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A STUDY OF THE EFFECT OF TEMPERATURE ON PARACHUTE TEXTILE MATERIALS

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Carpenter Litho & Prtg. Co., Springfield, O.
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FOREWORD

This report was prepared by the Textiles Branch and was initiated under Research and Development Order No. 612-12, "Textiles for High Speed Parachutes." The report was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with 1st Lt James W. Muse, Jr. acting as project engineer.

Acknowledgement is extended Cheney Brothers and Phoenix Trimming Company for their interest and cooperation in this study and for the textile items which they furnished in order that this study might be conducted.

ABSTRACT

The primary purpose of this investigation was to obtain data on the effect of oxygen, nitrogen, and compressed air on nylon and Dacron materials at various temperatures. A secondary purpose was to determine the effect of hot air, applied continuously and in an intermittent manner to parachute textile materials. The test method is described in the text of this report.

A group of standard nylon parachute textile materials comprised of webbings, cord and fabrics, was tested after exposure to various temperature conditions for continuous and intermittent intervals of time. Also tested were Dacron hot stretched threads and an experimental Dacron fabric.

The breaking strength of several nylon textile materials was found to vary with temperature and duration of exposure time. The nylon materials lost considerably more strength after exposure in hot air at 300°F than at 250°F for the same period.

The breaking strength of nylon webbings, treated with resin in accordance with Specification MIL-W-4088B, was affected more severely than the untreated webbings after exposure to the stated conditions.

The breaking strength of the Dacron hot stretched thread showed no appreciable loss in these tests.

The materials tested after exposure in hot air at 250°F for identical continuous and intermittent time intervals show no appreciable difference in breaking strength.

The materials tested after intermittent exposure in hot air at 300°F show more loss in breaking strength than when tested after continuous exposure.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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I INTRODUCTION AND OBJECTIVES:

The application of parachutes as braking and recovery devices for high speed aircraft, missiles and targets introduces the problem of heat degradation of parachute materials. The heat problem arises from two acknowledged conditions which are being encountered in the application of parachutes to high performance vehicles:

1. During operation of a parachute at high speeds the conversion of kinetic energy into heat will cause a rise in the surface temperature of the parachute.

2. The temperature in the parachute storage compartment will rise sufficiently high to cause degradation of currently used materials. This is expected to result from high skin temperature of the vehicle, or heat from the propulsion system.

The length of time the parachute is subjected to high temperatures will vary from a few seconds to several hours. The short exposure time occurs when a brake parachute is deployed at high speeds. The long exposure time will occur under storage conditions within the vehicle during flight. Repeated exposures to this type of heat will occur under both conditions.

The employment of parachutes at and after higher temperatures necessitates a requirement for heat resistance in fabrics. These fabrics should possess high strength and elongation at and after exposure to the higher temperatures.

A study of the effects of temperature from -70°F to 350°F on current textile fibers has been made by Fabric Research Laboratories, Inc. under Contract Number AF 33(038)22932, R612-12 and is presented in Wright Air Development Center Technical Report 53-21, "A Study Of The Effect Of Temperature On Textile Materials". Previous work in this field has consisted primarily of individual yarn studies by the manufacturer at considerably lower temperatures.

Results from this first organized study of the temperature effects on textile fibers show that at 350°F, Dacron yarn is equal to or better than comparable nylon yarn in most of the properties studied.

Results after exposure to temperatures of 350°F show that Dacron yarn is superior to comparable nylon yarn in most of the properties studied. Most noticeable is the energy absorbed at various stress levels, loop tenacity and efficiency, and especially Dacron's resistance to hot air degradation.

Concepts of fiber rheology are presented in that portion of Wright Air Development Center Technical Report 53-21 entitled, "Instantaneous vs Cumulative Effects Of Environment Upon The Mechanical Behavior Of Fibers".

Intelligent selection of materials for fabrication into parachutes and components necessitates further development of items to meet extremes of temperature for continuous or intermittent operation.

Based on the previous work accomplished, additional investigation was conducted by personnel of the Materials Laboratory.

Due to the promise which Dacron shows when exposed to high temperatures, the Materials Laboratory has undertaken a developmental contract to manufacture parachute materials using Dacron yarns instead of nylon. Items such as fabrics, ribbons, tapes, cords and webbings are to be included.

Until such time as these items can be woven satisfactorily from Dacron yarns, the following data in this Technical Report are submitted as a practical basis for a more accurate prediction of the life expectancy of nylon parachute items.

The temperature problems connected with parachute storage compartments of high speed aircraft may require parachutes to withstand high temperatures for several hours. Continuous or intermittent operation of parachutes for diversified time intervals requires further knowledge of the effect of an intermittent exposure in hot air on parachute textile materials in relationship to continuous exposure.

This report is compiled to show the effect of heat on representative standard nylon parachute materials, Dacron hot stretched threads, and on experimental Dacron fabric after subjection to hot air in an intermittent manner.

It is hoped that the differences in strength between nylon and Dacron after exposure to the conditions described, will receive due consideration by the Military and Industry when designing parachutes for specific applications.

II MATERIALS TESTED

The parachute items tested prior to and after exposure to the several temperatures were:

PARACHUTE ITEM	SPECIFICATION
Nylon Fabric, Type II	MIL-C-7020A
Nylon Fabric, Type I	MIL-C-7350
Nylon Fabric, Type I	16208A

PARACHUTE ITEM	SPECIFICATION
Nylon Webbing Type X, Condition U and R	MIL-W-4088B
Nylon Cord, Type III	MIL-C-5040
Nylon Tubular Webbing 9/16 inch wide	MIL-W-5625
Dacron Hot Stretched Thread V-69 Natural	Experimental Machine Twist Type I, Size E, Based on MIL-T-7807
Dacron Hot Stretched Thread V-69 Sage Green 511	Experimental Machine Twist Type I, Size E, Based on MIL-T-7807
Dacron Fabric	Experimental Fabric

III TEST METHODS

The sample materials listed in Section II of this report were subjected to the following conditions in a hot air oven in the Materials Laboratory:

250°F	For 2, 6, and 24 Hours
300°F	For 2, 6, and 24 Hours

Sample materials were also subjected to hot air applied in an intermittent manner to obtain data at both temperatures for comparison with continuous exposure. Samples were placed in an oven for subjection to hot air in the following manner:

TESTS AT 250° AND 300°F

Condition at standard conditions* for	2 Hours
Exposed to heat for	2 Hours
Condition at standard conditions for	2 Hours
Exposed to heat for	2 Hours
Condition at standard conditions for	2 Hours
Exposed to heat for	2 Hours

Specimens were then removed and tested after the above conditions. The 2 hours exposure under these conditions for 3 cycles is a total of 6 exposure hours.

* 70°F, 65% Relative Humidity

The required number of test specimens were suspended from a steel screen in such a manner as to prevent contact with the sides of the oven during tests. All specimens were subjected to each condition at the same time to insure identical exposure conditions. Samples were placed in a circulating hot air oven for the required time intervals at specified temperatures. An automatic temperature device recorded the temperature on a chart by means of a thermocouple located in the top center of the oven. In order to determine the actual temperature in the center of the oven a thermometer was used and verification of the predetermined setting was obtained. Plotting the actual temperatures for the time intervals required shows that the temperature average was ± 5°F of the predetermined setting for the tests conducted.

The cloth construction of the nylon fabrics was determined in accordance with Method 5050 in Specification CCC-T-191b. It was insured that the same number of warp and filling threads would be tested in all instances so as to eliminate error in ravel strip specimens.

After subjection to the stated conditions the samples were tested as soon as possible. Specimens in warp and filling were at least 1 1/2 inches wide then raveled to 1 inch, and 6 inches long. All warp specimens contained the same warp ends at every condition. All filling specimens did not contain the same filling threads as the total length of the samples required was greater than the width of the fabric.

The jaws of the vertical pendulum tester have smooth gripping surfaces which were padded with leather to prevent slippage of the specimen during the test and to minimize fiber damage, which might result in jaw breaks. All tests conducted on the nylon fabrics were in accordance with the methods stated in their respective specifications.

Preliminary tests were conducted to determine the amount of shrinkage occurring in the nylon webbings at 300°F for 24 hours so that samples could be cut sufficiently long to permit breaking strength tests after subjection to all conditions previously described. Test specimens were then cut 41 inches long. All breaking strength tests conducted on the nylon webbings Type X were in accordance with the requirements and the test methods of Specifications MIL-W-4088B and CCC-T-191b wherever applicable.

The nylon tubular webbing, 9/16 inch wide, was tested for breaking strength in accordance with the requirements and the test methods of Specifications MIL-W-5625 and CCC-T-191b wherever applicable.

The nylon cord Type III was tested for breaking strength in accordance with the requirements and the test methods of Specifications MIL-C-5040 and CCC-T-191b wherever applicable.

The Dacron hot stretched thread was tested for breaking strength on an Instron Tensile Tester. This tester is unique in that a constant rate of elongation of the specimen is obtainable and the initial specimen length is maintained within 1/100 of an inch. The rate of specimen elongation was 12 inches per minute. As no specification exists establishing test methods on Dacron, the tests were conducted in accordance with the usual laboratory procedures.

All specimen testing described herein was conducted at standard conditions of 65 ± 2% Relative Humidity and 70° ± 2°F.

IV SOME GENERAL CONSIDERATIONS

Condition R (resin) in this report refers to the currently used treatment on nylon webbings to increase the resistance to abrasion. It consists of a water dispersion of a polyvinyl butyral resin plasticized with butyl ricinoleate, evenly deposited on the webbing, followed by drying at a temperature of 240° - 360°F.

The term "cycling" used in Tables I - V presenting experimental data is construed to be synonymous with intermittent exposure as expressed elsewhere in this report.

V EXPERIMENTAL DATA AND DISCUSSION

Discussion of the experimental data obtained is presented in the conclusions. Tables I - V show the results obtained on the fabrics, webbings, cord and threads respectively. Figures 1 - 12 show the load elongation data on the nylon fabrics. Figures 13 - 16 are bar graphs which present the breaking strengths on the webbings, cords, and thread in graphic form.

TABLE I

BREAKING STRENGTH DATA, SPECIFICATION MATERIALS NYLON FABRICS

Property	Control Nylon Type II MIL-C-7020A		2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds per inch	Warp Filling	57.22 62.60	57.30 62.30	58.0 61.2	53.6 53.56	53.4 60.56	55.08 58.40	45.36 45.82	34.08 23.56	45.2 46.0
Elongation in percent	Warp Filling	28.80 39.33	30.13 36.66	31.73 38.66	27.93 32.60	27.13 32.33	24.80 28.33	20.66 22.73	15.46 13.73	19.66 22.53
Percent change in breaking strength from control	Warp Filling		.14+ .64-	1.36+ 2.24-	6.33- 14.44-	6.68 - 3.26 -	3.74 - 6.71 -	20.73 - 26.81 -	40.44 - 62.36 -	21.00 - 26.52 -
	Control Nylon Type I MIL-C-7350									
Breaking strength in pounds per inch	Warp Filling	109.34 102.22	111.8 102.16	110.0 102.0	98.6 94.72	108.8 100.62	103.36 97.8	93.26 81.20	56.04 43.68	85.3 75.3
Elongation in percent	Warp Filling	29.73 36.06	29.66 33.40	30.00 36.40	26.86 33.66	28.40 33.46	24.40 30.73	21.86 25.86	15.83 18.86	20.33 23.80
Percent change in breaking strength from control	Warp Filling		2.25+ .059-	.60+ .22-	9.82- 7.34-	.50- 1.57-	5.47- 4.32-	14.71- 20.56	48.75- 57.27-	21.99- 26.34-
	Control Nylon Type I 16208A									
Breaking strength in pounds per inch	Warp Filling	220.8 239.8	234.16 247.72	230.6 242.4	212.2 219.8	233.2 238.0	221.6 238.40	188.8 208.4	120.6 126.6	167.0 178.8
Elongation in percent	Warp Filling	32.73 34.26	34.73 42.80	35.73 42.60	34.33 42.50	36.33 42.00	35.60 41.40	31.00 36.53	22.80 26.93	28.53 34.06
Percent change in breaking strength from control	Warp Filling		6.05+ 3.30+	4.44+ 1.08+	3.89- 8.34-	5.62+ .75-	.36+ .58+	14.49- 13.09-	45.38- 47.21-	24.37- 25.44-

TABLE II

BREAKING STRENGTH DATA, SPECIFICATION MATERIALS NYLON WEBBINGS TYPE X CONDITION U AND R

Control Nylon Webbing Type X Condition U	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 9215	9418	8964	7874	9074
Percent loss in breaking strength from control	2.20+	2.72-	14.55-	1.53-

Control Nylon Webbing Type X Condition U	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds 9215	8212	6137	4045	5822
Percent loss in breaking strength from control	10.88-	33.40-	56.10-	36.82-

Control Nylon Webbing Type X Condition R	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 9310	8799	6982	5280	7118
Percent loss in breaking strength from control	5.48-	25.00-	43.29-	23.54-

Control Nylon Webbing Type X Condition R	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds 9310	5758	4433	2610	4446
Percent loss in breaking strength from control	38.15-	52.38-	71.97-	52.24-

TABLE III

BREAKING STRENGTH DATA, SPECIFICATION MATERIAL NYLON TUBULAR WEBBING

Control Tubular Webbing 9/16 inch wide 1500 pound MIL-W-5625	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 1595	1593.3	1575	1336.6	1536.6
Percent loss in breaking strength from original	.11-	1.25-	16.20-	3.66-

Control Tubular Webbing 9/16 inch wide 1500 pound MIL-W-5625	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds 1595	1428.3	1210	721.6	988.3
Percent loss in breaking strength from original	10.45-	24.14-	54.76-	38.04-

TABLE IV

BREAKING STRENGTH DATA, SPECIFICATION MATERIAL NYLON CORD

Control Nylon Cord Type III 550 pound MIL-C-5040	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 577	577	538	389	547
Percent loss in breaking strength from original	None	6.76-	32.58-	5.20-

Control Nylon Cord Type III 550 pound MIL-C-5040	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 250°F	Cycling at 300°F
Breaking strength in pounds 577	446	336	211.4	311.8
Percent loss in breaking strength from original	22.70-	41.77-	63.36-	45.96-

TABLE V

BREAKING STRENGTH DATA, EXPERIMENTAL MATERIAL DACRON HOT-STRETCHED THREAD

Control Dacron Yarn Hot Stretched Natural	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 8.92	8.85	8.92	8.68	8.95
Elongation in percent 13.4	15.7	19.3	19.0	18.8%
Percent loss in breaking strength from original	.785-	0	2.69-	.336+

Control Dacron Yarn Hot Stretched Natural	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds 8.92	8.68	8.84	8.73	8.80
Elongation in percent	21.5	22.5	22.4	22.7
Percent loss in breaking strength from original	2.69-	.897-	2.13-	1.345-

Control Dacron Yarn Hot Stretched Sage Green .511	2 Hours at 250°F	6 Hours at 250°F	24 Hours at 250°F	Cycling at 250°F
Breaking strength in pounds 7.74	7.57	7.82	7.50	7.84
Elongation in percent	14.4	16.0	15.2	16.2
Percent loss in breaking strength from original	2.196-	1.03+	3.10-	1.29+

Control Dacron Yarn Hot Stretched Sage Green 511	2 Hours at 300°F	6 Hours at 300°F	24 Hours at 300°F	Cycling at 300°F
Breaking strength in pounds 7.74	7.62	7.58	7.41	7.47
Elongation in percent 11.8	17.8	18.2	17.7	17.5
Percent loss in breaking strength from original	1.55-	2.07-	4.26-	3.49-

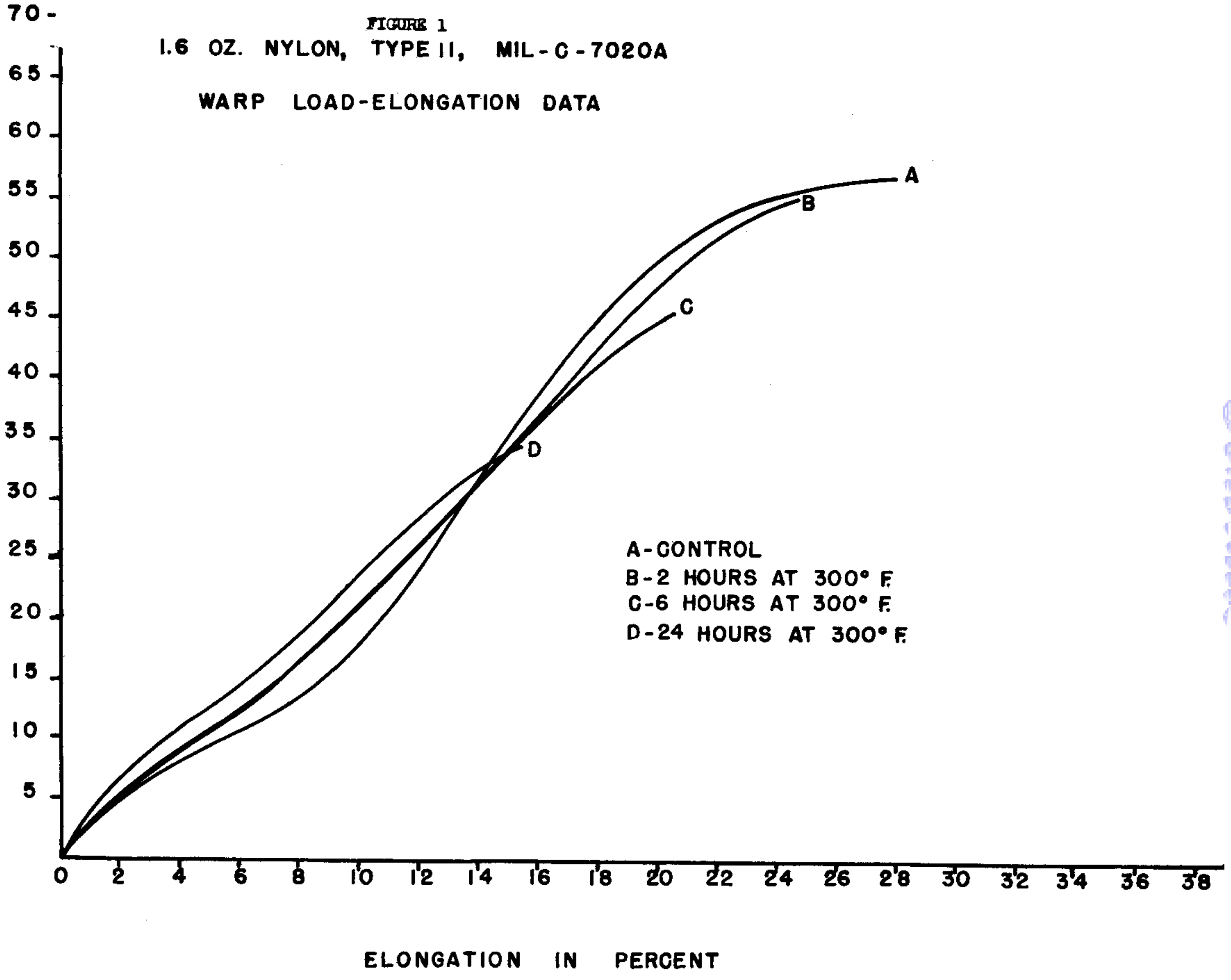


FIGURE 1

1.6 OZ. NYLON, TYPE II, MIL-C-7020A

WARP LOAD-ELONGATION DATA

FIGURE 2

1.6 OZ NYLON, TYPE II, MIL-7020A

FILLING LOAD-ELONGATION DATA

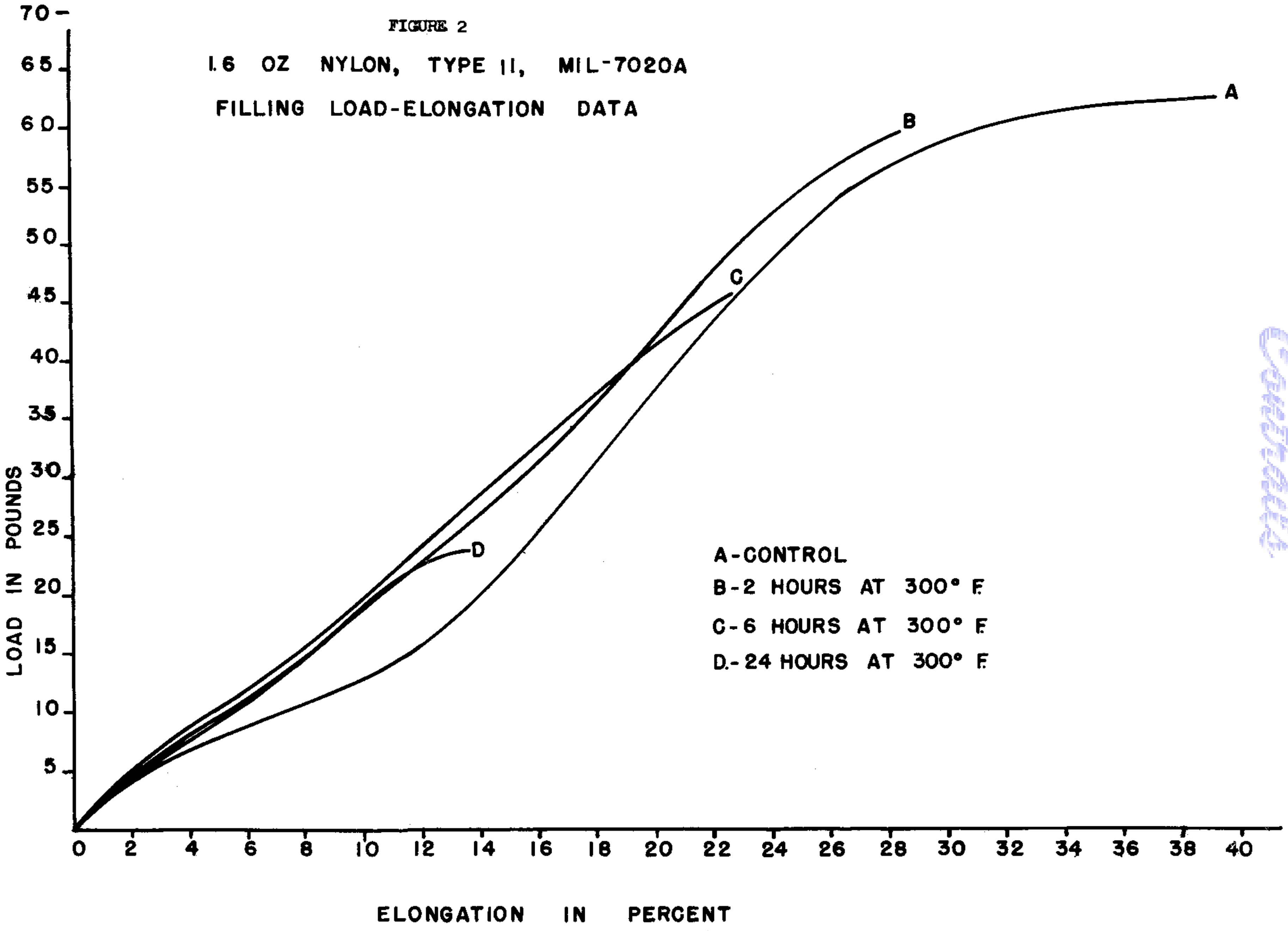


FIGURE 3

1.6 OZ. NYLON TYPE II, MIL-C-7020A

WARP LOAD-ELONGATION DATA

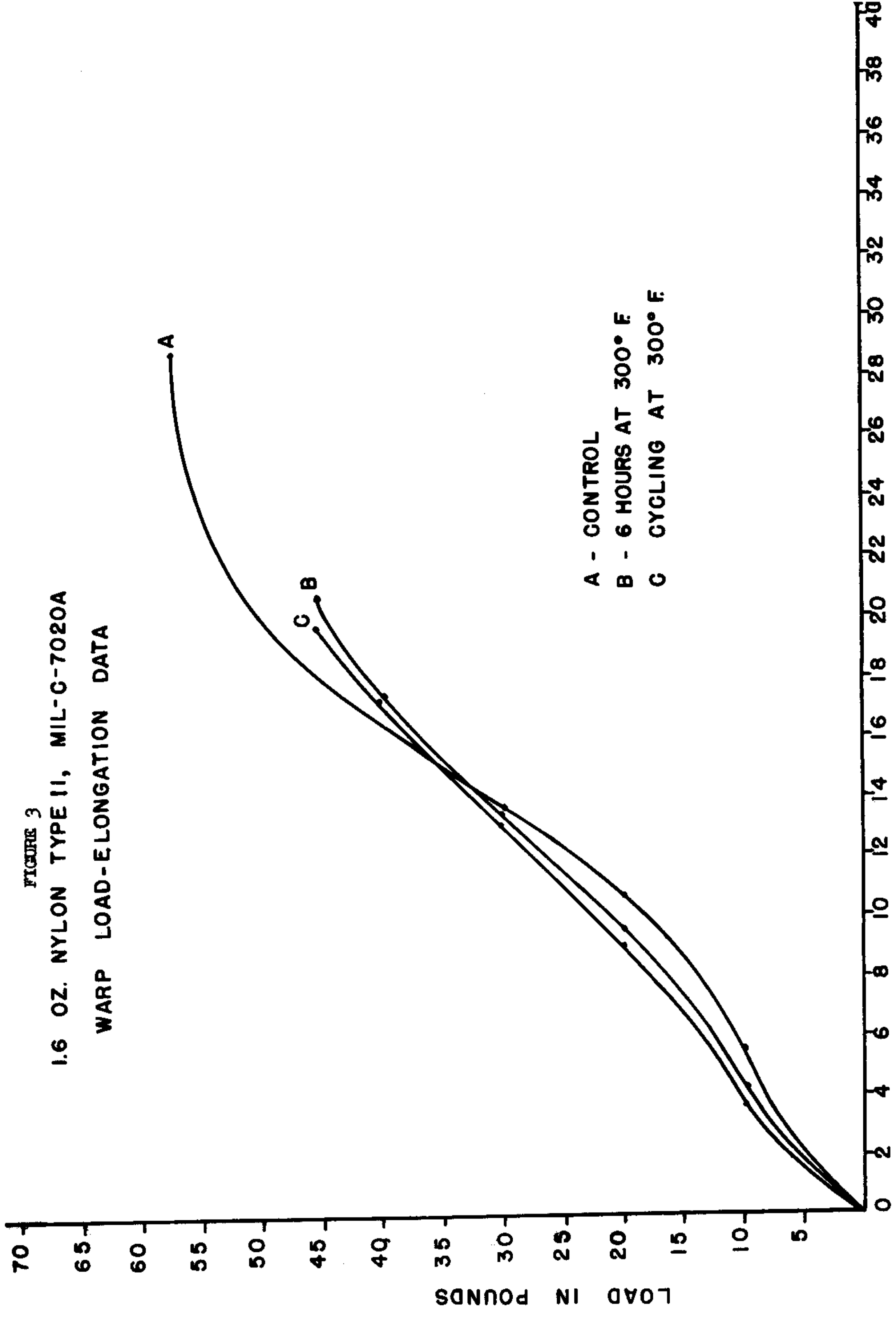


FIGURE 4

1.6 OZ NYLON, TYPE II, MIL-7020A

FILLING LOAD-ELONGATION

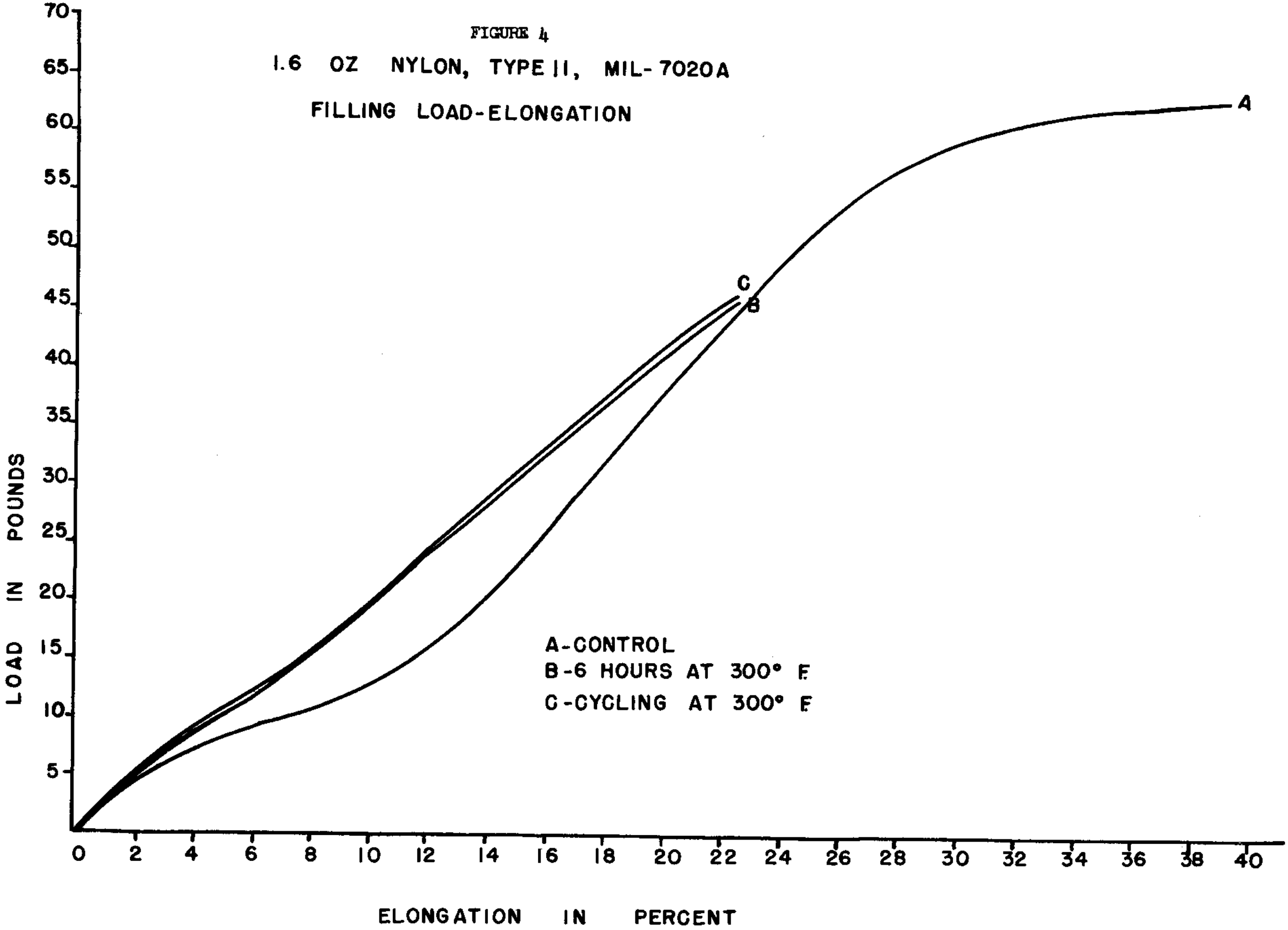


FIGURE 5

2.25 OZ. NYLON, TYPE I, MIL-C-7350

WARP LOAD-ELONGATION DATA

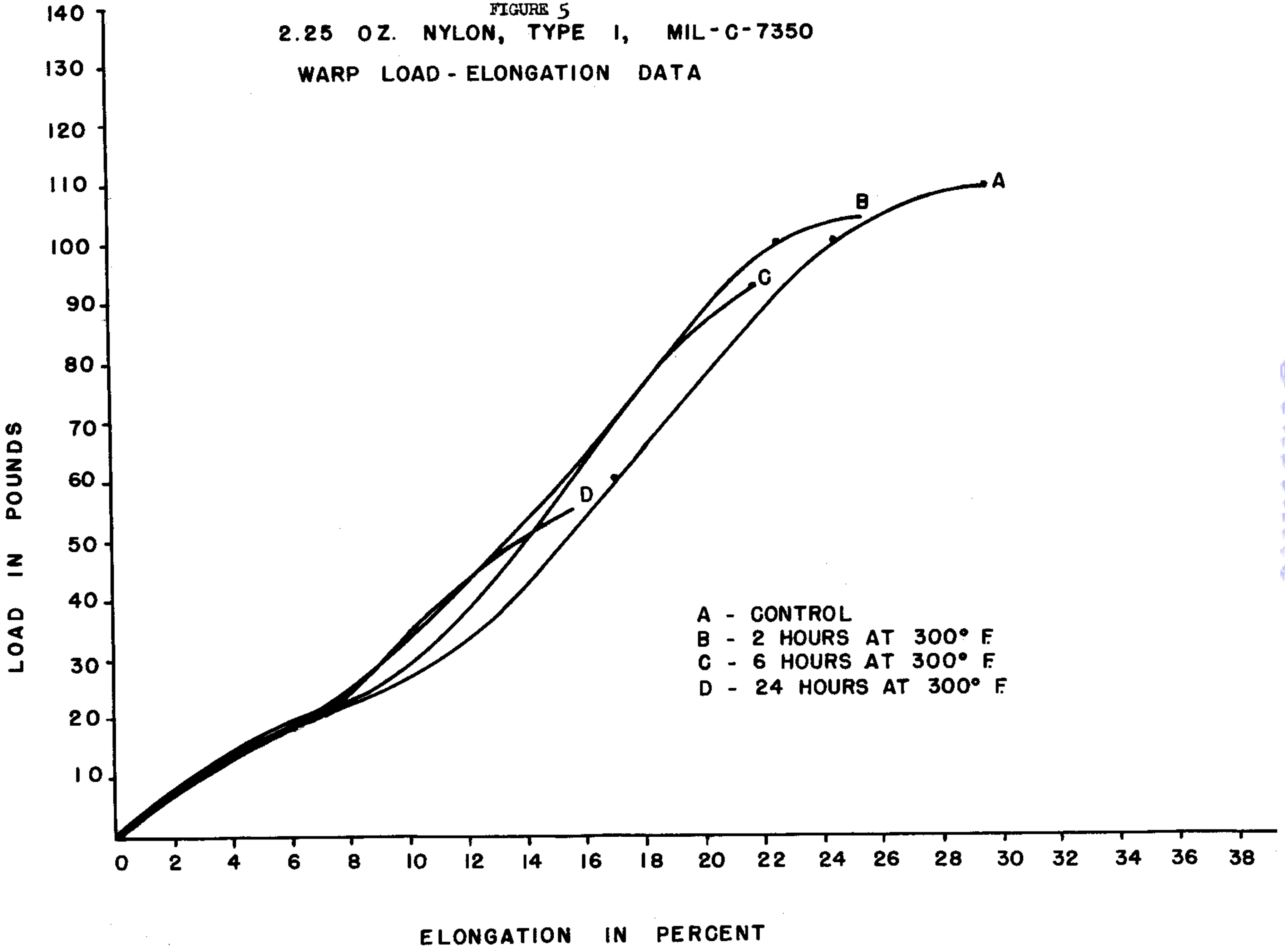


FIGURE 6

2.25 OZ NYLON, TYPE I, MIL-C-7350

FILLING LOAD-ELONGATION DATA

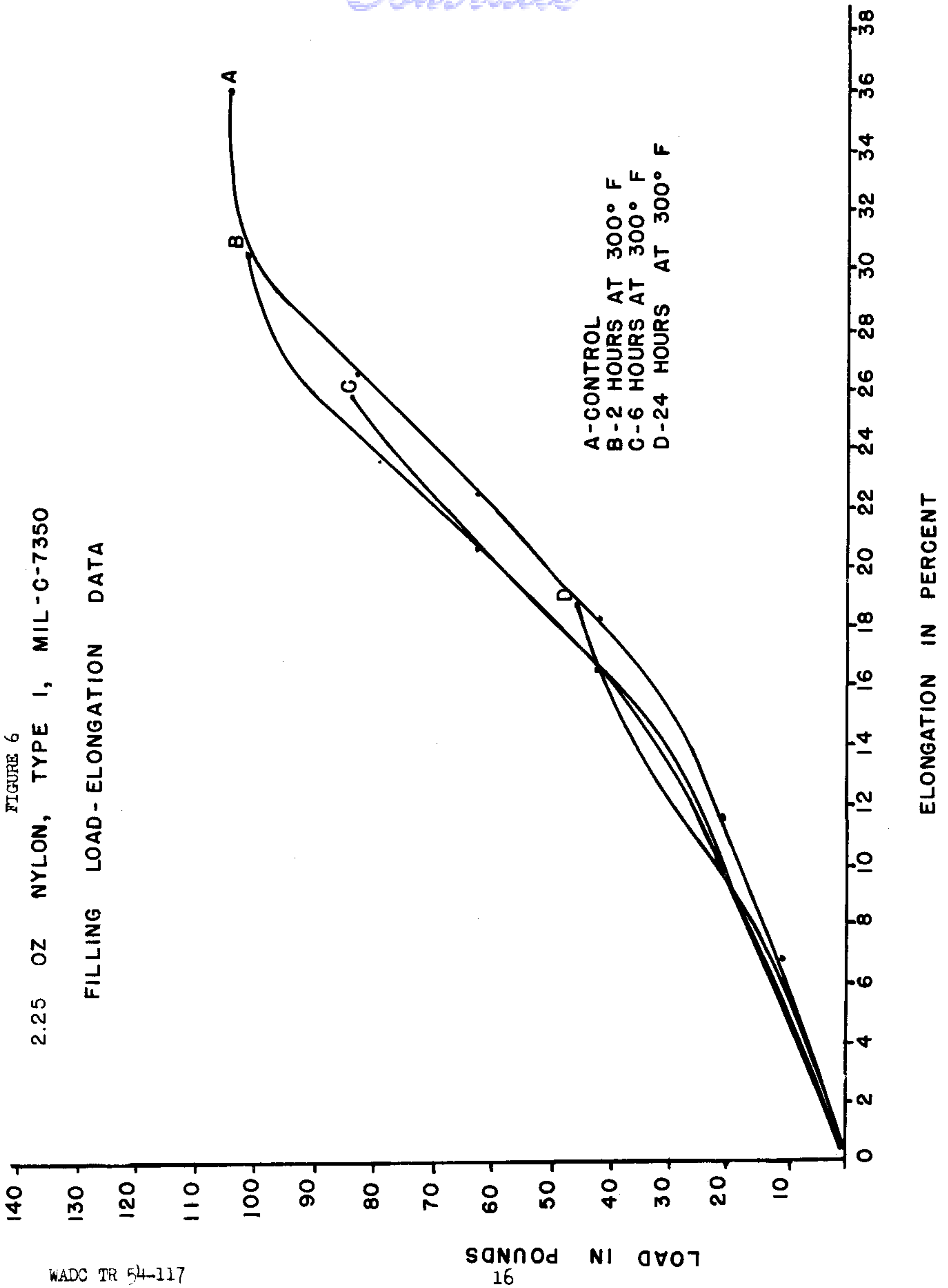


FIGURE 7

2.25 OZ. NYLON TYPE I, MIL-C-7350

WARP LOAD - ELONGATION DATA

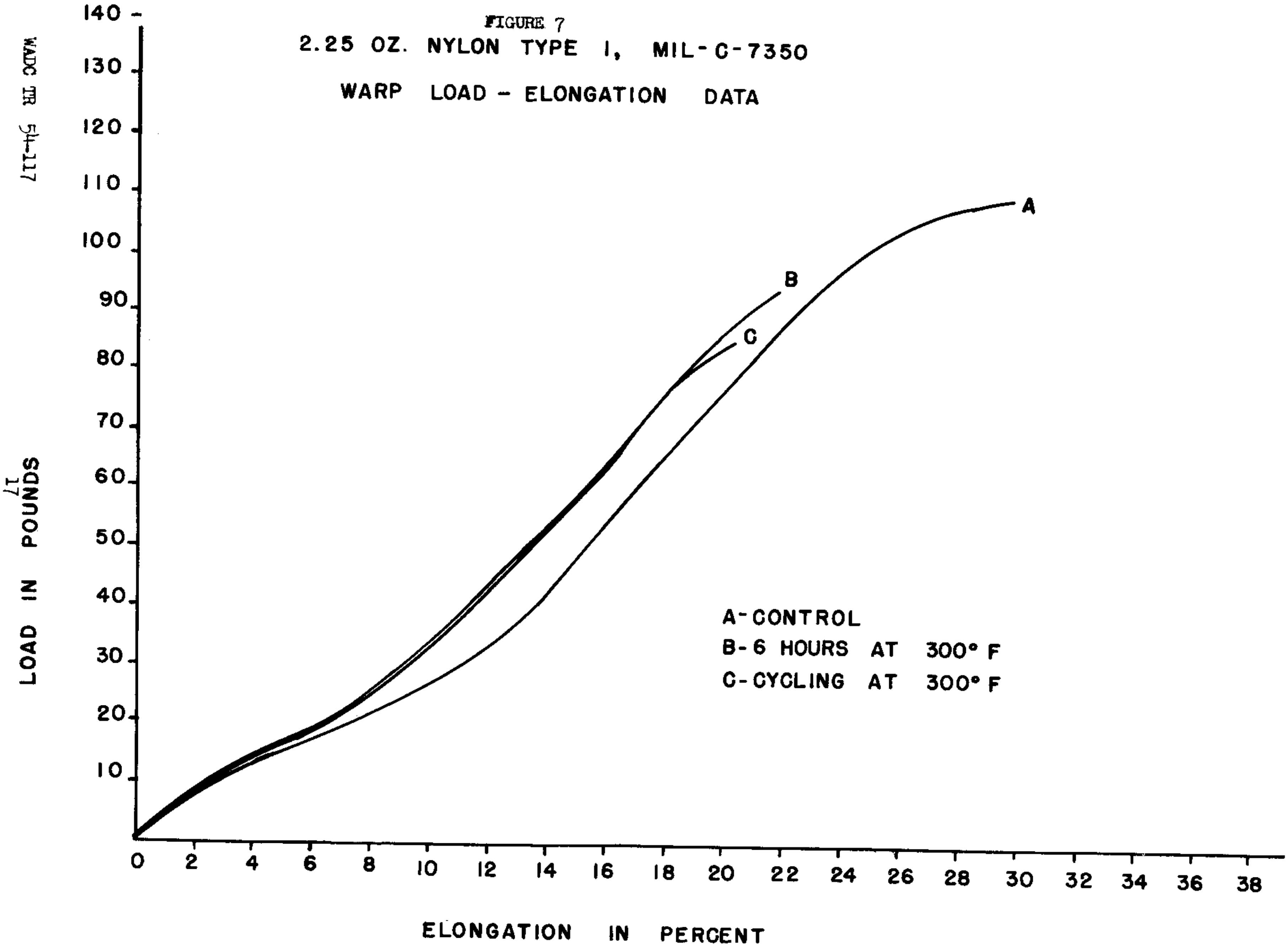


FIGURE 8

2.25 OZ NYLON, TYPE I, MIL-C-7350

FILLING LOAD-ELONGATION DATA

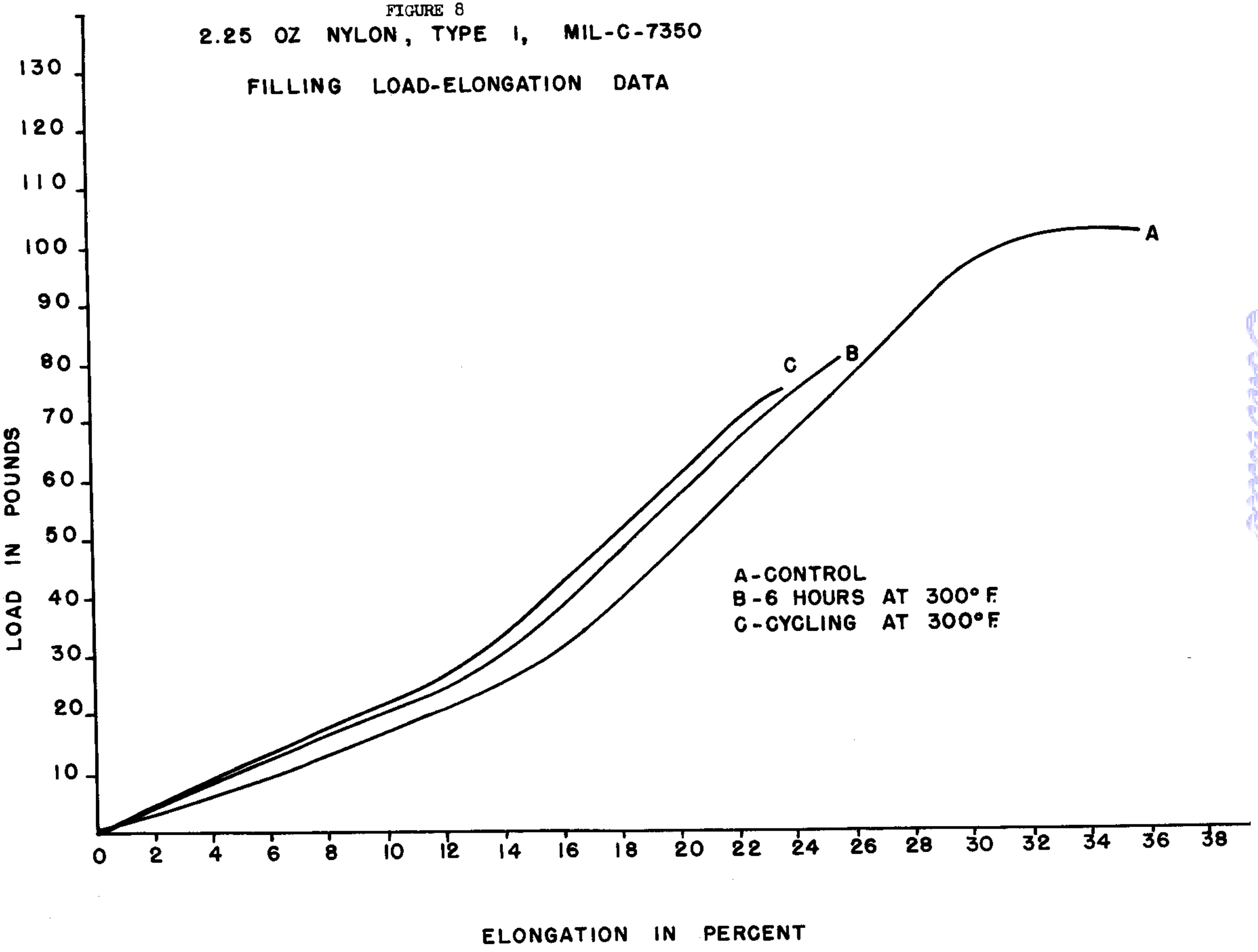


FIGURE 9

4.75 OZ. NYLON, TYPE I, 16208A

WARP LOAD-ELONGATION DATA

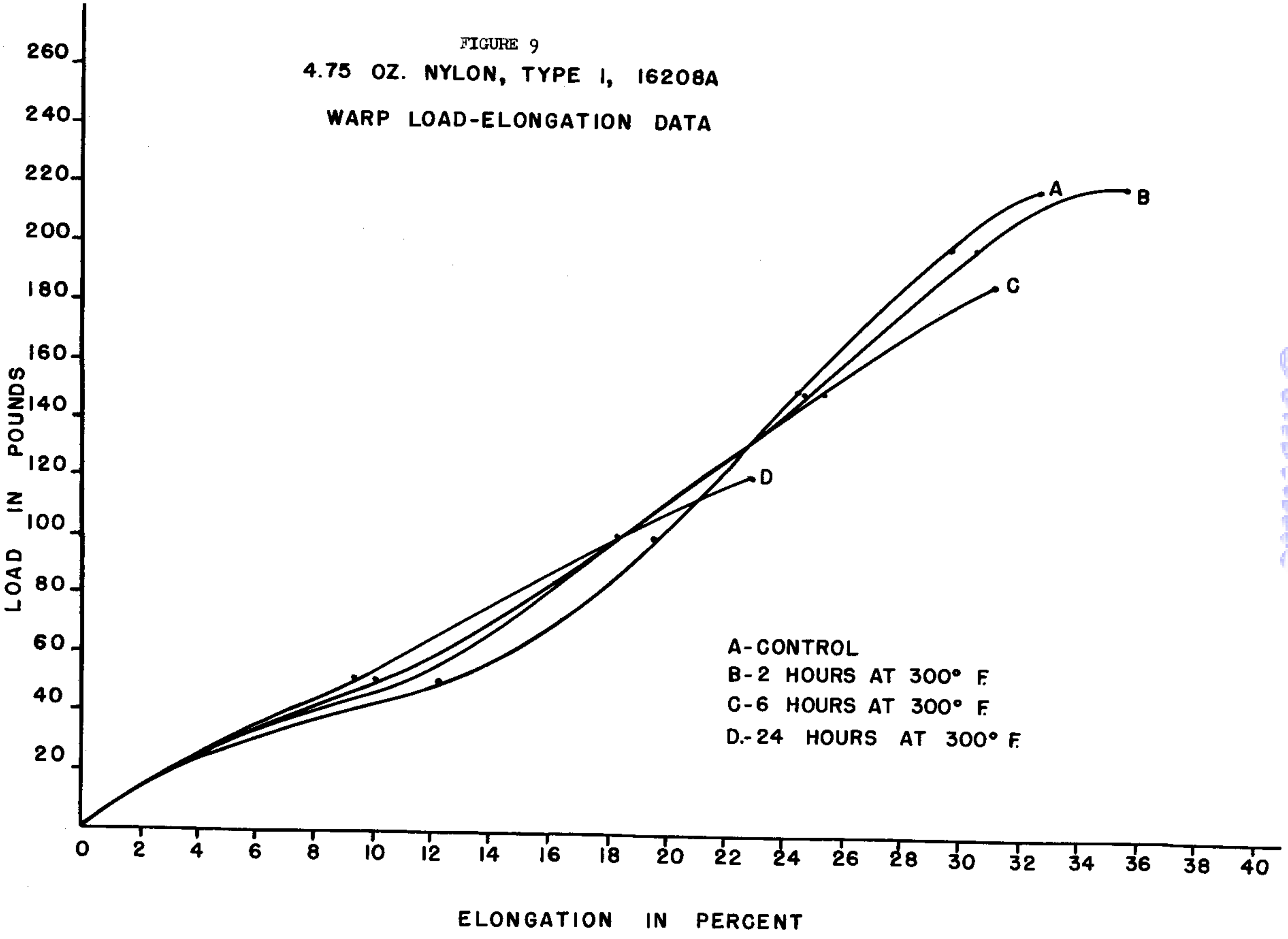


FIGURE 10

4.75 OZ NYLON, TYPE I, 16208A

FILLING LOAD-ELONGATION DATA

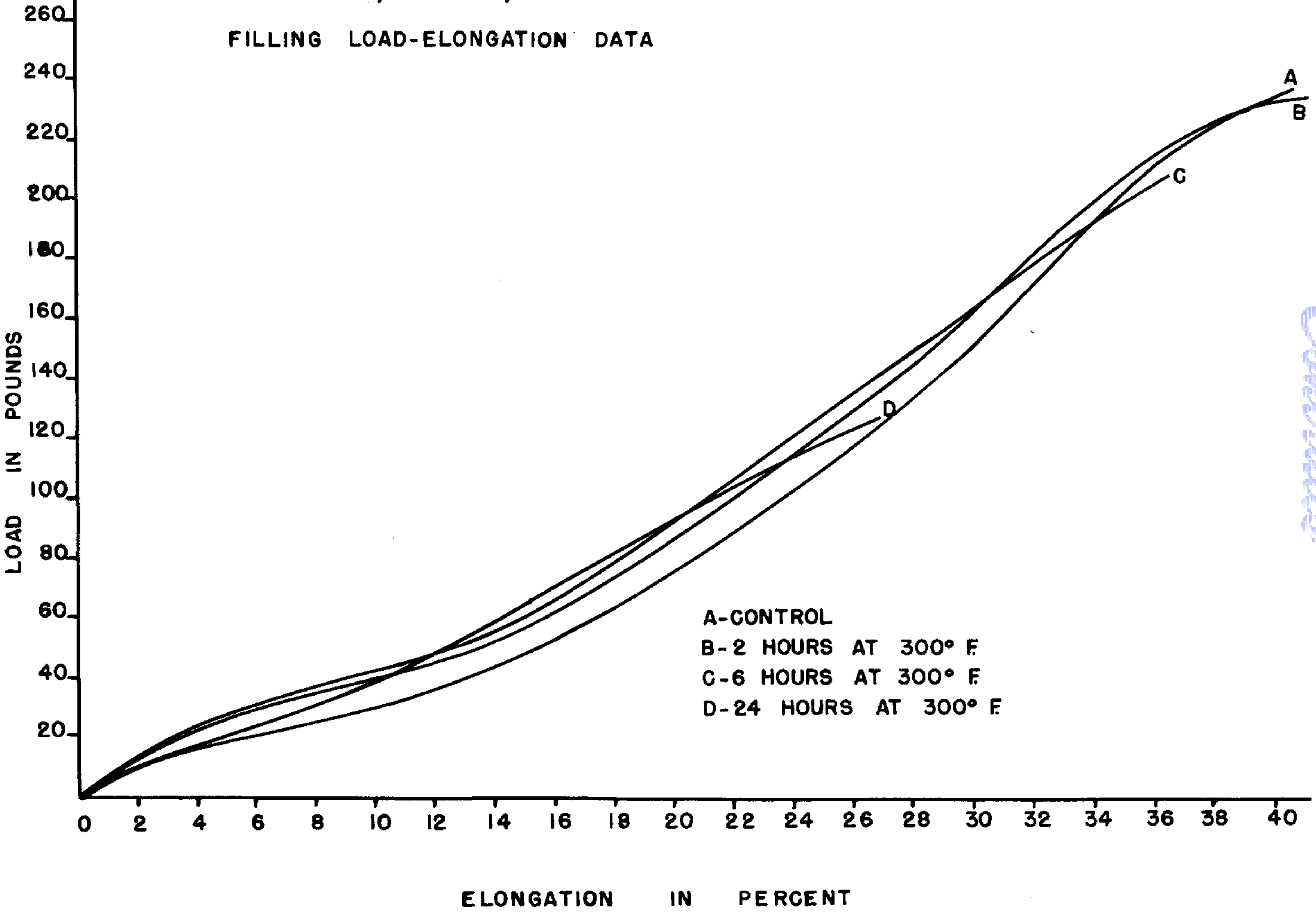


FIGURE 11

4.75 OZ NYLON TYPE I, 16208A

WARP LOAD-ELONGATION DATA

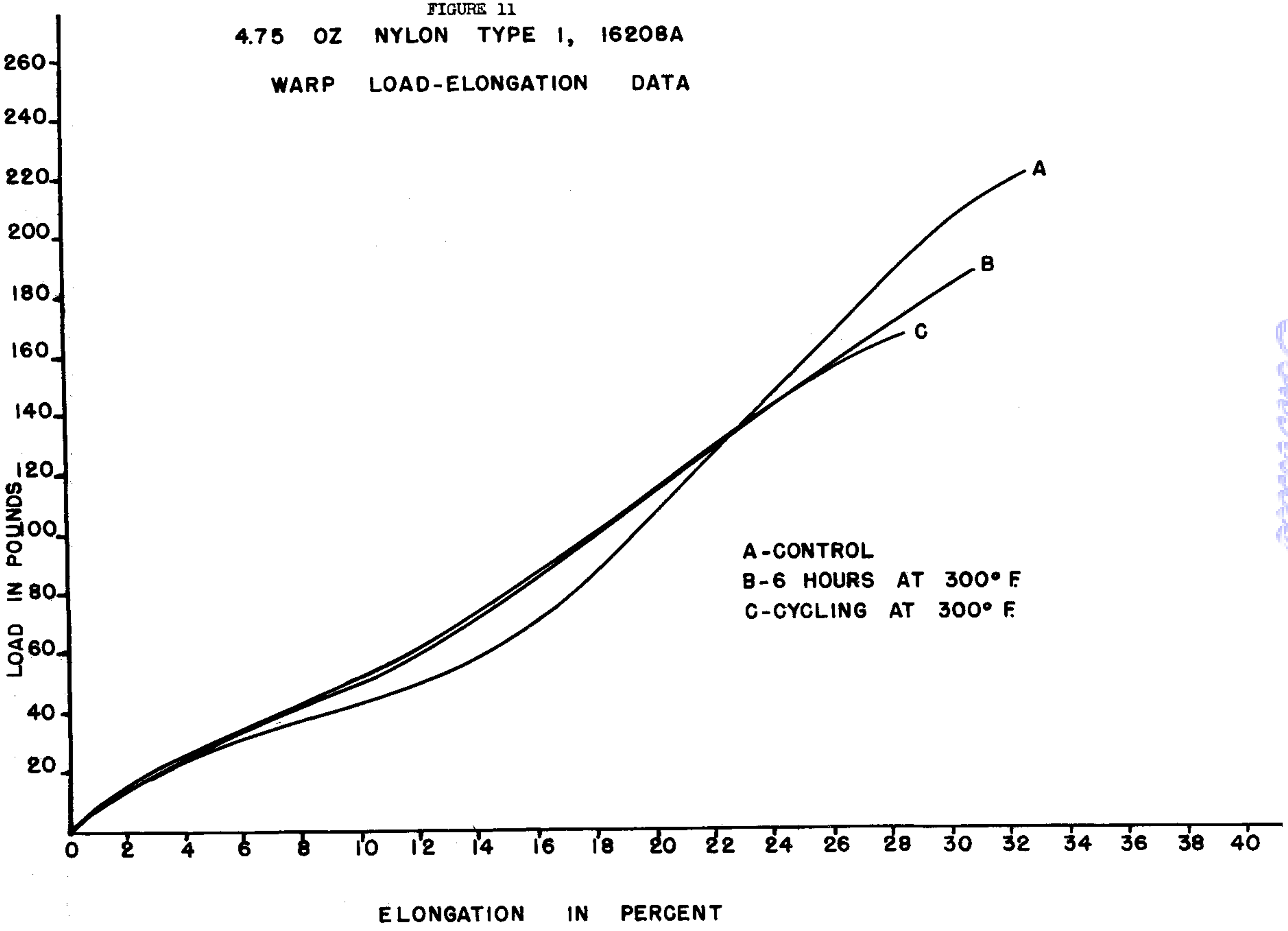


FIGURE 12

4.75 OZ NYLON, TYPE I, 16208A

FILLING LOAD-ELONGATION DATA

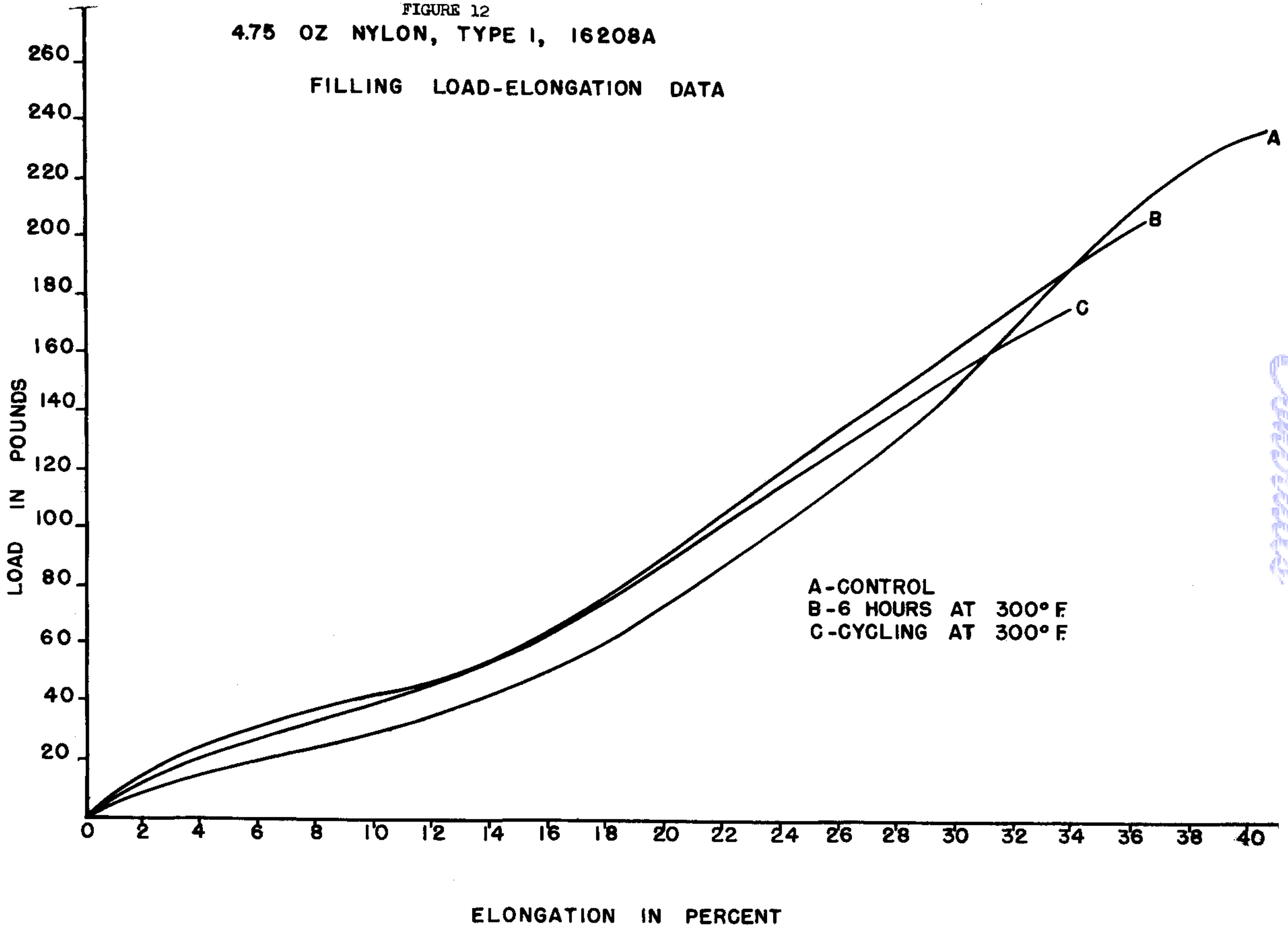


FIGURE 13

NYLON WEBBING, TYPE X, MIL-W-4088B

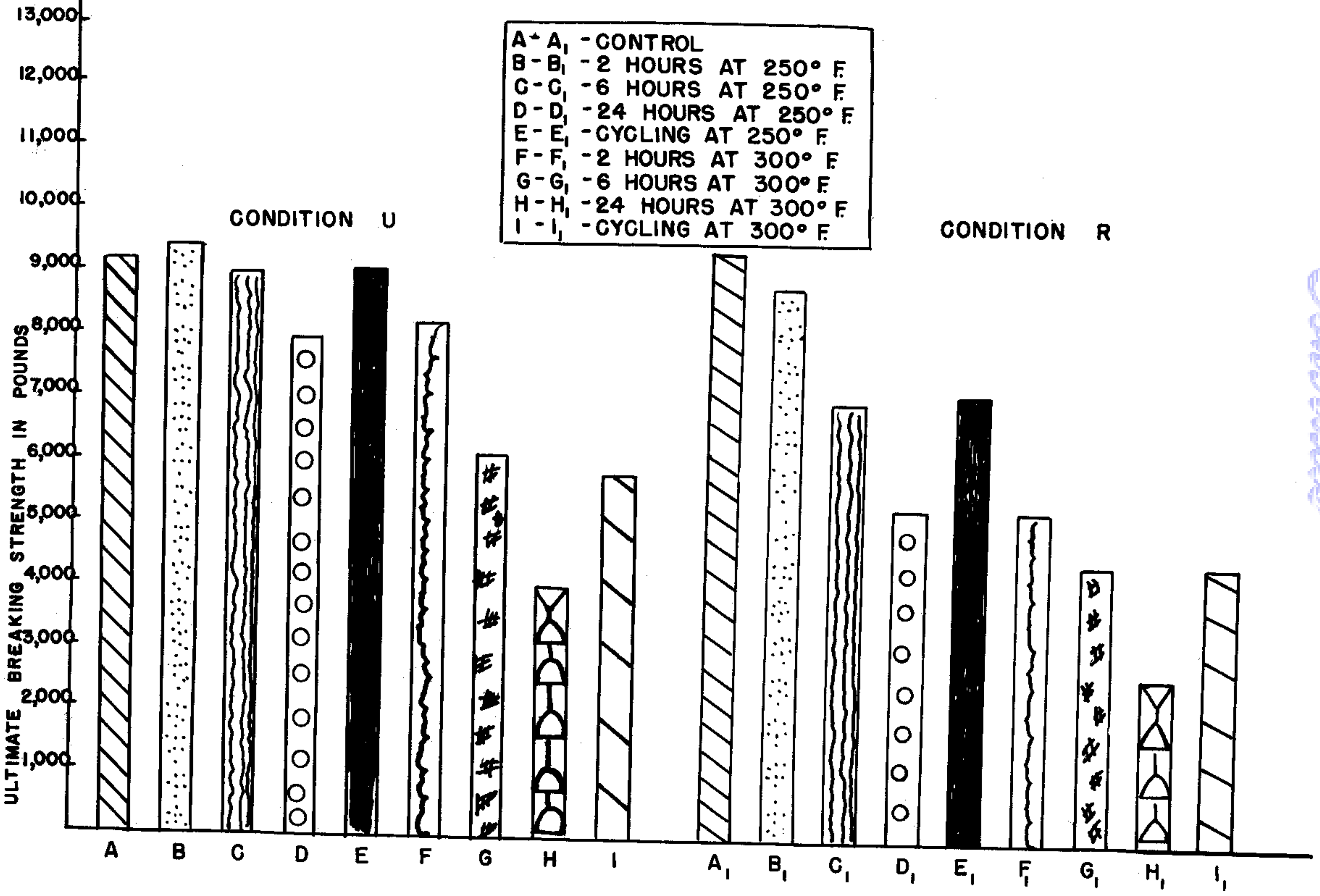


FIGURE 14

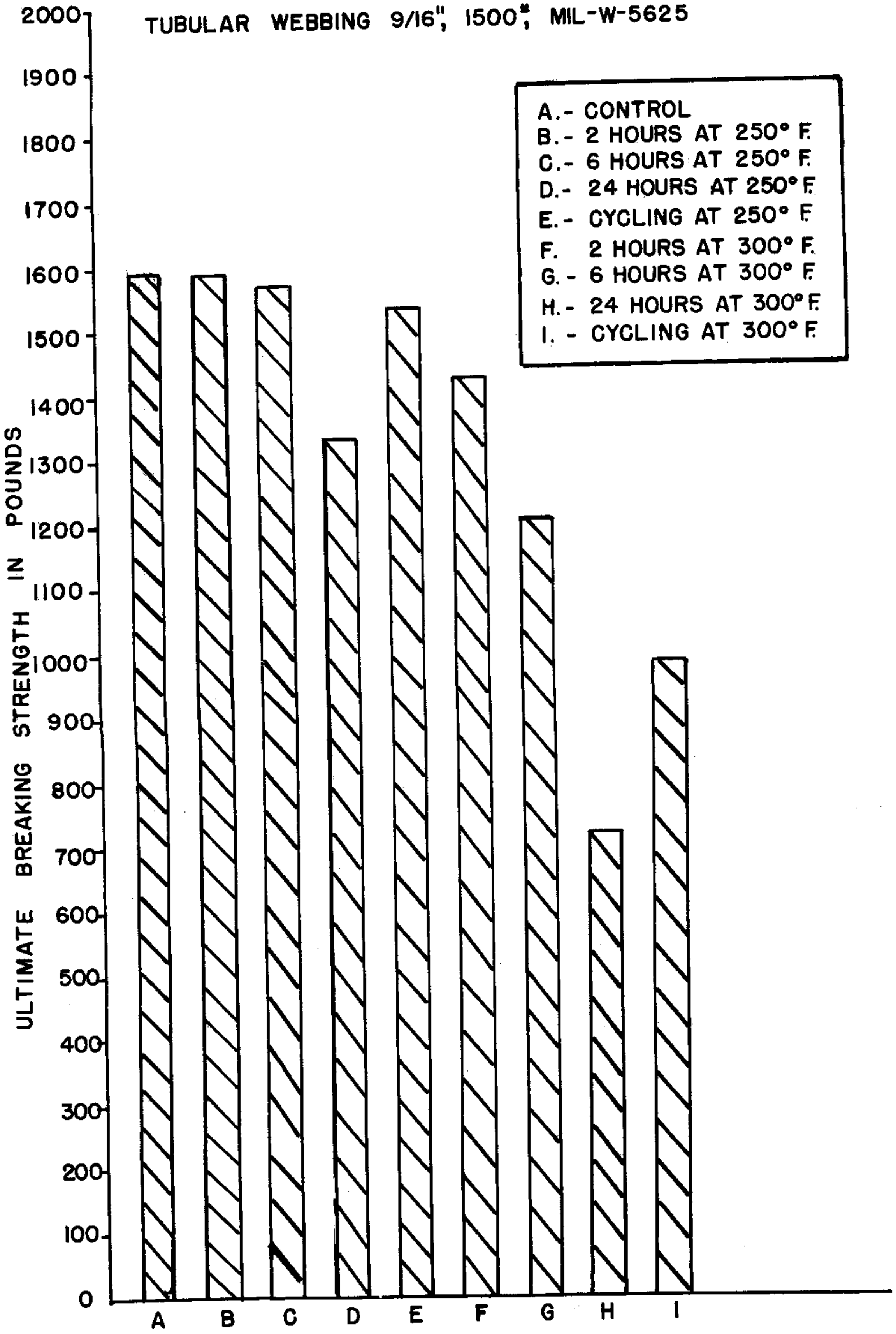
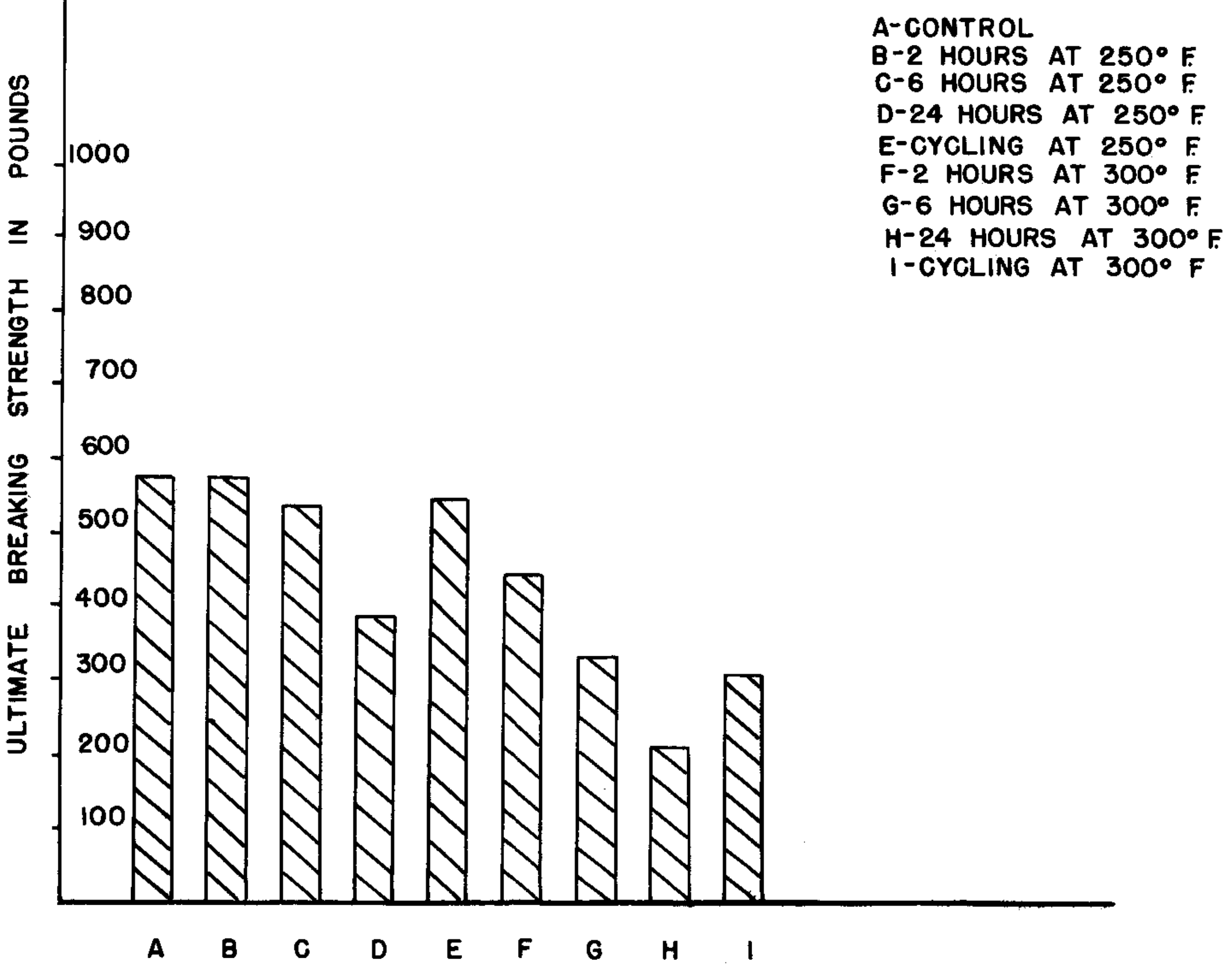

TUBULAR WEBBING 9/16", 1500#, MIL-W-5625
ULTIMATE BREAKING STRENGTH IN POUNDS
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
A
B
C
D
E
F
G
H
I
A.- CONTROL
B.- 2 HOURS AT 250° F.
C.- 6 HOURS AT 250° F.
D.- 24 HOURS AT 250° F.
E.- CYCLING AT 250° F.
F. 2 HOURS AT 300° F.
G.- 6 HOURS AT 300° F.
H.- 24 HOURS AT 300° F.
I. - CYCLING AT 300° F.

FIGURE 15

NYLON CORD TYPE III, 550#, MIL-C-5040



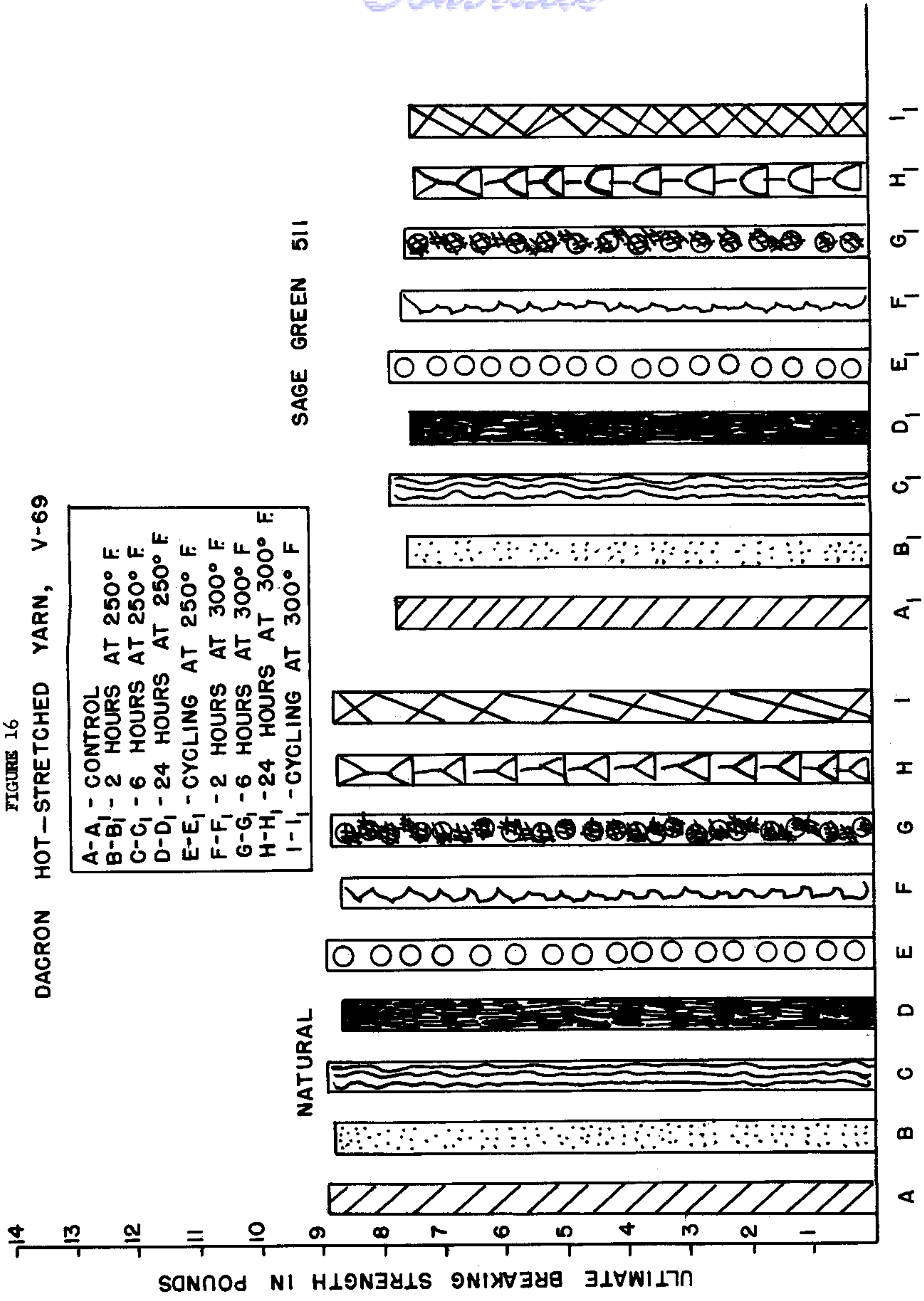


FIGURE 16

DACRON HOT-STRETCHED YARN, V-69

VI MISCELLANEOUS DATA AND DISCUSSION

To determine the effect of various gases, including air, on nylon and Dacron at temperatures above 200°F, skeins of sewing thread were placed in an oxygen bomb, the air evacuated and the bomb filled with the desired gaseous atmosphere (pure oxygen, pure nitrogen, compressed air). The bomb was equipped with temperature controls so that individual tests could be obtained for exposures of two (2), four (4), and eight (8) hours at temperatures of 212°F and 284°F. Pressures within the bomb were 300 #/in^{2} for pure oxygen and compressed air and 30 #/in^{2} for nitrogen. From a safety standpoint, it is recommended that the high pressure condition not be duplicated unless proper equipment is available due to danger of explosions. Data obtained from these tests are shown in Tables VI, VII and VIII.

It is important to note that the degree of degradation in nylon is very severe at the conditions for which successful application of parachute material may be critical. At maximum test conditions in oxygen, nylon lost 96% in strength in contrast to Dacron's loss of 9%. Nylon loses less than 10% in strength for the same conditions in an inert atmosphere. This is conclusive evidence that at the test temperatures the principle cause of degradation in nylon is oxygen. Subjection of nylon to elevated temperatures increases the rate of oxidation resulting in more severe degradation.

Data obtained on experimental Dacron fabric and nylon fabric are presented in Tables X and XI.

The experimental Dacron fabric did not meet all of the requirements of Specification MIL-C-7020A. It is important to note that the requirements which were not met are those which may possibly be improved by utilization of proper heat stabilizing processes.

Evaluation of oven aging tests shows Dacron to be superior to nylon in most instances. The Dacron fabric tested has shown favorable results even though it is not the optimum fabric which can be woven.

TABLE VI

EFFECT OF COMPRESSED AIR 300 POUNDS PER SQUARE INCH ON PHYSICAL PROPERTIES OF NYLON AND DACRON THREAD

	100°C (212°F)						140°C (284°F)						Standard Conditions	
	2 Hours		4 Hours		8 Hours		2 Hours		4 Hours		8 Hours		Untreated	
	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron
Tenacity, grams per denier	6.28	5.53	6.23	5.47	6.07	5.48	2.56	5.17	1.74	5.27	1.45	5.22	6.42	5.76
Percent loss in strength	2.18	3.99	2.95	5.03	5.45	4.86	60.1	10.2	72.8	8.5	77.4	9.3	--	--
Elongation percent	30.2	16.0	29.8	15.4	29.2	15.8	16.3	21.2	11.3	19.9	8.4	20.4	30.2	13.5
Shrinkage	0.0	2.1	1.0	2.2	1.8	2.6	1.7	7.0	0.0	7.2	0.0	7.2	--	--
Denier	742.7	679.7	740.8	676.6	741.0	682.1	740.0	714.6	736.8	709.6	731.9	716.1	743.9	661.0
Yards per pound	6010	6567	6026	6598	6024	6544	6032	6247	6058	6290	6099	6233	6000	6753

FIGURE 17

EFFECT OF COMPRESSED AIR 300° ON PHYSICAL PROPERTIES

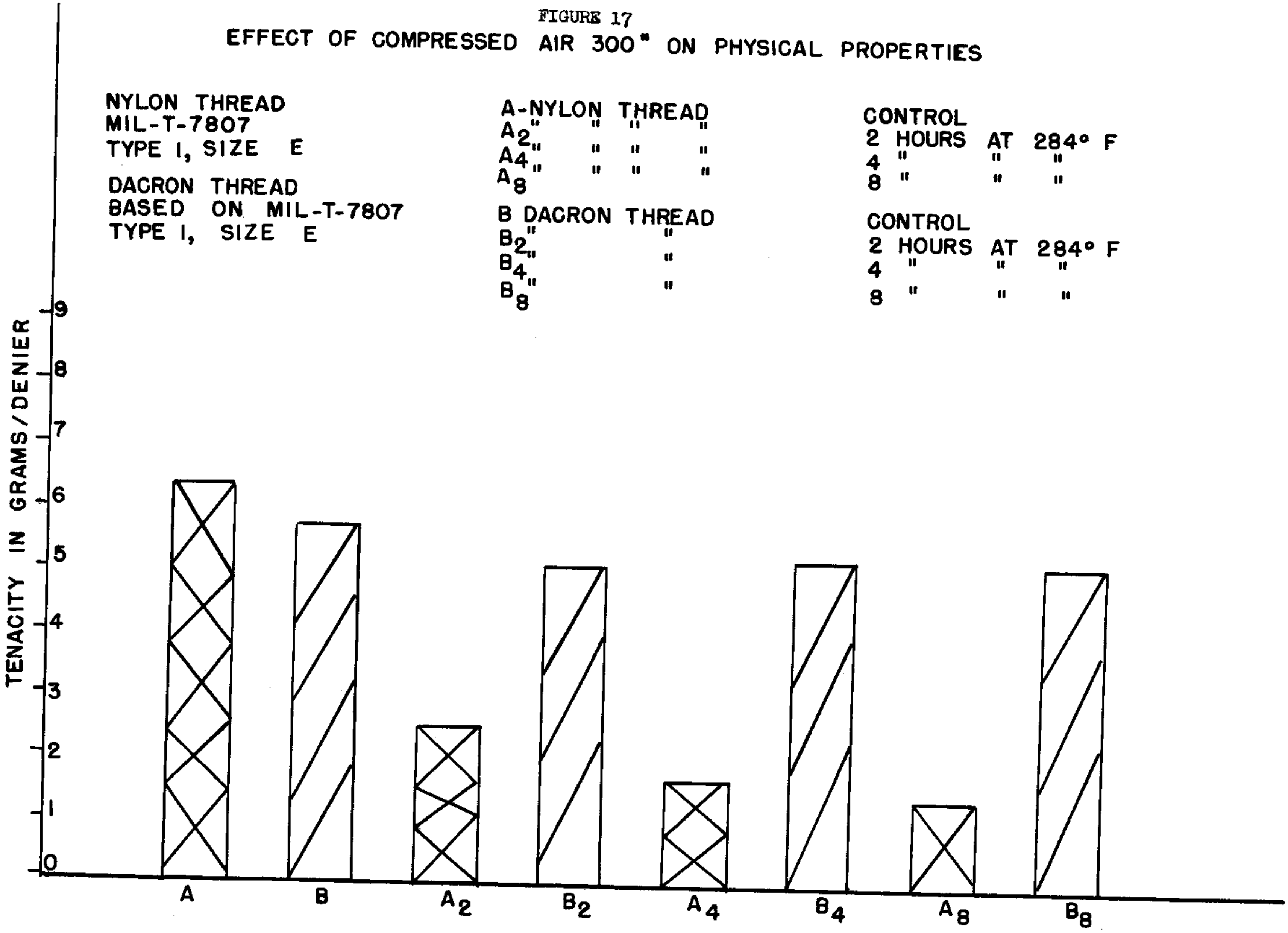


TABLE VII

EFFECT OF OXYGEN 300 POUNDS PER SQUARE INCH ON PHYSICAL PROPERTIES OF NYLON AND DACRON THREAD

	100°C (212°F)						140°C (284°F)						Standard Conditions	
	2 Hours		4 Hours		8 Hours		2 Hours		4 Hours		8 Hours		Untreated	
	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron
Tenacity, grams per denier	6.25	5.50	5.87	5.57	5.02	5.54	1.18	5.23	.520	5.27	.217	5.20	6.42	5.76
Percent loss in strength	2.64	4.51	8.56	3.29	21.8	3.81	81.6	9.2	91.9	8.5	96.6	9.7	—	--
Elongation percent	30.3	14.4	26.8	14.7	23.7	14.6	7.6	19.8	3.3	21.1	1.9	20.8	30.2	13.5
Shrinkage percent	4.0	3.4	0.6	3.2	0.6	2.6	4.0	6.0	4.0	7.0	0.0	7.4	—	--
Denier	741.4	677.4	743.1	678.7	742.3	677.6	736.0	710.0	735.0	707.3	716.3	713.4	743.9	661.0
Yards per pound	6021	6590	6007	6577	6013	6588	6065	6287	6074	6311	6231	6257	6000	6753

FIGURE 18

EFFECT OF OXYGEN 300# ON PHYSICAL PROPERTIES

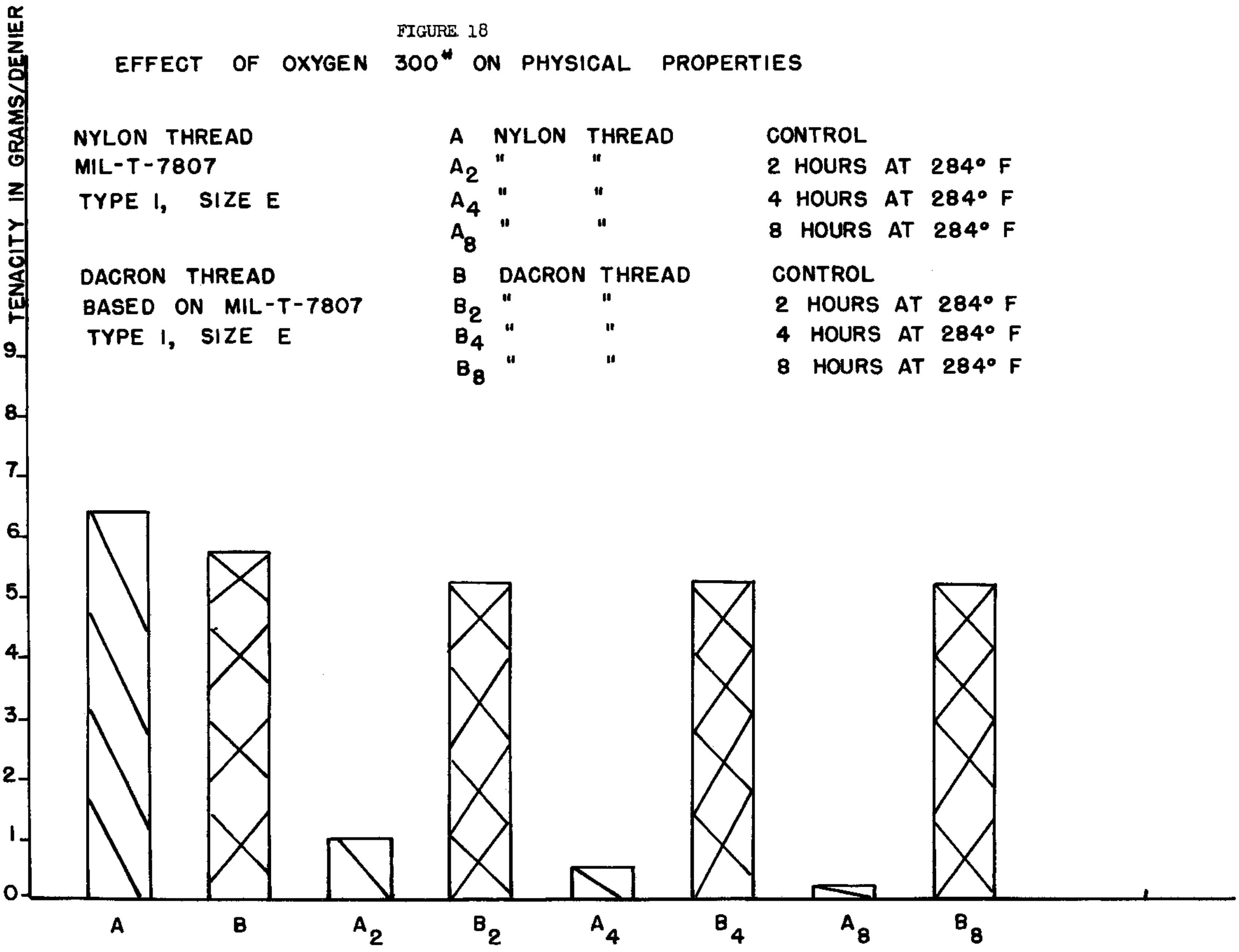


TABLE VIII

EFFECT OF NITROGEN 30 POUNDS PER SQUARE INCH ON PHYSICAL PROPERTIES OF NYLON AND DACRON THREAD

	100°C (212°F)						140°C (284°F)						Standard Conditions	
	2 Hours		4 Hours		8 Hours		2 Hours		4 Hours		8 Hours		Untreated	
	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron
Tenacity, grams per denier	6.5	5.65	6.52	5.67	6.56	5.58	6.35	5.31	6.00	5.23	5.87	5.31	6.42	5.76
Percent loss in strength	1.24*	1.90	1.55*	1.56	2.18*	3.12	1.09	7.81	6.54	9.20	8.56	7.81	--	--
Elongation percent	31.1	15.0	31.2	14.8	31.8	14.6	31.6	20.0	30.9	19.8	30.3	19.1	30.2	13.5
Shrinkage percent	0.5	2.5	2.5	1.0	2.5	0.5	0.5	6.5	0.5	7.0	0.5	6.0	--	--
Denier	740.9	674.0	739.3	671.0	738.5	667.7	740.1	702.9	738.7	712.1	735.82	710.2	743	661
Yards per pound	6025	6623	6038	6652	6044	6686	6031	6351	6043	6268	6067	6286	6000	6753

* Increase in strength

FIGURE 19

EFFECT OF NITROGEN 30" ON PHYSICAL PROPERTIES

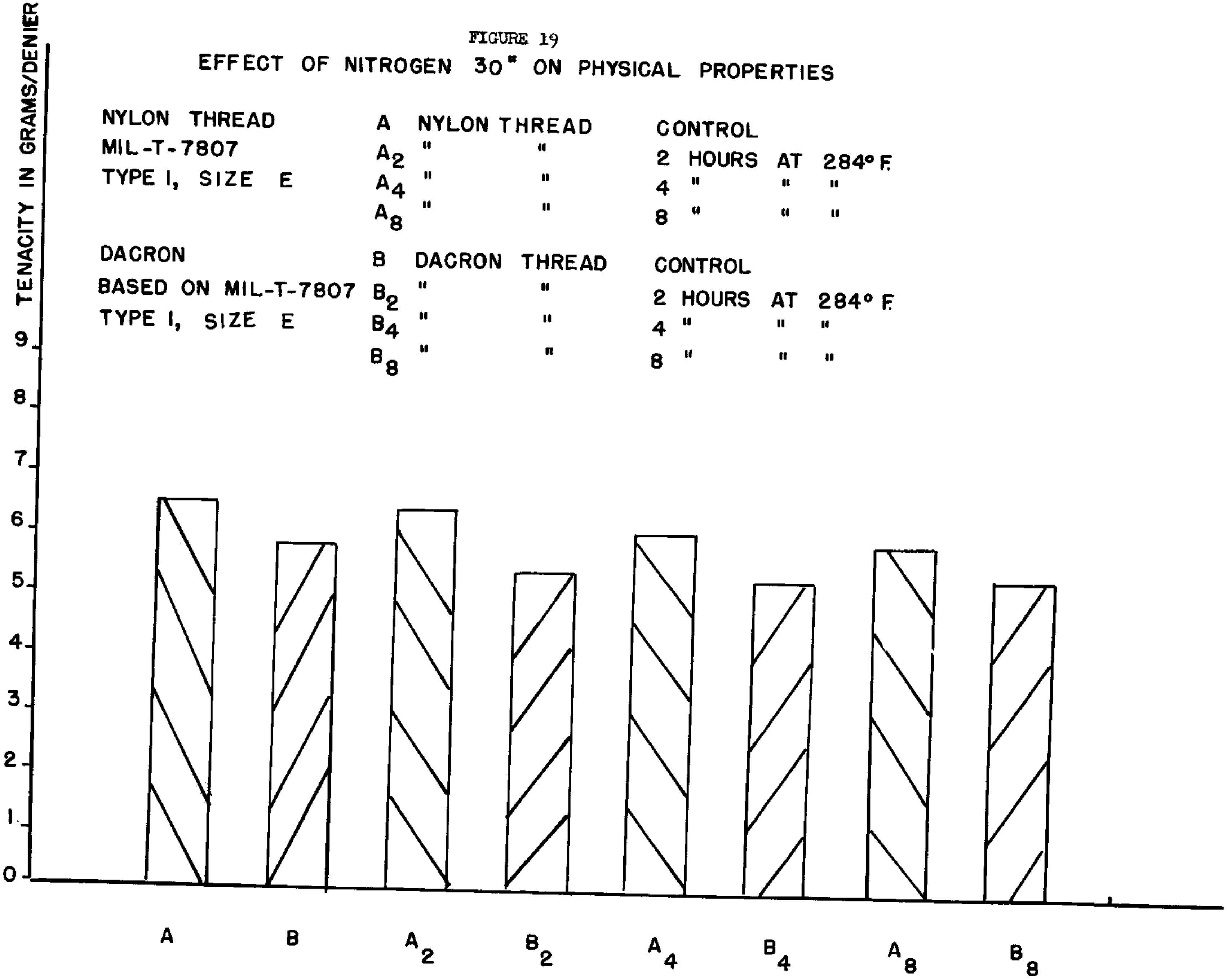


TABLE IX

EFFECT OF OVEN-AGING ON PHYSICAL PROPERTIES NYLON AND DACRON THREAD

	375°F						425°F						Standard Conditions Untreated	
	2 Hours		4 Hours		8 Hours		2 Hours		4 Hours		8 Hours			
	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron	Nylon	Dacron
Tenacity, grams per denier	2.19	4.77	1.85	4.48	1.43	4.46	.826	2.46	.314	2.55	.394	2.46	6.42	5.76
Percent loss in strength	65.8	1.71	71.1	22.2	77.7	22.5	87.1	57.2	95.1	55.7	93.8	57.2	—	--
Elongation percent	13.1	27.2	11.0	27.1	8.8	28.7	8.8	17.4	4.9	18.4	4.9	17.8	30.2	13.5
Shrinkage percent	2.5	4.0	2.0	2.0	2.0	3.5	4.0	5.0	2.0*	5.0	3.0	4.0	—	--
Denier	730.9	748.6	729.1	746.1	733.5	741.9	740.2	772.1	737.6	768.3	737.2	771.7	743.9	661.0
Yards per pound	6108	5963	6123	5983	6086	6017	6031	5782	6052	5810	6055	5785	6000	6754

* Increase in length rather than shrinkage.

FIGURE 20

EFFECT OF OVEN-AGING ON PHYSICAL PROPERTIES

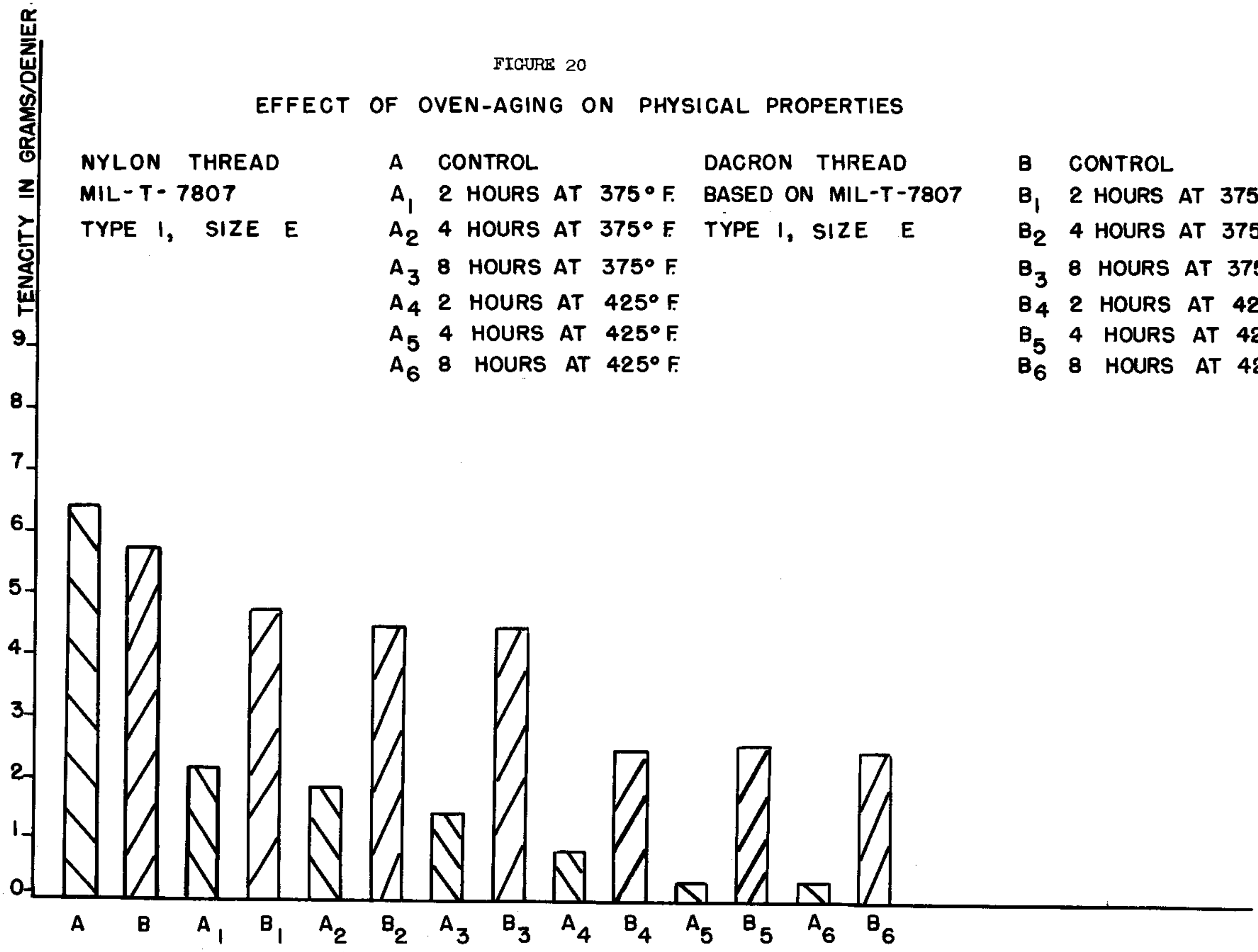


TABLE X

PHYSICAL PROPERTIES OF DACRON FABRICS
EXPERIMENTAL DACRON FABRIC

	Experimental Dacron Sample	Type II MIL-C-7020A (USAF)
Weight ounces per yard square	1.4	1.6 Maximum
Thickness inch	.0033	.0042 Maximum
Breaking strength pounds per inch		
Warp	46.8*	50 Minimum
Filling	50.5	50 Minimum
Ultimate elongation percent		
Warp	17.0	14 Minimum
Filling	22.6	14 Minimum
Tear resistance pounds		
Warp	3.5*	4 Minimum
Filling	4.0	4 Minimum
Air Permeability cubic feet per minute per square foot	99.2*	100 - 160
Weave	2 up - 1 down Twill	2 up - 1 down Twill
Width, inch	36.03	36.5 ± .5
Color	Natural white	Natural white unless otherwise specified
Non - fibrous material percent	1.5	2 Maximum
Acidity - pH	7.3	5.0 - 9.0
Permanence of finish		
Change of air permeability	22.4* gain	15 Maximum
Increase in thickness	18.2*	10 Maximum
Shrinkage percent		
Warp	6.8*	2 Maximum
Filling	2.9*	1 Maximum

* Does not comply with specification requirements.

TABLE XI

RESULTS OF OVEN-AGING TESTS AFTER SIX HOURS EXPOSURE NYLON AND DACRON FABRIC

	Dacron* 375°F	Nylon** 375°F	Dacron 425°F	Nylon 425°F
Breaking strength pounds per inch				
Warp	53.4	16.3	13.5	11.2
Filling	58.6	17.9	9.6	11.2
Percent change from original				
Warp	14.1 gain***	74.0 loss	71.2 loss	82.2 loss
Filling	16.0 gain	76.9 loss	80.9 loss	85.4 loss
Air permeability cubic feet per minute per square foot	51.3	115.5	46.5	92.6
Percent change from original	48.5 loss	38.5 gain	53.1 loss	29.1 gain
Shrinkage				
Warp	12.8	1.8	17.8	8.4
Filling	11.5	1.0	17.0	7.4
Elongation percent				
Warp	38.6	9.7	9.6	8.7
Filling	38.6	10.2	5.3	9.4
Percent change from original elongation				
Warp	127.1 gain	71.4 loss	43.5 loss	74.4 loss
Filling	70.8 gain	69.0 loss	76.5 loss	71.5 loss

* Experimental Dacron fabric having physical properties listed in Table X.

** Nylon fabric woven in accordance with the requirements of Specification MIL-C-7020A, Type II.

*** The gain in breaking strength of the fabric is attributed primarily to the high shrinkage which occurred.

VII CONCLUSIONS

Test data show that the nylon fabrics do not lose more than 15% breaking strength in warp or filling after 24 hours exposure in hot air at 250°F.

The nylon webbing, Type X Condition R loses 43% in strength in comparison with 14% for Condition U for the same conditions mentioned above. Darkening and stiffening of the Condition R webbing was noted. Apparently the resin accelerated degradation of the webbing.

The nylon tubular webbing 9/16 inch wide lost 16% in breaking strength and the nylon cord, Type III lost 32% in strength under the same conditions. It is probable that the heat caused an unbalanced condition in this cord, contributing to the excessive loss in breaking strength.

The Dacron thread was not appreciably affected under these conditions.

The nylon fabrics lost the following amounts in breaking strength after exposure for twenty four hours in hot air at 300°F:

Fabric	Percent loss in strength	
	Warp	Filling
Type II MIL-C-7020A	40.44	62.36
Type I MIL-C-7350	48.75	57.27
Type I 16208A	45.38	47.21

The nylon webbing Type X, Condition R lost 72% of its breaking strength after exposure in hot air at 300°F for twenty four hours in comparison with 56% for Condition U webbing.

Nylon tubular webbing 9/16 inch wide lost 54% in breaking strength and the nylon cord lost 63% after exposure for twenty four hours in hot air at 300°F.

The Dacron thread showed no appreciable loss in breaking strength for the conditions described above.

Exposure in an intermittent manner in hot air at 250°F appears to have no appreciable effect on the materials tested up to a total of 6 hours. It is important to note that repeated re-exposure at these temperatures may produce a significant loss in breaking strength.

It appears that exposure in an intermittent manner in hot air at 300°F up to a total of 6 hours was more severe than continuous exposure at 300°F for 6 hours in most instances. For ease of comparison some of the data are recapitulated here:

	Continuous 6 hours at 300°F		Intermittent 6 hours at 300°F	
Item	Percent Loss		Percent Loss	
Fabric Type II MIL-C-7020	Warp	20.73	Warp	21.00
	Filling	26.81	Filling	26.52
Fabric Type I MIL-C-7350	Warp	14.71	Warp	21.99
	Filling	20.56	Filling	26.34
Fabric Type I 16208A	Warp	14.49	Warp	24.37
	Filling	13.09	Filling	25.44
Nylon Webbing Type X Condition R		52.38		52.24
Nylon Webbing Type X Condition U		33.40		36.82
Nylon Tubular 9/16 inch wide		24.14		38.04
Nylon Cord, Type III		41.77		45.96

It is emphasized that the nylon webbing, Type X Condition R, which is treated with a resin, is severely affected in breaking strength at the high temperatures. The untreated nylon webbing retains more of its original strength than the resin treated after exposure to the stated conditions. Extreme stiffness was more apparent in the Condition R webbing.

Charts from the Brown recorder were used to plot the average temperature values for continuous and intermittent exposures in order to determine if the temperature was the same for both conditions. The charts show that the temperatures recorded were with 5° - 10°F of the predetermined setting in both instances. It is therefore concluded that the increased losses which occur as a result of intermittent exposures are probably not the result of any temperature differences for the respective conditions.

The superiority of Dacron over nylon in resistance to hot air degradation has been shown. Further evaluation is necessary to obtain data on parachute textile materials when tested at the temperatures rather than after when the items have cooled down. Further evaluation is necessary to accurately predict the superiority of properly designed Dacron parachute textile materials utilizing a satisfactorily heat stabilized yarn or proper heat setting of the woven items.

It is important to understand that the author does not desire to minimize or exaggerate the properties of the fibers under question, but to present data which will be useful for particular applications where one fiber possesses the required qualities to a greater degree.

At such time as the Dacron items are satisfactorily woven, further tests will be conducted to obtain complete comparison data between nylon and Dacron parachute textile materials.

BIBLIOGRAPHY

WADC Technical Report 53-21 Part 2, A Study Of The Effect Of Temperature On Textile Materials, 1953.