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FLIGHT SERVICE EVALUATION OF COMPOSITE HELICOPTER COMPONENTS

Final Report
FEBRUARY 1981 through NOVEMBER 1990

George H. Mardoian and Maureen B. Ezzo

SIKORSKY AIRCRAFT
DIVISION OF UNITED TECHNOLOGIES CORPORATION
Stratford, Connecticut 06601-1381

CONTRACT NO. NAS1-16542
NOVEMBER 1990

National Aeronautics and
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Langley Research Center
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c	Moisture concentration in a material, g/mm^3 (g/in^3)
D_o, R_o	Material constants in diffusivity equations
D_x	Mass diffusivity in the x direction, mm^2/sec (in^2/sec)
DLL	Design limit load
EF	Environmental factor, strength ratio to RTD value
ETD	Elevated temperature dry
ETW	Elevated temperature wet
M	Moment
ΔM	Moisture absorbed, percent weight
ΔM_s	Saturation moisture absorbed, percent weight, at a given RH
$\Delta M_{s,100}$	Saturation moisture absorbed, percent weight, at 100 percent RH
N	Cycles
RH	Relative humidity, percent
RTD	Room temperature dry
RTW	Room temperature wet
s	Laminate thickness, mm (in)

FOREWORD

This final technical report was prepared by the Sikorsky Aircraft Division of United Technologies Corporation, Stratford, Connecticut 06601-1381, under NASA Contract NAS1-16542 and covers the work performed during the period from February 1981 through November 1990. This program was jointly funded by the Materials Division of the NASA-Langley Research Center and the Aerostructures Directorate, U.S. Army Research and Technology Activity (AVSCOM). The contract was monitored by Mr. Donald J. Baker of the Aircraft Structures Branch.

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SUMMARY

This program was undertaken to determine the long term environmental effects and the subsequent test results in the design of helicopter composite structures after nine years field exposure of components and panels. Four Sikorsky S-76 horizontal stabilizers and ten tail rotor spars were returned from commercial service in the Gulf Coast region of Louisiana to determine the effects of the operating environment on their performance. Concurrent with the flight component evaluation, materials used in their fabrication were exposed to the environment in ground racks which were tested annually to determine the effects of exposure on physical and mechanical properties. Comparison of the results from field exposed components and panels with laboratory accelerated environmentally conditioned coupons is presented.

This environmental effects on composite materials program was organized into three major categories. The first category detailed in Section 3.1 documents the evaluation of four horizontal stabilizers returned from the field for full scale static and fatigue testing, followed by removal of coupons from the graphite/epoxy reinforcement cap strips for moisture analysis and small scale coupon testing. Data generated from the field exposed S-76 horizontal stabilizers was compared with a room temperature dry tested baseline stabilizer. The second category detailed in Section 3.2 documents the evaluation of ten tail rotor spars, five returned from commercial service for full scale fatigue testing and five for small coupon testing. The fatigue strengths of the in-service exposed tail rotor spars were compared with those tested under room temperature dry conditions for certification. The spar coupon tests consisted of interlaminar (short beam) shear static tests at room temperature and at 170°F, and short beam shear tests in fatigue at room temperature. The results of the spar tests were evaluated to determine the decrease in strength with increased exposure time and flight hours.

The third category presented in Section 4.1, documented the moisture analysis and determination of the mechanical properties of panels retrieved from weathering locations in Stratford, Connecticut and West Palm Beach, Florida. The actual moisture values were compared with predicted values for each laminate configuration. Environmental factors for panels returned from the weathering sites were compared to the S-76 environmental factor trends that had been generated using accelerated moisture conditioning techniques.

The results of 5846 hours of flight time and 91 months of field exposure time on the longest environmentally exposed horizontal stabilizer and 5816 hours of flight time and the maximum 100 months of field exposure on a tail rotor spar did not disclose any meaningful strength reductions. The four horizontal stabilizers removed from service passed the proof load test by meeting the center section torque tube FAA certification and baseline deflection requirements. Full scale fatigue test results of both the horizontal stabilizers and the tail rotor spars indicated no evidential reductions in strength when the data from field exposed components was compared with unused production components and baseline certification data. The results of the panel tests disclosed that the effects of real time environmental exposure on the properties of graphite (AS-1/6350) and Kevlar (285/5143) were accurately predicted by using accelerated moisture conditioning techniques.

Based on the results of this program, it can be concluded that the long term effects of the operating environment did not significantly reduce the strength of the S-76 helicopter components.

1. INTRODUCTION

1.1 Scope

This final flight service report is submitted in accordance with the requirements of contract NAS1-16542, which covers the performance period from February 1981 through November 1990.

Considerable effort has been expended in recent years to explore the potential of composite materials as a means of increasing the structural efficiency and fatigue life of aircraft structures. Accordingly, this program was initiated to determine the long-term effects of the environment on selected components and their composite materials. This report includes evaluation of components exposed to the operating environment under prolonged flight service conditions and also, assessment of the influence of ground based outdoor exposure on the physical and mechanical properties of composite materials.

Tail rotor spars and horizontal stabilizers were periodically returned from the operating environment for full scale static, fatigue and small scale coupon testing. Full scale test results were compared to initial Federal Aviation Administration (FAA) certification data. The amount of moisture absorbed by the components was determined and compared with predicted values.

The in-service components evaluated in this program were obtained from Sikorsky Model S-76 helicopters used in commercial operations in the Gulf Coast Region of Louisiana. The ground based, field exposed panels having the same ply configurations as the components evaluated, were obtained from weathering sites at West Palm Beach, Florida and Stratford, Connecticut. Comparison of the results between field exposed components, panels with real time environmental exposure and panels with laboratory accelerated conditioning is presented. The schedule followed for the return and testing of components and panels, shown in Table I, reflects a 15 month extension not originally included in the program. The extension was required late in the program owing to the long moisture desorption time required and a delay in the start of full scale fatigue testing of the last tail rotor spar.

Work on this contract was initiated in February of 1981. This is the Final Report published to document the results of the entire program. The first annual report, Reference (1), covered the period from March 1981 to April 1982. The second report, Reference (2), documented results from May 1982 to September 1983. The third report, Reference (3), documented the results from October 1983 through December 1985.

Measurements and calculations were made in the U.S. Customary Units. They are presented herein in the International System of Units (SI) with the equivalent values given parenthetically in the U.S. Customary Units.

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

S-76 HELICOPTER
NASA CONTRACT NAS1-16542

	CALENDAR YEAR									
	81	82	83	84	85	86	87	88	89	90
In-Service Component Selection										
Tracking	X	X	X	X	X	X	X	X		
Selection:										
Horizontal Stabilizer	X		X		X		X			
Tail Rotor Spar	X	X	X	X	X	X	X	X		
Tests of In-Service Components										
Horizontal Stabilizers:										
Fatigue Tests, Full Scale			X		X		X			
Static Tests, Full Scale	X				X					
Tail Rotor Spars:										
Fatigue Tests, Full Scale		X	X	X		X		X		
Coupon Tests, Small Scale			XX	X		X			X	
Material Evaluation	X	X	X	X	X	X	X	X	X	X
Analysis of Test Results	X	X	X	X	X	X	X	X	X	X

1.2 Technical Background

Advanced composite materials are being increasingly used throughout industry in commercial, military and space applications because of the advantages provided by their low weight, high strength and stiffness characteristics. As such, the influence of the operational environment on the behavior of composite materials and transport aircraft structures fabricated with these materials has been under evaluation for over 15 years by NASA sponsored programs. However, there is a continuing effort to build a data base and establish confidence in the long-term durability of advanced composite materials to increase the efficiency of rotary and fixed wing structures. Therefore, there is a need for a realistic assessment of the effects of environmental exposure on the static and fatigue strengths of advanced composite materials. This assessment, as described herein, was made through the utilization of primary helicopter structural components subjected to prolonged in-service environmental exposure and significant flight stresses to evaluate the performance and the criteria used for design. The use of high strength and high modulus filament composites has provided significant weight reductions for the Sikorsky Model S-76 commercial helicopter. Figure 1 illustrates the utilization of advanced composites on the aircraft and the extent of the applications.

A major objective of this program was to substantiate procedures for establishing in-service environmental factors for both design and component test verification.

The tasks for this effort were: (1) determination of the strength of composite structural components after in-service use, (2) comparison of the results with initial certification tests, (3) evaluation of the effects of component moisture content, and (4) comparison of the coupon test results for real time and accelerated environmental conditioning. Realistic environmental factors established through flight service and residual strength testing of components will allow more efficient design of composite components for future applications in the helicopter industry.

1.2.1 Environmental Effects

It is generally accepted that the mechanical properties of composite materials are effected by environmental conditions which include absorbed moisture and elevated temperatures.

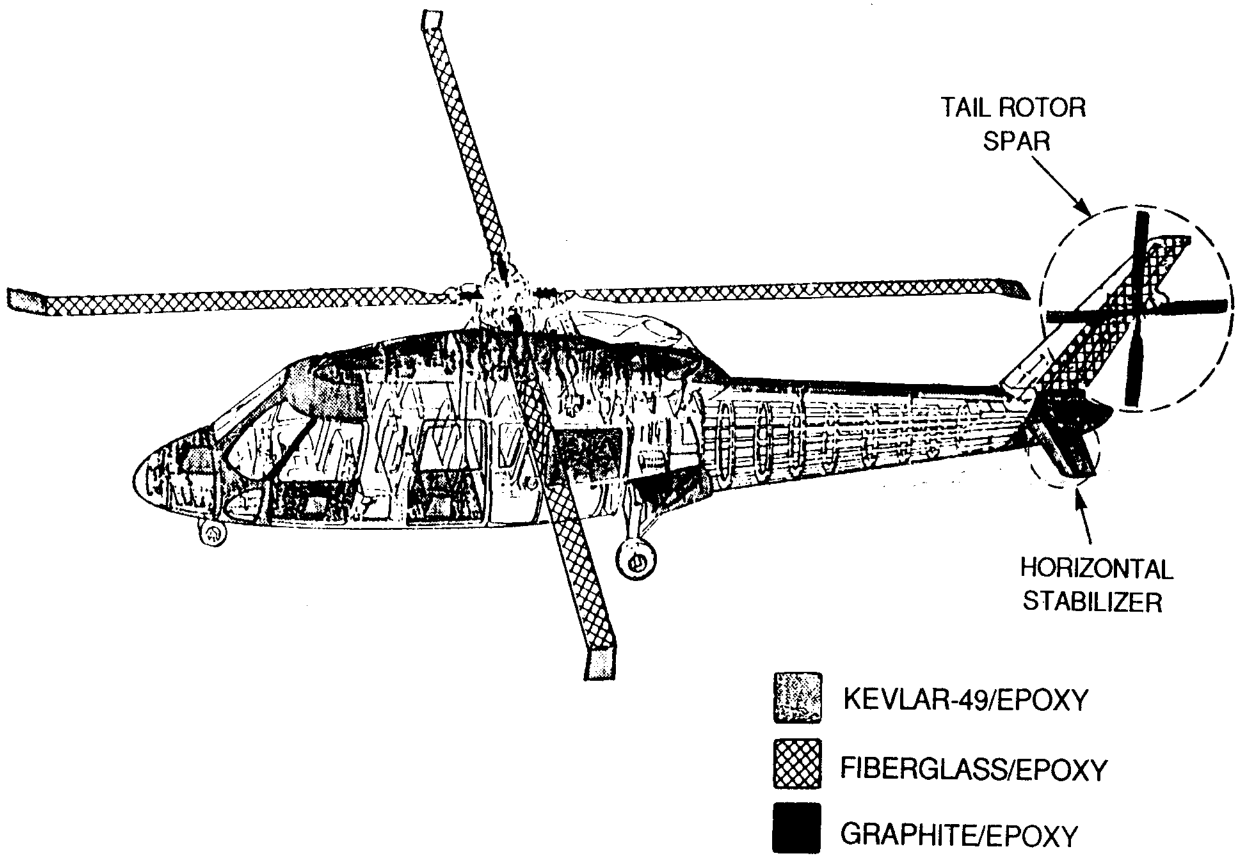


FIGURE 1. APPLICATION OF ADVANCED COMPOSITE MATERIALS FOR SIKORSKY S-76 HELICOPTER.

To utilize composite materials effectively, their response to environmental conditions needs to be defined. Owing to the restrictive times required to examine moisture absorption from real time exposure to environmental conditions, accelerated conditioning techniques must be utilized in characterizing the effects of moisture on material properties. Realistic levels of moisture absorption must be used in the testing of the resin matrix composites, as excessively high levels, easily obtained in a laboratory, may severely reduce composite mechanical properties, Reference (4).

From a survey of data at Sikorsky Aircraft and other sources, Reference (5), the amount of moisture absorbed when a material is fully submerged in a liquid is a constant. When the material is exposed to humid air, the amount of moisture absorbed is a function of the relative humidity, according to the following relationship:

$$\Delta M_s = \Delta M_{s,100} \left(\frac{RH}{100} \right)^b$$

where: ΔM_s is the saturation moisture absorption, percent weight, at a given RH

RH is the relative humidity, percent

$\Delta M_{s,100}$ is the saturation moisture absorption, percent weight, at 100 percent RH

and b is a constant which depends on the material.

Moisture can permeate into a composite laminate by capillary action along the fiber/matrix interface, and through cracks and voids in the resin. However, the primary method of moisture infusion is by surface absorption and diffusion through the matrix. Diffusion in the direction normal to the surface can be described by Fick's law, which has been found to be a reasonable approximation for many resin matrix composites, especially graphite/epoxy laminates by the expression, Reference (6):

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x} \left(D_x \frac{\partial c}{\partial x} \right)$$

where: c is the moisture concentration

t is the time, seconds

D_x is the diffusivity, inch^2/second

and x is the position through the thickness of the panel.

The diffusivity is assumed to be dependent only on temperature: for a given temperature, the diffusivity (diffusion coefficient) may be calculated using the following equation

$$D_x = D_o e^{-R_o/T}$$

where: D_o and R_o are empirical constants for the material

and T is the temperature, degrees Kelvin.

In reviewing moisture absorption data from different sources, there sometimes appears to be differences in results reported for the same fiber/resin systems. Apparent differences may be owing to variations in fiber volume fraction, cure cycle, processing parameters and test conditions.

An additional factor, not generally considered in environmental conditioning is the effect of the stress condition of the structure. Moisture penetrating the composite material by capillary action along the fiber matrix interface can increase owing to the stress condition. Moisture absorbed by this non-Fickian diffusion mechanism may cause leaching or cracking, and may be a significant factor in structures subjected to long term constant stresses under environmental conditions, Reference (7). However, data indicates that the stress effect should be negligible for helicopter structures where the stress time is small compared to the calendar period.

1.2.2 Design Criteria

The horizontal stabilizer, constructed mainly of Kevlar/epoxy with graphite/epoxy beam cap reinforcements is designed by static loads at an elevated temperature of 71°C (160°F) with a saturation moisture level corresponding to 68 percent relative humidity. The elevated temperature criteria is used to account for runway storage and subsequent cool down in flight. The tail rotor spar, an all graphite/epoxy structure, is designed by cyclic fatigue loading at room temperature with the saturation moisture level at 68 percent relative humidity. The tail rotor spar is designed for the large number of cyclic loadings at lower inflight temperatures.

Conservatively, no allowance is made for the time to reach the design moisture condition. The following expression, used to determine the time (t_m) required for a material to attain at least 99.9 percent of its maximum possible moisture content, is insensitive to the moisture content of the environment, but is dependent on the temperature through the diffusivity, D_x.

$$t_m = \frac{0.67\ s^2}{D_x}$$

where: s is the thickness for a material exposed on two sides to the same environment, inches

Using this equation, it can be calculated that the tail rotor spar would not actually reach saturation under field conditions for a minimum of 21 to 42 years, as shown in Figure 2.

The S-76 design moisture criteria used worldwide data from humid areas to project the effective relative humidity. In a NASA survey, Reference (8), moisture measurements were taken from panels located in humid areas to determine moisture absorption characteristics under actual field conditions. A large data base was established for six worldwide conditions (San Francisco, CA; San Diego, CA; Honolulu, HI; and Hampton, VA; in the United States, Frankfurt, Germany, Wellington, New Zealand; and Sao Paulo, Brazil, South America). It was reported that the worldwide moisture absorption was very nearly the same at the specified locations for T300/5208 12 ply graphite/epoxy laminates subject to field environmental conditions. For T300/5208 graphite/epoxy, the observed saturation level was 0.75 percent, corresponding to an effective relative humidity of 68 percent. A 68 percent relative humidity corresponds to saturation moisture levels of 2.2 percent for 285/5143 Kevlar/epoxy and 1.1 percent for AS-1/6350 graphite/epoxy, the moisture levels specified for the S-76 design. The saturation moisture absorption/relative humidity relationship is presented graphically for the three systems in Figure 3.

To evaluate the effects of absorbed moisture and elevated temperatures on the resin matrix composite materials used in the model S-76 helicopter program, accelerated conditioning was implemented in evaluating the static mechanical properties at room temperature dry (RTD), room temperature wet (RTW), elevated temperature dry (ETD) and elevated temperature wet (ETW). Fatigue properties were examined at RTD and RTW. All coupon test results were normalized to a nominal ply thickness for fiber dominated properties (0.012 inches per ply for graphite/epoxy laminates and 0.009 inches for Kevlar/epoxy laminates). No thickness correction was used for matrix dominated properties. (Fiber dominated properties are combinations of loadings and laminate orientations such that internal stresses are carried primarily by the fibers. In matrix dominated properties, the matrix material is the primary load path.)

Environmental factors were calculated for each property, as documented in Reference (9). The environmental factor is defined as the ratio of the mean strength at the environmental condition to the mean room temperature dry strength. Environmental factors calculated for 285/5143 Kevlar/epoxy are tabulated in Table II. Environmental factors generated for AS-1/6350 graphite/epoxy are presented in Table III. Environmental factor trends for interlaminar (short beam) shear (SBS) static, SBS fatigue, static tensile and static flexural properties being examined in this program are presented in Figure 4.

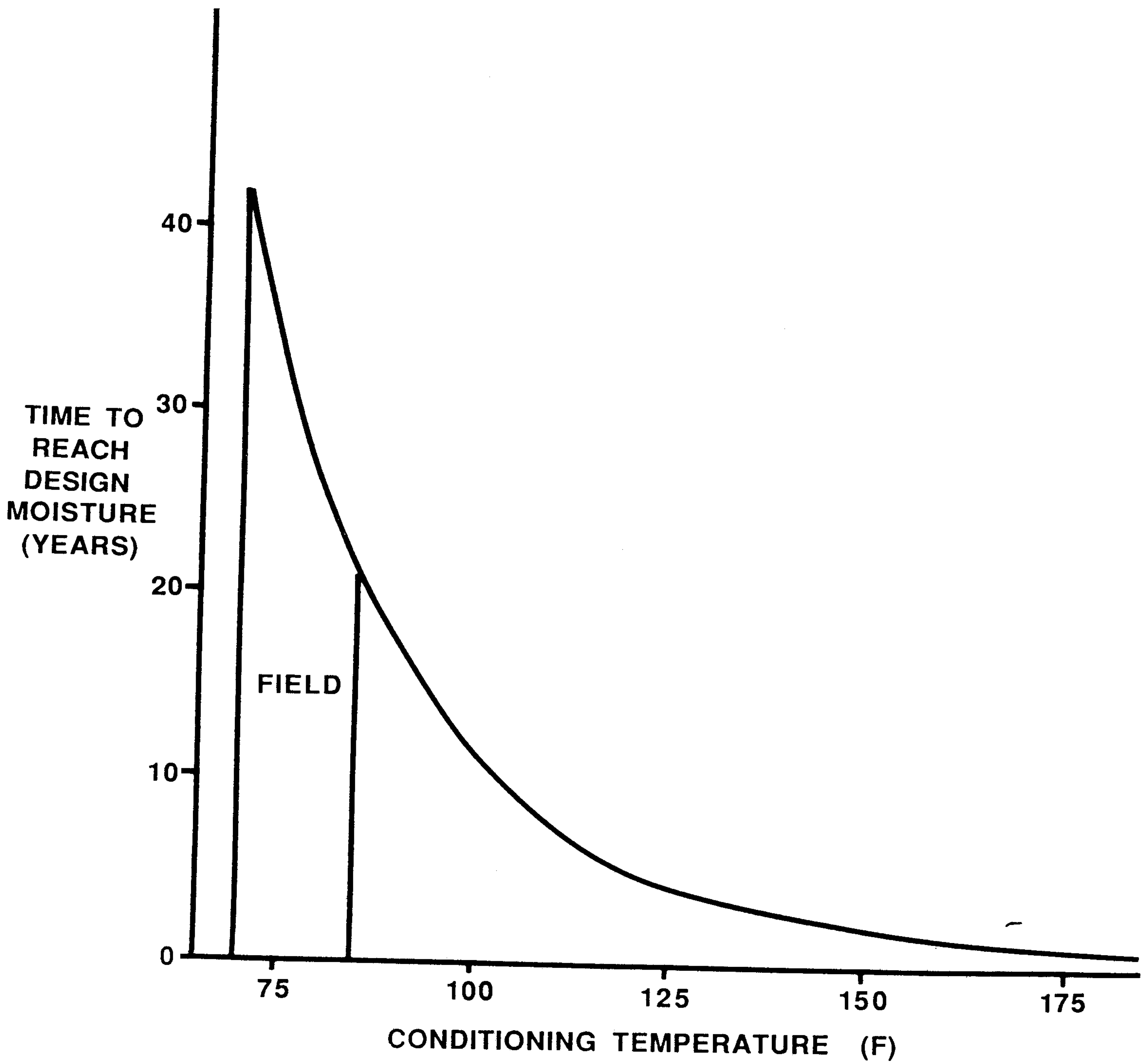


FIGURE 2. TAIL ROTOR SPAR ABSORPTION TIME

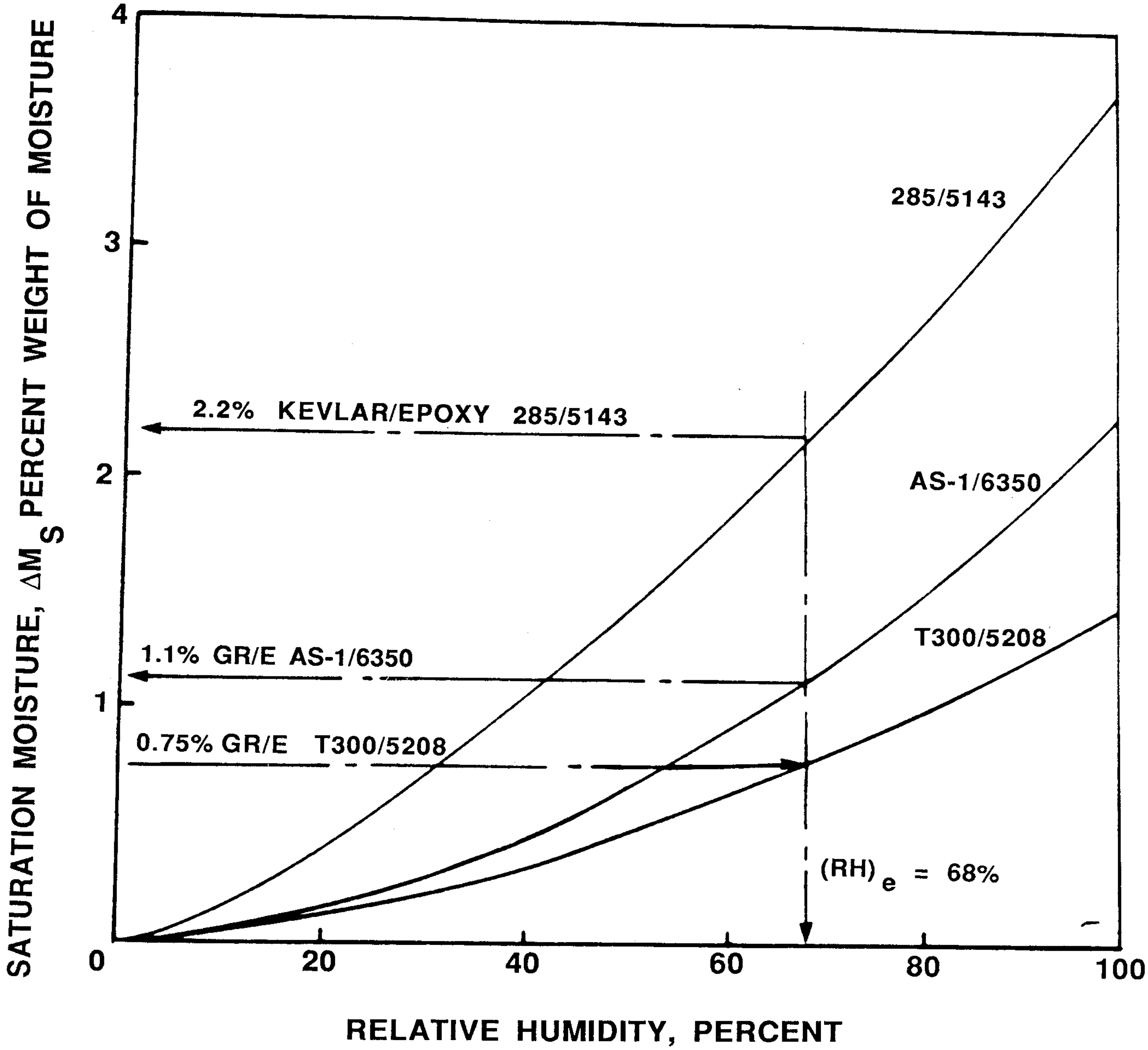


FIGURE 3. DESIGN MOISTURE LEVELS FOR KEVLAR AND GRAPHITE/EPOXY

TABLE II. 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)	1.00	.62	-	-
Axial (R = -1.0)	.90	.75	-	-
Inplane Shear (R = 0.1)	-	.87	-	-

(a) 2.2 percent moisture, 23°C (75°F)
(b) 2.2 percent moisture, 71°C (160°F)

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

Strength Property	Room Temperature Wet[a] 0° (Longitudinal)	Room Temperature Wet[a] 90° (Transverse)	Elevated Temperature Wet[b] 0° (Longitudinal)	Elevated Temperature Wet[b] 90° (Transverse)
<u>Static Strength</u>				
Tension	1.00	.78	.99	.72
Compression	.93	.78	.87	.73
Bending	.96	-	.78	-
Inplane Shear	.92	-	.89	-
Interlaminar Shear	.78	-	.73	-
Translaminar Shear	.78	-	.75	-
<u>Fatigue Strength</u> (10^7 cycles)				
Axial (R = 0.1)	1.00	-	-	-
Axial (R = -1.0)	.87	-	-	-
Interlaminar Shear (R = 0.1)	.82	-	-	-
Translaminar Shear (R = 0.1)	.92	-	-	-

(a) 1.1 percent moisture, 23°C (75°F)
(b) 1.1 percent moisture, 71°C (160°F)

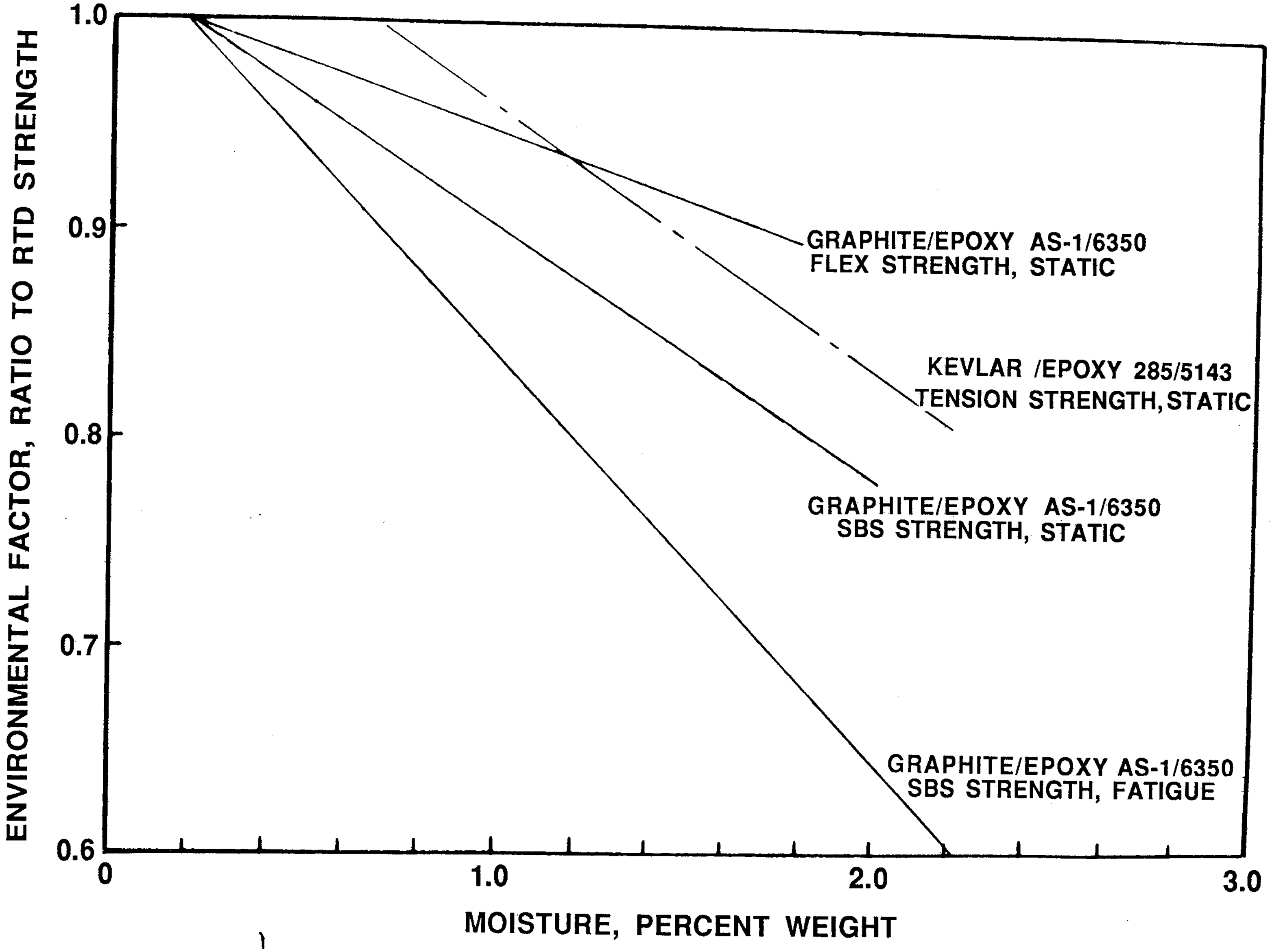


FIGURE 4. LABORATORY ENVIRONMENTAL FACTORS AS A FUNCTION OF MOISTURE CONTENT

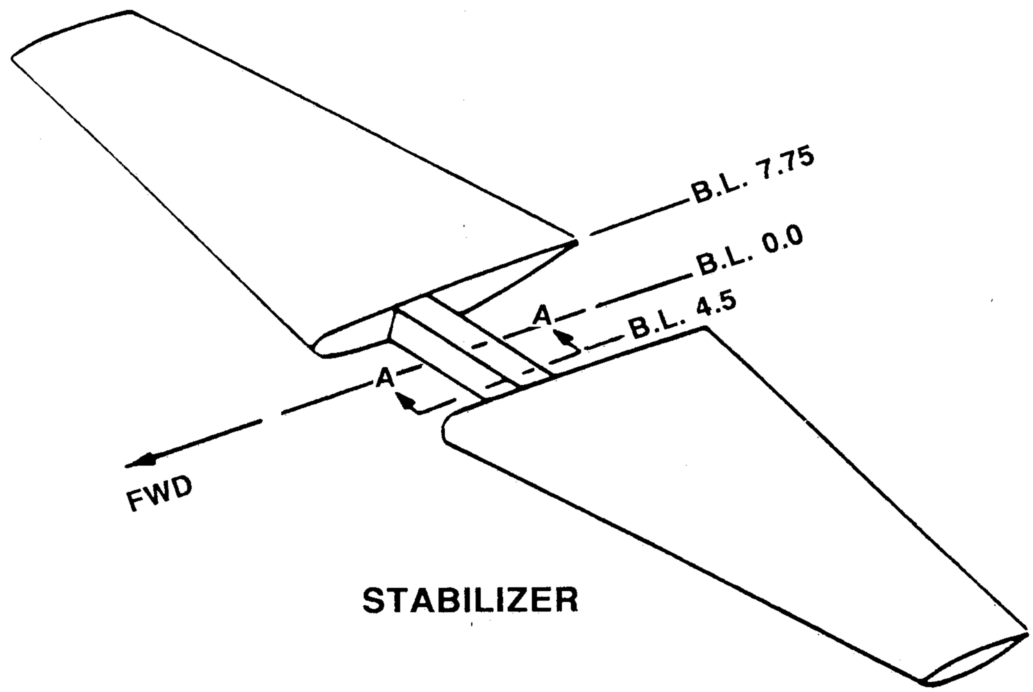
2. IN-SERVICE COMPONENT SELECTION

The components selected for in-service evaluation for this program were the S-76 horizontal stabilizer and the tail rotor spar. The horizontal stabilizer is a single unit, having its own part number and serial number; the left and right hand side are not separable. The horizontal stabilizer is constructed of ±45° oriented Kevlar/epoxy (285/American Cyanamid 5143) over Nomex honeycomb core with a torque box section fabricated of ±45° Kevlar/epoxy, aluminum honeycomb core and graphite/epoxy (Hercules AS-1/Ciba Geigy 6350) cap strip reinforcements. In addition, the torque box contains localized areas of Furane's Epocast 169 syntactic foam densified honeycomb core to provide stiffness for clamping to the airframe. A schematic diagram of the horizontal stabilizer is shown in Figure 5.

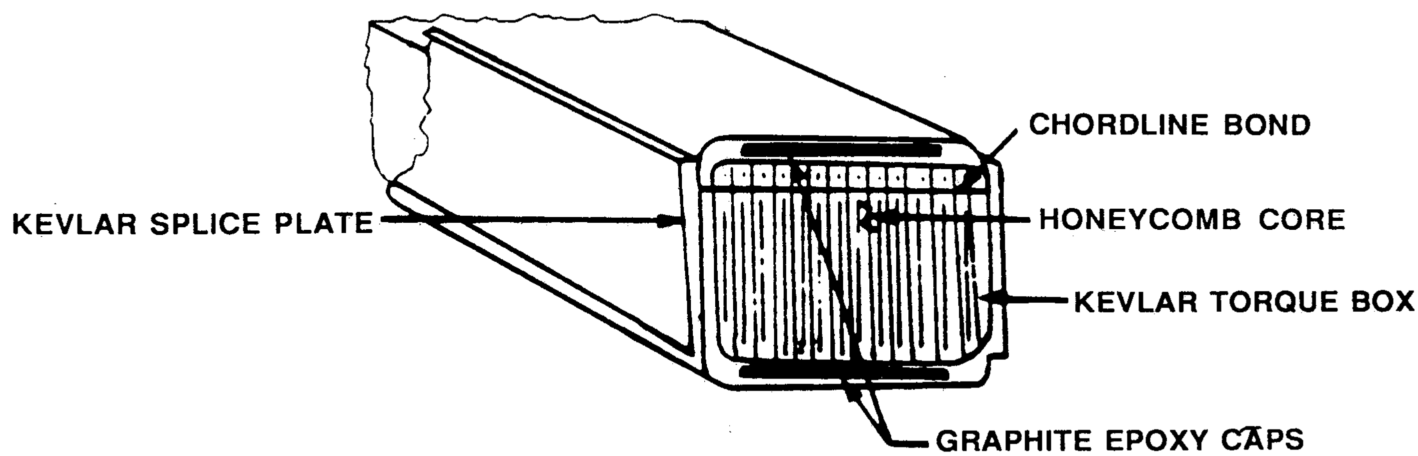
The tail rotor consists of two paddles, which are separable, with each paddle having its own serial number. The tail rotor spar is an integral part of the tail rotor paddle assembly. A schematic diagram of the tail rotor paddle is shown in Figure 6. Each paddle consists of two separable blades attached to one spar. The spar also has its own serial number. The tail rotor spar is constructed of uni-directional graphite/epoxy (Hercules AS-1/Ciba Geigy 6350), ranging in thickness from 14 to 33 plies. The geometry of the spar is illustrated in Figure 7.

Tail rotor spars and stabilizers were returned periodically from the field for full scale static, full scale fatigue or small scale testing in accordance with the schedule detailed in Table I. A total of four horizontal stabilizers and ten tail rotor spars were returned from the field for evaluation, as required for this program. Data from three additional spars, tested as part of an internal research and development program at Sikorsky Aircraft, is also included in this report for comparison purposes.

Components selected for testing in this contract were intentionally removed from aircraft operating in a hot, humid region. Accordingly, all tail rotor spars and stabilizers evaluated were removed from S-76 aircraft owned and operated by Air Logistics, a division of Offshore Logistics, Incorporated, located in the Gulf Coast region of Louisiana. Every three months, the Air Logistics' aircraft logs were inspected to verify that each part being tracked was still installed on an operating aircraft. In addition to the components being monitored for testing, extra spars and stabilizers were tracked as spares, for use in the event that one of the components scheduled for testing became unavailable. Each of the parts was tracked by its serial number, in as much as commercial operators do not always keep the same components on an aircraft. The number of flight hours and months of in-service environmental exposure were then recorded for each part and spare. A list of the tail rotor spars and horizontal stabilizers that were tracked is presented in Table IV.



STABILIZER



STABILIZER TORQUE BOX AT SECTION A-A

FIGURE 5. SCHEMATIC REPRESENTATION OF THE S-76 HORIZONTAL STABILIZER

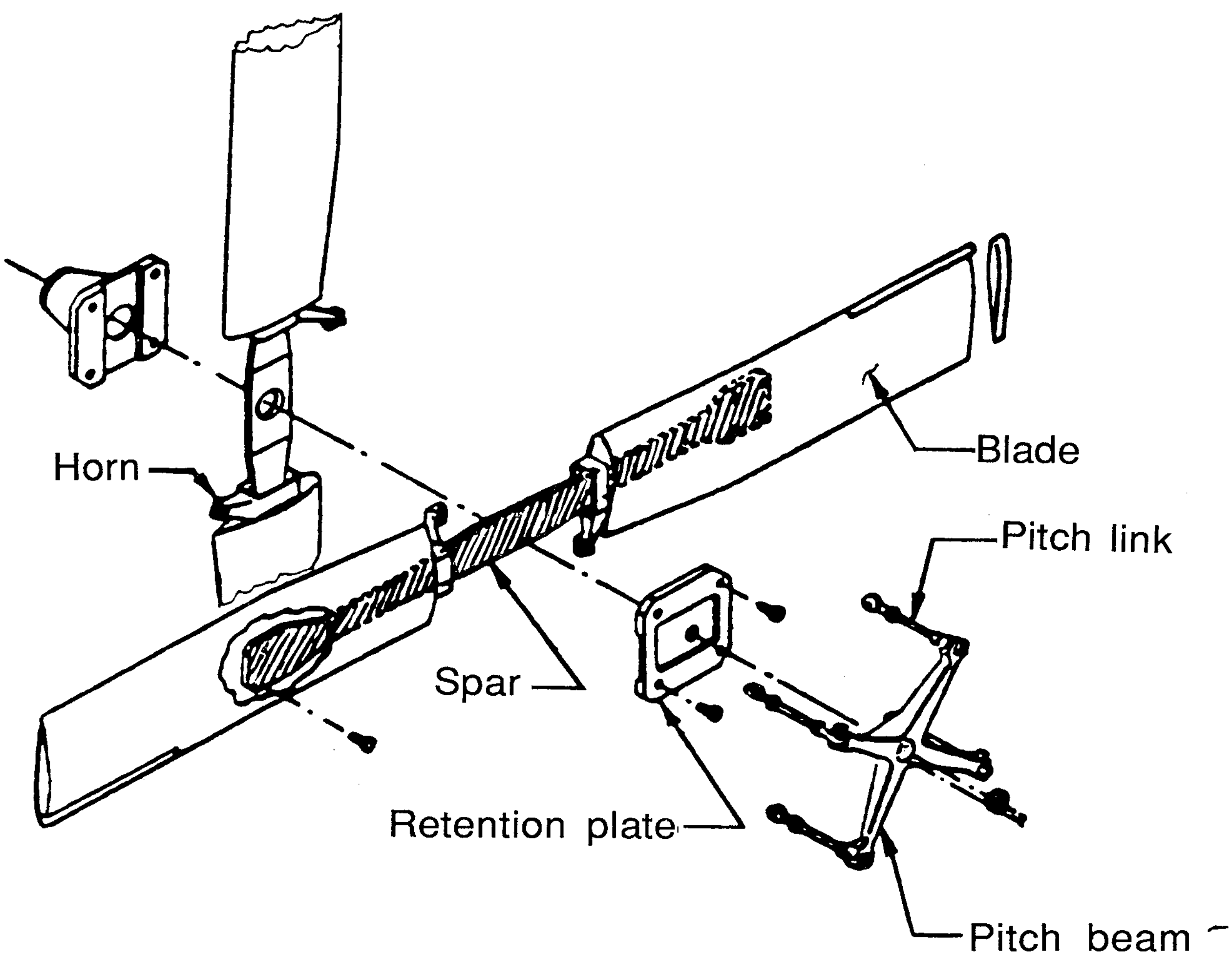


FIGURE 6. SCHEMATIC REPRESENTATION OF THE S-76 TAIL ROTOR PADDLE ASSEMBLY

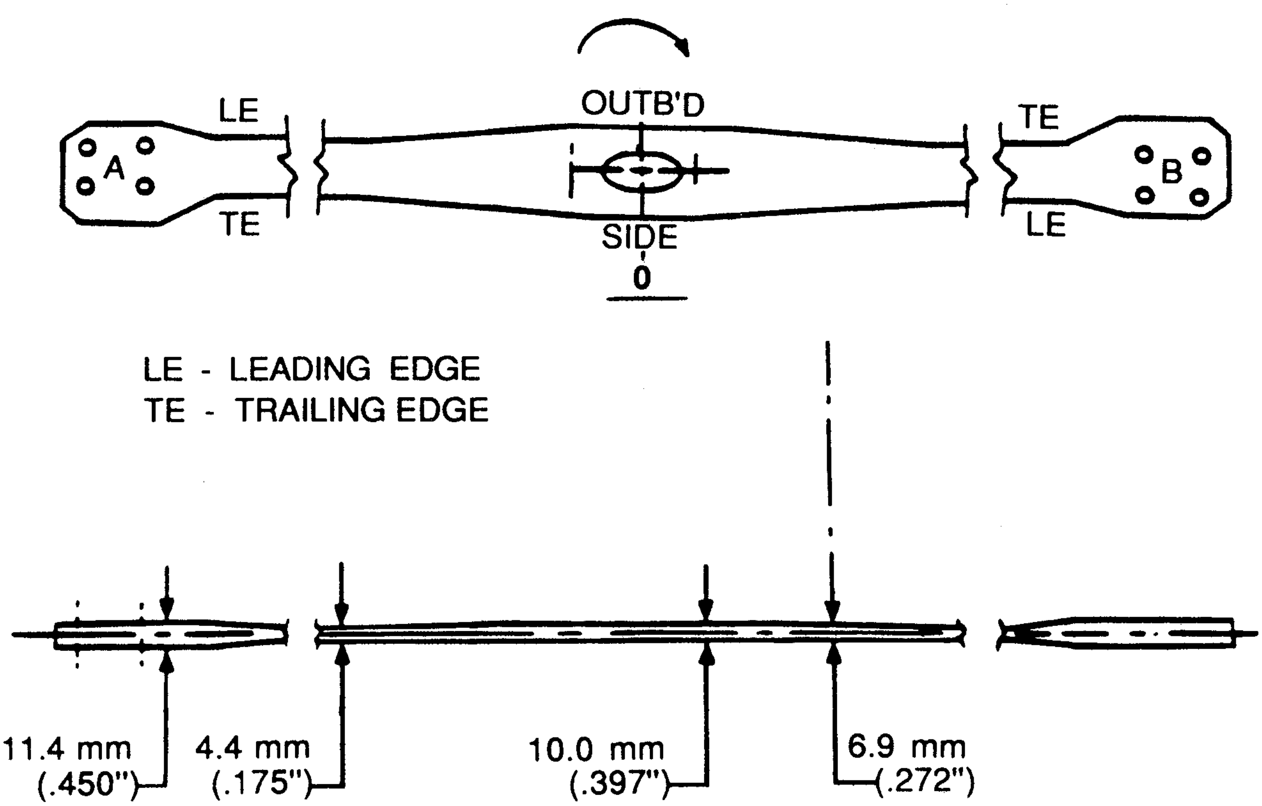


FIGURE 7. SCHEMATIC REPRESENTATION OF THE S-76 TAIL ROTOR SPAR

Table IV. S-76 Components Selected for Testing - Contract NAS1-16542

OMPONENT/SERIAL NO.	FLIGHT HOURS/ REMOVAL DATE	OPERATOR/LOCATION	FIELD EXPOSED TIME	REMARKS
ail Rotor Paddle/Spar addle S/N-137-00031 par S/N-116-00114	3358 Removed April 1983	Air Logistics Lake Charles, LA	52 months	Tested 1983, full scale fatigue
-00034 -00094	2390 Removed Sept. 1981	Air Logistics Lake Charles, LA	29 months	Tested 1981, full scale fatigue
-00067 -00178	3752 Removed June 1984	Air Logistics Lake Charles, LA	51 months	Tested 1984, coupon tests
-00068 -00237	1596 Removed Aug. 1982	Air Logistics Lake Charles, LA	42 months	Tested 1983, full scale fatigue
-00085 -00150	2385 Removed May 1982	Air Logistics Lake Charles, LA	38 months	Tested 1983, coupon tests
-00099 -00283	1884 Removed Nov. 1982	Air Logistics Lake Charles, LA	38 months	Tested 1983, coupon tests
-00107 -00069	4995 Removed July 1986	Air Logistics Lake Charles, LA	72 months	Tested 1987, full scale fatigue
-00152 -00415	5216 Removed July 1986	Air Logistics Lake Charles, LA	68 months	Tested 1987, coupon tests
-00231 -00493	5858 Removed Oct. 1988	Air Logistics Lake Charles, LA	97 months	Tested 1989, coupon tests
-00232 -00502	6526	Air Logistics Lake Charles, LA	96 months	Spare
-00205 -00480	5816 Removed Oct. 1988	Air Logistics Lake Charles, LA	100 months	Tested 1989, full scale fatigue
orizontal Stabilizer /N-B-157-00009	3999 Removed Aug. 1983	Air Logistics	56 months	Fatigue tested 1984
/N-B-157-00010	9095	Air Logistics	114 months	Spare
/N-B-157-00021	4051 Removed May 1985	Air Logistics	66 months	Static and fa- tigue tested 1985
/N-B-157-00027	5846 Removed June 1987	Air Logistics	91 months	Fatigue tested 1987
/N-B-157-00076	1600 Removed July 1982	Air Logistics	19 months	Static tested 1981

3. TESTS OF IN-SERVICE COMPONENTS

3.1 Horizontal Stabilizers - Description of Test Methods

Four horizontal stabilizers were returned from the field for evaluation as part of this program, S/N B-157-00076, S/N B-157-00009, S/N B-157-00021 and S/N B-157-00027.

Prior to full scale testing, each stabilizer was proof load tested in accordance with the same procedure required for production acceptance. A 2400 pound load was applied at Buttline 0 where it was reacted at each side of the upper surface of the stabilizer at BL 25.0 and STA 476.5. The reacted load was distributed over a sufficient area in the beam section on each side of the center of the stabilizer to prevent damage to the aerodynamic surface. A dial indicator measured the stabilizer deflection at the point of load application. The established production proof load acceptance criteria is a corresponding maximum deflection of 4.14mm (0.163 in) at BL 0.

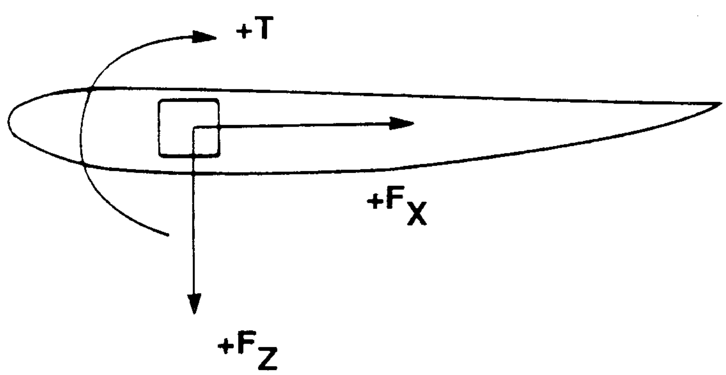
For full scale static testing, the horizontal stabilizer was tested in an asymmetrical load condition. The design loading combination consisted of drag and lift forces with a torsional moment as illustrated in Figure 8. Since the design condition is asymmetrical, the loads specified in Figure 8 were designated L for the left side and R for the right side of the stabilizer. The loads were applied by hydraulic cylinders and dead weight located at Buttlines 40R and L, which were attached to the stabilizer by test facility fittings. These fittings were located at a chordwise position such that the required flatwise, edgewise, and torsional load combinations developed by proper angling of the cylinders. Test loads were held in the same proportion as listed in Figure 8 with the combination increased as a percentage of limit load. A photograph of the stabilizer static test facility is shown in Figure 9. To allow direct comparison with the baseline (type certification) data, the static tests were conducted at a temperature of 160°F.

For full scale fatigue testing, asymmetrical vibratory loads were applied at Buttlines 40R and L, as shown in Figure 10. Loads were applied to the right and left ends of the stabilizer out of phase, so that shear forces were developed in the center torque box area of the stabilizer. Design limit roll and yaw moments generated were ±48,000 in-lbs and ±22,700 in-lbs, respectively. The full scale fatigue tests were conducted at room temperature.

3.1.1 Horizontal Stabilizer - Test Results

3.1.1.1 S/N B-157-00076

Stabilizer S/N B-157-00076 had accumulated 19 months calendar time and 1600 flight hours in the Gulf Coast Region of Louisiana. The field environmental history of the stabilizer is detailed in Table V of Reference (1).



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

L,R - left or right side loads, respectively

FIGURE 8. S-76 HORIZONTAL STABILIZER STATIC LIMIT DESIGN LOADING

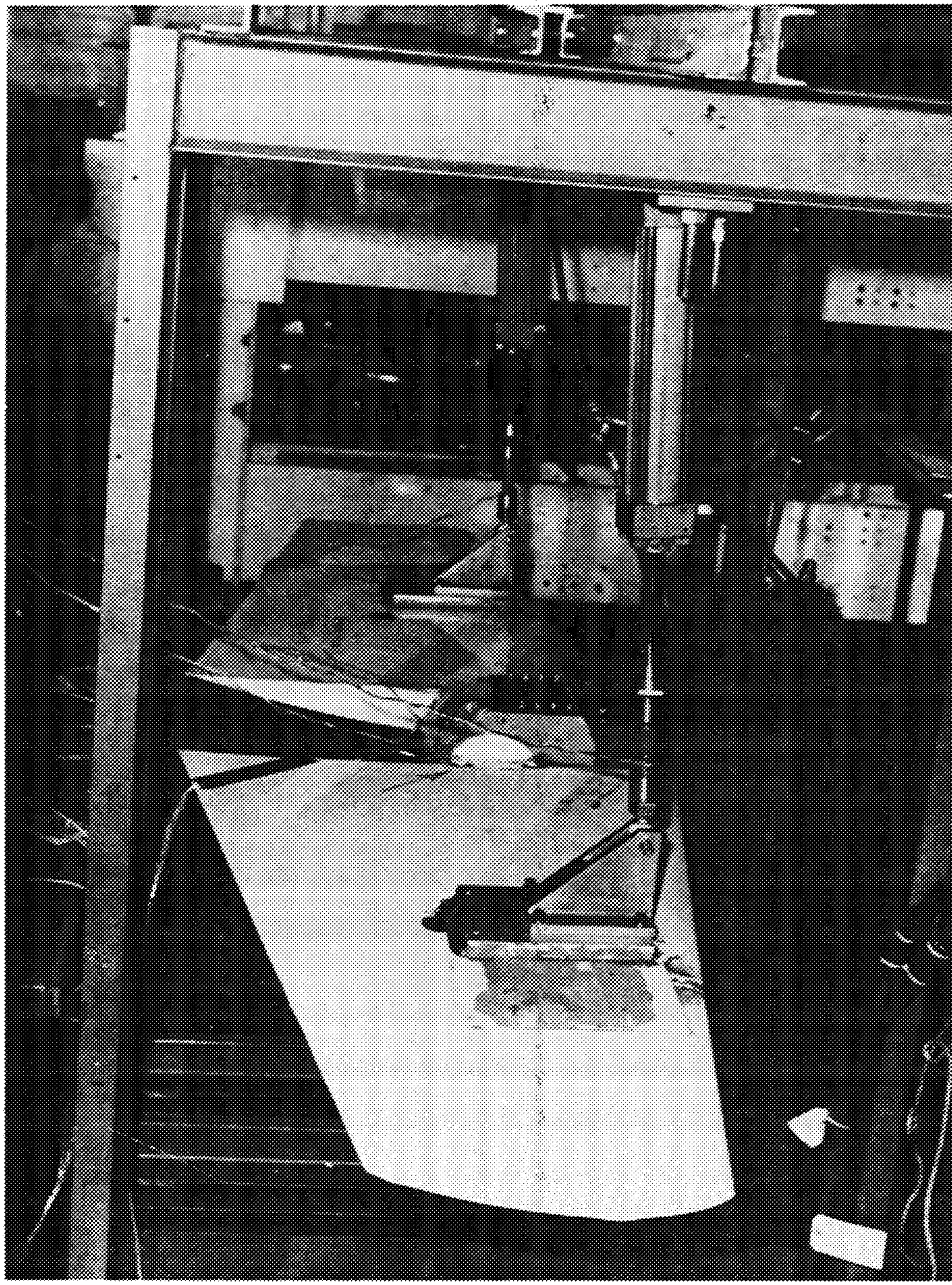
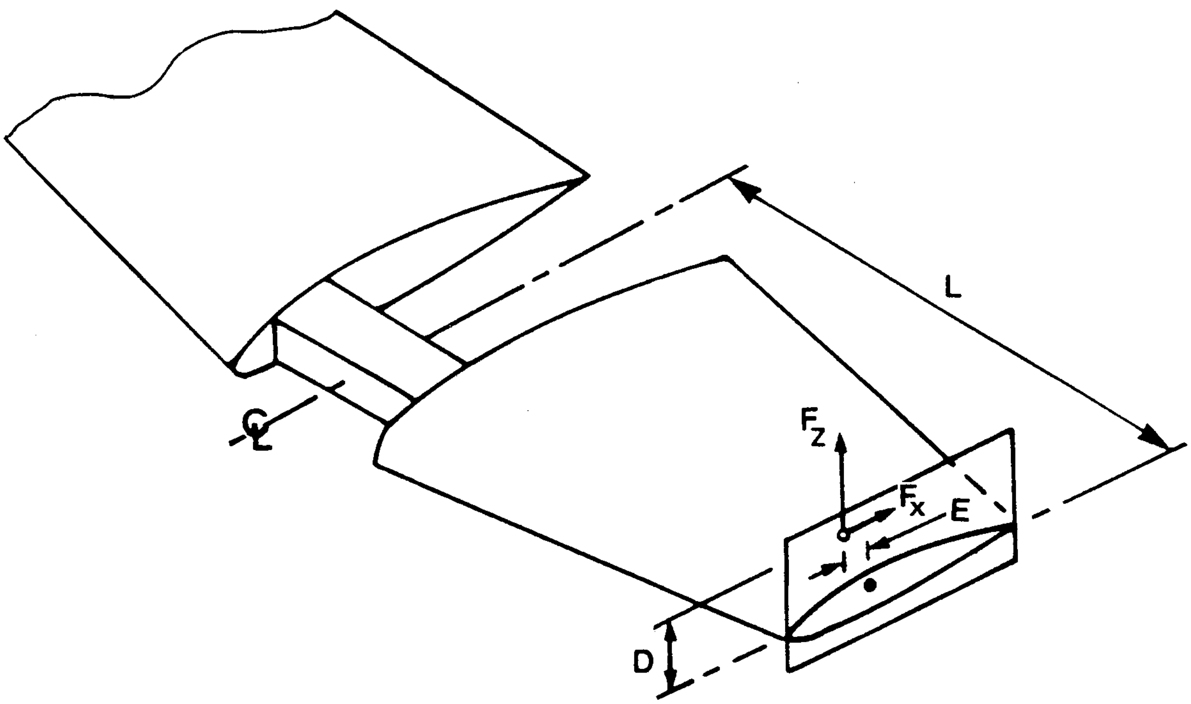


FIGURE 9. S-76 HORIZONTAL STABILIZER STATIC TEST FACILITY



F_z	±2624 N	(590 lb.)
F_x	±1214 N	(273 lb.)
D E L	193 mm 112 mm 1016 mm	(7.6 in.) (4.4 in.) (40.0 in.)

FIGURE 10. S-76 HORIZONTAL STABILIZER LOCATION AND MAGNITUDE OF FATIGUE TEST LOADS

A proof test load was applied and a resulting deflection of 3.89mm (0.153 in) was measured, the same as recorded in the initial acceptance test.

The stabilizer was then statically tested for the asymmetrical design condition. The test strains, at the locations shown in Figure 11, were monitored to enable assessment of the results. Plots of percent limit load as a function of strain are also shown in Figure 11, monitored by strain gages located along the top trailing edge (TTE) and the bottom trailing edge (BTE) at Buttline 4.5.

As shown in Figure 11, the tension strains remained linear up to the maximum applied load (220 percent DLL). The compression strain remained linear up to 170 percent DLL and thereafter, showed no increase of strain. Upon the application of 230 percent DLL a loud 'snap' was heard and the load dropped to 150 percent DLL. An attempt was made to increase the load beyond the 150 percent DLL, however, the structural deflection increased to the limit of the test fixture capability.

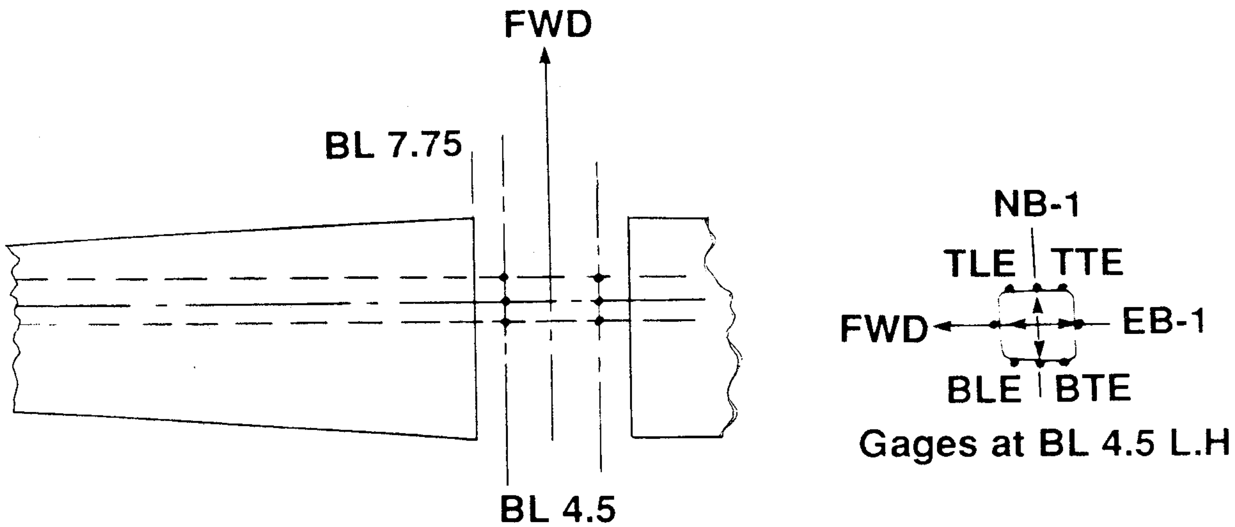
External visual inspection of the stabilizer revealed a buckle in the leading edge Kevlar splice plate at BL 4.5 on the left side. Upon teardown it was found that there was a loss of shear transfer of the composite material to the metal honeycomb. A schematic representation of the stabilizer static fracture modes is shown in Figure 12. The structural box is designed to have a redundant shear path so that shear loadings can be resisted by the honeycomb or the Kevlar box structure. The indication was that at 220 percent of DLL the shear transferred to the Kevlar box and eventually buckled the sidewall splice plate. However, the remaining shear strength in the Kevlar box provided the structural capability for at least 150 percent limit load with reduced rigidity.

Coupons were then removed from the graphite/epoxy reinforcement cap strips for moisture analysis. A photograph of the desorption coupons, typical of those removed from each of the stabilizers for moisture analysis is shown in Figure 13. The coupons were desorbed in an environmentally controlled chamber at 150 ± 2°F. An average of 0.28 percent moisture by weight was desorbed from the coupons.

3.1.1.2 S/N B-157-00009

Stabilizer S/N B-157-00009 was returned from the field after 56 months of service. The stabilizer had accumulated 3999 flight hours. Table III of Reference (3) details the environmental history of the stabilizer.

Prior to full scale fatigue testing, the stabilizer was proof load deflection tested. The deflection measured 3.81mm (0.150 inches), and therefore indicated no loss of stiffness after in service exposure.



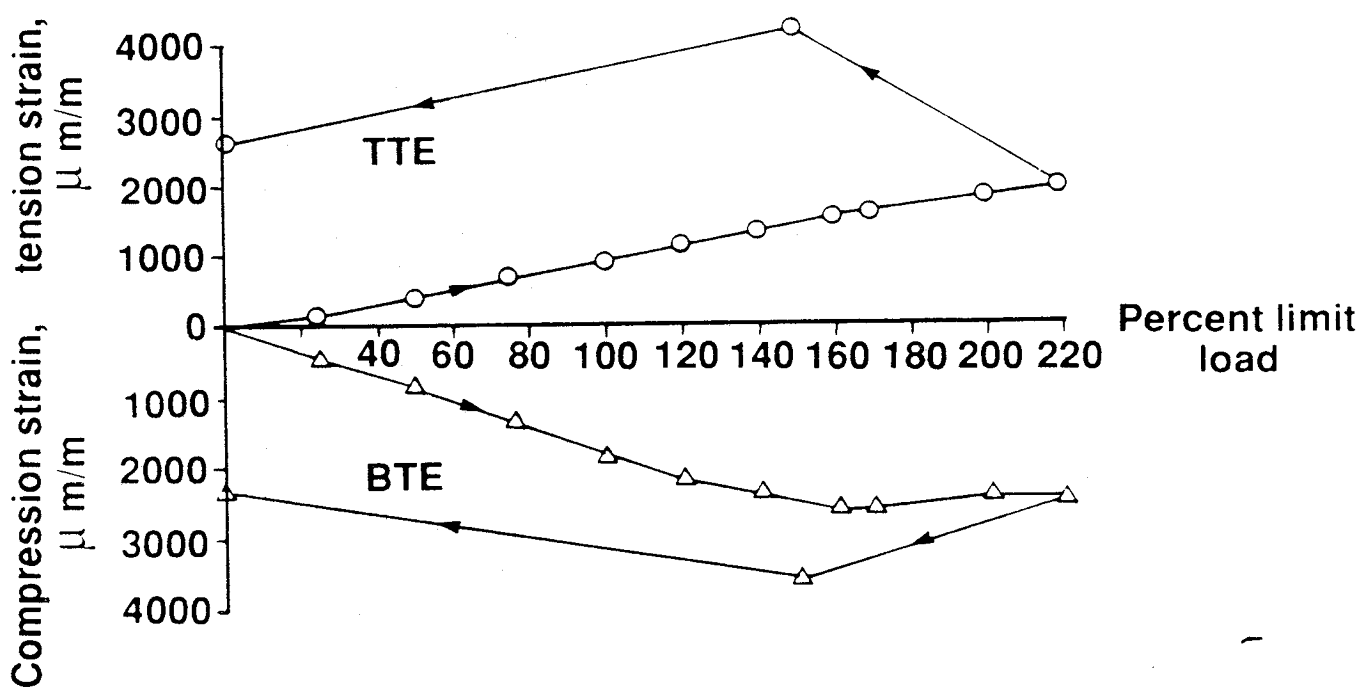
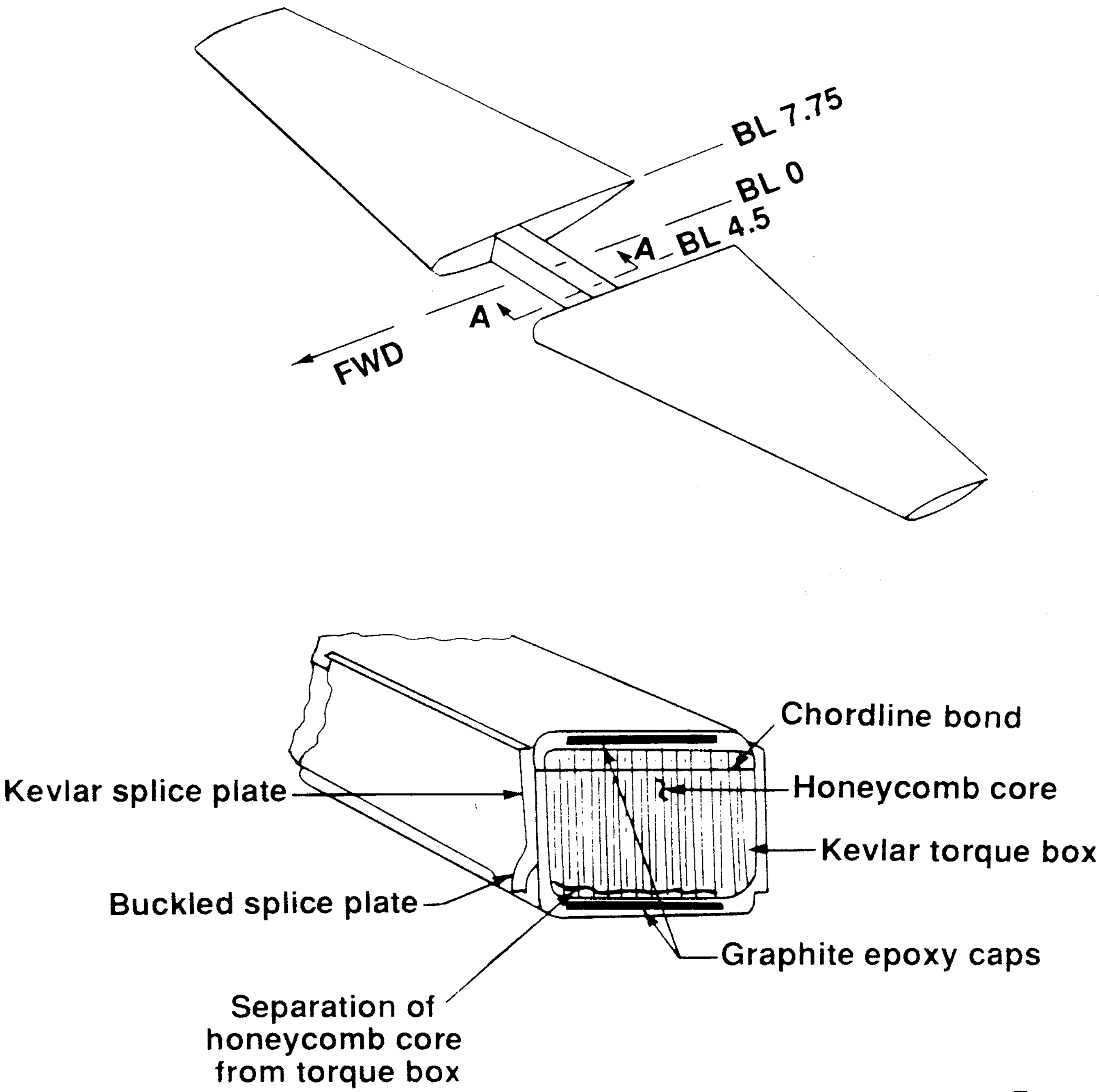


FIGURE 11. STRAIN AS A FUNCTION OF PERCENT LIMIT LOAD ON STABILIZER BOX SPAR, BL 4.5 (LEFT)

S/N B-157-00076



STABILIZER TORQUE BOX AT SECTION A-A

FIGURE 12. SCHEMATIC REPRESENTATION OF S-76 HORIZONTAL STABILIZER STATIC FRACTURE MODES

S/N B-157-00076

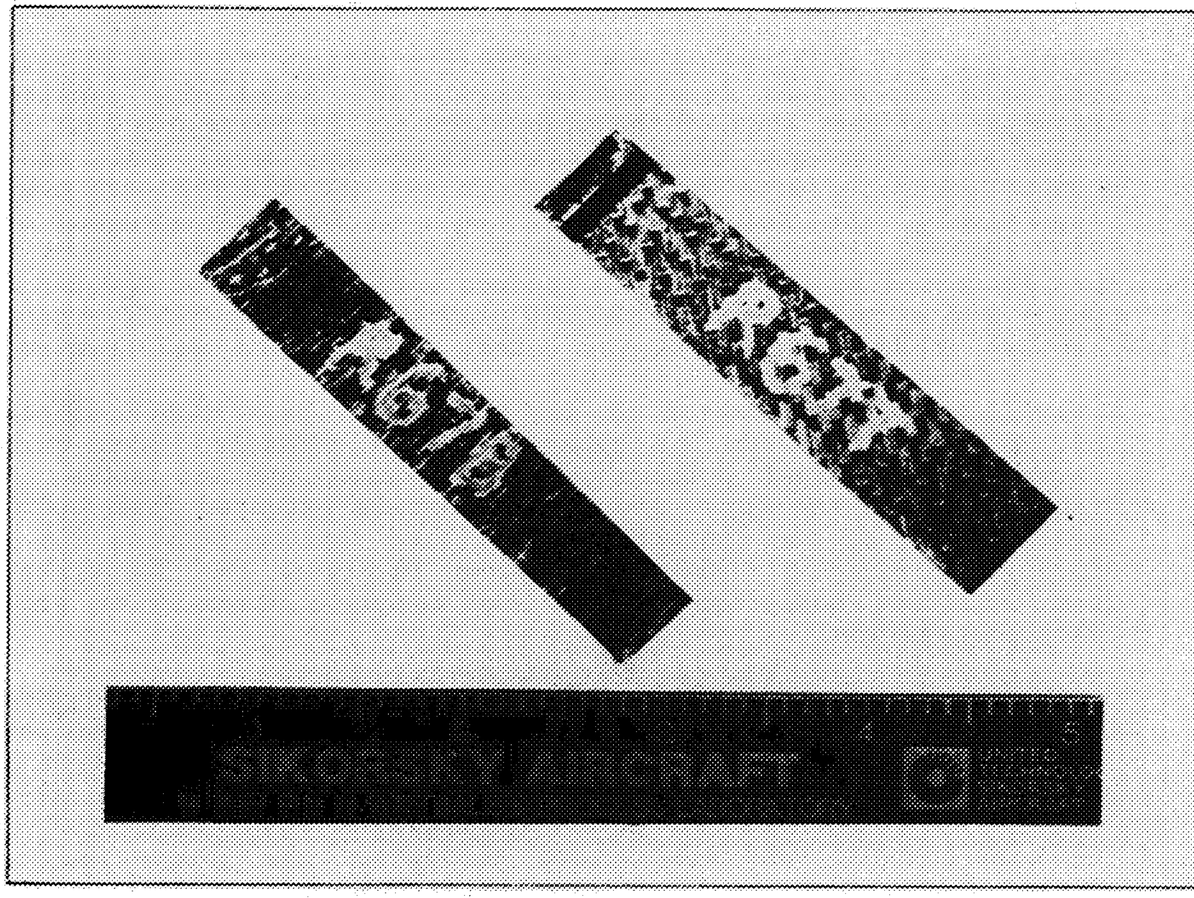


FIGURE 13. PHOTOGRAPH OF DESORPTION COUPONS, TYPICAL OF THOSE REMOVED FROM EACH HORIZONTAL STABILIZER FOR MOISTURE ANALYSIS

Stabilizer S/N B-157-00009 was loaded for fatigue testing in accordance with the values detailed in Figure 10. Loads were applied to the right and left ends of the stabilizer out of phase, so that shear forces were developed in the center torque box area. Roll and yaw moments generated were ±48,000 inch pounds and ±22,700 inch pounds, respectively, the design criteria. When no fracture occurred after $5x10^5$ cycles, the fatigue test was considered a runout. Loads were then increased by 5 percent, to produce a roll moment of ±50,240 inch pounds and a yaw moment of ±23,800 inch pounds. At $3x10^5$ cycles, a fracture in the torque box was noted, and the test was terminated.

External visual inspection of stabilizer S/N B-157-00009 disclosed that a disbond between the upper and lower channels caused surface cracks on the upper portion of the forward and aft sides. The disbond between the upper and lower channels extended from BL0.0 to the beginning of the syntactic foam filled regions between BL3.0 R-BL6.0 R and BL3.0 L - BL6.0 L as shown in Figure 14. The syntactic foam densified honeycomb regions had adequate strength to prevent crack propagation.

Upon teardown, a crack was observed in the bottom forward corner of the torque box, which ran through the wrap-around Kevlar laminates. This crack extended approximately 3 inches in either direction from BL0.0.

The core-to-core bond was intact throughout the torque box. The result of the upper-to-lower channel disbond, was a failure within the aluminum honeycomb. Thus, the core-to-core bond was stronger than the honeycomb itself. The core-to-channel wall bond was also intact throughout the structure. The only core-to-wall disbond occurred in regions where the core was filled with foam as was evident at BL 3R, shown in Figure 15. The foam strengthened the core to a point where the weakest link was in the core-to-wall bond. From the preceding failure modes, it was apparent that there was a loss of shear transfer in the bond between the upper and lower channels. This disbond propagated from the center outboard, until it was halted at the syntactic foam filled areas. The torque box disbond then precipitated the honeycomb failure. The through wall crack developed in the bottom forward corner of the torque box and propagated up to the syntactic foam filled region. While the stabilizer was fatigue tested to fracture, it was adequately designed to carry its design limit load at $5x10^5$ cycles, which was considered a run-out.

Coupons were removed from Buttlines 4.0-9.0 of the failed stabilizer for desorption. The moisture desorbed from graphite/epoxy coupons between Buttlines 4.0 and 9.0 was 0.42 percent. Desorption data is contained in Tables IV and V of Reference (3). A typical moisture desorption plot for S/N B-157-00009 is shown in Figure 16.

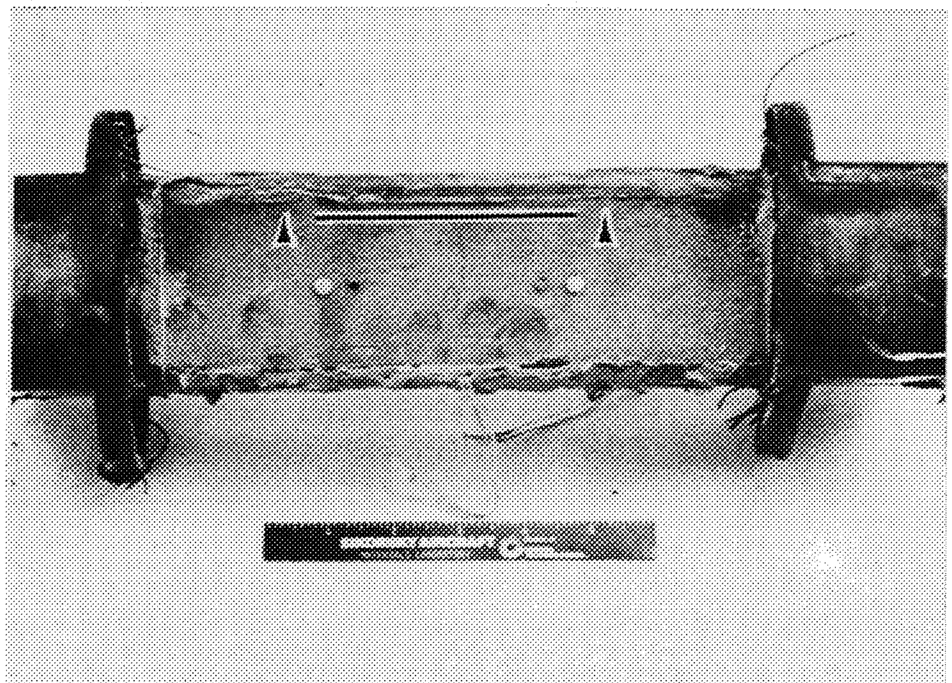


FIGURE 14. OVERALL VIEW OF TORQUE BOX, AFT SIDE, BL 7.5R-BL 7.5L, DISBOND BETWEEN UPPER AND LOWER CHANNELS, S-76 HORIZONTAL STABILIZER, S/N B-157-00009

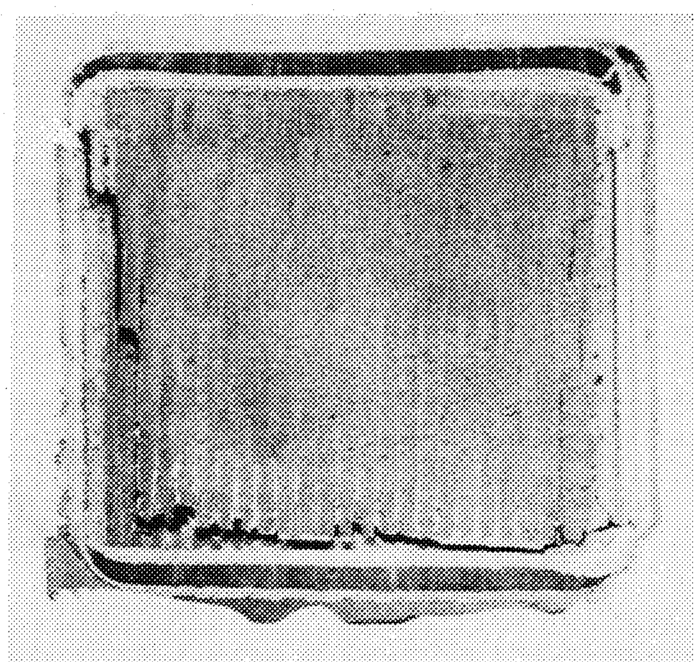


FIGURE 15. SECTION THROUGH BL 3R SHOWING DISBONDS ALONG BOTH EDGES OF THE BONDLINE BETWEEN CHANNELS IN FOAM DENSIFIED AREAS, S-76 HORIZONTAL STABILIZER, S/N B-157-00009

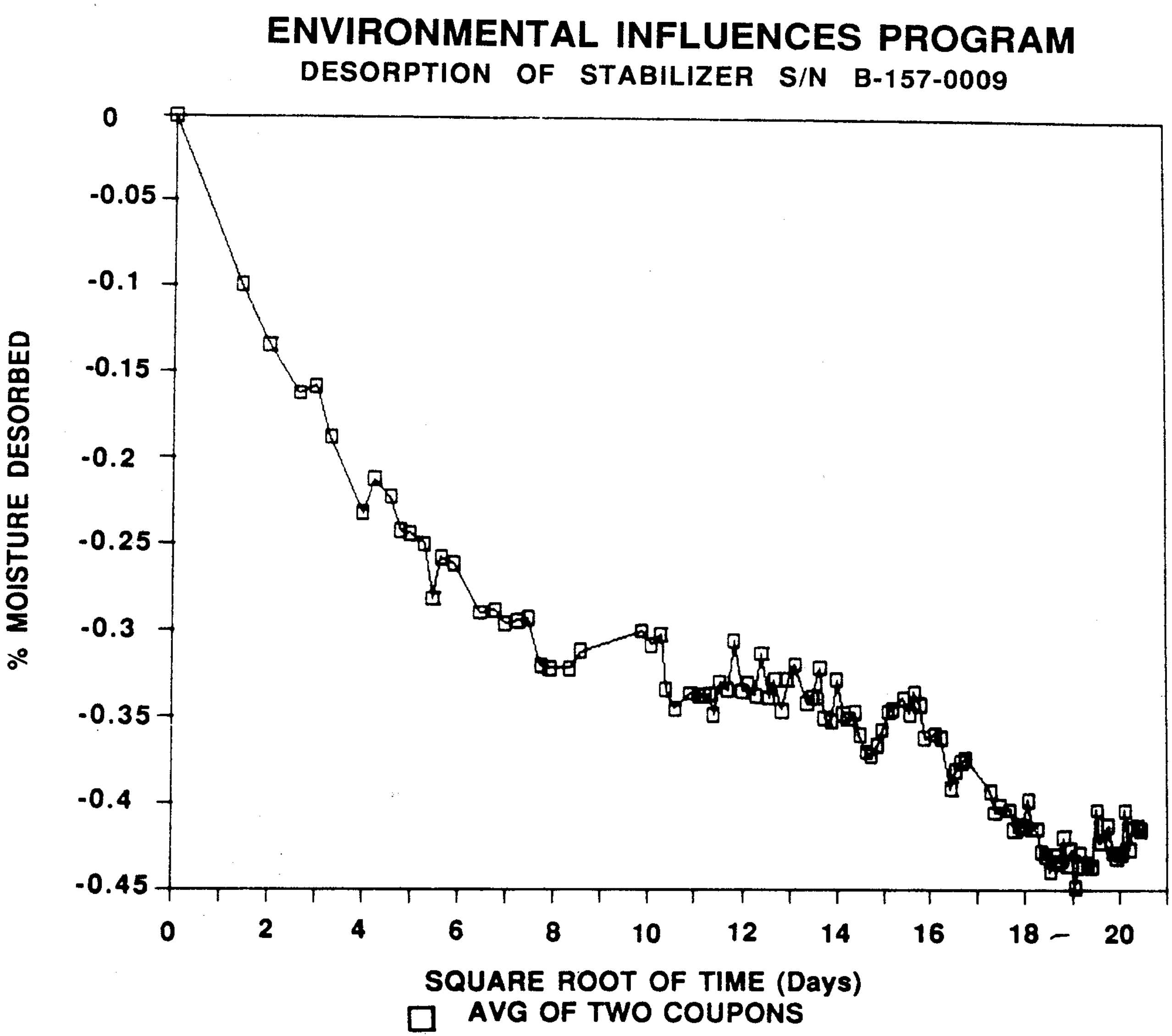


FIGURE 16. MOISTURE DESORPTION OF S-76 HORIZONTAL STABILIZER S/N B-157-00009 COUPONS BL 6-7T, BL 6-7B

3.1.1.3 <u>S/N B-157-00021</u>

Stabilizer S/N B-157-00021 was returned from the field for full scale static and small scale coupon testing. After 66 months of in-service environmental exposure, the stabilizer had accumulated 4213 flight hours. The environmental history of stabilizer S/N B-157-00021 is detailed in Table VI of Reference (3).

Prior to full scale testing, the horizontal stabilizer was proof load deflection tested. An acceptable deflection of 3.81mm (0.150 in) was measured, indicating no loss in stiffness after service.

Visual inspection and coin tapping revealed two small areas of disbond in the torque box section. One disbond measured approximately .75 inch long by 1.50 inch wide and was located at BL3.0 L. The other disbond measured approximately 1.0 inch long by 3.0 inches wide, located at BL3.0 R. Damage was thought to have been sustained during removal of the stabilizer from the aircraft. A schematic representation of the stabilizer disbond areas is shown in Figure 17.

Although stabilizer S/N B-157-00021 was scheduled for full scale static testing, concern over the disbond led to the conclusion that it would be more informative to first static test to 100 percent design limit load, and then test in fatigue.

The stabilizer was statically loaded as detailed in Figure 8. As the design limit load is asymmetrical, the loads shown in Figure 8 were designed L for the left side and R for the right side of the stabilizer as previously described. To allow for direct comparison with the baseline (type certificate) stabilizer, the static test was conducted at 160°F.

When no fracture occurred under static loading, the stabilizer was prepared for room temperature fatigue testing with the loads as detailed in Figure 10. However, owing to an error in setup, the fatigue loads applied were 23 percent higher than the baseline loads of Figure 10. During fatigue testing, the stabilizer disbonded from the test fixture. Proof load tests were run to insure that fracture did not occur in the stabilizer as well. The stabilizer was then rebonded into the test fixture with HYSOL EA934 paste adhesive and the test was continued. Testing was terminated at 59,980 cycles when a fracture was visually observed in the torque box.

Further visual examination of S/N B-157-00021 stabilizer disclosed cracking in two separate areas of the torque tube. One crack extended from BL5.5 R to BL5.5 L and was presumably caused by a disbond between the upper and lower channels.

An entire Kevlar ply was detached from the forward side of the torque tube as shown in Figure 18. This Kevlar ply "flap" extended through

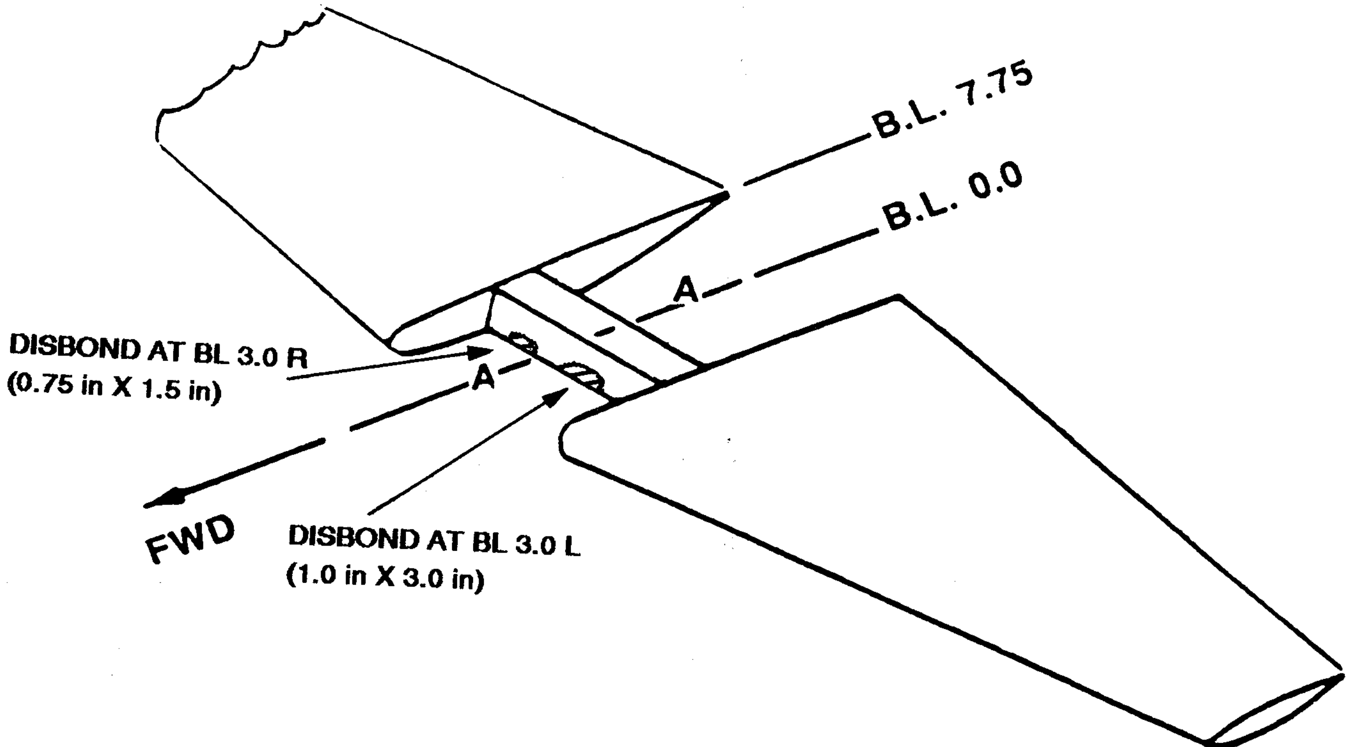


FIGURE 17. SCHEMATIC REPRESENTATION OF S-76 HORIZONTAL STABILIZER DISBOND AREAS EVIDENT PRIOR TO TESTING, S/N B-157-00021

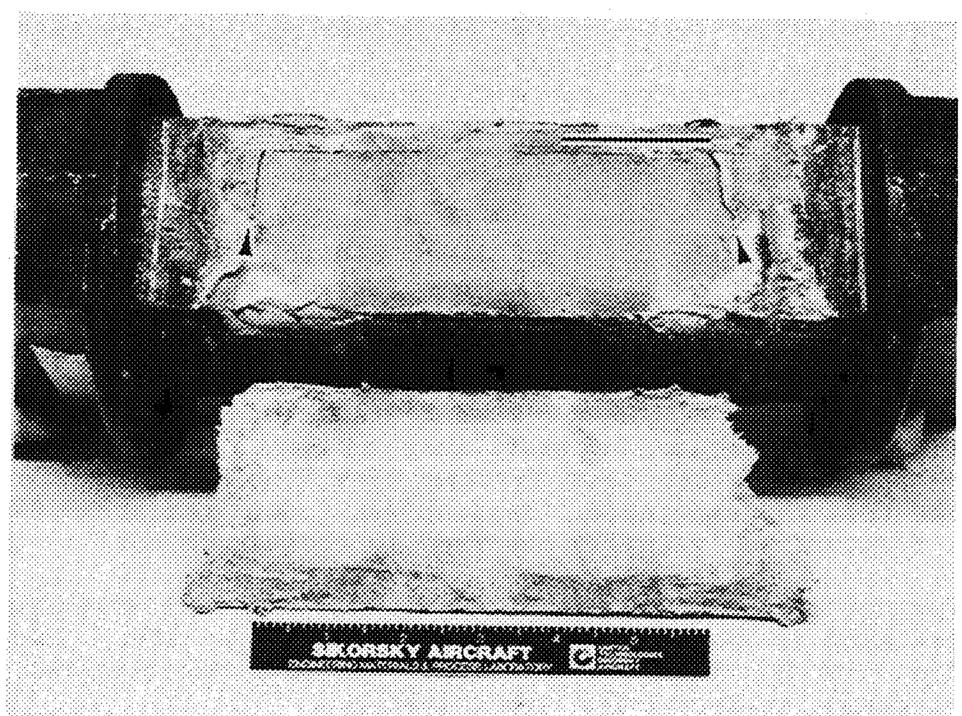


FIGURE 18. VIEW OF FORWARD SIDE OF TORQUE BOX SHOWING DELAMINATED FLAP, S-76 HORIZONTAL STABILIZER, S/N B-157-00021

the center section to the outside of both "C" clamp airframe clamping locations. Rubbing action was evident on the delaminated surfaces, particularly between both "C" clamps. Underneath the delamination, a crack was observed extending from BL3.5 R to BL3.5 L. This crack was presumably caused by the separation between the upper and lower channels. Each end of the crack terminated at a vertical through Kevlar crack in the lower channel sidewall. Both vertical cracks were under the "C" clamps and were approximately 2.25 inches long. No cracking was apparent in the bottom corner of the torque tube.

A Kevlar-to-Kevlar disbond was present from BL3.5 R to BL3.5 L. This disbond did not propagate beyond the syntactic foam filled areas. Between the regions filled with syntactic foam, a large degree of core breakdown was apparent.

Most of the core failure was within the core itself rather than at any bondlines. The entire core-to-core bondline was intact while only a small area of approximately one square inch of the core-to-lower channel showed any signs of disbond. In the small region between BL0.0 and BL1.0 R the disbond was at the adhesive-to-Kevlar interface. None of the several cross sectional cuts taken through the torque box disclosed any evidence of cracking in either corner of the lower channel. No damage was observed in the airfoil sections of the stabilizer. Although the stabilizer was fatigue tested to failure, the structural integrity was maintained under test conditions.

Six graphite/epoxy coupons were removed from failed stabilizer S/N B-157-00021 at Buttlines 4.0 - 9.0, for moisture desorption. Desorption data pertaining to the coupons is presented in Table V. The average percent moisture desorbed, 0.45 percent, is illustrated graphically in Figure 19 for S/N B-157-00021.

3.1.1.4 S/N B-157-00027

Stabilizer S/N B-157-00027 was returned from the field after 91 months of service. The stabilizer had accumulated 5846 flight hours. The environmental history of the stabilizer is contained in Table VI.

Prior to full scale fatigue testing, the stabilizer was proof load deflection tested in the manner previously described. The resulting deflection of 3.89mm (0.153 in), indicated that no loss of stiffness had occurred after in-service exposure in the Gulf Coast region of Louisiana.

Stabilizer S/N B-157-00027 was then asymmetrically loaded for fatigue testing in accordance with the load values detailed in Figure 10. Roll and yaw moments generated were ±47,200 inch pounds and ±21,840 inch pounds, respectively. Testing continued to 437,340 cycles, when visual examination and coin tapping located areas in the central region of the torque box to be suspected of disbonding. Teardown evaluation revealed that disbonding on the leading edge side had

TABLE V. MOISTURE DESORPTION OF HORIZONTAL STABILIZER S/N B-157-00021, BUTTLINES 4-9

DATE OF WEIGHING	DAYS	WEIGHT OF BL45B (grams)	WEIGHT OF BL45T (grams)	WEIGHT OF BL67B (grams)	WEIGHT OF BL67T (grams)	WEIGHT OF BL89B (grams)	WEIGHT OF BL89T (grams)
2/3/86	0	5.0589	4.85	5.4669	7.891	5.7893	7.5493
2/4/86	1	5.0539	4.8431	5.4618	7.8838	5.783	7.5411
2/5/86	2	5.0526	4.8408	5.4616	7.8816	5.7816	7.5393
2/6/86	3	5.0515	4.8394	5.4601	7.8804	5.78	7.5372
2/7/86	4	5.05	4.8378	5.4587	7.8788	5.7788	7.5356
2/10/86	7	5.048	4.8346	5.4576	7.8757	5.7761	7.5322
2/12/86	9	5.0461	4.8326	5.4558	7.8739	5.774	7.5295
2/14/86	11	5.0457	4.8316	5.4553	7.873	5.7733	7.5284
2/17/86	14	5.0443	4.8299	5.455	7.8714	5.7719	7.5265
2/19/86	16	5.0435	4.8283	5.4544	7.8704	5.7707	7.5246
2/21/86	18	5.0439	4.8288	5.4547	7.8708	5.7713	7.5254
2/24/86	21	5.0423	4.827	5.4541	7.869	5.7695	7.5236
2/26/86	23	5.0412	4.8258	5.453	7.8681	5.7692	7.5224
2/28/86	25	5.0407	4.8253	5.4527	7.8667	5.7679	7.5211
3/7/86	32	5.0395	4.8235	5.4515	7.8653	5.7661	7.5185
3/10/86	35	5.0399	4.8236	5.4521	7.8652	5.7668	7.5182
3/14/86	39	5.039	4.8229	5.4516	7.8644	5.766	7.5175
3/17/86	42	5.0389	4.8226	5.452	7.8642	5.7655	7.517
3/21/86	46	5.0381	4.8218	5.4508	7.8627	5.7645	7.5156
3/24/86	49	5.037	4.8208	5.4501	7.862	5.7639	7.5146
3/31/86	56	5.0376	4.8214	5.4514	7.8632	5.7641	7.5146
4/7/86	63	5.0377	4.821	5.4512	7.8624	5.7639	7.5138
4/14/86	70	5.0372	4.8205	5.4511	7.8615	5.7633	7.5127
4/21/86	77	5.0359	4.8193	5.4507	7.8603	5.7628	7.5114
4/28/86	84	5.037	4.8208	5.4516	7.8616	5.7634	7.512
5/5/86	91	5.0365	4.82	5.4509	7.8605	5.7628	7.5109
5/12/86	98	5.036	4.8197	5.4506	7.86	5.7622	7.5104
5/16/86	102	5.0368	4.8206	5.4514	7.861	5.7634	7.5113
5/19/86	105	5.0373	4.8214	5.4518	7.8614	5.7638	7.5111
6/2/86	119	5.0377	4.8214	5.4526	7.8628	5.7639	7.5119
6/9/86	126	5.0378	4.8216	5.4529	7.8629	5.7642	7.5116
6/16/86	133	5.038	4.8223	5.4535	7.8633	5.7647	7.5118

TABLE V. MOISTURE DESORPTION OF HORIZONTAL STABILIZER S/N B-157-00021, BUTTLINES 4-9 (Continued)

DATE OF WEIGHING	DAYS	% MOIST DESORBED BL45B	% MOIST DESORBED BL45T	% MOIST DESORBED BL67B	% MOIST DESORBED BL67T	% MOIST DESORBED BL89B	% MOIST DESORBED BL89T	AVERAGE % MOIST DESORBED
2/3/86	0	0	0	0	0	0	0	0
2/4/86	1	-0.10	-0.14	-0.09	-0.09	-0.11	-0.11	-0.11
2/5/86	2	-0.12	-0.19	-0.10	-0.12	-0.13	-0.13	-0.13
2/6/86	3	-0.15	-0.22	-0.12	-0.13	-0.16	-0.16	-0.16
2/7/86	4	-0.18	-0.25	-0.15	-0.15	-0.18	-0.18	-0.18
2/10/86	7	-0.22	-0.32	-0.17	-0.19	-0.23	-0.23	-0.23
2/12/86	9	-0.25	-0.36	-0.20	-0.22	-0.26	-0.26	-0.26
2/14/86	11	-0.26	-0.38	-0.21	-0.23	-0.28	-0.28	-0.27
2/17/86	14	-0.29	-0.41	-0.22	-0.25	-0.30	-0.30	-0.30
2/19/86	16	-0.30	-0.45	-0.23	-0.26	-0.32	-0.33	-0.32
2/21/86	18	-0.30	-0.44	-0.22	-0.26	-0.31	-0.32	-0.31
2/24/86	21	-0.33	-0.47	-0.23	-0.28	-0.34	-0.34	-0.33
2/26/86	23	-0.35	-0.50	-0.25	-0.29	-0.35	-0.36	-0.35
2/28/86	25	-0.36	-0.51	-0.26	-0.31	-0.37	-0.37	-0.36
3/7/86	32	-0.38	-0.55	-0.28	-0.33	-0.40	-0.41	-0.39
3/10/86	35	-0.38	-0.54	-0.27	-0.33	-0.39	-0.41	-0.39
3/14/86	39	-0.39	-0.56	-0.28	-0.34	-0.40	-0.42	-0.40
3/17/86	42	-0.40	-0.56	-0.27	-0.34	-0.41	-0.43	-0.40
3/21/86	46	-0.41	-0.58	-0.29	-0.36	-0.43	-0.45	-0.42
3/24/86	49	-0.43	-0.60	-0.31	-0.37	-0.44	-0.46	-0.43
3/31/86	56	-0.42	-0.59	-0.28	-0.35	-0.44	-0.46	-0.42
4/7/86	63	-0.42	-0.60	-0.29	-0.36	-0.44	-0.47	-0.43
4/14/86	70	-0.43	-0.61	-0.29	-0.37	-0.45	-0.48	-0.44
4/21/86	77	-0.45	-0.63	-0.30	-0.39	-0.46	-0.50	-0.46
4/28/86	84	-0.43	-0.60	-0.28	-0.37	-0.45	-0.49	-0.44
5/5/86	91	-0.44	-0.62	-0.29	-0.39	-0.46	-0.51	-0.45
5/12/86	98	-0.45	-0.62	-0.30	-0.39	-0.47	-0.52	-0.46
5/16/86	102	-0.44	-0.61	-0.28	-0.38	-0.45	-0.50	-0.44
5/19/86	105	-0.43	-0.59	-0.28	-0.38	-0.44	-0.51	-0.44
6/2/86	119	-0.42	-0.59	-0.26	-0.36	-0.44	-0.50	-0.43
6/9/86	126	-0.42	-0.59	-0.26	-0.36	-0.43	-0.50	-0.42
6/16/86	133	-0.41	-0.57	-0.25	-0.35	-0.42	-0.50	-0.42

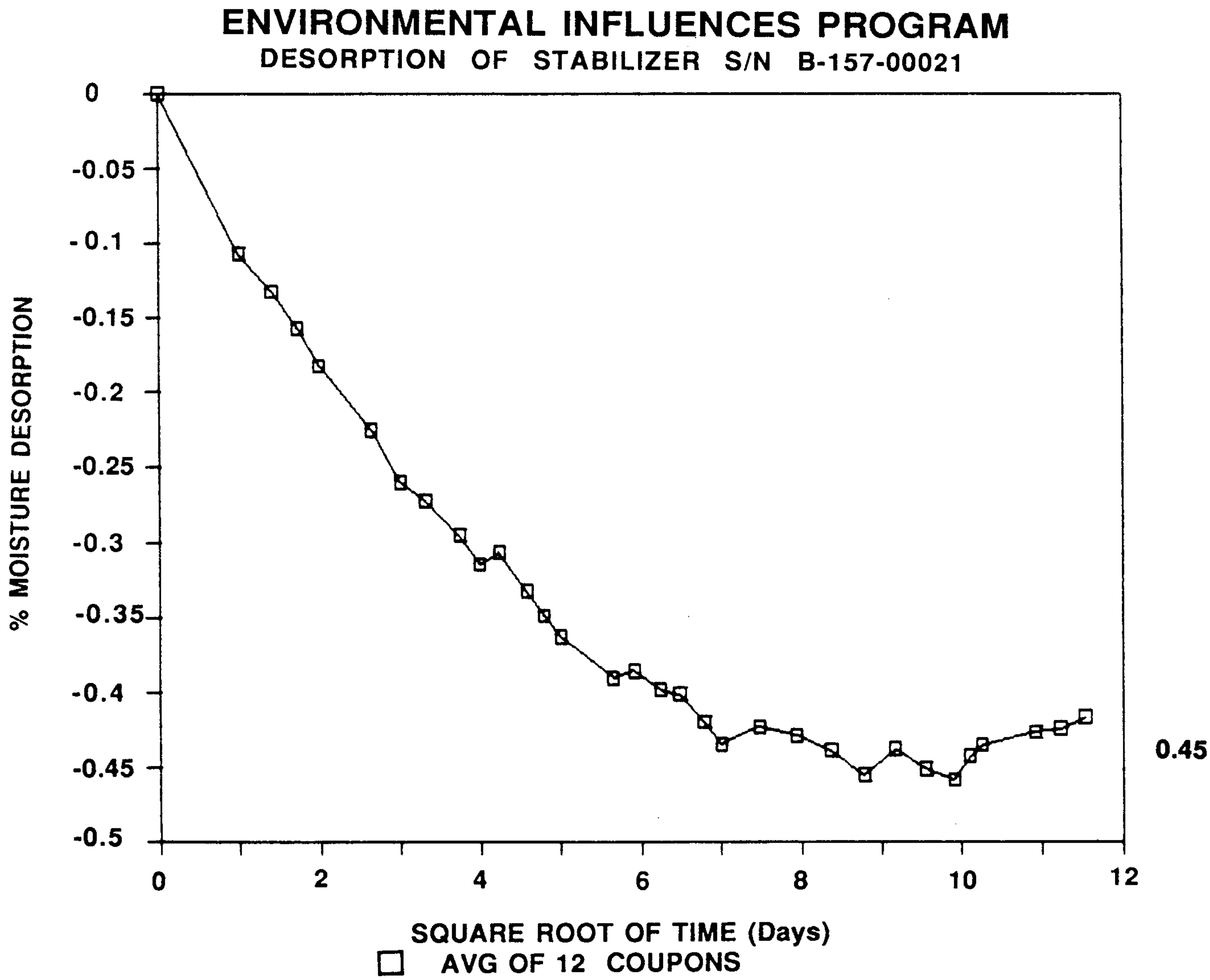


FIGURE 19. MOISTURE DESORPTION OF S-76 HORIZONTAL STABILIZER S/N B-157-00021 COUPONS FROM BL 4.0 - BL 9.0

TABLE VI.

STABILIZER S/N B-157-00027
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
11/28/79 - 11/30/79	12.4	54.4	75.4
12/01/79 - 12/31/79	10.3	50.5	78.1
1/01/80 - 1/31/80	11.9	33.4	86.4
2/01/80 - 2/29/80	10.3	50.6	80.5
3/01/80 - 3/31/80	15.2	59.4	81.4
4/01/80 - 4/30/80	18.4	65.1	76.5
5/01/80 - 5/31/80	23.9	74.8	83.9
6/01/80 - 6/30/80	27.1	80.8	80.3
7/01/80 - 7/31/80	28.2	82.8	72.5
8/01/80 - 8/31/80	27.4	81.3	74.0
9/01/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.4	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	22.6	72.6	73.3
6/01/81 - 6/30/81	26.8	80.3	82.1
7/01/81 - 7/31/81	27.3	81.1	81.8
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1

TABLE VI. (Continued)

STABILIZER S/N B-157-00027
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/30/83	17.5	63.5	73.4
5/01/83 - 5/31/83	23.0	73.4	77.1
6/01/83 - 6/30/83	25.6	78.0	81.3
7/01/83 - 7/31/83	28.2	92.8	78.1
8/01/83 - 8/31/83	27.8	82.1	81.4
9/01/83 - 9/30/83	24.2	75.6	77.9
10/01/83 - 10/31/83	21.1	69.9	73.3
11/01/83 - 11/30/83	16.7	62.1	75.8
12/01/83 - 12/31/83	9.1	48.3	73.3
1/01/84 - 1/31/84	8.9	48.1	74.3
2/01/84 - 2/29/84	13.3	55.9	68.1
3/01/84 - 3/31/84	16.9	62.4	72.5
4/01/84 - 4/30/84	21.1	69.9	66.9
5/01/84 - 5/31/84	23.9	75.0	72.3
6/01/84 - 6/30/84	26.4	79.5	79.0
7/01/84 - 7/31/84	26.9	80.4	82.1
8/01/84 - 8/31/84	26.7	80.1	84.1
9/01/84 - 9/30/84	23.8	74.8	79.1
10/01/84 - 10/31/84	22.7	72.8	85.9
11/01/84 - 11/30/84	14.3	57.8	78.8
12/01/84 - 12/31/84	16.4	61.6	86.5
1/01/85 - 1/31/85	6.8	44.3	78.4
2/01/85 - 2/28/85	9.9	49.9	82.0
3/01/85 - 3/31/85	17.8	64.1	81.4
4/01/85 - 4/30/85	21.0	69.8	73.6
5/01/85 - 5/31/85	23.9	75.1	76.0
6/01/85 - 6/30/85	27.0	80.6	75.1
7/01/85 - 7/31/85	26.9	80.5	80.5
8/01/85 - 8/31/85	27.7	81.8	80.3
9/01/85 - 9/30/85	25.3	77.5	79.5
10/01/85 - 10/31/85	22.2	71.9	82.8
11/01/85 - 11/30/85	18.8	65.9	83.8
12/01/85 - 12/31/85	9.7	49.4	75.8

TABLE VI. (Continued)

STABILIZER S/N B-157-00027
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
1/01/86 - 1/31/86	10.8	51.4	73.1
2/01/86 - 2/28/86	14.1	57.4	79.8
3/01/86 - 3/31/86	15.8	60.4	75.0
4/01/86 - 4/30/86	20.2	68.4	77.6
5/01/86 - 5/31/86	24.2	75.5	81.0
6/01/86 - 6/30/86	27.2	80.9	82.1
7/01/86 - 7/31/86	28.2	82.8	80.8
8/01/86 - 8/31/86	27.1	80.8	79.4
9/01/86 - 9/30/86	26.7	80.0	83.0
10/01/86 - 10/31/86	16.1	60.9	79.6
11/01/86 - 11/30/86	17.4	63.3	83.6
12/01/86 - 12/31/86	10.3	50.6	82.6
1/01/87 - 1/31/87	9.5	49.1	79.3
2/01/87 - 2/28/87	12.8	55.1	79.8
3/01/87 - 3/31/87	14.5	58.1	69.8
4/01/87 - 4/30/87	18.8	65.9	65.4
5/01/87 - 5/31/87	24.2	75.6	83.3
6/01/87 - 6/26/87	26.3	79.3	80.4

occurred between BL4.0L and BL4.0R, including, but not outboard of the clamping areas. Sections between the densified core clamping areas (BL2.0L, BL0.0 and BL2.0R) exhibited separation of the 3M Company EC2214 paste adhesive bondline between the vertical Kevlar splices and Kevlar upper channel, and horizontally through the Narmco (BASF) M1113 film adhesive between the upper and lower channels (Reference Figure 20). Cracking through the Kevlar plies was also noted at the forward bottom region, between BL2.0L and BL2.0R, although no abnormalities were observed in the Kevlar or the EC2214 adhesive. Some of the aforementioned cracking occurred adjacent to the graphite cap strip. No cracking was observed in the cap strip itself.

The honeycomb core in the BL2.0L-to-BL2.0R region, shown in Figure 21, was completely separated, mostly by cracking, apparently caused by fatigue. The core separations and cracking extended into the EPOCAST 169 densified areas under the clamping locations. The damage did not extend outboard of the clamping regions. The extent of the suspected damage depicted by coin tap inspection proved to be close to the actual amount of the separations found during sectioning.

Little or no "offset" was present between the upper and lower channels in the BL 8.0L to BL 8.0R region examined. Additionally, no bonding abnormalities were observed. As anticipated, no damage had been sustained in the airfoil regions.

Coupons were removed from Buttlines 4.0 - 9.0 of stabilizer S/N B-157-00027 for moisture desorption. The average moisture desorbed from graphite/epoxy coupons between Buttlines 4.0 and 9.0 was 0.49 percent. Desorption data is presented in Table VII. A plot of the average percent moisture desorbed is presented in Figure 22 for S/N B-157-00027.

3.1.1.5 Horizontal Stabilizers - Summary of Test Results

Results of the proof load deflection test data for all four of the stabilizers returned are presented graphically in Figure 23 for comparison. As can be seen in the figure, deflection measurements recorded for each of the four stabilizers returned from the field still remained below 4.14mm (0.163 in.), the maximum deflection allowed in production for a new stabilizer, indicating no loss of stiffness had occurred after in-service environmental exposure of the components.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

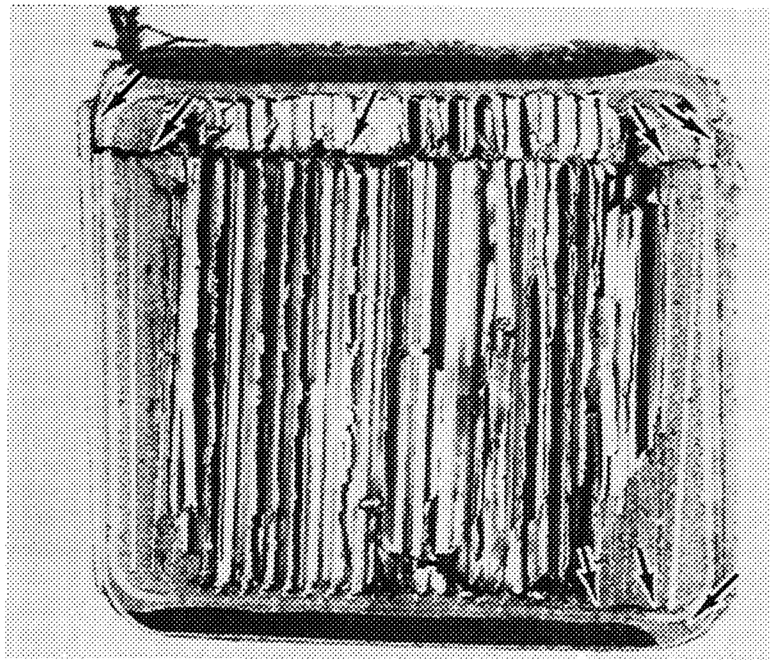


FIGURE 20. SECTION THROUGH BL 0 SHOWING BONDLINE SEPARATION ALONG UPPER AND LOWER CHANNEL INTERFACE, S-76 HORIZONTAL STABILIZER, S/N B-157-00027

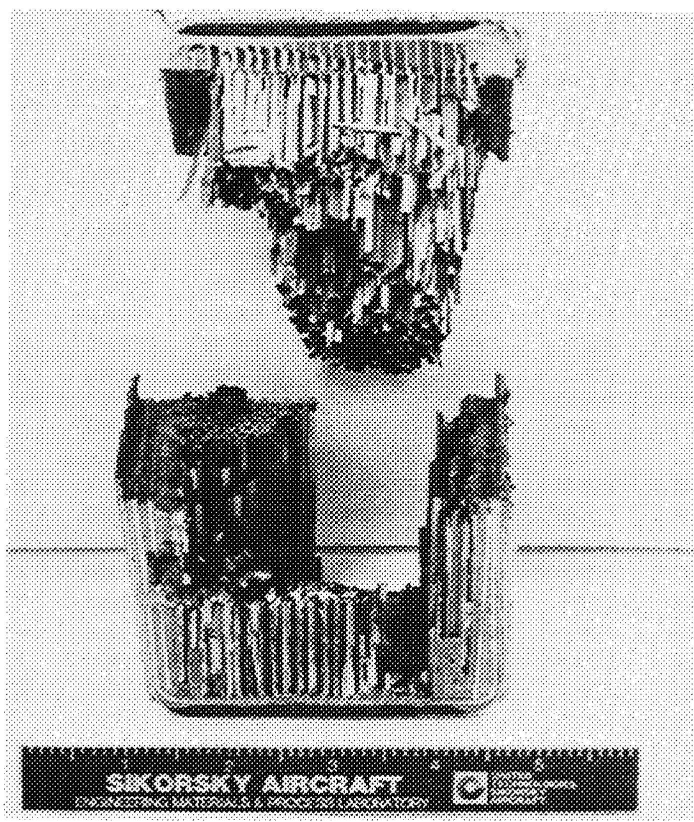


FIGURE 21. TYPICAL CORE CRACKING BETWEEN BL 2L AND BL 2R, S-76 HORIZONTAL STABILIZER, S/N B-157-00027

TABLE VII. MOISTURE DESORPTION OF HORIZONTAL STABILIZER
S/N B-157-00027, BUTTLINES 4-9

DATE OF WEIGHING	DAYS	WEIGHT OF BL45B (grams)	WEIGHT OF BR45B (grams)	WEIGHT OF BL45T (grams)	WEIGHT OF BR45T (grams)	WEIGHT OF BL67B (grams)	WEIGHT OF BR67B (grams)	WEIGHT OF BL67T (grams)	WEIGHT OF BR67T (grams)	WEIGHT OF BL89B (grams)	WEIGHT OF BR89B (grams)	WEIGHT OF BL89T (grams)	WEIGHT OF BR89T (grams)
3/21/88	0	6.6592	7.5464	6.621	7.1312	7.8534	5.8122	5.8234	7.1435	7.1463	7.1303	6.7218	7.4986
3/22/88	1	6.6537	7.5407	6.6155	7.1248	7.8486	5.8082	5.8173	7.1385	7.1419	7.1264	6.7178	7.4938
3/23/88	2	6.6528	7.5392	6.6145	7.1235	7.8464	5.8066	5.8159	7.1375	7.1413	7.1258	6.7159	7.493
3/25/88	4	6.651	7.5374	6.6122	7.1218	7.8449	5.8058	5.8148	7.1352	7.1407	7.125	6.7156	7.4917
3/28/88	7	6.6478	7.5338	6.6086	7.1184	7.8412	5.803	5.8112	7.132	7.1381	7.1223	6.7135	7.4893
3/30/88	9	6.6463	7.5321	6.6071	7.1164	7.8403	5.8016	5.8106	7.1302	7.1375	7.1214	6.7126	7.4879
4/4/88	14	6.6439	7.5301	6.6055	7.1142	7.8381	5.8009	5.8088	7.1289	7.1365	7.1214	6.7122	7.4878
4/8/88	18	6.6414	7.5279	6.603	7.1115	7.836	5.7987	5.8066	7.1266	7.1351	7.1195	6.7108	7.486
4/11/88	21	6.6395	7.5262	6.602	7.1099	7.8339	5.7978	5.8063	7.1253	7.1336	7.1186	6.7101	7.4849
4/13/88	23	6.6398	7.5256	6.6014	7.1095	7.834	5.7972	5.8048	7.125	7.1339	7.1186	6.7097	7.4846
4/15/88	25	6.6389	7.5249	6.6004	7.1085	7.8331	5.7966	5.8046	7.1241	7.1335	7.1182	6.7094	7.4841
4/18/88	28	6.6379	7.5241	6.5998	7.1076	7.8325	5.7962	5.8043	7.1236	7.1331	7.1182	6.7091	7.4838
4/20/88	30	6.6368	7.5228	6.5986	7.1063	7.8312	5.7949	5.8029	7.1222	7.1319	7.1168	6.7082	7.4827
4/22/88	32	6.6367	7.5227	6.5985	7.1059	7.8312	5.7948	5.803	7.122	7.132	7.1169	6.7086	7.4825
4/25/88	35	6.6358	7.5218	6.5978	7.1051	7.8304	5.7942	5.8023	7.1216	7.1316	7.1163	6.7081	7.4822
4/27/88	37	6.6355	7.5214	6.5975	7.105	7.83	5.7939	5.8019	7.1213	7.1315	7.1162	6.7081	7.4821
4/29/88	39	6.6349	7.5207	6.5965	7.1042	7.8292	5.7935	5.8018	7.1207	7.1311	7.116	6.7078	7.4818
5/2/88	43	6.6341	7.5198	6.5955	7.1033	7.8281	5.7929	5.8004	7.12	7.1302	7.1156	6.7069	7.4816
5/9/88	50	6.6334	7.5192	6.5952	7.1026	7.8274	5.7924	5.8007	7.1192	7.1302	7.1154	6.7068	7.4812
5/16/88	57	6.6331	7.5183	6.5949	7.1018	7.8267	5.792	5.8002	7.1183	7.13	7.1148	6.707	7.4809
5/23/88	63	6.6323	7.518	6.5941	7.1015	7.8264	5.7919	5.8004	7.1181	7.13	7.1149	6.707	7.4806
6/6/88	77	6.6297	7.5151	6.5918	7.0984	7.8238	5.79	5.7983	7.1157	7.1283	7.1136	6.7057	7.4788
6/20/88	91	6.6286	7.5148	6.5904	7.0981	7.8221	5.7898	5.7975	7.1154	7.1276	7.1134	6.7059	7.4786
6/27/88	98	6.6284	7.5139	6.5902	7.0974	7.8225	5.7891	5.798	7.1148	7.1278	7.1132	6.7053	7.478
7/5/88	106	6.6285	7.5137	6.5903	7.0973	7.8225	5.789	5.7976	7.1144	7.128	7.1133	6.7054	7.4781
7/11/88	112	6.6285	7.5138	6.5905	7.0975	7.8224	5.7893	5.7979	7.0975	7.1281	7.1132	6.7058	7.4786
7/18/88	119	6.6284	7.5136	6.5904	7.0966	7.8224	5.789	5.7979	7.097	7.1282	7.1132	6.7057	7.4787
7/25/88	126	6.6281	7.513	6.5894	7.0964	7.8215	5.7886	5.7971	7.0967	7.1278	7.113	6.7053	7.4778
8/1/88	133	6.6279	7.5128	6.5897	7.0963	7.8217	5.789	5.7977	7.0968	7.1281	7.1132	6.7055	7.4778
8/8/88	140	6.6274	7.5126	6.5892	7.0959	7.8214	5.7884	5.7976	7.0965	7.1275	7.113	6.7053	7.4775
8/15/88	147	6.6275	7.5126	6.5893	7.0958	7.8214	5.7885	5.7973	7.0963	7.1281	7.1131	6.7054	7.4775
8/22/88	154	6.6267	7.512	6.5886	7.0952	7.8203	5.7876	5.7965	7.0957	7.1272	7.1123	6.7047	7.4768
8/29/88	161	6.6268	7.5116	6.5885	7.0948	7.8207	5.7879	5.7969	7.0954	7.1276	7.1126	6.7049	7.477
9/12/88	175	6.6264	7.5112	6.5883	7.095	7.8199	5.7875	5.7966	7.0956	7.1274	7.1129	6.7047	7.4774
9/19/88	182	6.626	7.5107	6.5878	7.0937	7.8192	5.7866	5.7959	7.0944	7.1264	7.1114	6.7041	7.476
9/26/88	189	6.6256	7.5109	6.587	7.0934	7.819	5.7867	5.7954	7.0946	7.1262	7.1116	6.7039	7.476
10/3/88	196	6.6252	7.5103	6.5869	7.0932	7.819	5.7864	5.7956	7.0939	7.1263	7.1115	6.7038	7.4756
10/10/88	203	6.625	7.51	6.5867	7.0931	7.8188	5.7863	5.7953	7.094	7.1261	7.1112	6.704	7.4755
10/24/88	217	6.6249	7.51	6.5864	7.0928	7.8185	5.7865	5.7952	7.0938	7.1261	7.1114	6.7039	7.4757
10/31/88	224	6.6239	7.5089	6.5855	7.0916	7.8178	5.7854	5.7947	7.0926	7.1253	7.1103	6.7033	7.4741
11/7/88	231	6.6243	7.5092	6.586	7.0922	7.8183	5.7859	5.7948	7.0934	7.1254	7.1108	6.7032	7.4754
11/14/88	238	6.6241	7.5094	6.5858	7.0917	7.8181	5.7857	5.7948	7.0932	7.1256	7.1107	6.7034	7.4748
11/21/88	245	6.6232	7.5081	6.5845	7.0912	7.8165	5.7851	5.7934	7.092	7.124	7.1097	6.7023	7.4734
11/28/88	252	6.6246	7.5095	6.5863	7.092	7.8184	5.7857	5.7952	7.0927	7.1256	7.111	6.7037	7.4748
12/2/88	256	6.6237	7.5078	6.5846	7.0906	7.8168	5.7846	5.7938	7.0919	7.124	7.1096	6.7018	7.4735
12/5/88	259	6.623	7.5076	6.5839	7.0904	7.8164	5.7845	5.7931	7.0918	7.124	7.1094	6.7018	7.473
12/12/88	266	6.6224	7.5069	6.5837	7.0897	7.8159	5.7837	5.7926	7.0909	7.1237	7.1089	6.7012	7.4728
12/19/88	273	6.6223	7.5069	6.5836	7.09893	7.816	5.7837	5.7927	7.0911	7.1238	7.1089	6.7013	7.4724

TABLE VII. MOISTURE DESORPTION OF HORIZONTAL STABILIZER S/N B-157-00027, BUTTLINES 4-9 (Continued)

DATE OF WEIGHING	DAYS	WEIGHT OF BL45B (grams)	WEIGHT OF BR45B (grams)	WEIGHT OF BL45T (grams)	WEIGHT OF BR45T (grams)	WEIGHT OF BL67B (grams)	WEIGHT OF BR67B (grams)	WEIGHT OF BL67T (grams)	WEIGHT OF BR67T (grams)	WEIGHT OF BL89B (grams)	WEIGHT OF BR89B (grams)	WEIGHT OF BL89T (grams)	WEIGHT OF BR89T (grams)
12/26/88	280	6.6227	7.5073	6.5835	7.0899	7.816	5.7839	5.7928	7.0909	7.124	7.1089	6.7019	7.4729
1/9/89	294	6.6232	7.5074	6.5838	7.0898	7.8159	5.784	5.7932	7.0908	7.1238	7.1093	6.7016	7.4726
1/16/89	301	6.6225	7.5067	6.5836	7.0894	7.8159	5.7837	5.7931	7.0908	7.1238	7.1091	6.7012	7.4725
1/23/89	308	6.6209	7.5059	6.5826	7.0882	7.8146	5.7828	5.7916	7.0898	7.1226	7.108	6.7004	7.4716
1/30/89	315	6.622	7.5065	6.5829	7.0889	7.8155	5.7834	5.7925	7.0903	7.1235	7.1085	6.7011	7.4722
2/6/89	322	6.622	7.5062	6.5828	7.0888	7.8154	5.7829	5.7924	7.0899	7.1231	7.1082	6.7007	7.472
2/13/89	329	6.6218	7.5056	6.5827	7.0878	7.8152	5.7826	5.7923	7.0896	7.1236	7.108	6.7012	7.4712
2/20/89	336	6.6208	7.5055	6.582	7.0872	7.8146	5.7822	5.79	7.0894	7.1225	7.1077	6.7005	7.471
2/27/89	343	6.6213	7.5058	6.5823	7.0881	7.8149	5.7826	5.792	7.0901	7.1231	7.1086	6.7005	7.4718
3/6/89	350	6.6211	7.5048	6.5813	7.0872	7.8142	5.7818	5.7912	7.0891	7.1226	7.1075	6.7	7.4702
3/10/89	354	6.6214	7.505	6.5819	7.0873	7.8143	5.7825	5.7916	7.0897	7.1227	7.1078	6.7001	7.471
3/27/89	371	6.6219	7.5061	6.5828	7.0882	7.8153	5.783	5.7927	7.0898	7.1236	7.1083	6.701	7.4715
4/4/89	379	6.6214	7.5062	6.5830	7.0883	7.8153	5.7836	5.7925	7.0897	7.1236	7.1091	6.7009	7.4718
4/10/89	385	6.6213	7.5057	6.5817	7.0876	7.8145	5.7827	5.792	7.0893	7.1233	7.1078	6.7004	7.4712
4/17/89	392	6.6215	7.506	6.5821	7.0882	7.8149	5.7827	5.7933	7.0898	7.1231	7.1075	6.7008	7.4737
4/24/89	399	6.6212	7.5057	6.5821	7.0881	7.8145	5.7831	5.792	7.0898	7.123	7.1082	6.7	7.4715
5/1/89	406	6.6215	7.5065	6.5823	7.0873	7.8152	5.783	5.7921	7.09	7.1237	7.1081	6.7001	7.4712
5/8/89	413	6.6199	7.506	6.5821	7.0879	7.8146	5.7826	5.7921	7.0899	7.1231	7.1085	6.6998	7.472
5/15/89	420	6.6228	7.5065	6.5829	7.0885	7.8157	5.7831	5.7931	7.0901	7.1233	7.1092	6.7007	7.4725
6/4/89	440	6.623	7.5073	6.5830	7.0893	7.8158	5.7833	5.7938	7.0911	7.1245	7.1094	6.7004	7.4735
6/12/89	448	6.6227	7.5075	6.5837	7.0888	7.8164	5.7841	5.7938	7.0913	7.1249	7.109	6.7007	7.4732
6/19/89	455	6.6229	7.5075	6.5841	7.0893	7.8167	5.7841	5.7943	7.0912	7.1249	7.1098	6.7009	7.4732
6/26/89	462	6.6232	7.5084	6.5842	7.0902	7.817	5.7846	5.7946	7.0915	7.1255	7.11	6.7014	7.474

TABLE VII. MOISTURE DESORPTION OF HORIZONTAL STABILIZER
S/N B-157-00027, BUTTLINES 4-9 (Continued)

DATE OF WEIGHING	DAYS	% MOIST DESORB BL45B	% MOIST DESORB BR45B	% MOIST DESORB BL45T	% MOIST DESORB BR45T	% MOIST DESORB BL67B	% MOIST DESORB BR67B	% MOIST DESORB BL67T	% MOIST DESORB BR67T	% MOIST DESORB BL89B	% MOIST DESORB BR89B	% MOIST DESORB BL89T	% MOIST DESORB BR89T	AVERA % MO DESO
3/21/88	0	0	0	0	0	0	0	0	0	0	0	0	0	
3/22/88	1	-0.08	-0.08	-0.08	-0.09	-0.06	-0.07	-0.10	-0.07	-0.06	-0.05	-0.06	-0.06	-0
3/23/88	2	-0.10	-0.10	-0.10	-0.11	-0.09	-0.10	-0.13	-0.08	-0.07	-0.06	-0.09	-0.07	-0
3/25/88	4	-0.12	-0.12	-0.13	-0.13	-0.11	-0.11	-0.15	-0.12	-0.08	-0.07	-0.09	-0.09	-0
3/28/88	7	-0.17	-0.17	-0.19	-0.18	-0.16	-0.16	-0.21	-0.16	-0.11	-0.11	-0.12	-0.12	-0
3/30/88	9	-0.19	-0.19	-0.21	-0.21	-0.17	-0.18	-0.22	-0.19	-0.12	-0.12	-0.14	-0.14	-0.
4/4/88	14	-0.23	-0.22	-0.23	-0.24	-0.19	-0.19	-0.25	-0.20	-0.14	-0.12	-0.14	-0.14	-0.
4/8/88	18	-0.27	-0.25	-0.27	-0.28	-0.22	-0.23	-0.29	-0.24	-0.16	-0.15	-0.16	-0.17	-0.
4/11/88	21	-0.30	-0.27	-0.29	-0.30	-0.25	-0.25	-0.29	-0.25	-0.18	-0.16	-0.17	-0.18	-0.
4/13/88	23	-0.29	-0.28	-0.30	-0.30	-0.25	-0.26	-0.32	-0.26	-0.17	-0.16	-0.18	-0.19	-0.
4/15/88	25	-0.30	-0.28	-0.31	-0.32	-0.26	-0.27	-0.32	-0.27	-0.18	-0.17	-0.18	-0.19	-0.
4/18/88	28	-0.32	-0.30	-0.32	-0.33	-0.27	-0.28	-0.33	-0.28	-0.18	-0.17	-0.19	-0.20	-0.
4/20/88	30	-0.34	-0.31	-0.34	-0.35	-0.28	-0.30	-0.35	-0.30	-0.20	-0.19	-0.20	-0.21	-0.
4/22/88	32	-0.34	-0.31	-0.34	-0.35	-0.28	-0.30	-0.35	-0.30	-0.20	-0.19	-0.20	-0.21	-0.
4/25/88	35	-0.35	-0.33	-0.35	-0.37	-0.29	-0.31	-0.36	-0.31	-0.21	-0.20	-0.20	-0.22	-0.
4/27/88	37	-0.36	-0.33	-0.35	-0.37	-0.30	-0.31	-0.37	-0.31	-0.21	-0.20	-0.20	-0.22	-0.
4/29/88	39	-0.36	-0.34	-0.37	-0.38	-0.31	-0.32	-0.37	-0.32	-0.21	-0.20	-0.21	-0.22	-0.
5/2/88	43	-0.38	-0.35	-0.39	-0.39	-0.32	-0.33	-0.39	-0.33	-0.23	-0.21	-0.22	-0.23	-0.
5/9/88	50	-0.39	-0.36	-0.39	-0.40	-0.33	-0.34	-0.39	-0.34	-0.23	-0.21	-0.22	-0.23	-0.
5/16/88	57	-0.39	-0.37	-0.39	-0.41	-0.34	-0.35	-0.40	-0.35	-0.23	-0.22	-0.22	-0.24	-0.
5/23/88	63	-0.40	-0.38	-0.41	-0.42	-0.34	-0.35	-0.39	-0.36	-0.23	-0.22	-0.22	-0.24	-0.
6/6/88	77	-0.44	-0.41	-0.44	-0.46	-0.38	-0.38	-0.43	-0.39	-0.25	-0.23	-0.24	-0.26	-0.
6/20/88	91	-0.46	-0.42	-0.46	-0.46	-0.40	-0.39	-0.44	-0.39	-0.26	-0.24	-0.24	-0.27	-0.
6/27/88	98	-0.46	-0.43	-0.47	-0.47	-0.39	-0.40	-0.44	-0.40	-0.26	-0.24	-0.25	-0.27	-0.
7/5/88	106	-0.46	-0.43	-0.46	-0.48	-0.39	-0.40	-0.44	-0.41	-0.26	-0.24	-0.24	-0.27	-0.
7/11/88	112	-0.46	-0.43	-0.46	-0.47	-0.39	-0.39	-0.44	-0.64	-0.25	-0.24	-0.24	-0.27	-0.
7/18/88	119	-0.46	-0.43	-0.46	-0.49	-0.39	-0.40	-0.44	-0.65	-0.25	-0.24	-0.24	-0.27	-0.
7/25/88	126	-0.47	-0.44	-0.48	-0.49	-0.41	-0.41	-0.45	-0.66	-0.26	-0.24	-0.25	-0.28	-0.
8/1/88	133	-0.47	-0.45	-0.47	-0.49	-0.40	-0.40	-0.44	-0.65	-0.25	-0.24	-0.24	-0.28	-0.
8/8/88	140	-0.48	-0.45	-0.48	-0.50	-0.41	-0.41	-0.44	-0.66	-0.26	-0.24	-0.25	-0.28	-0.
8/15/88	147	-0.48	-0.45	-0.48	-0.50	-0.41	-0.41	-0.45	-0.66	-0.25	-0.24	-0.24	-0.28	-0.
8/22/88	154	-0.49	-0.46	-0.49	-0.50	-0.42	-0.42	-0.46	-0.67	-0.27	-0.25	-0.25	-0.29	-0.
8/29/88	161	-0.49	-0.46	-0.49	-0.51	-0.42	-0.42	-0.46	-0.67	-0.26	-0.25	-0.25	-0.29	-0.
9/12/88	175	-0.49	-0.47	-0.49	-0.51	-0.43	-0.42	-0.46	-0.67	-0.26	-0.24	-0.25	-0.28	-0.
9/19/88	182	-0.50	-0.47	-0.50	-0.53	-0.44	-0.44	-0.47	-0.69	-0.28	-0.27	-0.26	-0.30	-0.
9/26/88	189	-0.50	-0.47	-0.51	-0.53	-0.44	-0.44	-0.48	-0.68	-0.28	-0.26	-0.27	-0.30	-0.
10/3/88	196	-0.51	-0.48	-0.52	-0.53	-0.44	-0.44	-0.48	-0.69	-0.28	-0.26	-0.27	-0.31	-0.
10/10/88	203	-0.51	-0.48	-0.52	-0.53	-0.44	-0.45	-0.48	-0.69	-0.28	-0.27	-0.26	-0.31	-0.
10/24/88	217	-0.52	-0.48	-0.52	-0.54	-0.44	-0.44	-0.48	-0.70	-0.28	-0.27	-0.27	-0.31	-0.
10/31/88	224	-0.53	-0.50	-0.54	-0.56	-0.45	-0.46	-0.49	-0.71	-0.29	-0.28	-0.28	-0.33	-0.
11/7/88	231	-0.52	-0.49	-0.53	-0.55	-0.45	-0.45	-0.49	-0.70	-0.29	-0.27	-0.28	-0.31	-0.
11/14/88	238	-0.53	-0.49	-0.53	-0.55	-0.45	-0.46	-0.49	-0.70	-0.29	-0.27	-0.27	-0.32	-0.
11/21/88	245	-0.54	-0.51	-0.55	-0.56	-0.47	-0.47	-0.52	-0.72	-0.31	-0.29	-0.29	-0.34	-0.
11/28/88	252	-0.52	-0.49	-0.52	-0.55	-0.45	-0.46	-0.48	-0.71	-0.29	-0.27	-0.27	-0.32	-0.
12/2/88	256	-0.53	-0.51	-0.55	-0.57	-0.47	-0.47	-0.51	-0.72	-0.31	-0.29	-0.30	-0.33	-0.
12/5/88	259	-0.54	-0.51	-0.56	-0.57	-0.47	-0.48	-0.52	-0.72	-0.31	-0.29	-0.30	-0.34	-0.
12/12/88	266	-0.55	-0.52	-0.56	-0.58	-0.48	-0.49	-0.53	-0.74	-0.32	-0.30	-0.31	-0.34	-0.
12/19/88	273	-0.55	-0.52	-0.56	-0.45	-0.48	-0.49	-0.53	-0.73	-0.31	-0.30	-0.30	-0.35	-0.

TABLE VII. MOISTURE DESORPTION OF HORIZONTAL STABILIZER
S/N B-157-00027, BUTTLINES 4-9 (Continued)

DATE OF WEIGHING	DAYS	% MOIST DESORB BL45B	% MOIST DESORB BR45B	% MOIST DESORB BL45T	% MOIST DESORB BR45T	% MOIST DESORB BL67B	% MOIST DESORB BR67B	% MOIST DESORB BL67T	% MOIST DESORB BR67T	% MOIST DESORB BL89B	% MOIST DESORB BR89B	% MOIST DESORB BL89T	% MOIST DESORB BR89T	AVERAGE % MOIST DESORB
12/26/88	280	-0.55	-0.52	-0.57	-0.58	-0.48	-0.49	-0.53	-0.74	-0.31	-0.30	-0.30	-0.34	-0.47
1/9/89	294	-0.54	-0.52	-0.56	-0.58	-0.48	-0.49	-0.52	-0.74	-0.31	-0.29	-0.30	-0.35	-0.47
1/16/89	301	-0.55	-0.53	-0.56	-0.59	-0.48	-0.49	-0.52	-0.74	-0.31	-0.30	-0.31	-0.35	-0.48
1/23/89	308	-0.58	-0.54	-0.58	-0.60	-0.49	-0.51	-0.55	-0.75	-0.33	-0.31	-0.32	-0.36	-0.49
1/30/89	315	-0.56	-0.53	-0.58	-0.59	-0.48	-0.50	-0.53	-0.74	-0.32	-0.31	-0.31	-0.35	-0.48
2/6/89	322	-0.56	-0.53	-0.58	-0.59	-0.48	-0.50	-0.53	-0.75	-0.32	-0.31	-0.31	-0.35	-0.49
2/13/89	329	-0.56	-0.54	-0.58	-0.61	-0.49	-0.51	-0.53	-0.75	-0.32	-0.31	-0.31	-0.37	-0.49
2/20/89	336	-0.58	-0.54	-0.59	-0.62	-0.49	-0.52	-0.57	-0.76	-0.33	-0.32	-0.32	-0.37	-0.50
2/27/89	343	-0.57	-0.54	-0.58	-0.60	-0.49	-0.51	-0.54	-0.75	-0.32	-0.30	-0.32	-0.36	-0.49
3/6/89	350	-0.57	-0.55	-0.60	-0.62	-0.50	-0.52	-0.55	-0.76	-0.33	-0.32	-0.32	-0.38	-0.50
3/10/89	354	-0.57	-0.55	-0.59	-0.62	-0.50	-0.51	-0.55	-0.75	-0.33	-0.32	-0.32	-0.37	-0.50
3/27/89	371	-0.56	-0.53	-0.58	-0.60	-0.49	-0.50	-0.53	-0.75	-0.32	-0.31	-0.31	-0.36	-0.49
4/4/89	379	-0.57	-0.53	-0.57	-0.60	-0.49	-0.49	-0.53	-0.75	-0.32	-0.30	-0.31	-0.36	-0.49
4/10/89	385	-0.57	-0.54	-0.59	-0.61	-0.50	-0.51	-0.54	-0.76	-0.32	-0.32	-0.32	-0.37	-0.49
4/17/89	392	-0.57	-0.54	-0.59	-0.60	-0.49	-0.51	-0.52	-0.75	-0.32	-0.32	-0.31	-0.33	-0.49
4/24/89	399	-0.57	-0.54	-0.59	-0.60	-0.50	-0.50	-0.54	-0.75	-0.33	-0.31	-0.32	-0.36	-0.49
5/1/89	406	-0.57	-0.53	-0.58	-0.62	-0.49	-0.50	-0.54	-0.75	-0.32	-0.31	-0.32	-0.37	-0.49
5/8/89	413	-0.59	-0.54	-0.59	-0.61	-0.49	-0.51	-0.54	-0.75	-0.32	-0.31	-0.33	-0.35	-0.49
5/15/89	420	-0.55	-0.53	-0.58	-0.60	-0.48	-0.50	-0.52	-0.75	-0.32	-0.30	-0.31	-0.35	-0.48
6/4/89	440	-0.54	-0.52	-0.57	-0.59	-0.48	-0.50	-0.51	-0.73	-0.31	-0.29	-0.32	-0.33	-0.47
6/12/89	448	-0.55	-0.52	-0.56	-0.59	-0.47	-0.48	-0.51	-0.73	-0.30	-0.30	-0.31	-0.34	-0.47
6/19/89	455	-0.55	-0.52	-0.56	-0.59	-0.47	-0.48	-0.50	-0.73	-0.30	-0.29	-0.31	-0.34	-0.47
6/26/89	462	-0.54	-0.50	-0.56	-0.57	-0.46	-0.47	-0.49	-0.73	-0.29	-0.28	-0.30	-0.33	-0.46

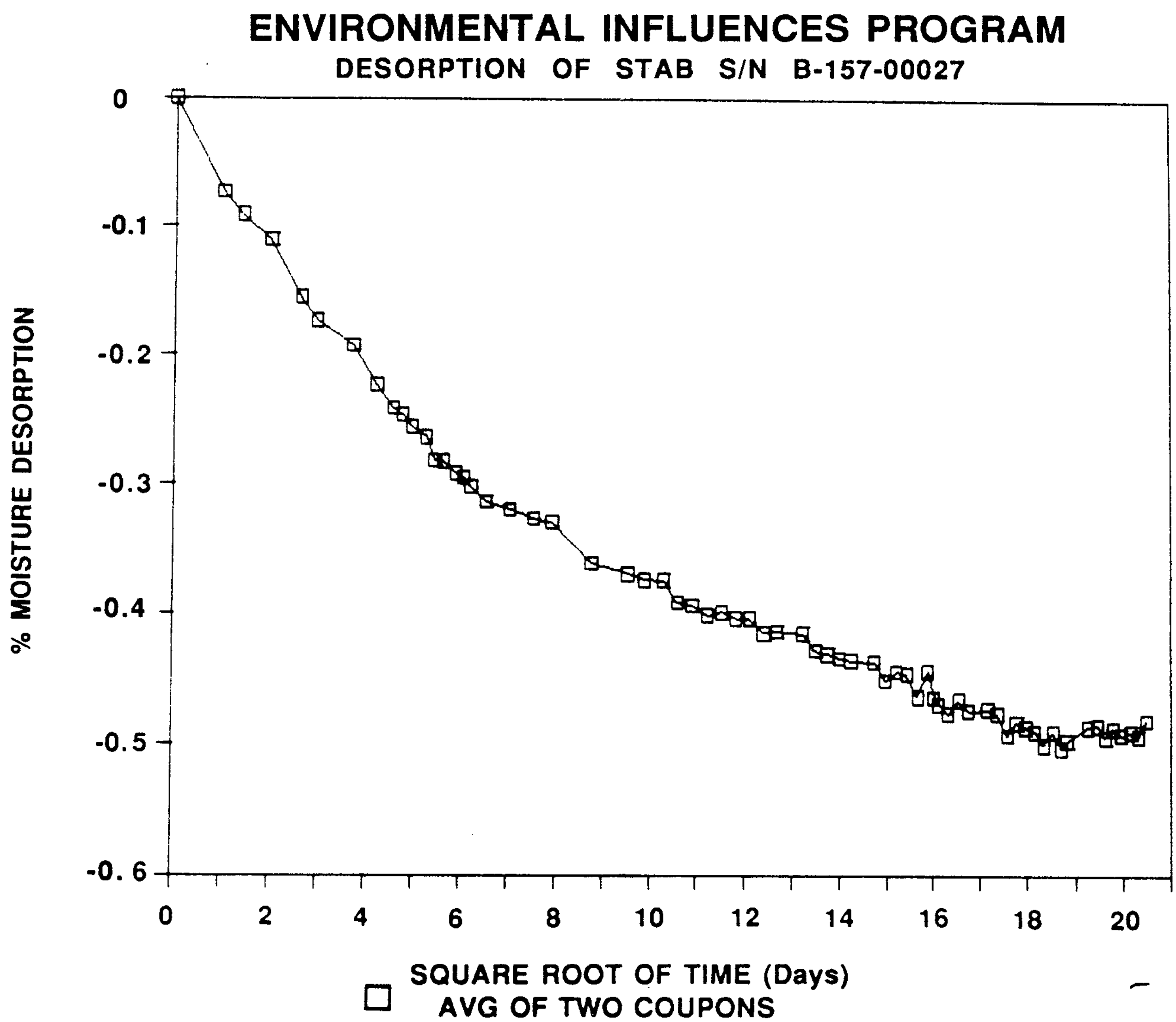


FIGURE 22. MOISTURE DESORPTION OF S-76 HORIZONTAL STABILIZER S/N B-157-00027 COUPONS FROM BL 4.0 - BL 9.0

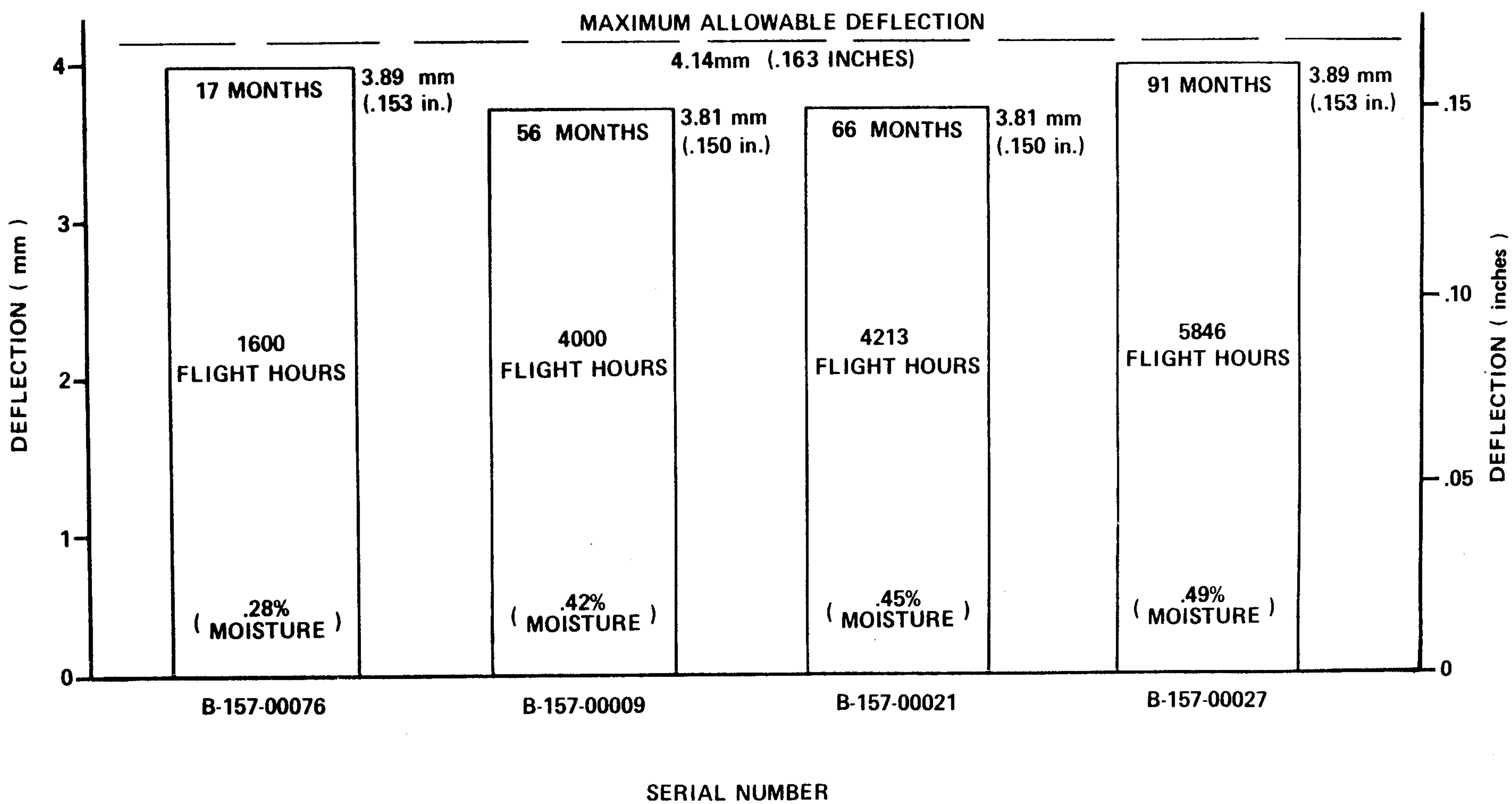


FIGURE 23. SUMMARY OF S-76 HORIZONTAL STABILIZER DEFLECTION AND MOISTURE DATA

Full scale static testing of horizontal stabilizer S/N B-157-00076 indicated the ultimate shear strength was 220 percent of the design limit load, as compared with the 268 percent maintained by a new room temperature dry stabilizer tested as part of the certification effort. At 220 percent of the design limit load, shear loads in stabilizer S/N B-157-00076 transferred to the Kevlar torque box and buckled the sidewall splice plate. However, the remaining shear strength in the Kevlar box provided the structural capability for maintaining 150 percent limit load.

Full scale fatigue data generated in testing stabilizers S/N B-157-00009, B-157-00021, and B-157-00027 was compiled for comparison to the full scale fatigue strength of a new (baseline) S-76 horizontal stabilizer, S/N B-157-00073, tested at room temperature dry. Plots of the roll moment versus number of cycles, and yaw moment versus number of cycles were generated for the room temperature dry tested stabilizer, as shown in Figures 24 and 25. To determine the effects of the environmental exposure and flight experience on the fatigue strength of the component, data from the stabilizers returned from the field was superimposed on the roll moment and yaw moment plots generated for the RTD baseline stabilizer, and the mean curves drawn. Mean fatigue curve shapes, defined as part of the certification effort, were of the standard form

$$\frac{S}{E} = 1 + \frac{\beta}{N^{\gamma}}$$

where: S is the fatigue stress (ksi)
E is the endurance limit (ksi)
N is the number of cycles to failure
and β and γ are empirical constants

The curves of the environmentally conditioned stabilizers were comparable to, while being somewhat (1.1 to 2.9 percent) higher than, the curves of the room temperature dry component. No evidence of structural degradation of the stabilizers returned from the field, when compared with the room temperature dry stabilizer, was indicated.

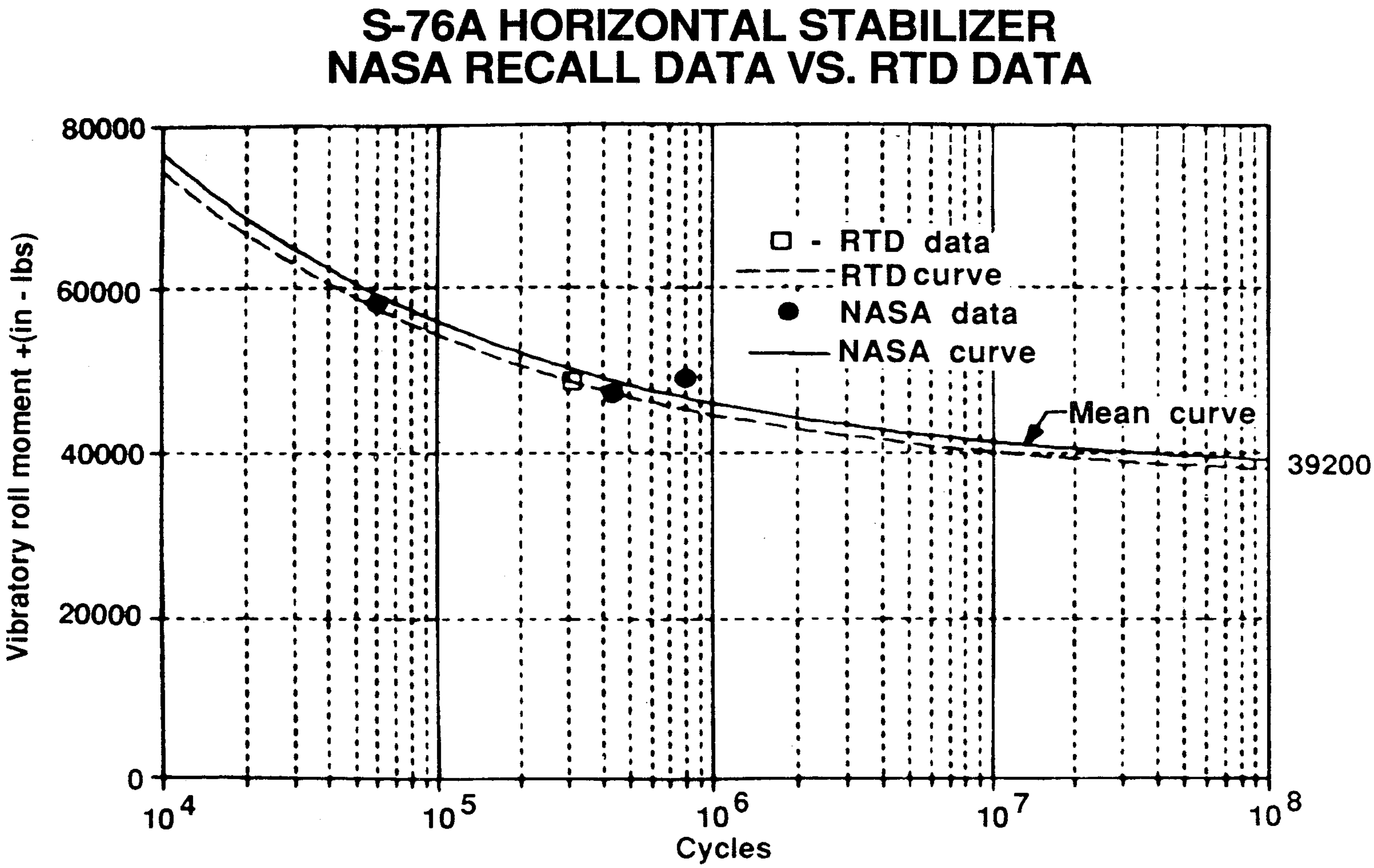


FIGURE 24. HORIZONTAL STABILIZER FULL SCALE FATIGUE TEST DATA-ROLL MOMENT VERSUS CYCLES TO FRACTURE, COMPARISON OF ENVIRONMENTALLY EXPOSED STABILIZER DATA WITH BASELINE RTD STABILIZER DATA

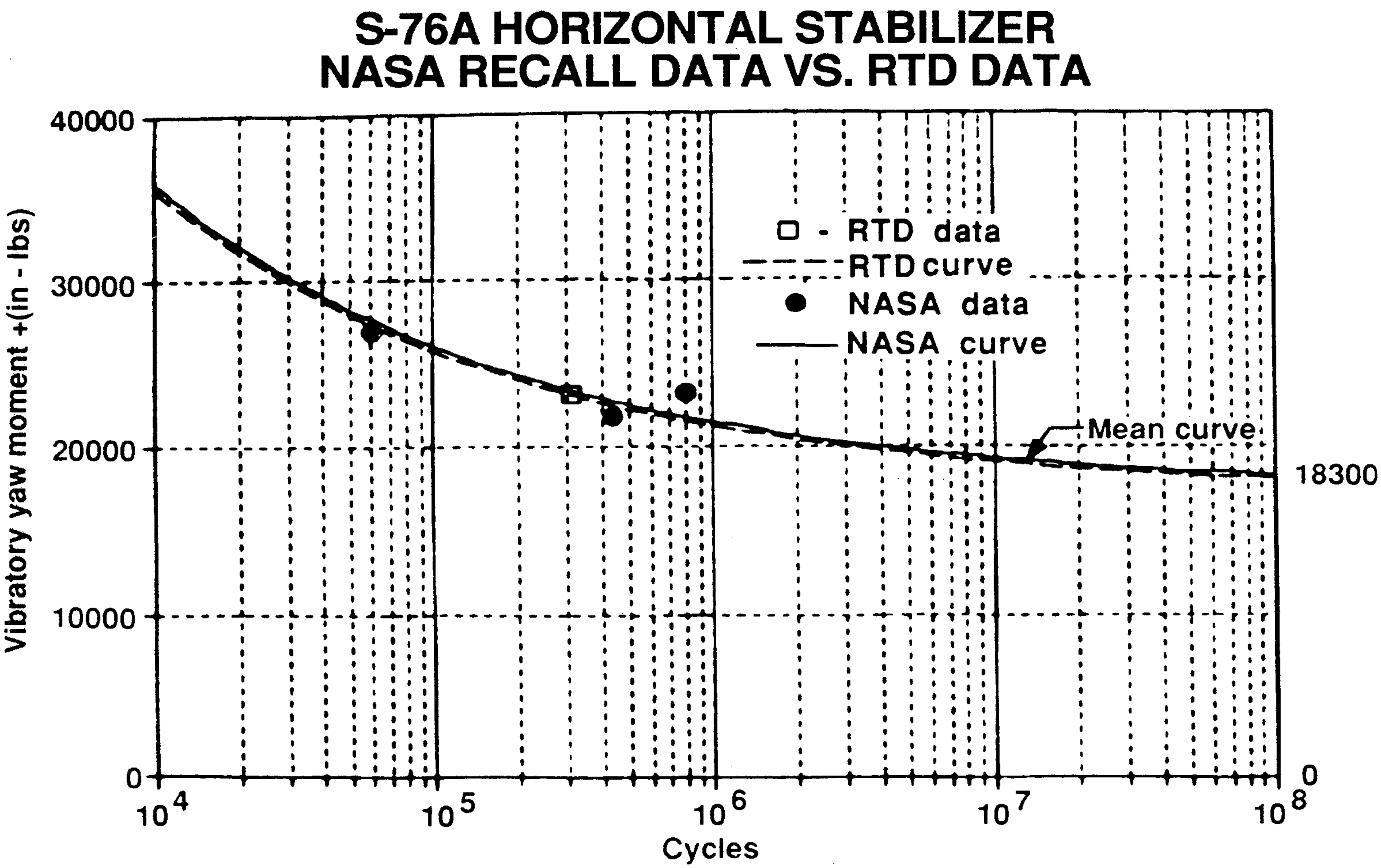


FIGURE 25. HORIZONTAL STABILIZER FULL SCALE FATIGUE TEST DATA-YAW MOMENT VERSUS CYCLES TO FRACTURE, COMPARISON OF ENVIRONMENTALLY EXPOSED STABILIZER DATA WITH BASELINE RTD STABILIZER DATA

3.1.2 Horizontal Stabilizers - Coupon Test Results

In addition to full scale testing, coupons were removed from undamaged sections of three of the stabilizers for small scale coupon tests. Specimens were removed from the graphite reinforcement cap strips between Buttlines 8.0 and 11.0 for static and fatigue interlaminar shear strength testing. The strength of specimens taken from horizontal stabilizer S/N B-157-00076 for room temperature interlaminar shear static testing averaged 16.1 ksi. Fatigue testing of interlaminar shear specimens removed from the stabilizer yielded a maximum stress of 8.1 ksi at 10^7 cycles. The maximum stress versus cycles to fracture data is listed in Table XV of Reference (1), and summarized in Figure 26. Specimens removed from horizontal stabilizer S/N B-157-00021 for static interlaminar shear testing averaged 14.5 ksi at room temperature. Interlaminar shear fatigue tests indicated a maximum stress of 8.5 ksi at 10^7 cycles, as shown graphically in Figure 27. Interlaminar shear coupons removed from horizontal stabilizer S/N B-157-00027 for testing at room temperature averaged 11.8 ksi. Coupons removed from the stabilizer for fatigue testing yielded a maximum stress of 7.5 ksi at 10^7 cycles. Maximum stress versus cycles to fracture data is summarized in Figure 28.

Results of the interlaminar shear static tests for each stabilizer are summarized by exposure time, flight hours and moisture level in Table VIII. Examination of the table reveals a general reduction in strength with increasing exposure time and flight hours. Interlaminar shear fatigue test results compiled in Table IX indicate the increasing exposure time, flight hours and moisture levels had little effect on fatigue properties.

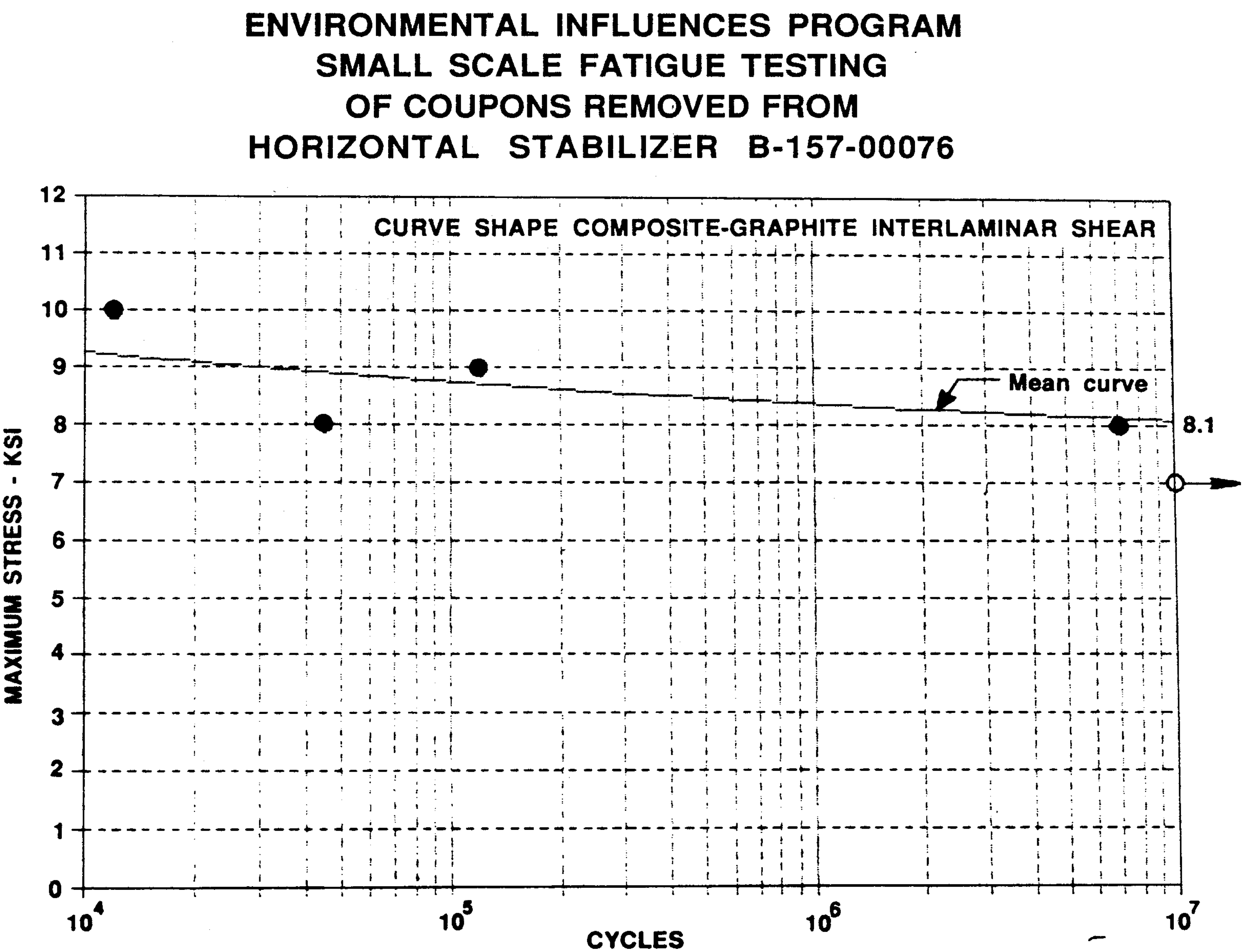


FIGURE 26. STABILIZER S/N B-157-00076 INTERLAMINAR SHEAR FATIGUE COUPON TESTING - MAXIMUM STRESS VERSUS CYCLES TO FRACTURE

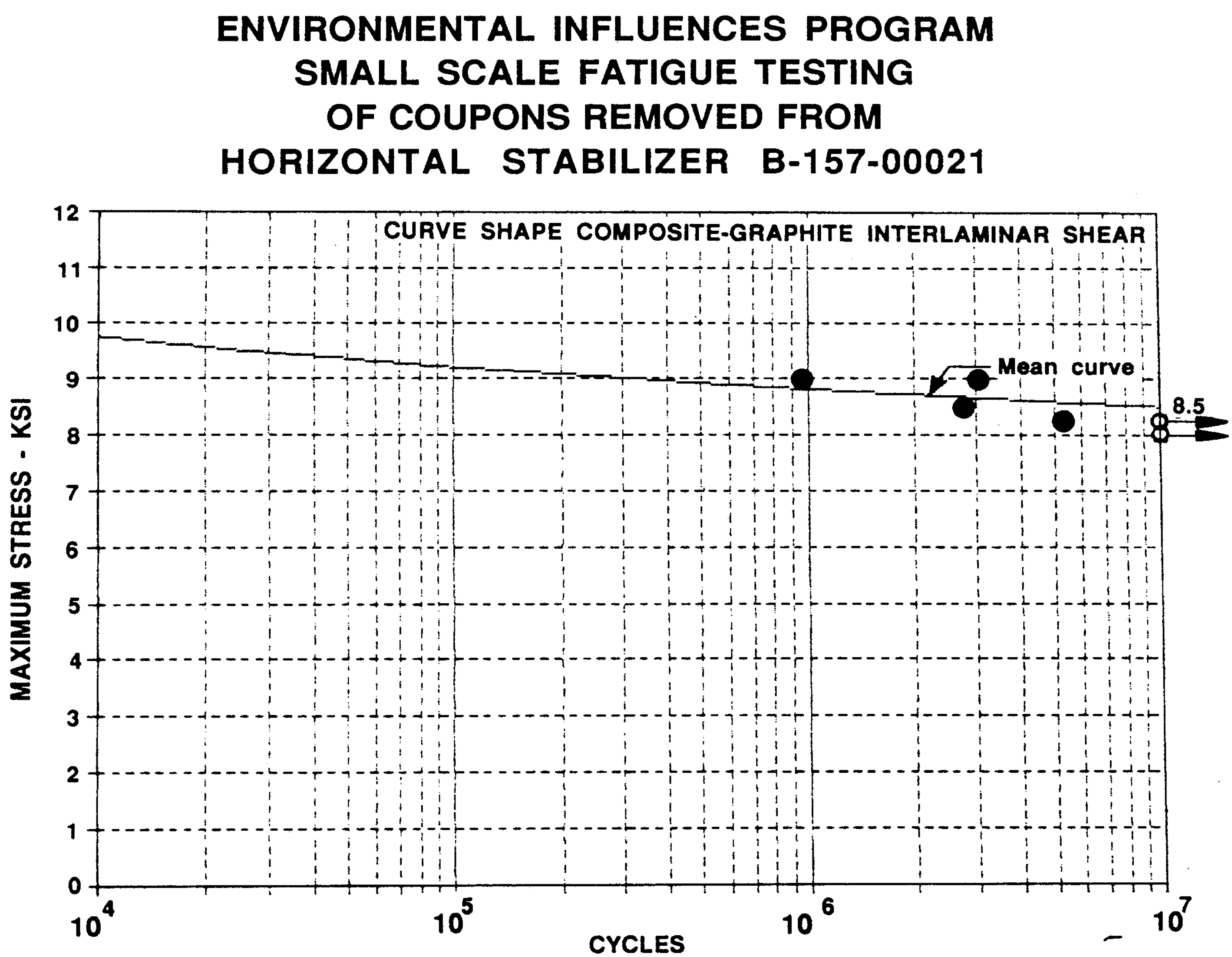


FIGURE 27. STABILIZER S/N B-157-00021 INTERLAMINAR SHEAR FATIGUE COUPON TESTING - MAXIMUM STRESS VERSUS CYCLES TO FRACTURE

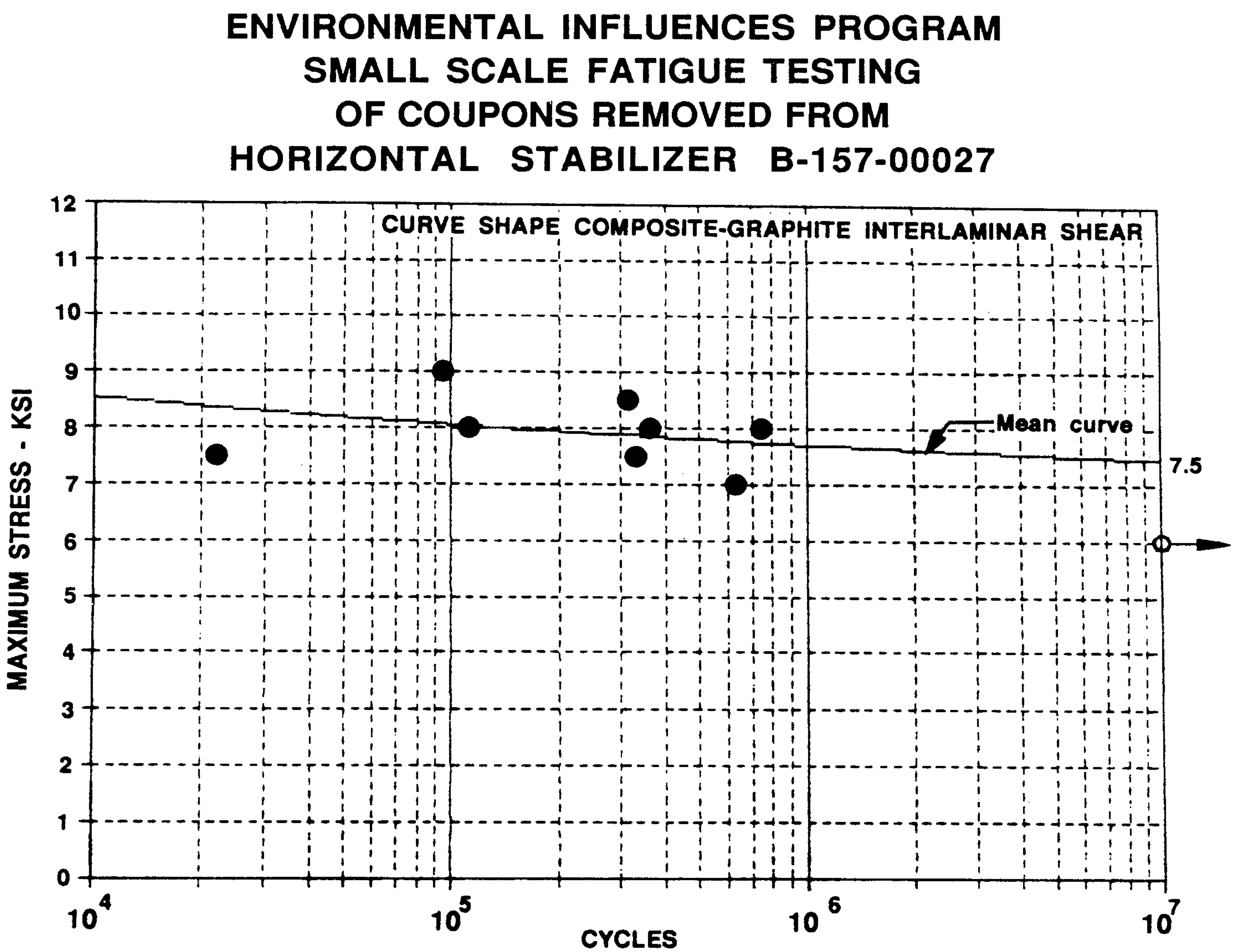


FIGURE 28. STABILIZER S/N B-157-00027
INTERLAMINAR SHEAR FATIGUE
COUPON TESTING - MAXIMUM
STRESS VERSUS CYCLES TO
FRACTURE

TABLE VIII. COMPILATION OF HORIZONTAL STABILIZER SMALL SCALE STATIC COUPON TEST RESULTS AT ROOM TEMPERATURE

STABILIZER S/N	EXPOSURE TIME (MONTHS)	FLIGHT HOURS	COUPON SBS STRENGTH (KSI)
00076	19	1600	16.1
00021	66	4213	14.5
00027	91	5846	11.8

TABLE IX. COMPILATION OF HORIZONTAL STABILIZER SMALL SCALE FATIGUE COUPON TEST RESULTS AT ROOM TEMPERATURE

STABILIZER S/N	EXPOSURE TIME (MONTHS)	FLIGHT HOURS	MAX. STRESS (KSI) AT 10^7 CYCLES
00076	19	1600	8.1
00021	66	4213	8.5
00027	91	5846	7.5

3.2 Tail Rotor Spars - Description of Test Methods

Ten tail rotor spars were returned from the field for evaluation as a part of this program:

S/N A-116-00094	S/N A-116-00178*
S/N A-116-00150*	S/N A-116-00069
S/N A-116-00283*	S/N A-116-00415*
S/N A-116-00237	S/N A-116-00493*
S/N A-116-00114	S/N A-116-00480

*For small scale coupon testing.

Five of the tail rotor spars were brought back for full scale fatigue testing and five for small scale coupon testing. The results of three additional tail rotor spars tested as part of an internal research and development program at Sikorsky Aircraft are also included in this report for comparison purposes. They were identified as follows:

S/N A-116-00046
S/N A-116-00064
S/N A-116-00172

Upon return from the field, each tail rotor spar was removed from the blade assembly and non-destructively inspected. No abnormalities were found in the spars examined. Spars returned for full scale fatigue testing were then cyclically loaded in a manner consistent with that used for initial qualification. To allow direct comparison with the baseline (type certificate) data, the fatigue tests were performed at room temperature. The fatigue test consists of combined edgewise (in-plane) and flatwise bending with a steady centrifugal (axial) load and torsion. The spar was clamped between an aircraft flange and retention plate. A short stub spar was used to take the place normally occupied by another blade spar (perpendicular to the test spar). Figure 29 illustrates the tail rotor combined load fatigue test setup and Figure 30 is a schematic diagram of the methods for load introduction. A photograph of the test facility is shown in Figure 31.

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

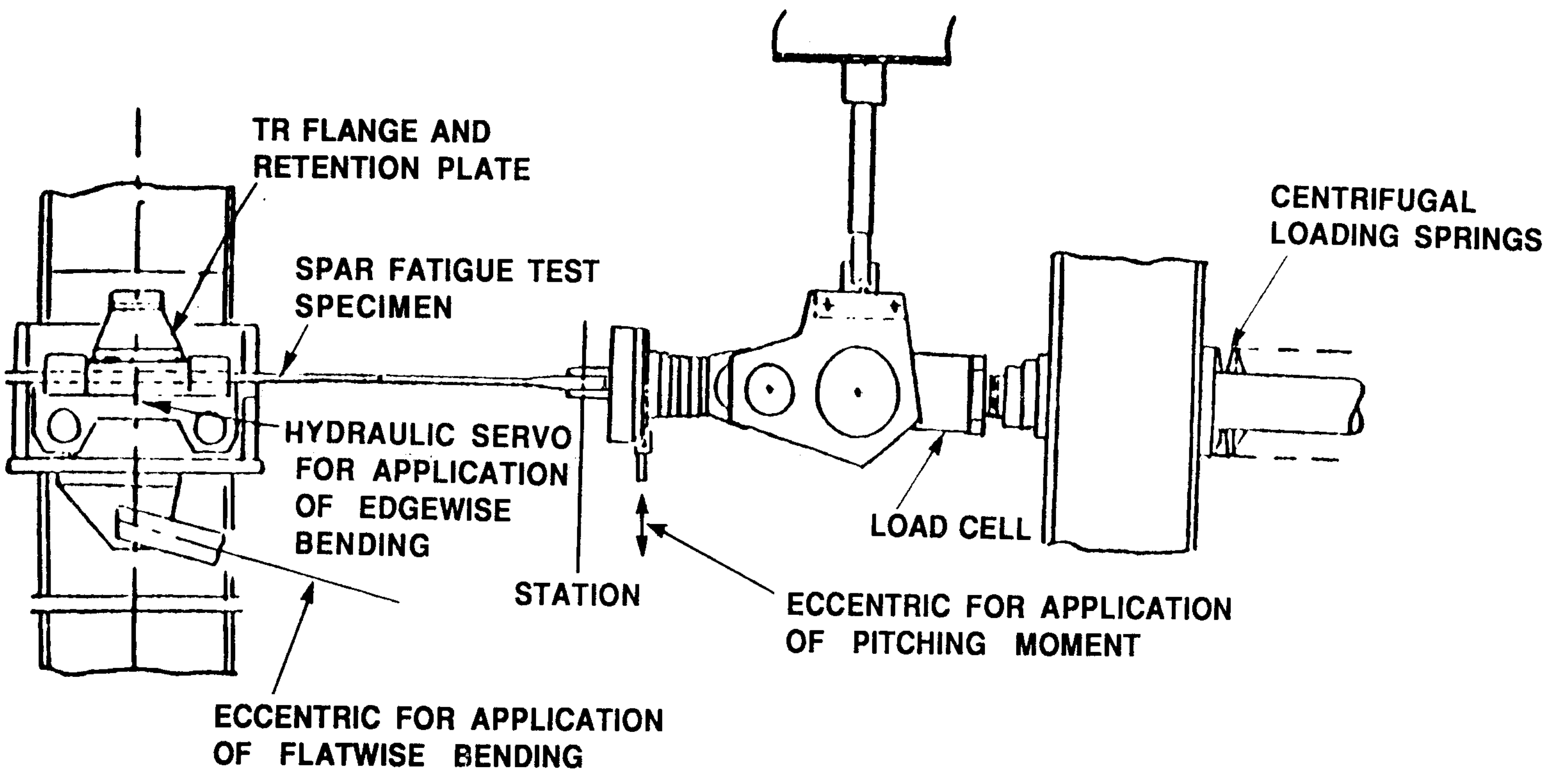


FIGURE 29. S-76 TAIL ROTOR SPAR COMBINED LOAD FATIGUE TEST SETUP
(ONE HALF OF SPECIMEN AND SETUP SHOWN)

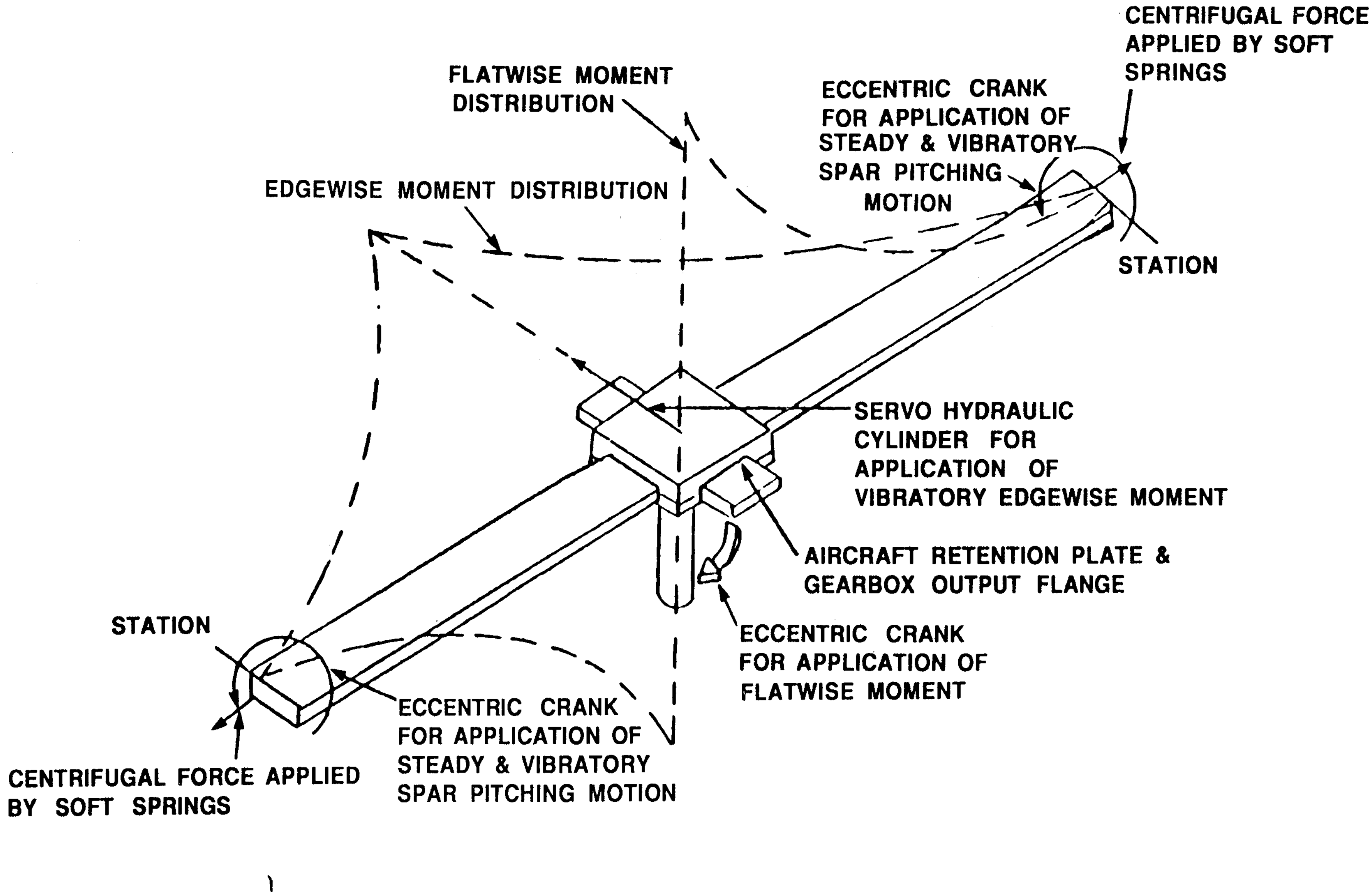


FIGURE 30. SCHEMATIC DIAGRAM OF THE S-76 TAIL ROTOR SPAR LOADINGS

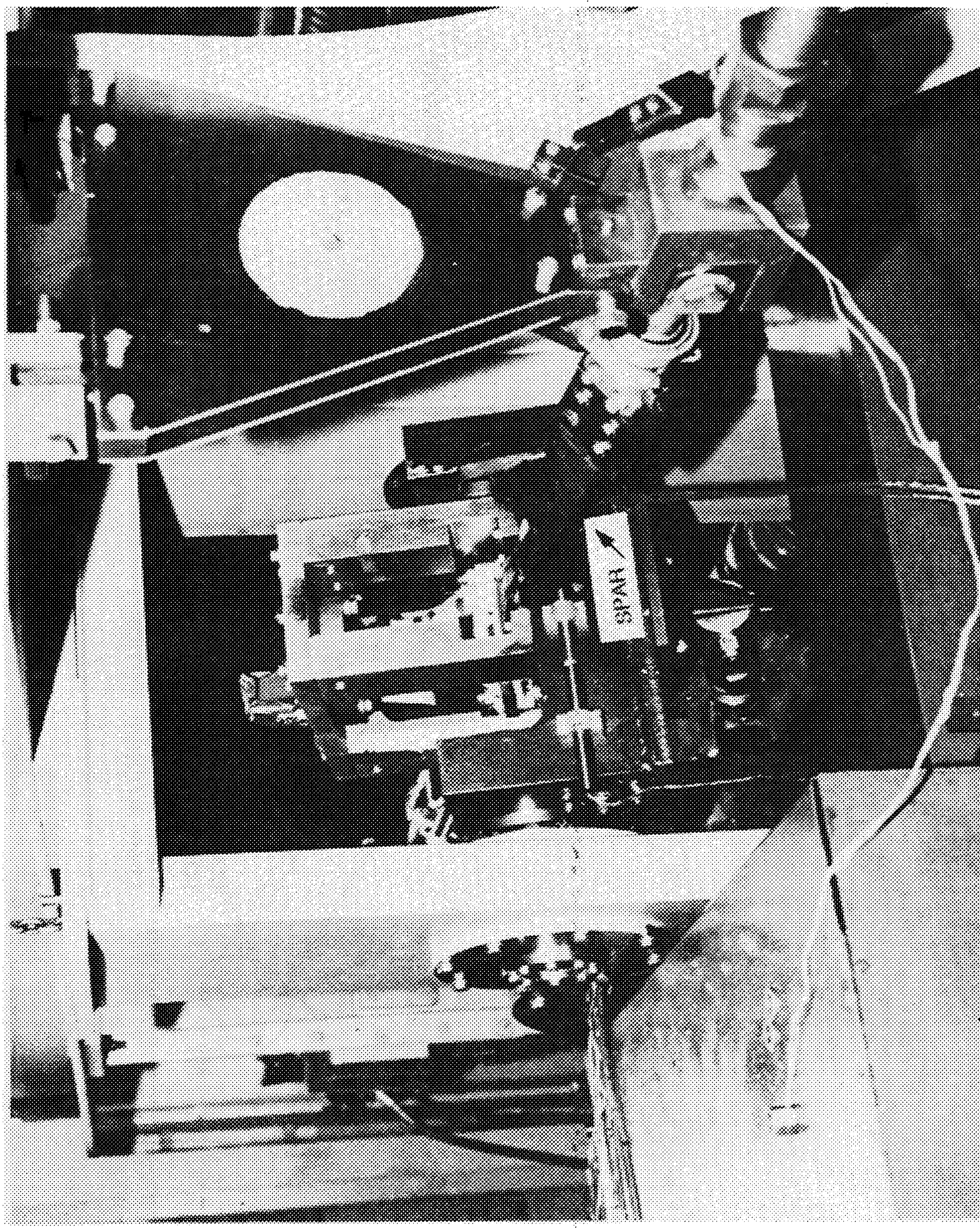


FIGURE 31. S-76 TAIL ROTOR SPAR TEST FACILITY

3.2.1 Tail Rotor Spar-Fatigue Test Results

3.2.1.1 S/N A-116-00046

Tail rotor spar S/N A-116-00046, removed from paddle S/N A-137-00020, was returned for testing as part of a Sikorsky Aircraft internal research and development program. The results are being reported herein for comparison purposes. Spar S/N A-116-00046 was returned from the field after 25 months of in-service environmental exposure on a Sikorsky Aircraft flight test helicopter operating in West Palm Beach, Florida. The spar had accumulated 150 flight hours prior to its return for testing. The spar was fatigue tested at a cyclic shear stress of 3980 psi until fracture of the A end occurred at .25 x 10^6 cycles. The test continued until fracture of the B end occurred at .466 x 10^6 cycles. Coupons were then removed from the tail rotor spar for the purpose of determining the moisture content. Locations are shown in Figure 32 for full scale fatigue tested spars. The coupons taken from the tail rotor spar were between Stations 5 and 7, the region of fatigue damage. Moisture coupons were desorbed in an environmentally controlled chamber at 150 ± 2°F. A total of 0.46 percent moisture by weight was desorbed.

3.2.1.2 S/N A-116-00064

Tail rotor spar S/N A-116-00064, was also evaluated as part of a Sikorsky internal research and development program. The tail rotor spar, removed from paddle S/N A-137-00021, was returned from the field after accumulating 150 flight hours and 25 months of in-service environmental exposure on a Sikorsky flight test helicopter operating in West Palm Beach, Florida. Spar S/N A-116-00064 was full scale fatigue tested at a cyclic shear stress of 4320 psi, when failure occurred at .035 x 10^6 cycles on the A end of the spar. Testing continued until fracture on the B end was noted at .071 x 10^6 cycles. Desorption coupons were removed from Stations 6-7 for moisture analysis. An average of 0.51 percent moisture, by weight, was desorbed from the coupons.

3.2.1.3 S/N A-116-00094

Tail rotor spar S/N A-116-00094 was removed from paddle S/N A-137-00034. The spar was returned from the field after 29 months and 2390 flight hours operating on an Air Logistics aircraft in the Gulf Coast region of Louisiana. The environmental history of the component is listed in Table VI of Reference (1). Spar S/N A-116-00094 was fatigue tested at a cyclic stress level of 3890 psi until failure was noted on the A end at .286 x 10^6 cycles. Failure of the B end occurred after .174 x 10^6 cycles at 3920 psi. Coupons removed for desorption analysis averaged 0.26 percent moisture, by weight.

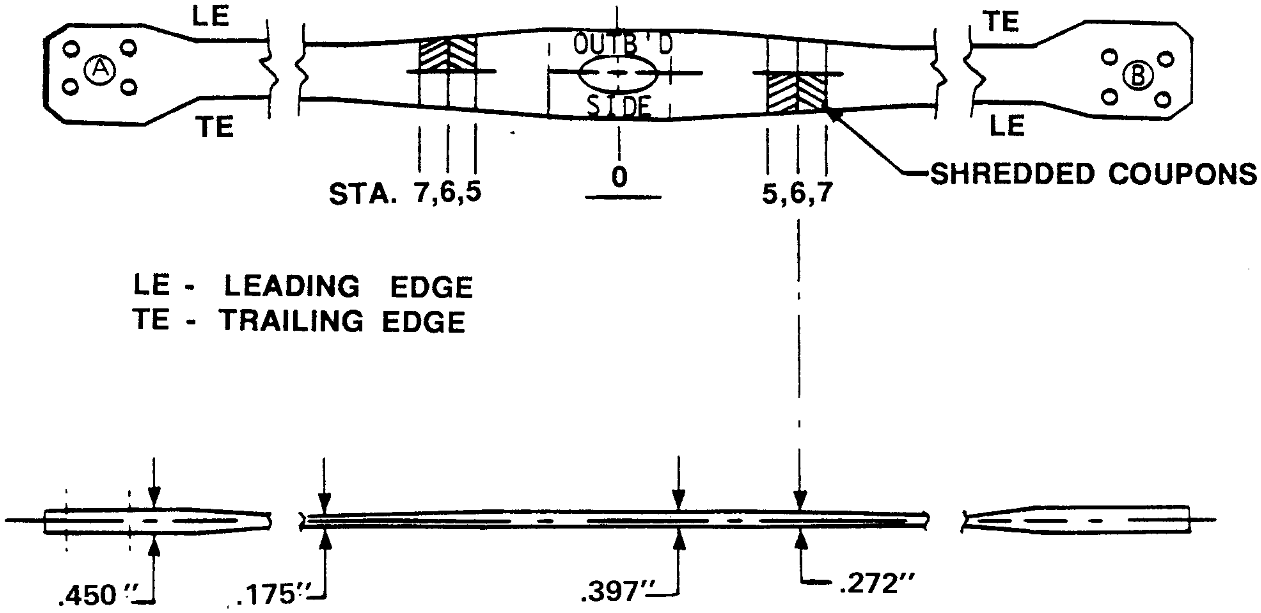


FIGURE 32. LOCATION OF MOISTURE DESORPTION COUPONS

3.2.1.4 S/N A-116-00237

Tail rotor spar S/N A-116-00237 was removed from paddle S/N A-137-00068. The tail rotor spar had accumulated 42 months and 1596 flight hours during commercial service in the Louisiana Gulf Coast region. The environmental history of the spar is documented in Table X of Reference (2). The spar was full scale fatigue tested at a cyclic shear stress of 4111 psi on the A end and 4377 psi on the B end. Failure was noted on the leading edge of the B end at .767 x 10^6 cycles and the test was stopped. Desorption coupons removed from Stations 5-7 for moisture analysis revealed an average of 0.47 percent moisture had been desorbed from the spar.

3.2.1.5 S/N A-116-00172

Spar S/N A-116-00172 was removed from tail rotor paddle S/N A-137-00047, and returned for testing as part of Sikorsky Aircraft's internal research and development program. Spar S/N A-116-00172 was returned from commercial service in the Gulf Coast region of Louisiana after 42 months and 2533 flight hours. The environmental history of the spar is detailed in Table XI of Reference (2). The spar was fatigue tested at a cyclic shear stress of 4272 psi until failure occurred on both sides at .218 x 10^6 cycles. Coupons removed for moisture analysis desorbed an average of 0.49 percent moisture.

3.2.1.6 S/N A-116-00114

Tail rotor spar A-116-00114 was removed from tail rotor paddle S/N A-137-00031 after 3358 flight hours and 52 months of in commercial service in the Gulf Coast region of Louisiana. The environmental history of the spar is listed in Table X. The spar was full scale fatigue tested at a cyclic shear stress of 4416 psi. Failure was recorded at .839 x 10^6 cycles. Moisture coupons were removed from Stations 5-7 for desorption. The desorption of coupon 5/6, removed from the leading edge of the A end is typical, and presented in Figure 33. An average of 0.56 percent moisture was desorbed from the specimen.

TABLE X.

SPAR S/N A-116-00114 (PADDLE S/N A-137-00031)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
1/10/79 - 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	15.9	60.7	74.5
4/01/79 - 4/30/79	20.0	68.1	80.5
5/01/79 - 5/31/79	22.4	72.3	78.6
6/01-79 - 6/30/79	26.0	78.9	78.4
7/01/79 - 7/31/79	26.8	80.3	85.4
8/01/79 - 8/31/79	26.6	80.0	83.8
9/01/79 - 9/30/79	23.6	74.7	80.3
10/01/79 - 10/31/79	20.4	68.9	79.0
11/01/79 - 11/30/79	12.4	54.4	75.4
12/01/79 - 12/31/79	10.3	50.5	78.1
1/01/80 - 1/31/80	11.9	33.4	86.4
2/01/80 - 2/29/80	10.3	50.6	80.5
3/01/80 - 3/31/80	15.2	59.4	81.4
4/01/80 - 4/30/80	18.4	65.1	76.5
5/01/80 - 5/31/80	23.9	74.8	83.9
6/01/80 - 6/30/80	27.1	80.8	80.3
7/01/80 - 7/31/80	28.2	82.8	72.5
8/01/80 - 8/31/80	27.4	81.3	74.0
9/01/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.4	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	22.6	72.6	73.3
6/01/81 - 6/30/81	26.8	80.3	82.1
7/01/81 - 7/31/81	27.3	81.1	81.8
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4

TABLE X. (CONTINUED)

SPAR S/N A-116-00114 (PADDLE S/N A-137-00031)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/24/83	17.5	63.5	73.4

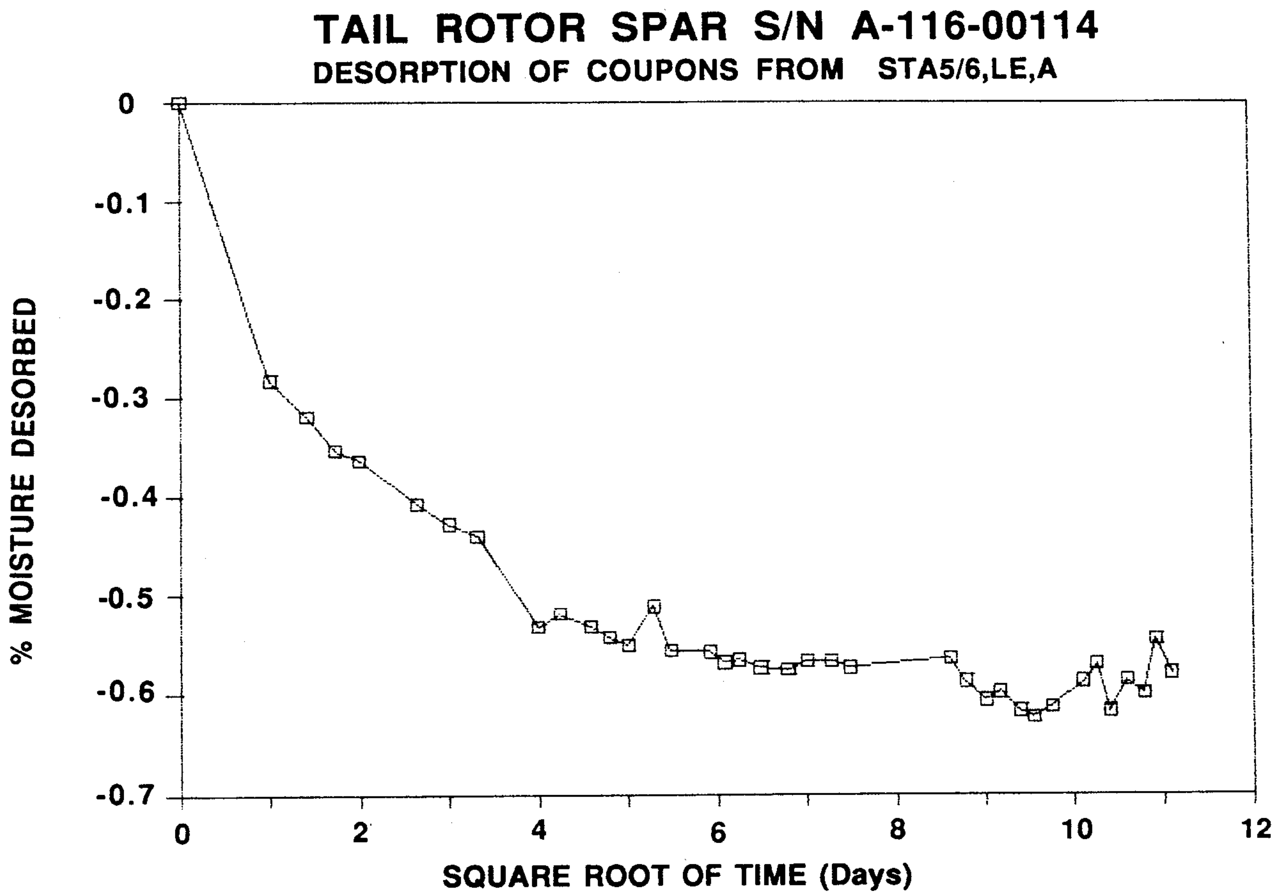


FIGURE 33. MOISTURE DESORPTION OF TAIL ROTOR SPAR
S/N A-116-00114, COUPONS FROM STATIONS 5 - 6

3.2.1.7 S/N A-116-00069

Spar S/N A-116-00069 was removed from tail rotor paddle S/N A-137-00107. The spar was returned from the field after 72 months of commercial service in the Gulf Coast region of Louisiana. The spar had accumulated 4995 flight hours prior to its return for testing. The environmental history of spar S/N A-116-00069 is detailed in Table XI. The spar was full scale fatigue tested at an equivalent cyclic shear stress of 3820 psi when failure occurred at $.146 \times 10^6$ cycles. Delamination was noted along the leading edge of the A end extending from Stations 4 through 11, 1.5 inches deep at Station 6, its widest point. Coupons were removed for moisture analysis, desorbing an average of 0.66 percent by weight. A plot of the average desorption of moisture coupons from Stations 5-7 is presented in Figure 34. The complete results of the spar coupon desorption analysis are detailed in Table XII.

3.2.1.8 S/N A-116-00480

Tail rotor spar S/N A-116-00480, removed from tail rotor paddle S/N A-137-00205, was exposed to the environment in the Gulf Coast region of Louisiana for 100 months. The environmental history of spar S/N A-116-00480 is listed in Table XIII. The spar had accumulated 5816 flight hours prior to its removal for testing. The spar was fatigue tested at an equivalent cyclic shear stress of 4640 psi until failure was audibly and visually noted at $.143 \times 10^6$ cycles. Coupons were removed from Stations 5-7 for desorption. An average of 0.98 percent moisture was desorbed from the component. The average desorption-time plot is shown in Figure 35. Full results of the spar coupon moisture desorption tests are detailed in Table XIV.

3.2.1.9 Tail Rotor Spars - Summary of Fatigue Test Results

A summary of the full scale fatigue test results for all of the spars is presented in Table XV, along with moisture desorption measurements. A graphical comparison of the fatigue strength of the in-service exposed tail rotor spars to the cyclic shear stress versus cycles to fracture curve of those tested for certification (room temperature dry) is presented in Figure 36. As can be seen in the plot, the curve generated for the environmentally conditioned tail rotor spars was comparable to that of the room temperature dry certification data with the average cyclic shear stress at 10^7 cycles for the two curves varying by 5 percent. The tail rotor spars retained 95 percent of the baseline fatigue strength after 9 years of exposure. Therefore, no significant reduction in strength was evidenced.

TABLE XI.

SPAR S/N A-116-00069 (PADDLE S/N A-137-00107)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
7/05/80 - 7/31/80	28.2	82.8	72.5
8/01/80 - 8/31/80	27.4	81.3	74.0
9/01/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.4	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	22.6	72.6	73.3
6/01/81 - 6/30/81	26.8	80.3	82.1
7/01/81 - 7/31/81	27.3	81.1	81.8
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/30/83	17.5	63.5	73.4
5/01/83 - 5/31/83	23.0	73.4	77.1
6/01/83 - 6/30/83	25.6	78.0	81.3
7/01/83 - 7/31/83	28.2	92.8	78.1

TABLE XI. (CONTINUED)

SPAR S/N A-116-00069 (PADDLE S/N A-137-00107)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
8/01/83 - 8/31/83	27.8	82.1	81.4
9/01/83 - 9/30/83	24.2	75.6	77.9
10/01/83 - 10/31/83	21.1	69.9	73.3
11/01/83 - 11/30/83	16.7	62.1	75.8
12/01/83 - 12/31/83	9.1	48.3	73.3
1/01/84 - 1/31/84	8.9	48.1	74.3
2/01/84 - 2/29/84	13.3	55.9	68.1
3/01/84 - 3/31/84	16.9	62.4	72.5
4/01/84 - 4/30/84	21.1	69.9	66.9
5/01/84 - 5/31/84	23.9	75.0	72.3
6/01/84 - 6/30/84	26.4	79.5	79.0
7/01/84 - 7/31/84	26.9	80.4	82.1
8/01/84 - 8/31/84	26.7	80.1	84.1
9/01/84 - 9/30/84	23.8	74.8	79.1
10/01/84 - 10/31/84	22.7	72.8	85.9
11/01/84 - 11/30/84	14.3	57.8	78.8
12/01/84 - 12/31/84	16.4	61.6	86.5
1/01/85 - 1/31/85	6.8	44.3	78.4
2/01/85 - 2/28/85	9.9	49.9	82.0
3/01/85 - 3/31/85	17.8	64.1	81.4
4/01/85 - 4/30/85	21.0	69.8	73.6
5/01/85 - 5/31/85	23.9	75.1	76.0
6/01/85 - 6/30/85	27.0	80.6	75.1
7/01/85 - 7/31/85	26.9	80.5	80.5
8/01/85 - 8/31/85	27.7	81.8	80.3
9/01/85 - 9/30/85	25.3	77.5	79.5
10/01/85 - 10/31/85	22.2	71.9	82.8
11/01/85 - 11/30/85	18.8	65.9	83.8
12/01/85 - 12/31/85	9.7	49.4	75.8
1/01/86 - 1/31/86	10.8	51.4	73.1
2/01/86 - 2/28/86	14.1	57.4	79.8
3/01/86 - 3/31/86	15.8	60.4	75.0
4/01/86 - 4/30/86	20.2	68.4	77.6
5/01/86 - 5/31/86	24.2	75.5	81.0
6/01/86 - 6/30/86	27.2	80.9	82.1
7/01/86 - 7/19/86	28.2	82.8	80.8

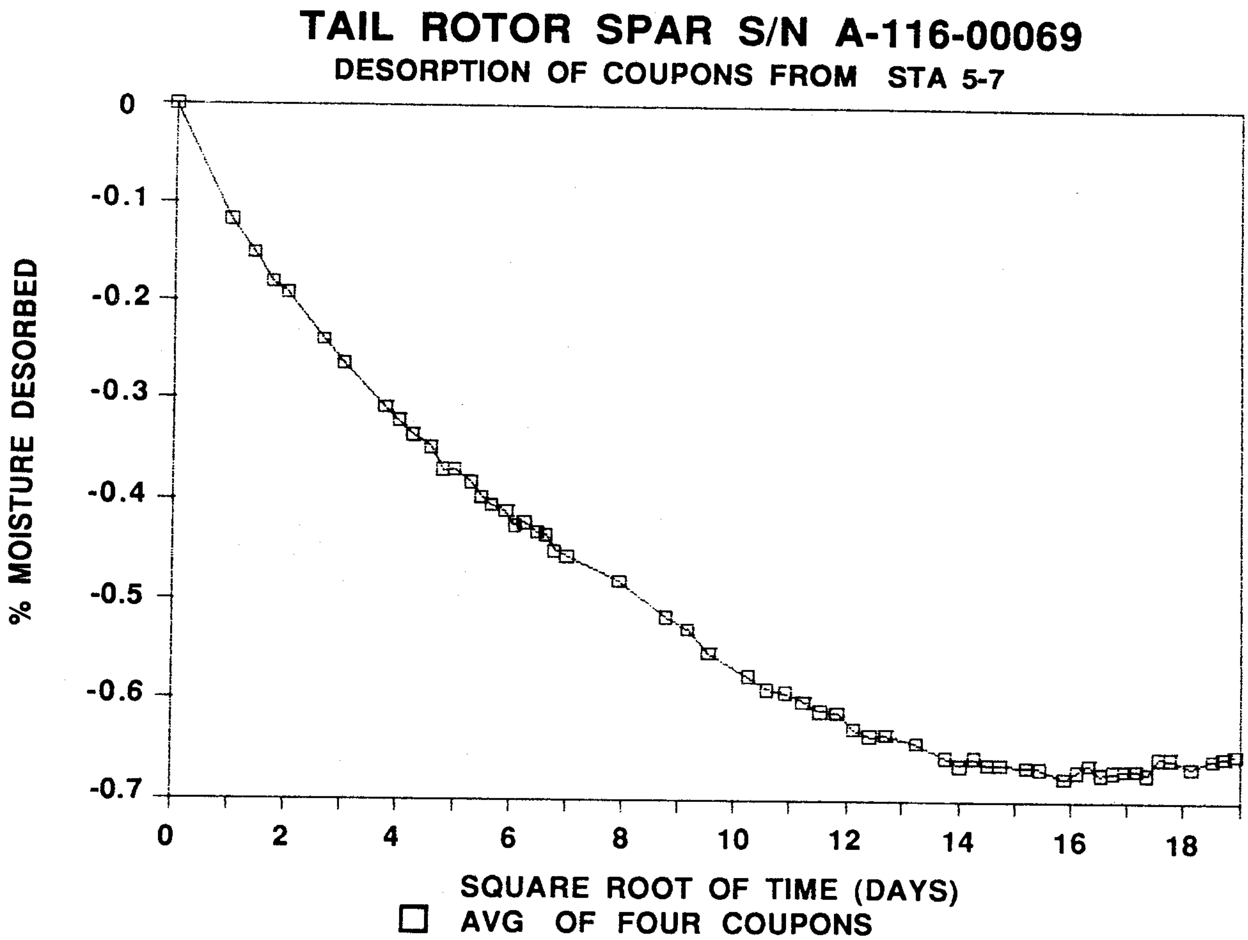


FIGURE 34. MOISTURE DESORPTION OF TAIL ROTOR SPAR S/N A-116-00069, COUPONS FROM STATIONS 5-7

TABLE XII.

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00069

DATE	DAYS	WEIGHT OF COUP A571	WEIGHT OF COUP A572	WEIGHT OF COUP B571	WEIGHT OF COUP B572	% MOIST DESORBED COUP A571	% MOIST DESORBED COUP A572	% MOIST DESORBED COUP B571	% MOIST DESORBED COUP B572	AVERAGE % MOIST STA 5-7
7/13/87	0	6.3088	5.3528	7.8594	10.8324	0	0	0	0	0
7/14/87	1	6.3011	5.3459	7.8501	10.8218	-0.12	-0.13	-0.12	-0.10	-0.12
7/15/87	2	6.2987	5.3441	7.8477	10.8186	-0.16	-0.16	-0.15	-0.13	-0.15
7/16/87	3	6.2969	5.3425	7.8452	10.8156	-0.19	-0.19	-0.18	-0.16	-0.18
7/17/87	4	6.2962	5.3421	7.8442	10.8141	-0.20	-0.20	-0.19	-0.17	-0.19
7/20/87	7	6.2932	5.3392	7.8403	10.8097	-0.25	-0.25	-0.24	-0.21	-0.24
7/22/87	9	6.2916	5.3379	7.838	10.8073	-0.27	-0.28	-0.27	-0.23	-0.26
7/27/87	14	6.2884	5.3355	7.8346	10.8027	-0.32	-0.32	-0.32	-0.27	-0.31
7/29/87	16	6.2876	5.3347	7.8336	10.8012	-0.34	-0.34	-0.33	-0.29	-0.32
7/31/87	18	6.2866	5.334	7.8325	10.8	-0.35	-0.35	-0.34	-0.30	-0.34
8/3/87	21	6.286	5.3334	7.8314	10.7984	-0.36	-0.36	-0.36	-0.31	-0.35
8/5/87	23	6.2843	5.3319	7.8301	10.7967	-0.39	-0.39	-0.37	-0.33	-0.37
8/7/87	25	6.2847	5.332	7.83	10.7962	-0.38	-0.39	-0.37	-0.33	-0.37
8/10/87	28	6.2837	5.3316	7.8288	10.7949	-0.40	-0.40	-0.39	-0.35	-0.38
8/12/87	30	6.2826	5.3309	7.8277	10.7935	-0.42	-0.41	-0.40	-0.36	-0.40
8/14/87	32	6.282	5.3301	7.8276	10.7928	-0.42	-0.42	-0.40	-0.37	-0.40
8/17/87	35	6.2817	5.3299	7.8267	10.7921	-0.43	-0.43	-0.42	-0.37	-0.41
8/19/87	37	6.2806	5.3291	7.8256	10.7911	-0.45	-0.44	-0.43	-0.38	-0.43
8/21/87	39	6.2811	5.3294	7.8257	10.7907	-0.44	-0.44	-0.43	-0.38	-0.42
8/24/87	42	6.2801	5.329	7.8249	10.7899	-0.45	-0.44	-0.44	-0.39	-0.43
8/26/87	44	6.2785	5.3272	7.8232	10.7979	-0.48	-0.48	-0.46	-0.32	-0.43
8/28/87	46	6.279	5.3279	7.8236	10.788	-0.47	-0.47	-0.46	-0.41	-0.45
8/31/87	49	6.2786	5.3277	7.8231	10.7876	-0.48	-0.47	-0.46	-0.41	-0.46
9/14/87	63	6.277	5.3264	7.8214	10.7844	-0.50	-0.49	-0.48	-0.44	-0.48
9/28/87	77	6.2747	5.3247	7.8182	10.7806	-0.54	-0.52	-0.52	-0.48	-0.52
10/5/87	84	6.2739	5.324	7.8172	10.7795	-0.55	-0.54	-0.54	-0.49	-0.53
10/12/87	91	6.2723	5.3226	7.8156	10.777	-0.58	-0.56	-0.56	-0.51	-0.55
10/26/87	105	6.2707	5.3215	7.8137	10.7746	-0.60	-0.58	-0.58	-0.53	-0.58
11/2/87	112	6.2699	5.3207	7.8128	10.7732	-0.62	-0.60	-0.59	-0.55	-0.59
11/9/87	119	6.2695	5.3207	7.8123	10.7731	-0.62	-0.60	-0.60	-0.55	-0.59
11/16/87	126	6.2692	5.3202	7.8117	10.7718	-0.63	-0.61	-0.61	-0.56	-0.60
11/23/87	133	6.2685	5.32	7.8108	10.7705	-0.64	-0.61	-0.62	-0.57	-0.61
11/30/87	140	6.2685	5.3197	7.8108	10.7704	-0.64	-0.62	-0.62	-0.57	-0.61
12/7/87	147	6.2674	5.3189	7.8094	10.7687	-0.66	-0.63	-0.64	-0.59	-0.63
12/14/87	154	6.2668	5.3183	7.8092	10.7684	-0.67	-0.64	-0.64	-0.59	-0.63
12/21/87	161	6.2669	5.3187	7.8093	10.7678	-0.66	-0.64	-0.64	-0.60	-0.63
1/4/88	175	6.2664	5.3182	7.8086	10.7669	-0.67	-0.65	-0.65	-0.60	-0.64
1/18/88	189	6.2655	5.3176	7.8076	10.7651	-0.69	-0.66	-0.66	-0.62	-0.66
1/25/88	196	6.265	5.3168	7.807	10.7648	-0.69	-0.67	-0.67	-0.62	-0.66
2/1/88	203	6.2654	5.3175	7.8077	10.7651	-0.69	-0.66	-0.66	-0.62	-0.66
2/8/88	210	6.265	5.3173	7.8069	10.7643	-0.69	-0.66	-0.67	-0.63	-0.66
2/15/88	217	6.265	5.3172	7.8072	10.7641	-0.69	-0.67	-0.66	-0.63	-0.66
2/29/88	231	6.2649	5.3173	7.8068	10.7638	-0.70	-0.66	-0.67	-0.63	-0.67
3/7/88	238	6.2647	5.3173	7.8068	10.7635	-0.70	-0.66	-0.67	-0.64	-0.67
3/21/88	252	6.2643	5.3166	7.8059	10.7627	-0.71	-0.68	-0.68	-0.64	-0.68
3/28/88	259	6.2644	5.3172	7.8066	10.7631	-0.70	-0.67	-0.67	-0.64	-0.67

TABLE XII. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00069

DATE	DAYS	WEIGHT OF COUP A571	WEIGHT OF COUP A572	WEIGHT OF COUP B571	WEIGHT OF COUP B572	% MOIST DESORBED COUP A571	% MOIST DESORBED COUP A572	% MOIST DESORBED COUP B571	% MOIST DESORBED COUP B572	AVERAGE % MOIST STA 5-7
4/4/88	266	6.265	5.3177	7.8071	10.7637	-0.69	-0.66	-0.67	-0.63	-0.66
4/11/88	273	6.2642	5.3172	7.8061	10.763	-0.71	-0.67	-0.68	-0.64	-0.67
4/18/88	280	6.2645	5.3174	7.8066	10.7626	-0.70	-0.66	-0.67	-0.64	-0.67
4/25/88	287	6.2647	5.3175	7.8066	10.7625	-0.70	-0.66	-0.67	-0.65	-0.67
5/2/88	294	6.2646	5.3177	7.8066	10.7627	-0.70	-0.66	-0.67	-0.64	-0.67
5/9/88	301	6.2643	5.3172	7.8065	10.7625	-0.71	-0.67	-0.67	-0.65	-0.67
5/16/88	308	6.2656	5.3181	7.8077	10.7638	-0.68	-0.65	-0.66	-0.63	-0.66
5/23/88	315	6.2654	5.318	7.8079	10.7638	-0.69	-0.65	-0.66	-0.63	-0.66
6/6/88	329	6.2646	5.3177	7.8071	10.7631	-0.70	-0.66	-0.67	-0.64	-0.67
6/20/88	343	6.2654	5.3181	7.8077	10.7636	-0.69	-0.65	-0.66	-0.64	-0.66
6/27/88	350	6.2654	5.3183	7.8081	10.7639	-0.69	-0.64	-0.65	-0.63	-0.65
7/5/88	358	6.265	5.3183	7.8088	10.7644	-0.69	-0.64	-0.64	-0.63	-0.65

TABLE XIII.

SPAR S/N A-116-00480 (PADDLE S/N A-137-00205)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
7/02/80 - 7/31/80	28.2	82.8	72.5
8/01/80 - 8/31/80	27.4	81.3	74.0
9/01/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.4	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	26.8	80.3	82.1
6/01/81 - 6/30/81	22.6	72.6	73.3
7/01/81 - 7/31/81	26.8	80.3	82.1
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1

TABLE XIII. (CONTINUED)

SPAR S/N A-116-00480 (PADDLE S/N A-137-00205)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/30/83	17.5	63.5	73.4
5/01/83 - 5/31/83	23.0	73.4	77.1
6/01/83 - 6/30/83	25.6	78.0	81.3
7/01/83 - 7/31/83	28.2	92.8	78.1
8/01/83 - 8/31/83	27.8	82.1	81.4
9/01/83 - 9/30/83	24.2	75.6	77.9
10/01/83 - 10/31/83	21.1	69.9	73.3
11/01/83 - 11/30/83	16.7	62.1	75.8
12/01/83 - 12/31/83	9.1	48.3	73.3
1/01/84 - 1/31/84	8.9	48.1	74.3
2/01/84 - 2/29/84	13.3	55.9	68.1
3/01/84 - 3/31/84	16.9	62.4	72.5
4/01/84 - 4/30/84	21.1	69.9	66.9
5/01/84 - 5/31/84	23.9	75.0	72.3
6/01/84 - 6/30/84	26.4	79.5	79.0
7/01/84 - 7/31/84	26.9	80.4	82.1
8/01/84 - 8/31/84	26.7	80.1	84.1
9/01/84 - 9/30/84	23.8	74.8	79.1
10/01/84 - 10/31/84	22.7	72.8	85.9
11/01/84 - 11/30/84	14.3	57.8	78.8
12/01/84 - 12/31/84	16.4	61.6	86.5
1/01/85 - 1/31/85	6.8	44.3	78.4
2/01/85 - 2/28/85	9.9	49.9	82.0
3/01/85 - 3/31/85	17.8	64.1	81.4
4/01/85 - 4/30/85	21.0	69.8	73.6
5/01/85 - 5/31/85	23.9	75.1	76.0
6/01/85 - 6/30/85	27.0	80.6	75.1
7/01/85 - 7/31/85	26.9	80.5	80.5
8/01/85 - 8/31/85	27.7	81.8	80.3
9/01/85 - 9/30/85	25.3	77.5	79.5
10/01/85 - 10/31/85	22.2	71.9	82.8
11/01/85 - 11/30/85	18.8	65.9	83.8
12/01/85 - 12/31/85	9.7	49.4	75.8

TABLE XIII. (CONTINUED)

SPAR S/N A-116-00480 (PADDLE S/N A-137-00205)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
1/01/86 - 1/31/86	10.8	51.4	73.1
2/01/86 - 2/28/86	14.1	57.4	79.8
3/01/86 - 3/31/86	15.8	60.4	75.0
4/01/86 - 4/30/86	20.2	68.4	77.6
5/01/86 - 5/31/86	24.2	75.5	81.0
6/01/86 - 6/30/86	27.2	80.9	82.1
7/01/86 - 7/31/86	28.2	82.8	80.8
8/01/86 - 8/31/86	27.1	80.8	79.4
9/01/86 - 9/30/86	26.7	80.0	83.0
10/01/86 - 10/31/86	16.1	60.9	79.6
11/01/86 - 11/30/86	17.4	63.3	83.6
12/01/86 - 12/31/86	10.3	50.6	82.6
1/01/87 - 1/31/87	9.5	49.1	79.3
2/01/87 - 2/28/87	12.8	55.1	79.8
3/01/87 - 3/31/87	14.5	58.1	69.8
4/01/87 - 4/30/87	18.8	65.9	65.4
5/01/87 - 5/31/87	24.2	75.6	83.3
6/01/87 - 6/30/87	26.3	79.3	80.4
7/01/87 - 7/31/87	27.4	81.3	80.8
8/01/87 - 8/31/87	28.5	83.3	78.5
9/01/87 - 9/30/87	24.9	76.8	75.9
10/01/87 - 10/31/87	18.4	65.1	68.5
11/01/87 - 11/30/87	15.3	59.6	75.4
12/01/87 - 12/31/87	13.8	56.9	80.3
1/01/88 - 1/31/88	8.3	47.0	71.1
2/01/88 - 2/29/88	11.5	52.8	79.0
3/01/88 - 3/31/88	15.7	60.3	75.3
4/01/88 - 4/30/88	19.9	67.9	72.4
5/01/88 - 5/31/88	23.3	73.9	70.9
6/01/88 - 6/30/88	25.9	78.6	77.3
7/01/88 - 7/31/88	27.2	80.9	83.0
8/01/88 - 8/31/88	27.5	81.5	81.9
9/01/88 - 9/30/88	25.3	77.6	79.3
10/01/88 - 10/21/88	19.4	66.9	76.6

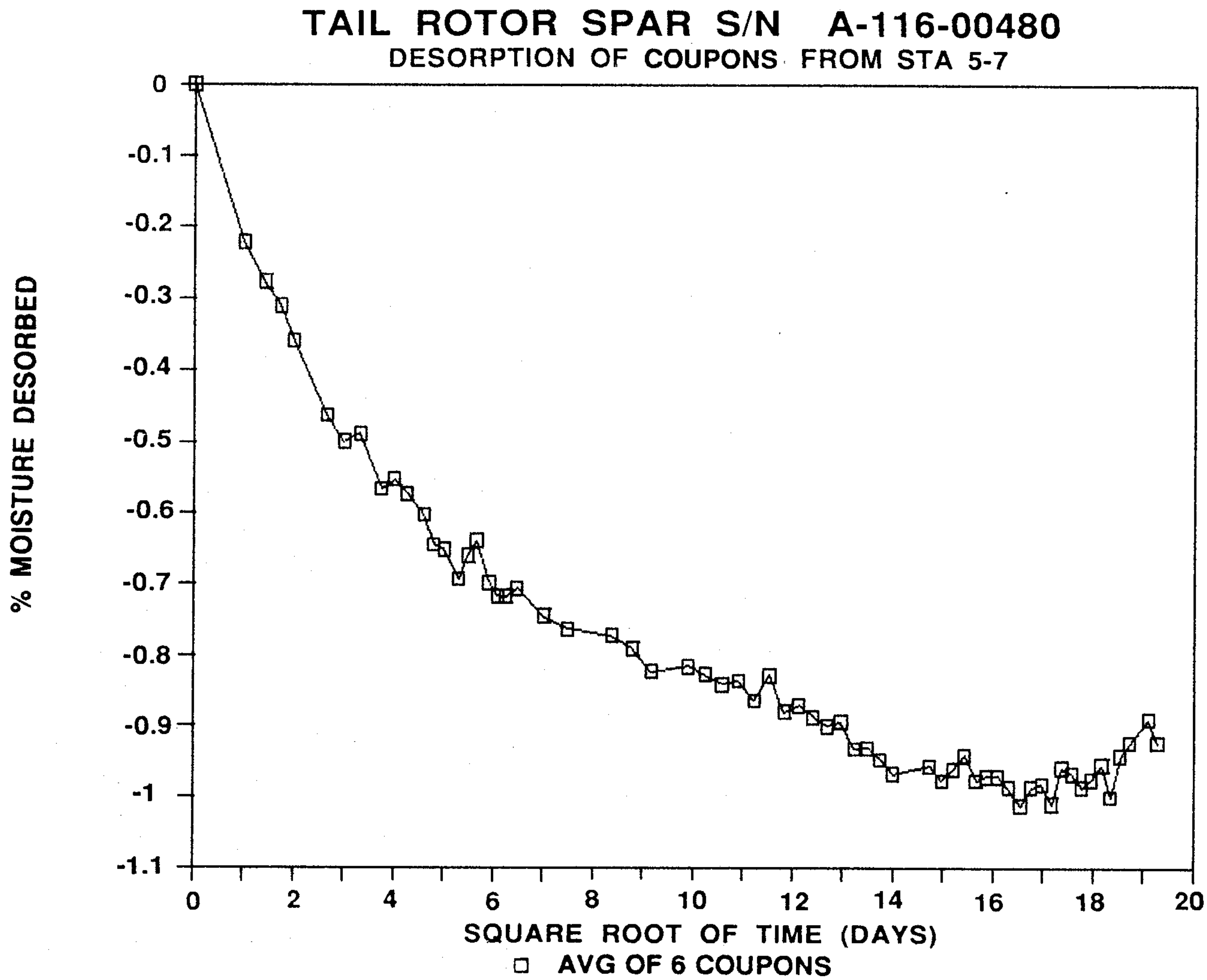


FIGURE 35. MOISTURE DESORPTION OF TAIL ROTOR SPAR S/N A-116-00480, COUPONS FROM STATION 5-7

TABLE XIV.

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00480

DATE OF WEIGHING	DAYS	WEIGHT OF A51 (grams)	WEIGHT OF A52 (grams)	WEIGHT OF B51 (grams)	WEIGHT OF B52 (grams)	WEIGHT OF B53 (grams)	WEIGHT OF B54 (grams)
6/5/89	0	1.7228	1.5985	1.3244	1.6837	2.2090	1.1828
6/6/89	1	1.7186	1.5947	1.3214	1.6803	2.2049	1.1801
6/7/89	2	1.7172	1.5939	1.3208	1.6796	2.2038	1.1793
6/8/89	3	1.717	1.5936	1.3202	1.6788	2.2030	1.1789
6/9/89	4	1.7163	1.5927	1.3196	1.6781	2.2022	1.178
6/12/89	7	1.7143	1.591	1.3183	1.6762	2.2005	1.1766
6/14/89	9	1.7137	1.5902	1.3181	1.6756	2.2003	1.1757
6/16/89	11	1.7134	1.5907	1.3178	1.6759	2.1999	1.1766
6/19/89	14	1.7127	1.5892	1.3166	1.6747	2.1984	1.1754
6/21/89	16	1.7129	1.5893	1.3165	1.6748	2.1992	1.1757
6/23/89	18	1.7124	1.5892	1.3167	1.6745	2.1982	1.1753
6/26/89	21	1.7118	1.5884	1.3161	1.6739	2.1980	1.1753
6/28/89	23	1.7112	1.5877	1.3157	1.6735	2.1974	1.1742
6/30/89	25	1.7111	1.5877	1.3152	1.6736	2.1970	1.1744
7/3/89	28	1.7103	1.587	1.3150	1.6728	2.1959	1.1738
7/5/89	30	1.7105	1.5875	1.3154	1.6731	2.1972	1.1743
7/7/89	32	1.7114	1.5877	1.3158	1.6735	2.1971	1.1745
7/10/89	35	1.7103	1.5869	1.3149	1.6719	2.1962	1.1741
7/12/89	37	1.7098	1.5864	1.3147	1.6725	2.1954	1.1736
7/14/89	39	1.7099	1.5864	1.3148	1.6726	2.1957	1.1732
7/17/89	42	1.7109	1.5863	1.3145	1.6725	2.1954	1.1739
7/24/89	49	1.7091	1.5859	1.3142	1.6724	2.1949	1.1733
7/31/89	56	1.71	1.5855	1.3138	1.6713	2.1943	1.1731
8/14/89	70	1.7091	1.5856	1.3140	1.6716	2.1940	1.1728
8/21/89	77	1.7083	1.5852	1.3137	1.6712	2.1938	1.173
8/28/89	84	1.7079	1.5846	1.3132	1.671	2.1932	1.1723
9/11/89	98	1.7079	1.5851	1.3134	1.671	2.1929	1.1724
9/18/89	105	1.7075	1.5849	1.3134	1.6708	2.1929	1.1722
9/25/89	112	1.7072	1.5844	1.3131	1.6709	2.1923	1.1723
10/2/89	119	1.7076	1.5846	1.3131	1.6707	2.1924	1.1723
10/9/89	126	1.7066	1.5842	1.3126	1.6703	2.1918	1.1724
10/16/89	133	1.7071	1.5861	1.3132	1.6707	2.1922	1.1721
10/23/89	140	1.7065	1.5836	1.3122	1.6714	2.1913	1.1716
10/30/89	147	1.7067	1.584	1.3127	1.6703	2.1915	1.172
11/6/89	154	1.7067	1.5838	1.3124	1.6699	2.1912	1.1717
11/13/89	161	1.7055	1.5836	1.3125	1.6702	2.1909	1.1716
11/20/89	168	1.7061	1.583	1.3125	1.6701	2.1912	1.172
11/27/89	175	1.7058	1.5828	1.3119	1.6691	2.1905	1.1712
12/4/89	182	1.7053	1.5831	1.3117	1.6695	2.1900	1.1716
12/11/89	189	1.7056	1.5824	1.3116	1.6692	2.1899	1.1711
12/18/89	196	1.7051	1.5829	1.3109	1.6692	2.1894	1.1705
1/8/90	217	1.7051	1.5823	1.3116	1.6689	2.1897	1.1712
1/15/90	224	1.7051	1.582	1.3111	1.6686	2.1891	1.1709
1/22/90	231	1.705	1.5821	1.3116	1.6688	2.1893	1.1713
1/29/90	238	1.7055	1.5823	1.3116	1.6691	2.1899	1.1717
2/5/90	245	1.7049	1.5822	1.3113	1.6685	2.1893	1.1707
2/12/90	252	1.7049	1.5821	1.3114	1.6685	2.1895	1.171
2/19/90	259	1.705	1.5818	1.3113	1.6692	2.1892	1.1709
2/26/90	266	1.705	1.5813	1.3112	1.6687	2.1890	1.1707

TABLE XIV. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00480

DATE OF WEIGHING	DAYS	WEIGHT OF A51 (grams)	WEIGHT OF A52 (grams)	WEIGHT OF B51 (grams)	WEIGHT OF B52 (grams)	WEIGHT OF B53 (grams)	WEIGHT OF B54 (grams)
3/5/90	274	1.7043	1.5813	1.3107	1.6682	2.1887	1.1704
3/12/90	281	1.7051	1.5814	1.3117	1.6683	2.1886	1.1706
3/19/90	288	1.7048	1.5819	1.3116	1.6695	2.1887	1.17
3/26/90	295	1.704	1.5818	1.3115	1.6688	2.1882	1.1695
4/2/90	302	1.7052	1.5821	1.3119	1.6686	2.1895	1.1711
4/9/90	309	1.7053	1.5807	1.3117	1.669	2.1899	1.1712
4/16/90	316	1.7043	1.5817	1.3114	1.6683	2.1895	1.1707
4/23/90	323	1.705	1.5821	1.3111	1.6688	2.1895	1.1707
4/30/90	330	1.7061	1.5827	1.3117	1.6686	2.1888	1.1709
5/7/90	337	1.705	1.5814	1.3109	1.6681	2.1886	1.1706
5/14/90	344	1.7056	1.5825	1.3116	1.6691	2.1898	1.1715
5/21/90	351	1.7061	1.5827	1.3119	1.6694	2.1903	1.1716
6/4/90	365	1.7061	1.5831	1.3133	1.6703	2.1899	1.172
6/11/90	372	1.7057	1.5825	1.3124	1.6702	2.1900	1.1712

TABLE XIV. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00480

DATE OF WEIGHING	DAYS	% MOIST DESORB A51	% MOIST DESORB A52	% MOIST DESORB B51	% MOIST DESORB B52	% MOIST DESORB B53	% MOIST DESORB B54	AVERAGE % MOIST DESORB
6/5/89	0	0	0	0	0	0	0	0
6/6/89	1	-0.24	-0.24	-0.23	-0.20	-0.19	-0.23	-0.22
6/7/89	2	-0.33	-0.29	-0.27	-0.24	-0.24	-0.30	-0.28
6/8/89	3	-0.34	-0.31	-0.32	-0.29	-0.27	-0.33	-0.31
6/9/89	4	-0.38	-0.36	-0.36	-0.33	-0.31	-0.41	-0.36
6/12/89	7	-0.49	-0.47	-0.46	-0.45	-0.38	-0.52	-0.46
6/14/89	9	-0.53	-0.52	-0.48	-0.48	-0.39	-0.60	-0.50
6/16/89	11	-0.55	-0.49	-0.50	-0.46	-0.41	-0.52	-0.49
6/19/89	14	-0.59	-0.58	-0.59	-0.53	-0.48	-0.63	-0.57
6/21/89	16	-0.57	-0.58	-0.60	-0.53	-0.44	-0.60	-0.55
6/23/89	18	-0.60	-0.58	-0.58	-0.55	-0.49	-0.63	-0.57
6/26/89	21	-0.64	-0.63	-0.63	-0.58	-0.50	-0.63	-0.60
6/28/89	23	-0.67	-0.68	-0.66	-0.61	-0.53	-0.73	-0.64
6/30/89	25	-0.68	-0.68	-0.69	-0.60	-0.54	-0.71	-0.65
7/3/89	28	-0.73	-0.72	-0.71	-0.65	-0.59	-0.76	-0.69
7/5/89	30	-0.71	-0.69	-0.68	-0.63	-0.53	-0.72	-0.66
7/7/89	32	-0.66	-0.68	-0.65	-0.61	-0.54	-0.70	-0.64
7/10/89	35	-0.73	-0.73	-0.72	-0.70	-0.58	-0.74	-0.70
7/12/89	37	-0.75	-0.76	-0.73	-0.67	-0.62	-0.78	-0.72
7/14/89	39	-0.75	-0.76	-0.72	-0.66	-0.60	-0.81	-0.72
7/17/89	42	-0.69	-0.76	-0.75	-0.67	-0.62	-0.75	-0.71
7/24/89	49	-0.80	-0.79	-0.77	-0.67	-0.64	-0.80	-0.74
7/31/89	56	-0.74	-0.81	-0.80	-0.74	-0.67	-0.82	-0.76
8/14/89	70	-0.80	-0.81	-0.79	-0.72	-0.68	-0.85	-0.77
8/21/89	77	-0.84	-0.83	-0.81	-0.74	-0.69	-0.83	-0.79
8/28/89	84	-0.86	-0.87	-0.85	-0.75	-0.72	-0.89	-0.82
9/11/89	98	-0.86	-0.84	-0.83	-0.75	-0.73	-0.88	-0.82
9/18/89	105	-0.89	-0.85	-0.83	-0.77	-0.73	-0.90	-0.83
9/25/89	112	-0.91	-0.88	-0.85	-0.76	-0.76	-0.89	-0.84
10/2/89	119	-0.88	-0.87	-0.85	-0.77	-0.75	-0.89	-0.84
10/9/89	126	-0.94	-0.89	-0.89	-0.80	-0.78	-0.88	-0.86
10/16/89	133	-0.91	-0.78	-0.85	-0.77	-0.76	-0.90	-0.83
10/23/89	140	-0.95	-0.93	-0.92	-0.73	-0.80	-0.95	-0.88
10/30/89	147	-0.93	-0.91	-0.88	-0.80	-0.79	-0.91	-0.87
11/6/89	154	-0.93	-0.92	-0.91	-0.82	-0.81	-0.94	-0.89
11/13/89	161	-1.00	-0.93	-0.90	-0.80	-0.82	-0.95	-0.90
11/20/89	168	-0.97	-0.97	-0.90	-0.81	-0.81	-0.91	-0.89
11/27/89	175	-0.99	-0.98	-0.94	-0.87	-0.84	-0.98	-0.93
12/4/89	182	-1.02	-0.96	-0.96	-0.84	-0.86	-0.95	-0.93
12/11/89	189	-1.00	-1.01	-0.97	-0.86	-0.86	-0.99	-0.95
12/18/89	196	-1.03	-0.98	-1.02	-0.86	-0.89	-1.04	-0.97
1/8/90	217	-1.03	-1.01	-0.97	-0.88	-0.87	-0.98	-0.96
1/15/90	224	-1.03	-1.03	-1.00	-0.90	-0.90	-1.01	-0.98
1/22/90	231	-1.03	-1.03	-0.97	-0.88	-0.89	-0.97	-0.96
1/29/90	238	-1.00	-1.01	-0.97	-0.87	-0.86	-0.94	-0.94
2/5/90	245	-1.04	-1.02	-0.99	-0.90	-0.89	-1.02	-0.98
2/12/90	252	-1.04	-1.03	-0.98	-0.90	-0.88	-1.00	-0.97
2/19/90	259	-1.03	-1.04	-0.99	-0.86	-0.90	-1.01	-0.97
2/26/90	266	-1.03	-1.08	-1.00	-0.89	-0.91	-1.02	-0.99

TABLE XIV. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00480

DATE OF WEIGHING	DAYS	% MOIST DESORB A51	% MOIST DESORB A52	% MOIST DESORB B51	% MOIST DESORB B52	% MOIST DESORB B53	% MOIST DESORB B54	AVERAGE % MOIST DESORB
3/5/90	274	-1.07	-1.08	-1.03	-0.92	-0.92	-1.05	-1.01
3/12/90	281	-1.03	-1.07	-0.96	-0.91	-0.92	-1.03	-0.99
3/19/90	288	-1.04	-1.04	-0.97	-0.84	-0.92	-1.08	-0.98
3/26/90	295	-1.09	-1.04	-0.97	-0.88	-0.94	-1.12	-1.01
4/2/90	302	-1.02	-1.03	-0.94	-0.90	-0.88	-0.99	-0.96
4/9/90	309	-1.02	-1.11	-0.96	-0.87	-0.86	-0.98	-0.97
4/16/90	316	-1.07	-1.05	-0.98	-0.91	-0.88	-1.02	-0.99
4/23/90	323	-1.03	-1.03	-1.00	-0.88	-0.88	-1.02	-0.98
4/30/90	330	-0.97	-0.99	-0.96	-0.90	-0.91	-1.01	-0.96
5/7/90	337	-1.03	-1.07	-1.02	-0.93	-0.92	-1.03	-1.00
5/14/90	344	-1.00	-1.00	-0.97	-0.87	-0.87	-0.96	-0.94
5/21/90	351	-0.97	-0.99	-0.94	-0.85	-0.85	-0.95	-0.92
6/4/90	365	-0.97	-0.96	-0.84	-0.80	-0.86	-0.91	-0.89
6/11/90	372	-0.99	-1.00	-0.91	-0.80	-0.86	-0.98	-0.92

TABLE XV. SUMMARY OF FATIGUE TEST DATA FOR TAIL ROTOR SPARS

TAIL ROTOR SPAR S/N	IN-SERVICE TIME MONTHS/FLT HRS	CYCLIC SHEAR STRESS, PSI	CYCLES TO CRACK	MOISTURE CONTENT PERCENT
00046	25 Months *1 150 flight hours	(a) 3980 (b) 3980	.25 X 10^6 (F) .466 X 10^6 (F)	.46
00064	25 Months *1 150 flight hours	(a) 4320 (b) 4320	.035 X 10^6 (F) .071 X 10^6 (F)	.51
00094	29 Months *2 2390 flight hours	(a) 3890 (b) 3920	.286 X 10^6 (F) .174 X 10^6 (F)	.26
00237	42 Months *2 1596 flight hours	(a) 4111 (b) 4377	.767 X 10^6 (F) .767 X 10^6 (Ro)	.47
00172	42 Months *2 2533 flight hours	(a) 4272 (b) 4272	.218 X 10^6 (F) .218 X 10^6 (F)	.49
00114	52 Months *2 3358 flight hours	(a) 4420 (b) 4420	.839 X 10^6 (Ro) .839 X 10^6 (F)	.56
00069	72 Months *2 4995 flight hours	(a) 3820 (b) 3820	.146 X 10^6 (Ro) .146 X 10^6 (F)	.66
00480	100 Months *2 5816 flight hours	(a) 4640 (b) 4640	.143 X 10^6 (F) .143 X 10^6 (Ro)	.98

*1 In-service location: West Palm Beach, Florida
*2 In-service location: Gulf Coast Region, Louisiana
(F): Failure
(Ro): Run out
(a): A side
(b): B side

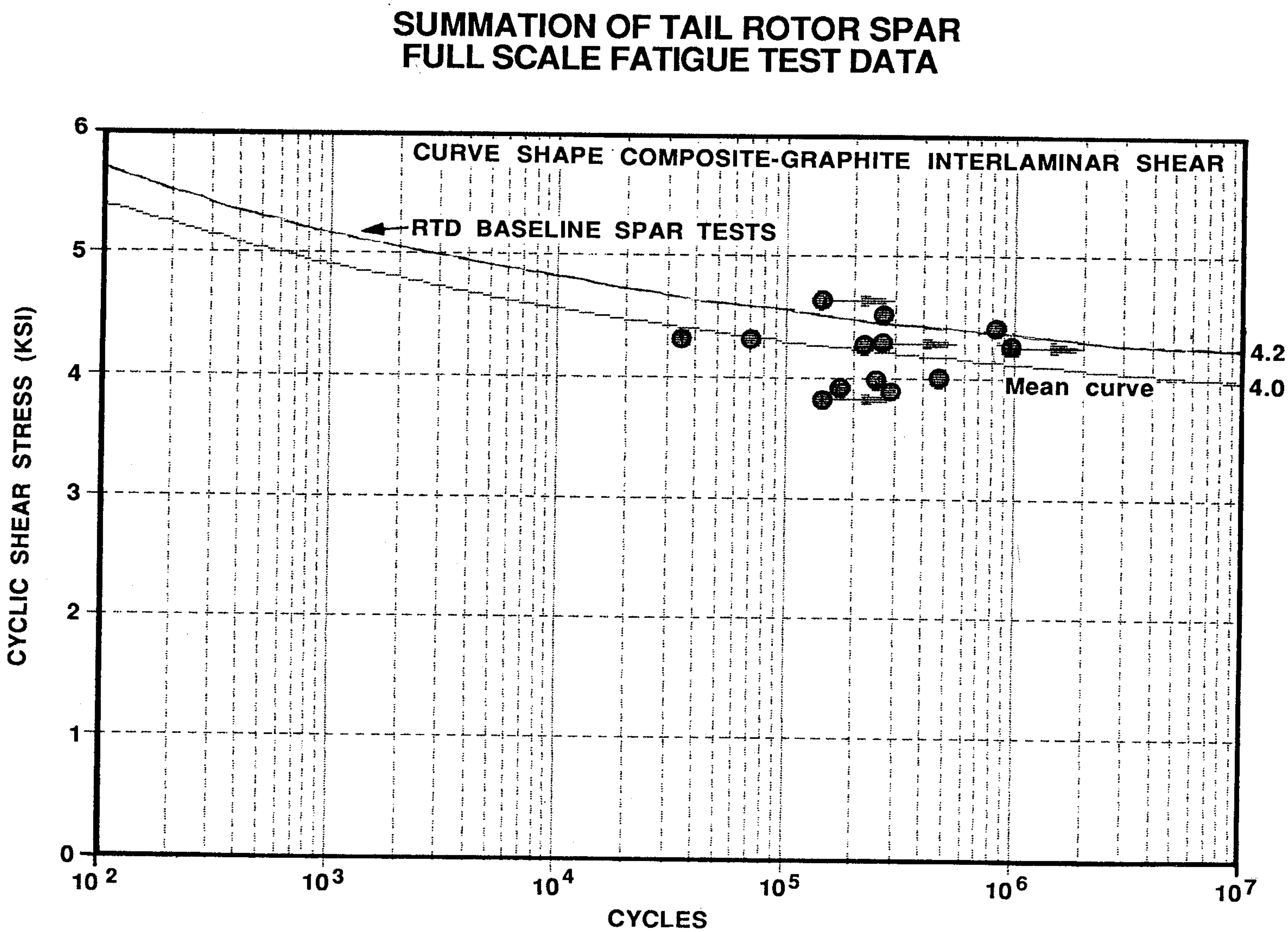


FIGURE 36. COMPARISION OF IN-SERVICE EXPOSED S-76 TAIL ROTOR SPAR TEST RESULTS WITH ROOM TEMPERATURE DRY CERTIFICATION DATA

3.2.2 Tail Rotor Spars - Coupon Test Results

Five tail rotor spars were returned from the field for small scale coupon testing (S/N A-116-00283, S/N A-116-00150, S/N A-116-00178, S/N A-116-00415 and S/N A-116-00493). Coupons were removed from each spar for moisture analysis and mechanical testing from the locations shown in Figure 37. As can be observed in the diagram, twelve short beam shear coupons were removed from each side of the spars, six for short beam shear static and six for short beam shear fatigue testing. Of the six static specimens removed from each end, three were tested at room temperature and three at 170°F, in accordance with ASTM D 2344, Reference (10). All coupon fatigue tests were performed at room temperature.

3.2.2.1 S/N A-116-00283

Tail rotor spar S/N A-116-00283, removed from paddle S/N A-137-00099, was returned from the field after 38 months of service. The spar had accumulated 1884 flight hours. Table IX of Reference (2) detailed the environmental history of the spar. Coupons were removed for short beam shear testing as indicated in Figure 37. A photograph of a typical static tested interlaminar shear test specimen is shown in Figure 38. Although specimens were marked A or B to designate the end of the spar from which they were removed, application of the t distribution test in accordance with Freund, Reference (11), for this and subsequent spars showed that the data was representative of the same population, and could be combined. An example of the t distribution test using the data from spar S/N A-116-00283, is included in Figure 39. At room temperature, the average interlaminar shear strength generated was 12.18 ksi. The average interlaminar shear strength at 170°F was 9.51 ksi. Fatigue testing of interlaminar shear specimens removed from tail rotor spar S/N A-116-00283 yielded a maximum stress of 7.5 ksi at 10^7 cycles. Plots graphically summarizing the maximum stress versus cycles to fracture data were presented in Figures 24 and 25 of Reference (2). Coupons were removed from Stations 5-7 for moisture analysis. Specimens were desorbed in an air circulating oven at 150 ± 2°F. An average of 0.36 percent moisture was desorbed from tail rotor spar S/N A-116-00283.

3.2.2.2 S/N A-116-00150

Tail rotor spar S/N A-116-00150, removed from tail rotor paddle S/N A-116-00085, was returned from the field for coupon testing with 38 months of in-service environmental exposure and 2385 flight hours. The environmental history of spar S/N A-116-00150 is documented in Table VIII of Reference (2). Specimens removed from the spar for room temperature interlaminar shear testing averaged a strength of 12.23 ksi. At 170°F, the interlaminar shear strength averaged 8.55 ksi. Interlaminar shear fatigue tests indicated a maximum stress of 7.4 ksi at 10^7 cycles. Maximum stress versus cycles to fracture data is summarized in Figures 22 and 23 of Reference (2). Coupons removed from the tail rotor spar for desorption analysis averaged 0.40 percent moisture, by weight.

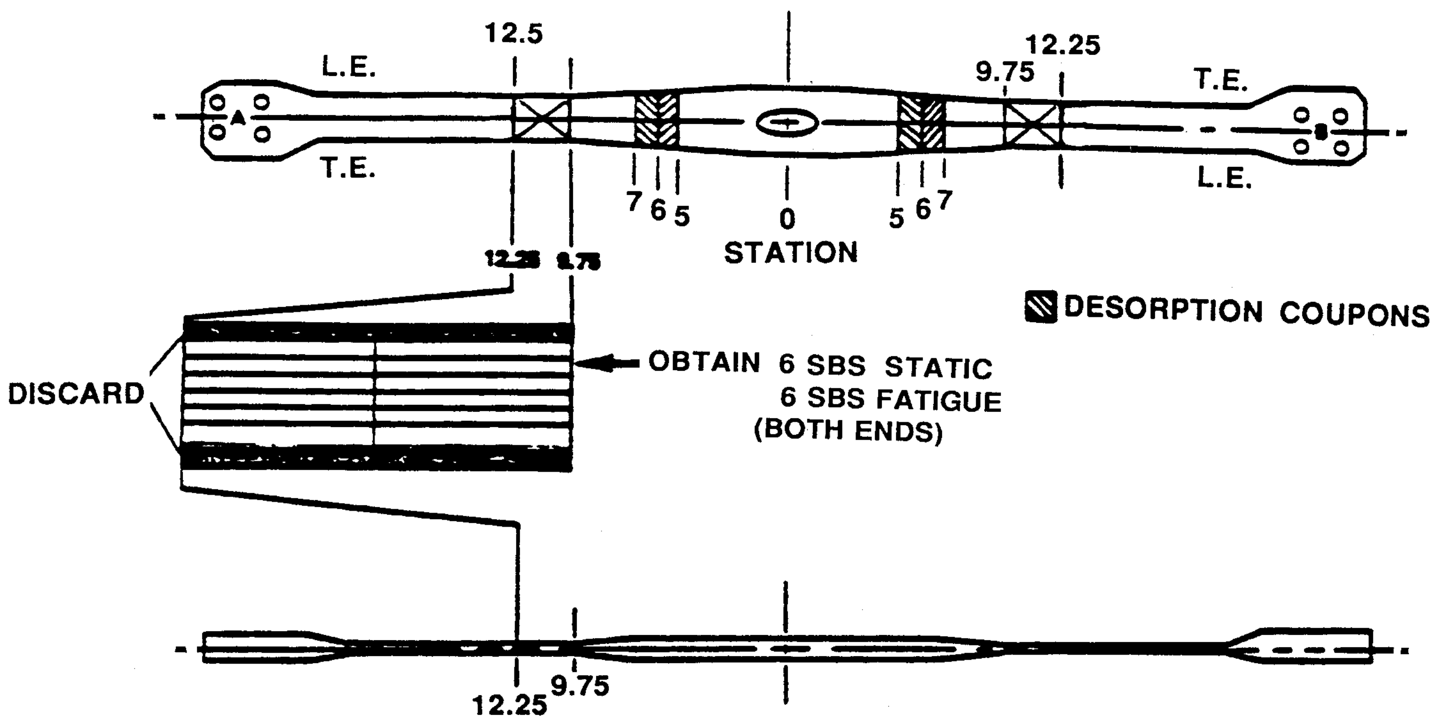


FIGURE 37. S-76 TAIL ROTOR SPAR - SKETCH OF COUPON LOCATIONS

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BLACK AND WHITE PHOTOGRAPH

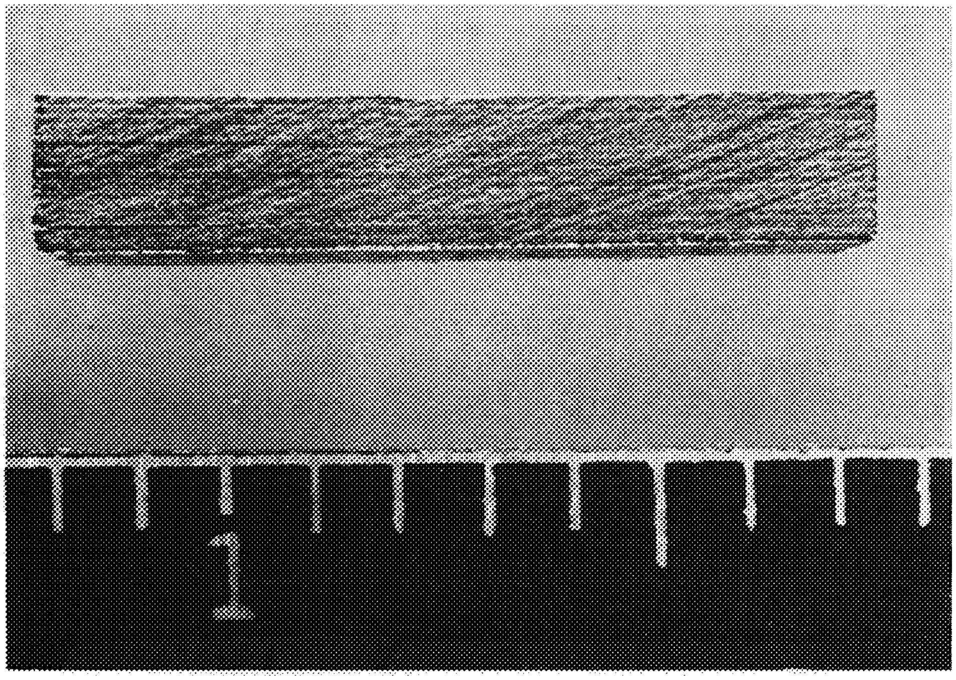


FIGURE 38. PHOTOGRAPH OF A STATIC TESTED INTERLAMINAR SHEAR TEST SPECIMEN, TYPICAL OF THOSE REMOVED FROM EACH TAIL ROTOR SPAR FOR COUPON TESTING

FOR ROOM TEMPERATURE TEST DATA

X_1	X_2
11.5	11.3
12.0	13.3
13.6	11.4

$n_1 = 3$ $\quad n_2 = 3$

$\bar{X}_1 = 12.37$ $\quad \bar{X}_2 = 12.0$

$\Sigma' X_1^2 = 2.407$ $\quad \Sigma' X_2^2 = 2.540$

$$\bar{S}(X) = \sqrt{\frac{2.407 + 2.540}{3 + 3 - 2}}$$

$$\bar{S}(X) = 1.112$$

$$t = \frac{|12.37 - 12.0|}{1.112 \sqrt{\frac{1}{3} + \frac{1}{3}}}$$

$$t = 0.404 < t_{.05,4} = 2.776$$

∴ Data from same population

FOR 170°F DATA

X_1	X_2
9.21	9.67
9.47	9.50
9.74	9.47

$n_1 = 3$ $\quad n_2 = 3$

$\bar{X}_1 = 9.47$ $\quad \bar{X}_2 = 9.55$

$\Sigma' X_1^2 = 0.140$ $\quad \Sigma' X_2^2 = 0.233$

$$\bar{S}(X) = \sqrt{\frac{0.140 + 0.233}{3 + 3 - 2}}$$

$$\bar{S}(X) = 0.202$$

$$t = \frac{|9.47 - 9.55|}{0.202 \sqrt{\frac{1}{3} + \frac{1}{3}}}$$

$$t = 0.444 < t_{.05,4} = 2.776$$

∴ Data from same population

FIGURE 39. T-TEST CALCULATIONS TO DETERMINE IF TEST RESULTS FROM A AND B ENDS OF TAIL ROTOR SPAR S/N A-116-00283 ARE FROM THE SAME POPULATION

3.2.2.3 S/N A-116-00178

Tail rotor spar S/N A-116-00178 had accumulated 51 months calendar time and 3752 flight hours in the field before being returned for coupon testing. The environmental history of the spar, removed from tail rotor paddle S/N A-116-00067, is detailed in Table VIII of Reference (3). Static tests conducted on coupons removed from the spar indicated an average interlaminar shear strength of 12.98 ksi at room temperature, and 10.21 ksi when tested at 170°F. Interlaminar shear fatigue tests generated a maximum stress of 8.4 ksi, as seen in Figure 9 of Reference (3). Desorption coupons removed from Stations 5-7 for moisture analysis showed an average of 0.60 percent moisture had been desorbed from the spar.

3.2.2.4 S/N A-116-00415

Tail rotor spar S/N A-116-00415 was returned from the field after 68 months of service. The spar, removed from tail rotor spar S/N A-116-00152, had logged 5216 flight hours. Table XVI lists the environmental history data for spar S/N A-116-00415. Specimens removed for small scale coupon testing averaged an interlaminar shear strength of 11.0 ksi at room temperature. The average interlaminar shear strength at 170°F was 9.13 ksi. Fatigue testing of interlaminar shear specimens yielded a maximum stress of 6.9 ksi at 10^7 cycles, as shown graphically in Figure 40. Coupons were removed from Stations 5-7 for moisture analysis. An average of 0.78 percent moisture, by weight, was desorbed. A plot of the average desorption of moisture coupons removed from spar S/N A-116-00415 is presented in Figure 41. The complete results of the spar coupon desorption analysis are detailed in Table XVII.

3.2.2.5 S/N A-116-00493

Tail rotor spar S/N A-116-00493, removed from paddle S/N A-116-00231, was the last tail rotor spar returned from the field for coupon testing. After 97 months of in-service environmental exposure, the spar had accumulated 5858 flight hours. The environmental history of spar S/N A-116-00493 is detailed in Table XVIII. At room temperature, the average interlaminar shear strength generated from the small scale coupons tested was 10.95 ksi. The average interlaminar shear strength at 170°F was 7.05 ksi. Fatigue testing of interlaminar shear specimens yielded a maximum stress of 7.6 ksi at 10^7 cycles. Maximum stress versus cycles to fracture data is summarized in Figure 42. Coupons removed from the spar for desorption analysis averaged 0.79 percent moisture, by weight, as seen graphically in Figure 43. Desorption data for the coupons is presented in Table XIX.

TABLE XVI.

SPAR S/N A-116-00415 (PADDLE S/N A-137-00152)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
2/29/80	10.3	50.6	80.5
3/01/80 - 3/31/80	15.2	59.4	81.4
4/01/80 - 4/30/80	18.4	65.1	76.5
5/01/80 - 5/31/80	23.9	74.8	83.9
6/01/80 - 6/30/80	27.1	80.8	80.3
7/01/80 - 7/31/80	28.2	82.8	72.5
8/01/80 - 8/31/80	27.4	81.3	74.0
9/01/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.4	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	26.8	80.3	82.1
6/01/81 - 6/30/81	22.6	72.6	73.3
7/01/81 - 7/31/81	26.8	80.3	82.1
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1

TABLE XVI. (CONTINUED)

SPAR S/N A-116-00415 (PADDLE S/N A-137-00152)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/30/83	17.5	63.5	73.4
5/01/83 - 5/31/83	23.0	73.4	77.1
6/01/83 - 6/30/83	25.6	78.0	81.3
7/01/83 - 7/31/83	28.2	92.8	78.1
8/01/83 - 8/31/83	27.8	82.1	81.4
9/01/83 - 9/30/83	24.2	75.6	77.9
10/01/83 - 10/31/83	21.1	69.9	73.3
11/01/83 - 11/30/83	16.7	62.1	75.8
12/01/83 - 12/31/83	9.1	48.3	73.3
1/01/84 - 1/31/84	8.9	48.1	74.3
2/01/84 - 2/29/84	13.3	55.9	68.1
3/01/84 - 3/31/84	16.9	62.4	72.5
4/01/84 - 4/30/84	21.1	69.9	66.9
5/01/84 - 5/31/84	23.9	75.0	72.3
6/01/84 - 6/30/84	26.4	79.5	79.0
7/01/84 - 7/31/84	26.9	80.4	82.1
8/01/84 - 8/31/84	26.7	80.1	84.1
9/01/84 - 9/30/84	23.8	74.8	79.1
10/01/84 - 10/31/84	22.7	72.8	85.9
11/01/84 - 11/30/84	14.3	57.8	78.8
12/01/84 - 12/31/84	16.4	61.6	86.5
1/01/85 - 1/31/85	6.8	44.3	78.4
2/01/85 - 2/28/85	9.9	49.9	82.0
3/01/85 - 3/31/85	17.8	64.1	81.4
4/01/85 - 4/30/85	21.0	69.8	73.6
5/01/85 - 5/31/85	23.9	75.1	76.0
6/01/85 - 6/30/85	27.0	80.6	75.1
7/01/85 - 7/31/85	26.9	80.5	80.5
8/01/85 - 8/31/85	27.7	81.8	80.3
9/01/85 - 9/30/85	25.3	77.5	79.5
10/01/85 - 10/31/85	22.2	71.9	82.8
11/01/85 - 11/30/85	18.8	65.9	83.8
12/01/85 - 12/31/85	9.7	49.4	75.8

TABLE XVI. (CONTINUED)

SPAR S/N A-116-00415 (PADDLE S/N A-137-00152)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
1/01/86 - 1/31/86	10.8	51.4	73.1
2/01/86 - 2/28/86	14.1	57.4	79.8
3/01/86 - 3/31/86	15.8	60.4	75.0
4/01/86 - 4/30/86	20.2	68.4	77.6
5/01/86 - 5/31/86	24.2	75.5	81.0
6/01/86 - 6/30/86	27.2	80.9	82.1
7/01/86 - 7/19/86	28.2	82.8	80.8

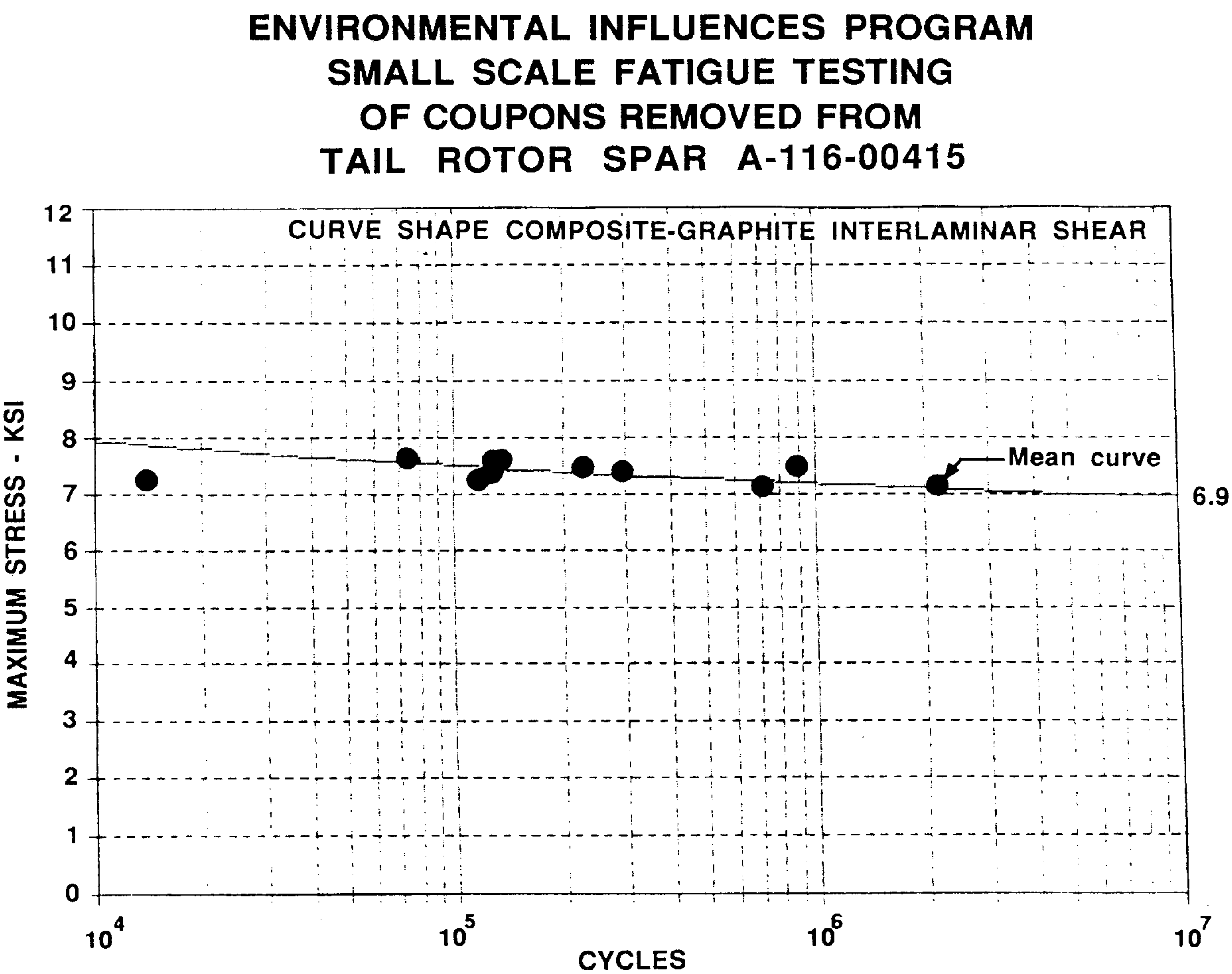


FIGURE 40. SPAR S/N A-116-00415
INTERLAMINAR SHEAR FATIGUE
COUPON TESTING - MAXIMUM
STRESS VERSUS CYCLES TO
FRACTURE

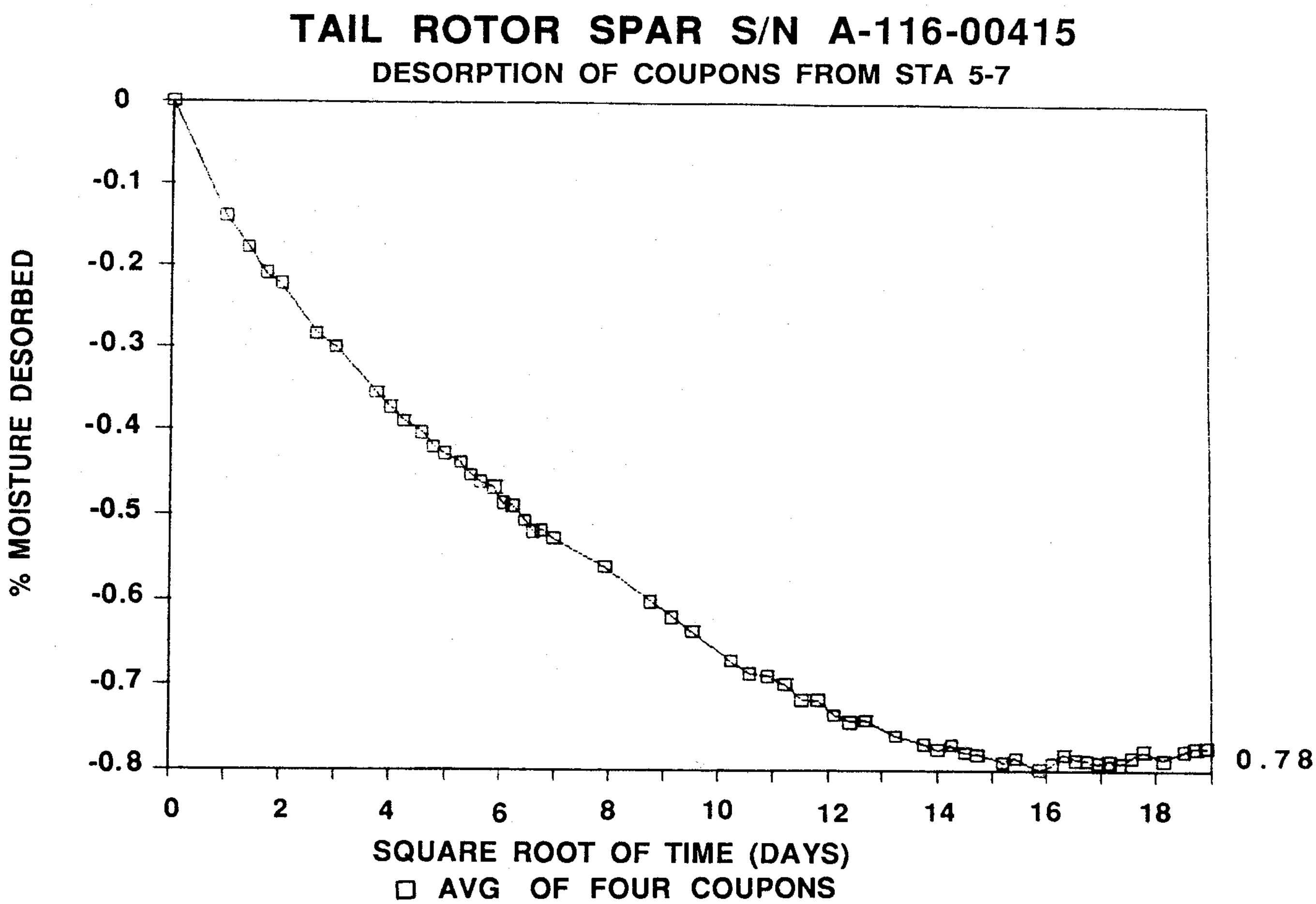


FIGURE 41. MOISTURE DESORPTION OF TAIL ROTOR SPAR S/N A-116-00415 COUPONS FROM STATIONS 5-7

TABLE XVII.

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00415

DATE	DAYS	WEIGHT OF COUP A571	WEIGHT OF COUP A572	WEIGHT OF COUP B571	WEIGHT OF COUP B572	% MOIST DESORBED COUP A571	% MOIST DESORBED COUP A572	% MOIST DESORBED COUP B571	% MOIST DESORBED COUP B572	AVERAGE % MOIST STA 5-7
7/13/87	0	9.8695	8.6258	8.7905	10.1306	0	0	0	0	0
7/14/87	1	9.8558	8.6137	8.7781	10.1165	-0.14	-0.14	-0.14	-0.14	-0.14
7/15/87	2	9.8527	8.6107	8.7741	10.1126	-0.17	-0.18	-0.19	-0.18	-0.18
7/16/87	3	9.8497	8.6073	8.7715	10.1094	-0.20	-0.21	-0.22	-0.21	-0.21
7/17/87	4	9.8486	8.6065	8.7703	10.1078	-0.21	-0.22	-0.23	-0.23	-0.22
7/20/87	7	9.843	8.6009	8.7651	10.1022	-0.27	-0.29	-0.29	-0.28	-0.28
7/22/87	9	9.8417	8.5996	8.7633	10.1002	-0.28	-0.30	-0.31	-0.30	-0.30
7/27/87	14	9.8366	8.5946	8.7582	10.0943	-0.33	-0.36	-0.37	-0.36	-0.36
7/29/87	16	9.8344	8.5927	8.7573	10.0929	-0.36	-0.38	-0.38	-0.37	-0.37
7/31/87	18	9.8332	8.5916	8.7554	10.0908	-0.37	-0.40	-0.40	-0.39	-0.39
8/3/87	21	9.8323	8.5902	8.7542	10.0892	-0.38	-0.41	-0.41	-0.41	-0.40
8/5/87	23	9.8304	8.5886	8.7527	10.0878	-0.40	-0.43	-0.43	-0.42	-0.42
8/7/87	25	9.8299	8.5878	8.752	10.0867	-0.40	-0.44	-0.44	-0.43	-0.43
8/10/87	28	9.8289	8.587	8.7511	10.0857	-0.41	-0.45	-0.45	-0.44	-0.44
8/12/87	30	9.8274	8.5856	8.7498	10.0843	-0.43	-0.47	-0.46	-0.46	-0.45
8/14/87	32	9.8268	8.585	8.7491	10.0832	-0.43	-0.47	-0.47	-0.47	-0.46
8/17/87	35	9.826	8.5846	8.7484	10.0826	-0.44	-0.48	-0.48	-0.47	-0.47
8/19/87	37	9.8247	8.5826	8.7467	10.0807	-0.45	-0.50	-0.50	-0.49	-0.49
8/21/87	39	9.8243	8.5825	8.7464	10.0805	-0.46	-0.50	-0.50	-0.49	-0.49
8/24/87	42	9.8222	8.5808	8.7448	10.0792	-0.48	-0.52	-0.52	-0.51	-0.51
8/26/87	44	9.8217	8.5797	8.7437	10.077	-0.48	-0.53	-0.53	-0.53	-0.52
8/28/87	46	9.8218	8.5799	8.7439	10.0773	-0.48	-0.53	-0.53	-0.53	-0.52
8/31/87	49	9.8206	8.5793	8.743	10.0764	-0.50	-0.54	-0.54	-0.54	-0.53
9/14/87	63	9.8172	8.576	8.7406	10.0728	-0.53	-0.58	-0.57	-0.57	-0.56
9/28/87	77	9.8138	8.5724	8.7368	10.0684	-0.56	-0.62	-0.61	-0.61	-0.60
10/5/87	84	9.812	8.571	8.735	10.0665	-0.58	-0.64	-0.63	-0.63	-0.62
10/12/87	91	9.81	8.5695	8.7336	10.0647	-0.60	-0.65	-0.65	-0.65	-0.64
10/26/87	105	9.8069	8.5671	8.7303	10.0607	-0.63	-0.68	-0.68	-0.69	-0.67
11/2/87	112	9.8055	8.5656	8.7289	10.0594	-0.65	-0.70	-0.70	-0.70	-0.69
11/9/87	119	9.8055	8.5653	8.7287	10.059	-0.65	-0.70	-0.70	-0.71	-0.69
11/16/87	126	9.8045	8.5645	8.7279	10.0579	-0.66	-0.71	-0.71	-0.72	-0.70
11/23/87	133	9.8022	8.5629	8.7266	10.0563	-0.68	-0.73	-0.73	-0.73	-0.72
11/30/87	140	9.8026	8.5629	8.7263	10.0561	-0.68	-0.73	-0.73	-0.74	-0.72
12/7/87	147	9.801	8.5617	8.7246	10.0541	-0.69	-0.74	-0.75	-0.76	-0.74
12/14/87	154	9.8002	8.5607	8.724	10.0534	-0.70	-0.75	-0.76	-0.76	-0.74
12/21/87	161	9.8001	8.5612	8.7243	10.0535	-0.70	-0.75	-0.75	-0.76	-0.74
1/4/88	175	9.7991	8.5592	8.7226	10.0514	-0.71	-0.77	-0.77	-0.78	-0.76
1/18/88	189	9.7976	8.5589	8.722	10.0502	-0.73	-0.78	-0.78	-0.79	-0.77
1/25/88	196	9.7973	8.5584	8.7211	10.0494	-0.73	-0.78	-0.79	-0.80	-0.78
2/1/88	203	9.7977	8.5587	8.7219	10.0499	-0.73	-0.78	-0.78	-0.80	-0.77
2/8/88	210	9.7968	8.558	8.7209	10.049	-0.74	-0.79	-0.79	-0.81	-0.78
2/15/88	217	9.7966	8.5578	8.7208	10.0488	-0.74	-0.79	-0.79	-0.81	-0.78
2/29/88	231	9.7947	8.5574	8.7203	10.0482	-0.76	-0.79	-0.80	-0.81	-0.79
3/7/88	238	9.7961	8.5576	8.7204	10.0483	-0.74	-0.79	-0.80	-0.81	-0.79
3/21/88	252	9.7947	8.5566	8.7192	10.0468	-0.76	-0.80	-0.81	-0.83	-0.80
3/28/88	259	9.7946	8.5572	8.72	10.0479	-0.76	-0.80	-0.80	-0.82	-0.79

TABLE XVII. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00415

DATE	DAYS	WEIGHT OF COUP A571	WEIGHT OF COUP A572	WEIGHT OF COUP B571	WEIGHT OF COUP B572	% MOIST DESORBED COUP A571	% MOIST DESORBED COUP A572	% MOIST DESORBED COUP B571	% MOIST DESORBED COUP B572	AVERAGE % MOIST STA 5-7
4/4/88	266	9.7965	8.5581	8.7207	10.0485	-0.74	-0.78	-0.79	-0.81	-0.78
4/11/88	273	9.7956	8.5575	8.7201	10.0483	-0.75	-0.79	-0.80	-0.81	-0.79
4/18/88	280	9.7954	8.5573	8.7205	10.0479	-0.75	-0.79	-0.80	-0.82	-0.79
4/25/88	287	9.7951	8.5574	8.7201	10.0475	-0.75	-0.79	-0.80	-0.82	-0.79
5/2/88	294	9.7955	8.5576	8.7202	10.0477	-0.75	-0.79	-0.80	-0.82	-0.79
5/9/88	301	9.7954	8.5574	8.72	10.0472	-0.75	-0.79	-0.80	-0.82	-0.79
5/16/88	308	9.796	8.5579	8.7207	10.0483	-0.74	-0.79	-0.79	-0.81	-0.78
5/23/88	315	9.7965	8.5587	8.7214	10.0488	-0.74	-0.78	-0.79	-0.81	-0.78
6/6/88	329	9.7956	8.5579	8.7203	10.0479	-0.75	-0.79	-0.80	-0.82	-0.79
6/20/88	343	9.7968	8.5587	8.7214	10.0485	-0.74	-0.78	-0.79	-0.81	-0.78
6/27/88	350	9.7969	8.5593	8.7216	10.0489	-0.74	-0.77	-0.78	-0.81	-0.77
7/5/88	358	9.7965	8.5592	8.7218	10.0497	-0.74	-0.77	-0.78	-0.80	-0.77

TABLE XVIII.

SPAR S/N A-116-00493 (PADDLE S/N A-137-00231)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	(°F)	Average Relative Humidity (%)
9/18/80 - 9/30/80	26.3	79.4	79.3
10/01/80 - 10/31/80	18.0	64.6	69.8
11/01/80 - 11/30/80	12.7	54.8	78.0
12/01/80 - 12/31/80	10.7	51.3	75.0
1/01/81 - 1/31/81	8.2	46.8	73.5
2/01/81 - 2/28/81	11.1	52.0	74.0
3/01/81 - 3/31/81	14.9	58.9	66.4
4/01/81 - 4/30/81	21.4	70.5	76.1
5/01/81 - 5/31/81	22.6	72.6	73.3
6/01/81 - 6/30/81	26.8	80.3	82.1
7/01/81 - 7/31/81	27.3	81.1	81.8
8/01/81 - 8/31/81	26.9	80.5	79.3
9/01/81 - 9/30/81	23.8	74.8	77.3
10/01/81 - 10/31/81	20.1	68.1	79.1
11/01/81 - 11/30/81	16.1	60.9	80.9
12/01/81 - 12/31/81	11.4	52.5	73.4
1/01/82 - 1/31/82	11.1	51.9	76.9
2/01/82 - 2/28/82	10.8	51.4	78.4
3/01/82 - 3/31/82	16.9	62.5	82.6
4/01/82 - 4/30/82	18.9	66.1	80.1
5/01/82 - 5/31/82	23.2	73.8	82.1
6/01/82 - 6/30/82	26.4	79.6	82.4
7/01/82 - 7/31/82	27.2	80.9	80.8
8/01/82 - 8/31/82	26.9	80.5	78.8
9/01/82 - 9/30/82	24.2	75.6	75.5
10/01/82 - 10/31/82	20.2	68.3	70.9
11/01/82 - 11/30/82	16.4	61.5	74.3
12/01/82 - 12/31/82	13.9	57.0	81.1
1/01/83 - 1/31/83	9.5	49.1	81.1
2/01/83 - 2/28/83	11.3	52.4	77.3
3/01/83 - 3/31/83	14.2	57.6	73.5
4/01/83 - 4/30/83	17.5	63.5	73.4
5/01/83 - 5/31/83	23.0	73.4	77.1
6/01/83 - 6/30/83	25.6	78.0	81.3
7/01/83 - 7/31/83	28.2	92.8	78.1
8/01/83 - 8/31/83	27.8	82.1	81.4
9/01/83 - 9/30/83	24.2	75.6	77.9

TABLE XVIII. (CONTINUED)

SPAR S/N A-116-00493 (PADDLE S/N A-137-00231)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
10/01/83 - 10/31/83	21.1	69.9	73.3
11/01/83 - 11/30/83	16.7	62.1	75.8
12/01/83 - 12/31/83	9.1	48.3	73.3
1/01/84 - 1/31/84	8.9	48.1	74.3
2/01/84 - 2/29/84	13.3	55.9	68.1
3/01/84 - 3/31/84	16.9	62.4	72.5
4/01/84 - 4/30/84	21.1	69.9	66.9
5/01/84 - 5/31/84	23.9	75.0	72.3
6/01/84 - 6/30/84	26.4	79.5	79.0
7/01/84 - 7/31/84	26.9	80.4	82.1
8/01/84 - 8/31/84	26.7	80.1	84.1
9/01/84 - 9/30/84	23.8	74.8	79.1
10/01/84 - 10/31/84	22.7	72.8	85.9
11/01/84 - 11/30/84	14.3	57.8	78.8
12/01/84 - 12/31/84	16.4	61.6	86.5
1/01/85 - 1/31/85	6.8	44.3	78.4
2/01/85 - 2/28/85	9.9	49.9	82.0
3/01/85 - 3/31/85	17.8	64.1	81.4
4/01/85 - 4/30/85	21.0	69.8	73.6
5/01/85 - 5/31/85	23.9	75.1	76.0
6/01/85 - 6/30/85	27.0	80.6	75.1
7/01/85 - 7/31/85	26.9	80.5	80.5
8/01/85 - 8/31/85	27.7	81.8	80.3
9/01/85 - 9/30/85	25.3	77.5	79.5
10/01/85 - 10/31/85	22.2	71.9	82.8
11/01/85 - 11/30/85	18.8	65.9	83.8
12/01/85 - 12/31/85	9.7	49.4	75.8
1/01/86 - 1/31/86	10.8	51.4	73.1
2/01/86 - 2/28/86	14.1	57.4	79.8
3/01/86 - 3/31/86	15.8	60.4	75.0
4/01/86 - 4/30/86	20.2	68.4	77.6
5/01/86 - 5/31/86	24.2	75.5	81.0
6/01/86 - 6/30/86	27.2	80.9	82.1
7/01/86 - 7/31/86	28.2	82.8	80.8
8/01/86 - 8/31/86	27.1	80.8	79.4
9/01/86 - 9/30/86	26.7	80.0	83.0
10/01/86 - 10/31/86	16.1	60.9	79.6
11/01/86 - 11/30/86	17.4	63.3	83.6
12/01/86 - 12/31/86	10.3	50.6	82.6

TABLE XVIII. (CONTINUED)

SPAR S/N A-116-00493 (PADDLE S/N A-137-00231)
SUMMARY OF ENVIRONMENTAL HISTORY

Date	Average Temperature (°C)	Average Temperature (°F)	Average Relative Humidity (%)
1/01/87 - 1/31/87	9.5	49.1	79.3
2/01/87 - 2/28/87	12.8	55.1	79.8
3/01/87 - 3/31/87	14.5	58.1	69.8
4/01/87 - 4/30/87	18.8	65.9	65.4
5/01/87 - 5/31/87	24.2	75.6	83.3
6/01/87 - 6/30/87	26.3	79.3	80.4
7/01/87 - 7/31/87	27.4	81.3	80.8
8/01/87 - 8/31/87	28.5	83.3	78.5
9/01/87 - 9/30/87	24.9	76.8	75.9
10/01/87 - 10/31/87	18.4	65.1	68.5
11/01/87 - 11/30/87	15.3	59.6	75.4
12/01/87 - 12/31/87	13.8	56.9	80.3
1/01/88 - 1/31/88	8.3	47.0	71.1
2/01/88 - 2/29/88	11.5	52.8	79.0
3/01/88 - 3/31/88	15.7	60.3	75.3
4/01/88 - 4/30/88	18.9	67.9	72.4
5/01/88 - 5/31/88	23.3	73.9	70.9
6/01/88 - 6/30/88	25.9	78.6	77.3
7/01/88 - 7/31/88	27.2	80.9	83.0
8/01/88 - 8/31/88	27.5	81.5	81.9
9/01/88 - 9/30/88	25.3	77.6	79.3
10/01/88 - 10/20/88	19.4	66.9	76.6

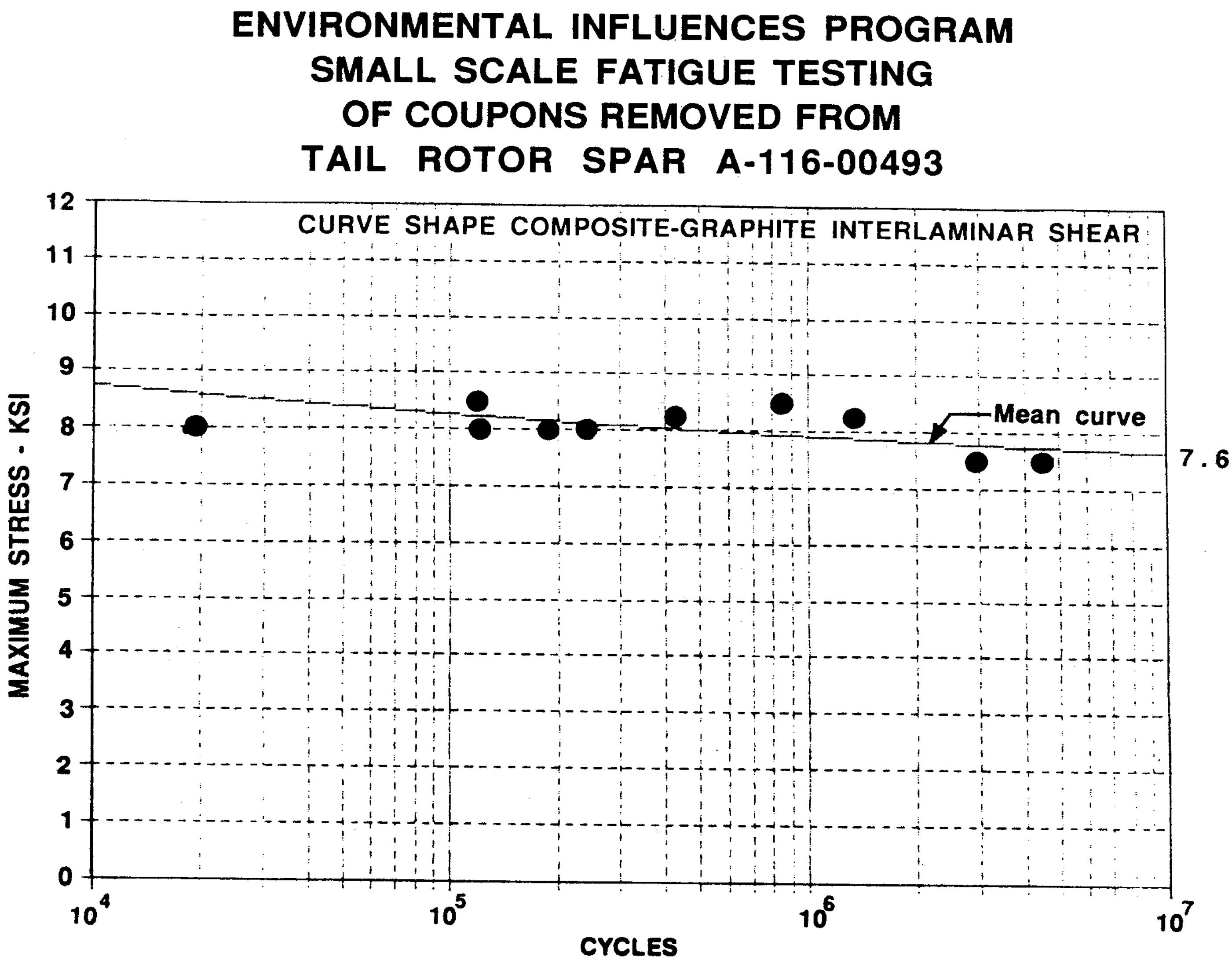


FIGURE 42. SPAR S/N A-116-00493
INTERLAMINAR SHEAR FATIGUE
COUPON TESTING - MAXIMUM
STRESS VERSUS CYCLES TO
FRACTURE

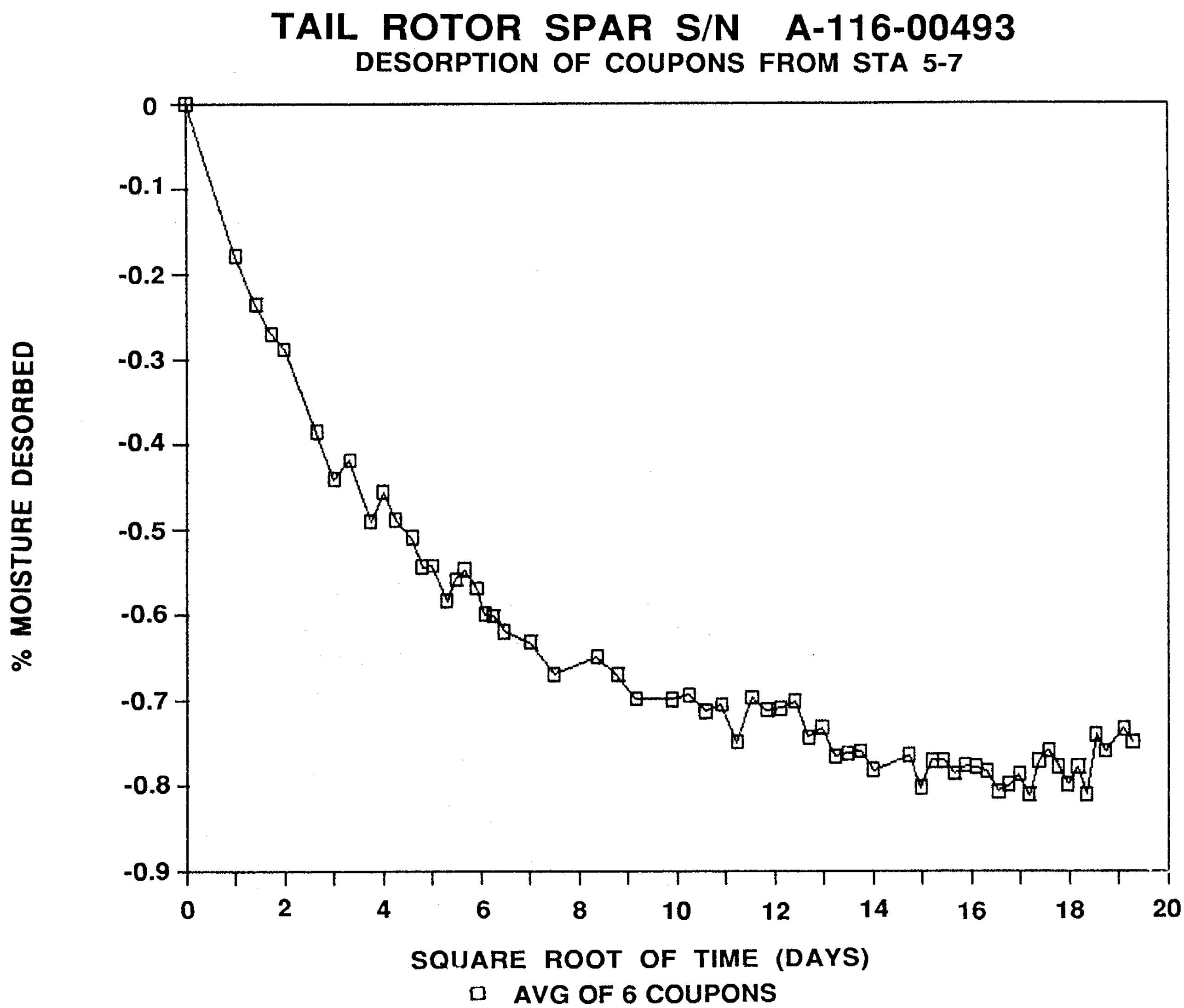


FIGURE 43. MOISTURE DESORPTION OF TAIL ROTOR SPAR
S/N A-116-00493 COUPONS FROM STATIONS 5-7

TABLE XIX.

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00493

DATE OF WEIGHING	DAYS	WEIGHT OF A51 (grams)	WEIGHT OF A52 (grams)	WEIGHT OF A53 (grams)	WEIGHT OF A54 (grams)	WEIGHT OF B51 (grams)	WEIGHT OF B52 (grams)	WEIGHT OF B53 (grams)	WEIGHT OF B54 (grams)
6/5/89	0	1.7223	1.7376	1.6643	1.6315	2.0867	1.7074	2.1973	1.7100
6/6/89	1	1.7192	1.7346	1.6613	1.6283	2.0830	1.7045	2.1940	1.7066
6/7/89	2	1.7175	1.7334	1.6602	1.6275	2.0818	1.7036	2.1926	1.7066
6/8/89	3	1.7172	1.7328	1.6597	1.6267	2.0810	1.7031	2.1918	1.7061
6/9/89	4	1.7167	1.7326	1.6594	1.6266	2.0809	1.7026	2.1914	1.7055
6/12/89	7	1.7152	1.7308	1.6576	1.6247	2.0788	1.7011	2.1895	1.7040
6/14/89	9	1.7136	1.7298	1.6566	1.6239	2.0778	1.7004	2.1886	1.7031
6/16/89	11	1.7144	1.7304	1.6571	1.6243	2.0781	1.7004	2.1886	1.7035
6/19/89	14	1.7131	1.7287	1.6556	1.6231	2.0766	1.6992	2.1877	1.7026
6/21/89	16	1.7134	1.7296	1.6563	1.6239	2.0772	1.6999	2.1883	1.7029
6/23/89	18	1.713	1.7293	1.6559	1.6231	2.0765	1.6994	2.1874	1.7021
6/26/89	21	1.7122	1.729	1.6554	1.6229	2.0761	1.6992	2.1870	1.7019
6/28/89	23	1.7119	1.7281	1.6544	1.6224	2.0756	1.6985	2.1863	1.7016
6/30/89	25	1.7121	1.728	1.6547	1.6221	2.0757	1.6987	2.1860	1.7016
7/3/89	28	1.7115	1.7274	1.6539	1.6217	2.0749	1.6978	2.1853	1.7005
7/5/89	30	1.7115	1.7279	1.6547	1.6222	2.0751	1.6981	2.1855	1.7015
7/7/89	32	1.712	1.7281	1.6546	1.6224	2.0753	1.6984	2.1860	1.7014
7/10/89	35	1.7115	1.7279	1.6543	1.6221	2.0748	1.698	2.1856	1.7009
7/12/89	37	1.7104	1.7273	1.6538	1.6216	2.0747	1.6976	2.1846	1.7007
7/14/89	39	1.7108	1.7275	1.6539	1.6213	2.0743	1.6972	2.1848	1.7006
7/17/89	42	1.71	1.7277	1.6531	1.6206	2.0746	1.6971	2.1843	1.7006
7/24/89	49	1.7103	1.7266	1.6535	1.6208	2.0737	1.697	2.1840	1.7000
7/31/89	56	1.7088	1.7261	1.6528	1.6207	2.0727	1.6965	2.1833	1.6996
8/14/89	70	1.7101	1.7263	1.6535	1.6203	2.0735	1.6967	2.1833	1.6997
8/21/89	77	1.71	1.7259	1.6528	1.62	2.0726	1.6964	2.1832	1.6995
8/28/89	84	1.709	1.7254	1.6523	1.6199	2.0719	1.6962	2.1824	1.6992
9/11/89	98	1.7094	1.7255	1.6523	1.6198	2.0721	1.6961	2.1822	1.6988
9/18/89	105	1.7093	1.7258	1.6523	1.6201	2.0720	1.6962	2.1822	1.6990
9/25/89	112	1.7092	1.7255	1.6522	1.6198	2.0715	1.6956	2.1815	1.6988
10/2/89	119	1.709	1.7258	1.6519	1.6195	2.0714	1.6957	2.1818	1.7000
10/9/89	126	1.7083	1.7249	1.6514	1.6192	2.0706	1.6952	2.1810	1.6981
10/16/89	133	1.7092	1.7258	1.6524	1.62	2.0719	1.6959	2.1825	1.6988
10/23/89	140	1.7088	1.7249	1.6518	1.6193	2.0710	1.6954	2.1815	1.6984
10/30/89	147	1.7088	1.7255	1.6519	1.6195	2.0709	1.6956	2.1811	1.6983
11/6/89	154	1.7088	1.7252	1.6517	1.6198	2.0709	1.6956	2.1815	1.6988
11/13/89	161	1.7081	1.7244	1.6511	1.6189	2.0703	1.6951	2.1806	1.698
11/20/89	168	1.7086	1.7249	1.6512	1.6193	2.0705	1.6948	2.1808	1.6979
11/27/89	175	1.7078	1.7243	1.6509	1.6182	2.0698	1.6948	2.1797	1.6977
12/4/89	182	1.7074	1.7245	1.6506	1.6188	2.0696	1.6943	2.1798	1.6979
12/11/89	189	1.7077	1.7241	1.6508	1.6189	2.0700	1.6946	2.1798	1.6978
12/18/89	196	1.707	1.7243	1.6507	1.6188	2.0690	1.6945	2.1797	1.6971
1/8/90	217	1.7075	1.7241	1.6505	1.6191	2.0695	1.6944	2.1793	1.698
1/15/90	224	1.7071	1.7237	1.6503	1.6179	2.0681	1.6937	2.1792	1.6972
1/22/90	231	1.7074	1.724	1.6507	1.6185	2.0695	1.6949	2.1796	1.6978
1/29/90	238	1.7078	1.7243	1.6511	1.6185	2.0698	1.6945	2.1795	1.6972
2/5/90	245	1.7073	1.7236	1.6501	1.6187	2.0690	1.6944	2.1797	1.6974
2/12/90	252	1.7074	1.724	1.6505	1.6185	2.0697	1.6943	2.1794	1.6975
2/19/90	259	1.7075	1.7241	1.6505	1.6193	2.0690	1.6944	2.1793	1.6977
2/26/90	266	1.7071	1.724	1.6502	1.618	2.0697	1.6946	2.1792	1.6977

TABLE XIX. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00493

DATE OF WEIGHING	DAYS	WEIGHT OF A51 (grams)	WEIGHT OF A52 (grams)	WEIGHT OF A53 (grams)	WEIGHT OF A54 (grams)	WEIGHT OF B51 (grams)	WEIGHT OF B52 (grams)	WEIGHT OF B53 (grams)	WEIGHT OF B54 (grams)
3/5/90	274	1.7066	1.7237	1.6499	1.6178	2.0687	1.6946	2.1787	1.6973
3/12/90	281	1.7066	1.723	1.65	1.6183	2.0692	1.6951	2.1792	1.6975
3/19/90	288	1.7073	1.724	1.6506	1.6181	2.0692	1.6947	2.1791	1.6973
3/26/90	295	1.7067	1.7235	1.6499	1.6179	2.0687	1.6936	2.1795	1.6967
4/2/90	302	1.708	1.7241	1.6506	1.6183	2.0693	1.6946	2.1805	1.6973
4/9/90	309	1.7079	1.7244	1.6503	1.6195	2.0699	1.6949	2.1791	1.6979
4/16/90	316	1.7078	1.724	1.6507	1.6186	2.0691	1.6947	2.1795	1.6973
4/23/90	323	1.7072	1.7241	1.6505	1.6177	2.0689	1.6946	2.1792	1.6969
4/30/90	330	1.7075	1.7244	1.6506	1.6182	2.0692	1.6645	2.1792	1.6975
5/7/90	337	1.7072	1.7236	1.6502	1.6178	2.0691	1.6937	2.1785	1.6966
5/14/90	344	1.7077	1.7246	1.6514	1.6194	2.0697	1.6947	2.1798	1.6985
5/21/90	351	1.7078	1.7245	1.6511	1.619	2.0700	1.6951	2.1794	1.6975
6/4/90	365	1.709	1.7246	1.6504	1.6195	2.0705	1.695	2.1802	1.6983
6/11/90	372	1.7079	1.725	1.6508	1.619	2.0698	1.6954	2.1800	1.698

TABLE XIX. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00493

DATE OF WEIGHING	DAYS	% MOIST DESORB A51	% MOIST DESORB A52	% MOIST DESORB A53	% MOIST DESORB A54	% MOIST DESORB B51	% MOIST DESORB B52	% MOIST DESORB B53	% MOIST DESORB B54	AVERAGE % MOIST DESORB
6/5/89	0	0	0	0	0	0	0	0	0	0
6/6/89	1	-0.18	-0.17	-0.18	-0.20	-0.18	-0.17	-0.15	-0.20	-0.18
6/7/89	2	-0.28	-0.24	-0.25	-0.25	-0.23	-0.22	-0.21	-0.20	-0.24
6/8/89	3	-0.30	-0.28	-0.28	-0.29	-0.27	-0.25	-0.25	-0.23	-0.27
6/9/89	4	-0.33	-0.29	-0.29	-0.30	-0.28	-0.28	-0.27	-0.26	-0.29
6/12/89	7	-0.41	-0.39	-0.40	-0.42	-0.38	-0.37	-0.35	-0.35	-0.38
6/14/89	9	-0.51	-0.45	-0.46	-0.47	-0.43	-0.41	-0.40	-0.40	-0.44
6/16/89	11	-0.46	-0.41	-0.43	-0.44	-0.41	-0.41	-0.40	-0.38	-0.42
6/19/89	14	-0.53	-0.51	-0.52	-0.51	-0.48	-0.48	-0.44	-0.43	-0.49
6/21/89	16	-0.52	-0.46	-0.48	-0.47	-0.46	-0.44	-0.41	-0.42	-0.46
6/23/89	18	-0.54	-0.48	-0.50	-0.51	-0.49	-0.47	-0.45	-0.46	-0.49
6/26/89	21	-0.59	-0.49	-0.53	-0.53	-0.51	-0.48	-0.47	-0.47	-0.51
6/28/89	23	-0.60	-0.55	-0.59	-0.56	-0.53	-0.52	-0.50	-0.49	-0.54
6/30/89	25	-0.59	-0.55	-0.58	-0.58	-0.53	-0.51	-0.51	-0.49	-0.54
7/3/89	28	-0.63	-0.59	-0.62	-0.60	-0.57	-0.56	-0.55	-0.56	-0.58
7/5/89	30	-0.63	-0.56	-0.58	-0.57	-0.56	-0.54	-0.54	-0.50	-0.56
7/7/89	32	-0.60	-0.55	-0.58	-0.56	-0.55	-0.53	-0.51	-0.50	-0.55
7/10/89	35	-0.63	-0.56	-0.60	-0.58	-0.57	-0.55	-0.53	-0.53	-0.57
7/12/89	37	-0.69	-0.59	-0.63	-0.61	-0.58	-0.57	-0.58	-0.54	-0.60
7/14/89	39	-0.67	-0.58	-0.62	-0.63	-0.59	-0.60	-0.57	-0.55	-0.60
7/17/89	42	-0.71	-0.57	-0.67	-0.67	-0.58	-0.60	-0.59	-0.55	-0.62
7/24/89	49	-0.70	-0.63	-0.65	-0.66	-0.62	-0.61	-0.61	-0.58	-0.63
7/31/89	56	-0.78	-0.66	-0.69	-0.66	-0.67	-0.64	-0.64	-0.61	-0.67
8/14/89	70	-0.71	-0.65	-0.65	-0.69	-0.63	-0.63	-0.64	-0.60	-0.65
8/21/89	77	-0.71	-0.67	-0.69	-0.70	-0.68	-0.64	-0.64	-0.61	-0.67
8/28/89	84	-0.77	-0.70	-0.72	-0.71	-0.71	-0.66	-0.68	-0.63	-0.70
9/11/89	98	-0.75	-0.70	-0.72	-0.72	-0.70	-0.66	-0.69	-0.65	-0.70
9/18/89	105	-0.75	-0.68	-0.72	-0.70	-0.70	-0.66	-0.69	-0.64	-0.69
9/25/89	112	-0.76	-0.70	-0.73	-0.72	-0.73	-0.69	-0.72	-0.65	-0.71
10/2/89	119	-0.77	-0.68	-0.75	-0.74	-0.73	-0.69	-0.71	-0.58	-0.71
10/9/89	126	-0.81	-0.73	-0.78	-0.75	-0.77	-0.71	-0.74	-0.70	-0.75
10/16/89	133	-0.76	-0.68	-0.72	-0.70	-0.71	-0.67	-0.67	-0.65	-0.70
10/23/89	140	-0.78	-0.73	-0.75	-0.75	-0.75	-0.53	-0.72	-0.68	-0.71
10/30/89	147	-0.78	-0.70	-0.75	-0.74	-0.76	-0.53	-0.74	-0.68	-0.71
11/6/89	154	-0.78	-0.71	-0.76	-0.72	-0.76	-0.50	-0.72	-0.65	-0.70
11/13/89	161	-0.82	-0.76	-0.79	-0.77	-0.79	-0.55	-0.76	-0.70	-0.74
11/20/89	168	-0.80	-0.73	-0.79	-0.75	-0.78	-0.56	-0.75	-0.71	-0.73
11/27/89	175	-0.84	-0.77	-0.81	-0.82	-0.81	-0.57	-0.80	-0.72	-0.77
12/4/89	182	-0.87	-0.75	-0.82	-0.78	-0.82	-0.56	-0.80	-0.71	-0.76
12/11/89	189	-0.85	-0.78	-0.81	-0.77	-0.80	-0.56	-0.80	-0.71	-0.76
12/18/89	196	-0.89	-0.77	-0.82	-0.78	-0.85	-0.60	-0.80	-0.75	-0.78
1/8/90	217	-0.86	-0.78	-0.83	-0.76	-0.82	-0.55	-0.82	-0.70	-0.77
1/15/90	224	-0.88	-0.80	-0.84	-0.83	-0.89	-0.60	-0.82	-0.75	-0.80
1/22/90	231	-0.87	-0.78	-0.82	-0.80	-0.82	-0.56	-0.81	-0.71	-0.77
1/29/90	238	-0.84	-0.77	-0.79	-0.80	-0.81	-0.60	-0.81	-0.75	-0.77
2/5/90	245	-0.87	-0.81	-0.85	-0.78	-0.85	-0.59	-0.80	-0.74	-0.79
2/12/90	252	-0.87	-0.78	-0.83	-0.80	-0.81	-0.58	-0.81	-0.73	-0.78
2/19/90	259	-0.86	-0.78	-0.83	-0.81	-0.85	-0.57	-0.82	-0.72	-0.78
2/26/90	266	-0.88	-0.78	-0.85	-0.83	-0.81	-0.57	-0.82	-0.72	-0.78

TABLE XIX. (CONTINUED)

ENVIRONMENTAL INFLUENCES ON COMPOSITE MATERIALS PROGRAM
DESORPTION OF COUPONS FROM TAIL ROTOR SPAR S/N A-116-00493

DATE OF WEIGHING	DAYS	% MOIST DESORB A51	% MOIST DESORB A52	% MOIST DESORB A53	% MOIST DESORB A54	% MOIST DESORB B51	% MOIST DESORB B52	% MOIST DESORB B53	% MOIST DESORB B54	AVERAGE % MOIST DESORB
3/5/90	274	-0.91	-0.80	-0.87	-0.84	-0.86	-0.59	-0.85	-0.74	-0.81
3/12/90	281	-0.91	-0.84	-0.86	-0.81	-0.84	-0.58	-0.82	-0.73	-0.80
3/19/90	288	-0.87	-0.78	-0.82	-0.82	-0.84	-0.59	-0.83	-0.74	-0.79
3/26/90	295	-0.91	-0.81	-0.87	-0.83	-0.86	-0.63	-0.81	-0.78	-0.81
4/2/90	302	-0.83	-0.78	-0.82	-0.81	-0.83	-0.59	-0.76	-0.74	-0.77
4/9/90	309	-0.84	-0.76	-0.84	-0.74	-0.81	-0.56	-0.83	-0.71	-0.76
4/16/90	316	-0.84	-0.78	-0.82	-0.79	-0.84	-0.59	-0.81	-0.74	-0.78
4/23/90	323	-0.88	-0.78	-0.83	-0.85	-0.85	-0.61	-0.82	-0.77	-0.80
4/30/90	330	-0.86	-0.76	-0.82	-0.82	-0.84	-0.58	-0.82	-0.73	-0.78
5/7/90	337	-0.88	-0.81	-0.85	-0.84	-0.84	-0.63	-0.86	-0.78	-0.81
5/14/90	344	-0.85	-0.75	-0.78	-0.74	-0.81	-0.52	-0.80	-0.67	-0.74
5/21/90	351	-0.84	-0.75	-0.79	-0.77	-0.80	-0.58	-0.81	-0.73	-0.76
6/4/90	365	-0.77	-0.75	-0.84	-0.74	-0.78	-0.53	-0.78	-0.68	-0.73
6/11/90	372	-0.84	-0.73	-0.81	-0.77	-0.81	-0.55	-0.79	-0.70	-0.75

In addition to the spars returned for coupon testing, additional small scale test coupons were removed from undamaged sections of two tail rotor spars that had been full scale fatigue tested, spar S/N A-116-00480, and A-116-00069. Specimens removed from spar A-116-00069 for room temperature interlaminar shear testing averaged a strength of 12.23 ksi. At 170°F, the interlaminar shear strength averaged 8.55 ksi. Interlaminar shear fatigue tests indicated a maximum stress of 7.6 ksi at 10^7 cycles. The maximum stress versus cycles to fracture data is summarized in Figure 44. An average of 0.66 percent moisture was desorbed from the component, as detailed earlier in Figure 34. Specimens removed from tail rotor spar A-116-00480 for interlaminar shear testing averaged 11.2 ksi at room temperature, and 7.37 ksi when tested at 170°F. Fatigue testing of interlaminar shear specimens yielded a maximum stress of 7.5 ksi at 10^7 cycles, as shown graphically in Figure 45. Coupons removed from the tail rotor spar for desorption analysis averaged 0.98 percent moisture by weight, as was shown in Figure 35.

3.2.2.6 Tail Rotor Spars - Summary of Coupon Test Results

Small scale static interlaminar shear room temperature test results of all the spars are summarized in Table XX. Inspection of the table reveals a small decrease in strength with increased exposure time and flight hours. Table XXI summarizes the 170°F interlaminar shear test results for the spars returned. As was seen with the room temperature properties, a small decrease in strength was noted with increased exposure time and flight hours. Results of coupon fatigue testing are compiled in Table XXII. Review of the data indicates no appreciable reduction in fatigue properties with increased in-service exposure time or flight hours.

ENVIRONMENTAL INFLUENCES PROGRAM SMALL SCALE FATIGUE TESTING OF COUPONS REMOVED FROM TAIL ROTOR SPAR A-116-00069

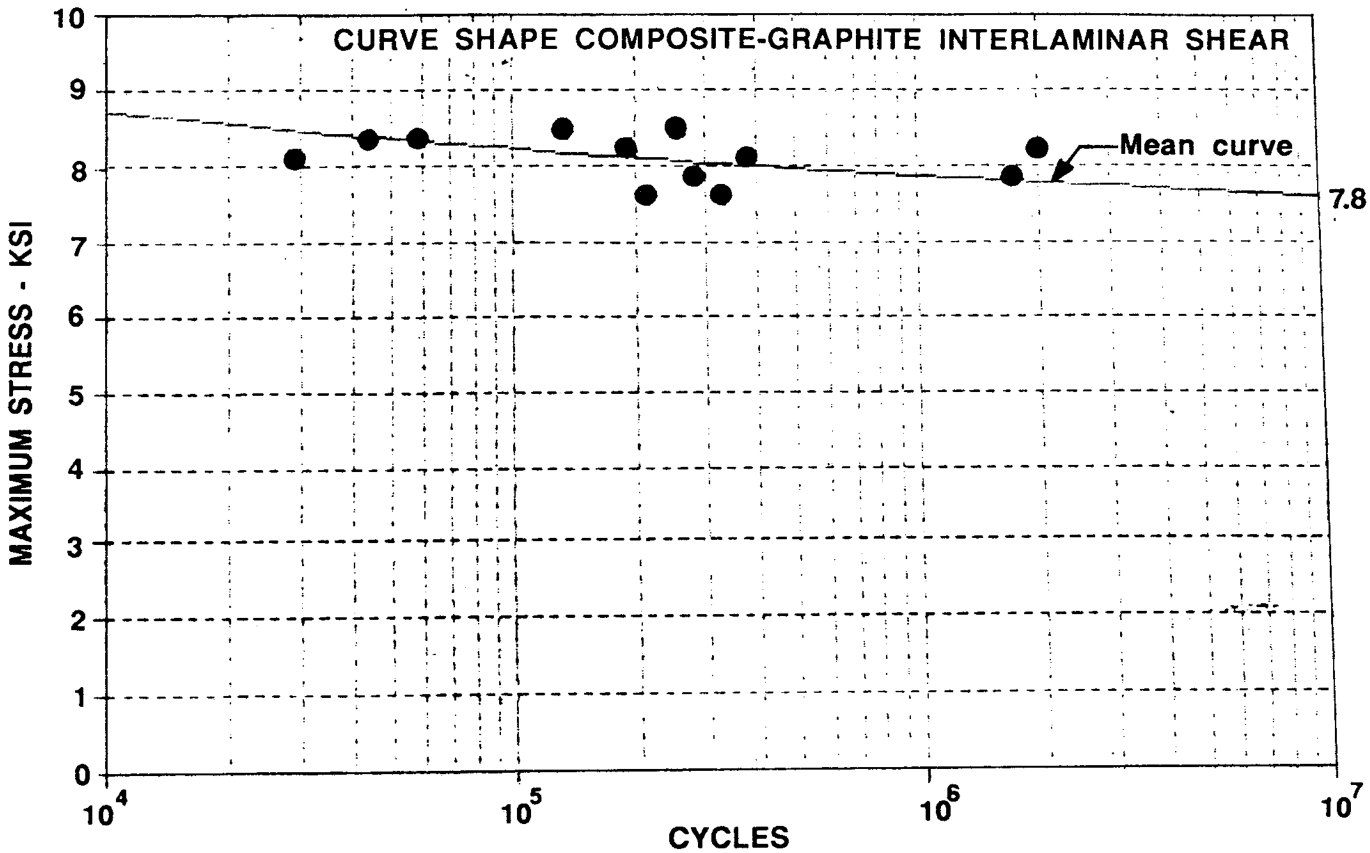


FIGURE 44. SPAR S/N A-116-00069
INTERLAMINAR SHEAR FATIGUE
COUPON TESTING - MAXIMUM
STRESS VERSUS CYCLES TO
FRACTURE

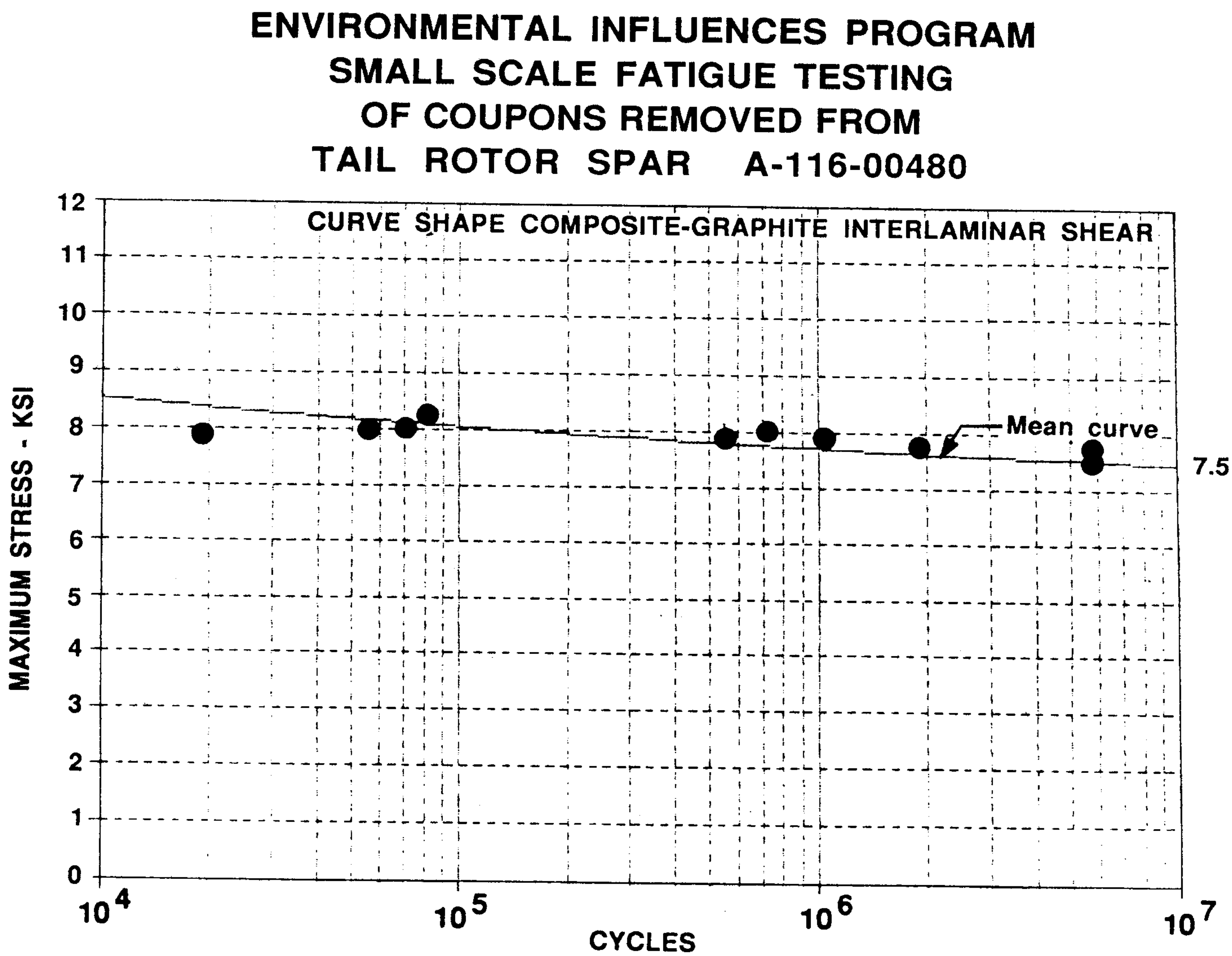


FIGURE 45. SPAR S/N A-116-00480
INTERLAMINAR SHEAR FATIGUE
COUPON TESTING - MAXIMUM
STRESS VERSUS CYCLES TO
FRACTURE

TABLE XX. COMPILATION OF TAIL ROTOR SPAR SMALL SCALE STATIC COUPON TEST RESULTS AT ROOM TEMPERATURE

SPAR S/N	EXPOSURE TIME (MONTHS)	FLIGHT HOURS	COUPON SBS STRENGTH (KSI)
00283	38	1884	12.2
00150	38	2385	12.2
00178	51	3752	13.0
00415	68	5216	11.0
00069	72	4995	12.2
00493	97	5858	11.0
00480	100	5816	11.2

TABLE XXI. COMPILATION OF TAIL ROTOR SPAR SMALL SCALE STATIC COUPON TEST RESULTS AT 170°F

SPAR S/N	EXPOSURE TIME (MONTHS)	FLIGHT HOURS	COUPON SBS STRENGTH (KSI)
00283	38	1884	9.5
00150	38	2385	8.6
00178	51	3752	10.2
00415	68	5216	9.1
00069	72	4995	8.6
00493	97	5858	7.1
00480	100	5816	7.4

TABLE XXII. COMPILATION OF TAIL ROTOR SPAR SMALL SCALE FATIGUE COUPON TEST RESULTS AT ROOM TEMPERATURE

SPAR S/N	EXPOSURE TIME (MONTHS)	FLIGHT HOURS	MAX. STRESS (KSI) AT 10^7 CYCLES
00283	38	1884	7.5
00150	38	2385	7.4
00178	51	3752	8.4
00415	68	5216	6.9
00069	72	4995	7.6
00493	97	5858	7.6
00480	100	5816	7.5

4. MATERIAL EVALUATION

4.1 Field Exposed Panels

As part of a Sikorsky internal research and development program, entitled the Life Extension Program for Composite Structures, AS-1/6350 graphite/epoxy and 285/5143 Kevlar/epoxy panels were exposed to the environment in two weathering locations: West Palm Beach, Florida and Stratford, Connecticut. Photographs of the panels at each of the weathering sites are shown in Figures 46 and 47. Three graphite/epoxy panel configurations were deployed as part of this evaluation: 6, 14 and 33 ply panels, with a nominal per ply thickness of 0.012 inch. One Kevlar/epoxy configuration was examined: 5 ply panels, having a nominal per ply thickness of 0.009 inch. Ply configurations of the panels were representative of the S-76 tail rotor spar and horizontal stabilizer components. Data is presented herein for comparison with the results of this program.

4.1.1 Moisture Measurements

Coupons From Field Exposed Panels

Panels were returned from the weathering locations annually to determine moisture content and mechanical properties. Panels having two to nine years exposure to the environment were returned for evaluation.

Typically, four desorption coupons were removed from each panel. Two of the four coupons were sanded to remove the S-76 white polyurethane paint from each face prior to desorption. The four coupons were then desorbed in an environmentally controlled chamber at 150 ± 2°F. Data from the four coupons was combined, and an average measured moisture content recorded. Photographs of typical graphite and Kevlar desorption coupons are shown in Figures 48 and 49. Summaries of the moisture measurements for panels with two through nine years of exposure are presented in Table XXIII for graphite/epoxy panels and Table XXIV for Kevlar/epoxy panels.

Final moisture levels for 14 and 33 ply panels with 6 years of exposure had to be estimated, owing to an oven malfunction during the dryout period. Inspection of the table shows moisture levels for 6 ply graphite/epoxy and 5 ply Kevlar/epoxy specimens having 8 and 9 years of environmental exposure are lower than anticipated, at both the Stratford, Connecticut and West Palm Beach, Florida weathering sites. A review of the conditioning environment and retrieval and dryout procedures has determined that some panel dryout must have occurred in preparing the specimens for desorption.

FIGURE 46. PANELS DEPLOYED FOR ENVIRONMENTAL EXPOSURE AT THE STRATFORD, CONNECTICUT EXPOSURE SITE

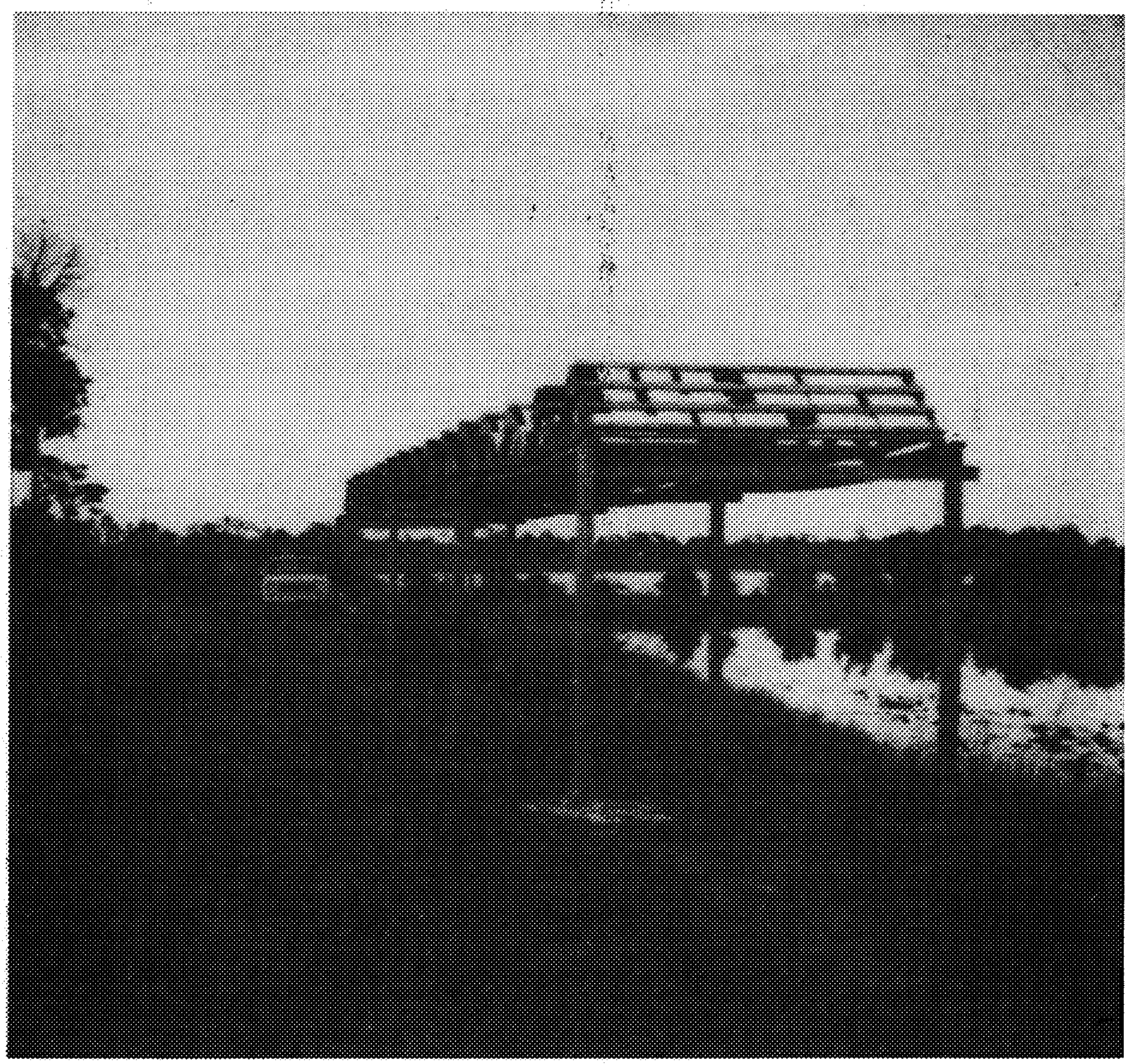


FIGURE 47. PANELS DEPLOYED FOR ENVIRONMENTAL EXPOSURE AT THE WEST PALM BEACH, FLORIDA EXPOSURE SITE

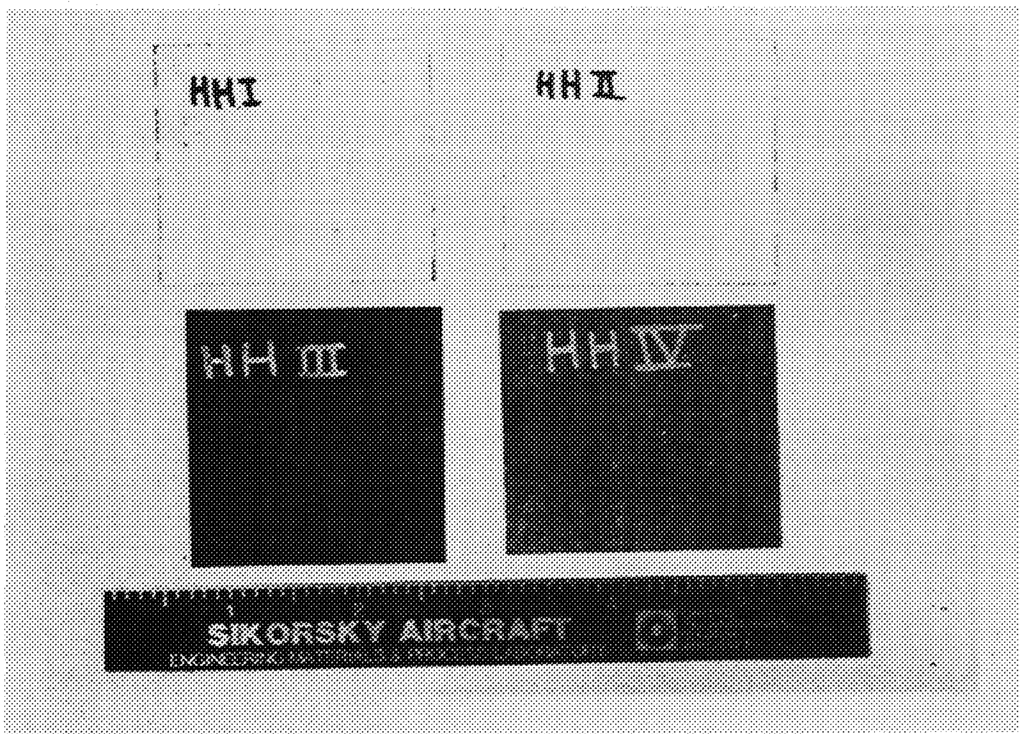


FIGURE 48. PHOTOGRAPH OF TYPICAL COUPONS REMOVED FROM PANELS FOR DESORPTION (GRAPHITE/EPOXY)

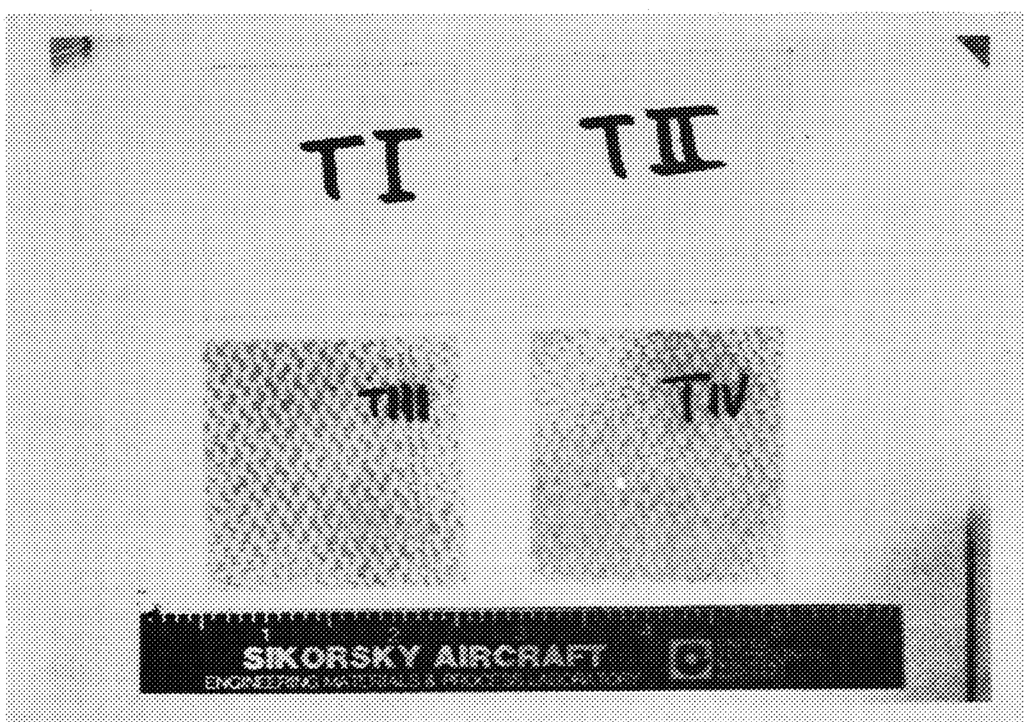


FIGURE 49. PHOTOGRAPH OF TYPICAL COUPONS REMOVED FROM PANELS FOR DESORPTION (KEVLAR/EPOXY)

TABLE XXIII. SUMMARY OF MOISTURE MEASUREMENTS FOR FIELD EXPOSED PANELS (GRAPHITE/EPOXY)

MATERIAL	NUMBER OF PLIES	EXPOSURE LOCATION	EXPOSURE TIME (MONTHS)	PERCENT MOISTURE (BY WEIGHT)
AS1/6350 GRAPHITE/ EPOXY	6	WPB	26	1.02
			35	1.23
			48.5	1.15
			60.5	1.40
			72.5	1.34
			84	1.18
			97	0.91
		WPB	108	0.81
		STRATFORD	25	0.86
			36	1.00
			49	0.99
			62	1.13
			73	1.07
			85	1.05
			98	0.82
	6	STRATFORD	108.5	0.71
AS1/6350 GRAPHITE/ EPOXY	14	STRATFORD	25	0.37
			34.5	0.48
			48	0.44
			61	0.65
			72	0.57**
			84.5	0.73
			96.5	0.71
	14	STRATFORD	107	0.72
AS1/6350 GRAPHITE/ EPOXY	33	WPB	26	0.27
			35	0.37
			48.5	0.35
			60.5	0.42
			72.5	0.45**
			84	0.50
			98	0.54
		WPB	108	0.52
		STRATFORD	25	0.18
			36	0.22
			49.5	0.24
			62	0.30
			73.5	0.25**
			85	0.33
			97	0.41
	33	STRATFORD	109	0.34

NOTES: ** - Estimated

TABLE XXIV. SUMMARY OF MOISTURE MEASUREMENTS FOR FIELD EXPOSED PANELS (KEVLAR/EPOXY)

MATERIAL	NUMBER OF PLIES	EXPOSURE LOCATION	EXPOSURE TIME (MONTHS)	PERCENT MOISTURE (BY WEIGHT)
285/5143 KEVLAR/ EPOXY	5	WPB	26	1.56
			35	2.08
			48.5	1.90
			60.5	1.88
			72.5	2.02
			84	1.87
			97	1.59
		WPB	108	1.75
		STRATFORD	26	1.53
			37	1.72
			50	1.75
			63	1.92
			74	1.70
			85.5	1.70
			99	1.36
	5	STRATFORD	109	1.37

A computer assisted, mathematically modelled moisture analysis program was generated to predict the amount of moisture absorbed by composite laminates exposed to environmental conditions. The analysis program is based on Fick's second law, and is dependent on the temperature and relative humidity of the conditioning environment, the geometry of the part being examined, and the absorption characteristics of the fiber/resin system and the equations described in Section 1.2.1. Diffusion is considered to be one dimensional. Moisture-time profiles were developed for each panel configuration, at both weathering locations. The data generated showed good correlation between the predicted and actual moisture levels. With the exception of the aforementioned 8 and 9 year 6 ply panels suspected of surface dryout, predicted and actual levels of moisture absorption for the graphite/epoxy panels generally varied by less than 10 percent. Figure 50 illustrates the comparison of measured and predicted moisture levels for the six ply AS-1/6350 graphite/epoxy panels weathered in Stratford, Connecticut.

4.1.2 Coupon Strength Tests

Coupons were also removed from the environmentally exposed panels for mechanical testing. Flexure, static interlaminar shear and interlaminar shear fatigue tests were conducted on graphite/epoxy specimens. Specimen configurations were as shown in Figure 51. The static flexure properties were determined in accordance with ASTM D 790, Reference (12). Static and fatigue interlaminar (short beam) shear strengths were determined in accordance with the ASTM methods previously described. Tensile tests were conducted on Kevlar/epoxy coupons in accordance with ASTM D 3039, Reference (13). Results of all field exposed coupon tests are summarized in Table XXV.

Environmental factors were calculated for each panel returned, and, with the measured moisture content, panel data was compared to the S-76 environmental factor trends that had been generated using accelerated conditioning techniques for the AS-1/6350 and 285/5143 materials. Figure 52 presents a comparison of environmentally exposed panel test results with a plot of the environmental factor trends for AS-1/6350 static interlaminar shear strength. Figure 53 presents a graphical comparison for AS-1/6350 flexure. A comparison of panel test data with environmental factor trends for 285/5143 tensile strength is shown in Figure 54.

Inspection of each of the plots shows that data generated from panels having real time exposure was comparable to, or higher than, environmental factor trends predicted for AS-1/6350 graphite/epoxy and 285/5143 Kevlar/epoxy using laboratory accelerated moisture conditioning techniques. Results indicate that the effects of absorbed moisture and elevated temperatures on the resin matrix composite materials used in the S-76 model helicopter program were accurately represented.

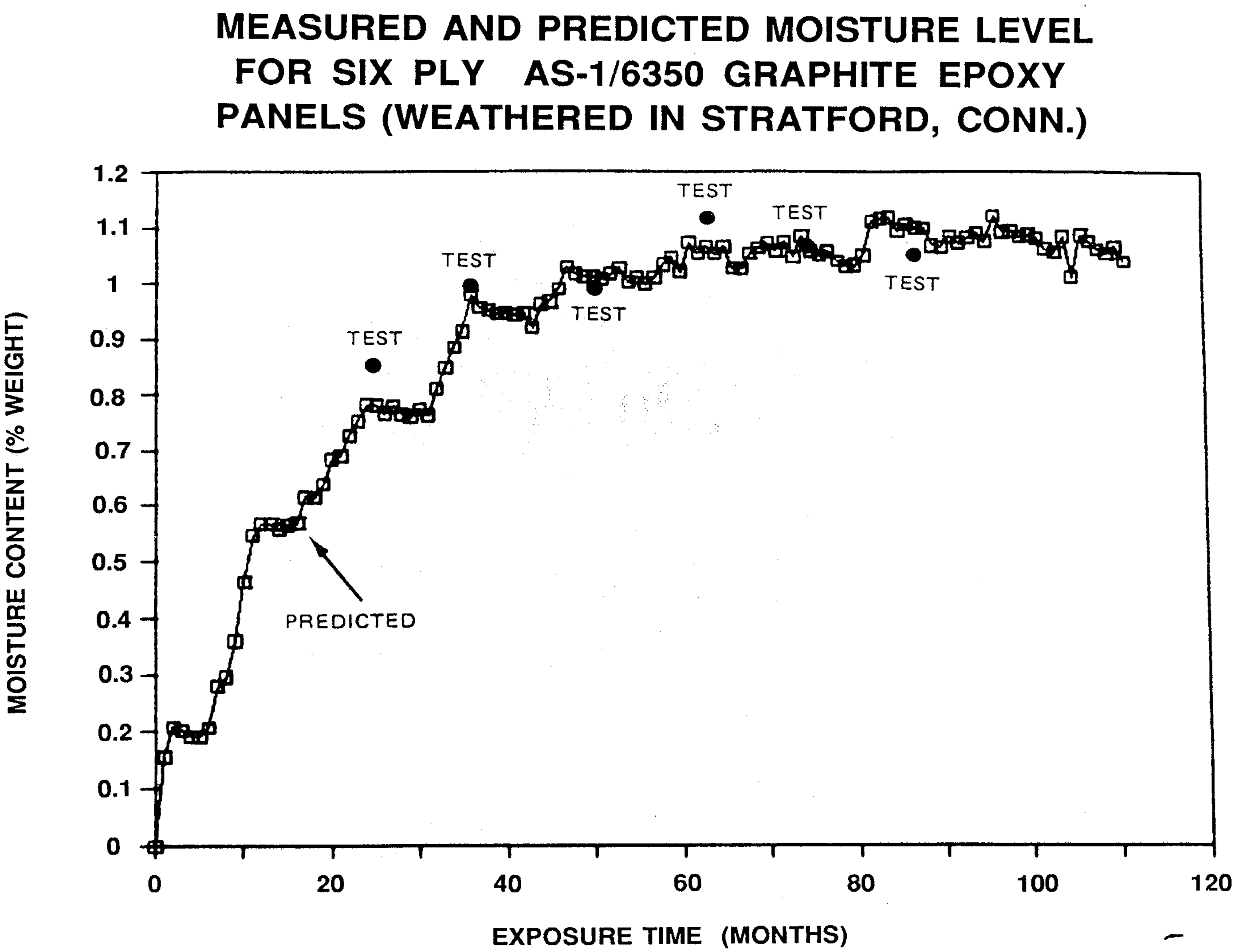
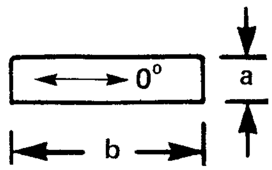


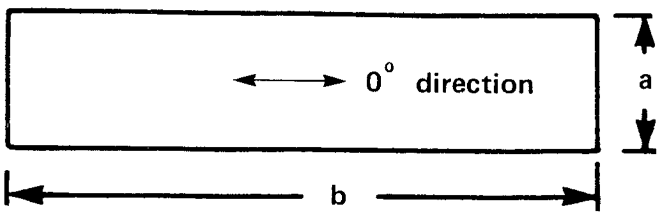
FIGURE 50. MEASURED AND PREDICTED MOISTURE LEVEL FOR SIX PLY AS-1/6350 GRAPHITE EPOXY PANELS (WEATHERED IN STRATFORD, CONNECTICUT)



AS/6350 Where:

a=0.25 in	b=1.0 in	For 6 ply panels
a=0.25 in	b=1.0 in	For 14 ply panels
a=0.4 in	b=3.5 in	For 33 ply panels

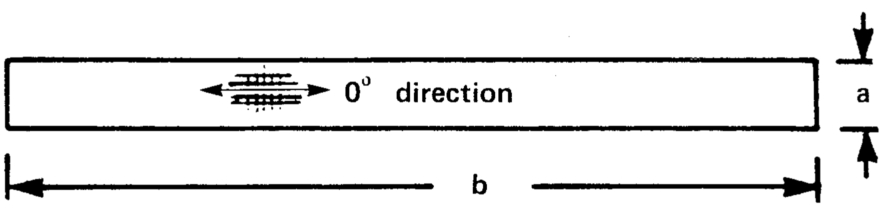
(a) Short Beam Shear Specimen Configuration



AS/6350 Where:

a=1.0 in	b=4.0 in	For 6 ply panels
a=1.0 in	b=5.5 in	For 14 ply panels
a=0.5 in	b=11.0 in	For 33 ply panels

(b) Flexural (Bending) Shear Specimen Configuration



285/5143 Where:

a=.875 in	b=16.5 in	For 5 ply panels

(c) Tensile Specimen Configuration

FIGURE 51. LIFE EXTENSION PROGRAM TEST SPECIMEN CONFIGURATIONS

TABLE XXV. SUMMARY OF COUPON TEST RESULTS FOR FIELD EXPOSED PANELS

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/ Epoxy AS1/6350	SBS, Static	0_6	23	23.8	(75)	110.3	(16.0)	4.6	Qualification Baseline, RTD
	SBS, Static	0_6	19	23.8	(75)	113.1	(16.4)	5.7	Panel Coupons, Baseline RTD
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	17	23.8	(75)	86.9	(12.6)	3.6	Panel Coupons, Baseline RTD
	SBS, Static	0_6	18	23.8	(75)	100.7	(14.6)	5.0	2 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	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	$(0_{12}/-20/0/+20/0_{1.5})_S$	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
	SBS, Static	0_6	18	23.8	(75)	91.0	(13.2)	3.7	3 Years, Stratford
	SBS. Static	0_6	18	23.8	(75)	95.9	(13.9)	2.5	3 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	89.0	(12.9)	3.1	3 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	88.3	(12.8)	3.6	3 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	91.7	(13.3)	7.0	3 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	53.8	(7.8)	4.2	3 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	15	23.8	(75)	75.9	(11.0)	4.6	3 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	15	23.8	(75)	77.9	(11.3)	2.6	3 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	89.6	(13.0)	3.4	4 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	90.3	(13.1)	1.9	4 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	89.6	(13.0)	4.3	4 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	67.6	(9.8)	4.8	4 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	82.0	(11.9)	3.8	4 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	10	23.8	(75)	80.0	(11.6)	3.3	4 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	90.0	(12.9)	4.8	5 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	90.0	(12.9)	2.9	5 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	84.8	(12.3)	3.7	5 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	86.9	(12.6)	3.5	5 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	93.1	(13.5)	2.6	5 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	64.1	(9.3)	2.2	5 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	80.5	(11.7)	3.5	5 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	78.8	(11.4)	4.0	5 Years, West Palm Beach
	SBS, Static	0_6	22	23.8	(75)	81.4	(11.8)	4.0	6 Years, West Palm Beach
	SBS, Static	0_6	22	23.8	(75)	91.0	(13.2)	3.3	6 Years, Stratford
	SBS, Static	0_{14}	13	23.8	(75)	84.1	(12.2)	2.5	6 Years, Stratford
	SBS, Static	0_{14}	13	23.8	(75)	80.7	(11.7)	3.9	6 Years, Stratford
	SBS, Static	0_{14}	8	76.6	(170)	49.6	(7.2)	2.1	6 Years, Stratford
	SBS, Static	0_{14}	8	76.6	(170)	51.7	(7.5)	4.8	6 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	68.9	(10.0)	4.4	6 Years, West Palm Beach
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	68.9	(10.0)	2.3	6 Years, Stratford

TABLE XXV. SUMMARY OF COUPON TEST RESULTS FOR FIELD EXPOSED PANELS (CONTINUED)

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/ Epoxy AS/6350	SBS, Static	0_6	17	23.8	(75)	99.3	(14.4)	2.6	7 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	99.3	(14.4)	2.2	7 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	90.3	(13.1)	2.5	7 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	91.7	(13.3)	1.5	7 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	90.3	(13.1)	4.0	7 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	60.7	(8.8)	4.5	7 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	15	23.8	(75)	76.7	(11.1)	5.4	7 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	13	23.8	(75)	75.5	(11.0)	2.1	7 Years, West Palm Beach
	SBS, Static	0_6	18	23.8	(75)	97.2	(14.1)	3.2	8 Years, Stratford
	SBS, Static	0_6	18	23.8	(75)	93.1	(13.5)	2.8	8 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	94.5	(13.7)	4.7	8 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	57.9	(8.4)	6.0	8 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	78.6	(11.4)	4.9	8 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	10	23.8	(75)	75.2	(10.9)	3.5	8 Years, West Palm Beach
	SBS, Static	0_6	17	23.8	(75)	91.7	(13.3)	5.0	9 Years, Stratford
	SBS, Static	0_6	17	23.8	(75)	94.5	(13.7)	6.9	9 Years, West Palm Beach
	SBS, Static	0_{14}	18	23.8	(75)	89.6	(13.0)	3.2	9 Years, Stratford
	SBS, Static	0_{14}	18	76.6	(170)	55.8	(8.1)	3.6	9 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	11	23.8	(75)	74.5	(10.8)	3.5	9 Years, Stratford
	SBS, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	11	23.8	(75)	73.1	(10.6)	5.9	9 Years, West Palm Beach
Graphite/ Epoxy AS/6350	SBS, Fatigue	0_6	10	23.8	(75)	64.1	(9.3)[1]	-	Qualification Baseline RTD
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	9	23.8	(75)	53.4	(7.7)[1]	-	Panel Coupon Baseline RTD
	SBS, Fatigue	0_6	4	23.8	(75)	58.6	(8.5)[1]	-	2 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	43.4	(6.3)[1]	-	2 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	10	23.8	(75)	42.1	(6.1)[1]	-	2 Years, West Palm Beach
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	50.6	(7.3)[1]	-	3 Years, West Palm Beach
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	56.5	(8.2)[1]	-	4 Years, West Palm Beach
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	9	23.8	(75)	56.5	(8.2)[1]	-	6 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	14	23.8	(75)	51.7	(7.5)[1]	-	7 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	16	23.8	(75)	51.7	(7.5)[1]	-	8 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	11	23.8	(75)	53.8	(7.8)[1]	-	9 Years, Stratford
	SBS, Fatigue	$(0_{12}/-20/0/+20/0_{1.5})_S$	10	23.8	(75)	49.6	(7.2)[1]	-	9 Years, West Palm Beach

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

TABLE XXV. SUMMARY OF COUPON TEST RESULTS FOR FIELD EXPOSED PANELS (CONTINUED)

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/ Epoxy AS/6350	Flex, Static	0_6	20	23.8	(75)	1696.0	(246.0)	5.9	Panel Coupon Baseline RTD
	Flex, Static	0_{14}	18	23.8	(75)	1449.9	(210.3)	5.6	Panel Coupon Baseline RTD
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	13	23.8	(75)	1209.3	(175.4)	5.5	Panel Coupon Baseline RTD
	Flex, Static	0_6	18	23.8	(75)	1782.3	(268.5)	4.4	2 Years, West Palm Beach
	Flex, Static	0_6	15	23.8	(75)	2011.2	(291.7)	5.8	2 Years, West Palm Beach
	Flex, Static	0_6	12	23.8	(75)	1876.7	(272.2)	7.5	2 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1375.5	(199.5)	3.2	2 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	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
	Flex, Static	0_6	18	23.8	(75)	1625.5	(235.7)	6.7	3 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1771.0	(256.8)	3.4	3 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1704.1	(247.1)	3.7	3 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1660.7	(240.8)	4.2	3 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1433.1	(207.8)	6.2	3 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1550.3	(224.8)	8.6	3 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1185.5	(171.9)	6.4	3 Years, West Palm Beach
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1235.2	(179.1)	6.0	3 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1761.6	(255.5)	6.5	4 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1860.9	(269.9)	7.3	4 Years, West Palm Beach
	Flex, Static	0_{14}	18	23.8	(75)	1431.4	(207.6)	3.7	4 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1391.4	(201.8)	3.5	4 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1206.6	(175.0)	4.3	4 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1142.5	(165.7)	4.0	4 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1681.4	(243.8)	7.1	5 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1730.3	(250.9)	7.1	5 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1620.0	(234.9)	8.0	5 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1620.0	(234.9)	6.6	5 Years, West Palm Beach
	Flex, Static	0_{14}	18	23.8	(75)	1453.8	(210.8)	4.4	5 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1476.6	(214.1)	3.8	5 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	1209.7	(175.4)	4.5	5 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	1174.5	(170.3)	3.5	5 Years, West Palm Beach
	Flex, Static	0_6	17	23.8	(75)	1701.6	(246.8)	6.6	6 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1723.7	(250.0)	7.1	6 Years, West Palm Beach
	Flex, Static	0_{14}	13	23.8	(75)	1371.4	(198.9)	4.6	6 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1346.6	(195.3)	3.0	6 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	16	23.8	(75)	1157.6	(167.9)	6.4	6 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1162.5	(168.6)	3.0	6 Years, West Palm Beach

TABLE XXV. SUMMARY OF COUPON TEST RESULTS FOR FIELD EXPOSED PANELS (CONTINUED)

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Graphite/ Epoxy AS/6350	Flex, Static	0_6	18	23.8	(75)	1685.8	(244.5)	7.9	7 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1773.3	(257.2)	8.5	7 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1670.6	(242.3)	5.1	7 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1723.0	(249.9)	7.2	7 Years, West Palm Beach
	Flex, Static	0_{14}	18	23.8	(75)	1387.9	(201.3)	3.6	7 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1365.9	(198.1)	3.2	7 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	1243.1	(180.3)	6.4	7 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	18	23.8	(75)	1163.2	(168.7)	4.4	7 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1656.1	(240.2)	4.1	8 Years, Stratford
	Flex, Static	0_6	14	23.8	(75)	1694.1	(245.7)	3.4	8 Years, West Palm Beach
	Flex, Static	0_{14}	18	23.8	(75)	1428.6	(207.2)	3.1	8 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1470.7	(213.3)	3.9	8 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	10	23.8	(75)	1155.6	(167.6)	3.4	8 Years, West Palm Beach
	Flex, Static	0_6	18	23.8	(75)	1785.8	(259.0)	5.4	9 Years, Stratford
	Flex, Static	0_6	18	23.8	(75)	1800.2	(261.1)	5.0	9 Years, West Palm Beach
	Flex, Static	0_{14}	15	23.8	(75)	1381.0	(200.3)	3.8	9 Years, Stratford
	Flex, Static	0_{14}	18	23.8	(75)	1402.4	(203.4)	4.5	9 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	11	23.8	(75)	1212.8	(175.9)	3.7	9 Years, Stratford
	Flex, Static	$(0_{12}/-20/0/+20/0_{1.5})_S$	12	23.8	(75)	1154.9	(167.5)	4.5	9 Years, West Palm Beach

TABLE XXV. SUMMARY OF COUPON TEST RESULTS FOR FIELD EXPOSED PANELS (CONTINUED)

Material	Test	Ply Orientation	Number of Tests	Test Temperature °C	(°F)	Strength MPa	(KSI)	Coefficient of Variation	Exposure
Kevlar/ Epoxy 285/5143	Tension,Static	$(0/90)_6$	14	23.8	(75)	590.2	(85.6)	4.4	Qualification Baseline RTD
	Tension,Static	$(0/90)_5$	18	23.8	(75)	631.5	(91.6)	6.0	Panel Coupon, Baseline RTD
	Tension,Static	$(0/90)_5$	9	23.8	(75)	666.7	(96.7)	8.7	2 Years, Stratford
	Tension,Static	$(0/90)_5$	10	23.8	(75)	632.2	(91.7)	6.5	2 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	10	76.6	(170)	677.7	(98.3)	6.6	2 Years, Stratford
	Tension,Static	$(0/90)_5$	7	23.8	(75)	476.6	(96.8)	6.5	3 Years, Stratford
	Tesnion,Static	$(0/90)_5$	7	23.8	(75)	465.5	(98.2)	12.9	3 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	7	76.6	(170)	435.9	(85.3)	11.7	3 Years, Stratford
	Tension,Static	$(0/90)_5$	7	76.6	(170)	419.3	(85.5)	6.6	3 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	8	23.8	(75)	688.6	(99.8)	4.9	4 Years, Stratford
	Tension,Static	$(0/90)_5$	7	23.8	(75)	672.5	(97.5)	3.3	4 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	8	76.6	(170)	688.3	(99.8)	7.6	4 Years, Stratford
	Tension,Static	$(0/90)_5$	4	23.8	(75)	602.1	(87.3)	4.0	5 Years, Stratford
	Tension,Static	$(0/90)_5$	4	23.8	(75)	644.1	(93.4)	6.0	5 Years, Stratford
	Tension,Static	$(0/90)_5$	4	23.8	(75)	646.2	(93.7)	2.8	5 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	23.8	(75)	627.6	(91.0)	9.2	5 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	76.6	(170)	636.6	(92.3)	2.0	5 Years, Stratford
	Tension,Static	$(0/90)_5$	4	76.6	(170)	629.7	(91.3)	7.7	5 Years, Stratford
	Tension,Static	$(0/90)_5$	4	76.6	(170)	664.7	(97.1)	6.4	5 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	76.6	(170)	651.0	(94.4)	5.3	5 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	8	23.8	(75)	658.5	(95.5)	6.0	6 Years, Stratford
	Tension,Static	$(0/90)_5$	8	23.8	(75)	630.9	(91.5)	9.3	6 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	7	76.6	(170)	664.7	(96.4)	4.3	6 Years, Stratford
	Tension,Static	$(0/90)_5$	7	76.6	(170)	657.8	(95.4)	5.2	6 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	8	23.8	(75)	612.9	(88.9)	5.0	7 Years, Stratford
	Tension,Static	$(0/90)_5$	8	23.8	(75)	618.5	(89.7)	5.8	7 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	8	76.6	(170)	659.8	(95.7)	8.6	7 Years, Stratford
	Tension,Static	$(0/90)_5$	8	76.6	(170)	586.0	(85.0)	4.0	7 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	23.8	(75)	507.5	(73.6)	6.3	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	23.8	(75)	617.1	(89.5)	4.3	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	23.8	(75)	569.5	(82.6)	7.4	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	3	76.6	(170)	322.7	(46.8)	16.6	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	76.6	(170)	348.2	(50.5)	12.3	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	4	76.6	(170)	319.2	(46.3)	8.7	8 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	7	23.8	(75)	546.8	(79.3)	5.1	9 Years, Stratford
	Tension,Static	$(0/90)_5$	7	23.8	(75)	550.2	(79.8)	4.9	9 Years, West Palm Beach
	Tension,Static	$(0/90)_5$	7	76.6	(170)	392.3	(56.9)	3.6	9 Years, Stratford
	Tension,Static	$(0/90)_5$	7	76.6	(170)	330.3	(47.9)	18.5	9 Years, West Palm Beach

COMPARISON OF REAL TIME EXPOSURE INTERLAMINAR SHEAR (STATIC) DATA WITH AS-1/6350 ENVIROMENTAL FACTOR TRENDS

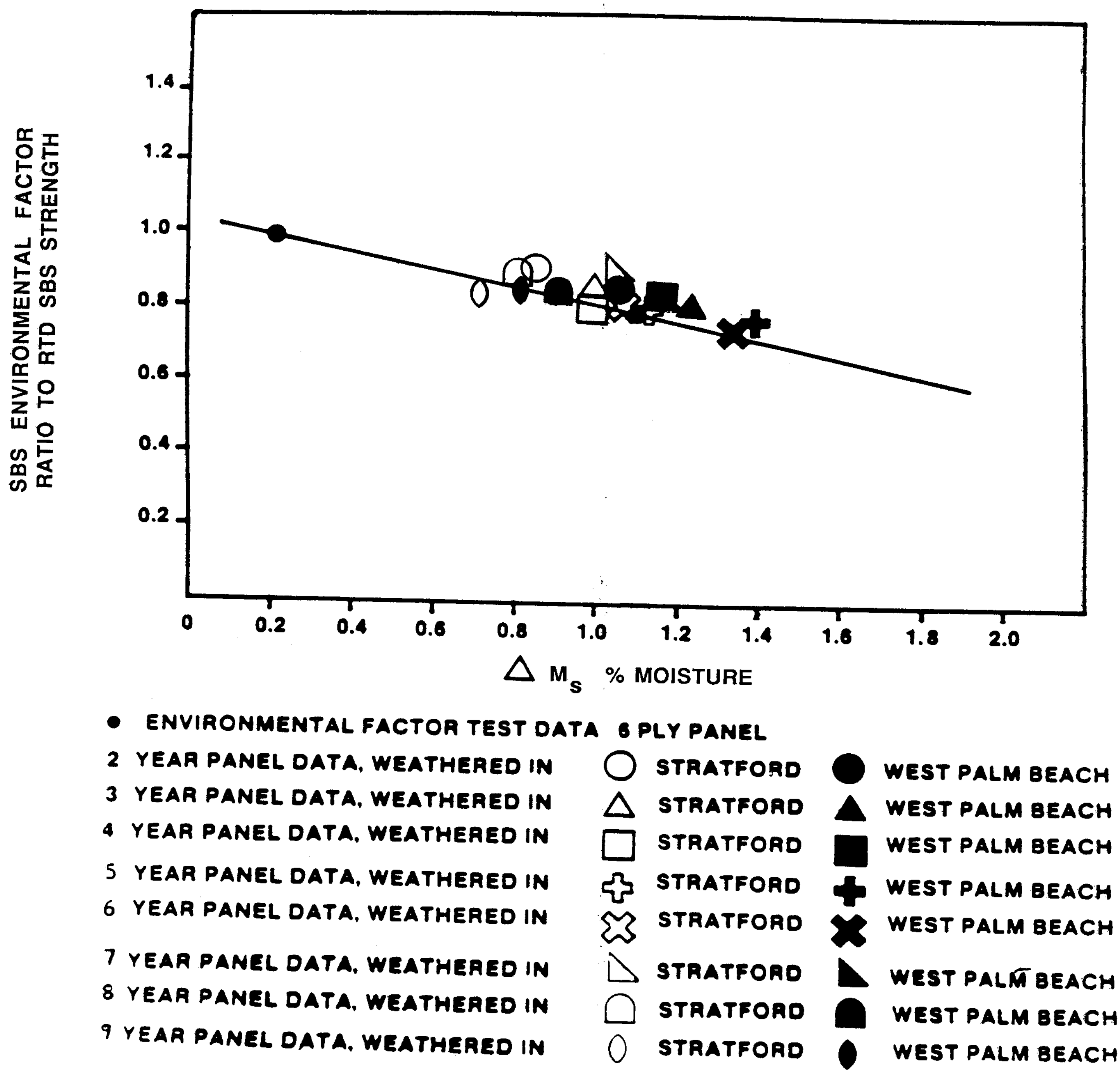


FIGURE 52. COMPARISON OF REAL TIME EXPOSURE INTERLAMINAR SHEAR (STATIC) DATA WITH AS-1/6350 ENVIRONMENTAL FACTOR TRENDS

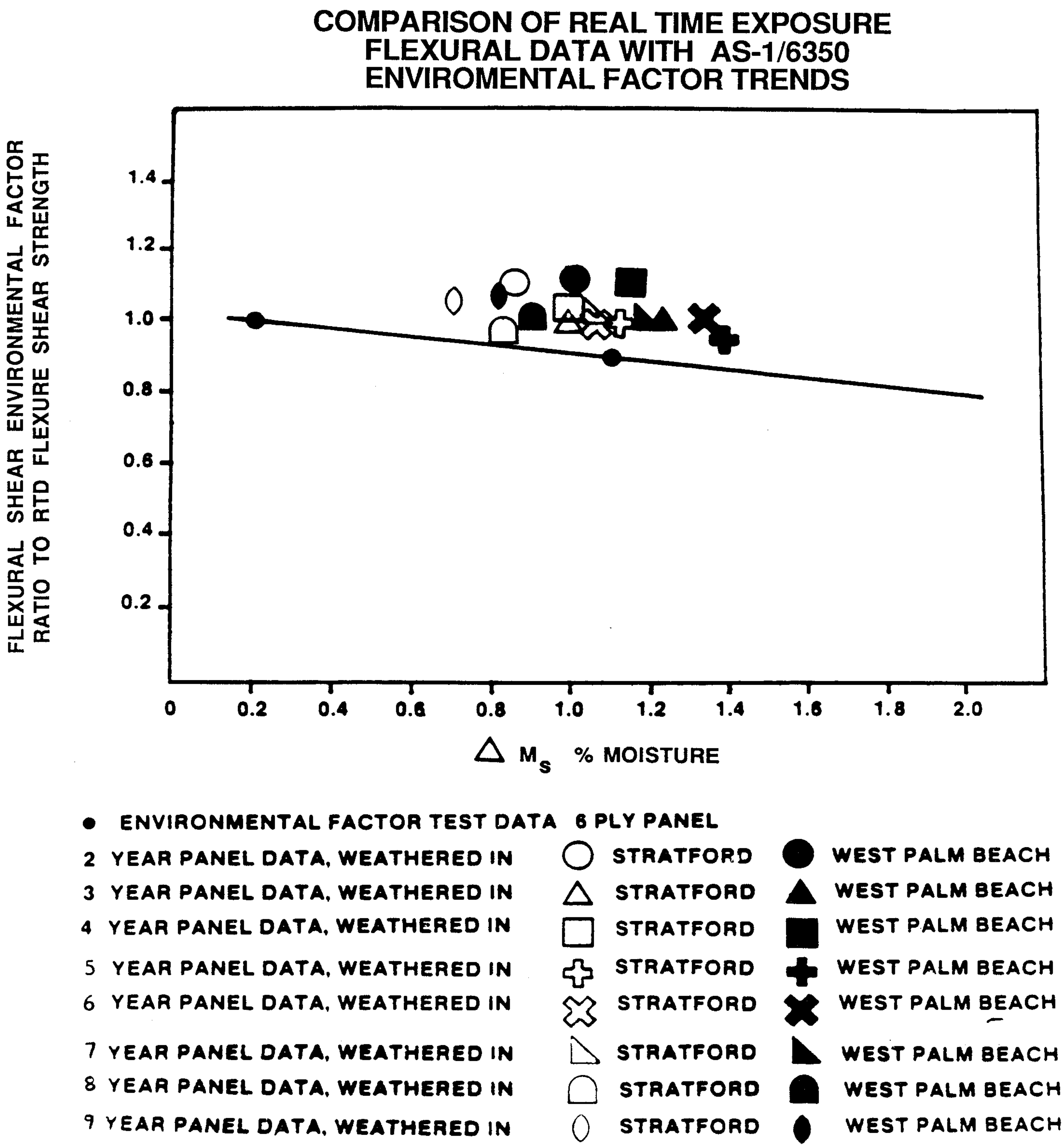


FIGURE 53. COMPARISON OF REAL TIME EXPOSURE FLEXURAL DATA WITH AS-1/6350 ENVIRONMENTAL FACTOR TRENDS

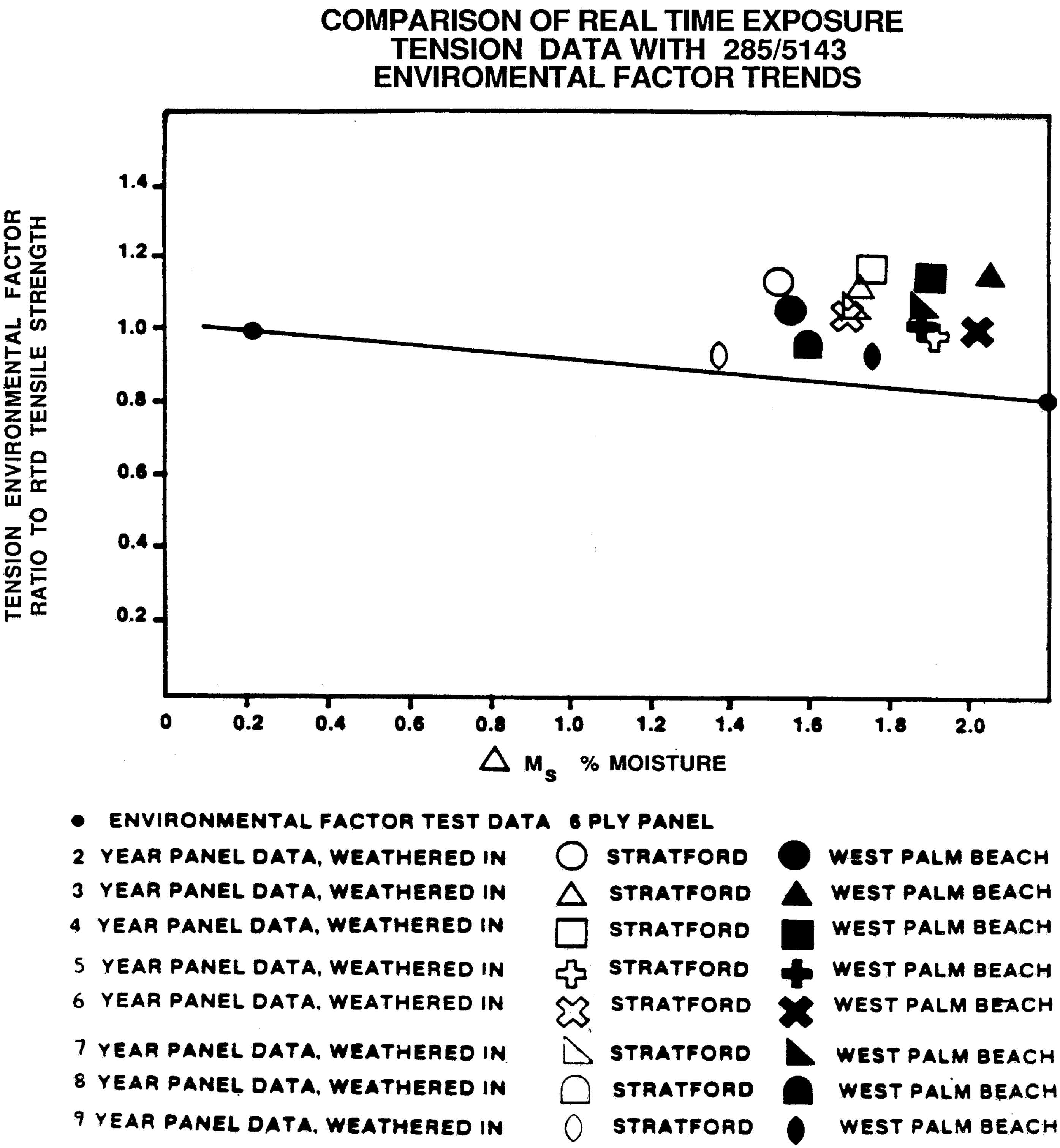


FIGURE 54. COMPARISON OF REAL TIME EXPOSURE TENSION DATA WITH 285/5143 ENVIRONMENTAL FACTOR TRENDS

5. SUMMARY OF TEST RESULTS

Composite components and panels with up to nine years of environmental exposure have been returned from the field for evaluation as part of this program.

Four horizontal stabilizers were returned from the field for evaluation. Proof load deflection tests of the components indicated no loss of stiffness had occurred after in-service environmental exposure.

One stabilizer was full scale static tested to fracture at 160°F. The stabilizer supported a maximum load of 220 percent of the design limit load (DLL), as compared with the initial 268 percent for certification. However, even after fracture occurred, loads equaling 150 percent DLL were maintained.

Three stabilizers were returned from commercial service for full scale fatigue testing at room temperature. Comparison of the roll and yaw moment versus cycles to fracture curves for the three stabilizers, to that of an unused production stabilizer, revealed the best fit curves for the exposed stabilizer data were comparable to, while being somewhat higher than, the curves of the room temperature dry component. No evidence of structural degradation of the stabilizers was indicated.

Ten tail rotor spars were returned from the field for evaluation as part of this program. Results of three additional tail rotor spars tested as part of an internal research and development program at Sikorsky Aircraft are also reported. Upon return from the field, each spar was removed from the blade assemblies and non-destructively inspected. No abnormalities were found in the spars examined. Eight tail rotor spars were full scale fatigue tested. Graphing cyclic shear stress versus cycles to crack initiation,to compare data generated for the environmentally conditioned spars to room temperature dry certification data, revealed that the data was comparable (within 5 percent), and no significant reductions in strength were evidenced.

Panels, fabricated with ply configurations representative of the tail rotor spar and the horizontal stabilizer were exposed to the environment in two weathering locations, and returned annually for moisture analysis and coupon testing. Results of the testing indicated that the effects of real time environmental exposure on the properties of AS-1/6350 and 285/5143 were accurately predicted using laboratory accelerated moisture conditioning techniques.

6. CONCLUSIONS

Through the evaluation of ground based panels and components returned from in-commercial service over a nine year time period, the Environmental Influences program has established confidence in the long term durability of advanced composite materials used in helicopter structural applications. The Environmental Influences program has demonstrated that moisture absorption characteristics of epoxy resin matrix composites, whose moisture absorption behavior follows Fick's second law, can be defined and effectively used in conjunction with design criteria to produce structurally and economically efficient components.

Real time moisture absorption data disclosed good correlation between measured and predicted moisture contents. The full scale static and fatigue tests performed on the stabilizers and tail rotor spars did not disclose any significant strength reductions. The structural integrity of the components evaluated has been maintained with no significant degradation in strength.

7. RECOMMENDATIONS

The results of this program support the greater use of composite materials and demonstrate that they need not be life limited in such advanced helicopters as the Army's future Light Helicopter (LH) for further weight and cost savings together with sound structural integrity.

The successful application of composites in airframe structures, such as the S-76 horizontal stabilizer and tail rotor spar, has led to the development of modified epoxy resin systems, able to withstand higher operating temperatures than standard epoxy laminates. Examination of the mechanical and physical properties of some second generation materials has indicated that moisture absorption profiles cannot be defined using the numerical solutions employed herein. It is therefore recommended that the effects of moisture on the properties of modified epoxy resin systems be examined and defined to allow for the continuation of effective utilization of advanced composite materials in future fixed wing and helicopter structural applications.

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15. Supplementary Notes

Final Report
Langley Technical Monitor: Donald J. Baker

16. Abstract

This report presents an assessment of ten composite tail rotor spars and four horizontal stabilizers exposed to the effects of in-flight commercial service for up to nine years to establish realistic environmental factors for use in future designs. This evaluation is supported by test results of helicopter components and panels which have been exposed to outdoor environmental effects since 1979. Full scale static and fatigue tests have been conducted on graphite/epoxy and Kevlar/epoxy composite components removed from Sikorsky Model S-76 helicopters in commercial operations off the Gulf Coast of Louisiana. Small scale static and fatigue tests were conducted on coupons obtained from panels exposed to outdoor conditions in Stratford, CT and West Palm Beach, Florida. The panel materials and ply configurations were representative of the S-76 components. This report discusses the results of moisture analyses and strength tests on both the S-76 components and composite panels after up to nine years of outdoor exposure. Full scale tests performed on the helicopter components did not disclose any significant reductions from the baseline strengths. The results of this investigation increased confidence in the long term durability of advanced composite materials in helicopter structural applications.

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