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GROUND EXPOSURE OF COMPOSITE MATERIALS FOR HELICOPTERS

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U.S. ARMY AVIATION SYSTEMS COMMAND

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Abstract

Residual strength results are presented on four composite material systems that have been exposed for three years at locations on the North American Continent. The exposure locations are near the areas where Bell Model 206L Helicopters, that are in a NASA/U.S. Army sponsored flight service program, are flying in daily commercial service. The composite systems are 1.) Kevlar-49 fabric/F-185 epoxy, 2.) Kevlar-49 fabric/ LRF-277 epoxy, 3.) Kevlar-49 fabric/CE-306 epoxy, 4.) T-300 graphite/E-788 epoxy. All material systems exhibited good strength retention in compression and short beam shear. The Kevlar-49/LRF-277 epoxy retained 88 to 93 percent of the baseline strength while the other material systems exceeded 95 percent of baseline strength. Residual tensile strength of all materials did not show a significant reduction. The available moisture absorption data are also presented.

Introduction

During the past ten years, NASA has sponsored programs to build a data base and establish confidence in the long-term durability of advanced composite materials (reference 1). Flight service experience is being obtained on primary and secondary structural components installed on commercial aircraft and from material specimens exposed at different locations. Although commercial aircraft and helicopters may fly in the same environment the behavior of composite materials on each vehicle may differ substantially. Most of the projected usage for composites in helicopter fuselage is Kevlar/epoxy with selective reinforcement of graphite/epoxy using 250°F curing epoxies. Most commercial aircraft are using 350°F cure graphite/epoxy systems with very little use of Kevlar/epoxy. Considering only the effects of moisture, materials in the minimum gage structure in most helicopter fuselage structure would reach the equilibrium moisture content in a short time whereas the heavier gage structure on a commercial aircraft could take months to reach an equilibrium moisture condition. Therefore, in 1978, NASA and the U.S. Army Research and Technology Laboratory initiated the first major program to evaluate composite helicopter components in flight service. The flight service program includes four components per aircraft. There are three secondary structural components fabricated from Kevlar-49/epoxy and one primary structural component fabricated from graphite/epoxy per aircraft. Concurrent with the flight program, specimens from materials used to fabricate the components are being exposed in ground racks and are being returned for testing at prescribed intervals.

This paper describes the results of tests on specimens that have been exposed for the first three years of a planned ten (10) year ground exposure program.

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Exposure Specimens

Composite material systems are being exposed on the North American Continent in areas that have varying environmental conditions. The composite systems are: 1.) Kevlar-49 fabric (style 281)/F-185 epoxy, 2.) Kevlar-49 fabric(style 120)/LRF-277 epoxy, 3.) Kevlar-49 fabric (style 281)/CE-306 epoxy, and 4.) T-300 Graphite tape/E-788 epoxy. The F-185 epoxy is a 250°F cure system manufactured by Hexcel Corp. The LRF-277 is a 250°F cure proprietary resin manufactured by Brunswick Corp. The CE-306, manufactured by Ferro Corp., is cured at 200°F for five (5) hours. The E-788 is a 350°F cure epoxy manufactured by U.S. Polymeric. Style 281 Kevlar-49 fabric is a plain weave with 17 ends/inch of 1140 denier yarn in each direction and has a weight of 5.0 ounces per square yard. Style 120 fabric is a plain weave with 34 ends/inch of 195 denier yarn in each direction and has a weight of 1.8 ounces per square yard.

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The materials are exposed in racks (figure 1) at five (5) locations on the North American Continent as shown in figure 2. The racks at Toronto, Canada and Hampton, VA are installed on the roofs of buildings. Racks at Cameron, LA and Ft. Greely, AK are installed on stands approximately 18 inches above the ground. The remaining rack is on a working oil platform in the Gulf of Mexico. The racks were installed in 1980 and contain five (5) panels each for removal after 1, 3, 5, 7, and 10 years of exposure. A panel contains 24 each of tension, short-beam-shear (SBS), IITRI compression specimens and four (4) 2.0 inch wide specimens to observe the weathering characteristics of each material system. The specimen design is shown in figure 3 and is also given in reference 2. The tension, compression and SBS specimens are painted with a polyurethane paint (DuPont IMIRON) that is used on the flight service helicopters. The remaining specimens were left unpainted to determine the weathering effect on on bare composites.

The specimens used for moisture determination were cut from the tested tension specimens. A 0.5 inch long section was cut from the undamaged area of the tension specimens as soon as possible after completion of testing. The paint was removed by sanding, using caution not to remove an excessive amount of the outer ply. Each specimen was weighed after the paint removal. A 0.5 inch long specimen was also removed from the unpainted exposure specimen and weighed prior to being used for moisture determination. All specimens were stored in sealed plastic bags between different operations.

Test Methods

Each panel was received at Langley Research Center sealed in a plastic bag. The panel remained in the sealed bag until testing was initiated. All tests were performed at room temperature on six (6) replicates for each specimen type. The tests were performed in accordance with the following ASTM standards; 1.) Tension-D3039, 2.) SBS-D2349, 3.) Compression-D3410 using the IITRI test fixture.

The specimens used for moisture determination were placed in a vacuum oven at 140°F. Each specimen was weighed periodically to determine weight loss as a function of drying time.

Results and Discussion

Average baseline strengths for the as-fabricated exposure specimens are given in Table 1. Residual compression strength data for painted specimens after three years of exposure are shown in figure 4. The data points represent a comparison of the average baseline compression strength with the average compression strength data of specimens exposed at the five different locations shown in figure 1. All material systems exhibit good strength retention in compression. The Kevlar-49/LRF-277 has the lowest strength retention of 90 percent and 88 percent after one and three years of exposure respectively. The other materials have a residual compression strength greater than 95 percent of the baseline strength. Effect of environment on the residual compression strength for each material is shown in figures 5 through 8. The data points represent a comparison of the average compression strength at each exposure site with the average baseline compression strength value for that material system. The Kevlar-49/LRF-277 material(figure 6) has lower compression strength retention than the other materials. The Kevlar-49/LRF-277 varies from 84 percent to 94 percent after one year exposure and 85 percent to 91 percent after three years of exposure while the other material systems exceeded 90 percent after one year of exposure and 94 percent after three years of exposure. The strength retention trends compare well with published data for other graphite/epoxy and Kevlar/epoxy systems used in NASA's worldwide exposure program (reference 1).

Residual SBS strength data for the painted specimens with three years of exposure are shown in figure 9. The Kevlar-49/LRF-277 material has the lowest SBS strength retention of 93 percent and 91 percent after one and three years of exposure, respectively. The other materials have a residual SBS strength greater than 97 percent of the baseline strength. Effect of environment on the residual SBS strength for each material is shown in figures 10 through 13. In general the Kevlar-49/LRF-277 material has lower SBS strength than the other material systems.

The tension specimens did not show any significant reduction in strength from exposure.

Moisture specimens from panels removed from the Gulf of Mexico, Cameron, LA and Hampton, VA have been drying for approximately six months. Specimen weight loss as a function of drying time is shown in figure 14 for Kevlar-49/LRF-277 material that was exposed at Cameron, LA. The triangle symbol is the weight change of one specimen that was weighed at regular intervals. The other 5 specimens are shown with a square symbol. The trend of data shown in figure 14 is typical of all painted specimens removed from the exposure sites at Cameron, LA, Gulf of Mexico, and Hampton, VA. Most specimens are approaching equilibrium. A curve has been faired through the data points. A summary of weight loss at 6 months drying time is shown in Table 2. Kevlar-49/epoxy absorbs approximately three times more moisture than graphite/epoxy because Kevlar fibers absorb moisture. The average values shown in Table 2 compare well with published values for other Kevlar/epoxy and graphite/epoxy systems (reference 1). The drying of speciimens removed from the unpainted material is approximately six weeks behind the first three panels tested. Weight loss as a function of drying time for unpainted Kevlar-49/LRF-277 is shown in figure 15 where a curve has been faired through the data points. Comparing the data in figures 14 and 15 at a drying time of 4 months indicates the unpainted Kevlar-49/LRF-277 specimens had approximately 0.1 percent greater weight loss. A summary of weight loss on unpainted specimens at 4 1/2 months drying time is given in Table 3. All values in Table 3 appear reasonable except for the 0.75 percent weight loss for the T-300/E-788 material exposed at the Gulf of Mexico. This specimen had a higher weight loss during the drying time as shown in figure 16 which shows data for specimens from all three sites. Because there is only one specimen available it is not possible at this time to determine if this is a valid data point. Comparing the average weight losses for Kevlar-49/F-185 and Kevlar-49/CE-306 in Tables 2 and 3 indicates that the painted specimens retain more moisture than the unpainted materials. The average weight loss for both painted and unpainted Kevlar-49/LRF-277 material were approximately equal. The T-300/E-788 material exposed at Cameron, LA and Hampton, VA also retained more moisture when painted.

Concluding Remarks

Results of three years of ground exposure indicates that all material systems exhibited good strength retention in compression and short beam shear. The Kevlar-49/LRF-277 epoxy retained 88 to 93 percent of the baseline strength while the other material systems exceeded 95 percent of baseline strength. Residual tensile strength of all materials did not show a significant reduction.

The available data on moisture absorption indicates the Kevlar-49/LRF-277 material absorbs the same moisture whether the material is painted or unpainted. The other material systems (Kevlar and graphite absorb more moisture when painted.

References

1. Dexter, H. Benson; and Baker, Donald J.: Worldwide Flight and Ground-Based Exposure of Composite Materials, NASA CP 2321, p.17-49, August 1984.

2. Zinberg, Herbert: Flight Service Evaluation of Composite Components on the Bell Model 206L: Design, Fabrication and Testing, NASA CR-166002, November 1982.

Table 1.-Baseline Strengths of as-fabricated Material Specimens

Material Systems	Strength (psi)					
	Short Beam Shear		Compression		Tension	
	Mean*	S.D.*	Mean*	S.D.*	Mean*	S.D.*
Kevlar-49/ F-185	6018	197	20176	489	57363	2448
Kevlar-49/ LRF-277	3873	119	22363	909	83658	2198
Kevlar-49/ CE-306	5277	258	18265	337	61090	2917
T-300/ E-788	11222	285	126343	4025	126478	4209

*) Mean of 6 Specimens

*) S.D. - Standard Deviation

Table 2.-Weight loss of Painted Specimens after 3 years Exposure Time

Material Systems	Drying Time (Days)	Weight Loss (percent)			
		Exposure Site			Avg.
		Cameron La.	Gulf of Mexico	Hampton, Va.	
Kevlar-49/ F-185	182	2.53	2.51	2.13	2.39
Kevlar-49/ LRF-277	182	2.17	2.05	1.98	2.07
Kevlar-49/ CE-306	182	2.05	1.92	1.81	1.93
T-300/ E-788	182	0.77	0.73	0.76	0.75

Table 3.-Weight loss of Unpainted Specimens after 3 years Exposure Time

Material Systems	Drying Time (Days)	Weight Loss (percent)			
		Exposure Site			Avg.
		Cameron La.	Gulf of Mexico	Hampton, Va.	
Kevlar-49/ F-185	147	1.63	1.83	1.47	1.64
Kevlar-49/ LRF-277	147	2.00	2.30	2.05	2.12
Kevlar-49/ CE-306	147	1.82	1.93	1.47	1.74
T-300/ E-788	147	0.46	0.75	0.43	0.55

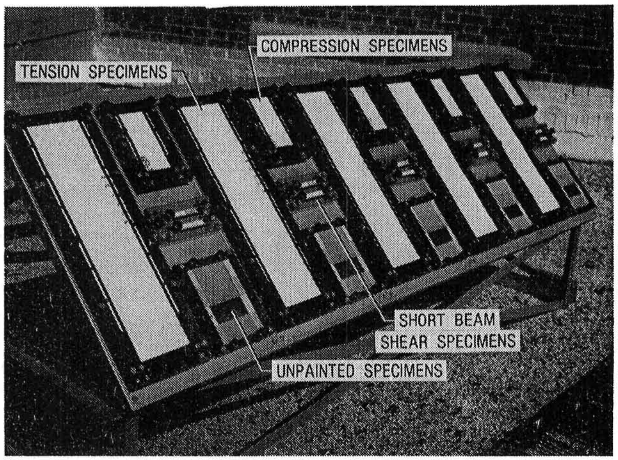

Figure 1.-Environmental Exposure Rack with Specimens Installed

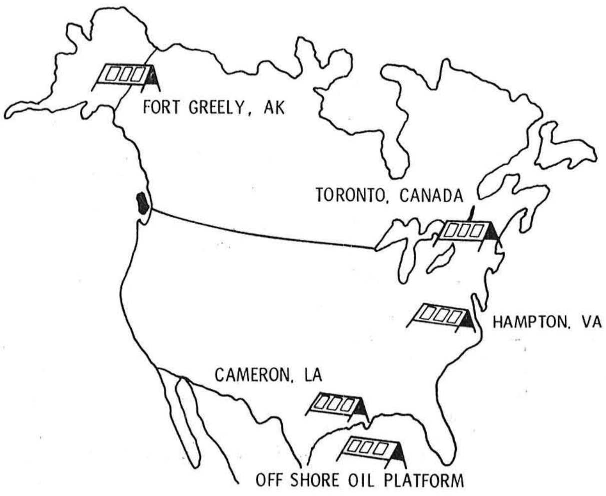

Figure 2.-Location of Environmental Exposure Racks

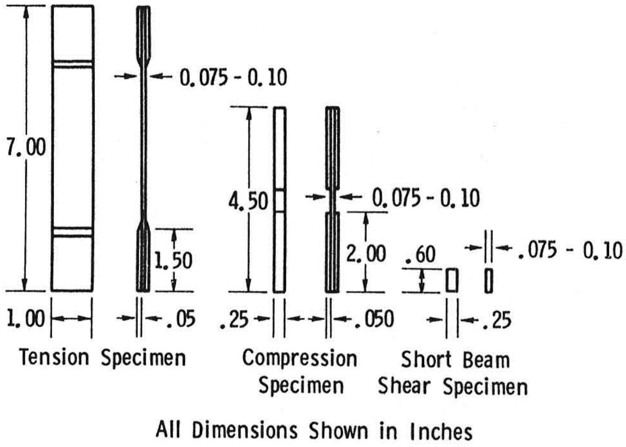

Figure 3.-Specimen geometry

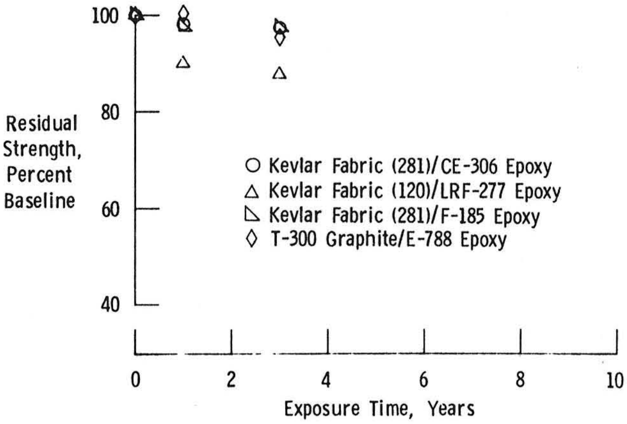

Figure 4.-Average Residual Compressive Strength of Composite Materials after Exposure at five different locations

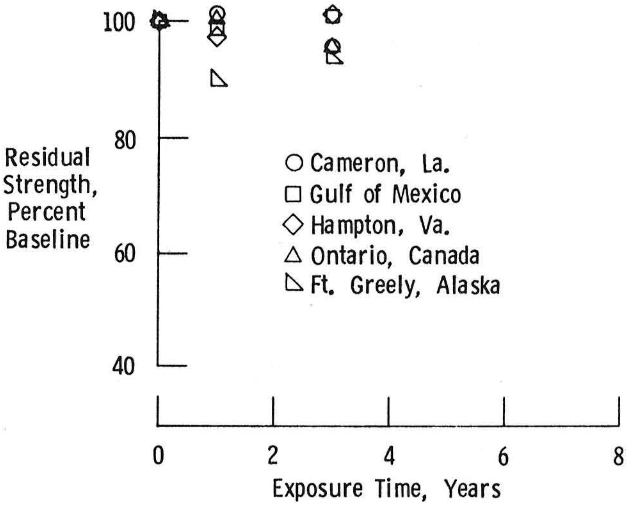

Figure 5.-Residual Compression Strength of Kevlar-49/F-185

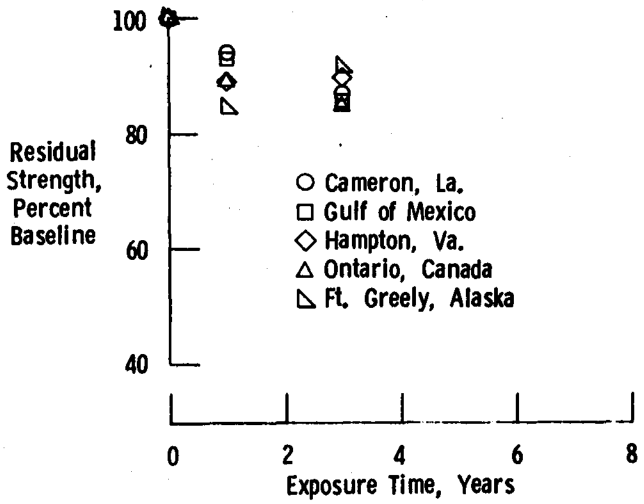

Figure 6.-Residual Compression Strength of Kevlar-49/LRF-277

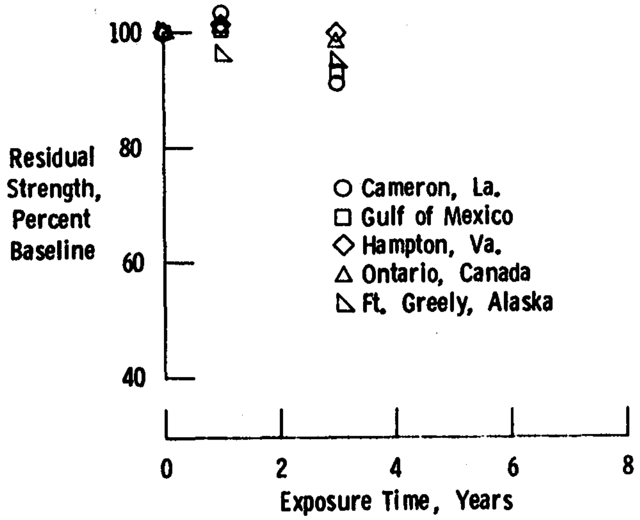

Figure 8.-Residual Compression Strength of T-300/E-788

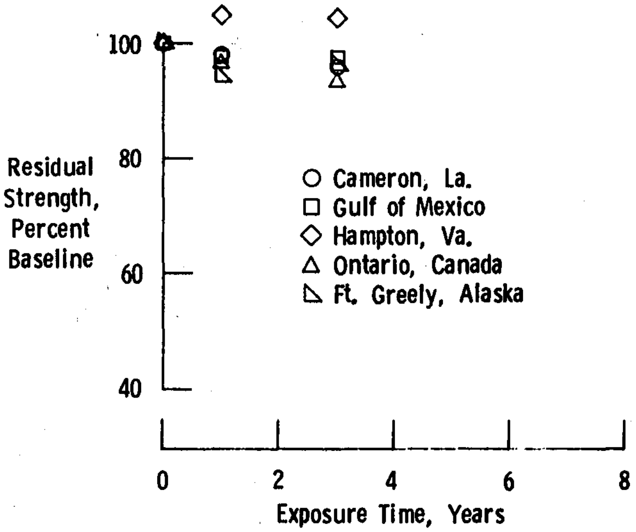

Figure 7.-Residual Compression Strength of Kevlar-49/CE-306

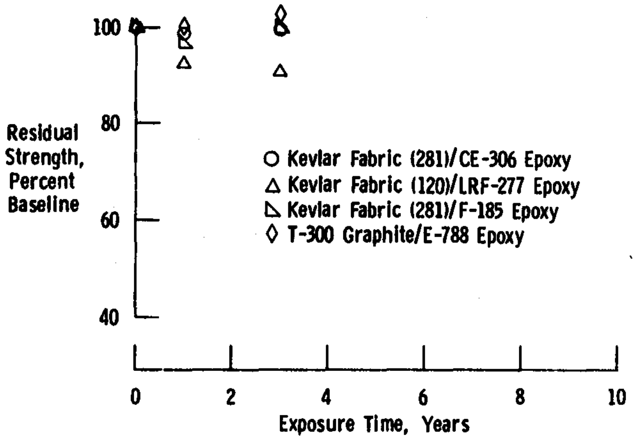

Figure 9.-Average Residual Short Beam Shear Strength of Composite Materials after Exposure at five different locations

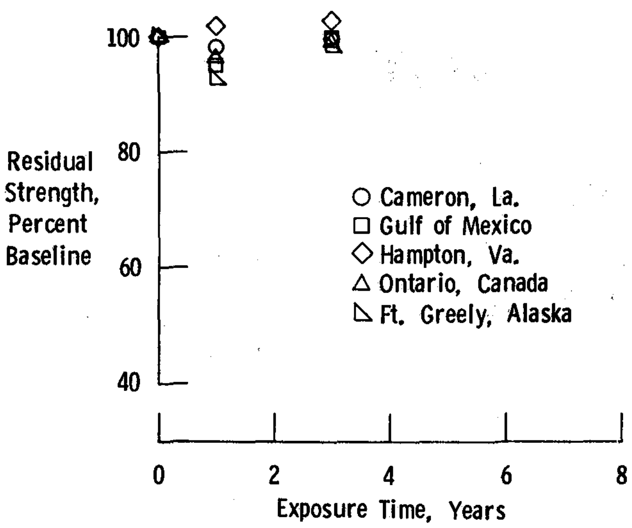

Figure 10.-Residual Short Beam Shear Strength of Kevlar-49/F-185

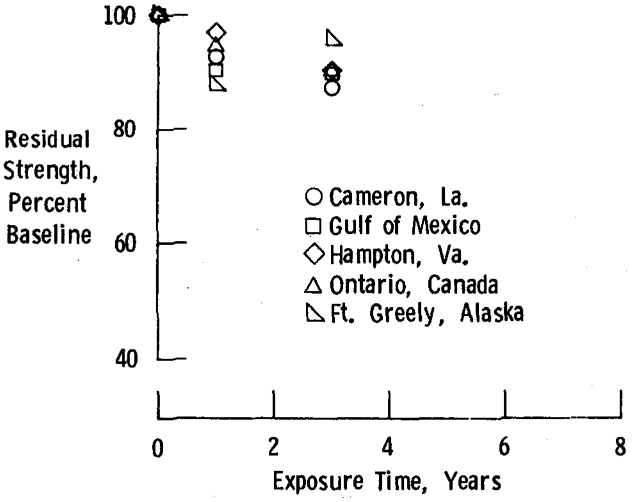

Figure 11.-Residual Short Beam Shear Strength of Kevlar-49/LRF-277

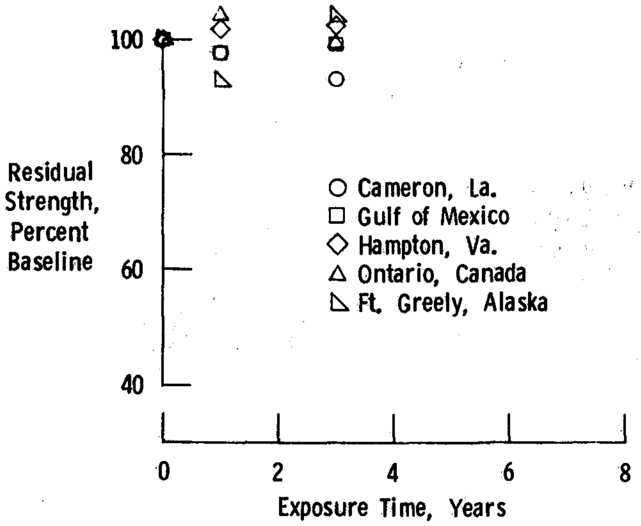

Figure 12.-Residual Short Beam Shear Strength of Kevlar-49/CE-306

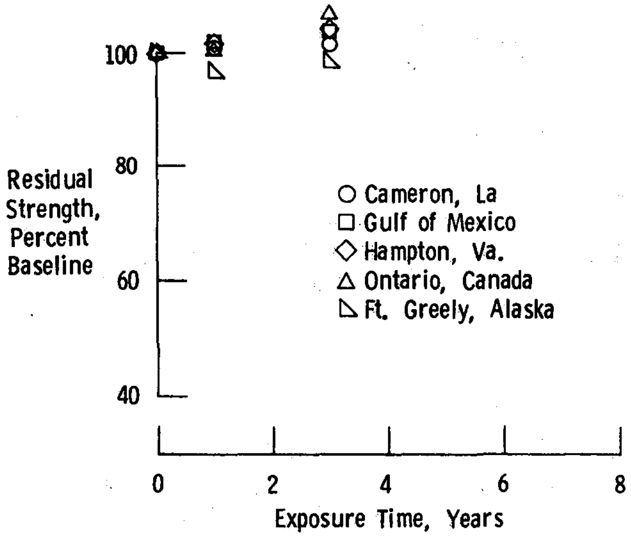

Figure 13.-Residual Short Beam Shear Strength of T-300/E-788

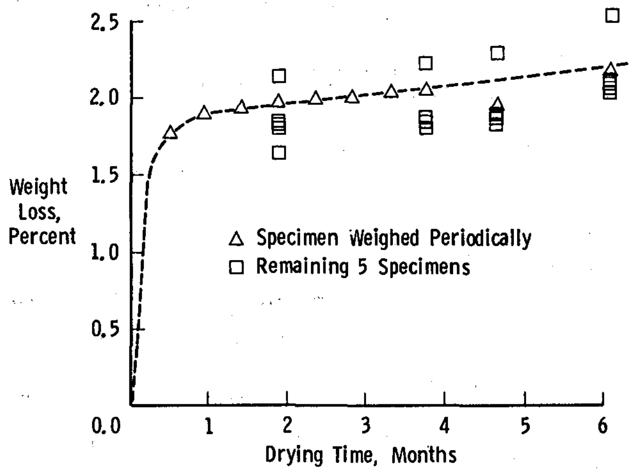

Figure 14.- Weight loss for painted Kevlar-49/LRF-277 Specimens from Cameron, LA.

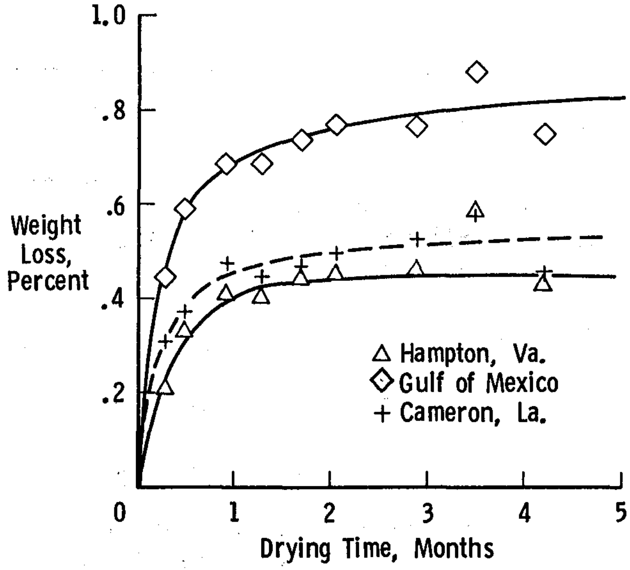

Figure 16.-Weight loss for unpainted T-300/E-788 Specimens.

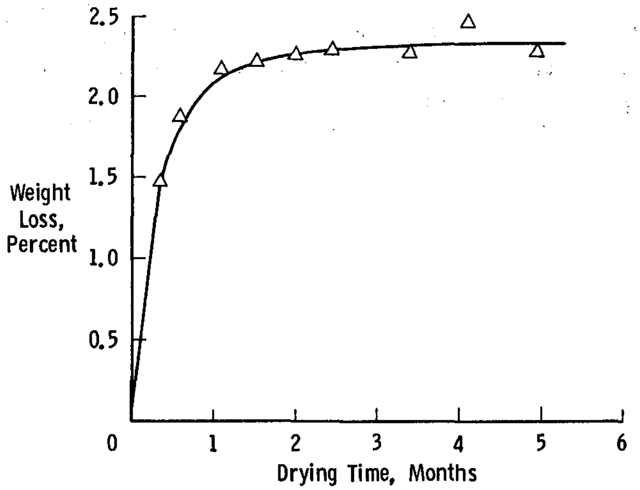

Figure 15.-Weight loss for Unpainted Kevlar-49/LRF-277 Specimens from Cameron, LA.

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