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D6-41185-6

(NASA-CR-158169) A STUDY OF THE EFFECTS OF LONG-TERM EXPOSURE TO FUELS AND FLUIDS ON THE BEHAVIOR OF ADVANCED COMPOSITE MATERIALS (Boeing Commercial Airplane Co., Seattle) 24 p HC A02/MF A01 CSCL 11D G3/24

N79-17918

Unclas 18251

1 Report No	2 Government Accession No	3 Recipient s Catalog No

4 Title and Subtitle	5 Report Date
A STUDY OF THE EFFECTS OF LONG-TERM EXPOSURE TO FUELS AND FLUIDS ON THE BEHAVIOR OF ADVANCED COMPOSITE MATERIALS	September 1977
	6 Performing Organization Code
7 Author(s)	8 Performing Organization Report No
Carl L. Hendricks	D6-41185-6
	10 Work Unit No
9 Performing Organization Name and Address	11 Contract or Grant No
Boeing Commercial Airplane Company P. O. Box 3707 Seattle, Washington 98124	NAS1-12428
	13 Type of Report and Period Covered
12 Sponsoring Agency Name and Address	
National Aeronautics and Space Administration Washington, D.C.	14 Sponsoring Agency Code

15 Supplementary Notes

NASA Technical Representative

16 Abstract

This report covers the Task 1 thirty-six-month and Task 2 twelve-month exposure of composite materials to fuel and fluid environments. Narmco T300/5209 (Task 1) shows no significant degradation. Slightly lower mechanical properties were obtained from fuel/water immersion exposure of this material. Kevlar 49/2544 (also Task 1) exhibits significant drop in short-beam shear when exposed to fuel/water immersion Task 2 materials (T300/5208, Kevlar 49 fabric/5209, and Kevlar 49 fibers) have not shown any significant mechanical property degradation to date.

17 Key Words (Suggested by Author(s))	18 Distribution Statement
Graphite-epoxy Kevlar-epoxy Environmental exposure	Unclassified - unlimited

19 Security Classif (of this report)	20 Security Classif (of this page)	21 No of Pages	22 Price
Unclassified			

*For sale by the National Technical Information Service Springfield Virginia 22151

D6-41185-6

A STUDY OF THE EFFECTS OF LONG-TERM EXPOSURE TO FUELS AND FLUIDS ON THE BEHAVIOR OF ADVANCED COMPOSITE MATERIALS - TASK 1 36-MONTH AND TASK 2 12-MONTH EXPOSURE REPORT

INTRODUCTION AND SUMMARY

This report covers the 36-month and 12-month exposure data of Task 1 and Task 2 composite materials, respectively. Task 1 exposure has been in effect since June 1974. Task 2 exposure was initiated in December 1975. The work is being conducted under Contract NAS1-12428. Program technical director is R. Pride.

The objective of this program is to determine the effects of long-term exposure to fuels and fluids on the behavior of advanced composite materials. Composite specimens are exposed to ambient air, immersion in JP-4, Skydrol, water, fuel-water mixture, wet (fuel) - dry (air) cycling, and immersion in water (added to Task 2).

TECHNICAL DISCUSSION

Task 1 materials that have completed 36 of 60 months exposure are T300/5209 tape laminates and Kevlar 49/2544 tape laminates.

Task 2 materials are T300/5208 tape laminates, Kevlar 49 (Style 281)/5209 fabric laminates, and Kevlar 49 bare fibers. These materials have completed 12 of 60 months exposure.

The composite mechanical properties used to measure effects of the various environments on the test materials are $[\pm 45°]_S$ stressed (25% of ultimate) and unstressed tension and unidirectional 0° short beam shear. Kevlar fibers are tension tested as individual filaments.

ENVIRONMENTAL EXPOSURE CONDITIONS

Environmental exposure test conditions imposed upon the laminate specimens started in Task 1 are

- o Ambient JP-4 immersion consisting of simple fuel soak at room temperature with periodic (approximately monthly) replacement of fresh fuel.
- o Ambient Skydrol immersion performed as described for fuel soak with periodic (approximately monthly) replacement of hydraulic fluid.
- o Ambient fuel/water immersion performed with the fuel-water interface maintained at the center of the test specimens Bacteria common to fuel tank environments are placed in the test tank.
- o Ambient wet (fuel) - dry (air) cycling exposure is performed on the test specimens by 24 hours fuel immersion followed by 24 hours air exposure.
- o Ambient air exposure (control).

Task 2 composite materials are exposed to the above conditions plus water immersion. Kevlar 49 fibers are water exposed only.

The exposure facility is monitored daily.

TESTING

Ten ± 45° tensile (IITRI) and ten short beam shear (4 1) specimens from each composite system were tested prior to exposure to establish baseline properties. Kevlar 49 fibers are tested in tension on an individual basis.

Exposure consists of submitting groups of four tensile and four shear specimens, from each material, to all environments for periods of 3, 6, 12, 24, 36, and 60 months. The test plan is shown in table I.

Two tensile specimens from each specimen group are subjected to a sustained stress of 25 percent of ultimate during environmental exposure. Aluminum load tabs are used to minimize creep and potential shear-out failure at the loading bolt. The jigs are a modified spring-loaded fixture used for sustained load studies of adhesive bonds.

After each exposure period, the specimens for test are removed from environmental exposure and tested to failure at room temperature.

Kevlar 49 fibers are tension tested on an individual basis. Ten fibers picked at random from 1420-1000-0 Type 968 Kevlar yarn are tested initially and after 3, 6, 12, 24, 36, and 60 months water immersion.

TABLE I

DISTRIBUTION OF ENVIRONMENTAL TEST SPECIMENS EACH SYSTEM

Environment	Tension, No. Specimens			Shear, No. Spec.
	Unstressed		Stressed	
	Composite	Kevlar 49 Fiber	Composite	Composite
None, Initial Test	10	10		
JP-4 Immersion				
3 months	2		2	4
6 months	2		2	4
12 months	2		2	4
24 months	2		2	4
36 months	2		2	4
Skydrol Immersion				
3 months	2		2	4
6 months	2		2	4
12 months	2		2	4
24 months	2		2	4
36 months	2		2	4
60 months	2		2	4
Fuel/Water Immersion				
3 months	2		2	4
6 months	2		2	4
12 months	2		2	4
24 months	2		2	4
36 months	2		2	4
60 months	2		2	4
Wet (fuel) - Dry (air) Cycling				
3 months	2		2	4
6 months	2		2	4
12 months	2		2	4
24 months	2		2	4
36 months	2		2	4
60 months	2		2	4
Ambient Air				
3 months	2		2	4
6 months	2		2	4
12 months	2		2	4
24 months	2		2	4
36 months	2		2	4
60 months	2		2	4
H_2O Immersion (Task 2)				
3 months	2	10	2	4
6 months	2	10	2	4
12 months	2	10	2	4
24 months	2	10	2	4
36 months	2	10	2	4
60 months	2	10	2	4

TEST RESULTS

TASK 1

The data after exposure to the various fluids at 3, 6, 12, 24, and 36 months indicate that T300/5209 is not significantly affected in ± 45° tensile properties or 0° short beam shear (figs. 1 through 3). Test values for this material are lowest on specimens subjected to fuel/water immersion. Stressed and unstressed tensile specimens did not show any major difference in test values.

Kevlar 49/2544 exhibits significant loss in short beam shear strength when exposed to fuel/water immersion (fig. 6). The other exposure conditions did not affect strength and/or modulus properties (figs. 4 and 5).

TASK 2

T300/5208 has shown some degradation at 12 months in ± 45° tensile modulus when epxosed to fuel/water, fuel/air cycling, and water immersion, as seen in figure 9. Other properties are not significantly affected to this time.

Kevlar 281 fabric/5209 tensile strength is lower after exposure to all conditions after 12 months. Water immersion exposure values were the lowest recorded, with a loss of about 34% (stressed) and about 30% (unstressed) in tensile strength. Tensile modulus values did not appear to be affected. Short beam shear strength was not significantly affected after 12 months exposure except for water immersion. This condition resulted in about a 15% loss in shear strength. No significant changes in properties were found between 6 and 12 months exposure. (See figs. 11 through 13).

Kevlar 49 fibers were reported to have lost approximately 10% tensile strength at the 3 months exposure test time. The 6 months and 12 months exposure data indicate no significant loss compared to the initial tensile strength and modulus values (table II). The difference in apparent values between initial and 3 months exposure is probably due to the scatter in data associated with testing individual Kevlar 49 fibers.

Figure 7 illustrates T300/5209 tensile strength data as a function of time.

CONCLUSIONS

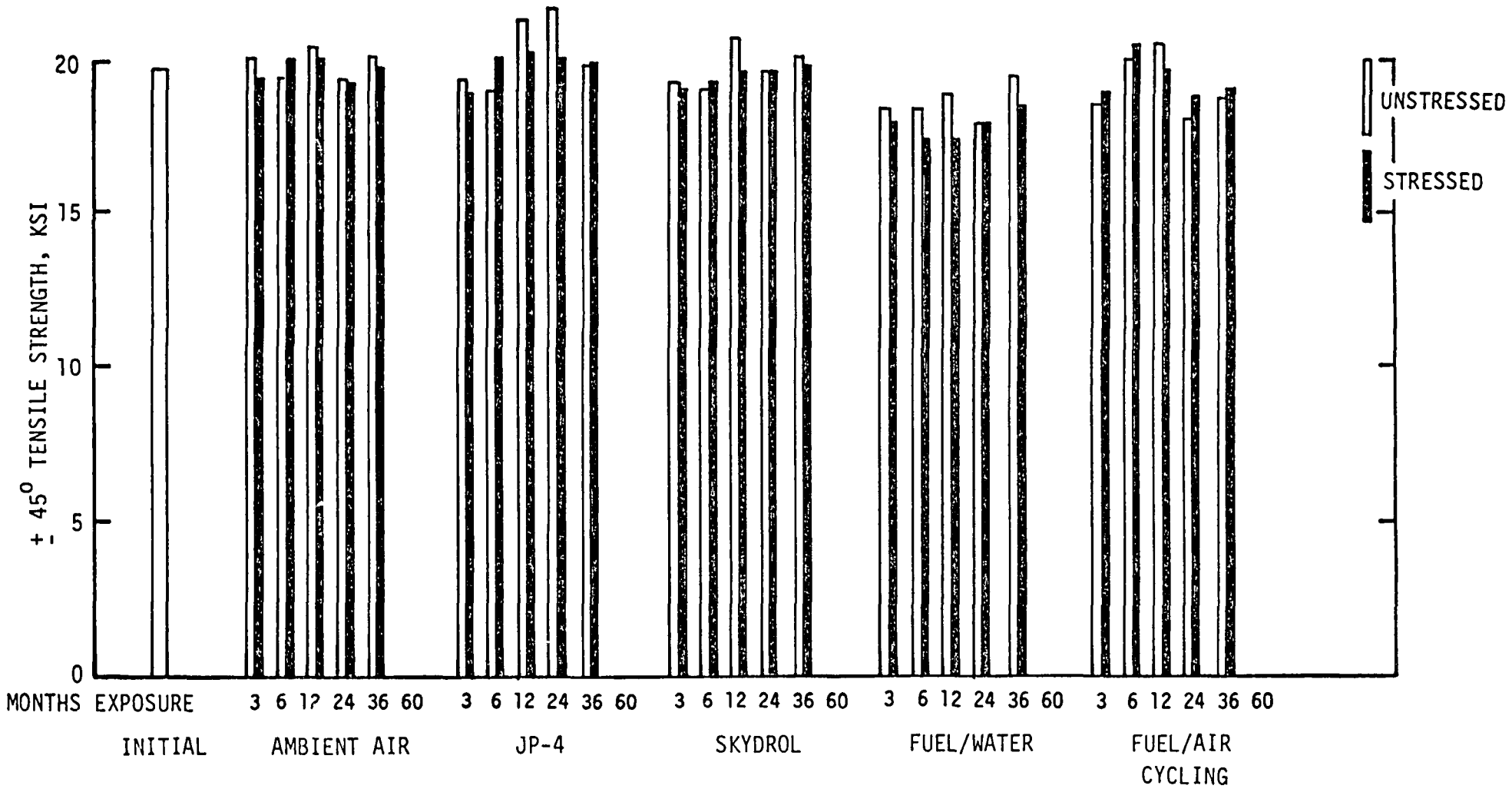
T300/5209 room-temperature mechanical properties (± 45° tensile and 0° short beam shear) are not significantly affected by 24 months exposure to the fuel and fluid environments of this program.

Kevlar 49/2544 room-temperature ± 45° tensile properties are also unaffected by the imposed environments. Short beam shear strength (room temperature) is significantly lower than initial values when exposed to fuel/water interface.

T300/5208 room-temperature mechanical properties have not been affected by 12 months exposure to the various environments except for ± 45° tensile modulus.

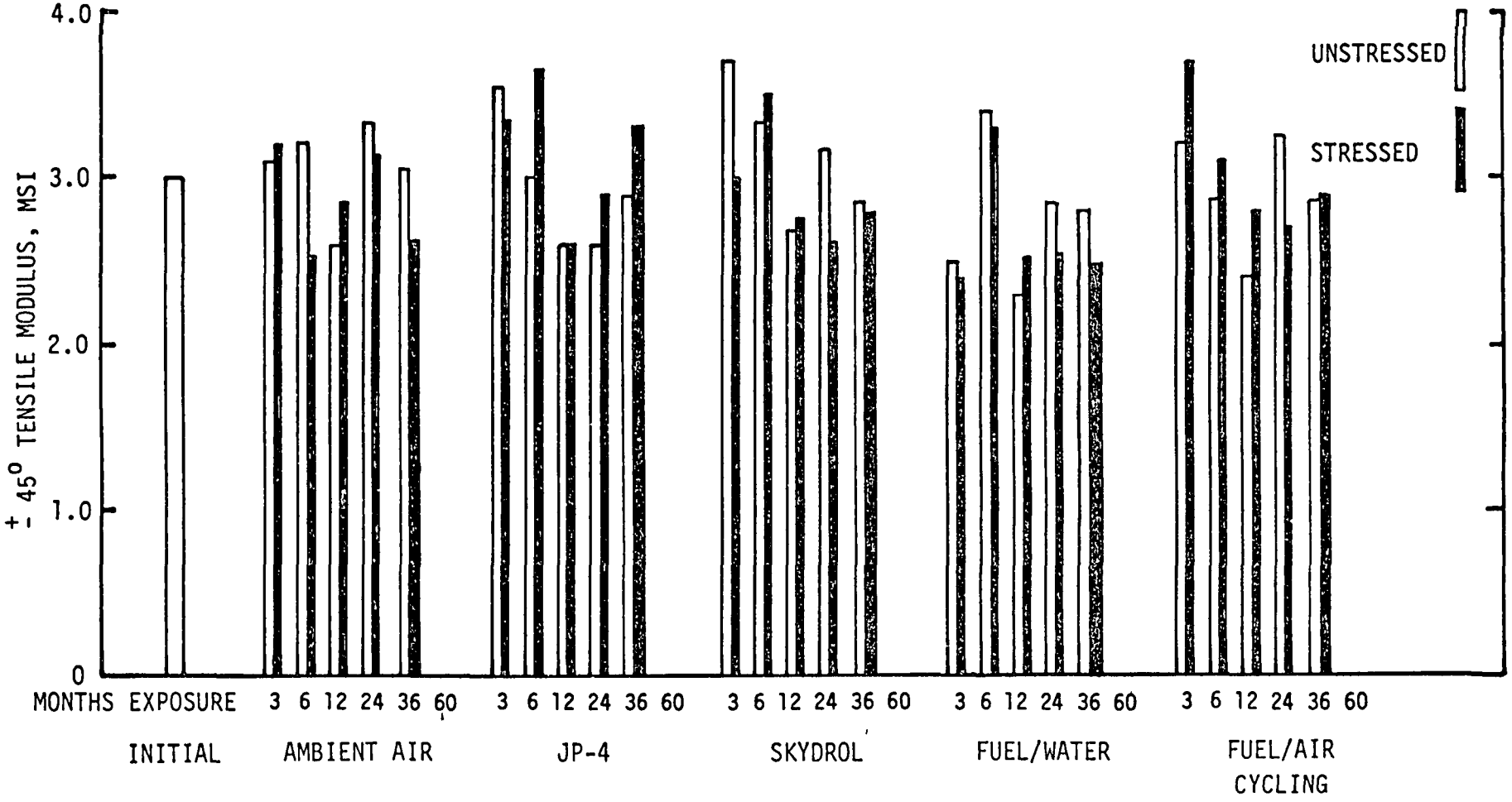
Kevlar 49 Style 281/5209 exhibited an initial (3 months) significant drop in room-temperature ± 45° tensile strength when immersed in water. Additional reduction in tensile strength was found after 6 months fuel/water and water immersion exposure. The other environmental conditions appear to affect this material, but to a lesser degree.

Kevlar 49 bare fiber room-temperature tensile strength and modulus have not been significantly affected by water immersion for up to the 12 months time exposure.



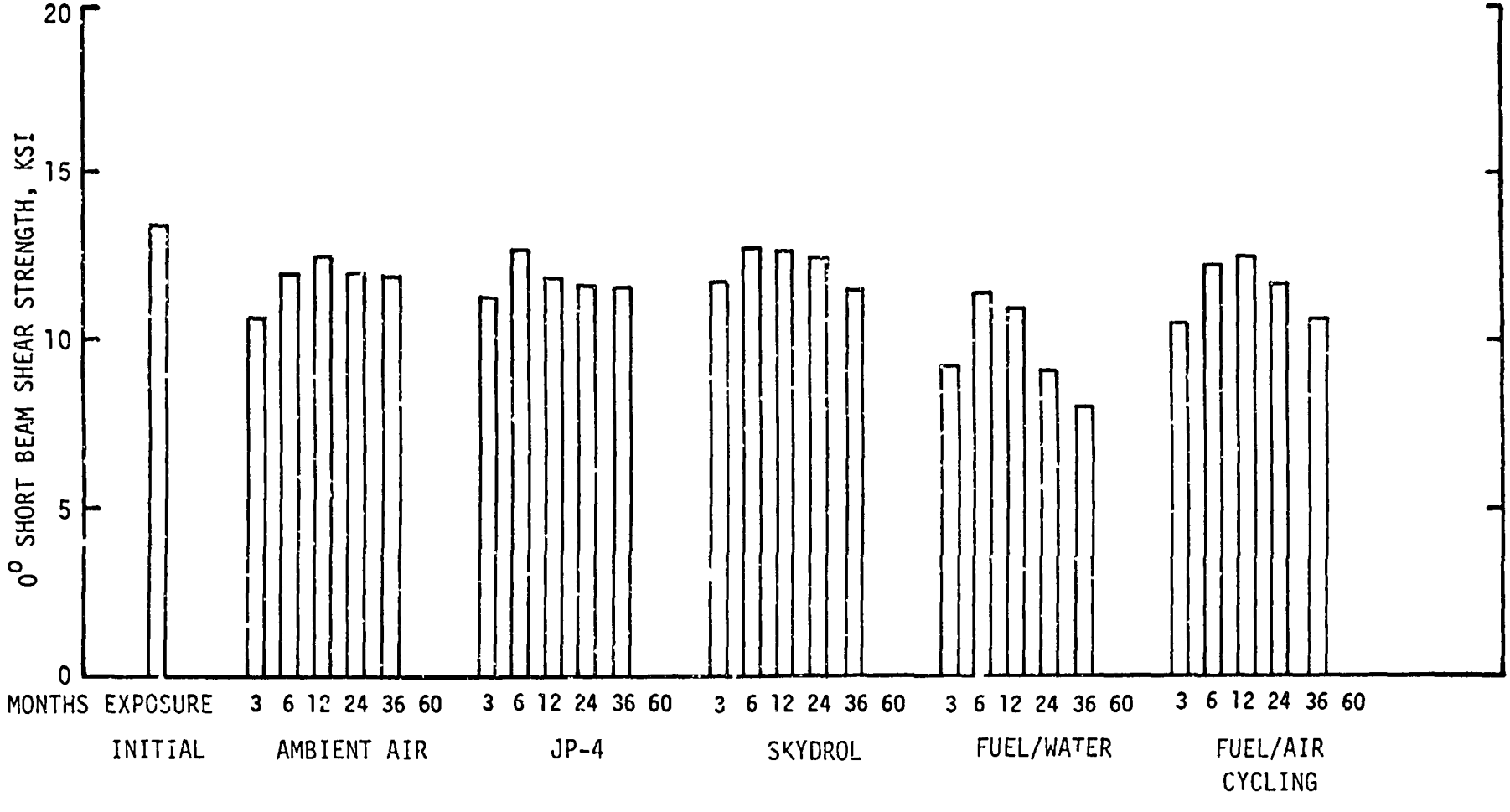
ENVIRONMENTAL EXPOSURE OF T300/5209 ($\pm 45^{o}$ TENSILE STRENGTH, V_F = 66.8%)

Figure 1



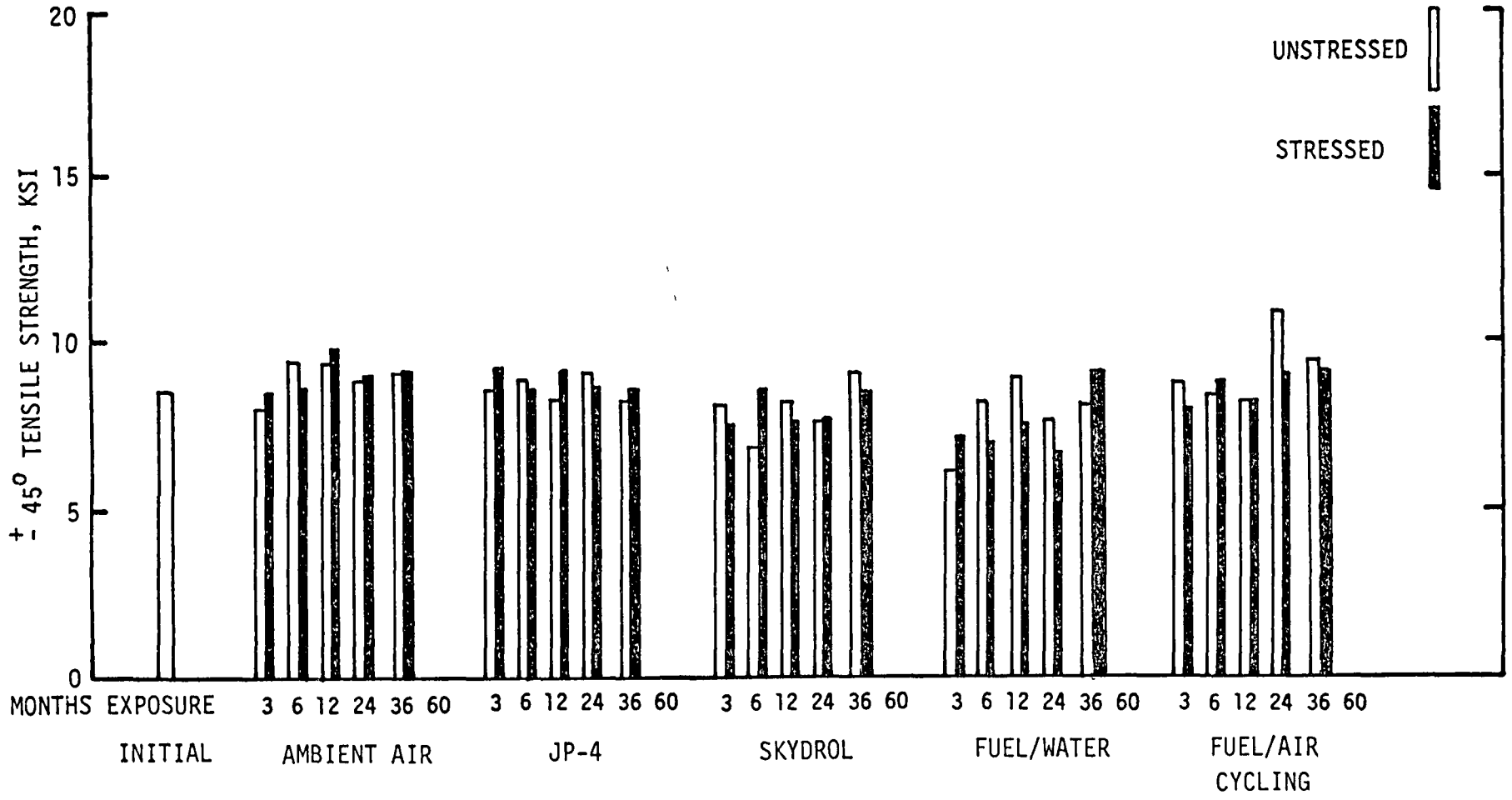
ENVIROMENTAL EXPOSURE OF T300/5209 ($\pm$ 45° TENSILE MODULUS, V_F = 66.8%)

Figure 2



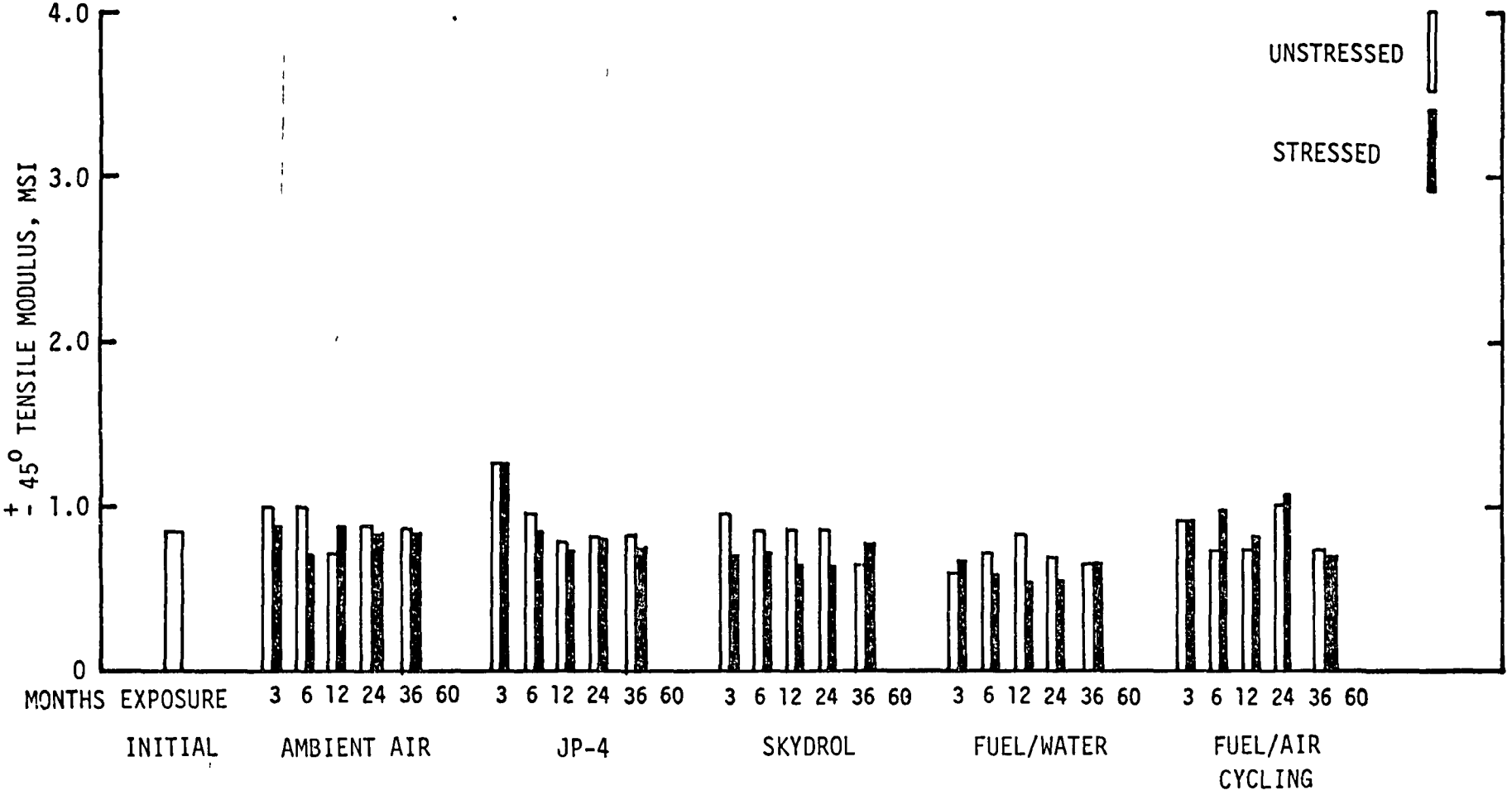
ENVIRONMENTAL EXPOSURE OF T300/5209 (0^{o} SHORT BEAM SHEAR, V_F= 66.8%)

Figure 3



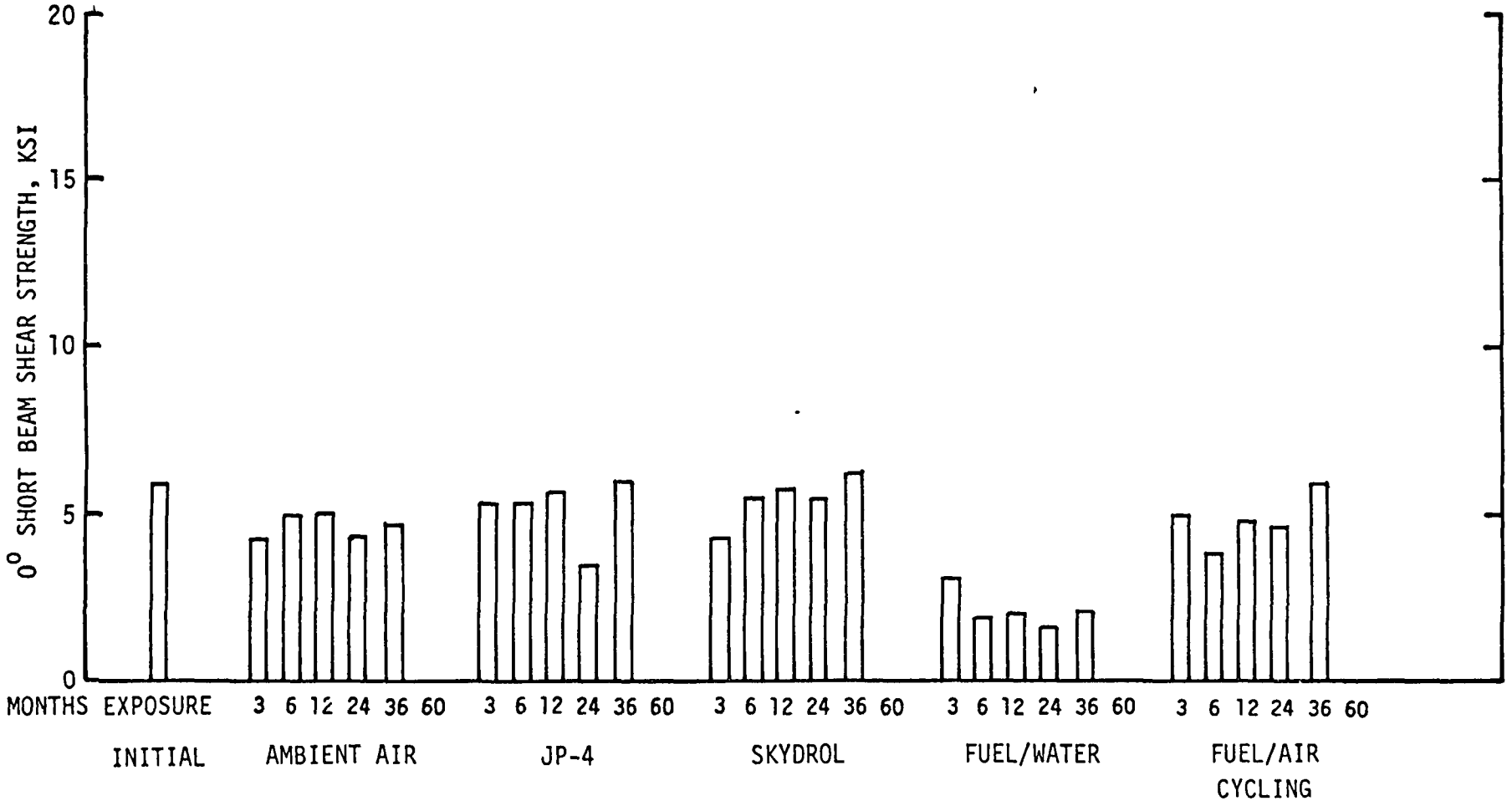
ENVIRONMENTAL EXPOSURE OF KEVLAR/2544 ($\pm$ 45° TENSILE STRENGTH, V_F = 78.2%)

Figure 4



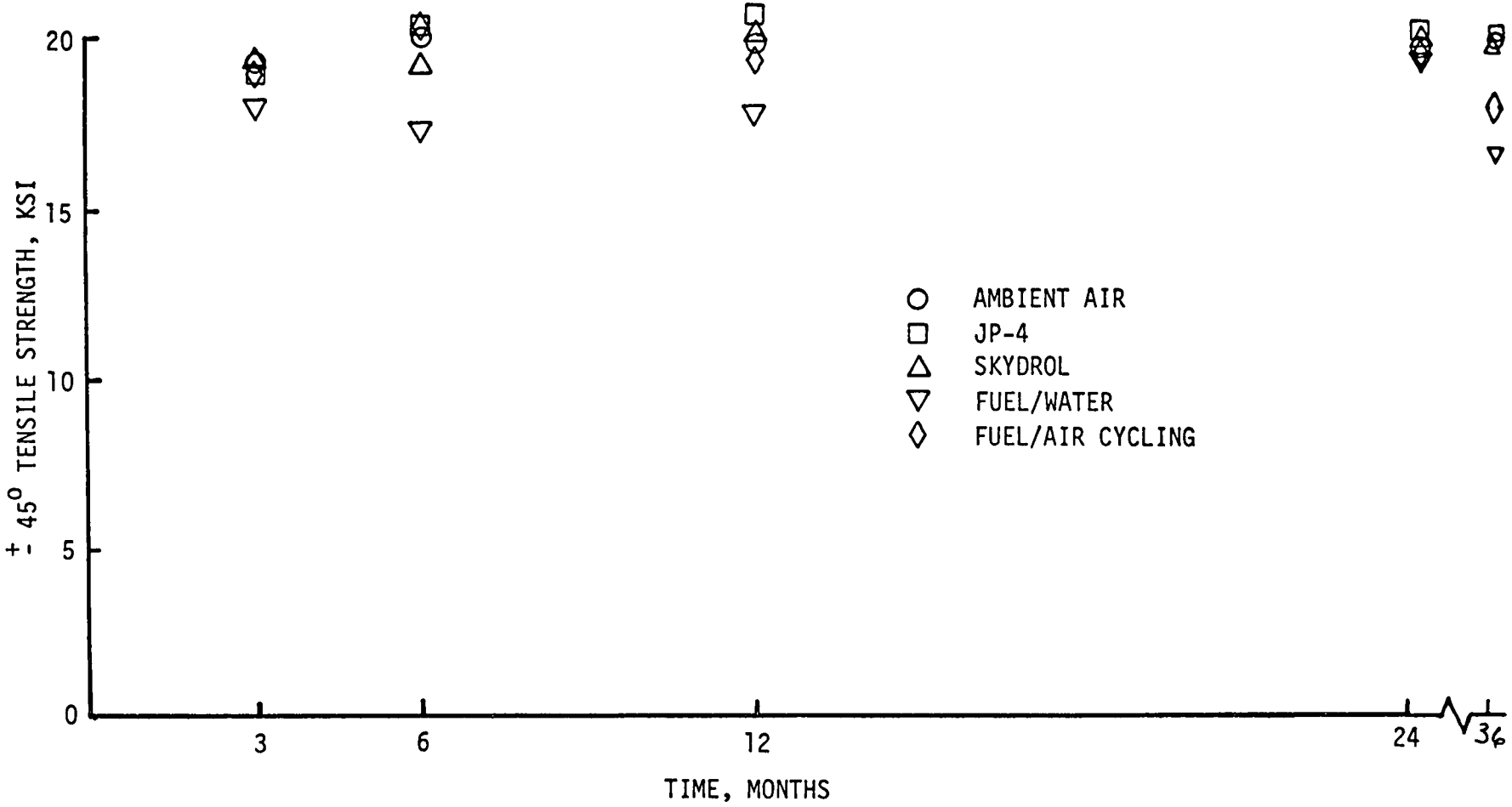
ENVIRONMENTAL EXPOSURE OF KEVLAR 49/2544 ($\pm$ 45° TENSILE MODULUS, V_F = 78.2%)

Figure 5



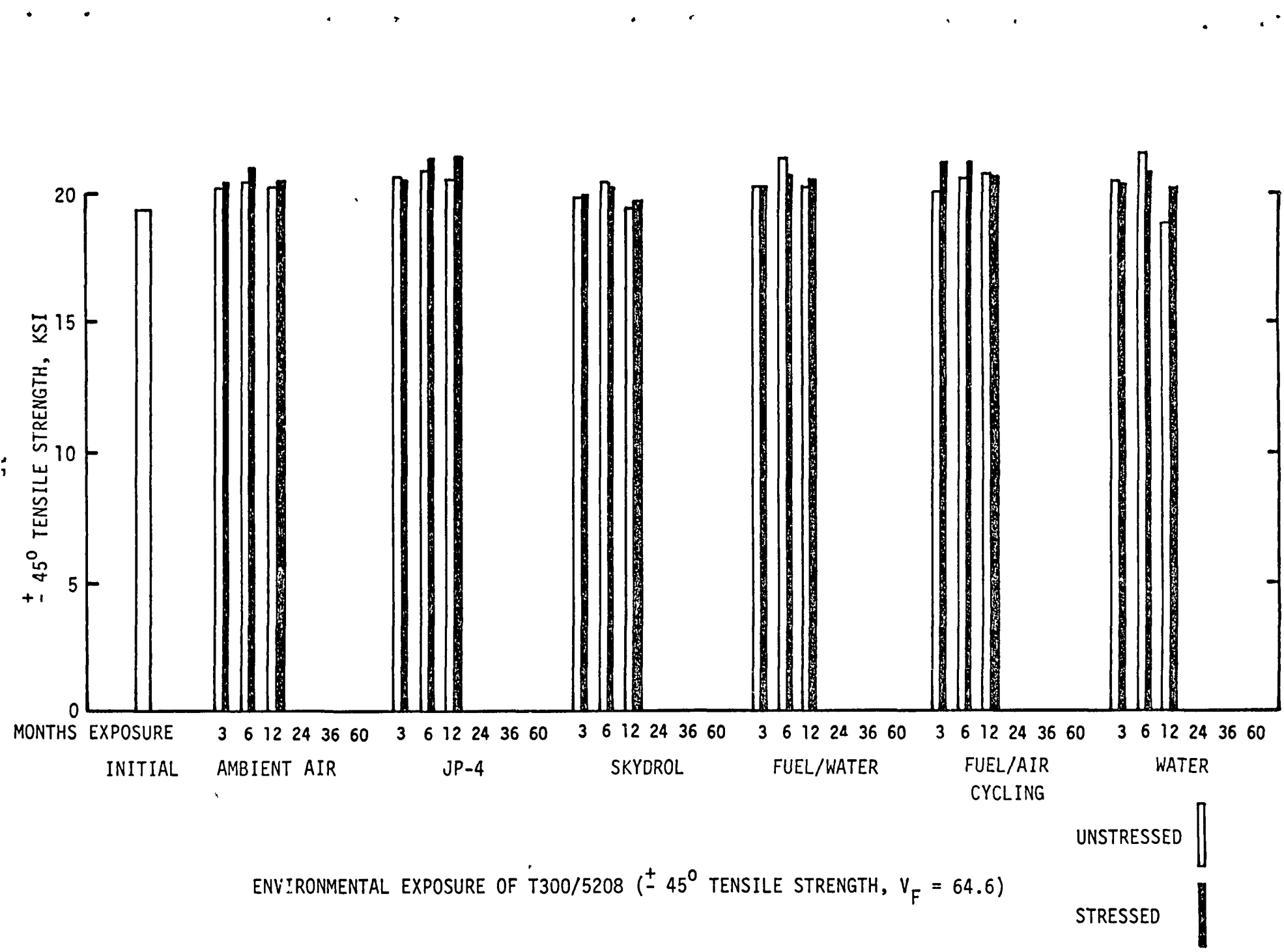
ENVIRONMENTAL EXPOSURE OF KEVLAR/2544 (0^{o} SHORT BEAM SHEAR, V_F = 64.2%).

Figure 6



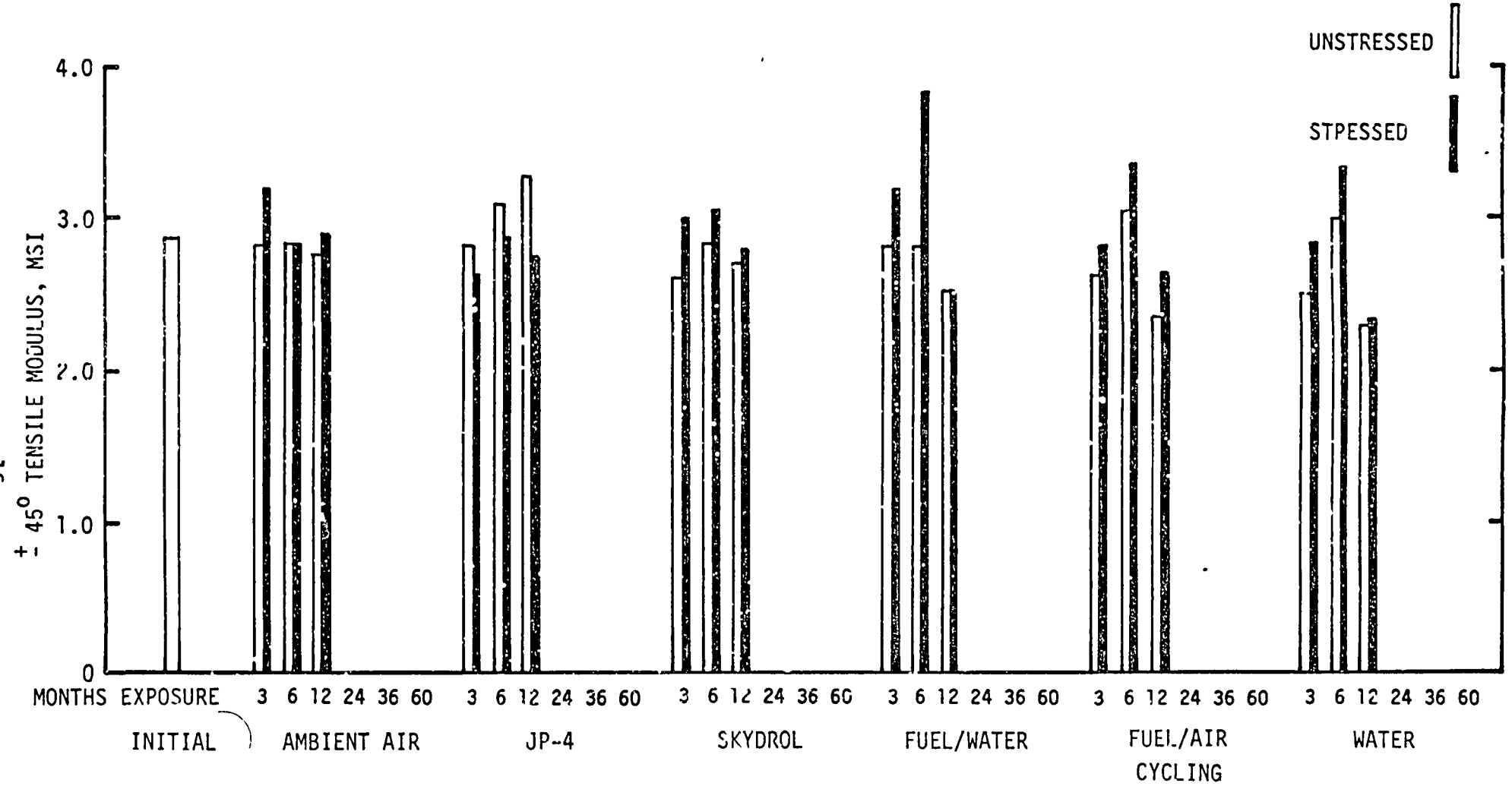
EFFECT OF FUELS AND FLUIDS UPON T300/5209 COMPOSITE

Figure 7



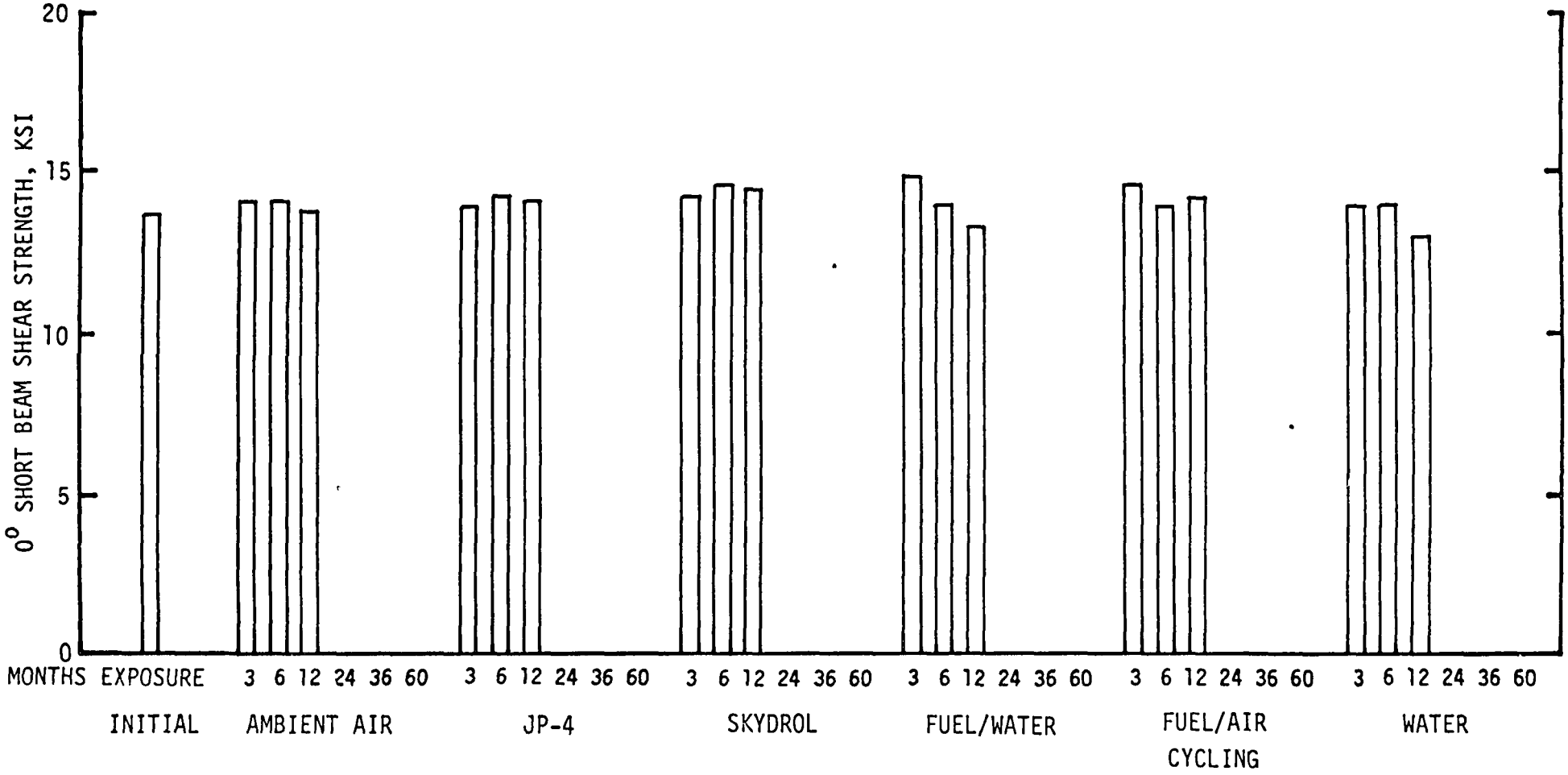
ENVIRONMENTAL EXPOSURE OF T300/5208 ($\pm$ 45° TENSILE STRENGTH, V_F = 64.6)

Figure 8



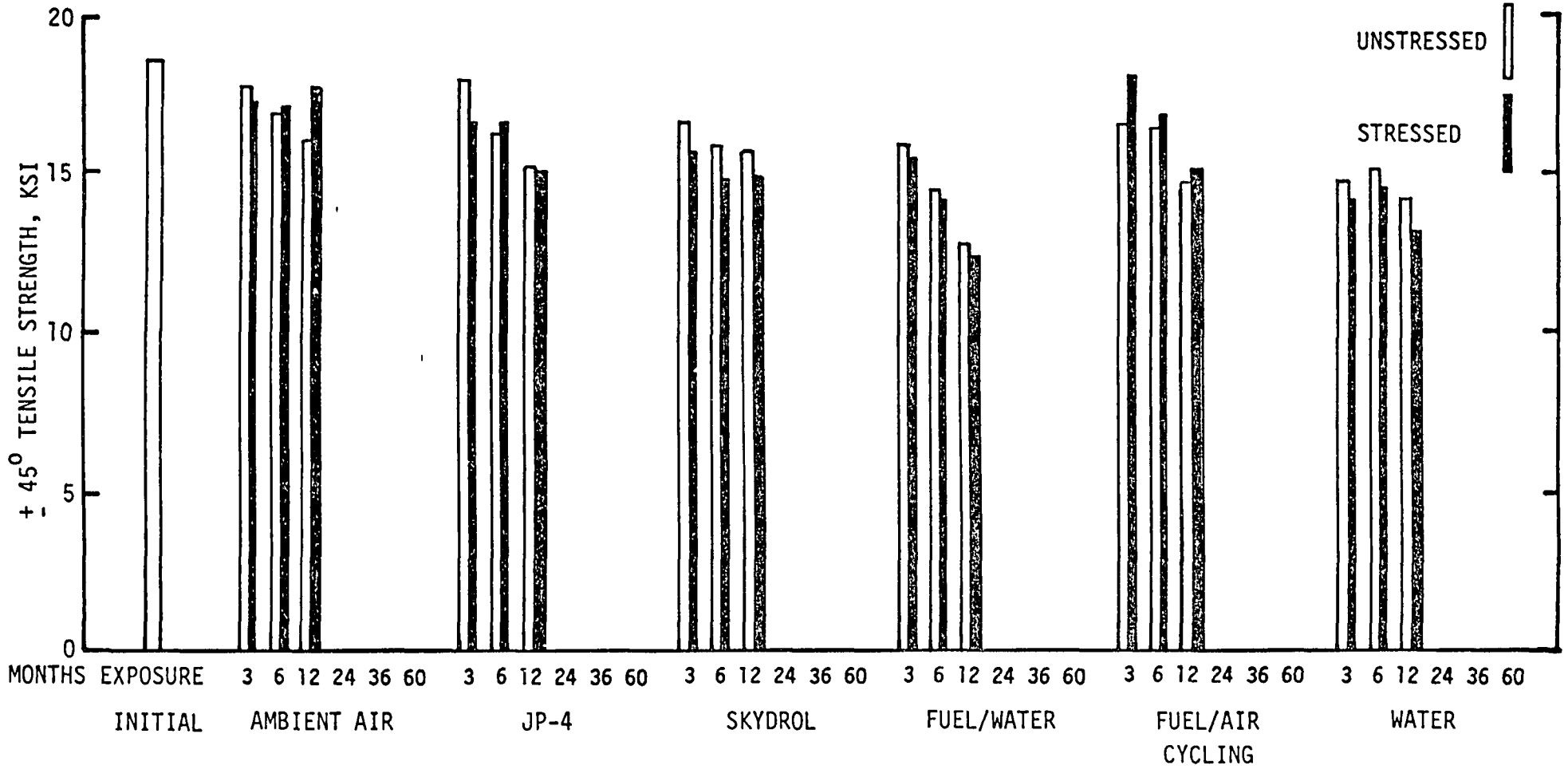
ENVIRONMENTAL EXPOSURE OF T300/5208 ($\pm$ 45° TENSILE MODULUS, V_F = 64.6)

Figure 9



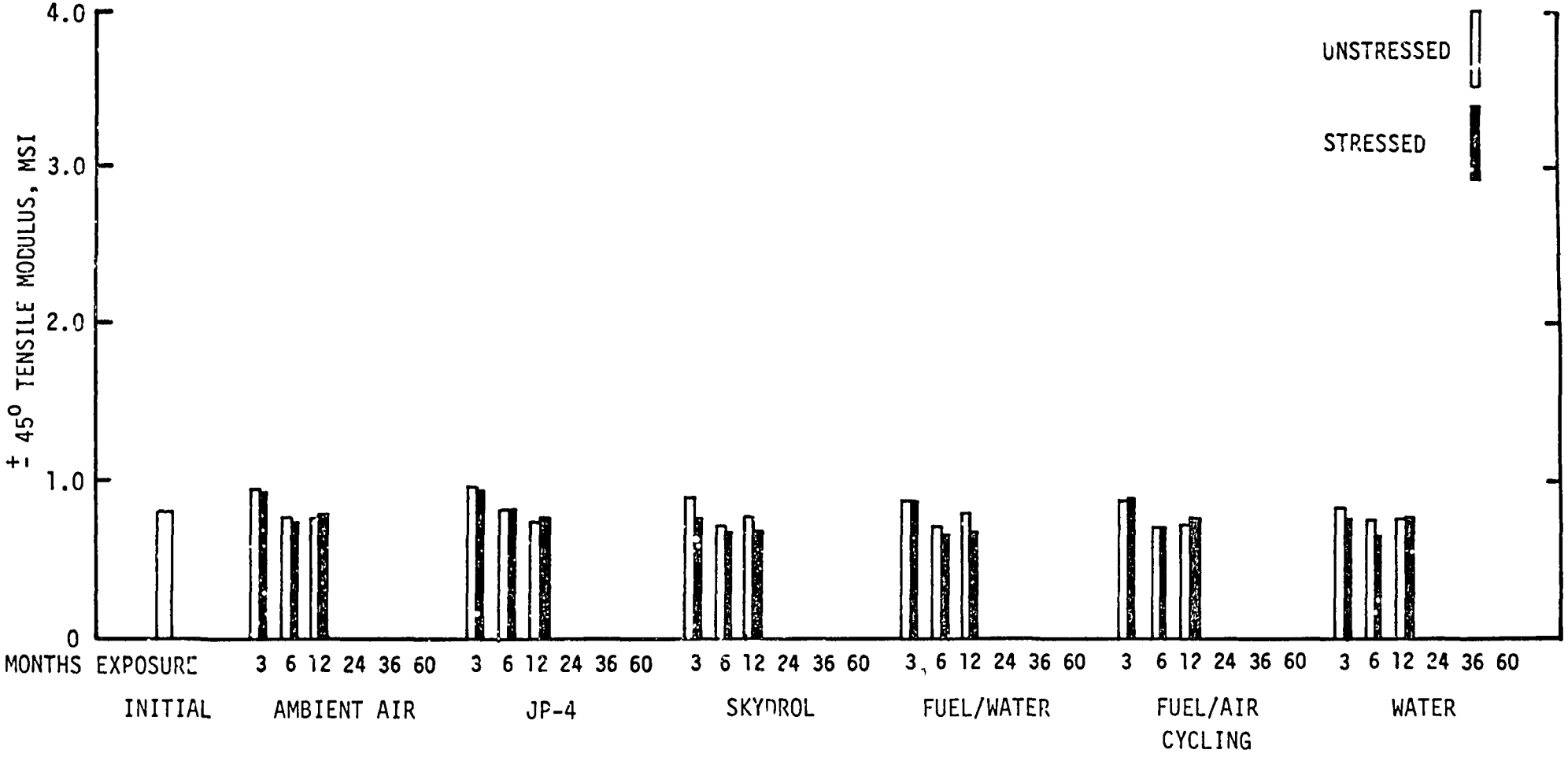
ENVIRONMENTAL EXPOSURE OF T300/5208 (0^{o} SHORT BEAM SHEAR, V_F + 69.8%)

Figure 10



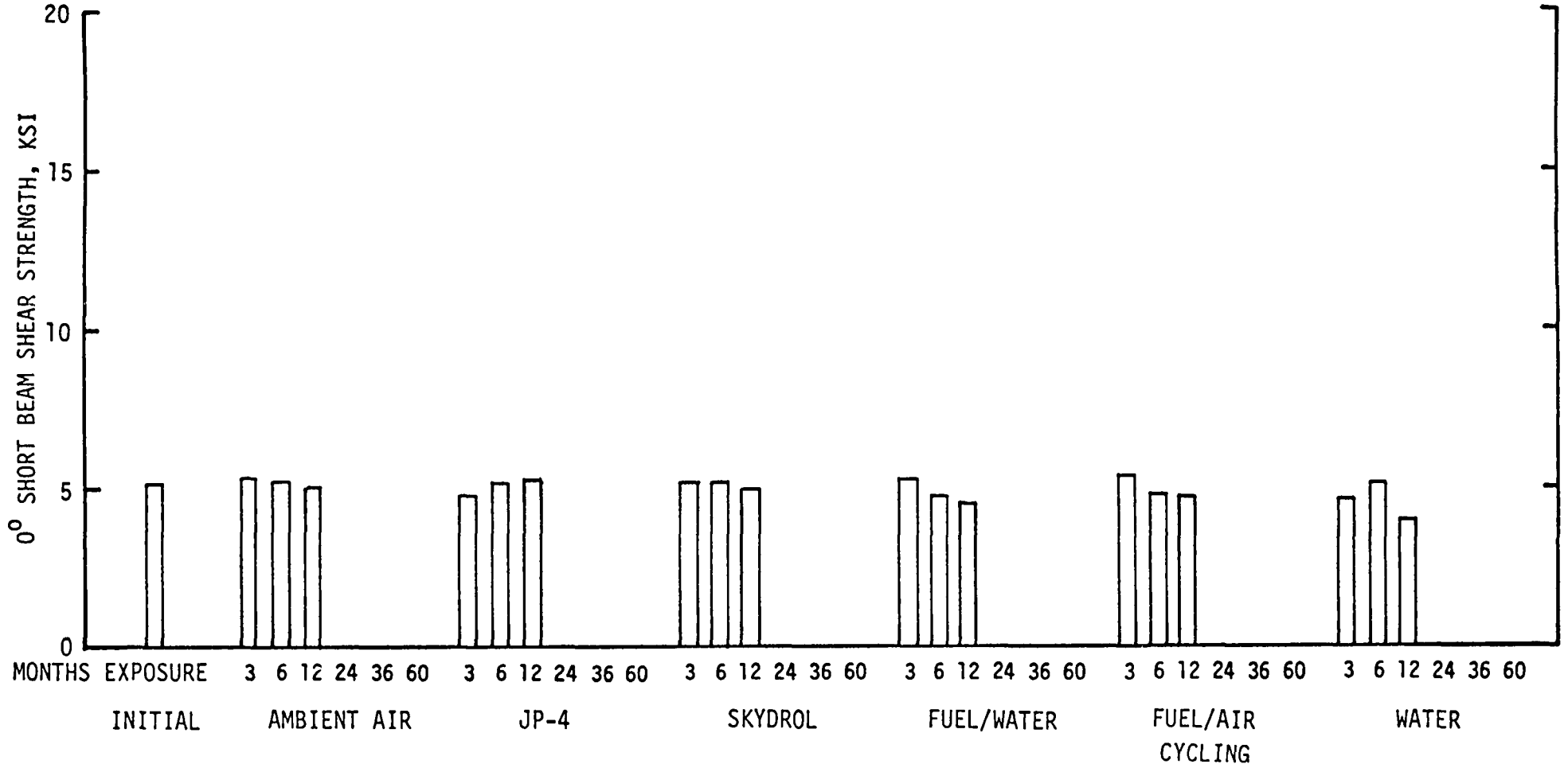
ENVIRONMENTAL EXPOSURE OF WOVEN KEVLAR (281)/5209 ($\pm$ 45° TENSILE STRENGTH, V_F = 64.4%)

Figure 11



ENVIRONMENTAL EXPOSURE OF WOVEN KEVLAR 49 (281)/5209 ($\pm$ 45° TENSILE MODULUS, V_F = 64.4%)

Figure 12



ENVIRONMENTAL EXPOSURE OF WOVEN KEVLAR (281)/5209 (0°SHORT BEAM SHEAR, V_F = 67.0%)

Figure 13

TABLE II

ENVIRONMENTAL EXPOSURE TEST RESULTS - KEVLAR 49 FIBERS

Property	Initial	Water Immersion		
		3 months	6 months	12 months
Tensile strength, ksi	497	352	462	459
	226	353	481	340
	277	390	333	459
	315	415	388	252
	484	359	409	334
	428	296	481	497
	428	---	291	459
	478	340	693	510
	534	334	274	715
	390	403	471	208
Average	406	358	428 (400)*	383
Tensile modulus, msi	12.5	15.4	22.2	18.1
	13.1	14.2	14.9	19.0
	15.6	14.6	15.1	16.1
	14.0	13.1	14.8	15.4
	13.8	14.6	14.3	16.1
	15.2	17.1	14.5	15.8
	16.6	--	14.5	16.0
	15.8	15.2	27.2	14.8
	14.9	13.3	11.7	17.2
	15.4	14.8	13.9	13.4
Average	14.7	14.7	16.3 (15.1)*	16.2

*Calculated without highest value -- 693 ksi strength and 27.2 msi modulus.