. 27		
	0.9	600	Glow		Medium smoke at 7 seconds
			20		
			15		
			15		
			Avg. 17		
	1.1	650	19		Medium-heavy smoke at 7 seconds
			19		
			17		
			Avg. 18		
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	Glow	Small Flame	Medium to heavy smoke at 3-5 seconds
			13	30	
			20	35	
			18	27	
			Avg. 17	31	
	1.1	650	16		Heavy smoke at 4 seconds
			19		
			21		
			Avg. 19		

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	Glow Only 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 6 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	Glow Only 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 11 Avg. 11	Medium smoke, melts at 4 seconds
	0.9	600	8 9 8 Avg. 8	Medium smoke, melts at 4 seconds
	1.1	650	5 4 4 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 4 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 / Small Flame 18 / 24 18 / 32 18 / 40 Avg. 18 / 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
Single-Layer Fabrics:								
36	0.40	5	5	6	33	38	55	Initial peak
100% cotton		40	40	45	64	79	76	Medium smoke
13.3 oz/sq yd		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	0.40	3	3	3	33	50	31	Initial peak
100% cotton		25	25	25	60	60	50	Light smoke
10.3 oz/sq yd		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	2	2	2	31	29	30	Initial peak
		7	8	8	68	80	82	Ignition
70	0.40	3	3	3	44	50	48	Initial peak
80/20 PFR rayon/		25	23	25	135	111	108	Melting
polyester		45	40	40	61	61	68	Heat transfer stabilizes
8.6 oz/sq yd								
	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	0.40	4	4	4	45	53	53	Initial peak
80/20 PFR rayon/		25	25	25	87	108	117	Light smoke
Nomex		45	45	40	64	65	75	Heat transfer stabilizes
8.5 oz/sq yd								
	0.75	3	3	2	53	52	49	Initial peak
		13	11	9	114	93	96	Heavy smoke
		—	—	10	—	—	96	Ignition
		30	25	—	71	61	—	Heat transfer stabilizes
	1.25	2	2	2	33	34	33	Initial peak
		4	4	4	59	47	42	Ignition, heavy smoke
10	0.40	4	4	3	40	40	38	Initial peak
rayon warp/		35	35	30	62	60	52	Heat transfer stabilizes
cotton fill								
9.2 oz/sq yd	0.75	2	2	2	43	45	48	Initial peak
		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/cm²/sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Single-Layer Fabrics: (cont)								
34	0.40	3	3	3	50	52	52	Initial peak
80/20 PFR		35	30	30	71	69	71	Heat transfer stabilizes
rayon/Nomex								
7.0 oz/sq yd	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	0.40	2	2	2	50	55	52	Initial peak
100% cotton		30	25	27	69	74	74	Heat transfer stabilizes
6.6 oz/sq yd								
	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	0.40	2	2	2	50	48	50	Initial peak
100% cotton		30	25	25	74	67	74	Heat transfer stabilizes
5.1 oz/sq yd								
	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	0.40	2	2	2	57	50	48	Initial peak
100% cotton		15	17	20	76	67	74	Light smoke
5.1 oz/sq yd		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	0.40	4	1	2	29	36	50	Initial peak
100% cotton		15	17	18	57	69	55	Light smoke
4.3 oz/sq yd		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	0.40	6	7	6	57	64	43	Initial peak
100% wool		30	23	25	48	55	48	Light smoke
15.7 oz/sq yd		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	0.40	5	4	4	37	32	32	Initial peak
70/30 wool/		30	28	27	107	90	85	Heavy smoke
modacrylic		37	38	40	124	122	137	Maximum heat transfer
12.8 oz/sq yd								
	0.75	3	4	5	23	36	36	Initial peak
		15	15	15	73	91	82	Heavy smoke
		20	18	—	100	100	—	Fabric split
		—	—	20	—	—	121	Maximum heat transfer
	1.25	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	0.40	6	7	4	51	56	29	Initial peak
100% wool		34	34	24	85	110	110	Heavy smoke
12.3 oz/sq yd		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
	1.25	3	3	2	27	30	43	Initial peak
		10	12	10	107	105	102	Melts, heavy smoke
		15	—	12	100	—	100	Fabric destroyed
		—	30	—	—	127	—	Ignition
46	0.40	8	5	6	27	51	39	Initial peak
100% wool		20	25	30	24	46	49	Medium smoke, intumesces
(moth-proof treated)		45	42	43	45	73	59	Maximum heat transfer
11.6 oz/sq yd								
	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
		43	—	—	79	—	—	Maximum heat transfer
	1.25	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	0.40	4	3	5	61	73	46	Initial peak
70/30 wool/		20	17	25	93	76	117	Heavy smoke
modacrylic		38	35	—	85	68	—	Heat transfer stabilizes
11.5 oz/sq yd		—	—	34	—	—	146	Maximum heat transfer
	0.75	4	5	5	27	41	26	Initial peak
		15	15	17	96	122	100	Heavy smoke
		20	30	20	100	100	100	Heat transfer stabilizes
	1.25	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	0.40	5	4	5	33	36	38	Initial peak
90/10 wool/nylon		30	35	30	45	60	54	Medium-heavy smoke
8.2 oz/sq yd		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
		35	35	35	80	100	100	Heat transfer stabilizes
	1.25	3	3	4	35	34	32	Initial peak
		10	12	12	24	49	30	Heavy smoke, intumesces
		12	18	23	44	50	100	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/cm²/sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Single-Layer Fabrics:	(cont)							
25	0.40	3	2	3	45	33	48	Initial peak
55/45 polyester/wool		30	25	25	119	160	102	Heavy smoke
6.6 oz/sq yd		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	0.40	10	5	8	29	27	24	Initial peak
100% acrylic		35	45	37	110	90	100	Heavy smoke
9.7 oz/sq yd		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	0.40	5	5	5	47	54	49	Initial peak
Amatex 16HT65		45	40	45	63	65	62	Heat transfer stabilizes
Corespun semi-carbon								
Kevlar FR	0.75	4	4	4	47	37	41	Initial peak
15.4 oz/sq yd		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	0.40	5	5	6	37	37	40	Initial peak
100% Kevlar		35	30	30	60	53	58	Heat transfer stabilizes
8.3 oz/sq yd								
	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	0.40	4	3	3	45	40	38	Initial curve
100% Nomex		20	20	25	69	71	60	Heat transfer stabilizes
8.1 oz/sq yd								
	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	0.40	3	3	3	41	41	50	Initial peak
50/50 Nomex/Kevlar		25	20	30	57	55	65	Heat transfer stabilizes
6.0 oz/sq yd								
	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/cm²/sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Single-Layer Fabrics:	(cont)							
73	0.40	3	2	3	39	45	43	Initial peak
95/5 Nomex/Kevlar		25	20	25	59	63	67	Heat transfer stabilizes
5.3 oz/sq yd								
	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	0.40	7	10	12	52	62	57	Initial curve
nylon - double		30	23	25	86	86	67	Melts
butyl coated		44	45	35	98	88	117	Heat transfer stabilizes
12.5 oz/sq yd								
	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	0.40	3	3	4	33	57	38	Initial peak
cotton, resin modified		25	35	25	62	67	67	Heat transfer stabilizes
butyl coated								
10.5 oz/sq yd	0.75	4	4	4	41	44	35	Initial peak
		20	15	19	69	71	99	Medium smoke
		26	—	—	81	—	—	Ignition
		--	30	30	—	60	62	Heat transfer stabilizes
	1.25	2	2	2	22	39	30	Initial peak
		6	5	6	35	34	89	Ignition
32	0.40	15	8	8	48	64	67	Initial peak
nylon, neoprene		40	37	40	79	79	119	Medium smoke
coated		45	45	50	81	74	169	Heat transfer stabilizes
7.7 oz/sq yd								
	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	0.40	5	8	8	71	71	67	Initial peak
nylon, polyurethane		15	20	16	100	100	100	Fabric melted
coated								
3.1 oz/sq yd	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	0.40	3	4	4	59	50	47	Initial peak
Polyacrylonitrile		45	50	40	73	73	59	Heat transfer stabilizes
(PAN)								
15.6 oz/sq yd	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/cm²/sec)	Time (sec)			Radiant Heat Transfer (%)			Fabric Event Description
Fabric Assemblies:								
43	0.40	5	6	7	54	58	49	Outer shell melted
polyester shell,		34	32	35	73	65	69	Medium smoke
wool liner		--	50	--	--	116	--	Maximum heat transfer
12.0 oz/sq yd		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	0.40	5	2	4	23	18	28	Initial peak
polyester batt,		15	--	--	12[illegible]	---	---	Assembly melts
nylon fabric		--	15	22	---	115	95	Heat transfer stabilizes
4.6 oz/sq yd								
	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	0.40	3	4	3	18	20	23	Initial peak
polyurethane		15	16	17	60	38	53	Second peak
coated nylon and		20	--	--	100	---	---	Assembly melts
1A above		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	0.40	7	10	10	20	32	29	Initial peak
50/50 cotton/nylon		40	35	35	41	55	41	Medium smoke
fluorocarbon treated		40	36	52	41	107	88	Maximum heat transfer
outer shell;								
100% nylon liner	0.75	10	10	10	25	33	30	Medium smoke
20.0 oz/sq yd		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	0.40	6	5	4	18	13	15	Initial peak
50/50 cotton/poly-ester outer shell;		35	30	30	53	43	55	Light smoke
100% nylon liner		50	45	40	58	48	53	Heat transfer stabilizes
12.5 oz/sq yd	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 during 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 ignition
polyester batt/								
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
212	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	23	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