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FLIGHT SERVICE EVALUATION OF COMPOSITE HELICOPTER COMPONENTS

FIRST ANNUAL REPORT
MARCH 1981 THROUGH APRIL 1982

Melvin J. Rich and David W. Lowry

Prepared under Contract No. NAS1-16542

SIKORSKY AIRCRAFT
DIVISION OF UNITED TECHNOLOGIES CORPORATION
STRATFORD, CONN.

June 1982

for

NASA
National
Aeronautics and
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FOREWORD

This report was prepared by Sikorsky Aircraft, Division of United Technologies Corporation, under NASA Contract NAS1-16542 and covers the work performed during the period of March 1981 through April 1982. This program was jointly funded by the Materials Division of NASA-Langley Research Center and Structures Laboratory, U.S. Army Research and Technology Laboratory. The contract is monitored by Mr. Donald Baker of the Materials Processing and Applications Branch.

The authors wish to acknowledge the contributions of the following Sikorsky personnel: R. Gallagher, component testing; G. Schneider, environmental analysis; M. Ezzo, D. Narain, material coupon evaluation and M. Rogers, graphical presentations.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (cont'd)

LIST OF SYMBOLS

DLL	Design limit load
EF	Environmental factor, strength ratio to RTD values
M	Moment, units defined in report
ΔM	Moisture absorbed weight, percent of dry weight
ΔM_s	Saturation absorbed weight for a given RH, percent of dry weight
$\Delta M_{s/100}$	Saturation absorbed weight at 100 percent RH, percent of dry weight
N	Cycles
R	Fatigue ratio, minimum to maximum stress in cycle
RH	Relative humidity, percent
$(RH)_A$	Ambient RH, at ambient dry bulb temperature and specific humdity and local (surface temperature, percent
$(RH)_e$	Effective RH, at ambient specific humidity and local (surface) temperature, percent
RTD	Room temperature dry
RTW	Room temperature wet
ETD	Elevated temperature dry
ETW	Elevated temperature wet
α, γ	Empirical contents for fatigue shape curve
ΔT	Temperature rise over ambient

FLIGHT SERVICE EVALUATION OF COMPOSITE HELICOPTER COMPONENTS

by
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SUMMARY

This first interim report presents the technical background for including environmental effects in the design of helicopter composite structures, and test results after approximately two year field exposure of components and panels. Comparison of results from field exposed components and panels with laboratory accelerated environmentaly conditioned coupons is presented.

Two Sikorsky S-76 helicopter structural components were returned from commercial in-service use in the Gulf Coast region (Louisiana). The tail rotor paddle had 29 months of service and 2390 hours flight time. The stabilizer had 17 months of service and 1600 hours flight time.

The graphite/epoxy tail rotor spar (obtained from the paddle) was fatigue tested and the results show a 94 percent strength retention compared with the orginal room temperature dry certification tests. This component strength retention closely agrees with that obtained from coupons for the same measured moisture content.

The stabilizer was proofload tested and the deflection measurement was the same as for the initial production stabilizer. The stabilizer, a combination of graphite/epoxy and Kevlar/epoxy was statically tested at 160°F. The test conditions were the same as for the initial certification. The stabilizer resisted up to 220 percent design limit (DLL) load and then the load resistance dropped off to 150% DLL. No fracture could be obtained within the deflection limitations of the test apparatus. Load drop off was attributed to an internal bonding delamination. It is not known, at this time, whether the strength reduction, from the certification capability of 268 percent DLL is an environmental effect or the variation between specimens. However, the tests did demonstrate that the structure is redundant and the alternate load path can retain the required 150 percent DLL. Future tests in this program will establish the effect of service time.

Graphite/epoxy and Kevlar/epoxy (painted for UV protection) panels are being exposed to the outdoor environment in Stratford, Connecticut and West Palm Beach (WPB), Florida. These panels will

be exposed to the environment for the duration of this program. Each year some panels will be brought back to measure their moisture content and test for strength. For this reporting period, the two year panels were returned and evaluated.

The measured moisture was found to be less than would be predicted using ambient relative humidity (RH) alone. This confirms the affect of solar radiation to reduce the effective RH, at least for the two year period of exposure. The effect of the environment on strength of graphite/epoxy and Kevlar/epoxy varied. The fatigue strength of graphite/epoxy is almost the same as laboratory conditioned coupons. The static interlaminar shear strength for graphite/epoxy was higher. The static flex strength for graphite/epoxy was lower. All test results are compared with the laboratory conditioned coupon tests.

The activities for the next reporting period will include returning three more tail rotor paddles from the Gulf Coast in-service use and panels from Stratford and WPB. One tail rotor paddle will be fatigue tested and the other two will be machined for moisture evaluation and coupon static/fatigue strength tests. It is anticipated the paddles, returned in 1982, will have over three years of service use.

The Stratford and WPB panels will have over three years exposure and the moisture and strength tests will be reported.

Use of commercial product or names of manufacturers in this report does not constitute official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration.

SECTION 1.0 INTRODUCTION AND TECHNICAL BACKGROUND

1.1 GENERAL

There is a continuing effort to increase the structural efficiency of helicopter structures. The use of high strength and modulus filament composites has provided significant weight reductions for the Sikorsky S-76 commercial helicopter. Figure 1 illustrates the use of advanced composites and the extent of the applications. However, there is a need to assess the in-service performance of composite structural components and evaluate the criteria used for design.

The objective of this program is to derive procedures for establishing in-service environmental factors for both design and component test verification.

The tasks for this program are: (1) determine the strength of composite structural components after in-service use, (2) compare such results with initial certification tests (3) evaluate the effects of component moisture content, and (4) compare coupon test results for real time and accelerated environmental conditioning.

The schedule for this program is shown in Table I. The components selected for in-service evaluation are the tail rotor spar and the horizontal stabilizer. The tail rotor spar is an all graphite/epoxy structure (AS-1/6350 Ciba-Geigy System) designed by cyclic loads. The horizontal stabilizer is constructed mainly of Kevlar/epoxy (285/5143 DuPont American Cyanamid System) with graphite/epoxy (AS-1/6350) beam cap reinforcements. The stabilizer is designed by static loads but will also be cyclicly tested under this program to ascertain in-service environmental effects on fatigue strength.

Further descriptions of the S-76 test components are presented in Figure 2 (Tail Rotor Spar) and Figure 3 (Stabilizer).

1.2. ENVIRONMENTAL EFFECTS

It is generally accepted that the mechanical properties of composite materials are effected by environmental conditions, i.e., absorbed moisture and elevated temperatures. However, as will be discussed later, there is a wide variation in the assessments.

From a survey (References 1, 2) the amount of moisture absorbed is a non-linear function of the relative humidity (RH) such as shown in Figure 4. However, the noted non-linearity is disputed in other surveys (Reference 3). The absorbed moisture is reported (Reference 1,2) as being a function of both temperature and RH. As illustrated in Figure 5, the effect of temperature is to increase the amount of moisture absorbed. Sikorsky data appears to be in partial agreement with the Reference (1,2) trend. However, it is noted that Reference (4) reports shows no temperature effect, at least up to 160°F. Thus, there is some doubt on affects of accelerated conditions which may only be resolved by real time ambient exposure results.

In reviewing moisture absorption data there also appear to be differences in results reported for the same resin system. Differences may well be due to fiber volume fraction, processing and test conditions. Sikorsky Aircraft conducted a group of moisture absorption tests at near 100% RH and at 70% RH. The results, shown in Table II, are used to determine the shape curve of saturation moisture level with RH. Using the data of Table II an evaluation of reported results can at least be used to assess the expected differences in moisture absorption for given field conditions of the various composite materials.

To evaluate the environmental effects on the composite materials, static mechanical properties were derived at room temperature dry (RTD), room temperature wet (RTW), elevated temperature dry (ETD), and elevated temperature wet (ETW). Fatigue tests were conducted at RTD and RTW. All coupon test results were normalized to a thickness representative of the specification fiber areal density for fiber dominated properties. No thickness correction was used for matrix dominated properties. Moisture contents were measured for all conditioned specimens. All conditioning was conducted at 87% RH and 88°C (190°F). The accelerated conditioning was accepted as a procedure to expedite the development of design allowables for the S-76 program.

The environmental effects on strength properties for AS-1/6350 graphite/epoxy tape and style 285/5143 Kevlar/epoxy fabric are presented in Reference (5). The specific components to be evaluated in this program involve Kevlar/epoxy for stabilizer static strength and Graphite/epoxy (0 degree orientation) interlaminar shear for the tail rotor fatigue strength.

The ±45° inplane static shear strength for dry Kevlar/epoxy was lower than the 'wet' strength. This was attributed to some fiber swelling that improves the 0/90 degree orientation compression strength. The environmental factors for wet and dry specimens as a function of temperature are presented in Figure 6.

The interlaminar shear fatigue strength for AS-1/6350 Graphite/epoxy was found to be a linear function of the absorbed moisture level. The environmental factor as a function of moisture level is presented in Figure 7. Other property environmental factors are presented in Figure 8.

The environmental factors for other properties for Kevlar and graphite epoxy (Reference 5) are summarized in Tables III and IV, respectively, at a specified design moisture level and temperature. The design criteria for moisture level is based on an effective relative humidity from a survey of world wide conditions, which are discussed in Section 3, Design Criteria.

The environmental factors listed in Tables III and IV are the ratios of the mean strengths at specified conditions to the room temperature 'dry' mean strength. The 'dry' condition, at time of coupon testing was .2% and .7% moisture level for thin coupons of Graphite and Kevlar epoxies, respectively. Accelerated conditions of generally about 88°C (190°F) was utilized. The values stated were determined experimentally for all properties except for the transverse direction (90°) of graphite/epoxy. The latter values were established by ratios to other matrix dominated properties.

It was found that Kevlar ±45 degree inplane shear could not be evaluated directly from either exposed panels or coupons cut from the stabilizer. Therefore, for the trend of environmental effects alternate tests were used; short beam shear (SBS) tests for the component and tension tests for the panels. The reduction in strength as a function of moisture content (environmental factor), for the properties being evaluated in this program, are presented in Figure 8.

1.3. DESIGN CRITERIA

The general static criteria are an elevated temperature of 71°C (160°F) with a saturation moisture level corresponding to a 68% RH. The elevated temperature criteria is to account for runway storage and subsequent cool down in flight.

The fatigue design criteria are room temperature wet (RTW) with a similar moisture condition previously stated. The tail rotor spar is designed for the large number of cyclic loadings which would be at the inflight lower temperatures. Conservatively, no allowance is made for the time to reach the design moisture condition.

The design moisture level could be established by a complete analysis using anticipated ambient temperature, relative humidity, solar radiation, wind velocity, and the absorption characteristics of the fiber/resin system (Reference (6)). The environmental analysis (Reference 7) has been reported to result in good correlation of moisture content with measured results. The basis of the environmental analysis is to use the time history of the ambient conditions and essentially correct the ambient relative humidity (RH_a) to an effective RH_e accounting for the surface temperature change ΔT. It should be noted that a small temperature rise (at the surface) appreciably reduces the effective RH that is used in analysis. A schematic of the procedure to determine effective and ambient RH is illustrated in Figure 9.

An alternate environmental procedure, used for the S-76 design criteria, is to use world wide data from humid areas and to project the effective RH directly. In the NASA survey (Reference 7), moisture measurements were taken from panels located in humid areas (San Francisco, San Diego, Honolulu, Hampton, VA. of the United States, and Frankfurt, Germany, Wellington, New Zealand, and Sao Paulo, South America). It was reported that the world wide moisture absorption was very nearly the same at the specified locations for T300/5208 12-ply laminates subject to field environmental conditions. Based on the data of Reference (7) and the associated environmental analysis shown in Figure 10, an effective RH of 68 percent was selected for design. In Table II the moisture parameters are given for the 5208 resin system. From Figure 11 it is projected that a 68% effective RH prevails for the .75 percent moisture level. As shown in Figure 11 the corresponding moisture levels are 2.2% for Kevlar/epoxy 285/5143 and 1.1% for Graphite/epoxy AS-1/6350.

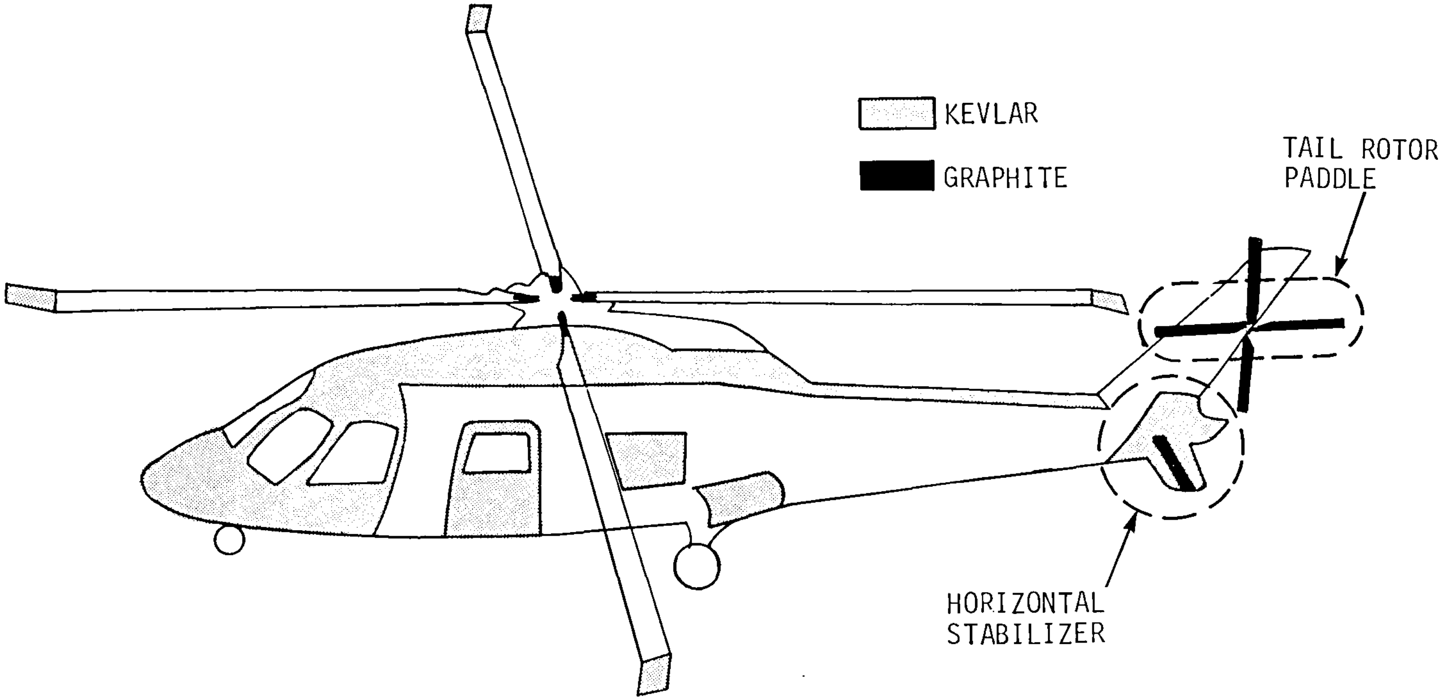


FIGURE 1. APPLICATION OF ADVANCED COMPOSITE MATERIALS FOR SIKORSKY S-76 HELICOPTER.

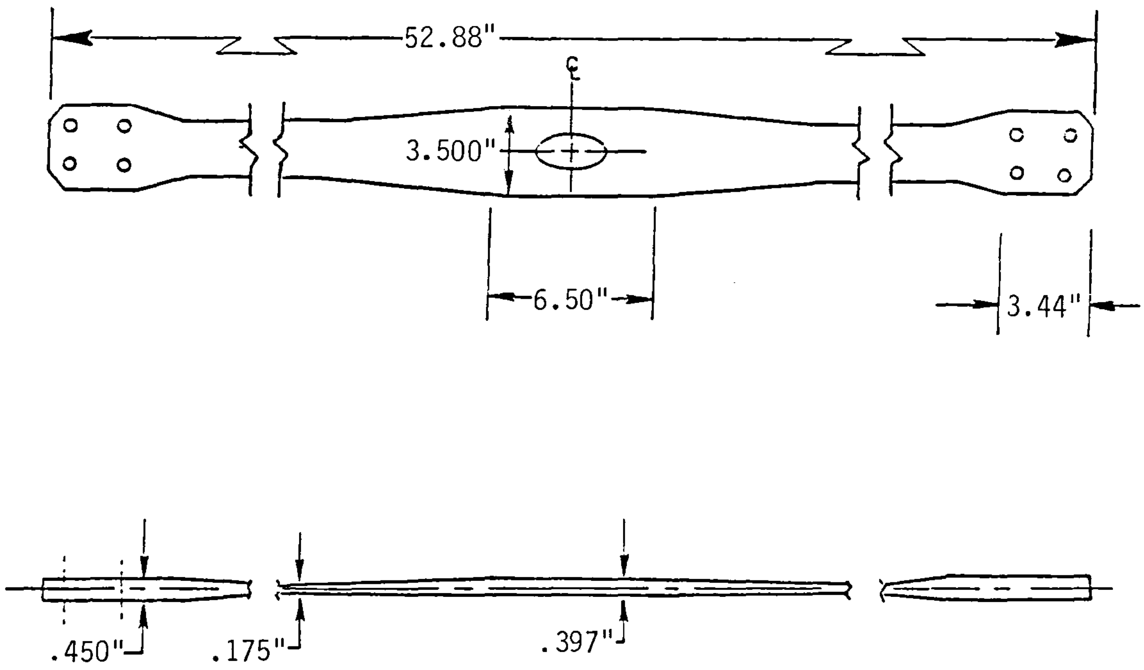
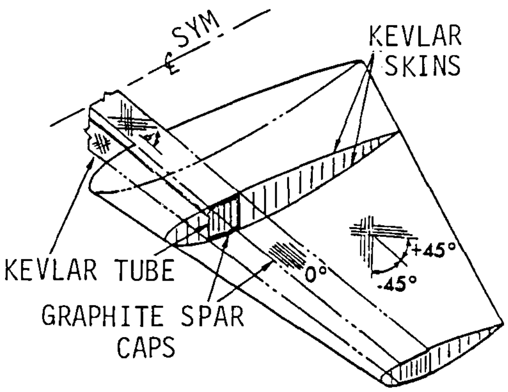


FIGURE 2. SCHEMATIC OF S-76 TAIL ROTOR SPAR.



- KEVLAR-49/EPOXY SKINS $\pm 45^{\circ}$ (NOMEX HONEYCOMB CORE)
- KEVLAR-49/EPOXY TORQUE TUBE $\pm 45^{\circ}$ (ALUMINUM HONEYCOMB CORE)
- GRAPHITE/EPOXY SPAR CAPS, 0°

FIGURE 3. SCHEMATIC OF S-76 HORIZONTAL STABILIZER.

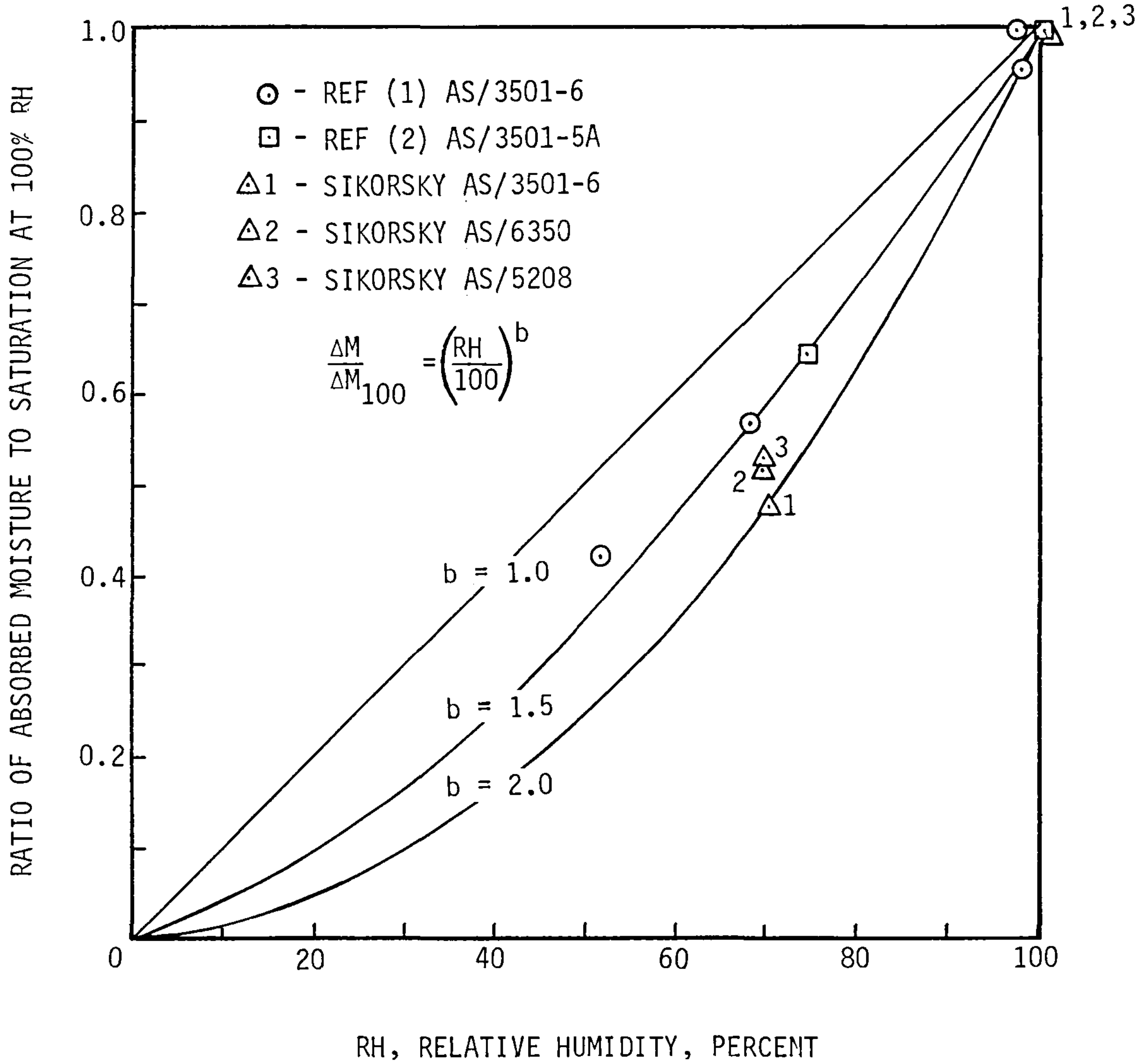


FIGURE 4. RATIO OF ABSORBED MOISTURE WITH RELATIVE HUMIDITY.

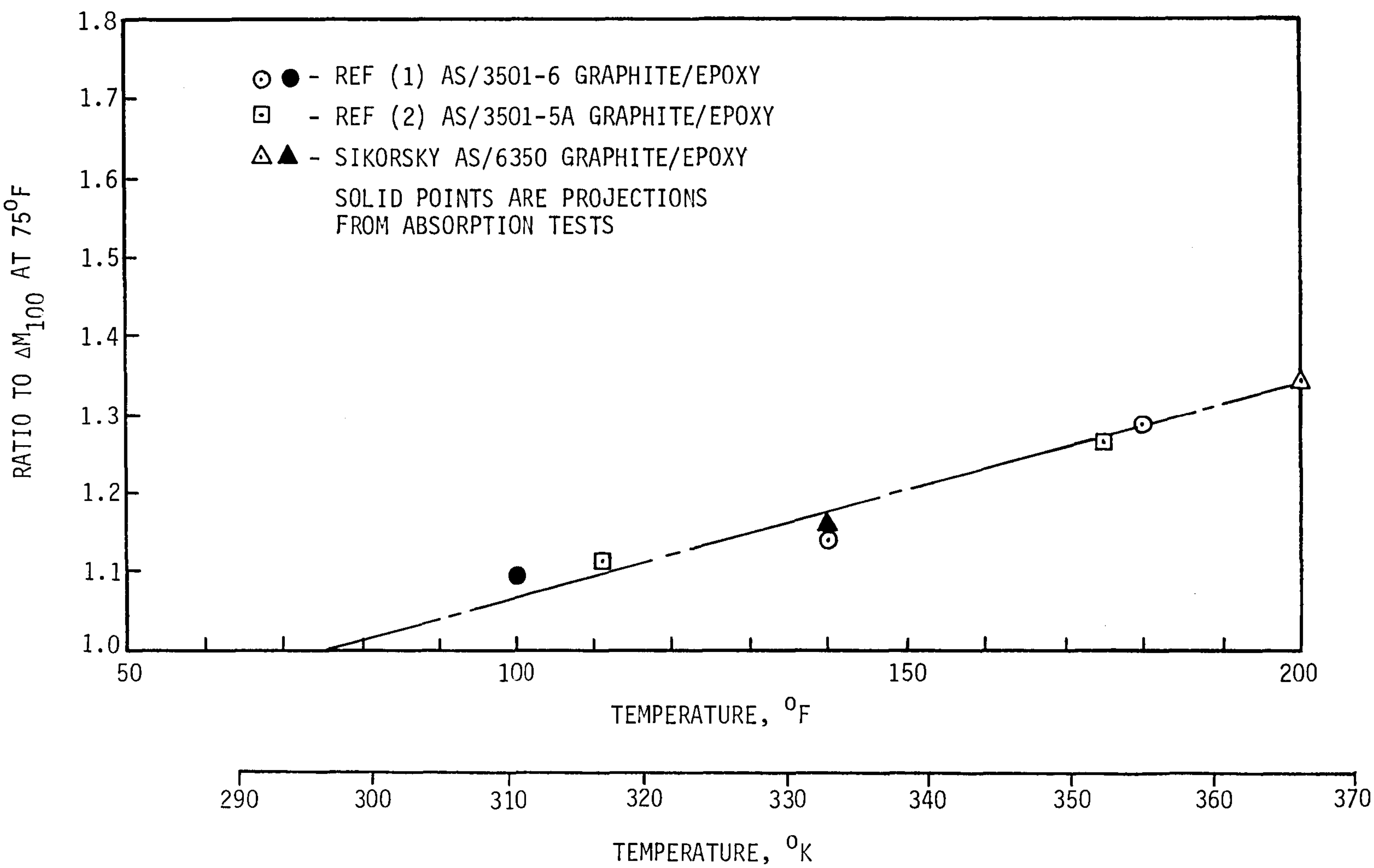


FIGURE 5. ACCELERATED TEMPERATURE CONDITIONING INCREASES SATURATION MOISTURE LEVEL.

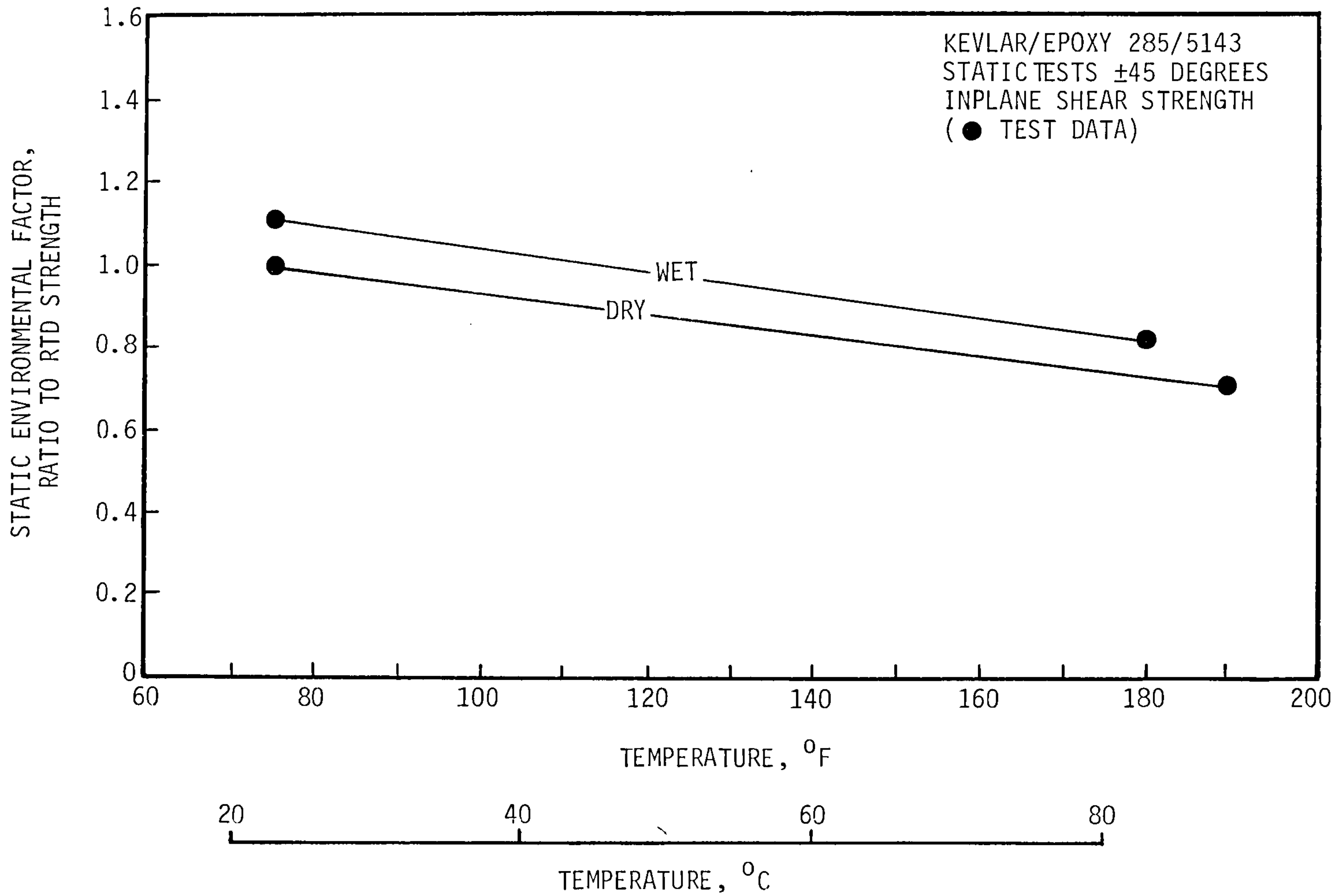


FIGURE 6. ENVIRONMENTAL FACTOR FOR KEVLAR/EPOXY (±45°) INPLANE SHEAR STATIC STRENGTH.

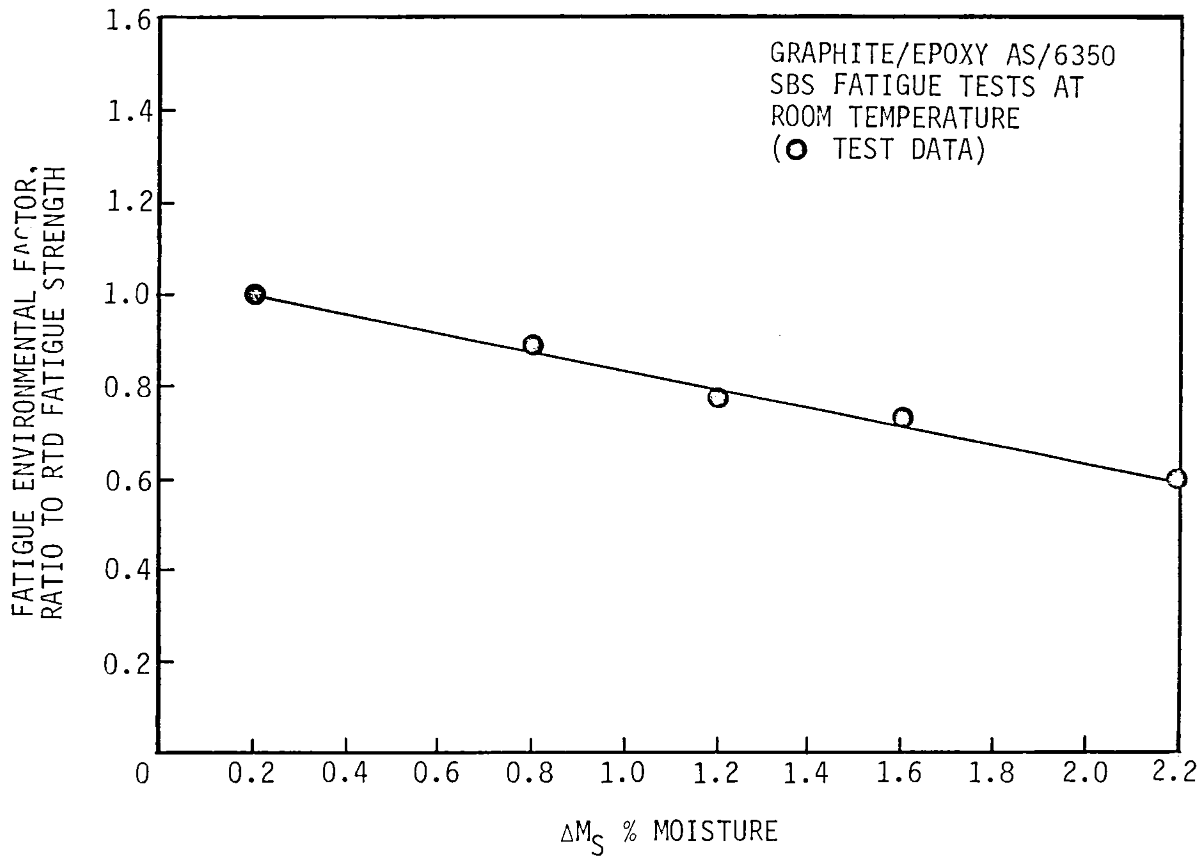


FIGURE 7. ENVIRONMENTAL FACTOR FOR GRAPHITE/EPOXY INTERLAMINAR FATIGUE STRENGTH.

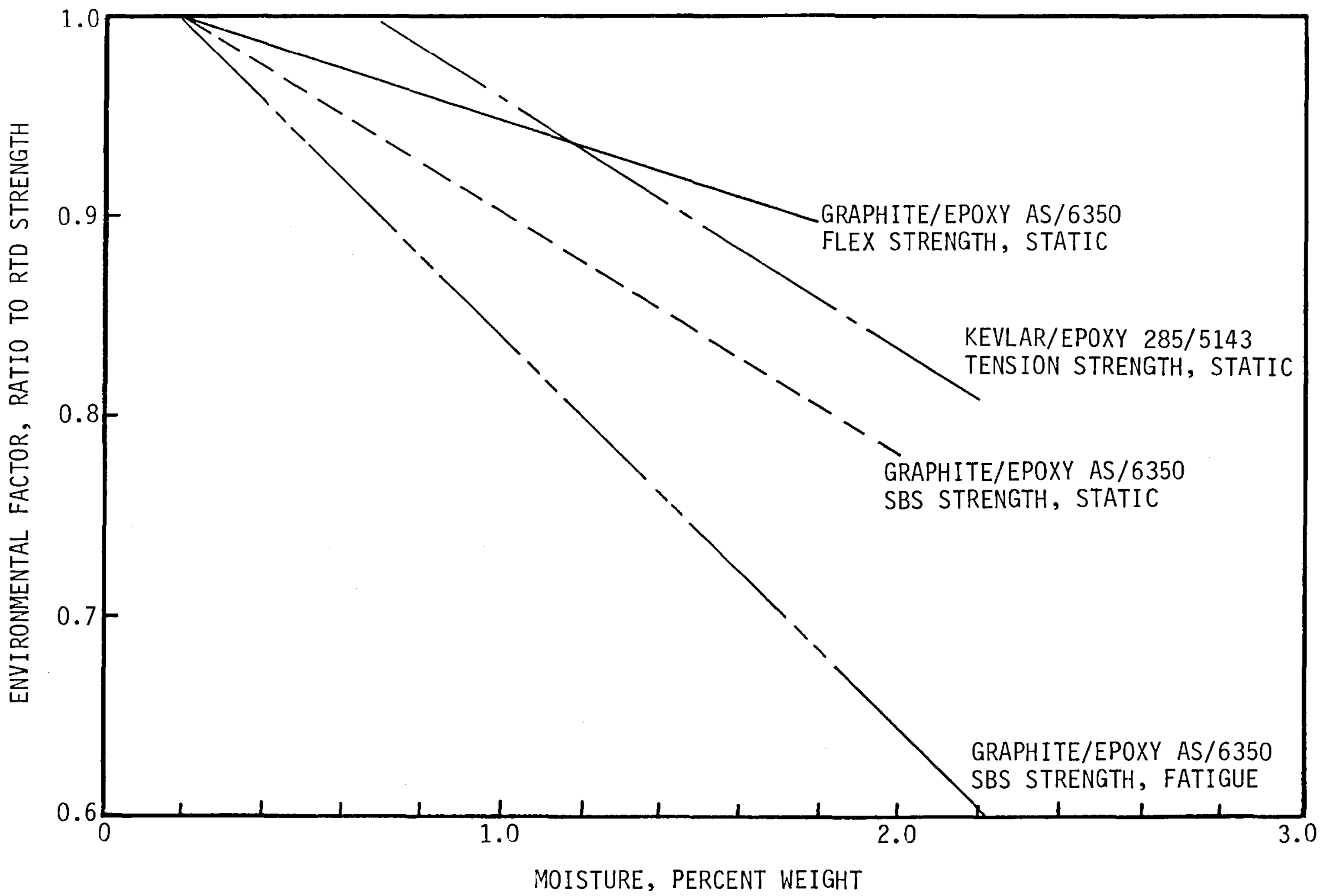
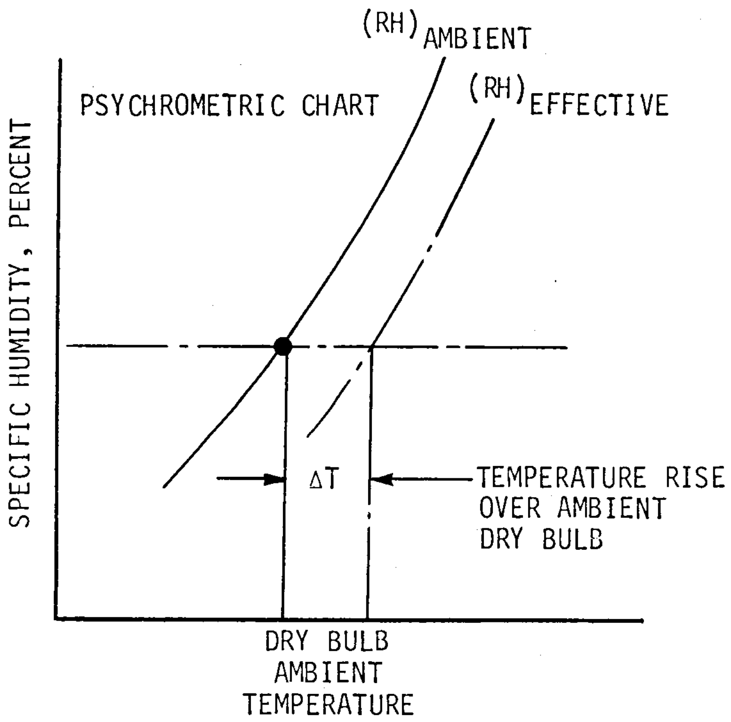


FIGURE 8. LABORATORY ENVIRONMENTAL FACTORS AS A FUNCTION OF MOISTURE CONTENT.



FOR $(RH)_A$ = 80%

T = 26.6°C (80°F)

ΔT	$(RH)_E$
0 (0)	80%
1.1 (2)	72%
2.2 (4)	68%
3.3 (6)	64%
5.5 (10)	57%

FIGURE 9. INCREASING SURFACE TEMPERATURE REDUCES EFFECTIVE RELATIVE HUMIDITY.

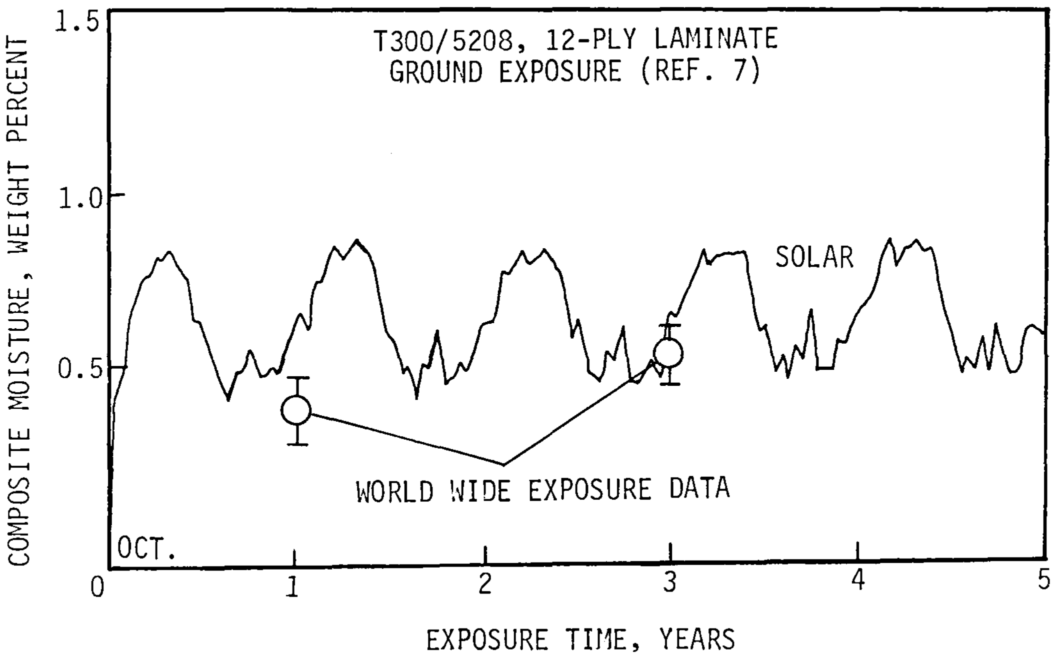


FIGURE 10. COMPARISON OF PREDICTED AND MEASURED MOISTURE CONTENTS.

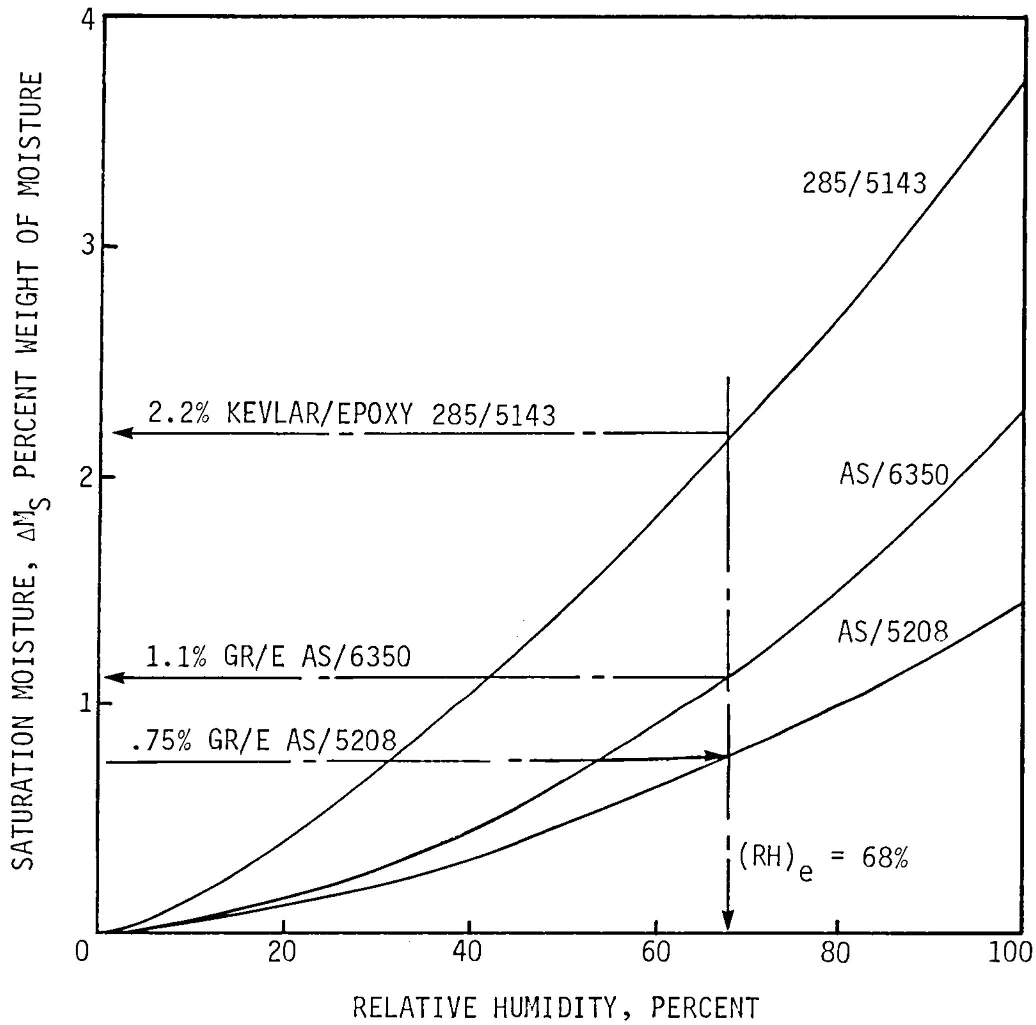


FIGURE 11. DESIGN MOISTURE LEVELS FOR KEVLAR AND GRAPHITE EPOXY.

TABLE I

SCHEDULE FOR EVALUATION OF IN-SERVICE ENVIRONMENTAL EFFECTS ON ADVANCED COMPOSITE STRUCTURES

S-76 HELICOPTER
CONTRACT EFFECTIVE DATE 2-9-81

TASK		CALENDAR YEAR 81	82	83	84	85	86	87	88
1.0	In-Service Component Selection								
1.1	Tracking	X	X	X	X	X	X	X	X
1.2	Selection:								
	- Horizontal Stabilizer	X		X		X		X	
	- Tail Rotor Spar	X	X	X	X	X	X	X	X
2.0	Tests of In-Service Components								
2.1	Horizontal Stabilizers:								
	- Fatigue Tests, Full Scale*			X				X	
	- Static Tests, Full Scale*	X		X		X		X	
2.2	Tail Rotor Spars:								
	- Fatigue Tests, Full Scale*	X	X	X	X		X		X
	- Coupon Static/Fatigue Tests*		XX		X		X		
3.0	Material Evaluation	X	X	X	X	X	X	X	X
4.0	Analysis of Test Results	X	X	X	X	X	X	X	X
5.0	Reports								
5.1	Technical Letter Reports (Quarterly)								
5.2	Oral Presentations		X	X	X	X	X	X	X
5.3	NASA Reports		X	X	X	X	X	X	X

*Actual Times in Each Year Are Approximate

TABLE II. MOISTURE CONTENT AND RELATIVE HUMIDITY*

$$\Delta M_s = \Delta M_{s\,100} \left(\frac{RH\%}{100}\right)^b \quad \text{Percent Moisture Absorption}$$

Material	Fiber Volume Fraction, %	ΔM_s @ 100% RH	b
Graphite/Epoxy			
AS-4/3501-6	62	1.40	1.943
AS-1/6350	60	2.30	1.871
AS-1/5208	62	1.45	1.667
Kevlar/Epoxy			
285/5143	57	3.70	1.395
285/9350	57	5.20	1.637
285/5208	57	4.10	1.444
Glass/Epoxy			
7781/5143	44	1.05	2.378
7781/7350	44	1.75	2.125
Tape/SP-114	50	~1.3	

*Conditioned at 93.3°C (200°F)

TABLE III. SUMMARY OF ENVIRONMENTAL FACTORS FOR KEVLAR/EPOXY 285/5143

Strength Property	Room Temperature Wet[a]		Elevated Temperature Wet[b]	
	0/90	±45	0/90	±45
Static Strength				
Tension	.82	.82	.78	.59
Compression	1.22	.77	.78	.63
Bending	.95	.99	.78	.86
Inplane Shear	.82	1.13	.59	.78 (Dry) .86 (Wet)
Interlaminar Shear	.30	-	.45	-
Fatigue Strength (10^7 cycles)				
Axial (R=0.1)	1.0	.62	-	-
Axial (R=-1.0)	.90	.75	-	-
Inplane Shear (R=0.1)	-	.87	-	-

(a) 2.2% Moisture, 23°C (75°F)
(b) 2.2% Moisture, 71°C (160°F)

TABLE IV. SUMMARY OF ENVIRONMENTAL FACTORS FOR GRAPHITE/EPOXY AS-1/6350

Strength Property	Room Temperature Wet[a]		Elevated Temperature Wet[b]	
	0° (Longitudinal)	90° (Transverse)	0° (Longitudinal)	90° (Transverse)
Static Strength				
Tension	1.0	.78	.99	.72
Compression	.93	.78	.87	.73
Bending	.96	-	.78	-
Inplane Shear	.92	-	.89	-
Interlaminar Shear	.78	-	.73	-
Translaminar Shear	.78	-	.75	-
Fatigue Strength (10^7 cycles)				
Axial (R=0.1)	1.0	-	-	-
Axial (R=-1.0)	.87	-	-	-
Interlaminar Shear (R=0.1)	.82	-	-	-
Translaminar Shear (R=0.1)	.92	-	-	-

(a) At 1.1% Moisture, 23°C (75°F)
(b) At 1.1% Moisture, 71°C (160°F)

SECTION 2.0. IN-SERVICE COMPONENT SELECTION

The selection of components under NASA Contract NAS1-16542 will be from aircraft operating in a humid hot region, generally located in the Gulf Coast Louisiana Region of the United States.

Components are selected from high time helicopters. However, the commercial operator may not keep the same components on the aircraft and calendar and flight hours are specified for the components. Since the stabilizer and tail rotor spars are serialized the operational data are obtained from their individual log cards.

The stabilizer is a unit, i.e., the left and right hand side are not separable. The tail rotor (T.R.) consists of two paddles, which are separable, and each paddle has its own serial number and log card. The T.R. spar has a separate serial number.

The first set of components selected for testing are from a commercial operator (Air Logistics), located in Louisiana:

Component	Total Operating Time	Calendar Time in Field
Stabilizer B-157-00076	1600 Hrs.	17 Months
Tail Rotor Paddle A-137-00034 (Spar 00094)	2390 Hrs.	29 Months

Tables V and VI list the field environmental history for the stabilizer and tail rotor paddle, respectively.

TABLE V

S-76 HELICOPTER HORIZONTAL STABILIZER
S/N B-157-00076 ENVIRONMENTAL HISTORY

DATE	AVERAGE TEMPERATURE		AVERAGE RELATIVE HUMIDITY %	LOCATION
	°C	(°F)		
2/01/80-2/29/80	16.0	(60.9)	76.0	West Palm Beach
3/01/80-3/31/80	21.2	(70.2)	77.3	West Palm Beach
4/01/80-4/30/80	22.1	(71.8	77.1	West Palm Beach
5/01/80-5/31/80	23.7	(74.8)	83.9	Lake Charles
6/01/80-6/30/80	27.1	(80.8)	80.3	Lake Charles
7/01/80-7/31/80	28.2	(82.8)	72.5	Lake Charles
8/01/80-8/31/80	27.4	(81.3)	74.0	Lake Charles
9/01/80-9/30/80	26.3	(79.4)	79.3	Lake Charles
10/01/80-10/30/80	17.9	(64.4)	69.8	Lake Charles
11/01/80-11/30/80	12.6	(54.8)	78.0	Lake Charles
12/01/80-12/31/80	10.7	(51.3)	75.0	Lake Charles
1/01/81-1/31/81	8.2	(46.8)	73.5	Lake Charles
2/01/81-2/28/81	11.1	(52.0)	74.0	Lake Charles
3/01/81-3/31/81	14.9	(58.9)	66.4	Lake Charles
4/01/81-4/30/81	21.4	(70.5)	76.1	Lake Charles
5/01/81-5/31/81	22.5	(72.6)	73.3	Lake Charles
6/01/81-6/30/81	26.8	(80.3)	82.1	Lake Charles
7/01/81-7/31/81	27.2	(81.1)	81.8	Lake Charles
8/01/81-8/31/81	26.9	(80.5)	79.3	Lake Charles

TABLE VI

S-76 HELICOPTER TAIL ROTOR PADDLE
S/N A-137-00034 ENVIRONMENTAL HISTORY

DATE	AVERAGE TEMPERATURE		AVERAGE RELATIVE HUMIDITY %	LOCATION
	°C	(°F)		
12/01/78-12/31/79	20.2	(68.4)	80.1	West Palm Beach
1/01/79-1/31/79	17.0	(62.7)	66.8	West Palm Beach
2/01/79-2/28/79	17.6	(63.7)	79.3	West Palm Beach
3/01/79-3/31/79	15.9	(60.7)	74.5	Lake Charles
4/01/79-4/30/79	20.0	(68.1)	80.5	Lake Charles
5/01/79-5/31/79	22.4	(72.3)	78.6	Lake Charles
6/01/79-6/30/79	26.0	(78.9)	78.4	Lake Charles
7/01/79-7/31/79	26.8	(80.3)	85.4	Lake Charles
8/01/79-8/31/79	26.6	(80.0)	83.8	Lake Charles
9/01/79-9/30/79	23.4	(74.7)	80.3	Lake Charles
10/01/79-10/30/79	20.5	(68.9)	79.0	Lake Charles
11/01/79-11/30/79	12.4	(54.4)	75.4	Lake Charles
12/01/79-12/31/79	10.3	(50.5)	78.1	Lake Charles
1/01/80-1/31/80	11.9	(53.4)	86.4	Lake Charles
2/01/80-2/29/80	10.3	(50.6)	80.5	Lake Charles
3/01/80-3/31/80	15.2	(59.4)	81.4	Lake Charles
4/01/80-4/30/80	18.4	(65.1)	76.5	Lake Charles
5/01/80-5/31/80	23.7	(74.8)	83.9	Lake Charles
6/01/80-6/30/80	27.1	(80.8)	80.3	Lake Charles
7/01/80-7/31/80	28.2	(82.8)	72.5	Lake Charles
8/01/80-8/31/80	27.4	(81.3)	74.0	Lake Charles
9/01/80-9/30/80	26.3	(79.4)	79.3	Lake Charles
10/01/80-10/30/80	17.9	(64.4)	69.8	Lake Charles
11/01/80-11/30/80	12.6	(54.8)	78.0	Lake Charles
12/01/80-12/31/80	10.7	(51.3)	75.0	Lake Charles
1/01/81-1/31/81	8.2	(46.8)	73.5	Lake Charles
2/01/81-2/28/81	11.1	(52.0)	74.0	Lake Charles
3/01/81-3/31/81	14.9	(58.9)	66.4	Lake Charles
4/01/81-4/30/81	21.4	(70.5)	76.1	Lake Charles
5/01/81-5/31/81	22.5	(72.6)	73.3	Lake Charles
6/01/81-6/31/81	26.8	(80.3)	82.1	Lake Charles
7/01/81-7/31/81	27.2	(81.1)	81.8	Lake Charles
8/01/81-8/31/81	26.9	(80.5)	79.3	Lake Charles

3.0. TESTS OF IN-SERVICE COMPONENTS

3.1 Stabilizer

3.1.1 Stabilizer Static Test Methods

Prior to conducting the static strength testing the stabilizer is proof tested with the same procedure as required for production acceptance. A 2400 lb load is applied at Buttline 0. The production acceptance criteria is a corresponding deflection of 3.89mm (.153) ± .25mm (.010).

The stabilizer is tested for an asymmetric load condition. The limit design loading combination consists of drag and lift forces with a torsional moment as illustrated in Figure 12. Since the design condition is asymmetrical the loads specified in Figure 12 are designated L for left side and R for right side of the stabilizer.

The test loads are held in the same proportion as listed in Figure 12 and the combination increased as a percent of limit load. The loads are applied by hydraulic cylinders and dead weight located at buttline 1016mm (40) which are attached to the stabilizer by facility fittings. These fittings are located at a chordwise position such that the required flatwise, edgewise, and torsional loads combination is developed by proper angling of the cylinders. The static test facility is shown in Figure 13. The test strains, at the locations shown in Figure 14, are monitored to enable assessing the test results.

To allow direct comparison with the baseline (type certificate) data, the test is conducted at an ambient temperature of 160°F. The 160°F ambient condition was selected for the baseline stabilizer test to provide a test factor of 1.0 for Kevlar/epoxy (see Section 4.0).

3.1.2 STABILIZER STATIC TEST RESULTS

Stabilizer S/N B-157-00076, the in-service test article, had 17 months calendar time and 1600 hours flight time in the Gulf Coast Region of Louisiana.

A proof test load was applied and the resulting deflection was 3.89mm (.153), the same as recorded in the initial acceptance. The stabilizer was then statically tested for the asymmetrical design condition. The results are summarized in Table VII with a comparison to type certificate data.

Plots of percent limit load as a function of strain are shown in Figure 14. The strain gage location BTE (Bottom Trailing Edge) is at Buttline 4.5.

As shown in Figure 14 the tension strains remain linear up to the maximum applied load (220% DLL). The compression strain remains linear up to 170% DLL and thereafter shows no increase of strain. Upon trying 230% DLL a loud 'snap' was heard and the load dropped to 150% DLL. An attempt was made to increase the load beyond the 150%, however, the structural deflection increased to the limit of the test fixture capability.

External visual inspection of the stabilizer showed a buckle in the leading edge Kevlar® splice plate at B.L. 4.5 on the left side. Upon teardown it was found that there was a loss of shear transfer of the composite material to the metal honeycomb. The structural box is designed to have redundant shear path so that shear loadings can be resisted by the honeycomb or the Kevlar box structure. The indication is that at 220% of DLL the shear transfered to the Kevlar box and eventually buckled the sidewall splice plate. However, the combination of some remaining shear capability in the Kevlar box provided the structural capability for at least 150% limit load with reduced rigidity. A schematic representation of the modes is shown in Figure 15.

3.2 TAIL ROTOR SPAR

3.2.1 FATIGUE TEST METHOD

The tail rotor spar is cyclicly loaded for combined edgewise (inplane) and flatwise bending with a steady centrifugal (axial) loading. The spar is clamped between an aircraft flange and retention plate. A short stub spar is used to take the place normally occupied by another blade spar (perpendicular to the test spar). Figure 16 illustrates the tail rotor combined load fatigue test setup and Figure 17 is a schematic diagram of the methods for load introduction. A photograph of the test facility is shown in Figure 18.

The load magnitudes are as stated in Table VIII. The steady centrifugal loading is kept constant for all tests and represents 110 percent of normal rotor speed. The cyclic loadings, edgewise and flatwise bending and torsional, are in phase and held in the proportions as stated in Table VIII. Absolute test levels are varied for the specific test so that fatigue fractures can be obtained between the range of 10^5 to 5×10^6 cycles. The resultant cyclic moment at strain gage location EB2S is measured and monitored by calibrated strain gages as shown in Figure 19.

The fatigue tests of a spar can produce two test points. The first (designated A) is the first fracture on one side of the spar. The other side (designated B) can continue to be tested until its fracture.

3.2.2 TAIL ROTOR SPAR FATIGUE TESTS

Three tail rotor spars have been returned from in-service environment and fatigue tested. Table IX presents the service time, location and measured moisture content and results of fatigue tests.

The tail rotor spars, as designated in Table IX, were all returned from humid areas. The first two (S/N 00046 and 00064) are from Sikorsky flight test helicopters and the third (S/N 00094) is from a commercial operation. The fatigue test results are plotted in Figure 20. The data shows a small but consistent reduction in fatigue strength for the 2 to 2½ years in-service exposed blades when compared to the mean load-cycle curve of the blades tested for type certification (room temperature dry).

The fatigue shape curve was originally derived from short beam shear small coupon tests. The mode of fracture of the tail rotor spars appears to start from an interlaminar shear delamination and the curve shape of the components fits the coupon tests for the following formula:

$$\frac{M(N)}{M(10^7)} = 1 + \frac{\beta}{N^\gamma}$$

where M(N) is the cyclic moment for N cycles
$M(10^7)$ is the cyclic moment for 10^7 cycles
N is in 10^6 cycles
β, γ are empirical constraints

For the tail rotor blades (and SBS coupons) $\beta = \gamma = .138$.

The edgewise cyclic moment is the dominent factor in the fatigue of the tail rotor spar. This moment is designated as (EB2S) in Figure 20 and is the variable in the moment cycle curve. The other loads, flatwise, torsion induced by cyclic pitch change and the steady centrifugal are also applied during the fatigue tests.

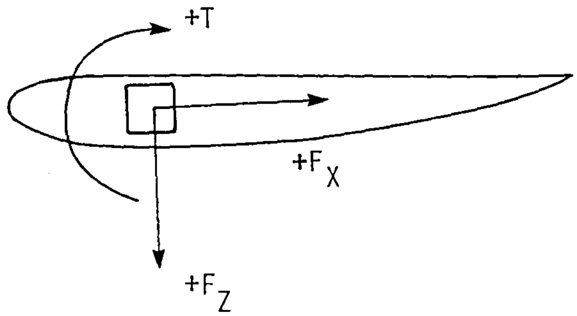
The EB2S strain gage locations were selected since previous testing resulted in fractures at that section (station 5, Figure 19).

The evaluation of the tail rotor spar fatigue tests will include the measured moisture contents and reduction from the mean load-cycle curve from the original RTD type certification tests (projected to 10^7 cycles). Section 5 of this report will compare the in-service component tests with prediction for coupon tests.

TABLE VII. SUMMARY OF STABILIZER STATIC TEST RESULTS

Test Stabilizer	In-Service Calendar Time Months	Flight Hours	Service Region	Proof Load Deflection mm (in)	Proof Load Deflection After Service	Maximum Asymmetrical Loading, % Design Limit *	Remarks
Type Certificate stabilizer	0	0	N/A	3.89 ± .25 (.153 ±.010) (general requirement)	N/A	268	No fracture, limited by deflection in test fixture.
In-Service Stabilizer S/N B-157-00076	17	1600	Gulf Coast Region, Louisiana	3.89 (.153)	3.89 (.153)	220	No fracture, load drop off to 150% DLL and further increase limited by deflection in test fixture.

*At 71°C (160°F) ambient test condition



F_{XL}	F_{ZL}	T_L	F_{XR}	F_{ZR}	T_R
511N (115)	4257N (957)	107N-m (950)	-476N (-107)	196N (44)	106N-m (935)

L,R - LEFT OR RIGHT SIDE LOADS, RESPECTIVELY

FIGURE 12. S-76 STABILIZER LIMIT DESIGN LOADING.

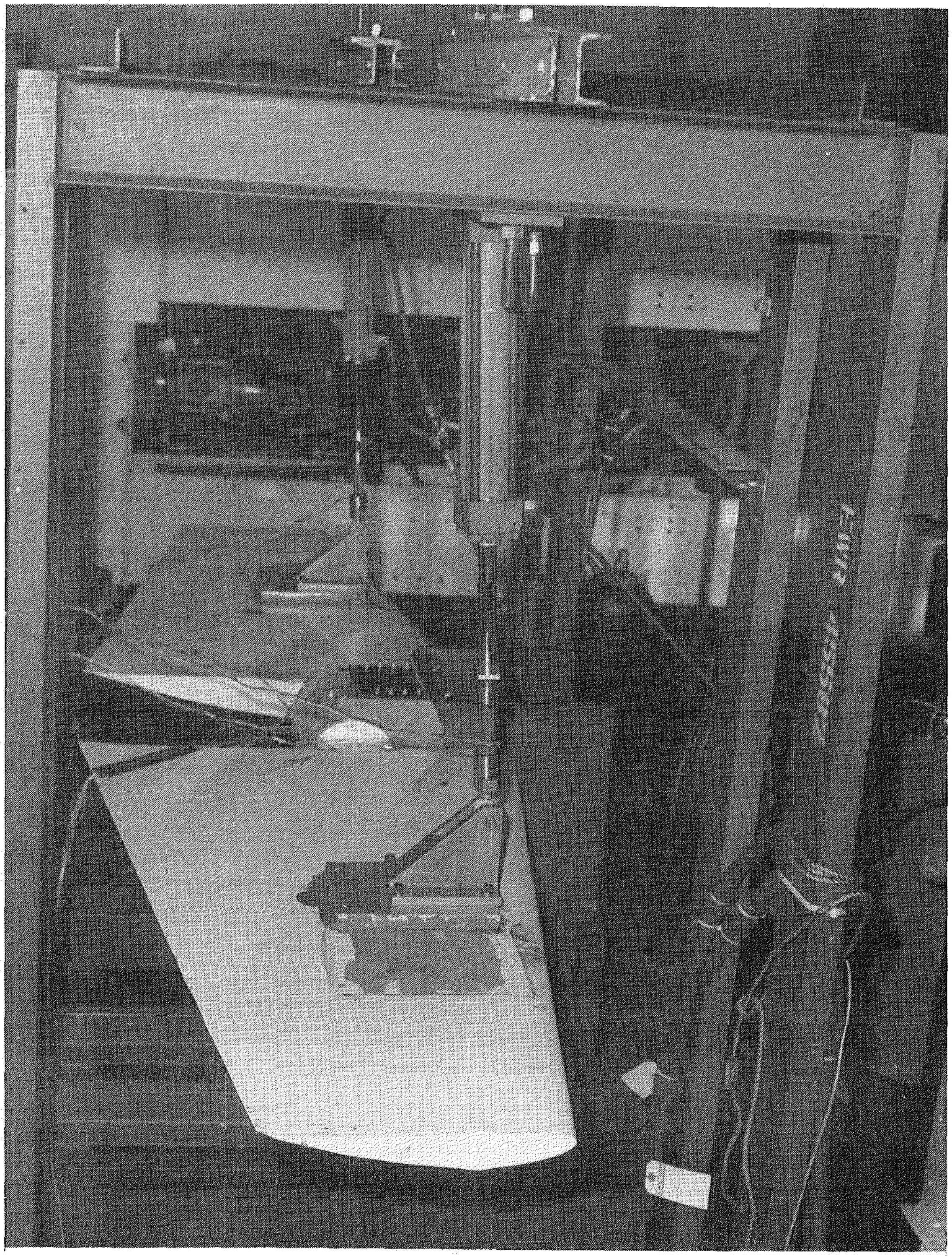
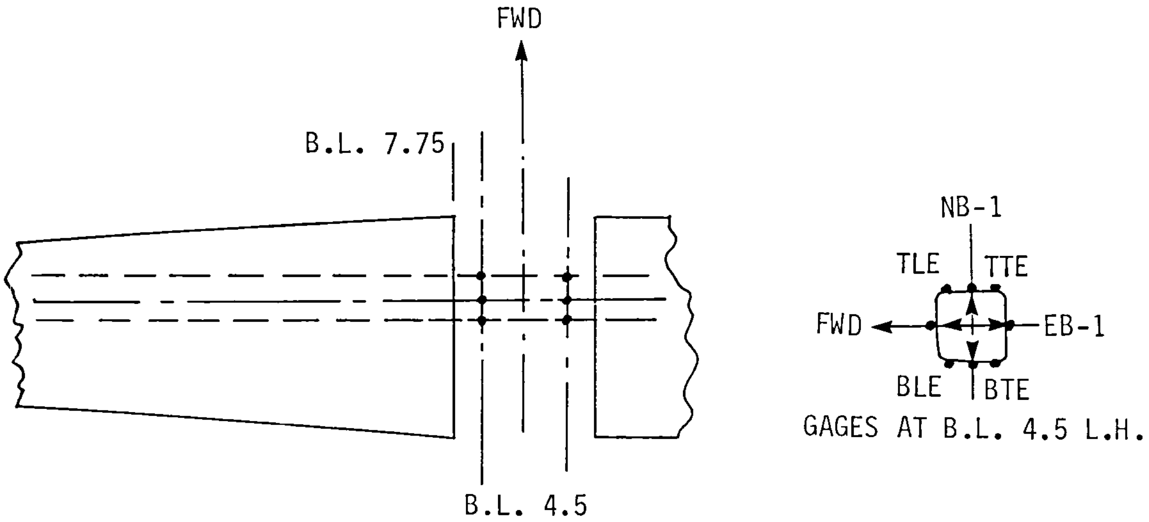


FIGURE 13. S-76 STABILIZER STATIC TEST FACILITY.



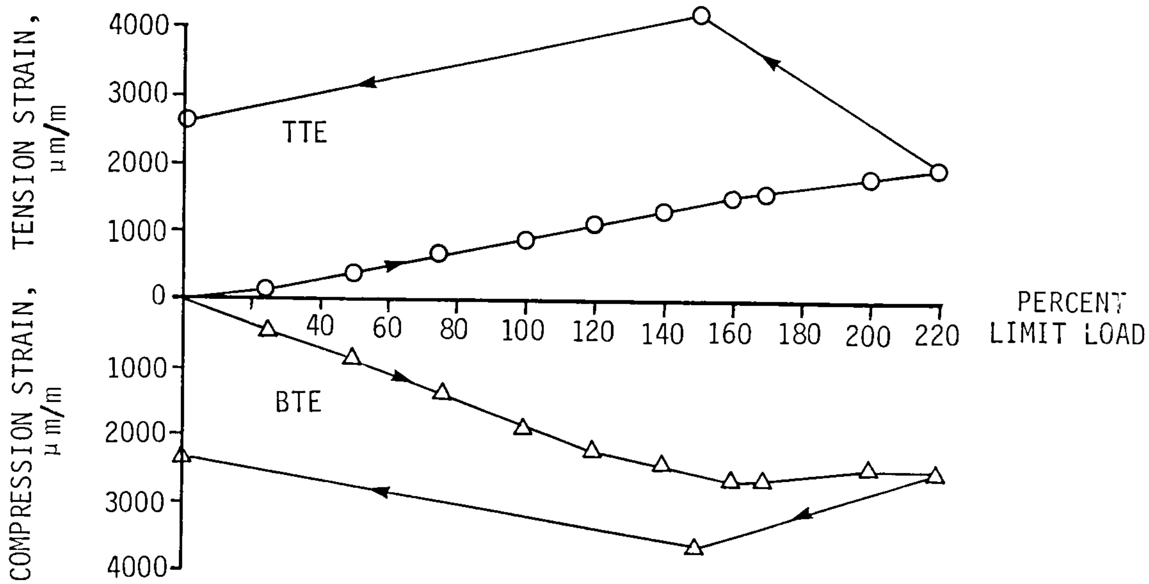
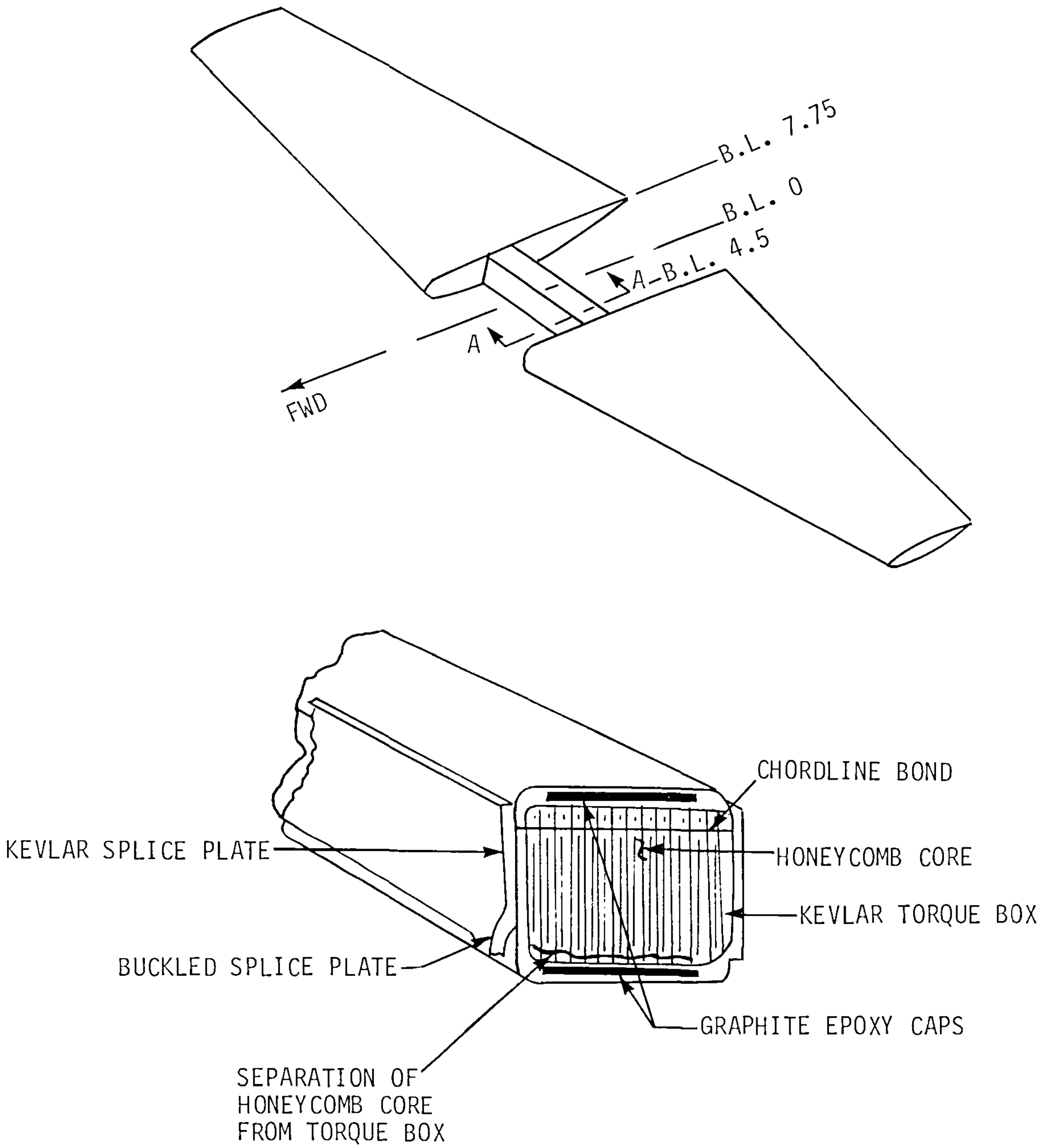


FIGURE 14. STRAIN AS A FUNCTION OF PERCENT LIMIT LOAD ON STABILIZER BOX SPAR, B.L. 4.5 (LEFT).



STABILIZER TORQUE BOX AT SECTION A-A

FIGURE 15. SCHEMATIC REPRESENTATION OF STABILIZER STATIC FRACTURE MODES.

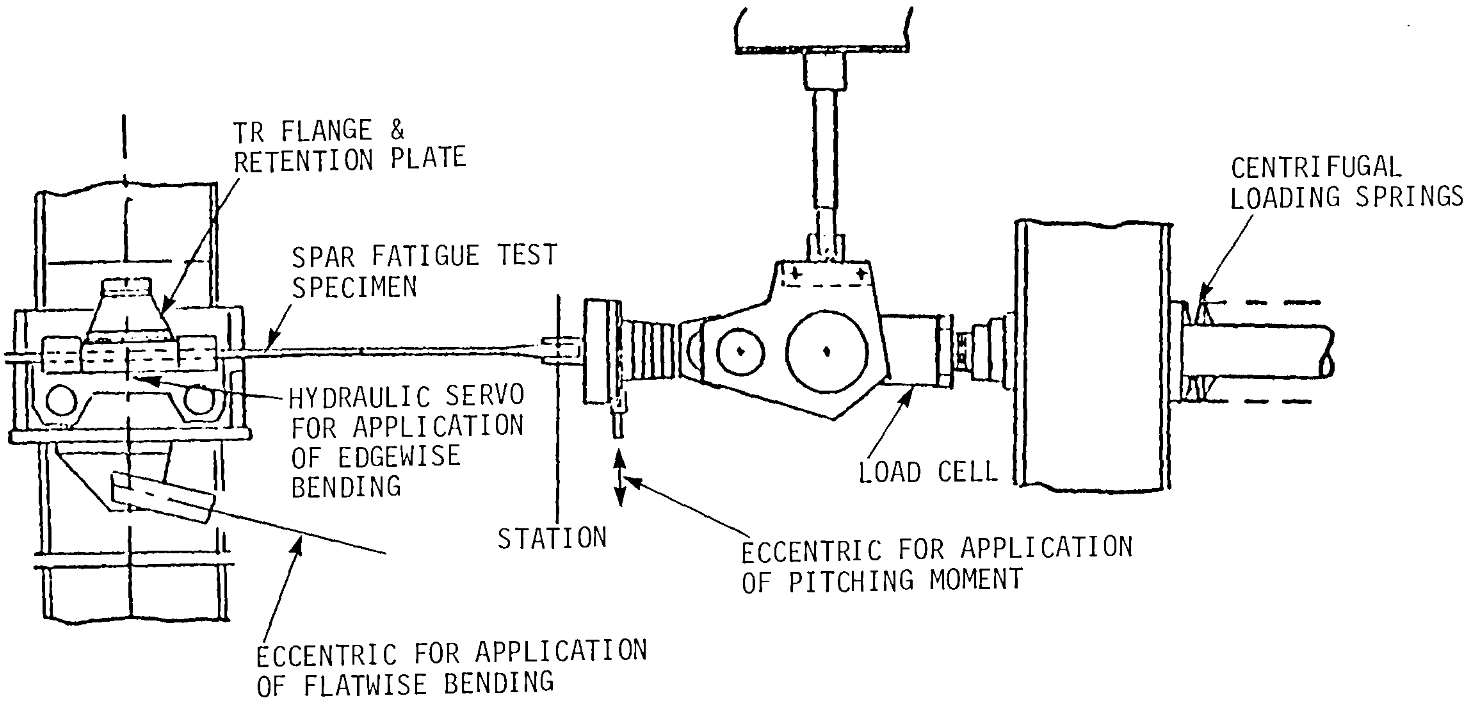


FIGURE 16. TAIL ROTOR SPAR COMBINED LOAD FATIGUE TEST SET-UP. (ONE HALF OF SPECIMEN AND SET-UP SHOWN).

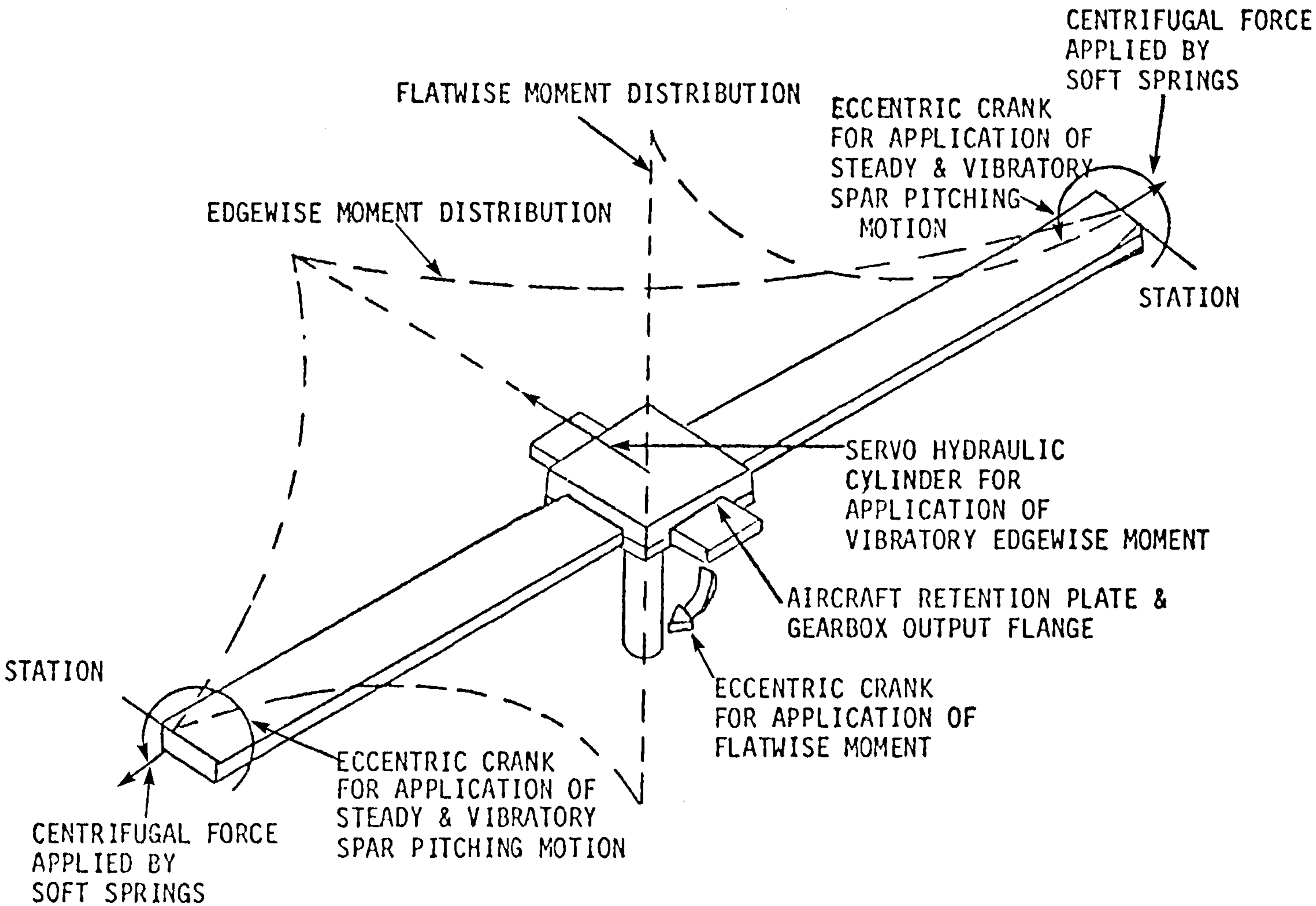


FIGURE 17. SCHEMATIC DIAGRAM OF TAIL ROTOR SPAR LOADINGS.

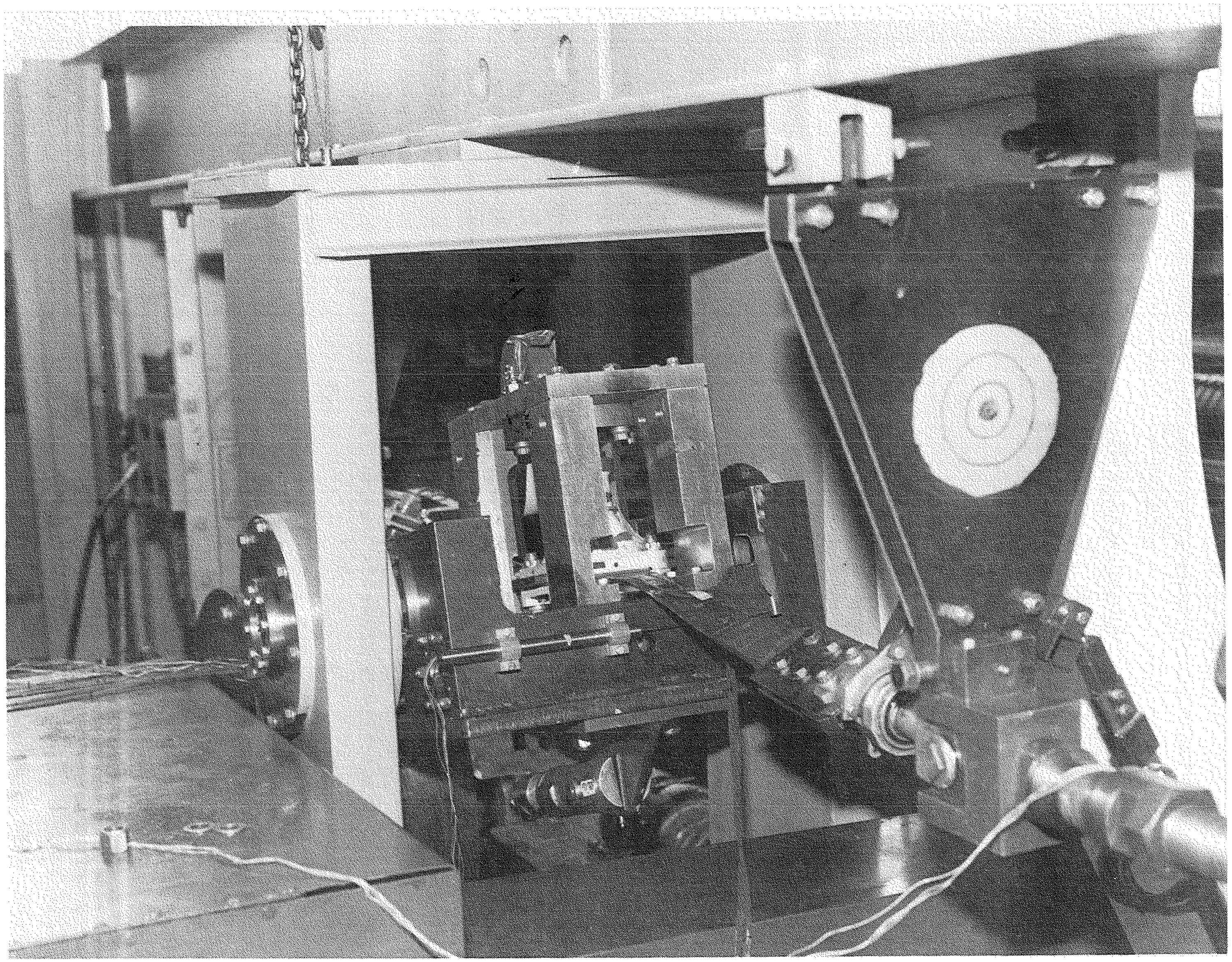


FIGURE 18. S-76 TAIL ROTOR SPAR FATIGUE TEST FACILITY.

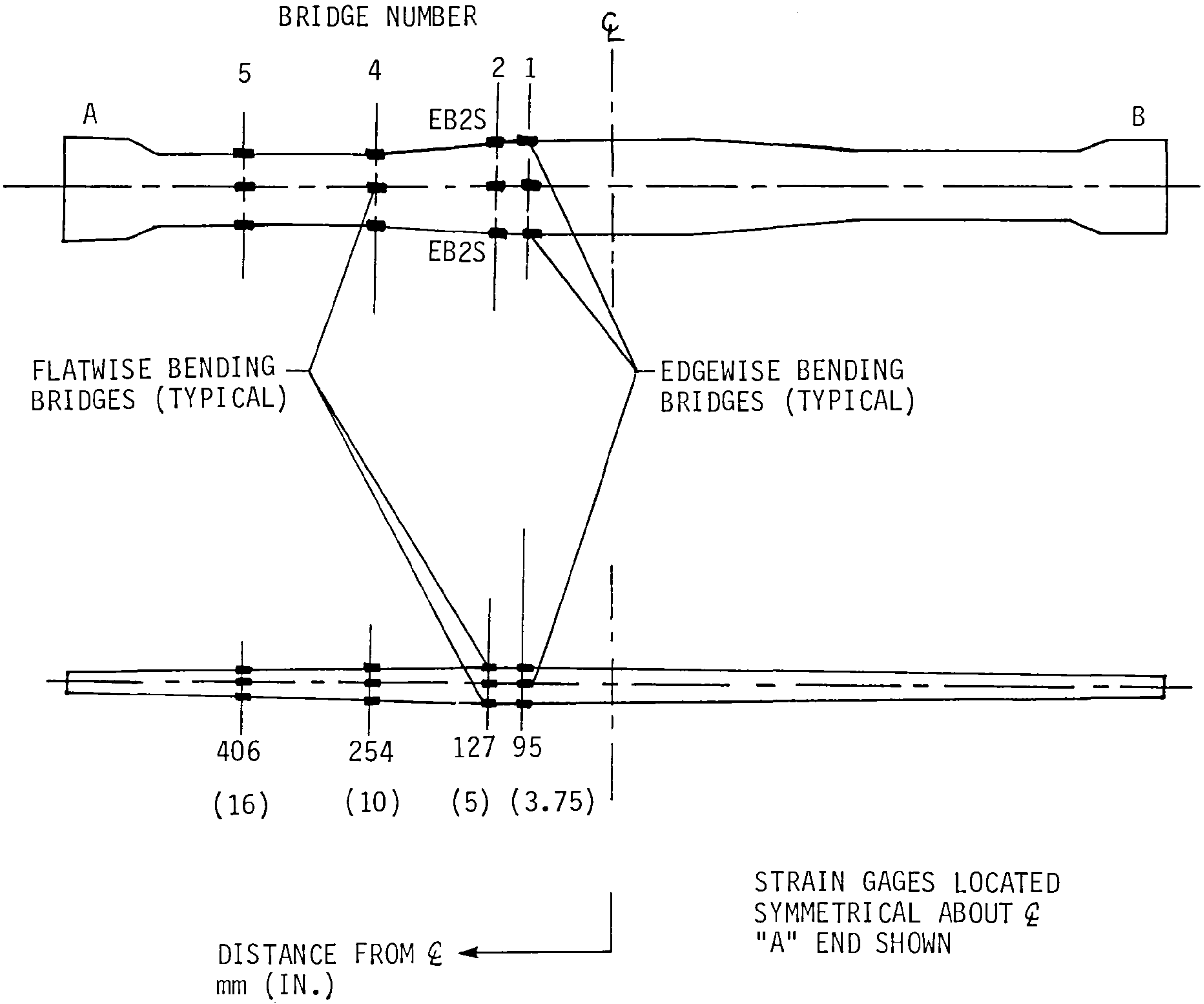


FIGURE 19. S-76 SPAR STRAIN GAGE LOCATIONS.

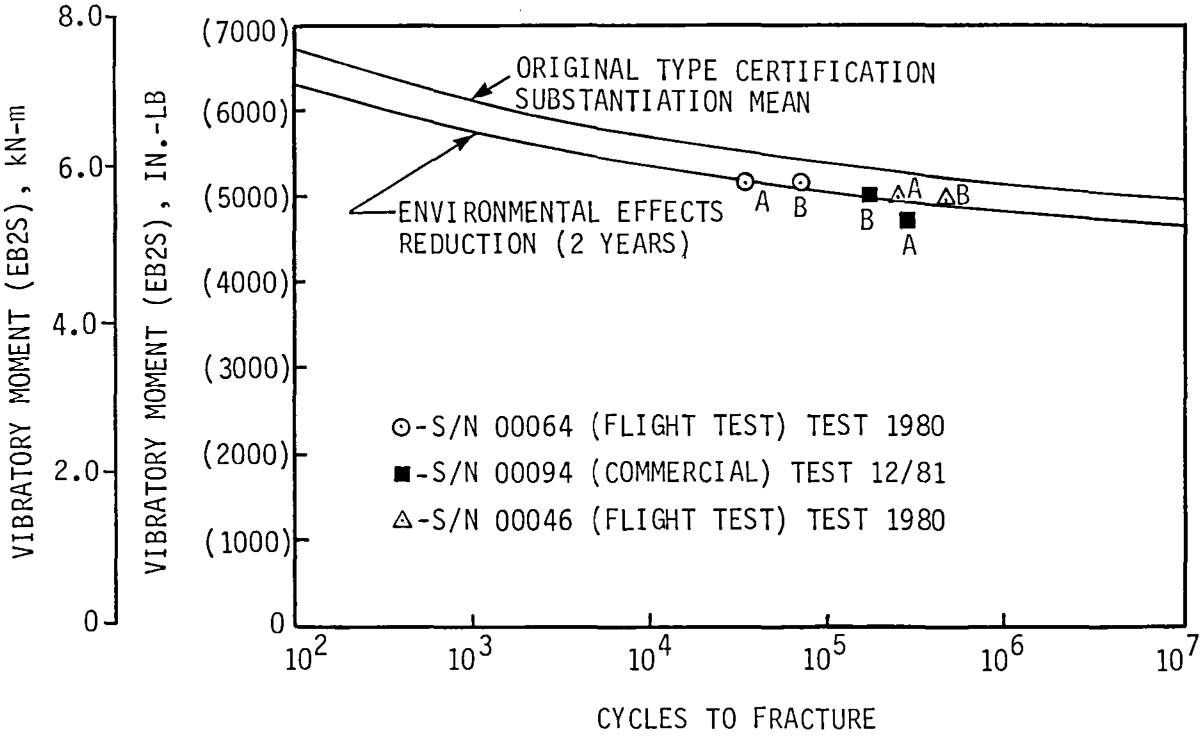


FIGURE 20. MOMENT-FATIGUE CYCLE RESULTS FOR S-76 TAIL ROTOR SPARS.

TABLE VIII. TAIL ROTOR SPAR FATIGUE TEST LOADINGS

Load Component	Steady N (Lbs)	Cyclic N-m (in-lb)	Load Introduction
Centrifugal (Axial)	48928 (11000)	-	Applied through spar-to-blade bolt holes at Station 610mm (24 in.)
*Edgewise Bending	-	553 (4900)	Moment is at Station 127mm (5 in.) and is produced by a shear force at Station 0 and reacted equally at Station 610mm (24 in.) on both ends of spar.
*Flatwise Bending	-	382 (3400)	Moment is at Station 95.25mm (3.45 in) and produced by forced flapping motion of retention plate as shown in Figure 16 and illustrated in Figure 18.
*Torsional	-	Pitch change of 65 degrees	Pitch change motions at Station 610mm (24 in.) induce the torsional loadings.

*In Phase

TABLE IX. FATIGUE TEST AND DATA SUMMARY FOR TAIL ROTOR SPARS

Tail Rotor Serial Number	In-Service Location	In-Service Time Months/Flt. Hrs.	EB2S		Moisture, Percent Weight
			Moment Nm (in-lb)	Cycles To Fracture	
00046	West Palm Beach, Fla. (Flight Test)	25 Months 150 Flight Hrs.	A553.7 (4900) B553.7 (4900)	$.25 \times 10^6$ $.38 \times 10^6$	.29[1]
00064	West Palm Beach, Fla. (Flight Test)	25 Months, 150 Flight Hrs.	A584.2 (5170) B584.2 (5170)	$.035 \times 10^6$ $.071 \times 10^6$	.32[1]
00094 (NASA)	Gulf Coast Region, La. (Commercial)	29 Months, 2390 Flight Hrs.	A536.8 (4750) B565.0 (5000)	$.286 \times 10^6$ $.170 \times 10^6$	.26[2]

NOTES: (1) Calculated from moisture measurements of spar

(2) Average of moisture measurements near fracture zone.

SECTION 4.0 MATERIAL EVALUATION

Material evaluation consists of determining moisture contents and strength reductions from coupons. The coupons are obtained from real time exposure of Graphite/epoxy and Kevlar/epoxy panels or from coupons obtained from in-service components after testing.

4.1 EXPOSED COMPOSITE PANEL DATA

AS-1/6350 graphite/epoxy and 285/5143 Kevlar/epoxy panels have been exposed to the outdoor environments at Stratford, Connecticut and West Palm Beach, Florida. Two year panels were returned and cut up into coupons for desorption and testing.

The graphite/epoxy panels are 6, 14, and 33 plies. Each ply is nominally .304mm (12 mils) thick. The Kevlar/epoxy panels are 5 plies. Each ply is nominally .228mm (9 mils) thick.

Static and fatigue tests are to be conducted of coupons from exposed panels and compared with baseline RTD data. The environmental factors are then calculated and related to the moisture contents. The data available at this time will be reported and future reports will present further data when completed. A summary of the completed coupon desorption data is presented in Table X.

The coupons were desorbed at 65°C (150°F) and typical desorption time histories are shown in Figures 21 and 22 for graphite and Kevlar epoxy coupons, respectively. Actual data values are available in the appendix. An environmental analysis was made using local area weather data (RH and solar radiation). Due to the difficulty of assessing effects of wind velocity the analysis neglected that effect and used a free convection absorption. The analytical predictions are presented in Figures 23 to 26. In these figures both a simple RH ambient analysis and a free convection solar radiation with ambient RH time histories are presented and related to the measured moisture of the panel. The average weather bureau data for these locations are listed in Tables XI and XII.

Static and fatigue tests were conducted to evaluate the material environmental factors. A summary of the results to date are listed in Table XIII.

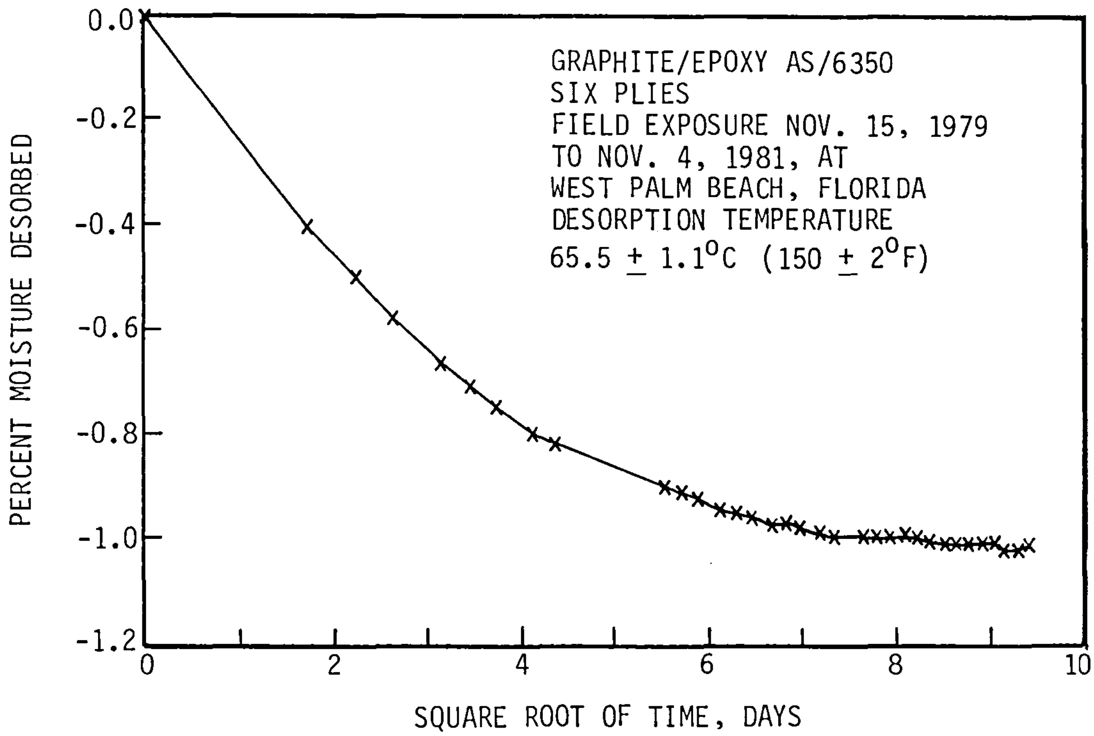


FIGURE 21. DESORPTION TIME HISTORY OF GRAPHITE/EPOXY.

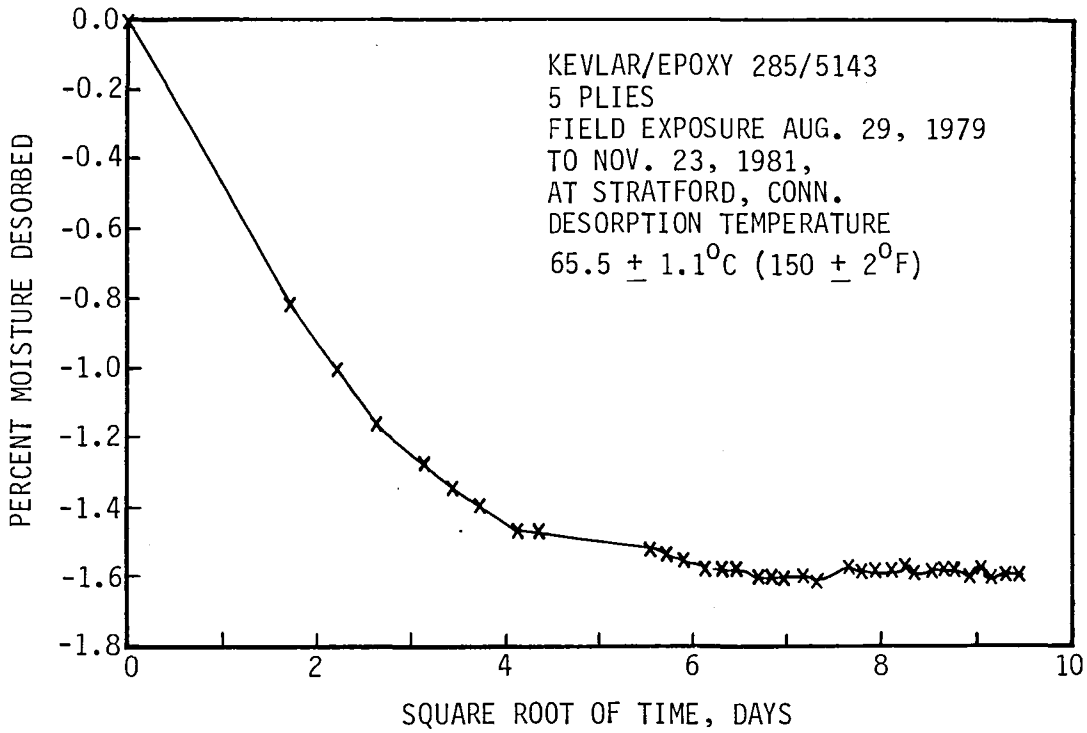


FIGURE 22. DESORPTION TIME HISTORY OF KEVLAR/EPOXY.

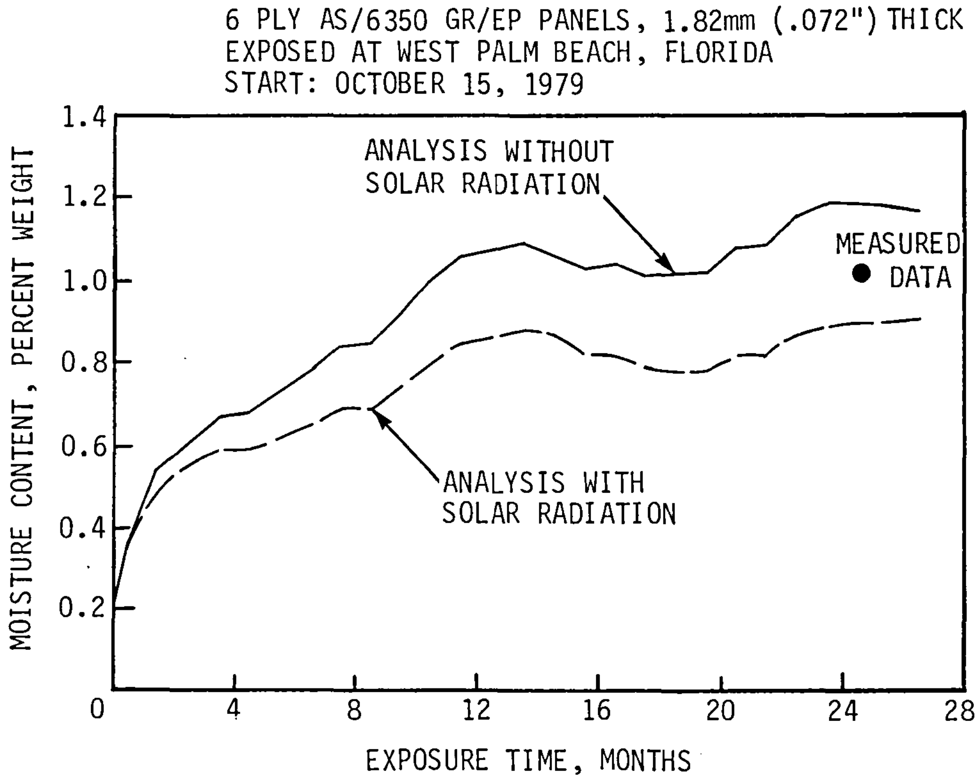


FIGURE 23. MOISTURE ABSORPTION FOR GRAPHITE/EPOXY PANELS, WPB.

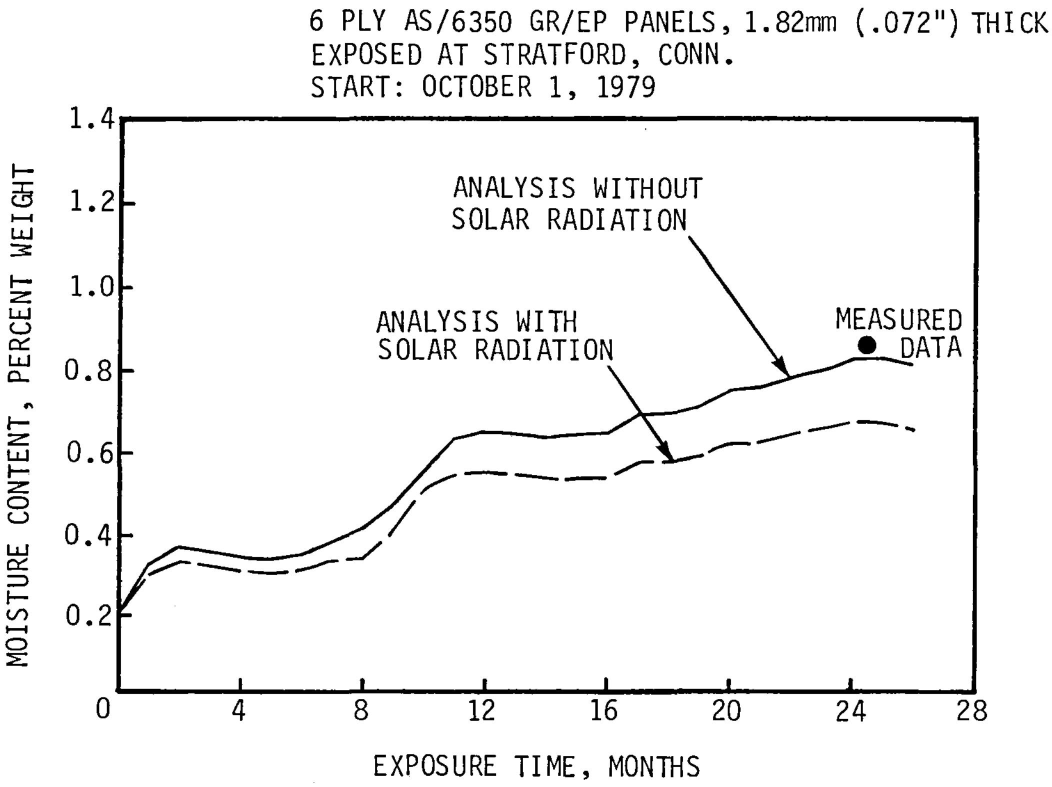


FIGURE 24. MOISTURE ABSORPTION FOR GRAPHITE/EPOXY PANELS, STRATFORD.

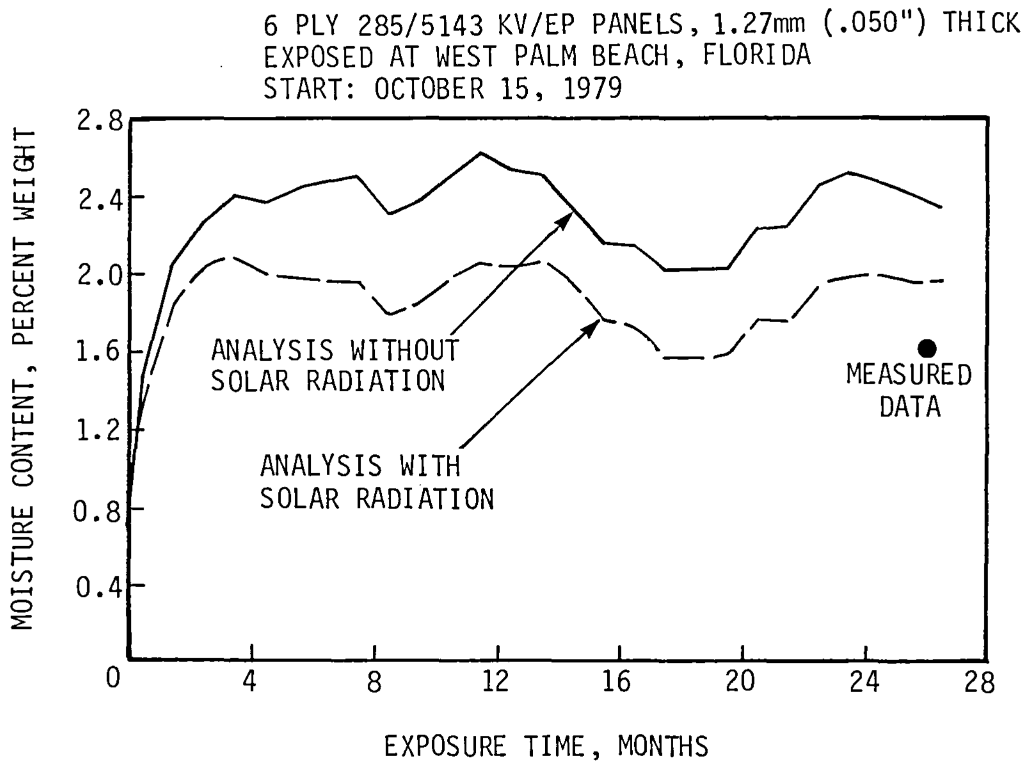


FIGURE 25. MOISTURE ABSORPTION FOR KEVLAR/EPOXY PANELS, WPB.

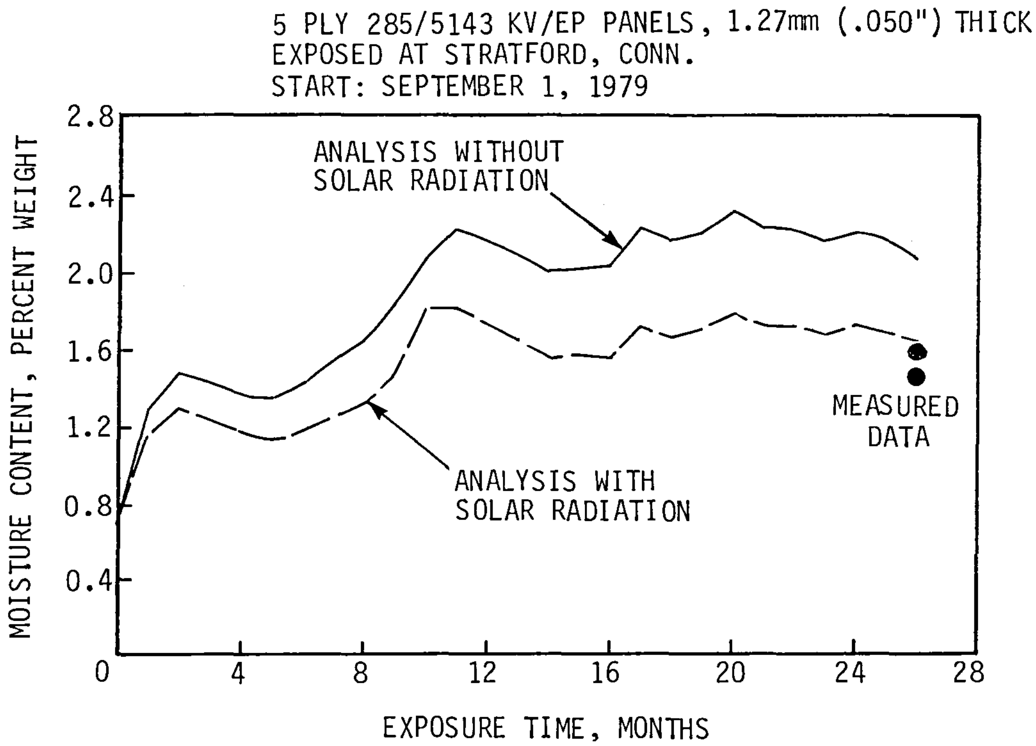


FIGURE 26. MOISTURE ABSORPTION FOR KEVLAR/EPOXY PANELS, STRATFORD.

TABLE X. SUMMARY OF EXPOSED PANEL COUPON MOISTURE ABSORPTION DATA

Material	Field Exposure Time (Months) and Location	Nominal Thickness mm (in.)	*Measured % Weight
AS-1/6350 Graphite/Epoxy	25/Stratford	1.83 (.072)	.86
	26/WPB	1.83 (.072)	1.02
	25/Stratford	4.27 (.168)	.37
	25/Stratford	10.05 (.396)	.18
	26/WPB	10.05 (.396)	.27
285/5143 Kevlar/Epoxy	26/Stratford	1.14 (.045)	1.60
	26/Stratford	1.14 (.045)	1.46
	26/WPB	1.14 (.045)	1.60

* Average of Four Coupons

TABLE XI

WEATHER BUREAU DATA, WEST PALM BEACH, FLORIDA

Dates	Average Temperature		Average RH
	C°	(°F)	%
4/01/78 - 4/30/78	22.9	(73.2)	67.9
5/01/78 - 5/31/78	26.0	(78.9)	77.5
6/01/78 - 6/30/78	27.5	(81.6)	78.3
7/01/78 - 7/31/78	27.8	(82.1)	76.3
8/01/78 - 8/31/78	27.9	(82.2)	73.3
9/01/78 - 9/30/78	27.0	(80.7)	76.4
10/01/78 - 10/31/78	24.9	(77.0)	74.9
11/01/78 - 11/30/78	23.1	(73.7)	79.4
12/01/78 - 12/31/78	20.2	(68.4)	80.1
1/01/79 - 1/31/79	17.0	(62.7)	66.8
2/01/79 - 2/28/79	17.6	(63.7)	79.3
3/01/79 - 3/31/79	20.0	(68.0)	66.8
4/01/79 - 4/30/79	23.5	(74.4)	68.6
5/01/79 - 5/31/79	24.4	(76.0)	79.3
6/01/79 - 6/30/79	26.8	(80.2)	75.4
7/01/79 - 7/31/79	28.1	(82.7)	75.9
8/01/79 - 8/31/79	28.0	(82.5)	73.0
9/01/79 - 9/30/79	27.4	(81.3)	83.5
10/01/79 - 10/31/79	25.3	(77.5)	77.4
11/01/79 - 11/30/79	22.9	(73.2)	80.1
12/01/79 - 12/31/79	19.5	(67.1)	80.3
1/01/80 - 1/31/80	17.8	(64.1)	80.5
2/01/80 - 2/29/80	16.0	(60.9)	76.0
3/01/80 - 3/31/80	21.2	(70.2)	77.3
4/01/80 - 4/30/80	22.1	(71.8)	77.1
5/01/80 - 5/31/80	24.8	(76.6)	77.1
6/01/80 - 6/30/80	27.4	(81.3)	70.9
7/01/80 - 7/31/80	28.0	(82.4)	75.1
8/01/80 - 8/31/80	22.4	(72.4)	78.9
9/01/80 - 9/30/80	26.7	(80.1)	80.3
10/01/80 - 10/31/80	25.3	(77.5)	76.4
11/01/80 - 11/30/80	17.6	(63.8)	68.1
12/01/80 - 12/31/80	18.3	(64.9)	61.4

TABLE XI (cont'd)

Dates	Average Temperature		Average RH
	C°	(°F)	%
1/01/81 - 1/31/81	14.4	(58.0)	56.3
2/01/81 - 2/29/81	19.3	(66.8)	67.9
3/01/81 - 3/31/81	15.4	(59.8)	63.5
4/01/81 - 4/30/81	23.9	(75.1)	65.6
5/01/81 - 5/31/81	25.5	(77.9)	60.1
6/01/81 - 6/30/81	28.1	(82.6)	72.8
7/01/81 - 7/31/81	28.7	(83.7)	72.1
8/01/81 - 8/31/81	27.5	(81.5)	77.9
9/01/81 - 9/30/81	26.5	(79.8)	77.9
10/01/81 - 10/31/81	25.2	(77.4)	75.4
11/01/81 - 11/30/81	19.7	(67.5)	74.4
12/01/81 - 12/31/81	18.3	(65.0)	73.0

TABLE XII

WEATHER BUREAU DATA, STRATFORD, CONNECTICUT

Dates	Average Temperature		Average RH
	C°	(°F)	%
1/01/79 - 1/31/79	-0.8	(30.6)	69.0
2/01/79 - 2/28/79	-4.1	(24.6)	59.2
3/01/79 - 3/31/79	6.1	(43.0)	64.8
4/01/79 - 4/30/79	9.7	(49.5)	63.4
5/01/79 - 5/31/79	16.5	(61.7)	72.8
6/01/79 - 6/30/79	19.2	(66.6)	73.8
7/01/79 - 8/31/79	23.2	(73.8)	77.0
8/01/79 - 8/31/79	22.2	(72.0)	82.5
9/01/79 - 9/30/79	18.2	(64.8)	80.3
10/01/79 - 10/30/79	11.8	(53.2)	69.9
11/01/79 - 11/31/79	8.5	(47.3)	69.8
12/01/79 - 12/31/79	3.3	(37.9)	58.3
1/01/80 - 1/31/80	0	(32.0)	49.1
2/01/80 - 2/29/80	-2.3	(27.8)	48.3
3/01/80 - 3/31/80	2.8	(37.1)	54.8
4/01/80 - 4/30/80	2.8	(37.1)	54.8
5/01/80 - 5/31/80	15.6	(60.1)	63.1
6/01/80 - 6/30/80	19.5	(67.1)	66.8
7/01/80 - 7/31/80	24.1	(75.4)	71.4
8/01/80 - 8/31/80	24.1	(75.5)	72.6
9/01/80 - 9/30/80	20.3	(68.6)	68.4
10/01/80 - 10/30/80	12.9	(55.3)	64.1
11/01/80 - 11/31/80	6.4	(43.6)	58.8
12/01/80 - 12/31/80	-0.3	(31.4)	62.3
1/01/81 - 1/31/81	-5.1	(22.8)	64.4
2/01/81 - 2/28/81	1.3	(34.3)	80.1
3/01/81 - 3/31/81	3.2	(37.9)	70.5
4/01/81 - 4/30/81	9.3	(48.8)	73.0
5/01/81 - 5/31/81	14.6	(58.3)	75.8
6/01/81 - 6/31/81	21.2	(70.2)	65.6
7/01/81 - 7/31/81	24.7	(76.6)	62.6
8/01/81 - 8/31/81	23.2	(73.8)	61.8
9/01/81 - 9/30/81	18.4	(65.2)	66.2
10/01/81 - 10/31/81	11.7	(53.0)	64.8
11/01/81 - 11/31/81	7.5	(45.6)	58.6

TABLE XIII. SUMMARY OF EXPOSED PANEL STRENGTH ENVIRONMENTAL FACTORS

Exposure Location	Number of Plies	Measured Moisture, % Wgt	Environmental Factors, Room Temperature				
			SBS Static	SBS Fatigue	Flex Static	Tension Static	Material
Stratford	6	.86	.89		.88		Graphite/Epoxy
Conn.	14	.37	.90	.91	.95		Graphite/Epoxy
	33	.18	.96	1.05	1.04		Graphite/Epoxy
	5	1.53	-	-	-	1.05	Kevlar/Epoxy
West Palm	6	1.02	.86		.84		Graphite/Epoxy
Beach, Fla.	33	.27	.97	1.02	1.03		Graphite/Epoxy
	5	1.61	-	-	-	1.00	Kevlar/Epoxy

4.2 COUPONS FROM IN-SERVICE COMPONENTS

Coupons were taken from the tail rotor and stabilizer for the purpose of determining the moisture contents. Locations are shown in Figures 27 and 28.

The coupons taken from the tail rotor spar were between stations 5 to 7, the region of final fracture. To accelerate the desorption tests some of the tail rotor coupons (from leading edge) were fragmented. The results of the fragmented desorption tests will be reported since the solid coupons are still in the early desorption process. However, past desorption testing of tail rotor spar coupons have shown no final difference in desorption results whether the coupons are fragmented or not.

The desorption time history of the coupon for the B end at Sta. 6-7 leading edge is typical and shown in Figure 29. The projected moisture absorbed is .26 percent weight. Due to the thickness of the tail rotor spar the initial dry condition at time of certification is considered to be near zero. Stabilizer desorption time history is presented in Figure 30 for Kevlar/epoxy.

The results of the spar coupon moisture desorption tests are listed in Table XIV. The average moisture content for Station 6, nearest the fracture zone, is .26% weight.

In addition graphite and Kevlar/epoxy coupons were taken from the stabilizer for SBS static and fatigue testing. The purpose of these tests is to determine the strength of the material as a function of calendar time during the program. No baseline is available and batch to batch variation is to be expected. Therefore these tests are considered comparative for the components. Table XV lists the results of the tests.

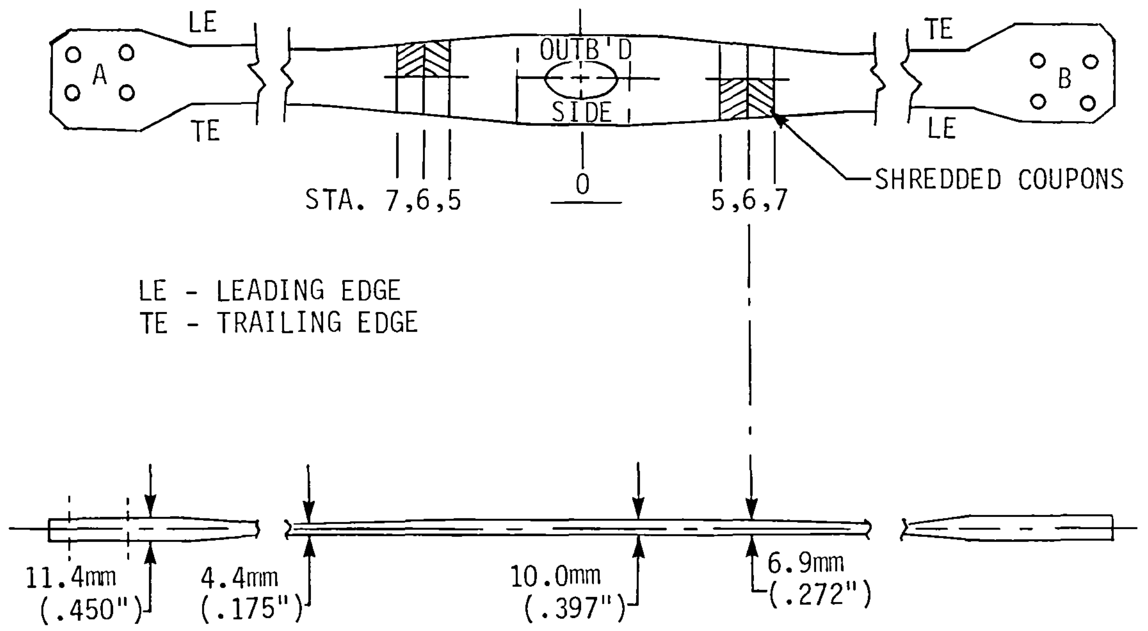


FIGURE 27. S-76 TAIL ROTOR SPAR - LOCATION OF MOISTURE MEASUREMENT COUPONS.

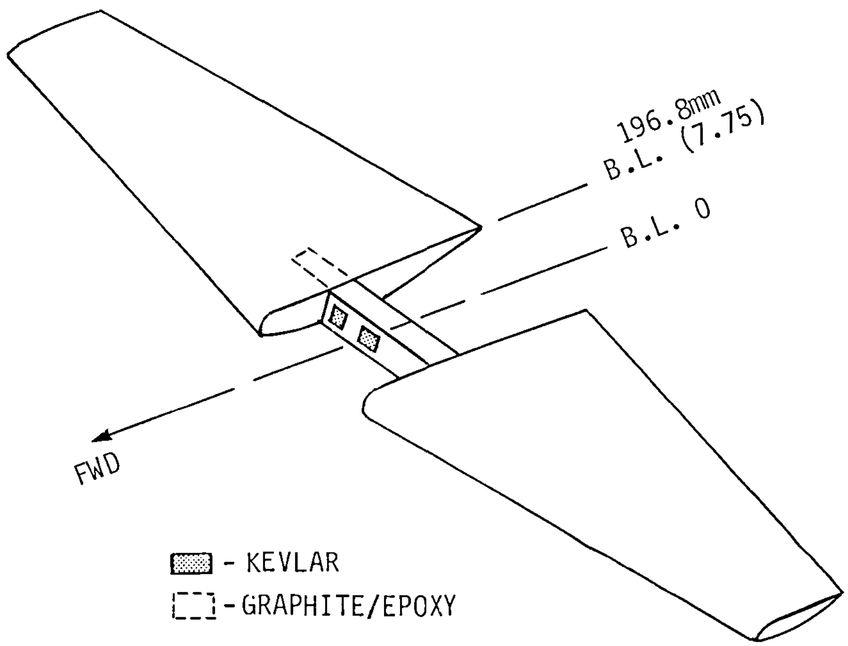


FIGURE 28. S-76 STABILIZER - LOCATION OF MOISTURE MEASUREMENT COUPONS.

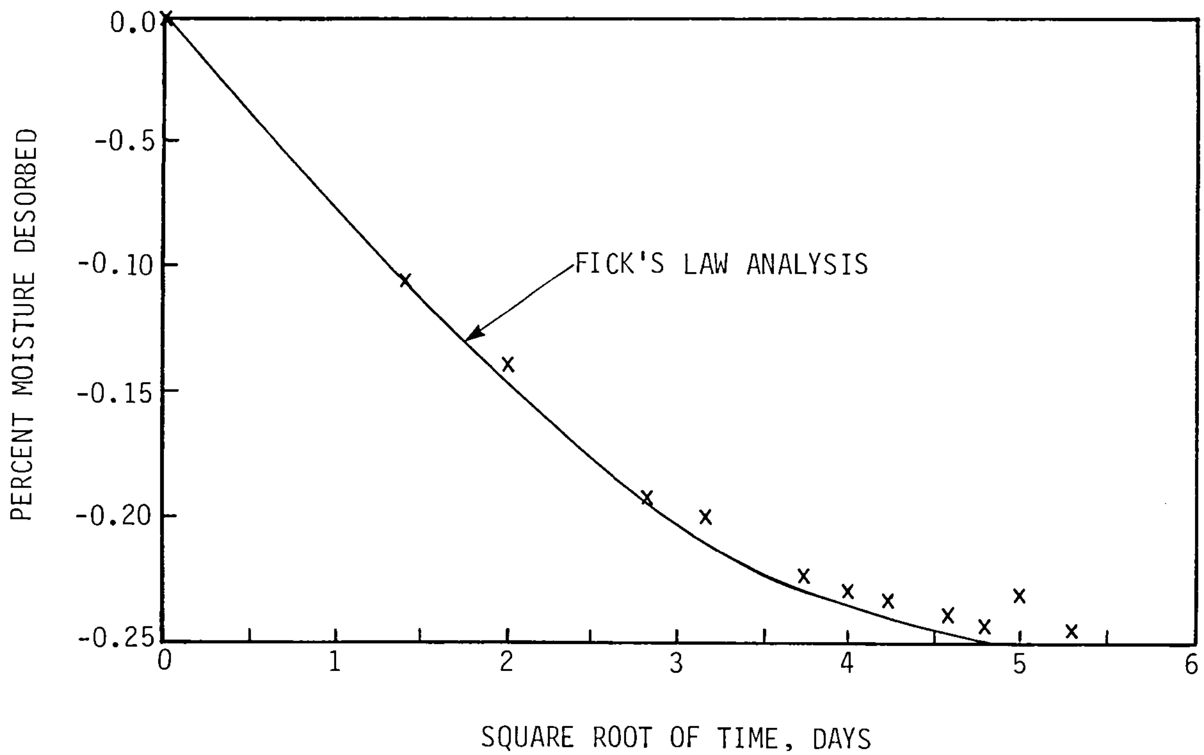


FIGURE 29. DESORPTION TIME HISTORY OF COUPON FROM TAIL ROTOR SPAR, S/N 00094. (STATION 6-7 L-E, END B).

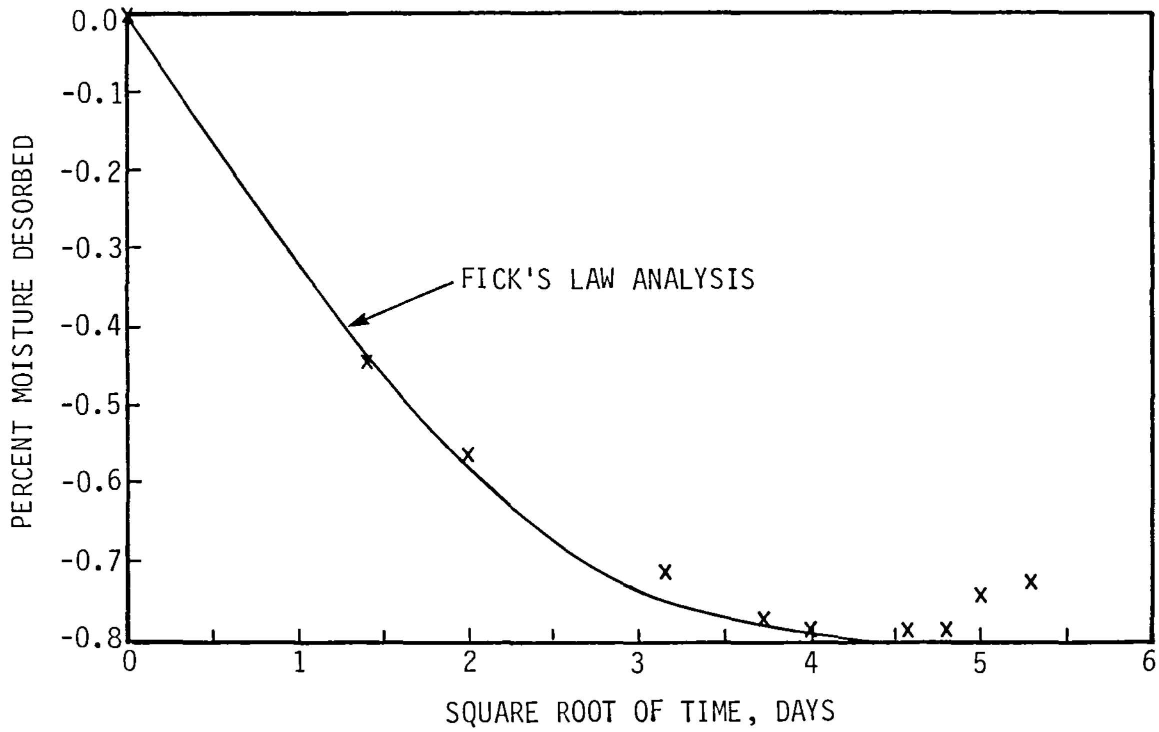


FIGURE 30. DESORPTION TIME HISTORY OF KEVLAR/EPOXY COUPON FROM STABILIZER S/N B-157-00076.

TABLE XIV. TAIL ROTOR SPAR COUPON DESORPTION RESULTS

Desorption Coupon	Thickness mm (in.)	ΔM % WGT
A 5-6 LE	7.49 to 6.30 (.295 to .248)	.23
B 5-6 LE	7.49 to 6.30 (.295 to .248)	.24
A 6-7 LE	6.30 to 5.36 (.248 to .211)	.30
B 6-7 LE	6.30 to 5.36 (.248 to .211)	.26
At Sta 6	6.30 (.248)	.26 Average from Above

TABLE XV. STABILIZER COUPON STRENGTH DATA

Component Material	SBS Static Strength MPa (KSI)	SBS Fatigue Strength	
		MPa (KSI)(2)	Cycles
Graphite/Epoxy	119.9 (16.1)(1)	68.9 (10) 62.0 (9) 55.1 (8) 55.1 (8) 48.2 (7)	1.2×10^4 1.2×10^5 4.5×10^4 7.0×10^6 $> 1 \times 10^7$ (runout)
Kevlar/Epoxy	31.0 (4.5)(1)	20.7 (3) 20.7 (3) 13.8 (2) 13.8 (2) 10.3 (1.5)	4.0×10^3 1.7×10^5 2.0×10^3 3.1×10^5 $> 1 \times 10^7$ (runout)

(1) Average of 3 tests
(2) Maximum stress in cycle, R = 0.1

SECTION 5.0 ANALYSIS OF TEST RESULTS

The exposed panels (24 to 26 months) at Stratford, Connecticut and West Palm Beach, Florida have provided real time moisture contents. Coupon tests from the exposed panels have been compared with RTD unexposed tests to determine environmental factors. The in-service components have provided measurements of moisture contents and strength tests for comparison with initial unexposed tested components. These data are assessed in the following paragraphs for their implications regarding environmental factors previously described.

The analysis of test results will be limited, at this time, due to the calendar life and service time of the in-service components. However, the available data will indicate trends. Future work in this program is expected to form a more quantitative relationship on the effects of environment on in-service components.

5.1 EXPOSED PANEL DATA

In general, the exposed panels appear to absorb less moisture than would be predicted by an environmental analysis using ambient RH only. A comparison shown in Figures 23 and 25 for the West Palm Beach Region panels shows absorbed moisture is significantly less than would be predicted by using ambient RH only. The reduction is close to the 24 percent projected in the study of Refernce (8) for graphite/epoxy and but even more for Kevlar/Epoxy. The results at the Stratford location (a less humid region) are mixed and kevlar/epoxy moisture is less than predicted. It should be noted that snow is a factor at the Stratford location and that effect is not accounted for in the environmental analysis.

A comparison of environmental factors derived from lab conditions and field exposure is presented in Figure 31.

The environmental factor (E.F.) is defined as the ratio of conditioned (field or lab) strength to the RTD strength. Figure 31 compares the field exposed E.F. with those determined from accelerated lab conditioning.

The results are based on approximately two years field exposure and future data is required to show the long term effects. In addition, the data developed in this program will provide more than thirty coupon points for each property which will then enable a reasonable statistical trend.

5.2 IN-SERVICE COMPONENT DATA

The stabilizer proof load test (S/N B-157-00076) showed that no loss of stiffness has resulted after 17 months in service. The ultimate strength was 220 percent of DLL as compared with the initial 268 percent for certification. However, the mode causing the reduction (no fracture was obtained in test) appears to be the result of loss of a local bond shear transfer to the honeycomb. Future tests are required to determine whether there is an environmental effect or a variation between specimens.

The tail rotor spar fatigue tests of S/N 00094 closely groups with previous two year field exposed components (illustrated in Figure 20). However, it should be noted that S/N 00094 has 4 months more exposure in a more severe humid region and had accumulated a far greater number of flight hours of operation than spars S/N 00046 and S/N 00064. The fatigue environmental factor for the in-service component, as shown in Table XVI appears to be about the same as projected from SBS coupon tests. Since the moisture content is still small (.26% weight) fatigue tests of longer exposed components are required to assess the long term trend.

Due to the spar thickness (about 6.35mm, .25 inches) the moisture absorption is a slow process under service conditions. The projected moisture absorption time history (without solar radiation and convection) is presented in Figure 32. The actual measured moisture for S/N 00094 is, as expected, far below the conservative analysis.

The analysis indicates that the next spars to be fatigue tested (calendar time at least 36 months) should have only a small moisture increase over spar S/N 00094. Thus the next program test will serve to confirm the moisture content results and the effects of calendar time and flight hours.

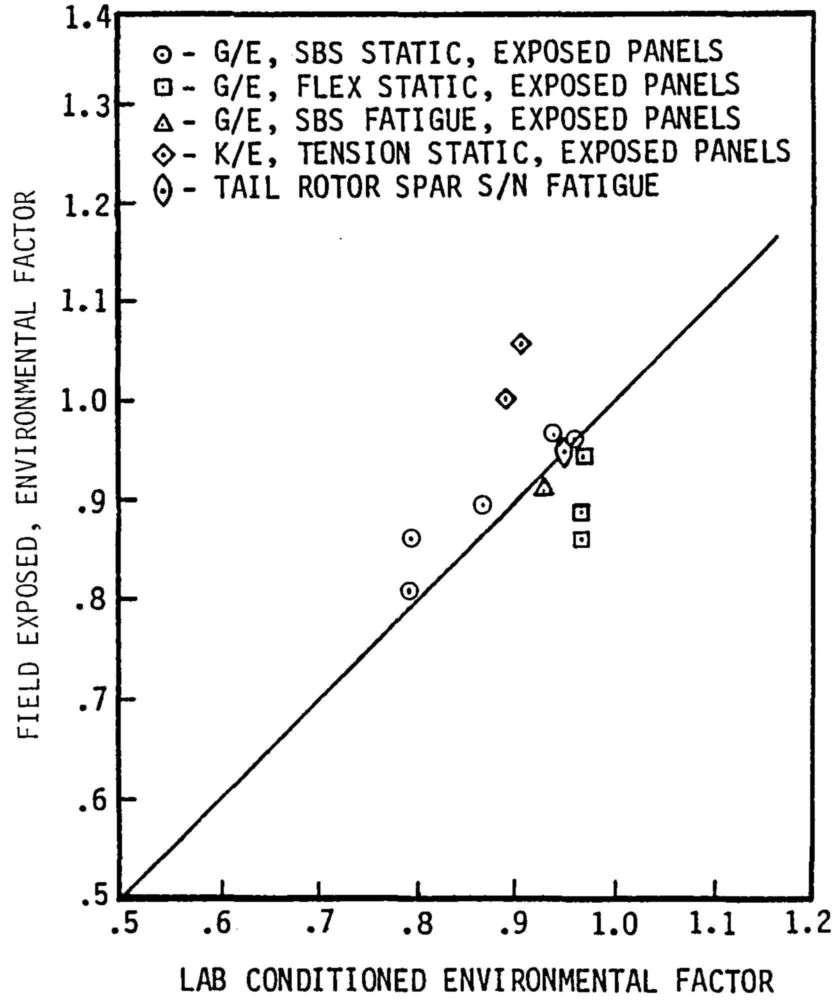


FIGURE 31. COMPARISON OF ENVIRONMENTAL FACTORS FOR FIELD EXPOSED AND LABORATORY CONDITIONED COUPONS.

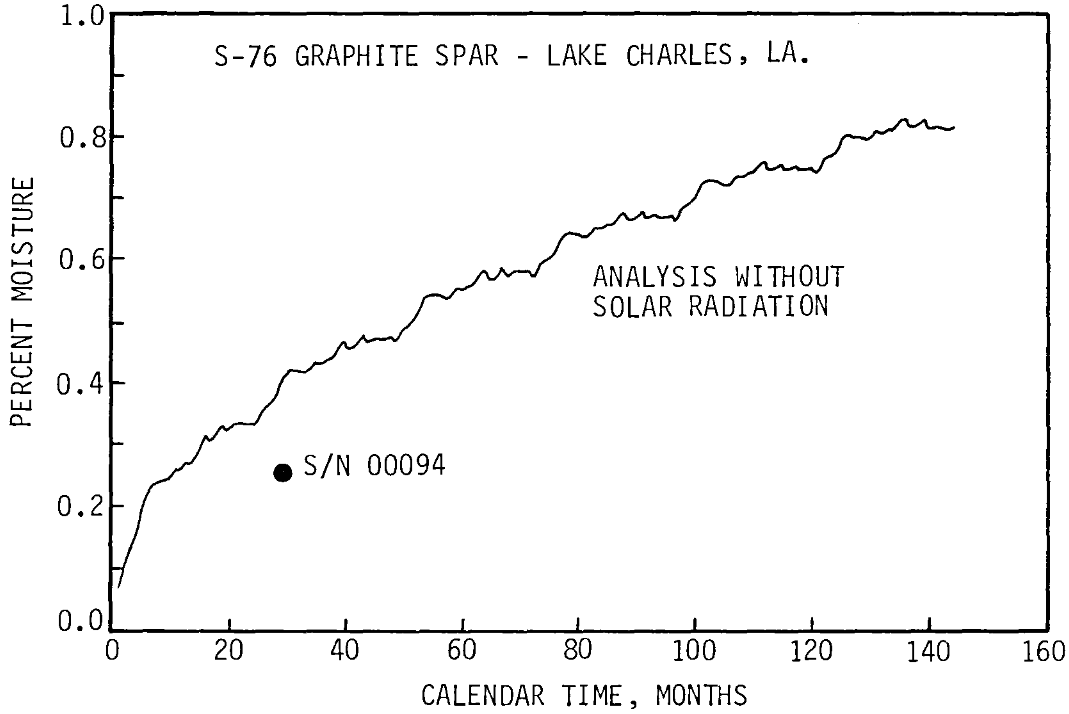


FIGURE 32. GRAPHITE TAIL ROTOR SPAR MOISTURE ANALYSIS, GULF COAST REGION.

TABLE XVI. SUMMARY OF TAIL ROTOR SPAR FATIGUE TESTS

Tail Rotor Spar Tests and Service Data	Moisture Content, % WGT Near Fracture Zone	Cyclic EB2S Moment At 10^7 Cycles (Fig. 20) N-m (in-lb)	Environmental Factor	
			Projected from Coupon Tests (Fig. 7)	In-Service Component Test
Initial Certification Zero Time Structure	~0	565 (5000)	-	-
S/N 00094, 29 Months and 2390 Flight Hrs. in Gulf Coast Region, Louisiana	.26 at Station 6	536 (4750)	.95	.94

SECTION 6.0 CONCLUSIONS

6.1 CONCLUSIONS

The following conclusions are based on the results of approximately two year exposure:

1. The fatigue strength retention of the tail rotor spar (S/N 00094) is about the same as obtained from the lab coupons for the same average moisture content (94 percent versus 95 percent). This conclusion appears to be confirmed by the fatigue strength retention of the two year exposed SBS coupons.

2. No definite conclusion on environmental effects on the stabilizer can be made since the mode of load drop off was due to an internal disbond at an interface. The reduction of 18 percent in maximum load capability from the initial certification may well be due to variation of specimens. It is concluded that the stabilizer has a effective redundant load path and can sustain loads in excess of the 150 percent DLL requirement.

3. From the material evaluation tests it is concluded that the moisture absorption (in the most humid region) is less than would be predicted using ambient RH alone. The effect on strength varies. Graphite/epoxy fatigue strength retention appears to be the same as for lab condition coupons. Graphite/epoxy static shear strength is somewhat greater than expected and the flexure strength is somewhat less than expected. Kevlar/epoxy static strength is far higher than expected.

SECTION 7.0 APPENDIX

Detailed data is contained in this appendix for future reference or analysis review.

TABLE XVII: Moisture desorption measurements of ten exposed panels, Stratford and WPB. Four coupons of each panel were desorbed at 65.5°C (150°F).

TABLE XVIII: Average values of coupons from values of Table XVII.

TABLE XIX: Summary of coupon test results.

TABLE XVII. MOISTURE DESORPTION MEASUREMENTS OF TEN EXPOSED PANELS, STRATFORD AND WEST PALM BEACH

% MOISTURE DESORBED FROM PANEL #1
6 PLY GRAPHITE-WEST PALM BEACH
WEATHERED 10-15-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.4346	.4384	.3616	.3888
12.9	.5268	.5273	.4553	.487
12.11	.6082	.6102	.5355	.5706
12.14	.6872	.6943	.6144	.6555
12.16	.7279	.737	.6633	.7033
12.18	.7698	.7784	.7054	.7497
12.21	.8225	.8294	.753	.7962
12.23	.8369	.8472	.7734	.8161
1.4	.9195	.9313	.8563	.8997
1.6	.9362	.9443	.8645	.909
1.8	.9494	.9585	.8821	.9209
1.11	.9698	.9751	.893	.9368
1.13	.9757	.9846	.9025	.9461
1.15	.9829	.9917	.9107	.9514
1.18	.9973	1.0059	.9243	.9647
1.2	1.0009	1.0095	.927	.9687
1.22	1.0105	1.019	.9365	.9766
1.25	1.0141	1.0225	.9406	.9793
1.27	1.0236	1.032	.9487	.9886
2.1	1.0224	1.0308	.9501	.9859
2.3	1.0248	1.0332	.9528	.9886
2.5	1.0272	1.0344	.9528	.9886
2.8	1.0284	1.0344	.9582	.9873
2.1	1.0296	1.0355	.9528	.9846
2.12	1.0416	1.0474	.9596	.9913
2.15	1.0392	1.045	.9637	.9926
2.17	1.0464	1.0498	.9637	.9926
2.19	1.044	1.0462	.9637	.9952
2.22	1.0584	1.0664	.9582	.97
2.24	1.0403	1.0462	.9623	.9926
2.26	1.0524	1.0592	.9732	1.0032
3.1	1.0643	1.0628	.9773	1.0059
3.3	1.0512	1.0533	.9705	.9979

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #2
33 PLY GRAPHITE-WEST PALM BEACH
WEATHERED 10-15-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.0979	.1041	.0679	.0554
12.9	.1161	.1244	.0832	.0696
12.11	.1345	.1449	.099	.0848
12.14	.153	.1658	.1122	.1013
12.16	.161	.1734	.1207	.1074
12.18	.1712	.1847	.1289	.1164
12.21	.1852	.1999	.1403	.1282
12.23	.1907	.206	.1451	.1331
1.4	.2166	.2341	.1656	.1553
1.6	.2231	.2407	.1706	.1593
1.8	.2287	.247	.1756	.1645
1.11	.2352	.2542	.1805	.1697
1.13	.2391	.2581	.1834	.1736
1.15	.2419	.2614	.1855	.1758
1.18	.2486	.2687	.1914	.1817
1.2	.252	.2728	.1946	.1867
1.22	.2555	.2761	.1972	.1894
1.25	.2568	.2782	.1981	.1905
1.27	.2626	.2841	.2033	.196
2.1	.2628	.2849	.2028	.196
2.3	.2674	.2894	.2058	.1984
2.5	.2685	.2911	.2074	.2007
2.8	.2726	.2954	.2093	.2021
2.1	.2728	.2952	.2095	.2023
2.12	.2778	.3005	.2132	.2066
2.15	.2788	.3013	.2141	.2097
2.17	.2814	.3038	.2158	.2095
2.19	.2817	.3052	.2162	.2104
2.22	.2801	.3044	.2156	.2086
2.24	.2832	.3073	.2173	.2125
2.26	.289	.3128	.2228	.2179
3.1	.2942	.3175	.2264	.2213
3.3	.292	.3157	.2236	.219

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #2
33 PLY GRAPHITE-WEST PALM BEACH
WEATHERED 10-15-79 TO 11-4-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.15	.2877	.3116	.2190	.2158
3.17	.2901	.3134	.2210	.2170
3.19	.2916	.3143	.2214	.2177
3.22	.2944	.3177	.2242	.2197
3.24	.2940	.3177	.2238	.2199
3.26	.2901	.3157	.2229	.2195
3.29	.2983	.3237	.2279	.2244
3.31	.3007	.3247	.2283	.2249
4.2	.2981	.3225	.2264	.2235
4.6	.3005	.3259	.2290	.2253
4.8	.3022	.3274	.2298	.2269
4.12	.3037	.3296	.2314	.2285
4.14	.3015	.3276	.2294	.2276
4.16	.3061	.3315	.2329	.2310
4.19	.3028	.3288	.2311	.2296
4.21	.3020	.3284	.2298	.2265
4.23	.3089	.3343	.2335	.2317
4.26	.2968	.3296	.2298	.2285
4.28	.3048	.3288	.2285	.2271
4.30	.3069	.3333	.2314	.2308
5.3	.3031	.3290	.2285	.2271
5.5	.3113	.3368	.2353	.2271
5.7	.3106	.3372	.2324	.2301
5.10	.3098	.3343	.2322	.2766
5.12	.3089	.3374	.2320	.2774
5.14	.3065	.3325	.2305	.2747
5.17	.3087	.3366	.2337	.2778
5.19	.3072	.3309	.2296	.2283
5.21	.3018	.3282	.2247	.2256
5.24	.3091	.3352	.2303	.2303
5.26	.3013	.3286	.226	.226
5.28	.3033	.3286	.227	.2269
6.3	.3061	.3315	.2275	.2283
6.7	.3065	.3323	.2277	.226
6.9	.3069	.3337	.2268	.2262
6.11	.3069	.3333	.2266	.226
6.14	.3063	.3331	.227	.2269
6.16	.3061	.3298	.2264	.2256

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #3
6 PLY GRAPHITE-STRATFORD
WEATHERED 9-28-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.3254	.3239	.2941	.2741
12.9	.3893	.3916	.3732	.34
12.11	.4533	.4559	.4457	.4036
12.14	.5116	.5279	.509	.4614
12.16	.5486	.5541	.5499	.5432
12.18	.5845	.5901	.5842	.5343
12.21	.6316	.6359	.6251	.5724
12.23	.6518	.6566	.6449	.5921
1.4	.7315	.7395	.7108	.6823
1.6	.7506	.7539	.72	.6939
1.8	.7696	.7722	.7345	.7112
1.11	.7865	.7897	.7464	.7274
1.13	.7887	.7919	.7477	.7332
1.15	.8067	.8093	.7583	.7343
1.18	.8212	.8224	.7688	.7598
1.2	.8302	.8322	.7728	.7644
1.22	.8369	.8409	.7794	.776
1.25	.8437	.8453	.7807	.7817
1.27	.8571	.8562	.7886	.7921
2.1	.8426	.8475	.7741	.7852
2.3	.8605	.8638	.7886	.7968
2.5	.8639	.8671	.7873	.8014
2.8	.8605	.8726	.7833	.8026
2.1	.8627	.8693	.7767	.8037
2.12	.8717	.8769	.7833	.8072
2.15	.8751	.8835	.7899	.813
2.17	.8785	.8846	.7873	.8153
2.19	.8785	.8846	.7912	.8187
2.22	.865	.8693	.7543	.7852
2.24	.8852	.8944	.7886	.8268
2.26	0	.9064	.8005	.8349
3.1	.9043	.9097	.8057	.8396
3.3	.8998	.9097	.8005	.8396

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #4
14 PLY GRAPHITE-STRATFORD
WEATHERED 11-6-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.136	.1296	.0824	.0966
12.9	.1627	.1436	.1024	.1189
12.11	.189	.1699	.1209	.1412
12.14	.2143	.1939	.1404	.1616
12.16	.2279	.2056	.1518	.1744
12.18	.2448	.2216	.1653	.1898
12.21	.265	.2399	.1793	.2047
12.23	.2701	.2455	.1843	.2106
1.4	.3076	.2821	.2163	.2458
1.6	.3175	.2901	.2218	.2523
1.8	.3259	.2985	.2283	.2592
1.11	.3348	.3075	.2343	.2656
1.13	.3405	.3126	.2392	.2706
1.15	.3447	.3168	.2432	.2746
1.18	.3555	.3276	.2517	.284
1.2	.3606	.3323	.2557	.2884
1.22	.3658	.338	.2597	.2934
1.25	.3695	.3413	.2627	.2969
1.27	.3775	.3488	.2692	.3033
2.1	.3752	.3464	.2677	.3023
2.3	.3827	.3549	.2747	.3087
2.5	.3873	.3586	.2782	.3122
2.8	.3916	.3614	.2782	.3167
2.1	.392	.3619	.2782	.3157
2.12	.3981	.3689	.2842	.3201
2.15	.4005	.3722	.2877	.3246
2.17	.4052	.3755	.2892	.3266
2.19	.4066	.3779	.2922	.3281
2.22	.4066	.3699	.2817	.3172
2.24	.4099	.3821	.2947	.333
2.26	.4183	.3905	.3017	.3385
3.1	.4244	.3943	.3062	.3424
3.3	.4216	.3943	.3047	.3415

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #4
14 PLY GRAPHITE-STRATFORD
WEATHERED 11-6-79 TO 11-4-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.15	.3845	.3544	.2812	.3157
3.17	.4197	.391	.3027	.3395
3.19	.4206	.3915	.3027	.34
3.22	.4258	.3962	.3082	.3439
3.24	.4258	.3976	.3067	.3449
3.26	.423	.3948	.3062	.3424
3.29	.433	.4051	.3137	.3514
3.31	.4319	.4032	.3137	.3504
4.2	.4314	.4037	.3127	.3509
4.6	.4356	.4074	.3152	.3534
4.8	.4394	.4112	.3172	.3553
4.12	.4399	.4121	.3202	.3583
4.14	.4389	.4098	.3187	.3573
4.16	.4417	.4126	.3207	.3593
4.19	.4464	.4145	.3207	.3618
4.21	.4361	.4112	.3162	.3543
4.23	.4446	.4173	.3227	.3603
4.26	.4413	.4117	.3197	.3563
4.28	.4385	.4117	.3192	.3558
4.30	.442	.4159	.3207	.3548
5.3	.4417	.4135	.3237	.3598
5.5	.4455	.4164	.3301	.3876
5.7	.4445	.4215	.3187	.3881
5.10	.4436	.4126	.3226	.385
5.12	.4399	.4201	.3212	.3835
5.14	.4417	.4131	.3207	.383
5.17	.4436	.4173	.3232	.3843
5.19	.4375	.4098	.3182	.3514
5.21	.4361	.4079	.3172	.3534
5.24	.4371	.4121	.3197	.3558
5.26	.4352	.4079	.3157	.3509
5.28	.4371	.4107	.3172	.3504
6.3	.438	.4117	.3172	.3534
6.7	.4403	.4182	.3197	.3529
6.9	.4356	.407	.3137	.3499
6.11	.4352	.4084	.3132	.3489
6.14	.4417	.4135	.3182	.3573
6.16	.4403	.4121	.3152	.3509

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #5
33 PLY GRAPHITE-STRATFORD
WEATHERED 9-14-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.0691	.0753	.0618	.0521
12.9	.0795	.0877	.0743	.0609
12.11	.0914	.1009	.0875	.0709
12.14	.1025	.114	.1005	.0821
12.16	.106	.1187	.1055	.0862
12.18	.1142	.127	.1143	.0938
12.21	.1229	.1373	.124	.102
12.23	.1234	.1382	.1253	.1028
1.4	.1365	.1536	.1411	.1171
1.6	.1415	.1587	.1454	.121
1.8	.1455	.1632	.1495	.1238
1.11	.1492	.1675	.1534	.1273
1.13	.1511	.1696	.1558	.1298
1.15	.152	.1707	.1567	.1303
1.18	.1578	.1771	.1621	.1359
1.2	.1601	.1794	.1644	.1381
1.22	.1624	.1822	.167	.1402
1.25	.1624	.1822	.167	.1404
1.27	.1668	.1869	.1716	.1445
2.1	.1628	.1833	.1686	.1409
2.3	.1664	.1867	.172	.1441
2.5	.1682	.1888	.174	.1454
2.8	.1705	.1914	.1759	.1476
2.1	.1699	.191	.1755	.1461
2.12	.1726	.1938	.1789	.1499
2.15	.1733	.1944	.1796	.1499
2.17	.1743	.1957	.1807	.1508
2.19	.1741	.1959	.1809	.151
2.22	.1804	.2036	.1889	.1582
2.24	.1753	.1972	.182	.1521
2.26	.1797	.2023	.1865	.1562
3.1	.1818	.2045	.1891	.159
3.3	.1812	.204	.1884	.1575

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #5
33 PLY GRAPHITE-STRATFORD
WEATHERED 9-14-79 TO 11-4-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.15	.1758	.1976	.1824	.1525
3.17	.176	.1983	.1841	.1521
3.19	.1772	.1993	.1841	.153
3.22	.177	.1998	.185	.1525
3.24	.1785	.201	.1858	.1549
3.26	.1753	.1978	.1826	.1519
3.29	.1829	.2053	.1895	.1584
3.31	.1816	.2036	.1887	.1566
4.2	.1806	.2027	.1876	.1562
4.6	.181	.2038	.188	.1573
4.8	.1835	.2064	.1906	.1588
4.12	.1837	.207	.1921	.1601
4.14	.182	.2053	.19	.1582
4.16	.1849	.2081	.1928	.1605
4.19	.1822	.2077	.1938	.1614
4.21	.1839	.2079	.1902	.1584
4.23	.1831	.2072	.1912	.1584
4.26	.1793	.2038	.1882	.1558
4.28	.1785	.2017	.1865	.1553
4.3	.181	.2042	.1882	.1564
5.3	.1806	.2038	.1999	.1566
5.5	.1833	.207	.1925	.1584
5.7	.1824	.2049	.1889	.1579
5.10	.1812	.2051	.1891	.1541
5.12	.1814	.2038	.1858	.1562
5.14	.1776	.2008	.1856	.1525
5.17	.1795	.2025	.1878	.1547
5.19	.1745	.1983	.183	.1502
5.21	.1728	.1972	.183	.1486
5.24	.1766	.2004	.1854	.1519
5.26	.1724	.1961	.1811	.1486
5.28	.1716	.1957	.1809	.1467
6.3	.1739	.1963	.1809	.1482
6.7	.1745	.1968	.1817	.1469
6.9	.1716	.1929	.1794	.1448
6.11	.1714	.1942	.1791	.1448
6.14	.1735	.1942	.1798	.1456
6.16	.1685	.191	.1766	.1441

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #6
5 PLY KEVLAR-STRATFORD
WEATHERED 8-29-79 TO 11-4-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.7318	.7457	.7496	.7117
12.9	.8995	.9201	.9381	.8834
12.11	1.0367	1.0629	1.0919	1.0173
12.14	1.1529	1.1816	1.2046	1.1325
12.16	1.2063	1.241	1.2566	1.1932
12.18	1.2577	1.2911	1.3042	1.2329
12.21	1.3244	1.3597	1.3757	1.302
12.23	1.3359	1.3727	1.3822	1.3083
1.4	1.395	1.4209	1.4212	1.3439
1.6	1.4197	1.445	1.4364	1.3564
1.8	1.4369	1.456	1.4515	1.3669
1.11	1.4483	1.4821	1.4667	1.3857
1.13	1.4578	1.4858	1.4667	1.3857
1.15	1.4655	1.4951	1.4645	1.3899
1.18	1.4883	1.5197	1.4884	1.4088
1.2	1.4902	1.5211	1.4754	1.4004
1.22	1.5055	1.5322	1.484	1.4067
1.25	1.5055	1.5285	1.4689	1.4004
1.27	1.5245	1.5453	1.484	1.4109
2.1	1.4788	1.4988	1.4299	1.3627
2.3	1.496	1.5155	1.445	1.3732
2.5	1.4979	1.5155	1.4407	1.3772
2.8	1.496	1.51	1.4429	1.3711
2.1	1.4883	1.5007	1.4255	1.3564
2.12	1.5017	1.5118	1.4364	1.3648
2.15	1.4979	1.5137	1.4385	1.369
2.17	1.4998	1.5081	1.4342	1.3669
2.19	1.4979	1.5081	1.4255	1.3648
2.22	1.4769	1.4914	1.3995	1.3125
2.24	1.4979	1.5007	1.4125	1.3564
2.26	1.5226	1.5266	1.4385	1.3753
3.1	1.5283	1.5266	1.4364	1.3795
3.3	1.5264	1.5211	1.4364	1.3732

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #7
14 PLY GRAPHITE-STRATFORD
WEATHERED 11-6-79 TO 11-23-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.1379	.1418	.1023	.0983
12.9	.1628	.1662	.1189	.1225
12.11	.1877	.1921	.1408	.137
12.14	.2084	.2133	.1579	.1429
12.16	.2229	.2288	.1729	.1687
12.18	.2369	.2428	.1847	.1805
12.21	.2582	.264	.2024	.1966
12.23	.2618	.2682	.2072	.203
1.4	.2971	.3039	.2425	.2374
1.6	.3074	.3137	.2495	.2433
1.8	.3152	.321	.2559	.2487
1.11	.3235	.3298	.2629	.2562
1.13	.3297	.3355	.2677	.2605
1.15	.3328	.3391	.2709	.2648
1.18	.3437	.3494	.28	.2734
1.2	.3468	.3531	.2848	.2782
1.22	.3525	.3593	.2896	.2831
1.25	.3567	.3624	.2923	.2858
1.27	.3629	.3686	.2982	.2911
2.1	.3603	.366	.2977	.2906
2.3	.3681	.3738	.3036	.297
2.5	.3728	.3779	.3084	.3003
2.8	.3753	.3805	.3089	.3019
2.1	.3759	.381	.31	.3024
2.12	.381	.3867	.3148	.3067
2.15	.3847	.3898	.3175	.3094
2.17	.3873	.3914	.3196	.3121
2.19	.3883	.394	.3212	.3137
2.22	.3966	.4007	.3282	.3201
2.24	.2945	.3997	.3266	.3174
2.26	.4059	.4069	.3319	.3239
3.1	.4054	.4105	.3357	.3271
3.3	.407	.4095	.3367	.3276

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #7
14 PLY GRAPHITE-STRATFORD
WEATHERED 11-6-79 TO 11-23-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.15	.4002	.4028	.3287	.3207
3.17	.3992	.4048	.3309	.3223
3.19	.4018	.4064	.3325	.3244
3.22	.4033	.4079	.3335	.3266
3.24	.4049	.41	.3346	.3276
3.26	.4013	.4059	.333	.3233
3.29	.4122	.4141	.3405	.3325
3.31	.4096	.4157	.3416	.3336
4.2	.4106	.4147	.3394	.3319
4.6	.4132	.4157	.3405	.333
4.8	.4158	.4209	.3448	.3368
4.12	.4173	.423	.3469	.3384
4.14	.4147	.4198	.3442	.3379
4.16	.4189	.4224	.3464	.3384
4.19	.4184	.4245	.3496	.3454
4.21	.4179	.4235	.3453	.333
4.23	.4189	.4255	.348	.3379
4.26	.4122	.4178	.3432	.3336
4.28	.4137	.4167	.3416	.3325
4.30	.4179	.4209	.3432	.3373
5.3	.4163	.4219	.3459	.3379
5.5	.4241	.4255	.3437	.3411
5.7	.4122	.4188	.3416	.3325
5.10	.4111	.4235	.3464	.34
5.12	.4158	.4204	.3453	.3352
5.14	.4147	.4178	.3416	.3341
5.17	.4147	.4198	.3426	.3362
5.19	.407	.411	.3357	.3293
5.21	.409	.4126	.34	.3255
5.24	.4116	.4162	.3389	.3309
5.26	.4085	.41	.3357	.3276
5.28	.4065	.4116	.3367	.3271
6.3	.4096	.4136	.3367	.3276
6.7	.4101	.4141	.3362	.3287
6.9	.4065	.4131	.3357	.3276
6.11	.4075	.4131	.3357	.3271
6.14	.407	.4152	.3394	.3303
6.16	.4059	.4095	.333	.3228

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #8
5 PLY KEVLAR-STRATFORD
WEATHERED 8-29-79 TO 11-23-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
12.7	.84	.8284	.817	.7933
12.9	1.0202	1.0108	1.0099	.9857
12.11	1.1698	1.1575	1.1691	1.1414
12.14	1.2888	1.2792	1.2886	1.2581
12.16	1.3609	1.3472	1.3514	1.323
12.18	1.4168	1.4009	1.4038	1.3705
12.21	1.4816	1.4796	1.4666	1.4289
12.23	1.4997	1.4885	1.4729	1.4375
1.4	1.5537	1.5458	1.5085	1.4721
1.6	1.5736	1.569	1.5253	1.4829
1.8	1.5844	1.612	1.5274	1.4916
1.11	1.6096	1.6352	1.5484	1.511
1.13	1.6132	1.646	1.5484	1.511
1.15	1.6168	1.646	1.5463	1.5067
1.18	1.6457	1.671	1.5651	1.5305
1.2	1.6511	1.671	1.5588	1.5283
1.22	1.6619	1.6818	1.5546	1.5326
1.25	1.6565	1.6818	1.5274	1.5132
1.27	1.6691	1.6943	1.5525	1.5326
2.1	1.6258	1.6513	1.4786	1.4786
2.3	1.6475	1.671	1.4981	1.4981
2.5	1.6475	1.671	1.5148	1.4937
2.8	1.6493	1.6782	1.5127	1.4894
2.1	1.6421	1.671	1.5002	1.4829
2.12	1.6511	1.6853	1.5106	1.4829
2.15	1.6493	1.6925	1.5106	1.4829
2.17	1.6493	1.6925	1.5044	1.4743
2.19	1.6511	1.6925	1.5044	1.4743
2.22	1.6493	1.68	1.4876	1.4527
2.24	1.6547	1.6907	1.4981	1.4678
2.26	1.6691	1.7157	1.5127	1.4851
3.1	1.6763	1.7229	1.5127	1.4764
3.3	1.6763	1.7211	1.5127	1.4764

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #9
6 PLY GRAPHITE-WEST PALM BEACH
WEATHERED 10-15-79 TO 12-16-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
1.25	.4005	.4044	.3018	.345
1.27	.5847	.5123	.4619	.4506
2.1	.6535	.6673	.6259	.6059
2.3	.6979	.7134	.678	.653
2.5	.7378	.755	.7177	.6899
2.8	.7822	.7988	.7624	.7319
2.1	.8055	.8235	.7885	.7523
2.12	.8355	.8527	.8158	.7778
2.15	.8621	.8842	.8481	.8061
2.17	.8821	.9033	.8655	.8185
2.19	.8932	.9179	.8804	.8372
2.22	.9243	.9448	.9065	.8541
2.24	.9342	.9538	.9164	.8656
2.26	.9509	.974	.9338	.8809
3.1	.9675	.9898	.9524	.8949
3.3	.9775	.9999	.9599	.9012
3.5	.9797	1.0021	.9624	.9038
3.8	.9908	1.0145	.9711	.9102
3.10	.9975	1.019	.9798	.9127
3.12	.9864	1.0078	.9698	.9038
3.15	.9953	1.0235	.9798	.9127
3.17	.9975	1.0235	.981	.914
3.19	1.0041	1.0302	.9897	.9191
3.22	1.0108	1.0358	.9934	.9229
3.24	1.0163	1.0426	.9971	.9254
3.26	1.0041	1.0291	.9897	.9165

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL #9
6 PLY GRAPHITE-WEST PALM BEACH
WEATHERED 10-15-79 TO 12-16-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.29	1.0363	1.0583	1.0158	.942
3.31	1.0241	1.0516	1.0058	.9292
4.2	1.0319	1.0538	1.0096	.9343
4.6	1.0341	1.0617	1.0145	.9356
4.8	1.0396	1.0628	1.0183	.942
4.12	1.0419	1.0673	1.0207	.9433
4.14	1.0374	1.0628	1.0195	.9394
4.16	1.0419	1.0684	1.0232	.942
4.19	1.0396	1.0673	1.0183	.942
4.21	1.033	1.0594	1.017	.9311
4.23	1.0408	1.0684	1.022	.9394
4.26	1.0241	1.0527	1.0108	.9242
4.28	1.0352	1.061	1.012	.9292
4.30	1.0363	1.0561	1.0183	.9369
5.3	1.0363	1.0662	1.0158	.9292
5.5	1.0518	1.0668	1.0207	.9509
5.7	1.0385	1.0673	1.017	.9318
5.10	1.0385	1.0774	1.0096	.9292
5.12	1.0308	1.0459	1.012	.928
5.14	1.0308	1.0606	1.0096	.9242
5.17	1.0374	1.0673	1.0108	.9292

TABLE XVII. CONTINUED

% MOISTURE DESORBED FROM PANEL 10
5 PLY KEVLAR-WEST PALM BEACH
WEATHERED 10-15-79 TO 12-16-81

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
1.25	.8019	.7715	.8416	.8155
1.27	1.0391	.9872	1.0805	1.054
2.1	1.3117	1.2377	1.3567	1.3308
2.3	1.3931	1.309	1.4377	1.4096
2.5	1.448	1.3601	1.475	1.4479
2.8	1.5082	1.4241	1.5364	1.5033
2.10	1.5294	1.4442	1.5539	1.5246
2.12	1.5649	1.479	1.5868	1.5565
2.15	1.5843	1.5027	1.6043	1.5757
2.17	1.5949	1.5119	1.6065	1.58
2.19	1.6038	1.5265	1.6175	1.5885
2.22	1.6197	1.5393	1.6262	1.5949
2.24	1.6303	1.5448	1.6262	1.5949
2.26	1.6498	1.5667	1.6503	1.6226
3.1	1.6622	1.5814	1.6569	1.6353
3.3	1.6622	1.5814	1.6569	1.6353
3.5	1.6587	1.574	1.646	1.6268
3.8	1.6569	1.5704	1.6394	1.614
3.10	1.6604	1.5759	1.6416	1.6119
3.12	1.6286	1.543	1.5999	1.5714
3.15	1.6392	1.5521	1.6065	1.5821
3.17	1.641	1.5521	1.6109	1.5842
3.19	1.641	1.5539	1.6131	1.5821
3.22	1.6339	1.5503	1.6065	1.5672
3.24	1.6445	1.5631	1.6109	1.5757
3.26	1.6144	1.532	1.578	1.5416

TABLE XVII. CONCLUDED

% MOISTURE DESORBED FROM PANEL 10
5 PLY KEVLAR-WEST PALM BEACH
WEATHERED 10-15-79 TO 12-16-81
(CONTINUED)

DATE	COUPON I	COUPON II	COUPON III	COUPON IV
3.29	1.664	1.5832	1.624	1.5927
3.31	1.6427	1.6889	1.5999	1.5693
4.2	1.641	1.6871	1.6021	1.5763
4.6	1.6463	1.6907	1.6043	1.5714
4.8	1.6498	1.6962	1.6175	1.5864
4.12	1.6481	1.6907	1.6065	1.5757
4.14	1.6339	1.6798	1.5955	1.5608
4.16	1.6457	1.6816	1.5955	1.5672
4.19	1.6233	1.667	1.5824	1.548
4.21	1.5985	1.6432	1.5539	1.5225
4.23	1.625	1.6724	1.5758	1.5459
4.26	1.5843	1.6341	1.5386	1.5097
4.28	1.5967	1.6396	1.5451	1.514
4.30	1.6091	1.6524	1.5517	1.5289
5.3	1.602	1.6469	1.5451	1.514
5.5	1.6215	1.639	1.5429	1.5267
5.7	1.6056	1.6341	1.5495	1.5289
5.10	1.618	1.6396	1.4969	1.5544
5.12	1.5879	1.6213	1.5188	1.4991
5.14	1.5772	1.6195	1.5188	1.4905
5.17	1.5826	1.6286	1.5276	1.4905

TABLE XVIII. AVERAGED MOISTURE DESORPTION MEASUREMENTS OF TEN EXPOSED PANELS, STRATFORD AND WEST PALM BEACH

MOISTURE DESORBED FROM PANEL #1
6 PLY GRAPHITE-WEST PALM BEACH
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
0	0	1.11	.9437	2.8	1.0021
12.7	.4059	1.13	.9522	2.1	1.0006
12.9	.4991	1.15	.9592	2.12	1.01
12.11	.5811	1.18	.9731	2.15	1.0101
12.14	.6629	1.2	.9765	2.17	1.0131
12.16	.7079	1.22	.9856	2.19	1.0123
12.18	.7508	1.25	.9891	2.22	1.0133
12.21	.8003	1.27	.9982	2.24	1.0104
12.23	.8184	2.1	.9973	2.26	1.022
1.4	.9017	2.3	.9999	3.1	1.0276
1.6	.9135	2.5	1.0008	3.3	1.0182
1.8	.9277				

TABLE XVIII. CONTINUED

% MOISTURE DESORBED FROM PANEL #2
33 PLY GRAPHITE-WEST PALM BEACH
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
12.4	0	2.10	.245	4.19	.2731
12.7	.0813	2.12	.2495	4.21	.2717
12.9	.0983	2.15	.251	4.23	.2771
12.11	.1158	2.17	.2526	4.26	.2712
12.14	.1331	2.19	.2534	4.28	.2723
12.16	.1406	2.22	.2522	4.30	.2756
12.18	.1503	2.24	.2551	5.3	.2719
12.21	.1634	2.26	.2606	5.5	.2776
12.23	.1687	3.1	.2649	5.7	.2776
1.4	.1929	3.3	.2626	5.10	.2766
1.6	.1984	3.15	.2585	5.12	.2774
1.8	.204	3.17	.2604	5.14	.2747
1.11	.2099	3.19	.2613	5.17	.2778
1.13	.2136	3.22	.264	5.19	.274
1.15	.2162	3.24	.2639	5.21	.27007
1.18	.2226	3.26	.2621	5.24	.27622
1.20	.2265	3.29	.2686	5.26	.27047
1.22	.2296	3.31	.2697	5.28	.27145
1.25	.2309	4.2	.2676	6.3	.27335
1.27	.2365	4.6	.2702	6.7	.27312
2.1	.2366	4.8	.2716	6.9	.2734
2.3	.2403	4.12	.2733	6.11	.2732
2.5	.2419	4.14	.2715	6.14	.27332
2.8	.2449	4.16	.2754	6.16	.27197

TABLE XVIII. CONTINUED

% MOISTURE DESORBED FROM PANEL #3
6 PLY GRAPHITE-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
0	0	1.11	.7625	2.8	.8298
12.7	.3044	1.13	.7654	2.1	.8281
12.9	.3735	1.15	.7772	2.12	.8348
12.11	.4396	1.18	.7931	2.15	.8404
12.14	.5025	1.2	.7999	2.17	.8414
12.16	.549	1.22	.8083	2.19	.8433
12.18	.5733	1.25	.8129	2.22	.8185
12.21	.6163	1.27	.8235	2.24	.8488
12.23	.6364	2.1	.8124	2.26	.8648
1.4	.716	2.3	.8274	3.1	.8624
1.6	.7296	2.5	.8299	3.3	
1.8	.7469				

TABLE XVIII. CONTINUED

% MOISTURE DESORBED FROM PANEL #4
14 PLY GRAPHITE-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
12.4	0	2.10	.337	4.19	.3859
12.7	.1112	2.12	.3428	4.21	.3795
12.9	.1319	2.15	.3463	4.23	.3862
12.11	.1553	2.17	.3492	4.26	.3823
12.14	.1776	2.19	.3512	4.28	.3813
12.16	.1899	2.22	.3439	4.30	.3834
12.18	.2054	2.24	.3549	5.3	.3847
12.21	.2222	2.26	.3623	5.5	.3876
12.23	.2276	3.1	.3668	5.7	.3881
1.4	.263	3.3	.3655	5.10	.385
1.6	.2704	3.15	.334	5.12	.3835
1.8	.278	3.17	.3632	5.14	.383
1.11	.2856	3.19	.3637	5.17	.3843
1.13	.2907	3.22	.3685	5.19	.37922
1.15	.2948	3.24	.3688	5.21	.37865
1.18	.3047	3.26	.3666	5.24	.38117
1.20	.3093	3.29	.3759	5.26	.37742
1.22	.3142	3.31	.3748	5.28	.37885
1.25	.3176	4.2	.3747	6.3	.38007
1.27	.3247	4.6	.3779	6.7	.38277
2.1	.3229	4.8	.3808	6.9	.37655
2.3	.3303	4.12	.3826	6.11	.37642
2.5	.3341	4.14	.3812	6.14	.38267
2.8	.337	4.16	.3836	6.16	.37962

TABLE XVIII. CONTINUED

MOISTURE DESORBED FROM PANEL #5
33 PLY GRAPHITE-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
12.4	0	2.10	.1706	4.19	.1863
12.7	.0646	2.12	.1738	4.21	.1851
12.9	.0756	2.15	.1743	4.23	.185
12.11	.0877	2.17	.1754	4.26	.1818
12.14	.0998	2.19	.1755	4.28	.1805
12.16	.1041	2.22	.1828	4.30	.1825
12.18	.1123	2.24	.1767	5.3	.1852
12.21	.1216	2.26	.1812	5.5	.1853
12.23	.1224	3.1	.1836	5.7	.1835
1.4	.1371	3.3	.1828	5.10	.1824
1.6	.1417	3.15	.1771	5.12	.1818
1.8	.1455	3.17	.1776	5.14	.1791
1.11	.1494	3.19	.1784	5.17	.1811
1.13	.1516	3.22	.1786	5.19	.1765
1.15	.1524	3.24	.1801	5.21	.1754
1.18	.1582	3.26	.1769	5.24	.17857
1.20	.1605	3.29	.184	5.26	.17455
1.22	.163	3.31	.1826	5.28	.17372
1.25	.163	4.2	.1818	6.3	.17482
1.27	.1675	4.6	.1825	6.7	.17497
2.1	.1639	4.8	.1848	6.9	.17217
2.3	.1673	4.12	.1857	6.11	.17237
2.5	.1691	4.14	.1839	6.14	.17327
2.8	.1714	4.16	.1866	6.16	.17005

TABLE XVIII. CONTINUED

MOISTURE DESORBED FROM PANEL #6
5 PLY KEVLAR-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
0	0	1.11	1.4457	2.8	1.455
12.7	.7347	1.13	1.449	2.1	1.4427
12.9	.9103	1.15	1.4538	2.12	1.4537
12.11	1.0522	1.18	1.4762	2.15	1.4548
12.14	1.1679	1.2	1.4718	2.17	1.4523
12.16	1.2243	1.22	1.4821	2.19	1.4491
12.18	1.2715	1.25	1.4758	2.22	1.4201
12.21	1.3405	1.27	1.4912	2.24	1.4419
12.23	1.3498	2.1	1.4426	2.26	1.4658
1.4	1.3953	2.3	1.4574	3.1	1.4677
1.6	1.4144	2.5	1.4579	3.3	1.4643
1.8	1.4278				

TABLE XVIII. CONTINUED

MOISTURE DESORBED FROM PANEL #7
14 PLY GRAPHITE-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
12.4	0	2.10	.3423	4.19	.3845
12.7	.1201	2.12	.3473	4.21	.3799
12.9	.1426	2.15	.3504	4.23	.3826
12.11	.1644	2.17	.3526	4.26	.3767
12.14	.1806	2.19	.3543	4.28	.3761
12.16	.1983	2.22	.3614	4.30	.3798
12.18	.2112	2.24	.3596	5.3	.3805
12,21	.2303	2.26	.3672	5.5	.3836
12.23	.2351	3.1	.3697	5.7	.3763
1.4	.2702	3.3	.3702	5.10	.3803
1.6	.2785	3.15	.3631	5.12	.3792
1.8	.2852	3.17	.3643	5.14	.3771
1.11	.2931	3.19	.3663	5.17	.3783
1.13	.2984	3.22	.3478	5.19	.37075
1.15	.3019	3.24	.3693	5.21	.37177
1.18	.3116	3.26	.3659	5.24	.3744
1.20	.3157	3.29	.3748	5.26	.37045
1.22	.3211	3.31	.3751	5.28	.37047
1.25	.3243	4.2	.3742	6.3	.37187
1.27	.3302	4.6	.3756	6.7	.37227
2.1	.3287	4.8	.3796	6.9	.37072
2.3	.3356	4.12	.3814	6.11	.37085
2.5	.3399	4.14	.3792	6.14	.37297
2.8	.3417	4.16	.3815	6.16	.3678

TABLE XVIII. CONTINUED

MOISTURE DESORBED FROM PANEL #8
5 PLY KEVLAR-STRATFORD
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
0	0	1.11	1.5761	2.8	1.5824
12.7	.8197	1.13	1.5797	2.1	1.5741
12.9	1.0067	1.15	1.579	2.12	1.5825
12.11	1.1595	1.18	1.6031	2.15	1.5838
12.14	1.2787	1.2	1.6023	2.17	1.5801
12.16	1.3456	1.22	1.6077	2.19	1.5806
12.18	1.398	1.25	1.5947	2.22	1.5974
12.21	1.4642	1.27	1.6121	2.24	1.5778
12.23	1.4747	2.1	1.5656	2.26	1.5957
1.4	1.52	2.3	1.5839	3.1	1.5971
1.6	1.5377	2.5	1.5818	3.3	1.5966
1.8	1.5539				

TABLE XVIII. CONTINUED

% MOISTURE DESORBED FROM PANEL #9 6 PLY GRAPHITE-WEST PALM BEACH AVERAGE OF DATA FROM FOUR COUPONS					
DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
1.22	0	3.3	.9596	4.12	1.0183
1.25	.3629	3.5	.962	4.14	1.0148
1.27	.5024	3.8	.9717	4.16	1.0189
2.1	.6382	3.10	.9773	4.19	1.0168
2.3	.6856	3.12	.967	4.21	1.0106
2.5	.7251	3.15	.9778	4.23	1.0177
2.8	.7688	3.17	.979	4.26	1.003
2.10	.7925	3.19	.9858	4.28	1.0094
2.12	.8205	3.22	.9907	4.30	1.0119
2.15	.8501	3.24	.9954	5.3	1.0119
2.17	.8674	3.26	.9849	5.5	1.0078
2.19	.8822	3.29	1.0131	5.7	1.0137
2.22	.9074	3.31	1.0027	5.10	1.0137
2.24	.9175	4.2	1.0074	5.12	1.0042
2.26	.9349	4.6	1.0115	5.14	1.0063
3.1	.9512	4.8	1.0157	5.17	1.0112

TABLE XVIII. CONCLUDED

% MOISTURE DESORBED FROM PANEL 10
5 PLY KEVLAR-WEST PALM BEACH
AVERAGE OF DATA FROM FOUR COUPONS

DATE	% WT. CHANGE	DATE	% WT. CHANGE	DATE	% WT. CHANGE
1.22	0	3.3	1.634	4.12	1.6303
1.25	.8076	3.5	1.6264	4.14	1.6175
1.27	1.0402	3.8	1.6202	4.16	1.62
2.1	1.3092	3.10	1.6225	4.19	1.6052
2.3	1.3874	3.12	1.5857	4.21	1.5795
2.5	1.4328	3.15	1.595	4.23	1.6048
2.8	1.493	3.17	1.5971	4.26	1.5667
2.10	1.513	3.19	1.5975	4.28	1.5739
2.12	1.5468	3.22	1.5895	4.30	1.5855
2.15	1.5668	3.24	1.5986	5.3	1.577
2.17	1.5733	3.26	1.5665	5.5	1.5637
2.19	1.5841	3.29	1.616	5.7	1.5795
2.22	1.595	3.31	1.6252	5.10	1.5772
2.24	1.5991	4.2	1.626	5.12	1.5568
2.26	1.6224	4.6	1.6282	5.14	1.5515
3.1	1.634	4.8	1.6375	5.17	1.5573

TABLE XIX. SUMMARY OF COUPON TEST RESULTS

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/	SBS, Static	0_8	23	23.8	(75)	110.3	(16.0)	4.6	Qualification baseline, RTD
Epoxy	SBS, Static	0_6	19			113.1	(16.4)	5.7	Panel Coupons, Baseline RTD
AS/6350	SBS, Static	0_6	18			100.7	(14.6)	5.0	2 Years, Stratford
	SBS, Static	0_6	18			96.5	(14.0)	3.4	2 Years, West Palm Beach
	SBS, Static	0_6	19	23.8	(75)	90.9	(13.2)	3.0	2 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	102.0	(14.8)	4.1	2 Years, Stratford
	SBS, Static	0_{14}	13	76.6	(170)	73.8	(10.7)	2.7	2 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	17	23.8	(75)	86.9	(12.6)	3.6	Panel Coupon, Baseline RTD
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	15	23.8	(75)	83.4	(12.1)	5.3	2 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	15	23.8	(75)	84.1	(12.2)	5.0	2 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	18	23.8	(75)	631.5	(91.6)	6.0	Panel Coupon, Baseline RTD
Kevlar/	Tension,Static	$(0/90)_5$	9	23.8	(75)	666.7	(96.7)	8.7	2 Years, Stratford
Epoxy	Tension,Static	$(0/90)_5$	10	23.8	(75)	632.2	(91.7)	6.5	2 Years, West Palm Beach
285/5143	Tension,Static	$(0/90)_5$	10	23.8	(170)	677.7	(98.3)	6.6	2 Years, Stratford
Grahpite/	Flex,Static	0_6	20	23.8	(75)	2127.0	(308.5)	5.9	Panel Coupon Baseline RTD
Epoxy	Flex,Static	0_6	18			1782.3	(258.5)	4.4	2 Years, West Palm Beach
AS/6350	Flex,Static	0_6	15			2011.2	(291.7)	5.8	2 Years, West Palm Beach
	Flex,Static	0_6	12			1876.7	(272.2)	7.5	2 Years, Stratford
	Flex,Static	0_{14}	18			1449.9	(210.3)	5.6	Panel Coupon Baseline RTD
	Flex,Static	0_{14}	18			1375.5	(199.5)	3.2	2 Years, Stratford
	Flex,Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	13			1209.3	(175.4)	5.5	Panel Coupon Baseline RTD
	Flex,Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18			1260.3	(182.8)	6.7	2 Years, Stratford
	Flex,Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	1246.6	(180.8)	5.9	2 Years, West Palm Beach

TABLE XIX. (CONTINUED)

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/	SBS, Static	0_8	3	23.8	(75)	110.3	(16.1)	2.1	1½ Yrs, Gulf Coast, Stabilizer
Epoxy	SBS, Fatigue	0_8	10			64.1	(9.3)[1]		Qualification Baseline RTD
AS/6350	SBS, Fatigue	0_8	4			58.6	(8.5)[1]		2 Years, Stratford
	SBS, Fatigue	0_{14}	10			53.8	(7.8)[1]		1½ Yrs, Gulf Coast, Stabilizer
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$		9			41.4	(6.0)[1]	Panel Coupon Baseline RTD
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$		12			43.4	(6.3)[1]	2 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$		10			42.1	(6.1)[1]	2 Years, West Palm Beach
Kevlar/	SBS, Fatigue	$(0/90)_6$	5	23.8	(75)	10.3	(1.5)[1]		1½ Yrs, Gulf Coast, Stabilizer
Epoxy	Tension, Static	$(0/90)_6$	14			590.2	(85.6)	4.4	Qualification Baseline RTD
285/5143	Tension, Static	$(0.90)_5$	18	23.8	(75)	631.6	(91.6)	6.1	Panel Coupon Baseline RTD

Note:

1. Maximum stress in cycle, R = 0.1, at 10^7 cycles.

SECTION 8.0 REFERENCES

1. Murry, J.E. "F/A-18 Composite Development Tests" Report MDCA 7052, January 1981.

2. Anon "Environmental Sensitivity of Advanced Composites" Contract F33615-76-5324 Fifth Quarterly Progress Report, December 15, 1977 (Grumman Aerospace Corporation Report).

3. Bergmann, H.W. and Nitsch, P. "Predictability of Moisture Absorption in Graphite/Epoxy Sandwich Panels" Published in Effect of Service Environment on Composite Materials AGARD Conference Proceedings No. CP-288, April 1980.

4. Kays, A. "Determination of Moisture Content in Composites by Dielectric Measurements" Technical Report AFFDL-TR-3086, June 1959.

5. Rich, M. and Maass, D. "Developing Design Allowables for Composite Helicopter Structures" ASTM STP734 C.C. Chamis Editor, American Society for Testing and Materials, 1981, pp 181-194.

6. Tenney, D. and Unham, J. "Analytical Prediction of Moisture Absorption in Composites" Journal of Aircraft, Vol. 15 No. 3, March 1978, pp 148-154.

7. Pride, R. "Environmental Effects on Composites for Aircraft" NASA TM 7816 May 1978.

8. Tompkins, S., Tenney, D., and Unham, J. "Prediction of Moisture and Temperature Changes in Composites During Atmospheric Exposure" NASA TM 78711, April 1978.

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15. Supplementary Notes

Langley technical monitor: Donald Baker

16. Abstract

This first interim report presents the technical background for including environmental effects in the design of helicopter composite structures, and test results after approximately two year field exposure of components and panels.

Composite structural components were removed from Sikorsky S-76 helicopters commercially operated in the Gulf Coast region of Louisiana. Fatigue tests were conducted for a graphite/epoxy tail rotor spar and static test for a graphite/epoxy and Kevlar/epoxy stabilizer.

Graphite/epoxy and Kevlar/epoxy panels are being exposed to the outdoor environment in Stratford, Connecticut and West Palm Beach, Florida. For this reporting period the two year panels were returned, moisture measurements taken, and strength tests conducted.

Results are compared with initial type certificate strengths for components and with initial laboratory coupon tests for the exposed panels. Comparisons are also presented with predicted and measured moisture contents.

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