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LONG-TERM ENVIRONMENTAL EFFECTS AND FLIGHT SERVICE EVALUATION OF COMPOSITE MATERIALS

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INTRODUCTION

The influence of ground-based and operational environments on the long-term durability of advanced composite materials and aircraft components fabricated from them is an ongoing concern of aircraft manufacturers and airline operators. Some of the uncertainties include the effects of moisture absorption, ultraviolet radiation, aircraft fuels and fluids, long-term sustained stress, and fatigue loading. The combination of absorbed moisture and elevated temperature is known to plasticize polymeric materials, and thus reduce their glass transition temperature. Ultraviolet radiation can attack polymeric materials and reduce their effectiveness as a matrix in fiber reinforced composites. Aircraft fuels and fluids can soften some polymeric materials and adversely effect their load carrying capability. Long-term sustained load is known to cause some materials to creep and fatigue loads can degrade the strength and stiffness of aircraft materials.

In the early 1970's the NASA Langley Research Center initiated programs to establish the effects of ground and flight environments on several composite material systems. Residual strength and stiffness as a function of exposure time were determined after 10 years of worldwide outdoor exposure. Service performance, maintenance characteristics, and residual strength of numerous composite components installed on commercial and military aircraft and helicopters were determined as a function of flight hours and years in service. The purpose of this paper is to summarize the results of 10 years of environmental exposure of composite materials and to discuss results of 13 years of flight service of composite components in rotorcraft and transport aircraft.

The use of trade names in this paper does not constitute endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

ENVIRONMENTAL EFFECTS ON COMPOSITE MATERIALS

Commercial and military aircraft operate in diverse worldwide environments. Composite structures for these aircraft must be designed to withstand all of these environments, including large variations in temperature and moisture, contact with aircraft fuels and fluids such as jet fuel and hydraulic fluid, and lightning strikes. A series of ground-based exposure programs was conducted to establish the effects of these environments on composite materials. Small unpainted test specimens were mounted in outdoor exposure racks to measure residual strength and stiffness as a function of exposure location, exposure environment, and exposure time. Unpainted specimens were used to achieve the maximum effect of the exposure environments. Figure 1 shows the exposure locations and types of composite test specimens that were evaluated. A series of tests was selected that would measure matrix dependent and fiber dependent properties. Included were unstressed short-beam shear, compression, and flexure specimens, plus sustained-stress tension specimens. Short-beam shear and compression strengths are primarily matrix dependent, whereas flexure and tension properties are more fiber dependent. All the tests were conducted in accordance with ASTM recommended procedures.

A variety of exposure sites was selected to represent a broad range of outdoor temperature and relative humidity conditions. The sites selected also have major airport terminals nearby that are used by aircraft with composite components installed. Exposure sites included NASA Langley Research Center, Hampton, Virginia; San Francisco, California; San Diego, California; Honolulu, Hawaii; Frankfurt, W. Germany; Wellington, New Zealand; and Sao Paulo, Brazil. Unpainted specimens were exposed for up to 10 years and residual properties were measured after 1, 3, 5, 7, and 10 years of exposure. In addition, specimens were exposed to various fuels and fluids in a controlled environment in Seattle, Washington.

- Ten-Year Worldwide Ground-Based Exposure -

Triplicate specimens were mounted in exposure racks and placed on rooftops to receive maximum exposure to the environment. The average residual properties (moisture absorption, strength, and modulus of elasticity) were compared to average baseline properties. The unstressed short-beam shear, compression, and flexure specimens were deployed worldwide; the stressed and unstressed tension specimens were deployed at NASA Langley and San Francisco only.

A variety of graphite and Kevlar reinforced composite material systems was selected for the test program, including 250°F and 350°F cure materials. The material systems selected were also used to fabricate flight service components that are discussed in a later section of this paper. The seven fiber reinforced composite material systems involved in the test program included T300/5209 graphite/epoxy, T300/2544 graphite/epoxy, AS/3501 graphite/epoxy, T300/5208 graphite/epoxy, T300/P1700 graphite/polysulfone, Kevlar-49/F-155 Kevlar/epoxy, and Kevlar-49/F-161 Kevlar/epoxy. The material suppliers, nominal specimen thicknesses, and fiber lay-up patterns are presented in table I for each of the materials tested. All the test specimens were machined from laminates that were autoclave-cured according to material supplier's recommended cure cycles. The graphite tape reinforced test specimens had a nominal per ply thickness of 5 mils, and the Kevlar fabric reinforced test specimens had a nominal per ply thickness of 10 mils.

The short-beam shear specimens were 0.25-in. wide and were tested in 3-point bending with a nominal span-to-thickness ratio of four. The IITRI compression specimens were 0.25-in. wide and had fiberglass/epoxy loading tabs bonded to the surfaces of the specimens. A nominal gage length of 0.50 in. was used for the graphite specimens and a gage length of 0.25 in. was used for the Kevlar specimens. The flexure specimens were tested in 3-point bending with a nominal span of 2.00 in. The graphite flexure specimens were 0.50-in. wide, and the Kevlar flexure specimens were 1.00-in. wide. The span-to-thickness ratio was 16 for the Kevlar flexure specimens and ranged from 25 to 32 for the various graphite reinforced materials. The flexure specimens were used to measure ultraviolet radiation effects and moisture absorption. The effects of ultraviolet radiation were determined by viewing the exposed surface of the flexure specimens in a scanning electron microscope. Moisture absorption was determined by drying the flexure specimens in an oven after they were tested for residual strength.

Moisture Absorption - The amount of moisture that composite materials absorb is a function of matrix and fiber type, temperature, relative humidity, and exposure conditions. Accelerated laboratory tests are often used to saturate composite materials for subsequent mechanical property testing. However, the objective of the tests reported herein was to establish the effects of various realtime outdoor environments on the moisture absorption of composite materials. Moisture absorption (as a fraction of composite specimen weight) is plotted as a function of exposure time for the various exposure locations in figures 2-7. Data for the T300/P1700 graphite/polysulfone specimens are not reported because of highly erratic measurements. The T300/5209 and T300/5208 graphite/epoxy materials, figures 2 and 7, respectively, absorbed the least amount of moisture after the 10 year exposure period, about 0.5-0.7 percent. The Brazil and New Zealand exposures resulted in the highest moisture absorption, about 0.7 percent. The moisture absorbed at the other exposure sites ranged from 0.52-0.64 percent after 10 years of exposure. The moisture contents for the specimens exposed in Brazil and New Zealand for 5 years were somewhat higher than for the 7 and 10-year exposures. The AS/3501 graphite/epoxy specimens absorbed about 1.2 percent moisture after 10-year exposures in Brazil and New Zealand, figure 4. The moisture absorption for AS/3501 at the other exposure sites averaged about 1.1 percent. The T300/2544 graphite/epoxy specimens absorbed about 2.2 percent moisture after 10-year exposures in Brazil and New Zealand, figure 3. Moisture absorption for the T300/2544 graphite/epoxy at the other four exposure sites ranged from 1.7-1.9 percent. The Kevlar/epoxy materials absorbed the highest amount of moisture during the 10 year exposure period, approximately 2.6 percent, figures 5 and 6. There was little difference in the amount of moisture absorbed for the Kevlar-49/F-155 and Kevlar-49/F-161 material systems. Again the Brazil and New Zealand exposures resulted in the highest moisture absorption. These results are not surprising, since the average annual relative humidity in Sao Paulo, Brazil and Wellington, New Zealand is about 75 to 80 percent. The moisture absorption at the other exposure sites ranged from 2.2-2.3 percent after 10 years of exposure. The graphite reinforced composite materials reached moisture equilibrium after about 3 years of exposure, whereas the thicker Kevlar reinforced materials reached moisture equilibrium after about 7 years of exposure. The effects of moisture on the residual properties of the composite materials will be discussed in a subsequent section of this paper.

Ultraviolet Degradation - The effects of ultraviolet radiation on unpainted flexure coupons were determined after various outdoor exposure periods. Degradation of surface resin was noticeable after 3 years of exposure. Typical results for AS/3501 graphite/epoxy and Kevlar-49/F-155 after 7 years of outdoor exposure are shown in figure 8. The scanning electron micrographs on the left of figure 8, for specimens with no outdoor exposure, indicate that the surface fibers are fully coated with resin. The micrographs on the right of figure 8 indicate that the surface fibers are fully exposed due to ultraviolet degradation of the epoxy surface layer. The T300/2544 graphite/epoxy and Kevlar-49/F-155 systems were affected the most by ultraviolet radiation. The materials that were most affected by ultraviolet radiation also absorbed the highest amount of moisture. These results substantiate the need to keep composite aircraft structures painted to prevent degradation of surface resin and exposure of bare fibers. Controlled laboratory weatherometer tests results reported in reference 1 indicated that polyurethane aircraft paint offered substantial protection against ultraviolet radiation.

Residual Flexural Strength - Three-point flexure tests were conducted to assess the effects of outdoor environments on surface fiber strength. The specimens were tested with the exposed surface in compression; in general, however, failure occurred in tension at mid-span of the specimens. Baseline flexural strength and modulus results for the seven different material systems tested are presented in table II. Residual strength, modulus, and moisture absorption test results after 1, 3, 5, 7, and 10 years of outdoor exposure are tabulated in tables III-IX, and the average flexural strength results are presented in figures 9-15. The T300/5208 and T300/P1700 material systems entered the test program at a later date than the other materials, hence the exposure times are different. In addition to outdoor exposure results, test results are included for specimens that were stored in an office for 10 years at NASA Langley. The T300/5208 material was not exposed outdoors at NASA Langley. A scatter band for the baseline strength of the respective materials is plotted in each figure. The data points plotted are the average residual strength/baseline strength of three replicate test specimens.

The test results for the T300/5209 specimens, figure 9, indicate that most of the data falls within the baseline strength scatter band. A few data points fall above and below the baseline scatter.

Test results for the T300/2544 specimens, figure 10, indicate a 26 percent strength reduction after 10 years of exposure at NASA Langley. The strength reduction for the other exposure sites is less than 20 percent. The flexural strength reduction for the T300/2544 specimens is partially due to severe surface degradation due to ultraviolet radiation and to the high moisture absorption, about 2 percent, discussed previously.

The flexure strength for the AS/3501 material, figure 11, was consistently above the baseline strength after the 1-year tests. These results indicate that batch-to-batch strength variations may have occurred and a larger number of baseline tests should have been conducted. Results of flexure tests on specimens that were stored in an office at NASA Langley for 10 years indicate an average strength that is 18 percent higher than the average baseline strength.

The Kevlar-49/F-155 specimens indicated a steady decrease in strength during the 10 year exposure period, figure 12. The Hawaii environment caused the largest strength reduction, approximately 25 percent after 10 years. This is partially due to the intense ultraviolet radiation exposure in Hawaii and to the high moisture absorption, about 2.3 percent.

The Kevlar-49/F-161 specimens indicated a steady decline in strength, figure 13, but not as large a decrease as for the Kevlar-49/F-155 specimens. The maximum strength loss after 10 years of exposure was approximately 12 percent for the specimens exposed in California. These results indicate that the 250°F cure F-155 resin system was affected more by the outdoor exposure than was the 350°F cure F-161 resin system.

The T300/P1700 flexure specimens did not indicate any significant strength loss at any of the exposure sites during the 10-year exposure period, figure 14. Several of the data points fell above the baseline strength scatter band.

The flexure strength for most of the T300/5208 specimens, figure 15, fell within the baseline strength scatter band, however, some of the data points fell above the baseline.

Some of the flexure data scatter could be related to the nature of the 3-point flexure test. The maximum stress occurs at mid-span in the outer fibers. Material strength variations along the beam span could cause variations in the test results.

Although failures were primarily in tension, the flexure test results indicate that specimens with high ultraviolet radiation damage to the compression surface and the highest moisture absorption, also had the highest strength loss. The residual flexural strength of all the 10 year office storage specimens, except for the AS/3501 specimens, fell within the baseline strength scatter bands.

Residual Flexural Modulus - Load-deflection response was recorded for each flexure test and flexural modulus was calculated using large deflection beam equations. Average flexural modulus results as a function of exposure time are presented in figures 16-22. Baseline modulus data were not available for the T300/P1700 and T300/5208 material systems. For comparison with other exposure conditions, the 10 year office storage data were used as a "baseline."

Only three material systems indicated any significant loss in flexural modulus during the 10-year exposure period. The two materials that incurred the most ultraviolet radiation damage also had the highest reduction in flexural modulus. These results are expected since the unsupported outer fibers could not contribute to bending stiffness. The T300/2544 graphite/epoxy materials had a 20-22 percent loss in flexural modulus after 10 years of exposure at Hawaii and NASA Langley, figure 17. The Kevlar-49/F-155 material had a 28 percent loss in flexural modulus after 7 years of exposure to the intense ultraviolet radiation in Hawaii, figure 19. The maximum loss in modulus, 17 percent, for the Kevlar-49/F-161 material occurred after 7 years of exposure at Hawaii and 10 years of exposure at NASA Langley, figure 20.

The data presented in figures 16, 18, 21, and 22 for T300/5209, AS/3501, T300/P1700, and T300/5208, respectively, indicate essentially no reduction in flexural modulus during the 10 year exposure period. The flexural modulus for all the 10 year office storage specimens fell within the baseline modulus scatter bands.

Residual Short-Beam Shear Strength - Short-beam shear tests were conducted to provide a measure of fiber-to-matrix bond degradation as a function of outdoor exposure time and exposure site. In general, interlaminar failures occurred at the mid-plane of the specimens, in a horizontal shear mode. Baseline short-beam shear strength results for the seven different material systems tested are presented in table X. Residual strength test results as a function of outdoor exposure time are tabulated in tables XI-XVII, and the average shear strength results are presented in figures 23-29. Some of the T300/5208 specimens were not included in the test program because of processing problems with certain lots of material.

The test results for the T300/5209 specimens, figure 23, indicate that a maximum strength reduction of about 10 percent occurred during the 10 year exposure period. Test results for the T300/2544 specimens, figure 24, indicate that a maximum strength reduction of about 26 percent occurred during the 10 year exposure period. The 2 percent moisture absorption discussed previously for the T300/2544 material appears to have caused a significant shear strength reduction. Most of the average shear strength data for the AS/3501 graphite/epoxy specimens, figure 25, fell within the baseline strength scatter band.

The Kevlar-49/F-155 specimens, figure 26, had a maximum strength reduction of 28 percent during the 10-year exposure in Brazil. As discussed previously, the specimens exposed in Brazil had the highest moisture absorption, over 2.6 percent. The Kevlar-49/F-161 specimens, figure 27, had a maximum strength reduction of 19 percent after 5 years of exposure in San Diego, California. However, the highest moisture absorption was for specimens exposed in Brazil. These results indicate that the 250°F cure F-155 resin system was affected more by the outdoor exposure than was the 350°F cure F-161 resin system.

The T300/P1700 graphite/polysulfone specimens had a significant shear strength loss for the New Zealand exposure, even after 2 years, figure 28. A maximum strength loss of 38 percent was indicated after 9 years of exposure in New Zealand. The maximum strength loss for T300/P1700 at the other exposure sites was about 22 percent. Although moisture results are not presented because of erratic measurements, the specimens exposed in New Zealand appeared to absorb only about 0.2 percent moisture. The cause of the significant shear strength loss for the T300/P1700 material was not determined.

The limited data for the T300/5208 material, figure 29, indicate a maximum strength loss of 20 percent after 9 years of New Zealand exposure. The material exposed in New Zealand also had the highest moisture absorption, about 0.75 percent.

The data trends for the short-beam shear tests indicate that the T300/2544, Kevlar-49/F-155, and T300/P1700 materials had the highest strength loss during the 10 year exposure period. Results also indicate that the humid environments of Brazil and New Zealand were in most cases the most degrading to the shear strength. These results correlate with the highest moisture absorption for specimens exposed in Brazil and New Zealand.

The short-beam shear specimens that were stored in an office at NASA Langley for 10 years incurred strength losses ranging from 6-12 percent. In general, a larger number of specimens were tested after 10 year office storage than were tested to establish baseline properties.

Residual Compression Strength - Compression tests were conducted to determine the effects of outdoor exposure on strength. In general, failure occurred in the gage section near the end of the fiberglass loading tabs. In some instances for the graphite specimens, failure occurred under the loading tabs. Baseline compression strength results for the seven material systems tested are presented in table XVIII. Residual strength results as a function of outdoor exposure time are tabulated in tables XIX-XXIV, and the average compression strength results are presented in figures 30-35. The T300/5208 specimens were not included in the test program because of processing problems with certain lots of material.

The test results for the T300/5209 specimens, figure 30, indicate that most of the data are within the baseline strength scatter band. However, a strength reduction of about 26 percent occurred for the specimens exposed in Hawaii and New Zealand after 3 and 5 years, respectively. The reason for greater strength degradation at these locations after 3 and 5 years compared to 7 and 10 years of exposure was not determined.

Most of the strength data for the T300/2544 specimens, figure 31, are below the baseline strength scatter band. A strength reduction of about 27 percent occurred for the specimens exposed in New Zealand after 5 years of exposure.

A strength reduction of 26 percent occurred for the AS/3501 specimens exposed in New Zealand after 5 years, figure 32. The reason why the 10-year strength for the specimens exposed in New Zealand is 14 percent above the average baseline strength was not determined.

The Kevlar-49/F-155 and Kevlar-49/F-161 specimens, figures 33 and 34, respectively, indicated similar strength trends throughout the 10 year exposure period. After an initial strength increase for most of the exposure sites after 1 year of exposure, the residual strengths for both Kevlar materials indicated a steady decline after 3, 5, 7, and 10 years of exposure.

A strength reduction of about 25 percent occurred for both Kevlar systems after 10 years of exposure in Hawaii. These results indicate that the combination of intense ultraviolet radiation and high relative humidity in Hawaii affected the Kevlar materials more than the graphite/epoxy materials.

Most of the strength data for the T300/P1700 compression specimens, figure 35, are within the baseline strength scatter band. The reason for the anomalous 25 percent strength reduction for the specimens exposed in California for 4 years was not determined. The strength was considerably higher after 6 and 9 years of exposure in California.

The graphite materials stored for 10 years in an office at NASA-Langley indicated a slight decrease in compression strength, whereas the Kevlar materials indicated a slight increase in strength.

- Effect of Aircraft Fluids and Fuels on Composite Strength -

Aircraft structures are frequently exposed to various combinations of fluids such as fuel, hydraulic fluid, and water. The effects of various combinations of these fluids on composite materials have been evaluated after 5 years of exposure. Short-beam shear and ±45° tension specimens were exposed to six different environmental conditions as follows: ambient air, water, JP-4 fuel, Skydrol hydraulic fluid, fuel/water mixture, and fuel/air cycling. The water, JP-4 fuel, and Skydrol were replaced monthly to maintain fresh exposure conditions. Specimens exposed in the fuel/water mixture were positioned at the fuel/water interface. The fuel/air cycling environment consisted of 24 hours of fuel immersion followed by 24 hours of exposure to air. Residual strengths of T300/5208 graphite/epoxy, T300/5209 graphite/epoxy, and Kevlar-49/5209 fabric were determined after exposure to the six different environments.

The residual strength results for ±45° tension specimens are shown in figure 36. The most degrading environment for the T300/5209 and Kevlar-49/5209 materials was the fuel/water combination. The T300/5209 specimens lost about 11 percent in tensile strength, whereas the Kevlar-49/5209 specimens lost about 25 percent in tensile strength. The short-beam shear test is particularly resin sensitive, and the results shown in figure 37 indicate that the residual shear strengths were degraded more than the tensile strengths shown in figure 36. The largest short-beam shear strength reduction was about 40 percent for the T300/5209 material system when exposed to the fuel/water combination. The Kevlar-49/5209 fabric specimens lost about 30-35 percent in shear strength when exposed to water and the fuel/water combination.

These results indicate that the water-based fluids were the most degrading. The Kevlar tension specimens were affected more than the graphite specimens and the Kevlar and graphite short-beam shear specimens indicated similar strength losses. These tests were more severe than actual aircraft flight exposures, and the results should represent an upper bound on material property degradation. Additional details on the fluids and fuels exposure program can be found in reference 2.

- Effect of Sustained-Stress Exposures on Strength and Modulus -

The effects of sustained-stress on tensile strength and modulus were determined during 10 year outdoor exposures at NASA-Langley in Hampton, Virginia and San Francisco, California. Quasi-isotropic [0, ±45, 90] T300/5208 tensile specimens were stressed at 40 percent of baseline ultimate strength. Unstressed specimens were included in the outdoor exposure racks for comparison purposes. Specimens were removed from the racks after 1, 3, 5, 7, and 10 years of exposure to measure residual strength and modulus. The tensile strength results shown in figure 38 indicate that most of the data are within the baseline strength scatter band for both the stressed and unstressed specimens. The residual tensile modulus data are shown in figure 39. A 10-15 percent reduction in modulus is indicated after 5 and 7 years of exposure, but no reduction is indicated after 10 years of exposure. There is no significant difference between the results for stressed and unstressed specimens. These results indicate that the T300/5208 quasi-isotropic tensile specimens were not significantly affected by either outdoor environment or sustained tensile stress at the exposure sites indicated.

- Effect of Sustained-Stress Exposures on Strength of Bolted Joints -

The effects of sustained-stress on the tensile strength of quasi-isotropic graphite/epoxy bolted joints were determined after 7 years of outdoor exposure. Two bolted joint configurations were tested. The first configuration had a single row of bolts and was fabricated with T300/5208 graphite/epoxy. The T300/5208 specimens were approximately 0.53-in. thick and 7.9-in. wide. The baseline T300/5208 specimens failed at 117.8 kips. The second joint configuration had a double row of bolts and was fabricated with T300/5209 graphite/epoxy. The T300/5209 specimens were approximately 0.56-in. thick and 7.50-in. wide. The baseline T300/5209 specimens failed at 120.0 kips. The test specimens were installed in outdoor loading frames at the NASA Langley Research Center as shown in figure 40. The specimens were subjected to a sustained tensile load of 27 percent of the design ultimate load. In addition to sustained-load outdoor exposure for 1, 3, 5, and 7 years, 0.4 lifetimes of spectrum fatigue loads were applied to the test specimens at the end of each year of exposure.

Test results after 1, 3, 5, and 7 years of exposure are shown in figure 41. The single row T300/5208 joint indicated a 7.5 percent decrease in residual strength after 5 years of exposure and two lifetimes of fatigue loading. The double row T300/5209 joints indicated a 5.3 percent decrease in residual strength after 7 years of exposure and 2.8 lifetimes of fatigue loading. These results indicate excellent performance of both graphite/epoxy systems and joint configurations after being subjected to outdoor sustained-load and laboratory spectrum fatigue loading. Additional details on the bolted joint test program are presented in reference 3.

FLIGHT SERVICE EVALUATION OF COMPOSITE COMPONENTS

In 1973 the NASA Langley Research Center initiated a series of programs to evaluate the effects of realistic flight environments on composite components. The objective was to establish confidence in the long-term durability of advanced composites through flight service of numerous composite components on transport aircraft. Emphasis was on commercial aircraft because of their high utilization rates, exposure to worldwide environmental conditions, and systematic maintenance. In 1979 NASA-Langley and the U.S. Army initiated joint programs to evaluate composite components on commercial and military helicopters. Although helicopters accumulate fewer flight hours than transport aircraft, in many instances the environments and fatigue loading are more severe for the helicopter components. Primary emphasis for the helicopter components is to establish the effects of realistic operating service environments on the strength of primary and secondary composite components. These environmental factors can then be applied with more confidence and less conservatism in the future design of composite components.

- Transport Aircraft Components -

The transport aircraft that are flying composite components in the

NASA Langley service evaluation program are shown in figure 42. Eighteen Kevlar-49/epoxy fairings have been in service on Lockheed L-1011 aircraft since 1973. In April 1982, eight graphite/epoxy ailerons were installed on four L-1011 aircraft for service evaluation. One hundred and eight Boeing 737 graphite/epoxy spoilers have been in service on six different commercial air lines in worldwide service since 1973. Ten Boeing 737 graphite/epoxy horizontal stabilizers have been installed on five aircraft for commercial service. Fifteen graphite/epoxy DC-10 upper aft rudders have been in service on five commercial airlines and three boron/aluminum aft pylon skin panels were installed on DC-10 aircraft in 1975. Ten graphite/epoxy elevators have been in service on B-727 aircraft since 1980. In addition to the commercial aircraft components indicated in figure 42, two boron/epoxy reinforced aluminum center-wing boxes have been in service on U.S. Air Force C-130 transport aircraft since 1974.

L-1011 Kevlar-49/Epoxy Fairings - The L-1011 fairings were fabricated with Kevlar-49 fibers and F-155 and F-161 epoxy resins. The configurations of the center-engine fairing, under-wing fillet, and wing-to-body fairing are shown in figure 43. The center-engine sandwich fairings were fabricated with Nomex honeycomb and 3-ply Kevlar-49/F-161 fabric skins. The under-wing fillets were fabricated with 9-ply Kevlar-49/F-155 laminated fabric. The wing-to-body fairings were fabricated with Nomex honeycomb and 3-ply Kevlar-49/F-155 fabric skins.

During the 10 year service evaluation period, the Kevlar-49/epoxy fairings installed on L-1011 aircraft were inspected annually to document condition. The photographs shown in figure 44 indicate various types of damage incurred in service. Minor impact damage from equipment and foreign objects has been noted on several fairings, primarily the honeycomb sandwich wing-to-body fairings. Surface cracks and indentations have been repaired with filler epoxy and, in general, the cracks have not propagated with continued service. Paint adherence has been a minor problem, particularly for parts that have been in contact with hydraulic fluid. Frayed fastener holes have been noted in several fairings, primarily due to nonoptimum drilling procedures and improper fit. Elongated holes have been noted, primarily due to improper fit and nonuniform fastener load distribution. There have been no moisture intrusion problems with the Kevlar-49/epoxy fairings, and they have performed similar to production fiberglass/epoxy fairings. The fairings are still in service, and the three participating airlines are monitoring their performance during normal maintenance inspections. Additional details on the design, fabrication, and service evaluation of the Kevlar-49/epoxy fairings are presented in references 4 and 5.

B-737 Graphite/Epoxy Spoilers - The B-737 spoilers were fabricated with three different graphite/epoxy systems: T300/5209, T300/2544, and AS/3501. The configuration of the spoiler is indicated in figure 45. The spoilers were fabricated with upper and lower graphite/epoxy skins, aluminum fittings and spar, aluminum honeycomb core, and fiberglass/epoxy ribs. The graphite/epoxy skins were fabricated with six plies of unidirectional tape with a (+15, -45, 90_2, +45, -15) lay-up pattern. The 90° fibers were oriented in the spanwise direction of the spoiler. Additional reinforcements were included along the trailing edge.

During the 13 year service evaluation period for the graphite/epoxy spoilers, several types of damage have been encountered. Over 75 percent of the damage incidents have been related to design details. The most prevalent damage has been caused by actuator rod interference with the graphite/epoxy skin. This problem was resolved by redesigning the actuator rod ends. The second most frequent damage is caused by moisture intrusion and corrosion at the spar-to-center hinge fitting splice. This damage could be prevented by redesigning the splice to prevent disbonds between the skin and spar cap. Miscellaneous cuts and dents related to airline usage have also been encountered. Damage due to hailstones, bird strike, and ground handling equipment has been noted on several spoilers. Minor repairs have been conducted by the airlines after proper instruction by Boeing repair personnel. Because of the expense involved, spoilers with major damage are removed from service.

A typical corrosion damage scenario for a spar-to-center hinge fitting splice is shown in figure 46. The corrosion damage can be characterized by three phases of development. Phase 1 involves corrosion initiation at an aluminum fitting or at the aluminum spar splice. The corrosion initiates due to moisture intrusion through cracked paint and sealant material. If the corrosion products are not removed and new sealant applied, the damage progresses to phase 2 where moisture penetrates under the graphite/epoxy skin along the aluminum C-channel front spar. Normal service loads combined with moisture contribute to crack growth and subsequent corrosion. If the phase 2 corrosion is not repaired, the damage progresses to phase 3 where extensive skin-to-spar separation takes place. Phase 3 corrosion can result in significant strength and stiffness loss.

Residual strength tests have been conducted annually to establish the effects of service environments on the graphite/epoxy spoilers. The spoilers were tested with compression load pads on the upper surface to simulate airloads. Trailing edge tip deflection was measured as a function of applied load for each spoiler tested. The test results are compared with the strength of 16 new spoilers in figure 47. The strength for each spoiler through 6 years of service generally falls within the strength scatter band for the baseline spoilers. However, spoilers with significant corrosion damage which were tested after 7 and 8 years of service, respectively, indicated a 35 percent strength reduction. An additional T300/2544 spoiler with no corrosion damage was tested after 7 1/2 years of service, which verified that the 7 year strength reduction was related to corrosion damage. Three spoilers tested after 9 years of service with little or no corrosion damage exhibited strengths equal to the strength of the baseline spoilers. A AS/3501 spoiler with 10 years of service and known corrosion damage failed at 78 percent of the average strength of the baseline spoilers. Two other spoilers with 10 years of service with no corrosion damage failed within the baseline strength scatter band. These results indicate that the corrosion-free graphite/epoxy reinforced spoilers exhibited better residual strength than the outdoor exposure unpainted test specimens fabricated with similar graphite/epoxy materials. Additional spoiler tests will be conducted after 12 and 15 years of service.

The load-deflection response of two T300/5209 graphite/epoxy spoilers tested after 8 and 10 years, respectively, is compared with that of a baseline spoiler in figure 48. The 8-year spoiler with 17,141 flight hours on Air New Zealand with known corrosion damage failed at 210 percent of design limit load compared to 270 percent design limit load for the baseline spoiler. Note that the 8 year spoiler strength is significantly above the design ultimate load requirement. The 10-year spoiler with 28,337 flight hours on Frontier was corrosion free and failed at 290 percent of design limit load or about 7 percent higher than the baseline. The stiffness variation between the three spoilers is typical of other spoilers tested throughout the program. In general, more extensive corrosion damage causes more skin-to-spar separation and a subsequent reduction in overall spoiler stiffness and strength.

In addition to structural tests of the spoilers, measurements have been made to determine absorbed moisture content of the graphite/epoxy skins. The moisture content was determined from plugs cut near the trailing edge as shown in figure 49. The plugs consist of aluminum honeycomb core, two graphite/epoxy facesheets, two layers of epoxy film adhesive, and two exterior coats of polyurethane paint. About 90 percent of the plug mass is in the composite facesheets, including the paint and adhesive. The moisture content was determined by drying the plugs and recording the mass change. The data shown in figure 49 for plugs removed from three spoilers after 9 years of service indicate moisture levels in the graphite/epoxy skins ranging from 0.59 to 0.90 percent for T300/5209, T300/2544, and AS/3501 material systems. The moisture levels for the T300/5209 and AS/3501 systems are similar to moisture levels determined for unpainted material coupons exposed to worldwide outdoor environments. However, the moisture content of 0.90 percent for the T300/2544 plugs is only about one-half the moisture content of the unpainted outdoor exposure material coupons. Extensive ultraviolet radiation degradation to the T300/2544 unpainted specimens may partially explain the reason for the higher moisture absorption. Although design related corrosion damage has been sustained by a few of the graphite/epoxy reinforced spoilers, they have had less maintenance problems than production aluminum spoilers. Additional details for the design, fabrication, test, and service evaluation of the B-737 graphite/epoxy spoilers are presented in references 6 and 7.

C-130 Boron/Epoxy Reinforced Center-Wing Boxes - Boron/epoxy reinforced aluminum center-wing boxes were installed on two U.S. Air Force C-130 aircraft for service evaluation in 1974. Configuration of the boron/epoxy reinforced wing box and reinforcement concepts are shown in figure 50. The design included uniaxial strips of boron/epoxy bonded to the aluminum alloy skin panels and to the hat-section stringer crown. The material used to fabricate the reinforcement strips was Avco Rigidite 5505/4 boron/epoxy.

The objective of this program was to demonstrate improved strength and fatigue endurance for the boron/epoxy reinforced boxes compared to equivalent all-aluminum wing boxes. The boron/epoxy reinforced aluminum wing boxes have performed excellently in service with no damage or defects reported. No maintenance actions have been required during the 12-year service evaluation period. Based on the results of ground tests on a third wing box, the boron/epoxy reinforced wing boxes are predicted to have superior fatigue endurance than the baseline aluminum boxes. Additional details on the design, fabrication, and ground test of the boron/epoxy reinforced wing boxes can be found in references 8-10.

DC-10 Boron/Aluminum Aft Pylon Skins - Boron/Aluminum skin panels were installed on three DC-10 aircraft in 1975 for flight service evaluation. The flat skin panel is located above the aft-engine and encounters high acoustic fatigue loading and moderate thermal loads. The location and configuration of the skin panels are shown in figure 51. The panels were fabricated with 5.6 mil diameter boron filaments and 6061 aluminum matrix. The panels were 11 plies thick with a (90, +45, 90, 0, -45, 0, -45, 0, 90, +45, 90) lay-up pattern. The 0° plies were oriented along the length of the panel.

Two of the skin panels are still in service. However, one panel was removed from service after 7 years because of corrosion damage, figure 52. The degree of corrosion was such that the outer layer of boron filaments on the inside of the panel was almost completely exposed. The panel contained a light residue of ester oil similar to turbine engine oil; however, the specific corrodent was not identified. A second panel also has some corrosion damage and a small crack, but the panel is still in service and is being monitored closely to check for crack growth and further corrosion damage. The crack in the panel was probably caused by exterior mechanical damage during removal and reinstallation of the panels during inspection. It has been concluded that the method of corrosion protection used was inadequate. In general, the boron/aluminum panels have not performed as well as similar production titanium panels. Additional details on the DC-10 boron/aluminum skin panels are presented in reference 11.

DC-10 Graphite/Epoxy Rudders - Fifteen T300/5208 graphite/epoxy upper aft rudders have been in service on DC-10 aircraft since 1976. The configuration of the graphite/epoxy rudder is shown in figure 53. The graphite/epoxy rudder is a multi-rib structure with front and rear spars. The skins were constructed with a 6-ply $(0, +45, -45)_s$ lay-up with the 0° plies in the spanwise direction. The basic ribs were constructed with a similar lay-up. The ribs at the five hinge locations had a $(0, +45, 90, -45)_s$ lay-up. A single 0° chordwise ply was added to each rib cap at the skin interface to increase bending strength and rigidity. The entire structure was co-cured in an oven at the material supplier's recommended cure cycle for T300/5208. Expandable rubber was used inside of the rudder to apply pressure against an outside steel tool.

There have been seven incidents which required rudder repairs. The damage sustained by the rudders included minor disbonds, rib damage due to ground handling, and skin damage due to lightning strike. Figure 54 shows minor in-service lightning strike damage to the trailing edge of a rudder and rib damage that occurred while a rudder was off the aircraft for other maintenance. The lightning strike damage was limited to the outer four layers of graphite/epoxy and a room temperature repair was performed in accordance with procedures established at the time the rudders were certified by the FAA. The rib damage was more extensive and a portion of a rib was removed and rebuilt. A detailed discussion of the repair procedure is given in reference 12.

More extensive lightning damage was sustained on another graphite/epoxy rudder as shown in figure 55. Upon inspection of the rudder, it was discovered that the lightning protection strap was inadvertently left off after the previous maintenance check. The skin in the damaged area is eight plies thick over an 8-ply spar cap. Fiber damage and resin vaporization extended through the skin forward of the spar, and the skin and spar cap aft of the rear spar were completely destroyed. Details of the repair procedures are given in reference 13.

A graphite/epoxy rudder was removed from service for residual strength testing after 5.7 years and 22,265 flight hours on Air New Zealand. The load-deflection response shown in figure 56 indicates that the 5.7-year rudder had an initial stiffness higher than the baseline rudder, but the overall response is similar for the two rudders. The baseline and the 5.7-year tests were stopped at approximately 400 percent limit load because of instability of the loading apparatus. Although the rudders are designed by stiffness considerations and only one residual strength test has been conducted, the overall response of the rudder indicates that no degradation has occurred as a result of 22,265 flight hours.

B-727 Graphite/Epoxy Elevators - The configuration of the T300/5208 graphite/epoxy elevator is shown in figure 57. The graphite/epoxy elevator is constructed with Nomex honeycomb sandwich skins and ribs and laminated spars. The basic skins were constructed with one ply of 90° tape and one ply of ±45° fabric which were bonded on each side of Nomex honeycomb core with FM 300 adhesive. Additional layers of fabric were included over rib and spar attachments and honeycomb closeouts. The C-channel ribs were constructed with two plies of ±45° fabric on each side of Nomex honeycomb core. Additional reinforcements were included in rib caps, attachments and closeouts. The C-channel front spar consists of 6 plies of ±45° fabric with 10 plies of 0° tape along the spar caps. The C-channel rear spar consists of 4 plies of ±45° fabric and 3 plies of (0, 90) fabric.

Since initiation of flight service of 10 elevators in 1980, there have been two B-727 graphite/epoxy elevators damaged by minor lightning strikes and two elevators damaged during ground handling. Figure 58 shows typical lightning damage to the trailing edge of an elevator and trailing edge fracture of another elevator caused by impact from a deicing apparatus. Damage from lightning strikes ranged in severity from scorched paint to skin delamination. The most severe damage to an elevator occurred when the static discharge probe of one B-727 penetrated the elevator of another B-727 during ground handling. Skin panels were punctured, four holes in the lower surface and one hole in the upper surface, and the lower horizontal flange at the front spar was cut inboard of the outboard hinge. All the elevator repairs were performed by airline maintenance personnel.

The lightning damage was repaired with epoxy filler and milled glass fibers. The skin punctures were repaired with T300/5208 prepreg fabric and Nomex honeycomb core plugs. The front spar was repaired with a machined titanium doubler, which was mechanically fastened to the lower skin flange of the spar chord. The repaired graphite/epoxy elevators will be reinstalled on aircraft for continued commercial service. Details of the design and fabrication of the graphite/epoxy elevators are given in reference 14.

L-1011 Graphite/Epoxy Ailerons - Four shipsets of T300/5208 graphite/epoxy inboard ailerons were installed on L-1011 aircraft in 1982 for flight service evaluation. An additional shipset was installed on Lockheed's L-1011 flight test aircraft for evaluation. The configuration of the L-1011 graphite/epoxy aileron is shown in figure 59. The graphite/epoxy aileron incorporates sandwich skins of graphite/epoxy facesheets with a syntactic (microballoon filled) epoxy core. The front spar is graphite/epoxy tape and the ribs were constructed with fabric and tape. The basic skins were constructed with 3 plies of (45, 0, 135) tape on each side of a 0.0375-in. thick syntactic epoxy core. The 0° ply is in the spanwise direction of the aileron. Additional reinforcements were added over the main and end ribs to provide additional chordwise stiffness. The C-channel front spar was constructed with 10 plies of $(45, 0, 135, 90, 0)_s$ tape with the 0° ply in the spanwise direction. The rear spar was fabricated with 7075-T6 aluminum alloy. The C-channel main ribs were constructed with 4 plies of fabric with a $(45, 90_2, 45)$ lay-up pattern. Additional reinforcement was added in the rib caps to increase strength and stiffness. The C-channel intermediate and closure ribs consisted of 5 plies of fabric with a (45, 90, 135, 90, 45) lay-up pattern. The 0° direction is in the lengthwise direction for all the ribs.

During the 4 year service evaluation period there have been no damage incidents or major maintenance actions required. Minor paint touch-up has been performed periodically and loose fibers around one fastener hole on the Lockheed aircraft were rebonded with epoxy. Details on the development of the graphite/epoxy ailerons, are reported in reference 15.

B-737 Graphite/Epoxy Horizontal Stabilizers - Five shipsets of T300/5208 graphite/epoxy horizontal stabilizers were installed on B-737 aircraft starting in 1984 for flight service evaluation. The configuration of the B-737 graphite/epoxy horizontal stabilizer is shown in figure 60. The graphite/epoxy stabilizer features stringer-reinforced skins, laminated spars, and Nomex honeycomb reinforced ribs. The basic skins were constructed with 5 plies of $\pm45°$ fabric and 2 plies of (0, 90) fabric with additional reinforcements inboard of the stabilizer. The stringers were fabricated with back-to-back channel sections that consisted of two plies of $\pm45°$ fabric plus 2 plies of (0, 90) fabric. The stringer caps had one ply of $\pm45°$ fabric and 6 plies of 0° tape. The honeycomb ribs had two plies of $\pm45°$ fabric on each side of Nomex core. The basic spar sections consisted of 9 plies of $\pm45°$ fabric plus 6 plies of (0, 90) fabric. Additional reinforcement was added in attachment areas.

There have been no damage incidents or maintenance actions required for any of the 10 stabilizers. Details on the development of the graphite/epoxy stabilizers are reported in reference 16.

- Helicopter Components -

The helicopters that are flying composite components in the NASA Langley service evaluation program are shown in figure 61. Forty shipsets of Kevlar-49/epoxy doors and fairings and graphite/epoxy vertical fins have been installed on Bell 206L commercial helicopters for 10 years of service evaluation. The helicopters are operating in diverse environments in Alaska, Canada, U.S. Gulf Coast, Northeast U.S., and Southwest U.S. Selected components are periodically removed from service for residual strength testing. Details on the design, fabrication, and test of the Bell 206L composite components can be found in reference 17.

Ten graphite/epoxy tail rotors and four hybrid Kevlar-49-graphite/epoxy horizontal stabilizers are removed periodically from Sikorsky S-76 production helicopters to determine the effects of realistic operational service environments. Static and fatigue tests are conducted on the components removed from service, and the results are compared with baseline certification test results. Details on the design, fabrication, and test of the S-76 composite components are reported in reference 18.

A Kevlar-49/epoxy cargo ramp skin is installed on a U.S. Marine Corps CH-53D helicopter for service evaluation. Details of the design, fabrication, and installation of the cargo ramp skin are reported in reference 19.

Bell 206L Composite Components - The four composite components that are being evaluated on the Bell 206L are shown in figure 62. The forward fairing is a sandwich structure with a single ply of Kevlar-49 fabric/CE-306 epoxy composite skin that was co-cured on a Klegecell polyvinylchloride foam core. The litter door consists of 3-ply outer and inner skins of Kevlar-49 fabric/F-185 epoxy composite material. Unidirectional Kevlar-49/F-560 tape was used for local reinforcement at hinges, latches, and in the hat-section stiffeners. The baggage door was constructed with 3-ply Kevlar-49 fabric/LRF-277 epoxy composite facesheets bonded on Nomex honeycomb core. Additional reinforcements were added in the latch area and along the edges. The vertical fin was constructed with T300/E-788 epoxy composite facesheets bonded to a FIBERTRUSS honeycomb core. Installation of the 40 shipsets of composite components was initiated in March 1981.

Design related and normal usage problems have been encountered with some of the composite components. Excellent service experience has been achieved with the forward fairing and the vertical fin. Two graphite/epoxy vertical fins have been struck by lightning. One fin was repaired and returned to service and the second fin was returned to Bell Helicopter for residual strength testing. Service experience with the Kevlar-49/epoxy litter door has been good. However, problems have been experienced with underdesigned metal hinges. New hinges have been installed on all the litter doors. A design related thermal distortion problem has been experienced with plexiglass windows in the litter doors. A redesign of the window attachment to the door was required to solve the distortion problem. The baggage doors have the poorest service record. The major problem has been disbonding of the outer Kevlar-49/epoxy skin from the Nomex honeycomb core. The outer skin was co-cured to the core with no additional adhesive added. Poor resin filleting is the primary cause of the skin-to-core-disbonds. A film adhesive between the skin and core would probably have alleviated this problem.

Residual strength tests have been conducted on 24 components removed from service and the results are shown in table XXV. The components were subjected to simulated aerodynamic pressure loads. The composite components were removed from service in the following regions: Gulf of Mexico, East Canada, Northeast U.S.A., and Alaska. The service times range from 12 to 34 months and flight times range from 668 to 3387 hours. Residual strength is compared to the design strength and the baseline strength of five components selected at random from the 45 shipset production lot. The design strength shown in table XXV is the strength that an unconditioned (as-fabricated) component must meet or exceed. The design strength is the product of ultimate strength and environmental factors determined from laboratory environmentally conditioned material coupons. Five of the litter doors exceeded the design strength of 0.58 psi. The reason why the Alaska litter door failed at 81 percent of the design strength was not determined. Poor facesheet-to-core bonding for some of the baggage doors caused some significant strength reductions. The large scatter (0.31 to 1.57 psi) in the baggage door strengths is attributed to nonuniform resin filleting and subsequent skin-to-core debonding. Some of the baggage doors with the highest service times have exhibited a significant increase in stiffness and strength which may be due to continuing resin cure with increased exposure. Although all the forward fairings failed below the average baseline strength, they exceeded the design strength by more than a factor of three. Failure strengths for the vertical fins ranged from 1.12 to 1.80 psi, all exceeding the design strength of 1.05 psi. Except for a design related disbonding problem with the baggage doors, the Bell 206L composite components have performed better than their metal production counterparts. The graphite/epoxy vertical fin eliminated a metal corrosion problem which is significant for aircraft that fly in the humid salt-spray environment of the Gulf of Mexico. Additional details on flight service performance of the Bell 206L composite components are reported in reference 20.

<u>Sikorsky S-76 Composite Components</u> - The two composite components that are being evaluated on the Sikorsky S-76 are shown in figure 63. The composite components are baseline designs for the S-76 and are in commercial production. The tail rotor has a laminated AS1/6350 graphite/epoxy spar with a glass/epoxy skin. The spar was constructed with 33 plies of tape with a $(0_{12}, -20, 0, +20, 0_{1.5})_s$ lay-up pattern. The horizontal stabilizer has a Kevlar-49/epoxy torque tube reinforced with full-depth aluminum honeycomb and graphite/epoxy spar caps, full-depth Nomex honeycomb sandwich core, and Kevlar-49/epoxy skins. The ±45° crossplied skins and the torque tube shear webs were fabricated with Kevlar-49 fabric/5143 epoxy. The spar caps were reinforced with unidirectional AS1/6350 graphite/epoxy.

Three horizontal stabilizers have been removed from service for residual strength testing. The first stabilizer removed had 1600 flight hours and 17 months of service. The stabilizer was static tested and failure occurred at 220 percent of design limit load. Failure was initiated due to a buckle in the splice plate of the torque box. The baseline stabilizer test was stopped at 268 percent of design limit load when the test fixture deflection limit was reached. The second stabilizer had 3999 flight hours and 56 months of service. After successful proof loading to the certification test requirements, the stabilizer was fatigue tested to failure. The third stabilizer had 4051 flight hours and 66 months of service. This stabilizer had two small service induced disbonds in the torque box. The stabilizer passed the proof load test requirement, and it was then tested to failure in fatigue.

Seven tail rotor spars have been removed from service for either static or fatigue testing. No defects were found during inspection of the spars. Four spars were fatigue tested and the remaining three were cut-up for coupon tests. The results for the spars that were fatigue tested are shown in figure 64. Cyclic shear stress is plotted as a function of cycles to crack initiation. Test results for two spars that had 25 months and 150 hours of service on a Sikorsky flight test helicopter in West Palm Beach, Florida are plotted for comparison with the four spars removed from helicopters operating in the Lake Charles, Louisiana area. The test results are compared to baseline room temperature dry strength of 10 spars tested for FAA certification. The results indicate that the minimum strength retention is 94 percent of the baseline test average curve shown in figure 64. These results compare well with strength retention factors projected from laboratory-conditioned specimens, reference 18.

The coupons cut from the three spars were tested in short-beam shear, and the results are compared with coupons cut from panels exposed in an outdoor exposure rack located in Stratford, Connecticut. The average short-beam shear strength for the spar coupons is 5 percent lower than the strength of the coupons machined from the outdoor ground exposure panels. The spar coupons had service times ranging from 37 to 51 months, and the panel coupons had outdoor exposure times ranging from 35 to 49 months. These results indicate excellent in-service performance for all the S-76 composite components. Additional details on the flight service evaluation program are reported in reference 21.

Sikorsky CH-53D Composite Cargo Ramp Skin - A ±45° Kevlar-49 fabric/5143 epoxy composite skin was installed on the aft end of a CH-53D cargo ramp for U.S. Marine Corps service evaluation in 1981. The objective of this evaluation program is to assess the wear, impact, and damage resistance of Kevlar-49/epoxy in an environment where ground impact is a frequent occurrence. The skin panel is 20.0 in. long by 80.0 in. wide and ranges in thickness from 0.04 in. to 0.08 in. Because of the location of the panel and small thickness, the potential for damage is significant. However, the panel has been inspected annually since installation and no damage or service related problems have been reported by the U.S. Marine Corps.

- NASA Composite Structures Flight Service Summary -

Over 300 composite components have been in service with foreign and domestic airlines, the U.S. Air Force, and the U.S. Marines. The NASA Langley flight service program was initiated in 1973 for the components indicated in table XXVI. Over 4 million component flight hours have been accumulated with the high-time aircraft having more than 37,000 hours. Some components have been removed from service for residual strength testing and other components have been retired due to damage or other service related problems. As of November 1986, 199 composite components were still in service. Design related corrosion problems have been encountered with B-737 spoilers with graphite/epoxy skins bonded to aluminum honeycomb and aluminum spars. Several graphite/epoxy components have been struck by lightning and appropriate repairs have been performed to allow continued service. Disbonds have been noted between Kevlar-49/epoxy facesheets and Nomex honeycomb core on Bell 206L baggage doors. Poor resin filleting was identified as the cause of the skin-to-core disbonds.

In general, the composite components have performed excellently during the 13 year flight service evaluation. The moisture absorption for the flight components is lower than the moisture absorbed for unpainted ground based exposure specimens. Strength retention for the composite components is as good or better than strength retention for ground-based exposure specimens with comparable exposure periods. The success of these components has led transport and helicopter manufacturers to make production commitments to selected composite components.

CONCLUDING REMARKS

The influence of ground-based and aircraft operational environments on the long-term durability of several advanced composite materials and structural components has been studied. Results of 10 years of outdoor exposure indicate that Kevlar/epoxy material systems were more affected by the various environments than were graphite/epoxy material systems. Kevlar reinforced composites absorbed about 2.4 percent moisture during outdoor exposure, whereas moisture absorption in commonly used graphite reinforced composites ranged from 0.6-1.2 percent. The specimens exposed to humid environments in New Zealand and Brazil absorbed the highest amount of moisture. The intense ultraviolet radiation environment in Hawaii caused the most damage to surface resin and fibers.

Residual strength tests were conducted to establish the effects of various environments on composite materials. In general, strength losses on the order of 25 percent were experienced. However, in some instances strength losses up to 40 percent occurred. The T300/2544 graphite/epoxy material was damaged the most by ultraviolet radiation and lost about 25 to 30 percent in strength and modulus. The other graphite reinforced composite materials did not sustain any significant loss in modulus. The only significant strength loss (15 to 25 percent) exhibited by the AS/3501 graphite/epoxy material occurred in the compression specimens after 3 and 5 years of exposure in New Zealand. The T300/P1700 graphite/polysulfone material exhibited a steady decline in short-beam shear strength, with a maximum loss of 38 percent after 9 years of exposure in New Zealand. The 250°F cure Kevlar-49/F-155 material exhibited a 20 to 30 percent loss in strength and modulus during the 10-year exposure period. The 350°F cure Kevlar-49/F-161 material exhibited a 10 to 20 percent loss in strength and modulus. The intense ultraviolet radiation in Hawaii caused the most degradation to the Kevlar reinforced composites.

Residual strength tests on composites that were exposed continuously for 5 years to aircraft fuels and fluids indicated strength losses ranging from 25 to 40 percent. The fuel/water mixture was the most degrading environment. Similar composite material specimens were stored in an office at NASA Langley for 10 years and residual strength tests did not indicate any significant strength or stiffness loss as a result of the office storage.

Quasi-isotropic graphite/epoxy tension specimens and bolted joints were subjected to sustained-tension load and outdoor exposure for up to 10 years. Sustained stress of 40 percent of baseline ultimate material strength did not significantly affect the residual tensile properties of graphite/epoxy. Sustained stress of 27 percent of design ultimate strength, along with 2.8 lifetimes of laboratory fatigue loading, did not significantly affect the strength of bolted joints after 7 years of outdoor exposure.

Over 300 composite components have been in service on rotorcraft and transport aircraft since the NASA-Langley flight service evaluation program was initiated in 1973. Over 4 million total component flight hours have been accumulated with the high-time aircraft component having more than 37,000 flight hours. Overall service performance has been excellent. However, a few design and manufacturing related problems have been encountered. Normal maintenance and in-service related damage such as ground handling damage, foreign object damage, and lightning strikes have occurred. Corrosion damage has been experienced on aluminum fittings and splices on some graphite/epoxy reinforced spoilers. Residual strength tests of spoilers with significant corrosion damage indicated strength losses up to 35 percent. Spoilers with no corrosion damage and 10 years of service with nearly 30,000 flight hours had residual strengths equivalent to baseline spoiler strength. Skin-to-core disbonds have been experienced on some Kevlar/epoxy reinforced honeycomb baggage doors for rotorcraft. Lack of adhesive and poor resin filleting caused strength reductions up to 50 percent.

In general, the composite aircraft components have performed better than comparable metallic components. Maintenance characteristics are superior to metal counterparts primarily because of less fatigue and corrosion problems with composite components. However, lightning strikes to composite components have required more repair than for comparable metal components. Moisture absorption for the flight service components is lower than the moisture absorbed for unpainted ground-based exposure specimens. In addition, residual strengths of composite components removed from service are as good or better than strength retention of unpainted ground-based exposure specimens.

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TABLE I.- DESCRIPTION OF WORLDWIDE GROUND-BASED EXPOSURE SPECIMENS

Material type	Material supplier	Nominal specimen thickness, in.			Fiber lay-up pattern*
		Flexure	Short-beam shear	Compression	
T300/5209 graphite/ epoxy	Union Carbide Corp./ Narmco Materials	0.081	0.120	0.170	0° tape
T300/2544 graphite/ epoxy	Union Carbide Corp.	0.070	0.104	0.138	0° tape
AS/3501 graphite/ epoxy	Hercules, Inc.	0.069	0.100	0.121	0° tape
K-49/F-155 Kevlar/ epoxy	E. I. Dupont, Inc./ Hexcel Corp.	0.122	0.121	0.050	(0/90) fabric
K-49/F-161 Kevlar/ epoxy	E. I. Dupont, Inc./ Hexcel Corp.	0.114	0.116	0.049	(0/90) fabric
T300/P1700 graphite/ polysulfone	Union Carbide Corp./ U.S. Polymeric	0.076	0.102	0.135	$(+75,-45,0_2,+45,-75)_s$ tape
T300/5208 graphite/ epoxy	Union Carbide Corp./ Narmco Materials	0.083	0.125	Not tested	0° tape

*The 0° fiber direction is oriented along the length of the test specimens.

TABLE II.- BASELINE FLEXURAL STRENGTH AND MODULUS OF COMPOSITE MATERIALS

Material type	Specimen number	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
T300/5209 Graphite/epoxy	1-106	0.5022	0.0858	266	218.0	14.9
	-107	.5037	.0794	213	203.5	14.7
	-108	.5021	.0810	253	233.5	15.4
	-109	.5032	.0756	218	231.1	15.1
	-110	.5019	.0736	199	223.1	15.3
				Average...	221.8	15.1
T300/2544 Graphite/epoxy	2-106	0.5007	0.0694	175	221.6	15.4
	-107	.5013	.0725	197	228.3	15.0
	-108	.5008	.0711	194	234.2	15.6
	-109	.5010	.0696	178	224.4	15.4
	-110	.5011	.0685	192	251.2	15.6
				Average...	231.9	15.4
AS/3501 Graphite/epoxy	3-106	0.5006	0.0710	156	189.3	12.6
	-107	.4998	.0684	167	219.4	14.2
	-108	.5007	.0718	162	192.1	13.3
	-109	.4995	.0674	167	226.9	13.8
	-110	.5007	.0679	168	222.6	14.7
				Average...	210.1	13.7
K-49/F-155 Kevlar/epoxy	4-098	0.998	0.1206	263	56.8	3.6
	-099	1.001	.1227	298	61.3	3.8
	-100	1.000	.1211	263	55.9	3.7
	-101	1.000	.1200	275	59.5	3.7
	-102	1.000	.1259	289	56.6	3.4
	-103	1.000	.1207	256	54.7	3.6
				Average...	57.5	3.6
K-49/F-161 Kevlar/epoxy	5-097	1.005	0.1130	215	51.9	3.5
	-098	1.003	.1127	235	57.1	3.8
	-099	1.001	.1133	214	51.7	3.4
	-100	1.001	.1116	223	55.8	3.7
	-101	1.000	.1138	233	55.7	3.4
				Average...	54.4	3.6
T300/P1700 Graphite/polysulfone	6-031	0.5033	0.0759	106	109.7	-
	-032	.5021	.0772	111	111.3	-
	-033	.5025	.0769	106	107.0	-
				Average...	109.3	-

TABLE II.- CONCLUDED

Material type	Specimen number	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
T300/5208 Graphite/epoxy	7-031	0.5088	0.0789	279	264.3	-
	-032	.5057	.0792	287	271.4	-
	-033	.5049	.0869	267	210.1	-
	-034	.5140	.0821	299	258.9	-
				Average...	251.2	-

TABLE III.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED T300/5209 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-076	1-year outdoor	0.5010	0.0841	240	205.5	14.3	0.28
-077		.5022	.0828	225	198.1	14.4	.24
-078		.5013	.0825	245	218.2	14.4	.34
				Average...	207.3	14.4	0.29
1-082	3-year outdoor	0.5029	0.0827	262	231.4	15.4	0.54
-083		.5031	.0824	250	226.7	14.8	.58
-084		.5009	.0818	284	230.2	15.0	.51
				Average...	229.4	15.1	0.54
1-079	5-year outdoor	0.5011	0.0840	275	236.1	14.9	0.70
-080		.5023	.0829	276	243.1	15.6	.67
-081		.5021	.0796	258	247.0	15.6	.70
				Average...	242.1	15.4	0.69
1-085	7-year outdoor	0.5035	0.0874	266	209.4	14.8	0.59
-086		.5023	.0795	239	228.9	15.4	.60
-087		.5012	.0833	267	233.2	14.7	.57
				Average...	223.8	15.0	0.59
1-088	10-year outdoor	0.5011	0.0827	247	218.5	15.0	0.55
-089		.5016	.0857	241	197.8	14.2	.61
-090		.5031	.0874	246	193.3	14.2	.57
				Average...	208.3	14.5	0.58
1-111	10-year office storage	0.5018	0.0803	221	207.0	15.4	-
-112		.5017	.0847	254	213.7	15.2	-
-113		.5028	.0809	220	202.8	14.7	-
-114		.5031	.0819	240	215.7	15.4	-
-115		.4994	.0848	236	198.6	15.2	-
-116		.5023	.0832	233	202.7	15.6	-
-117		.5024	.0765	200	206.7	14.8	-
-118		.5012	.0748	200	217.2	15.1	-
-119		.5034	.0858	264	215.6	15.3	-
-120		.5024	.0865	262	210.9	14.8	-
				Average...	209.1	15.2	-

TABLE III.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-001	1-year outdoor	0.5017	0.0813	220	200.9	15.6	0.34
-002		.5019	.0840	253	216.6	15.7	-
-003		.5039	.0842	266	225.6	15.6	.08
				Average...	214.4	15.6	0.21
1-004	3-year outdoor	0.5026	0.0777	246	247.8	15.8	0.52
-005		.5018	.0778	235	236.6	14.5	.61
-006		.5040	.0751	215	230.9	15.3	.56
				Average...	238.4	15.2	.56
1-007	5-year outdoor	0.5016	0.0757	216	229.5	14.7	0.64
-008		.5032	.0814	268	244.6	15.6	.53
-009		.5043	.0823	269	239.6	15.1	.52
				Average...	237.9	15.1	0.56
1-010	7-year outdoor	0.5020	0.0868	279	223.7	14.4	-
-011		.4993	.0849	273	230.0	15.1	0.52
-012		.4959	.0797	207	199.2	15.3	.49
				Average...	217.6	14.9	0.51
1-013	10-year outdoor	0.5029	0.0807	212	196.3	14.0	0.66
-014		.5024	.0818	205	184.5	13.6	.68
-015		.4985	.0854	261	217.4	15.3	.58
				Average...	199.4	14.3	0.64

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-031	1-year outdoor	0.5028	0.0839	239	204.8	15.2	0.33
-032		.5039	.0842	261	221.4	16.1	.35
-033		.4995	.0854	261	216.9	15.8	.37
				Average...	214.4	15.7	0.35
1-034	3-year outdoor	0.5018	0.0787	210	204.9	15.1	0.56
-035		.5033	.0792	212	203.8	14.8	.63
-036		.5023	.0834	225	194.8	15.1	.56
				Average...	201.2	15.0	0.58

TABLE III.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-037	5-year outdoor	0.5027	0.0822	258	231.1	14.7	0.61
-038		.5025	.0806	240	224.0	14.1	.66
-039		.4965	.0757	212	227.2	15.1	.80
				Average...	227.4	14.6	0.69
1-040	7-year outdoor	0.5014	0.0812	265	244.3	15.6	0.61
-041		.5031	.0783	209	205.9	13.7	.70
-042		.5017	.0838	274	236.5	14.8	-
				Average...	228.9	14.7	0.66
1-043	10-year outdoor	0.5032	0.0867	252	201.4	14.7	0.56
-044		.5026	.0787	228	222.5	15.1	.55
-045		.5020	.0819	218	195.8	14.3	.45
				Average...	206.6	14.7	0.52

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-046	1-year outdoor	0.5026	0.0784	233	229.7	15.6	-
-047		.5015	.0829	237	208.7	14.7	0.10
-048		.5023	.0831	232	203.6	12.7	.29
				Average...	214.0	14.3	0.20
1-049	3-year outdoor	0.4993	0.0764	225	235.9	15.4	0.47
-050		.5008	.0856	274	226.7	14.8	.47
-051		.5012	.0783	232	230.2	15.0	.50
				Average...	230.9	15.1	0.48
1-052	5-year outdoor	0.5024	0.0774	248	251.7	15.9	0.38
-053		.5032	.0797	197	186.8	13.8	.83
-054		.5019	.0754	230	246.7	15.6	.47
				Average...	228.4	15.1	0.56
1-055	7-year outdoor	0.5012	0.0794	252	243.5	15.8	0.53
-056		.5029	.0811	268	246.7	15.8	.54
-057		.5027	.0830	256	224.2	15.5	.50
				Average...	238.1	15.7	0.52

TABLE III.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-058	10-year outdoor	0.4968	0.0807	233	218.7	14.8	0.63
-059		.5005	.0779	223	222.9	15.6	.57
-060		.5003	.0807	202	187.4	14.8	.60
				Average...	209.7	15.1	0.60

(e) Exposed at Wellington, New Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-016	1-year outdoor	0.5019	0.0806	241	224.4	15.8	-
-017		.4985	.0804	238	224.1	15.7	0.13
-018		.4996	.0751	208	225.1	15.3	.41
				Average...	224.4	15.6	0.27
1-019	3-year outdoor	0.5027	0.0767	189	193.3	16.0	0.63
-020		.5029	.0768	190	193.8	15.8	.63
-021		.5024	.0826	226	199.5	15.5	.66
				Average...	195.5	15.8	0.64
1-022	5-year outdoor	0.5011	0.0812	200	182.8	14.9	0.81
-023		.5030	.0806	222	205.6	15.2	.77
-024		.5013	.0846	226	190.6	14.2	.80
				Average...	193.0	14.8	0.79
1-025	7-year outdoor	0.5025	0.0793	242	233.1	15.0	0.50
-026		.5039	.0775	217	218.3	13.9	.58
-027		.5019	.0846	236	198.9	14.2	.56
				Average...	216.8	14.4	0.55
1-028	10-year outdoor	0.5017	0.0827	230	203.0	14.5	0.76
-029		.5026	.0829	237	207.9	14.5	.72
-030		.5023	.0832	234	203.4	15.0	.65
				Average...	204.8	14.7	0.71

TABLE III.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
1-061	1-year outdoor	0.5017	0.0788	194	186.8	14.0	-
-062		.5022	.0828	260	226.5	15.2	0.30
-063		.5030	.0838	276	234.4	15.7	.28
				Average...	215.9	15.0	0.29
1-064	3-year outdoor	0.5019	0.0857	256	210.4	14.8	0.45
-065		.5025	.0746	205	224.1	14.5	.64
-066		.4988	.0792	218	211.6	15.3	.44
				Average...	215.4	14.9	0.51
1-067	5-year outdoor	0.5029	0.0826	252	222.8	15.1	0.83
-068		.4988	.0804	227	213.4	15.6	.93
-069		.5020	.0818	258	233.1	15.7	.92
				Average...	223.1	15.5	0.89
1-070	7-year outdoor	0.5022	0.0833	257	223.7	14.7	-
-071		.5034	.0844	275	232.6	14.9	0.75
-072		.5032	.0809	237	219.0	13.6	.80
				Average...	225.1	14.4	0.78
1-073	10-year outdoor	0.5023	0.0846	261	220.2	14.5	0.68
-074		.5026	.0831	256	224.0	14.0	.72
-075		.5013	.0858	284	233.2	14.6	.72
				Average...	225.8	14.4	0.71

TABLE IV.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED T300/2544 AFTER ENVIRONMENTAL EXPOSURE.

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-076	1-year outdoor	0.5012	0.0659	134	188.8	14.8	1.41
-077		.5017	.0707	183	223.4	15.4	1.26
-078		.5011	.0685	166	216.1	15.4	1.36
				Average...	209.4	15.2	1.34
2-082	3-year outdoor	0.5000	0.0708	183	224.1	15.2	1.81
-083		.5009	.0715	207	248.1	15.6	1.67
-084		.5011	.0660	153	215.7	14.3	1.92
				Average...	229.3	15.0	1.80
2-079	5-year outdoor	0.5013	0.0724	195	227.4	14.0	2.22
-080		.5017	.0728	193	222.2	15.0	2.04
-081		.5005	.0714	190	228.3	15.0	2.17
				Average...	226.0	14.7	2.14
2-085	7-year outdoor	0.5009	0.0678	139	185.9	13.0	1.99
-086		.5014	.0656	142	203.9	13.9	1.82
-087		.5015	.0670	142	195.0	13.4	1.71
				Average...	194.9	13.4	1.84
2-088	10-year outdoor	0.5015	0.0725	148	172.6	12.1	1.90
-089		.5025	.0714	140	168.4	11.8	1.74
-090		.5015	.0693	134	172.0	12.2	1.84
				Average...	171.0	12.0	1.83
2-111	10-year office storage	0.5008	0.0719	198	233.6	15.9	-
-112		.5011	.0696	188	237.7	15.0	-
-113		.5016	.0735	196	220.3	15.6	-
-114		.5004	.0638	162	245.8	15.7	-
-115		.5008	.0653	146	210.0	14.9	-
-116		.5021	.0713	195	233.5	15.5	-
-117		.5023	.0682	167	219.6	14.3	-
-118		.5017	.0727	220	254.1	16.0	-
-119		.5008	.0651	168	243.9	15.3	-
-120		.5013	.0701	195	242.8	15.9	-
				Average...	234.1	15.4	-

TABLE IV.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-001	1-year outdoor	0.5011	0.0694	165	208.7	15.6	0.88
-002		.5018	.0719	188	221.8	15.3	1.20
-003		.5025	.0700	191	238.1	15.8	0.66
				Average...	222.9	15.6	0.91
2-004	3-year outdoor	0.5008	0.0703	200	248.6	16.1	1.72
-005		.5005	.0695	185	235.4	15.0	1.76
-006		.5011	.0694	197	251.6	15.6	1.71
				Average...	245.2	15.6	1.73
2-007	5-year outdoor	0.5014	0.0728	206	238.5	14.9	1.75
-008		.5013	.0715	197	236.0	14.7	1.83
-009		.5010	.0716	202	241.1	15.3	1.84
				Average...	238.5	15.0	1.81
2-010	7-year outdoor	0.5012	0.0712	181	219.0	14.4	1.69
-011		.5020	.0709	179	218.6	14.0	1.55
-012		.5019	.0719	200	236.8	14.9	1.69
				Average...	224.8	14.4	1.64
2-013	10-year outdoor	0.5013	0.0723	176	206.1	14.0	2.03
-014		.5009	.0727	179	207.7	13.5	1.81
-015		.5008	.0710	156	189.9	12.8	1.90
				Average...	201.2	13.4	1.91

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-031	1-year outdoor	0.5016	0.0649	145	210.8	15.7	1.51
-032		.5017	.0719	171	200.2	15.5	1.36
-033		.5011	.0711	188	228.0	15.5	1.26
				Average...	213.0	15.6	1.38
2-034	3-year outdoor	0.5013	0.0662	164	229.8	15.0	1.86
-035		.5018	.0727	192	222.0	13.9	1.87
-036		.5014	.0723	203	237.1	15.6	1.83
				Average...	229.6	14.8	1.85

TABLE IV.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-037	5-year outdoor	0.5000	0.0738	195	219.5	13.7	2.01
-038		.5014	.0724	199	233.0	13.7	1.49
-039		.5000	.0730	173	198.3	14.1	2.06
				Average...	216.9	13.8	1.85
2-040	7-year outdoor	0.5013	0.0696	175	222.1	13.6	-
-041		.5014	.0710	179	218.3	12.7	1.72
-042		.5008	.0725	197	230.5	13.5	2.00
				Average...	223.6	13.3	1.86
2-043	10-year outdoor	0.5011	0.0718	163	193.9	12.6	1.71
-044		.5031	.0701	158	197.3	12.1	1.49
-045		.5008	.0660	128	182.7	12.2	1.83
				Average...	191.3	12.3	1.68

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-046	1-year outdoor	0.5017	0.0738	209	233.5	15.5	0.93
-047		.5012	.0702	194	241.1	15.8	1.12
-048		.5017	.0713	184	220.0	15.5	1.11
				Average...	231.5	15.6	1.05
2-049	3-year outdoor	0.5011	0.0720	208	246.4	15.3	1.63
-050		.5008	.0733	202	230.6	14.8	1.63
-051		.5009	.0720	200	235.9	15.5	1.64
				Average...	237.6	15.2	1.63
2-052	5-year outdoor	0.5013	0.0725	215	251.0	15.2	1.49
-053		.5018	.0714	203	243.5	15.3	1.49
-054		.5007	.0700	205	257.3	15.7	1.51
				Average...	250.6	15.4	1.50
2-055	7-year outdoor	0.5011	0.0719	206	244.0	16.0	1.78
-056		.5012	.0726	213	248.0	15.5	1.81
-057		.5010	.0691	173	221.9	15.7	1.87
				Average...	238.0	15.7	1.82

TABLE IV.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-058	10-year outdoor	0.5005	0.0721	193	227.7	13.6	1.87
-059		.5018	.0704	183	226.1	14.2	1.67
-060		.5015	.0708	182	221.7	14.3	1.74
				Average...	225.2	14.0	1.76

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-016	1-year outdoor	0.5014	0.0657	166	236.0	16.2	-
-017		.5008	.0715	194	232.4	15.6	0.84
-018		.5017	.0709	181	219.0	15.8	-
				Average...	229.1	15.9	0.84
2-019	3-year outdoor	0.5023	0.0719	182	213.3	15.6	2.28
-020		.5015	.0731	172	195.5	14.2	2.62
-021		.5025	.0655	151	215.7	14.2	2.39
				Average...	208.2	14.7	2.43
2-022	5-year outdoor	0.5005	0.0713	182	219.4	14.0	2.18
-023		.5012	.0714	185	221.7	14.8	2.22
-024		.5010	.0725	180	208.9	14.5	2.37
				Average...	216.7	14.4	2.26
2-025	7-year outdoor	0.5023	0.0642	141	211.4	12.8	1.60
-026		.5012	.0711	172	208.6	13.0	1.61
-027		.5004	.0722	177	208.8	12.2	1.65
				Average...	209.6	12.7	1.62
2-028	10-year outdoor	0.5010	0.0735	162	183.6	12.2	2.31
-029		.5016	.0718	165	196.4	12.7	2.01
-030		.5010	.0723	167	196.3	13.2	2.36
				Average...	192.1	12.7	2.23

TABLE IV.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
2-061	1-year outdoor	0.5008	0.0717	185	215.6	15.4	1.29
-062		.5014	.0677	164	214.1	14.1	1.49
-063		.5008	.0728	203	229.5	17.3	1.44
				Average...	219.7	15.6	1.41
2-064	3-year outdoor	0.5015	0.0717	190	226.2	14.4	2.14
-065		.5004	.0727	188	217.2	14.8	1.84
-066		.5008	.0648	151	221.3	14.7	2.10
				Average...	221.6	14.6	2.03
2-067	5-year outdoor	0.5011	0.0672	158	213.9	14.7	2.49
-068		.5013	.0662	148	206.8	16.0	2.98
-069		.5011	.0719	196	232.2	14.5	2.63
				Average...	217.6	15.1	2.70
2-070	7-year outdoor	0.5005	0.0667	152	210.4	13.5	1.99
-071		.5016	.0665	152	210.9	14.0	2.00
-072		.5012	.0704	187	230.4	15.0	1.92
				Average...	217.2	14.2	1.97
2-073	10-year outdoor	0.5014	0.0696	158	200.2	13.8	2.27
-074		.5004	.0725	183	212.8	14.4	2.28
-075		.5018	.0706	164	201.4	13.3	2.28
				Average...	204.8	13.8	2.28

TABLE V.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED AS/3501 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-076	1-year outdoor	0.5001	0.0694	180	230.7	14.4	-
-077		.5009	.0683	156	204.6	13.9	0.38
-078		.5006	.0678	146	194.2	14.5	0.68
				Average...	209.8	14.3	0.53
3-082	3-year outdoor	0.5000	0.0677	180	243.1	14.1	1.04
-083		.5005	.0700	226	287.2	14.8	1.04
-084		.5005	.0662	166	234.0	14.2	1.09
				Average...	254.8	14.4	1.06
3-079	5-year outdoor	0.4994	0.0669	190	264.1	14.4	1.19
-080		.5005	.0725	165	191.5	13.6	1.57
-081		.5019	.0648	193	286.9	14.6	1.30
				Average...	247.5	14.2	1.35
3-085	7-year outdoor	0.5000	0.0663	177	249.6	13.7	1.20
-086		.5001	.0649	192	282.2	15.9	0.92
-087		.4995	.0664	175	246.0	14.0	1.15
				Average...	259.3	14.5	1.09
3-088	10-year outdoor	0.5006	0.0670	166	227.7	13.6	1.18
-089		.5007	.0668	185	257.3	13.7	1.01
-090		.5015	.0697	208	265.1	13.2	1.05
				Average...	250.0	13.5	1.08
3-112	10-year office storage	0.5010	0.0664	183	257.7	13.9	-
-113		.5011	.0706	222	275.6	14.5	-
-114		.4996	.0687	170	222.0	13.2	-
-115		.4996	.0668	178	246.9	14.8	-
-116		.5004	.0685	160	209.4	13.4	-
-118		.5004	.0676	187	253.6	14.5	-
-119		.5010	.0676	199	269.2	14.9	-
-120		.5002	.0674	179	243.3	14.2	-
				Average...	247.2	14.2	-

TABLE V.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-001	1-year outdoor	0.5008	0.0701	-	-	14.5	0.66
-002		.5001	.0700	177	221.6	14.8	.61
-003		.5006	.0714	182	218.8	14.3	-
				Average...	220.2	14.5	0.64
3-004	3-year outdoor	0.5004	0.0720	206	244.9	14.1	0.99
-005		.4999	.0675	183	249.1	14.2	1.02
-006		.4995	.0682	183	244.0	14.0	1.06
				Average...	246.0	14.1	1.02
3-007	5-year outdoor	0.5002	0.0677	186	251.6	14.2	1.15
-008		.5008	.0672	195	267.9	14.7	1.09
-009		.5025	.0670	177	241.7	14.8	1.18
				Average...	253.7	14.6	1.14
3-010	7-year outdoor	0.4998	0.0638	155	234.9	14.6	0.82
-011		.5000	.0704	201	250.4	13.8	.84
-012		.5005	.0732	204	234.9	12.7	.84
				Average...	240.1	13.7	0.83
3-013	10-year outdoor	0.5000	0.0680	181	242.8	13.0	1.12
-014		.4998	.0653	181	264.9	14.1	1.11
-015		.4999	.0673	185	253.3	13.8	1.06
				Average...	253.7	13.6	1.10

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-031	1-year outdoor	0.5008	0.0688	145	187.0	13.9	0.68
-032		.5004	.0670	156	213.6	14.3	.70
-033		.5011	.0677	155	207.5	13.9	.70
				Average...	202.7	14.0	0.69
3-034	3-year outdoor	0.5003	0.0749	221	242.3	13.6	1.09
-035		.5000	.0678	170	227.6	14.2	1.22
-036		.5008	.0725	206	241.5	13.5	1.13
				Average...	237.1	13.8	1.15

TABLE V.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-037	5-year outdoor	0.5010	0.0704	188	234.1	12.9	1.14
-038		.5003	.0670	194	268.7	15.7	1.07
-039		.5011	.0685	188	247.9	14.3	1.09
				Average...	250.2	14.3	1.10
3-040	7-year outdoor	0.5012	0.0672	212	293.8	13.5	-
-041		.5005	.0754	242	262.9	13.1	0.94
-042		.5006	.0682	207	277.4	13.5	.96
				Average...	278.0	13.4	0.95
3-043	10-year outdoor	0.5005	0.0690	186	242.8	12.5	1.05
-044		.5012	.0682	187	249.2	13.3	0.98
-045		.5008	.0674	174	236.4	13.0	1.03
				Average...	242.8	12.9	1.02

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-046	1-year outdoor	0.5008	0.0668	177	244.2	14.4	0.55
-047		.5002	.0753	187	201.5	13.4	.60
-048		.5006	.0685	167	219.1	14.0	.53
				Average...	221.6	13.9	0.56
3-049	3-year outdoor	0.5009	0.0714	206	249.7	13.7	0.99
-050		.5006	.0663	174	245.8	13.7	.99
-051		.5006	.0674	184	251.0	14.1	.99
				Average...	248.8	13.8	0.99
3-052	5-year outdoor	0.5002	.0673	201	275.6	15.1	0.95
-053		.5014	.0746	-	-	-	.94
-054		.5004	.0686	205	270.1	14.6	.91
				Average...	272.9	14.8	0.93
3-055	7-year outdoor	0.5008	0.0682	-	-	-	1.01
-056		.5000	.0750	233	255.0	14.3	0.95
-057		.4997	.0749	238	261.8	14.4	.95
				Average...	258.4	14.4	0.97

TABLE V.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-058	10-year outdoor	0.4998	0.0691	182	234.2	13.8	1.11
-059		.5003	.0715	-	-	-	1.08
-060		.5010	.0693	195	250.9	13.2	1.21
				Average...	242.6	13.5	1.13

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-016	1-year outdoor	0.5018	0.0695	186	236.7	14.2	-
-017		.5002	.0700	169	211.2	14.6	0.64
-018		.4997	.0644	140	213.3	14.8	.16
				Average...	220.4	14.5	0.40
3-019	3-year outdoor	0.5005	0.0728	180	207.5	13.4	1.42
-020		.5007	.0645	140	205.7	15.5	1.44
-021		.5003	.0679	168	224.3	13.9	1.43
				Average...	212.5	14.3	1.43
3-022	5-year outdoor	0.4998	0.0710	190	231.3	14.5	1.31
-023		.5001	.0704	189	234.3	14.3	1.16
-024		.5001	.0675	148	199.6	13.8	1.30
				Average...	221.7	14.2	1.26
3-025	7-year outdoor	0.5004	0.0674	183	249.6	13.1	0.90
-026		.5011	.0735	217	248.2	12.2	.87
-027		.5000	.0694	176	225.8	12.7	.89
				Average...	241.2	12.7	0.88
3-028	10-year outdoor	0.5018	0.0683	195	258.1	14.0	1.22
-029		.4996	.0682	196	262.7	13.5	1.16
-030		.5002	.0666	188	263.5	13.9	1.26
				Average...	261.4	13.8	1.21

TABLE V.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
3-061	1-year outdoor	0.5022	0.0653	170	238.2	15.0	0.71
-062		.5007	.0675	175	230.1	14.0	.77
-063		.5004	.0677	165	215.8	15.1	.81
				Average...	228.0	14.7	0.76
3-064	3-year outdoor	0.5004	0.0696	193	246.5	13.7	1.05
-065		.5000	.0687	193	254.2	13.7	1.01
-066		.5005	.0686	185	242.9	14.2	1.00
				Average...	247.9	13.9	1.02
3-067	5-year outdoor	0.5004	0.0671	167	223.1	13.7	1.55
-068		.5007	.0678	209	287.9	15.5	1.46
-069		.5009	.0671	185	231.9	12.8	1.47
				Average...	247.6	14.0	1.49
3-070	7-year outdoor	0.5005	0.0702	215	270.2	14.1	1.20
-071		.4997	.0677	203	276.4	13.8	1.19
-072		.5008	.0678	191	257.7	13.5	1.21
				Average...	268.1	13.8	1.20
3-073	10-year outdoor	0.5007	0.0684	206	273.6	14.2	1.15
-074		.4998	.0655	189	276.0	13.8	1.18
-075		.4998	.0673	186	255.5	13.4	1.30
				Average...	268.4	13.8	1.21

TABLE VI.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED K-49/F-155 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-076	1-year outdoor	0.999	0.1206	252	53.6	3.5	1.56
-077		1.001	.1198	251	53.9	3.4	1.60
-078		0.999	.1208	252	53.2	3.5	1.62
				Average...	53.6	3.5	1.59
4-082	3-year outdoor	0.999	0.1286	279	51.7	3.1	1.85
-083		0.998	.1234	270	55.0	3.4	1.85
-084		1.000	.1207	251	53.4	3.4	1.89
				Average...	53.4	3.3	1.86
4-079	5-year outdoor	1.000	0.1256	255	49.5	3.0	2.14
-080		0.998	.1212	245	51.7	2.9	2.04
-081		1.000	.1258	257	49.7	3.1	2.16
				Average...	50.3	3.0	2.11
4-085	7-year outdoor	0.999	0.1224	263	54.7	3.1	2.20
-086		0.999	.1207	252	53.9	3.1	2.33
-087		1.001	.1283	257	47.6	2.2	2.38
				Average...	52.1	2.8	2.30
4-088	10-year outdoor	0.999	0.1207	228	48.5	2.9	2.19
-089		1.001	.1202	227	48.7	2.9	2.20
-090		1.000	.1254	220	42.5	2.7	2.21
				Average...	46.6	2.8	2.20
4-091	10-year office storage	0.999	0.1223	275	57.4	3.4	-
-092		.996	.1214	266	56.1	3.6	-
-093		.996	.1248	270	53.5	3.4	-
-094		.999	.1213	261	54.8	3.5	-
-095		.997	.1228	283	58.9	3.5	-
				Average...	56.1	3.5	-

TABLE VI.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-001	1-year outdoor	1.003	0.1199	248	53.0	3.4	1.52
-002		1.001	.1275	272	51.1	3.4	1.60
-003		1.001	.1258	265	51.2	3.4	1.67
				Average...	51.8	3.4	1.60
4-004	3-year outdoor	0.997	0.1211	269	57.3	3.5	1.73
-005		1.001	.1277	284	53.4	3.2	1.80
-006		1.001	.1267	270	51.3	3.3	1.81
				Average...	54.0	3.3	1.78
4-007	5-year outdoor	1.000	0.1200	248	53.7	3.1	2.10
-008		1.001	.1265	250	47.5	3.1	2.10
-009		1.002	.1275	260	48.6	3.1	2.09
				Average...	49.9	3.1	2.10
4-010	7-year outdoor	1.003	0.1260	242	46.2	3.0	2.23
-011		1.002	.1247	246	48.1	3.2	2.23
-012		1.001	.1206	247	52.7	3.1	2.24
				Average...	49.0	3.1	2.23
4-013	10-year outdoor	1.001	0.1272	228	43.2	2.8	2.27
-014		1.002	.1251	222	43.5	2.9	2.29
-015		1.003	.1205	227	48.3	3.0	2.17
				Average...	45.0	2.9	2.24

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-031	1-year outdoor	1.000	0.1256	257	49.8	3.4	1.75
-032		1.001	.1284	255	47.2	3.4	1.77
-033		1.000	.1263	257	49.2	3.2	1.68
				Average...	48.7	3.3	1.73
4-034	3-year outdoor	1.001	0.1247	251	49.4	3.1	2.02
-035		1.001	.1248	247	48.2	3.2	2.02
-036		1.000	.1265	249	47.5	3.2	2.00
				Average...	48.4	3.2	2.01

TABLE VI.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-037	5-year	0.999	0.1259	241	46.4	3.0	2.16
-038	outdoor	0.999	.1209	233	48.8	3.0	2.23
-039		1.001	.1256	235	45.4	2.9	2.20
				Average...	46.9	3.0	2.20
4-040	7-year	0.999	0.1246	236	47.2	2.5	2.24
-041	outdoor	.999	.1192	223	48.5	2.9	2.41
-042		.999	.1262	232	44.3	2.5	2.39
				Average...	46.7	2.6	2.35
4-043	10-year	1.000	0.1246	213	42.1	2.7	2.27
-044	outdoor	1.000	.1211	220	46.4	2.8	2.24
-045		1.000	.1260	211	40.5	2.6	2.27
				Average...	43.0	2.7	2.26

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-046	1-year	0.999	0.1222	272	56.3	3.5	1.54
-047	outdoor	0.998	.1209	268	56.8	3.5	1.57
-048		1.001	.1264	279	53.4	3.5	1.67
				Average...	55.5	3.5	1.59
4-049	3-year	1.001	0.1240	281	56.4	3.2	1.62
-050	outdoor	0.999	.1219	275	58.3	3.3	1.59
-051		0.999	.1203	260	55.7	3.4	1.59
				Average...	56.8	3.3	1.60
4-052	5-year	1.001	0.1266	269	51.4	2.9	1.79
-053	outdoor	1.002	.1260	267	51.7	3.0	1.86
-054		1.000	.1254	266	52.0	3.0	1.80
				Average...	51.7	3.0	1.82
4-055	7-year	1.002	0.1252	258	50.5	3.0	2.22
-056	outdoor	1.000	.1275	283	53.4	2.9	2.15
-057		1.000	.1204	254	54.3	3.0	2.15
				Average...	52.7	3.0	2.17

TABLE VI.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-058	10-year outdoor	1.001	0.1260	252	48.5	3.2	2.09
-059		1.000	.1267	254	48.3	3.2	2.15
-060		0.999	.1203	250	53.9	3.2	2.20
				Average...	50.2	3.2	2.15

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-016	1-year outdoor	0.997	0.1216	262	54.8	3.4	1.61
-017		1.003	.1256	267	51.6	3.3	1.72
-018		1.000	.1243	269	53.3	3.5	1.68
				Average...	53.2	3.4	1.67
4-019	3-year outdoor	1.000	0.1257	256	49.6	3.1	2.04
-020		1.000	.1250	265	52.1	3.4	2.04
-021		1.001	.1256	260	50.4	3.2	2.04
				Average...	50.7	3.2	2.04
4-022	5-year outdoor	1.003	0.1255	244	47.2	3.1	2.30
-023		1.000	.1250	240	46.9	3.0	2.31
-024		1.001	.1202	228	47.9	2.5	2.29
				Average...	47.3	2.9	2.30
4-025	7-year outdoor	0.999	0.1210	236	50.0	2.7	2.36
-026		1.001	.1258	244	47.0	2.7	2.37
-027		0.999	.1218	248	52.1	3.0	2.34
				Average...	49.7	2.8	2.36
4-028	10-year outdoor	0.999	0.1196	222	48.2	2.8	2.51
-029		1.000	.1275	222	41.5	2.8	2.63
-030		1.000	.1206	230	49.3	2.9	2.56
				Average...	46.3	2.8	2.57

TABLE VI. CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
4-061	1-year outdoor	0.997	0.1216	260	52.9	-	1.67
-062		1.000	.1254	263	50.2	-	1.87
-063		1.002	.1254	268	51.0	-	2.01
				Average...	51.4	-	1.85
4-064	3-year outdoor	0.999	0.1256	253	49.2	3.3	2.08
-065		1.001	.1210	243	51.7	3.4	2.08
-066		1.002	.1209	248	52.8	3.3	2.10
				Average...	51.2	3.3	2.09
4-067	5-year outdoor	1.001	0.1253	249	48.3	3.1	2.21
-068		1.000	.1258	262	50.7	3.3	2.46
-069		1.003	.1265	263	50.0	3.5	2.46
				Average...	49.7	3.3	2.38
4-070	7-year outdoor	1.001	0.1257	243	46.4	2.9	2.55
-071		0.999	.1206	237	49.8	3.0	2.56
-072		0.999	.1275	241	44.9	2.8	2.51
				Average...	47.0	2.9	2.54
4-073	10-year outdoor	0.999	0.1257	222	42.8	2.9	2.64
-074		0.999	.1204	229	49.0	3.1	2.70
-075		1.000	.1198	230	49.8	3.0	2.64
				Average...	47.2	3.0	2.66

TABLE VII.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED K-49/F-161 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-076	1-year outdoor	1.002	0.1139	220	51.9	3.6	1.67
-077		0.997	.1136	222	53.0	3.6	1.58
-078		1.003	.1123	219	53.2	3.8	1.56
				Average...	52.7	3.7	1.60
5-082	3-year outdoor	1.002	0.1131	235	57.2	3.7	2.11
-083		1.000	.1134	208	49.8	3.5	2.16
-084		1.000	.1131	230	55.9	3.7	2.16
				Average...	54.3	3.6	2.14
5-079	5-year outdoor	1.003	0.1131	210	50.7	3.2	2.41
-080		1.002	.1129	216	52.2	3.3	2.38
-081		1.003	.1126	209	50.9	3.1	2.38
				Average...	51.3	3.2	2.39
5-085	7-year outdoor	0.996	0.1162	227	52.2	3.2	2.33
-086		0.998	.1137	218	52.3	3.4	2.35
-087		1.001	.1158	213	48.9	3.2	2.38
				Average...	51.1	3.3	2.35
5-088	10-year outdoor	0.999	0.1145	210	49.9	3.0	2.28
-089		1.001	.1138	196	46.8	3.0	2.32
-090		0.999	.1177	231	52.1	3.0	2.32
				Average...	49.6	3.0	2.31
5-091	10-year office storage	0.999	0.1179	249	55.5	3.7	-
-092		1.002	.1123	216	52.6	3.5	-
-093		1.000	.1163	241	55.0	3.6	-
-094		1.000	.1169	240	54.1	4.0	-
				Average...	54.3	3.7	-

TABLE VII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-001 -002 -003	1-year outdoor	1.001 1.002 1.002	0.1133 .1122 .1140	218 220 232	52.1 53.6 54.6	3.7 3.8 3.9	1.71 1.46 1.50
				Average...	53.4	3.8	1.56
5-004 -005 -006	3-year outdoor	1.000 1.002 0.999	0.1176 .1120 .1178	241 220 246	53.8 54.1 54.9	3.8 3.8 3.6	1.95 2.02 1.99
				Average...	54.3	3.7	1.99
5-007 -008 -009	5-year outdoor	0.997 1.001 0.999	0.1198 .1147 .1168	245 225 245	53.1 53.1 55.7	3.2 3.3 3.4	2.18 2.26 2.07
				Average...	54.0	3.3	2.17
5-010 -011 -012	7-year outdoor	1.004 1.002 1.000	0.1137 .1145 .1128	204 206 216	48.6 48.2 52.6	3.2 3.3 3.6	2.26 2.21 2.25
				Average...	49.8	3.4	2.24
5-013 -014 -015	10-year outdoor	1.000 1.002 1.003	0.1145 .1117 .1128	202 196 198	47.6 48.4 47.8	3.2 3.4 3.3	2.25 2.22 2.26
				Average...	47.9	3.3	2.24

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-031 -032 -033	1-year outdoor	0.999 0.999 1.002	0.1144 .1137 .1132	219 218 221	51.4 51.7 52.9	3.6 3.9 3.7	1.77 1.75 1.73
				Average...	52.0	3.7	1.75
5-034 -035 -036	3-year outdoor	1.002 1.003 0.996	0.1121 .1139 .1143	212 218 218	52.2 51.7 52.1	3.5 3.4 3.3	2.21 2.18 2.15
				Average...	52.0	3.4	2.18

TABLE VII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-037	5-year outdoor	1.001	0.1139	220	52.8	3.2	2.29
-038		1.004	.1129	206	49.7	3.2	2.33
-039		0.996	.1145	216	51.2	3.2	2.19
				Average...	51.2	3.2	2.27
5-040	7-year outdoor	1.000	0.1131	216	52.5	3.1	2.37
-041		1.002	.1120	196	48.1	2.9	2.31
-042		1.002	.1180	226	50.1	2.9	2.36
				Average...	50.2	3.0	2.35
5-043	10-year outdoor	0.997	0.1173	222	50.3	3.2	2.24
-044		1.002	.1142	203	48.2	3.4	2.33
-045		0.996	.1177	225	50.6	3.1	2.30
				Average...	49.7	3.2	2.29

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-046	1-year outdoor	1.000	0.1131	234	56.5	3.7	1.47
-047		1.000	.1171	247	55.4	3.7	1.55
-048		1.002	.1119	233	57.4	3.7	1.39
				Average...	56.4	3.7	1.47
5-049	3-year outdoor	1.002	0.1172	238	53.6	3.6	1.87
-050		1.002	.1125	227	55.6	3.6	1.92
-051		1.002	.1129	229	55.6	3.7	1.91
				Average...	54.9	3.6	1.90
5-052	5-year outdoor	1.000	0.1170	234	52.7	3.2	2.03
-053		1.003	.1119	217	53.6	3.0	2.16
-054		1.003	.1120	217	53.6	3.1	2.13
				Average...	53.3	3.1	2.11
5-055	7-year outdoor	1.000	0.1139	228	54.5	3.2	2.40
-056		1.001	.1129	216	52.4	3.2	-
-057		1.002	.1177	237	52.8	3.1	2.28
				Average...	53.2	3.2	2.34

TABLE VII.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-058	10-year outdoor	1.000	0.1134	218	52.5	3.5	2.32
-059		1.004	.1121	206	50.4	3.4	2.32
-060		1.000	.1127	210	51.1	3.5	2.36
				Average...	51.3	3.5	2.33

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-016	1-year outdoor	1.002	0.1188	244	53.0	3.5	1.55
-017		1.001	.1120	227	55.8	3.7	1.59
-018		1.000	.1129	227	54.9	3.7	1.50
				Average...	54.6	3.6	1.55
5-019	3-year outdoor	1.000	0.1137	218	52.0	3.3	2.31
-020		1.001	.1147	229	53.8	3.6	2.32
-021		1.001	.1126	219	53.4	3.6	2.38
				Average...	53.1	3.5	2.34
5-022	5-year outdoor	1.003	0.1165	225	51.2	3.2	2.51
-023		0.996	.1144	209	49.5	3.5	2.52
-024		0.999	.1189	228	49.9	2.8	2.39
				Average...	50.2	3.2	2.47
5-025	7-year outdoor	1.001	0.1141	217	51.8	2.9	2.35
-026		1.001	.1147	214	50.2	3.1	2.41
-027		1.000	.1183	240	53.4	3.3	2.35
				Average...	51.8	3.1	2.37
5-028	10-year outdoor	0.999	0.1137	218	52.6	3.3	2.67
-029		1.000	.1181	218	48.4	3.0	2.60
-030		0.996	.1189	227	49.7	3.2	2.62
				Average...	50.2	3.2	2.63

TABLE VII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
5-061	1-year outdoor	1.003	0.1140	220	50.6	-	1.78
-062		1.001	.1132	233	54.5	-	1.68
-063		0.998	.1142	225	51.9	-	1.78
				Average...	52.3	-	1.75
5-064	3-year outdoor	1.004	0.1120	205	50.3	3.6	2.17
-065		1.004	.1120	205	50.3	3.8	2.22
-066		0.997	.1126	211	51.7	3.6	2.19
				Average...	50.8	3.7	2.19
5-067	5-year outdoor	1.005	0.1164	242	55.0	3.7	2.61
-068		1.001	.1124	204	49.7	3.5	2.64
-069		0.997	.1138	222	53.4	3.5	2.58
				Average...	52.7	3.6	2.61
5-070	7-year outdoor	1.001	0.1167	223	49.7	3.4	-
-071		1.005	.1130	197	46.6	3.2	2.67
-072		1.000	.1137	222	52.3	3.4	2.47
				Average...	49.5	3.3	2.57
5-073	10-year outdoor	0.999	0.1125	203	49.7	3.3	2.64
-074		1.000	0.1140	211	50.3	3.3	2.63
				Average...	50.0	3.3	2.64

TABLE VIII.- FLEXURAL STRENGTH AND MODULUS OF UNPAINTED T300/P1700 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-083	1.7-year outdoor	0.5013	0.0755	112	121.8	5.9
-084		0.5019	.0765	114	121.1	5.5
				Average...	121.4	5.7
6-079	3.7-year outdoor	0.5028	0.0632	61	95.9	-
-080		.5022	.0762	91	95.5	5.8
-081		.5003	.0751	101	111.1	5.4
				Average...	100.8	5.6
6-085	5.7-year outdoor	0.4989	0.0752	114	125.8	5.8
-086		.5025	.0758	107	114.8	5.6
-087		.5022	.0761	108	114.5	6.0
				Average...	118.4	5.8
6-088	8.8-year outdoor	0.5014	0.0758	97	103.7	5.5
-089		.5027	.0759	102	108.8	5.5
-090		.5018	.0770	107	111.4	5.2
				Average...	108.0	5.4
6-001	10-year office storage	0.5027	0.0762	107	113.4	5.6
-002		.5008	.0738	91	102.9	5.6
-003		.5032	.0752	101	109.5	5.9
-016		.5039	.0758	106	113.3	5.7
-017		.5037	.0762	95	99.8	5.6
-018		.5022	.0756	101	108.7	5.6
-047		.5003	.0758	96	103.7	5.1
-048		.4979	.0748	106	118.2	5.8
-111		.5019	.0761	104	110.7	5.6
-112		.5022	.0767	105	109.5	5.8
-113		.5039	.0761	110	117.1	5.7
-114		.5029	.0774	103	105.2	5.8
-115		.5018	.0741	93	104.5	5.6
-116		.5008	.0764	111	117.7	5.7
-117		.5030	.0755	112	121.7	5.6
-118		.5015	.0767	114	120.0	5.7
-119		.4989	.0733	93	107.5	5.5
-120		.5023	.0751	105	114.8	5.8
				Average...	111.0	5.6

TABLE VIII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-004	1.7-year outdoor	0.5016	0.0759	118	127.9	5.7
-005		.5028	.0763	116	123.0	5.8
-006		.5028	.0758	112	120.2	6.1
				Average...	123.7	5.9
6-007	3.7-year outdoor	0.5014	0.0652	62	90.6	4.9
-008		.5039	.0757	102	108.9	5.7
-009		.5012	.0758	108	116.0	5.9
				Average...	105.2	5.5
6-010	5.7-year outdoor	0.5017	0.0768	105	109.4	5.8
-011		.5036	.0753	99	107.5	5.2
-012		.5019	.0761	111	118.8	5.4
				Average...	111.9	5.5
6-013	8.8-year outdoor	0.5038	0.0757	107	115.1	5.3
-014		.5037	.0772	118	122.5	5.4
-015		.4962	.0722	98	119.5	4.9
				Average...	119.0	5.2

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-034	1.7-year outdoor	0.5039	0.0758	102	108.6	5.9
-035		.5026	.0771	111	115.5	5.5
-036		.5038	.0771	106	109.4	5.6
				Average...	111.2	5.7
6-037	3.7-year outdoor	0.5037	0.0750	117	128.7	6.0
-038		.5014	.0759	107	114.5	5.8
-039		.5032	.0766	87	90.1	5.5
				Average...	111.1	5.8

TABLE VIII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-040	5.7-year outdoor	0.5037	0.0759	102	108.5	5.7
-041		.5054	.0759	120	128.7	5.6
-042		.5022	.0737	100	114.1	5.5
				Average...	117.1	5.6
6-043	8.8-year outdoor	0.5021	0.0757	114	123.4	5.5
-044		.5018	.0764	112	118.7	5.5
				Average...	121.1	5.5

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-049	1.7-year outdoor	0.5024	0.0755	110	119.5	5.7
-050		.5036	.0760	109	116.4	5.6
-051		.5020	.0751	98	106.6	5.9
				Average...	114.2	5.7
6-052	3.7-year outdoor	0.5023	0.0762	103	108.7	5.9
-053		.5034	.0761	103	108.9	5.8
-054		.5022	.0765	102	107.2	5.5
				Average...	108.3	5.7
6-055	5.7-year outdoor	0.5052	0.0754	118	128.2	5.9
-056		.5023	.0757	111	119.7	5.9
-057		.5038	.0757	114	122.8	5.9
				Average...	123.6	5.9
6-058	8.8-year outdoor	0.5039	0.0754	96	103.2	5.5
-059		.5022	.0753	95	102.6	5.7
-060		.5050	.0749	108	118.3	5.8
				Average...	108.0	5.7

TABLE VIII.- CONTINUED

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-019	1.7-year outdoor	0.5012	0.0754	106	116.5	5.2
-020		.5020	.0742	98	110.1	5.5
-021		.5038	.0757	108	116.1	5.7
				Average...	114.2	5.5
6-022	3.7-year outdoor	0.5026	0.0765	112	118.1	5.7
-023		.5041	.0752	101	109.6	5.6
-024		.5027	.0770	110	113.9	5.8
				Average...	113.9	5.7
6-025	5.7 year outdoor	0.5028	0.0751	104	113.5	5.7
-026		.5038	.0767	114	119.1	5.8
-027		.5019	.0623	58	94.0	4.6
				Average...	108.9	5.4
6-028	8.8-year outdoor	0.5023	0.0752	94	101.7	5.7
-030		.5029	.0777	120	122.8	5.6
				Average...	112.2	5.6

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-061	1-year outdoor	0.5046	0.0751	103	108.6	5.7
-062		.5038	.0758	113	117.1	5.8
-063		.5012	.0754	102	107.4	5.9
				Average...	111.0	5.8
6-064	2.5-year outdoor	0.5034	0.0628	57	90.4	4.8
-065		.5030	.0753	105	114.2	5.7
-066		.5025	.0769	99	102.3	5.8
				Average...	102.3	5.4
6-068	4.3-year outdoor	0.5028	0.0758	106	113.3	6.4
-069		.4969	.0751	114	126.6	5.9
				Average...	120.0	6.2

TABLE VIII.- CONCLUDED

(f) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi
6-070	5.7-year outdoor	0.5027	0.0752	92	99.5	5.4
-071		.5031	.0750	101	110.4	5.5
-072		.5038	.0692	70	89.3	5.3
				Average...	99.7	5.4
6-074	9.5-year outdoor	0.5044	0.0764	100	104.5	5.2
-075		.5029	.0756	100	107.1	5.7
				Average...	105.8	5.4

TABLE IX.- FLEXURAL STRENGTH, MODULUS, AND MOISTURE CONTENT OF UNPAINTED T300/5208 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-072	10-year office storage	0.5024	0.0780	246	244.1	18.6	Not determined
-073		.5040	.0781	246	242.9	18.6	
-074		.5024	.0805	275	254.0	18.9	
-075		.4931	.0817	275	253.3	18.6	
-076		.5105	.0827	275	238.2	18.4	
-078		.5008	.0828	258	227.4	17.6	
-079		.5036	.0820	275	246.2	18.2	
-080		.4904	.0805	243	231.8	17.6	
-084		.4970	.0850	253	213.0	16.7	
-093		.5042	.0818	259	232.7	17.5	
-099		.5043	.0854	285	234.7	17.3	
-100		.4783	.0850	258	225.6	18.0	
-101		.5020	.0833	267	231.7	18.3	
-102		.5038	.0828	258	226.1	16.8	
-103		.5034	.0837	263	225.6	17.5	
-104		.5046	.0875	293	229.0	17.6	
-107		.5118	.0830	272	233.5	18.4	
-108		.5023	.0860	280	227.7	18.0	
-109		.5050	.0825	258	227.2	17.9	
-110		.5074	.0830	265	229.5	18.6	
				Average...	233.7	18.0	-

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-001	1.7-year outdoor	0.5079	0.0818	303	270.5	18.7	0.56
-002		.5128	.0834	340	289.6	19.0	.57
-003		.5055	.0797	294	278.5	18.4	.57
				Average...	279.5	18.7	0.57
7-036	2.7-year outdoor	0.5059	0.0789	258	248.6	18.5	0.58
-037		.4696	.0725	216	267.2	18.4	.65
-038		.4983	.0767	272	283.1	18.4	.64
				Average...	266.3	18.4	0.62
7-039	4.7-year outdoor	0.5084	0.0795	277	261.5	18.8	0.61
-040		.4976	.0770	241	248.0	18.1	.50
-041		.4985	.0805	268	253.1	17.8	.53
				Average...	254.2	18.2	0.55

TABLE IX.- CONTINUED

(b) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-004	8.8-year outdoor	0.5084	0.0804	295	272.9	18.2	0.66
-005		.5048	.0807	282	260.1	18.2	.69
-006		.5060	.0807	298	274.6	18.6	.66
				Average...	269.2	18.3	0.67

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-013	1.7-year outdoor	0.5072	0.0807	292	268.4	18.6	0.62
-014		.5023	.0785	273	268.0	18.5	.64
-015		.5110	.0806	296	270.7	19.2	.59
				Average...	269.0	18.8	0.62
7-048	2.7-year outdoor	0.4966	0.0817	315	289.0	19.1	0.62
-049		.4954	.0801	313	298.0	19.0	.62
-050		.5052	.0760	251	261.6	18.8	.72
				Average...	282.9	19.0	0.65
7-051	4.7-year outdoor	0.5047	0.0744	225	245.9	16.8	0.57
-052		.5066	.0814	277	249.7	19.0	.57
-053		.4914	.0820	297	272.8	18.9	.59
				Average...	256.1	18.2	0.58
7-016	8.8-year outdoor	0.5065	0.0807	304	280.3	18.5	0.61
-017		.5039	.0870	302	239.7	16.7	.74
-018		.5048	.0794	288	275.6	21.8	-
				Average...	265.2	19.0	0.68

TABLE IX.- CONTINUED

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-019	1.7-year outdoor	0.5060	0.0785	282	275.0	19.3	0.49
-020		.5084	.0780	275	271.0	19.1	.52
-021		.5077	.0810	301	274.5	19.0	.55
				Average...	273.5	19.1	0.52
7-054	2.7-year outdoor	0.5047	0.0809	294	270.3	18.0	0.64
-055		.5043	.0815	319	289.7	18.7	.52
-056		.5073	.0740	212	230.8	20.2	.52
				Average...	263.6	19.0	0.56
7-057	4.7-year outdoor	0.5059	0.0805	252	232.4	19.8	0.54
-058		.5053	.0724	194	222.4	18.0	.66
-059		.4949	.0732	232	267.7	19.1	.56
				Average...	240.8	19.0	0.59
7-022	8.8-year outdoor	0.5075	0.0796	296	279.7	19.1	0.65
-023		.5070	.0814	307	277.5	18.3	.64
-024		.5038	.0789	276	267.8	17.8	.66
				Average...	275.0	18.4	0.65

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-007	1.7-year outdoor	0.5056	0.0786	247	239.0	20.0	0.62
-008		.5080	.0772	254	254.3	19.7	.67
-009		.5043	.0773	251	252.7	19.2	.71
				Average...	248.7	19.6	0.67
7-042	2.7-year outdoor	0.4750	0.0818	299	286.0	18.8	0.72
-043		.5034	.0812	283	258.2	19.1	.76
-044		.5075	.0754	252	266.5	17.9	.84
				Average...	270.2	18.6	0.77
7-045	4.7-year outdoor	0.5058	0.0697	208	258.2	19.3	0.66
-046		.5027	.0742	234	258.1	18.0	.59
-047		.5070	.0798	272	256.6	18.4	.51
				Average...	257.6	18.6	0.59

TABLE IX.- CONCLUDED

(e) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-010	8.8-year outdoor	0.5117	0.0798	307	286.5	19.0	0.71
-011		.5057	.0800	263	246.2	18.8	.74
-012		.5072	.0792	270	257.3	19.3	.84
				Average...	263.3	19.0	0.76

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi	Flexural modulus, msi	Moisture content, percent
7-025	2.5-year outdoor	0.5052	0.0808	301	277.4	19.2	0.62
-026		.5053	.0795	283	269.3	18.5	.69
-027		.5067	.0795	297	282.0	19.6	.67
				Average...	276.2	19.1	0.66
7-060	4.3-year outdoor	0.5040	0.0822	278	246.9	18.8	-
-061		.5043	.0794	264	251.3	19.8	0.79
-062		.5041	.0821	306	273.2	18.7	.82
				Average...	257.1	19.1	0.81
7-063	5.7-year outdoor	0.5068	0.0744	226	244.5	18.2	0.60
-064		.4989	.0816	290	264.6	18.8	.57
-065		.4630	.0819	218	212.6	18.7	.58
				Average...	240.6	18.6	0.58
7-028	9.5-year outdoor	0.5056	0.0797	302	285.5	19.5	0.68
-029		.5074	.0782	284	278.8	17.7	.72
-030		.5094	.0802	222	204.4	18.0	.74
				Average...	256.2	18.4	0.71

TABLE X.- BASELINE SHORT-BEAM SHEAR STRENGTH OF COMPOSITE MATERIALS

Material type	Specimen number	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
T300/5209 Graphite/epoxy	1-106	0.2517	0.1261	481	11.4
	-107	.2518	.1270	468	11.0
	-108	.2514	.1164	413	10.6
	-109	.2519	.1207	455	11.2
	-110	.2518	.1234	483	11.7
				Average...	11.2
T300/2544 Graphite/epoxy	2-106	0.2509	0.1062	402	11.3
	-107	.2513	.1032	410	11.9
	-108	.2515	.1077	434	12.0
	-109	.2508	.1057	405	11.5
				Average...	11.7
AS/3501 Graphite/epoxy	3-106	0.2499	0.1005	407	12.2
	-107	.2497	.0992	452	13.7
	-108	.2500	.0956	411	12.9
	-109	.2499	.0927	352	11.4
	-110	.2500	.1002	423	12.7
				Average...	12.6
K-49/F-155 Kevlar/epoxy	4-098	0.2472	0.1222	257	6.4
	-099	.2568	.1231	309	7.3
	-100	.2567	.1193	279	6.8
	-101	.2472	.1232	275	6.8
	-102	.2493	.1197	278	7.0
	-103	.2475	.1211	285	7.1
	-104	.2482	.1188	281	7.1
				Average...	6.9
K-49/F-161 Kevlar/epoxy	5-095	0.2484	0.1137	173	4.5
	-097	.2477	.1163	184	4.8
	-098	.2491	.1177	189	4.8
	-099	.2497	.1152	189	4.9
	-100	.2557	.1163	179	4.5
				Average...	4.7
T300/P1700 Graphite/ polysulfone	6-031	0.2528	0.1038	240	6.9
	-032	.2511	.1066	242	6.8
	-033	.2528	.1071	250	6.9
				Average...	6.9

TABLE X.- CONCLUDED

Material type	Specimen number	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
T300/5208 Graphite/epoxy	7-032	0.2554	0.1241	647	15.3
	-033	.2564	.1244	614	14.4
	-034	.2517	.1235	610	14.7
	-035	.2531	.1217	615	15.0
				Average...	14.8

TABLE XI.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED T300/5209 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-076	1-year outdoor	0.2511	0.1155	No Test	-
-077		.2524	.1169	447	11.4
-078		.2523	.1179	443	11.2
				Average...	11.3
1-082	3-year outdoor	0.2511	0.1211	458	11.3
-083		.2513	.1239	463	11.2
-084		.2531	.1266	490	11.5
				Average...	11.3
1-079	5-year outdoor	0.2521	0.1114	448	12.0
-080		.2512	.1187	485	12.2
-081		.2513	.1210	473	11.7
				Average...	11.9
1-085	7-year outdoor	0.2483	0.1073	369	10.4
-086		.2521	.1224	464	11.3
-087		.2497	.1198	461	11.6
				Average...	11.1
1-088	10-year outdoor	0.2516	0.1181	422	10.7
-089		.2516	.1227	482	11.7
-090		.2514	.1221	431	10.5
				Average...	11.0
1-111	10-year office storage	0.2514	0.1155	437	11.3
-112		.2523	.1140	435	11.3
-113		.2539	.1227	435	10.5
-114		.2489	.1184	461	11.7
-115		.2536	.1235	452	10.8
-116		.2521	.1237	480	11.5
-117		.2528	.1174	441	11.1
-118		.2524	.1220	480	11.7
-119		.2524	.1196	463	11.5
-120		.2513	.1109	418	11.2
				Average...	11.3

TABLE XI.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-001	1-year outdoor	0.2517	0.1241	489	11.7
-002		.2520	.1269	461	10.8
-003		.2520	.1287	498	11.5
				Average...	11.4
1-004	3-year outdoor	0.2523	0.1150	457	11.8
-005		.2509	.1256	475	11.3
-006		.2524	.1107	422	11.3
				Average...	11.5
1-007	5-year outdoor	0.2517	0.1163	471	12.1
-008		.2522	.1144	442	11.5
-009		.2526	.1246	486	11.6
				Average...	11.7
1-010	7-year outdoor	0.2518	0.1215	477	11.7
-011		.2537	.1231	498	12.0
-012		.2513	.1220	479	11.7
				Average...	11.8
1-013	10-year outdoor	0.2521	0.1136	428	11.2
-014		.2518	.1252	483	11.5
-015		.2514	.1201	453	11.3
				Average...	11.3

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-031	1-year outdoor	0.2519	0.1193	450	11.2
-032		.2499	.1240	472	11.4
-033		.2524	.1203	458	11.3
				Average...	11.3
1-034	3-year outdoor	0.2524	0.1237	492	11.8
-035		.2528	.1253	506	12.0
-036		.2518	.1187	466	11.7
				Average...	11.8

TABLE XI.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-037	5-year outdoor	0.2526	0.1212	452	11.1
-038		.2517	.1256	461	10.9
-039		.2530	.1181	434	10.9
				Average...	11.0
1-040	7-year outdoor	0.2516	0.1177	429	10.9
-041		.2518	.1230	463	11.2
-042		.2514	.1186	438	11.0
				Average...	11.0
1-043	10-year outdoor	0.2516	0.1167	393	10.0
-044		.2513	.1214	458	11.3
-045		.2512	.1208	423	10.5
				Average...	10.6

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-046	1-year outdoor	0.2520	0.1082	397	10.9
-047		.2522	.1243	424	10.1
-048		.2520	.1202	413	10.2
				Average...	10.4
1-049	3-year outdoor	0.2512	0.1177	463	11.7
-050		.2522	.1264	513	12.1
-051		.2511	.1207	477	11.8
				Average...	11.9
1-052	5-year outdoor	0.2522	0.1143	439	11.4
-053		.2519	.1154	415	10.7
-054		.2515	.1202	472	11.7
				Average...	11.3
1-055	7-year outdoor	0.2522	0.1168	432	11.0
-056		.2502	.1259	497	11.8
-057		.2514	.1218	466	11.4
				Average...	11.4

TABLE XI.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-058 -059 -060	10-year outdoor	0.2537 .2514 .2527	0.1268 .1268 .1176	493 472 464	11.5 11.1 11.7
				Average...	11.4

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-016 -017 -018	1-year outdoor	0.2531 .2520 .2543	0.1239 .1200 .1277	502 457 517	12.0 11.3 11.9
				Average...	11.8
1-019 -020 -021	3-year outdoor	0.2516 .2522 .2508	0.1240 .1264 .1192	485 479 428	11.7 11.3 10.7
				Average...	11.2
1-022 -023 -024	5-year outdoor	0.2515 .2516 .2517	0.1247 .1141 .1206	452 402 430	10.8 10.5 10.6
				Average...	10.6
1-025 -026 -027	7-year outdoor	0.2509 .2527 .2523	0.1226 .1252 .1227	443 476 466	10.8 11.3 11.3
				Average...	11.1
1-028 -029 -030	10-year outdoor	0.2517 .2517 .2522	0.1227 .1224 .1125	442 445 404	10.7 10.8 10.7
				Average...	10.7

TABLE XI.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-061	1-year outdoor	0.2517	0.1177	408	10.3
-062		.2517	.1077	400	11.1
-063		.2511	.1215	440	10.8
				Average...	10.7
1-064	3-year outdoor	0.2499	0.1260	475	11.3
-065		.2516	.1261	490	11.6
-066		.2514	.1186	451	11.3
				Average...	11.4
1-067	5-year outdoor	0.2510	0.1252	470	11.2
-068		.2527	.1230	445	10.7
-069		.2527	.1217	480	11.7
				Average...	11.2
1-070	7-year outdoor	0.2516	0.1275	457	10.7
-071		.2513	.1172	415	10.6
-072		.2520	.1225	433	10.5
				Average...	10.6
1-073	10-year outdoor	0.2519	0.1245	422	10.1
-074		.2520	.1188	405	10.1
-075		.2478	.1118	378	10.2
				Average...	10.2

TABLE XII.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED T300/2544 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-076	1-year outdoor	0.2510	0.0954	359	11.2
-077		.2515	.1038	377	10.8
-078		.2520	.1076	360	10.0
				Average...	10.7
2-082	3-year outdoor	0.2515	0.1064	341	9.6
-083		.2509	.1085	320	8.8
-084		.2511	.1075	381	10.6
				Average...	9.7
2-079	5-year outdoor	0.2510	0.1072	370	10.3
-080		.2503	.1058	373	10.6
-081		.2501	.1044	381	10.9
				Average...	10.6
2-085	7-year outdoor	0.2508	0.1099	378	10.3
-086		.2512	.0933	294	9.4
-087		.2510	.1065	353	9.9
				Average...	9.9
2-088	10-year outdoor	0.2519	0.1071	366	10.2
-089		.2503	.1055	378	10.7
-090		.2519	.1090	358	9.8
				Average...	10.2
2-111	10-year office storage	0.2512	0.1045	379	10.8
-112		.2500	.1063	345	9.7
-113		.2508	.0946	316	10.0
-114		.2515	.1055	423	12.0
-115		.2513	.0990	312	9.4
-116		.2512	.0946	330	10.4
-117		.2509	.1075	435	12.1
-118		.2508	.1075	373	10.4
-119		.2514	.1047	345	9.8
-120		.2509	.1055	395	11.2
				Average...	10.6

TABLE XII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-001	1-year outdoor	0.2516	0.1075	419	11.6
-002		.2514	.0986	358	10.8
-003		.2510	.0969	326	10.1
				Average...	10.8
2-004	3-year outdoor	0.2504	0.1114	379	10.2
-005		.2512	.0950	335	10.5
-006		.2513	.0968	261	8.0
				Average...	9.6
2-007	5-year outdoor	0.2517	0.0968	338	10.4
-008		.2505	.1048	422	12.1
-009		.2513	.1035	350	10.1
				Average...	10.9
2-010	7-year outdoor	0.2513	0.1053	309	8.8
-011		.2510	.1096	407	11.1
-012		.2512	.1075	319	8.9
				Average...	9.6
2-013	10-year outdoor	0.2505	0.1057	330	9.3
-014		.2509	.1098	355	9.6
-015		.2516	.1043	330	9.4
				Average...	9.5

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-031	1-year outdoor	0.2509	0.0996	288	8.6
-032		.2507	.0975	318	9.8
-033		.2518	.1056	345	9.7
				Average...	9.4
2-034	3-year outdoor	0.2510	0.1057	433	12.2
-035		.2510	.1065	375	10.5
-036		.2502	.1027	365	10.7
				Average...	11.1

TABLE XII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-037	5-year outdoor	0.2519	0.1048	332	9.4
-038		.2506	.1029	333	9.7
-039		.2512	.1071	415	11.6
				Average...	10.2
2-040	7-year outdoor	0.2517	0.1070	363	10.1
-041		.2504	.1012	352	10.4
-042		.2504	.1034	352	10.2
				Average...	10.2
2-043	10-year outdoor	0.2506	0.1125	383	10.2
-044		.2507	.1036	368	10.6
-045		.2500	.1064	328	9.2
				Average...	10.0

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-046	1-year outdoor	0.2512	0.0949	340	10.7
-047		.2505	.0975	347	10.7
-048		.2498	.1020	350	10.3
				Average...	10.6
2-049	3-year outdoor	0.2503	0.1058	265	7.5
-050		.2512	.1043	285	8.2
-051		.2512	.0950	327	10.3
				Average...	8.6
2-052	5-year outdoor	0.2520	0.0935	356	11.3
-053		.2520	.1044	326	9.3
-054		.2508	.1074	362	10.1
				Average...	10.2

TABLE XII.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-055	7-year outdoor	0.2509	0.1075	326	9.1
-056		.2513	.1064	330	9.3
-057		.2514	.0946	318	10.0
				Average...	9.4
2-058	10-year outdoor	0.2508	0.1058	396	11.2
-059		.2514	.1076	377	10.5
-060		.2515	.0961	330	10.2
				Average...	10.6

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-016	1-year outdoor	0.2513	0.0952	338	10.6
-017		.2512	.1086	352	9.7
-018		.2517	.1105	425	11.5
				Average...	10.6
2-019	3-year outdoor	0.2504	0.0945	278	8.8
-020		.2512	.1066	344	9.6
-021		.2507	.1089	340	9.3
				Average...	9.3
2-022	5-year outdoor	0.2515	0.0956	257	8.0
-023		.2497	.0997	317	9.6
-024		.2510	.0931	298	9.6
				Average...	9.0
2-025	7-year outdoor	0.2509	0.1025	309	9.0
-026		.2510	.1100	362	9.8
-027		.2506	.0948	302	9.5
				Average...	9.5
2-028	10-year outdoor	0.2512	0.1028	328	9.5
-029		.2504	.0943	333	10.6
-030		.2512	.1073	330	9.2
				Average...	9.8

TABLE XII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-061	1-year outdoor	0.2514	0.1081	404	11.1
-062		.2515	.1026	360	10.5
-063		.2508	.0991	290	8.8
				Average...	10.1
2-064	3-year outdoor	0.2512	0.1052	387	11.0
-065		.2513	.1068	323	9.0
-066		.2503	.1115	388	10.4
				Average...	10.1
2-067	5-year outdoor	0.2507	0.0987	436	13.2
-068		.2506	.0981	398	12.1
-069		.2508	.1037	399	11.5
				Average...	12.3
2-070	7-year outdoor	0.2518	0.1046	353	10.1
-071		.2512	.0932	308	9.9
-072		.2510	.1061	334	9.4
				Average...	9.8
2-073	10-year outdoor	0.2502	0.1079	336	9.3
-074		.2514	.1097	340	9.4
-075		.2517	.1066	361	10.1
				Average...	9.6

TABLE XIII.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED AS/3501 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-076	1-year outdoor	0.2499	0.0985	417	12.7
-077		.2499	.0979	393	12.0
-078		.2501	.1018	437	12.9
				Average...	12.5
3-082	3-year outdoor	0.2498	0.1059	512	14.5
-083		.2505	.1012	438	13.0
-084		.2503	.1064	427	12.0
				Average...	13.2
3-079	5-year outdoor	0.2500	0.1029	421	12.3
-080		.2499	.0997	440	13.2
-081		.2500	.1060	438	12.4
				Average...	12.6
3-085	7-year outdoor	0.2510	0.1029	442	12.8
-086		.2502	.0992	323	9.8
-087		.2500	.0939	421	13.5
				Average...	12.0
3-089	10-year outdoor	0.2496	0.1044	440	12.7
-090		.2495	.1027	463	13.6
				Average...	13.1
3-112	10-year office storage	0.2502	0.1040	402	11.6
-113		.2496	.1060	454	12.9
-114		.2502	.0975	448	13.8
-115		.2503	.0997	388	11.7
-116		.2499	.0959	438	13.7
-117		.2494	.0998	422	12.7
-118		.2500	.1008	486	14.5
-119		.2495	.1064	510	14.4
-120		.2502	.1019	423	12.4
				Average...	13.1

TABLE XIII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-001	1-year outdoor	0.2501	0.1004	398	11.9
-002		.2502	.1067	462	13.0
-003		.2489	.1032	399	11.7
				Average...	12.2
3-004	3-year outdoor	0.2496	0.0944	382	12.2
-005		.2500	.0972	377	11.6
-006		.2497	.0980	435	13.3
				Average...	12.4
3-007	5-year outdoor	0.2498	0.1016	433	12.8
-008		.2500	.0980	440	13.5
-009		.2495	.1049	486	13.9
				Average...	13.4
3-010	7-year outdoor	0.2496	0.0951	430	13.6
-011		.2500	.0991	432	13.1
-012		.2505	.1049	453	12.9
				Average...	13.2
3-013	10-year outdoor	0.2499	0.0975	415	12.8
-014		.2497	.1001	427	12.8
-015		.2500	.1010	362	10.8
				Average...	12.1

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-031	1-year outdoor	0.2497	0.1024	458	13.4
-032		.2500	.1019	440	13.0
-033		.2499	.0948	385	12.2
				Average...	12.9
3-034	3-year outdoor	0.2502	0.1021	340	10.0
-035		.2500	.0989	386	11.7
-036		.2499	.0996	453	13.7
				Average...	11.8

TABLE XIII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-037	5-year outdoor	0.2500	0.0981	466	14.3
-038		.2498	.0979	455	14.0
-039		.2495	.0990	402	12.2
				Average...	13.5
3-040	7-year outdoor	0.2500	.0994	456	13.8
-041		.2497	.1021	415	12.2
-042		.2500	.1000	405	12.2
				Average...	12.7
3-043	10-year outdoor	0.2501	0.1056	375	10.6
-044		.2503	.1027	453	13.2
-045		.2499	.0977	406	12.5
				Average...	12.1

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-046	1-year outdoor	0.2500	0.0978	375	11.5
-047		.2497	.1023	393	11.5
-048		.2501	.0970	355	11.0
				Average...	11.3
3-049	3-year outdoor	0.2499	0.1077	451	12.6
-050		.2500	.0922	384	12.5
-051		.2498	.0943	430	13.7
				Average...	12.9
3-052	5-year outdoor	0.2499	0.0985	400	12.2
-053		.2497	.0949	372	11.8
-054		.2500	.0950	340	10.7
				Average...	11.6
3-055	7-year outdoor	0.2502	0.1020	427	12.5
-056		.2500	.0955	381	12.0
-057		.2501	.1027	421	12.3
				Average...	12.3

TABLE XIII.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-058	10-year	0.2500	0.1047	420	12.0
-059	outdoor	.2498	.1020	419	12.3
-060		.2501	.1012	465	13.8
				Average...	12.7

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-016	1-year	0.2497	0.0941	325	10.4
-017	outdoor	.2498	.0978	444	13.6
-018		.2498	.0988	438	13.3
				Average...	12.4
3-019	3-year	0.2504	0.0954	273	8.6
-020	outdoor	.2497	.1051	405	11.6
-021		.2499	.1009	436	13.0
				Average...	11.0
3-022	5-year	0.2499	0.1041	379	10.9
-023	outdoor	.2500	.0945	308	9.8
-024		.2504	.1067	486	13.6
				Average...	11.4
3-025	7-year	0.2495	0.0989	449	13.6
-026	outdoor	.2501	.0962	396	12.3
-027		.2503	.0989	389	11.8
				Average...	12.6
3-028	10-year	0.2502	0.1023	413	12.1
-029	outdoor	.2491	.1024	382	11.2
-030		.2493	.0969	405	12.6
				Average...	12.0

TABLE XIII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-061	1-year outdoor	0.2506	0.0940	385	12.3
-062		.2500	.1019	440	13.0
-063		.2497	.0941	316	10.1
				Average...	11.8
3-064	3-year outdoor	0.2499	0.1015	428	12.7
-065		.2498	.1011	428	12.7
-066		.2499	.0989	388	11.8
				Average...	12.4
3-067	5-year outdoor	0.2500	0.1022	436	12.8
-068		.2501	.0972	398	12.3
-069		.2500	.0991	399	12.1
				Average...	12.4
3-070	7-year outdoor	0.2498	0.1028	427	12.5
-071		.2502	.0988	388	11.8
-072		.2501	.1048	417	11.9
				Average...	12.1
3-073	10-year outdoor	0.2500	0.0927	359	11.6
-074		.2499	.0937	384	12.3
-075		.2496	.0990	416	12.6
				Average...	12.2

TABLE XIV- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED K-49/F-155 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-076	1-year outdoor	0.2601	0.1220	275	6.5
-077		.2536	.1223	263	6.4
-078		.2585	.1217	267	6.4
				Average...	6.4
4-082	3-year outdoor	0.2522	0.1228	234	5.7
-083		.2508	.1221	239	5.8
-084		.2513	.1216	241	5.9
				Average...	5.8
4-079	5-year outdoor	0.2553	0.1215	229	5.5
-080		.2537	.1228	243	5.8
-081		.2523	.1225	241	5.8
				Average...	5.7
4-085	7-year outdoor	0.2468	0.1218	238	5.9
-086		.2569	.1199	248	6.0
-087		.2507	.1235	241	5.8
				Average...	5.9
4-088	10-year outdoor	0.2476	0.1212	215	5.4
-089		.2509	.1205	214	5.3
-090		.2560	.1224	230	5.5
				Average...	5.4
4-091	10-year office storage	0.2552	0.1195	248	6.1
-092		.2566	.1209	258	6.2
-093		.2490	.1215	255	6.3
-094		.2489	.1220	242	6.0
-095		.2473	.1200	233	5.9
				Average...	6.1

TABLE XIV.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-001 -002 -003	1-year outdoor	0.2497 .2524 .2554	0.1216 .1225 .1226	262 265 264	6.5 6.4 6.3
				Average...	6.4
4-004 -005 -006	3-year outdoor	0.2576 .2506 .2495	0.1214 .1220 .1233	253 258 253	6.1 6.3 6.2
				Average...	6.2
4-007 -008 -009	5-year outdoor	0.2478 .2488 .2480	0.1218 .1223 .1222	244 247 230	6.1 6.1 5.7
				Average...	6.0
4-010 -011 -012	7-year outdoor	0.2474 .2473 .2479	0.1200 .1219 .1236	234 243 249	5.9 6.1 6.1
				Average...	6.0
4-013 -014 -015	10-year outdoor	0.2486 .2486 .2480	0.1208 .1207 .1223	212 220 220	5.3 5.5 5.4
				Average...	5.4

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-031 -032 -033	1-year outdoor	0.2560 .2567 .2586	0.1223 .1214 .1223	259 268 270	6.2 6.4 6.4
				Average...	6.3
4-034 -035 -036	3-year outdoor	0.2580 .2584 .2560	0.1191 .1208 .1228	248 251 252	6.1 6.0 6.0
				Average...	6.0

TABLE XIV.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-037	5-year outdoor	0.2577	0.1203	280	6.8
-038		.2558	.1213	285	6.9
-039		.2564	.1188	256	6.3
				Average...	6.7
4-040	7-year outdoor	0.2541	0.1211	249	6.1
-041		.2552	.1224	252	6.1
-042		.2545	.1214	234	5.7
				Average...	6.0
4-043	10-year outdoor	0.2560	0.1200	220	5.4
-044		.2572	.1223	225	5.4
-045		.2568	.1217	198	4.8
				Average...	5.2

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-046	1-year outdoor	0.2546	0.1215	287	7.0
-047		.2617	.1217	284	6.7
-048		.2642	.1204	282	6.6
				Average...	6.8
4-049	3-year outdoor	0.2550	0.1225	266	6.4
-050		.2560	.1190	265	6.5
-051		.2572	.1214	262	6.3
				Average...	6.4
4-052	5-year outdoor	0.2553	0.1221	295	7.1
-053		.2561	.1230	296	7.1
-054		.2560	.1213	274	6.6
				Average...	6.9

TABLE XIV.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-055	7-year outdoor	0.2564	0.1217	263	6.3
-056		.2571	.1181	253	6.2
-057		.2554	.1185	221	5.5
				Average...	6.0
4-058	10-year outdoor	0.2547	0.1218	242	5.8
-059		.2558	.1221	241	5.8
-060		.2567	.1211	234	5.6
				Average...	5.7

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-016	1-year outdoor	0.2486	0.1219	271	6.7
-017		.2468	.1221	263	6.6
-018		.2483	.1225	269	6.6
				Average...	6.6
4-019	3-year outdoor	0.2477	0.1200	220	5.6
-020		.2492	.1227	228	5.6
-021		.2469	.1220	221	5.6
				Average...	5.6
4-022	5-year outdoor	0.2488	0.1220	218	5.4
-023		.2468	.1201	215	5.4
-024		.2483	.1225	222	5.5
				Average...	5.4
4-025	7-year outdoor	0.2513	0.1199	228	5.7
-026		.2509	.1222	233	5.7
-027		.2491	.1212	233	5.8
				Average...	5.7
4-028	10-year outdoor	0.2559	0.1196	204	5.0
-029		.2560	.1229	223	5.3
-030		.2563	.1206	217	5.3
				Average...	5.2

TABLE XIV.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-061	1-year outdoor	0.2549	0.1222	262	6.3
-062		.2570	.1225	247	5.9
-063		.2575	.1210	260	6.3
				Average...	6.2
4-064	3-year outdoor	0.2547	0.1221	240	5.8
-065		.2479	.1091	157	4.4
-066		.2475	.1226	232	5.7
				Average...	5.3
4-067	5-year outdoor	0.2567	0.1223	235	5.6
-068		.2540	.1228	242	5.8
-069		.2493	.1222	235	5.8
				Average...	5.7
4-070	7-year outdoor	0.2493	0.1225	211	5.2
-071		.2468	.1149	170	4.5
-072		.2513	.1223	217	5.3
				Average...	5.0
4-073	10-year outdoor	0.2528	0.1217	212	5.2
-074		.2496	.1219	206	5.1
-075		.2535	.1215	209	5.1
				Average...	5.1

TABLE XV.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED K-49/F-161 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-076 -077 -078	1-year outdoor	0.2568 .2480 .2547	0.1146 .1160 .1145	202 185 181	5.2 4.8 4.6
				Average...	4.9
5-082 -083 -084	3-year outdoor	0.2548 .2548 .2563	0.1169 .1159 .1155	173 175 174	4.4 4.4 4.4
				Average...	4.4
5-079 -080 -081	5-year outdoor	0.2567 .2473 .2470	0.1133 .1165 .1169	180 167 174	4.6 4.4 4.5
				Average...	4.5
5-085 -086 -087	7-year outdoor	0.2505 .2548 .2504	0.1158 .1176 .1122	173 173 167	4.5 4.3 4.5
				Average...	4.4
5-089 -090	10-year outdoor	0.2487 .2446	0.1119 .1132	155 152	4.1 4.2
				Average...	4.2
5-091 -092 -093 -094	10-year office storage	0.2550 .2548 .2462 .2445	0.1152 .1153 .1194 .1185	176 173 155 175	4.5 4.4 4.0 4.5
				Average...	4.4

TABLE XV.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-001 -002 -003	1-year outdoor	0.2485 .2496 .2558	0.1196 .1172 .1138	190 173 186	4.8 4.4 4.8
				Average...	4.7
5-004 -005 -006	3-year outdoor	0.2514 .2519 .2476	0.1152 .1165 .1141	184 172 176	4.8 4.4 4.7
				Average...	4.6
5-007 -008 -009	5-year outdoor	0.2523 .2476 .2540	0.1166 .1095 .1027	174 132 118	4.4 3.6 3.4
				Average...	3.8
5-010 -011 -012	7-year outdoor	0.2501 .2440 .2474	0.1141 .1140 .1165	156 153 168	4.1 4.1 4.4
				Average...	4.2
5-013 -014	10-year outdoor	0.2464 .2465	0.1194 .1173	170 161	4.3 4.2
				Average...	4.2

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-031 -032 -033	1-year outdoor	0.2438 .2505 .2563	0.1192 .1163 .1155	157 181 201	4.1 4.7 5.1
				Average...	4.6
5-034 -035 -036	3-year outdoor	0.2238 .2550 .2580	0.1159 .1136 .1130	170 171 185	4.9 4.4 4.8
				Average...	4.7

TABLE XV.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-037	5-year outdoor	0.2458	0.1155	195	5.2
-038		.2472	.1171	213	5.5
-039		.2504	.1141	203	5.3
				Average...	5.3
5-040	7-year outdoor	0.2481	0.1157	142	3.7
-041		.2458	.1147	169	4.5
-042		.2497	.1116	148	4.0
				Average...	4.1
5-043	10-year outdoor	0.2505	0.1177	160	4.1
-044		.2446	.1143	153	4.1
-045		.2495	.1180	168	4.3
				Average...	4.2

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-046	1-year outdoor	0.2511	0.1200	188	4.7
-047		.2431	.1137	162	4.4
				Average...	4.6
5-049	3-year outdoor	0.2475	0.1185	183	4.7
-050		.2466	.1114	168	4.6
-051		.2242	.1178	170	4.8
				Average...	4.7
5-052	5-year outdoor	0.2475	0.1119	176	4.8
-053		.2572	.1180	214	5.3
-054		.2229	.1149	202	5.9
				Average...	5.3
5-055	7-year outdoor	0.2529	0.1165	183	4.7
-056		.2517	.1169	182	4.6
-057		.2517	.1145	162	4.2
				Average...	4.5

TABLE XV.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-058 -059	10-year outdoor	0.2450 .2450	0.1167 .1169	165 162	4.3 4.2
				Average...	4.2

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-016 -017 -018	1-year outdoor	0.2544 .2471 .2459	0.1139 .1166 .1156	182 190 194	4.7 5.0 5.1
				Average...	4.9
5-019 -020 -021	3-year outdoor	0.2464 .2531 .2486	0.1176 .1167 .1153	182 182 196	4.7 4.6 5.1
				Average...	4.8
5-022 -023 -024	5-year outdoor	0.2513 .2456 .2456	0.1172 .1158 .1159	171 163 163	4.4 4.3 4.3
				Average...	4.3
5-025 -026 -027	7-year outdoor	0.2452 .2483 .2443	0.1162 .1193 .1177	177 162 176	4.7 4.1 4.6
				Average...	4.5
5-028 -029 -030	10-year outdoor	0.2502 .2509 .2452	0.1194 .1141 .1160	176 162 163	4.4 4.2 4.3
				Average...	4.3

TABLE XV.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-061	1-year outdoor	0.2491	0.1149	183	4.8
-062		.2551	.1159	185	4.7
-063		.2465	.1171	201	5.2
				Average...	4.9
5-064	3-year outdoor	0.2491	0.1168	178	4.6
-065		.2555	.1119	172	4.5
-066		.2560	.1146	170	4.4
				Average...	4.5
5-067	5-year outdoor	0.2441	0.1165	188	5.0
-068		.2503	.1159	193	5.0
-069		.2564	.1109	167	4.4
				Average...	4.8
5-070	7-year outdoor	0.2472	0.1129	136	3.6
-071		.2503	.1117	163	4.4
-072		.2545	.1169	183	4.6
				Average...	4.2
5-073	10-year outdoor	0.2483	0.1166	165	4.3
-074		.2499	.1138	162	4.3
-075		.2555	.1157	174	4.4
				Average...	4.3

TABLE XVI.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED T300/P1700 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-082	1.7-year outdoor	0.2501	0.1057	229	6.5
-083		.2499	.0986	215	6.5
-084		.2501	.1006	217	6.5
				Average...	6.5
6-079	3.7-year outdoor	0.2505	0.1096	246	6.7
-080		.2518	.0969	203	6.2
-081		.2509	.1080	235	6.5
				Average...	6.5
6-085	5.7-year outdoor	0.2526	0.1098	233	6.3
-086		.2522	.1052	224	6.3
-087		.2503	.1048	213	6.1
				Average...	6.2
6-088	8.8-year outdoor	0.2506	0.1078	200	5.6
-089		.2522	.1064	232	6.5
-090		.2498	.1019	188	5.5
				Average...	5.9
6-016	10-year office storage	0.2507	0.0984	213	6.5
-017		.2522	.0980	220	6.7
-018		.2523	.0974	210	6.4
				Average...	6.5

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-004	1.7-year outdoor	0.2513	0.0942	196	6.2
-005		.2528	.0993	223	6.7
-006		.2528	.1072	248	6.9
				Average...	6.6

TABLE XVI.- CONTINUED

(b) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-007	3.7-year outdoor	0.2532	0.1039	207	5.9
-008		.2536	.0959	235	7.2
-009		.2505	.1054	235	6.7
				Average...	6.6
6-010	5.7-year outdoor	0.2525	0.1035	232	6.7
-011		.2534	.1044	236	6.7
-012		.2509	.1063	238	6.7
				Average...	6.7
6-013	8.8-year outdoor	0.2529	0.1011	182	5.3
-014		.2514	.1049	225	6.4
-015		.2536	.1061	226	6.3
				Average...	6.0

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-034	1.7-year outdoor	0.2519	0.1014	232	6.8
-035		.2518	.1012	234	6.9
-036		.2518	.1041	228	6.5
				Average...	6.7
6-037	3.7-year outdoor	0.2520	0.0962	257	8.0
-038		.2528	.1000	261	7.7
-039		.2518	.1071	278	7.7
				Average...	7.8
6-040	5.7-year outdoor	0.2513	0.1066	234	6.6
-041		.2492	.0994	212	6.4
-042		.2517	.0937	144	4.6
				Average...	5.9
6-043	8.8-year outdoor	0.2509	0.1000	221	6.6
-044		.2522	.0978	158	4.8
-045		.2523	.1057	203	5.7
				Average...	5.7

TABLE XVI.- CONTINUED

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-049	1.7-year outdoor	0.2517	0.0964	204	6.3
-050		.2518	.1007	193	5.7
-051		.2517	.0991	214	6.4
				Average...	6.1
6-052	3.7-year outdoor	0.2517	0.1004	215	6.4
-053		.2524	.0993	222	6.6
-054		.2534	.1024	223	6.4
				Average...	6.5
6-055	5.7-year outdoor	0.2530	0.0996	212	6.3
-056		.2526	.1027	217	6.3
-057		.2513	.0979	173	5.3
				Average...	6.0
6-058	8.8-year outdoor	0.2526	0.0973	182	5.6
-059		.2518	.1053	230	6.5
-060		.2520	.0968	192	5.9
				Average...	6.0

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-019	1.7-year outdoor	0.2531	0.1018	220	6.4
-020		.2517	.0929	153	4.9
-021		.2521	.0948	132	4.1
				Average...	5.1
6-022	3.7-year outdoor	0.2508	0.0977	152	4.6
-023		.2518	.1017	170	5.0
-024		.2518	.0913	138	4.5
				Average...	4.7
6-025	5.7-year outdoor	0.2514	0.1062	183	5.1
-026		.2497	.0901	144	4.8
-027		.2522	.0937	148	4.7
				Average...	4.9

TABLE XVI.- CONCLUDED

(e) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-028	8.8-year outdoor	0.2514	0.0926	131	4.2
-029		.2510	.0982	157	4.8
-030		.2511	.0933	125	4.0
				Average...	4.3

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-061	1-year outdoor	0.2518	0.1050	230	6.5
-062		.2531	.0993	189	5.6
-063		.2523	.0962	204	6.3
				Average...	6.1
6-064	2.5-year outdoor	0.2526	0.1056	238	6.7
-065		.2521	.1066	235	6.6
-066		.2521	.1060	226	6.3
				Average...	6.5
6-067	4.3-year outdoor	0.2517	0.1055	234	6.6
-068		.2524	.1041	233	6.6
-069		.2519	.1061	242	6.8
				Average...	6.7
6-070	5.7-year outdoor	0.2518	0.0942	197	6.2
-071		.2485	.0958	206	6.5
-072		.2473	.0856	138	4.9
				Average...	5.9
6-073	9.5-year outdoor	0.2510	0.0903	189	6.2
-074		.2487	.0919	163	5.4
-075		.2478	.0974	144	4.5
				Average...	5.4

TABLE XVII.- SHORT-BEAM SHEAR STRENGTH OF UNPAINTED T300/5208 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-077	10-year office storage	0.2542	0.1241	640	15.2
-078		.2528	.1225	633	15.3
-079		.2535	.1215	600	11.0
-080		.2519	.1297	645	14.8
-081		.2555	.1268	668	15.0
-090		.2547	.1217	560	13.5
-091		.2537	.1248	630	14.9
-092		.2560	.1231	650	15.5
-093		.2553	.1256	627	14.7
-094		.2564	.1282	690	15.7
-095		.2523	.1220	634	15.4
-100		.2550	.1281	669	15.4
-101		.2524	.1265	635	14.9
-102		.2550	.1243	631	14.9
-103		.2522	.1231	624	15.1
-104		.2525	.1260	591	13.9
-105		.2533	.1268	614	14.3
				Average...	14.7

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-001	1.7-year outdoor	0.2569	0.1244	681	16.0
-002		.2567	.1243	660	15.5
-003		.2564	.1277	622	14.2
				Average...	15.2
7-004	8.8-year outdoor	0.2519	0.1242	526	12.6
-005		.2548	.1280	597	13.7
-006		.2546	.1251	570	13.4
				Average...	13.3

TABLE XVII.- CONTINUED

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-013	1.7-year outdoor	0.2541	0.1247	665	15.7
-014		.2581	.1206	649	15.6
-015		.2572	.1185	618	15.2
				Average...	15.5
7-016	8.8-year outdoor	0.2592	0.1224	468	11.1
-017		.2589	.1234	569	13.4
-018		.2524	.1246	600	14.3
				Average...	12.9

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-019	1.7-year outdoor	0.2534	0.1230	658	15.8
-020		.2541	.1227	632	15.2
-021		.2555	.1236	652	15.5
				Average...	15.5
7-022	6.25-year outdoor	0.2555	0.1214	609	14.7
-023		.2567	.1207	549	13.3
-024		.2551	.1219	619	14.9
				Average...	14.3

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-007	1.7-year outdoor	0.2525	0.1228	644	15.6
-008		.2521	.1260	585	13.8
-009		.2515	.1240	581	14.0
				Average...	14.5
7-010	8.8-year outdoor	0.2525	0.1251	485	11.5
-011		.2533	.1256	490	11.6
-012		.2542	.1246	525	12.4
				Average...	11.8

TABLE XVII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
7-025	2.5-year outdoor	0.2544	0.1205	568	13.9
-026		.2559	.1236	642	15.2
-027		.2569	.1242	575	13.5
				Average...	14.2
7-028	9.5-year outdoor	0.2580	0.1235	560	13.2
-029		.2546	.1256	536	12.6
-030		.2545	.1243	559	13.3
				Average...	13.0

TABLE XVIII.- BASELINE COMPRESSION STRENGTH OF COMPOSITE MATERIALS

Material type	Specimen number	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
T300/5209 Graphite/epoxy	1-106	0.2508	0.1738	4950	113.6
	-107	.2506	.1721	5330	123.6
	-108	.2504	.1720	4120	95.7
	-109	.2508	.1683	4640	109.9
	-110	.2505	.1689	4400	104.0
				Average...	109.4
T300/2544 Graphite/epoxy	2-107	0.2507	0.1407	5180	146.8
	-108	.2509	.1419	5540	155.6
	-109	.2509	.1383	5120	147.6
	-110	.2514	.1411	5200	146.6
				Average...	149.2
AS/3501 Graphite/epoxy	3-106	0.2502	0.1197	5150	172.0
	-107	.2532	.1223	4730	152.7
	-108	.2538	.1203	4960	162.4
	-109	.2542	.1215	4800	155.4
	-110	.2514	.1196	4830	160.6
				Average...	160.6
K-49/F-155 Kevlar/epoxy	4-091	0.2485	0.0501	248	19.9
	-092	.2494	.0501	248	19.8
	-093	.2469	.0507	245	19.6
	-094	.2503	.0501	254	20.3
	-095	.2502	.0502	251	20.0
				Average...	19.9
K-49/F-161 Kevlar/epoxy	5-091	0.2488	0.0494	249	20.3
	-092	.2494	.0492	213	17.4
	-093	.2471	.0492	223	18.3
	-094	.2506	.0490	226	18.4
	-095	.2458	.0494	224	18.4
				Average...	18.6
T300/P1700 Graphite/ polysulfone	6-106	0.2482	0.1362	2185	64.6
	-107	.2444	.1363	1680	50.4
	-108	.2483	.1357	1725	51.2
	-109	.2516	.1358	1760	51.5
	-110	.2539	.1355	1925	56.0
	-111	.2495	.1355	1860	55.0
				Average...	54.8

TABLE XIX.- COMPRESSION STRENGTH OF UNPAINTED T300/5209 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-076	1-year outdoor	0.2497	0.1682	4930	117.4
-077		.2506	.1794	4575	101.8
-078		.2500	.1712	4785	111.8
				Average...	110.3
1-082	3-year outdoor	0.2507	0.1707	4410	103.1
-083		.2511	.1641	3800	92.2
-084		.2494	.1669	4505	108.2
				Average...	101.2
1-079	5-year outdoor	0.2502	0.1685	4010	95.1
-080		.2501	.1695	4870	114.9
-081		.2493	.1662	4490	108.4
				Average...	106.1
1-085	7-year outdoor	0.2500	0.1654	4830	116.8
-086		.2487	.1797	4193	93.8
-087		.2513	.1738	4505	103.1
				Average...	104.6
1-088	10-year outdoor	0.2501	0.1722	4510	104.7
-089		.2504	.1714	5040	117.4
-090		.2507	.1730	4175	96.3
				Average...	106.1
1-111	10-year office storage	0.2499	0.1694	4600	108.7
-112		.2510	.1786	4170	93.0
-113		.2503	.1661	4980	119.8
-114		.2505	.1637	4730	115.3
-115		.2495	.1675	4240	101.5
-116		.2501	.1697	4865	114.6
-117		.2505	.1717	4565	106.1
-118		.2510	.1706	4370	102.1
-119		.2504	.1656	4665	112.5
-120		.2502	.1738	3985	91.6
				Average...	106.5

TABLE XIX.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-001	1-year outdoor	0.2496	0.1637	4485	109.8
-002		.2504	.1662	4295	103.2
-003		.2506	.1736	4300	98.8
				Average...	103.9
1-004	3-year outdoor	0.2509	0.1770	4120	92.8
-005		.2523	.1759	4030	90.8
-006		.2502	.1717	4350	101.2
				Average...	94.9
1-007	5-year outdoor	0.2502	0.1711	3750	87.6
-008		.2510	.1749	3910	89.1
-009		.2509	.1796	3970	88.1
				Average...	88.3
1-010	7-year outdoor	0.2503	0.1702	4790	112.4
-011		.2507	.1745	4640	106.1
-012		.2510	.1713	4564	106.1
				Average...	108.2
1-013	10-year outdoor	0.2501	0.1772	4435	100.1
-014		.2532	.1737	4050	92.1
-015		.2507	.1771	4190	94.4
				Average...	95.5

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-031	1-year outdoor	0.2508	0.1743	4380	100.2
-032		.2503	.1638	3920	95.6
-033		.2492	.1705	4180	98.4
				Average...	98.1
1-034	3-year outdoor	0.2500	0.1710	3045	71.2
-035		.2506	.1672	3040	72.6
-036		.2503	.1701	4255	99.9
				Average...	81.2

TABLE XIX.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-037	5-year outdoor	0.2487	0.1680	4400	105.3
-038		.2493	.1688	4300	102.2
-039		.2504	.1645	4125	100.1
				Average...	102.5
1-040	7-year outdoor	0.2510	0.1667	5153	123.2
-041		.2504	.1715	4870	113.4
-042		.2502	.1538	3970	103.2
				Average...	113.3
1-043	10-year outdoor	0.2544	0.1755	4040	90.5
-044		.2501	.1672	4370	104.5
-045		.2513	.1585	4460	112.0
				Average...	102.3

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-046	1-year outdoor	0.2503	0.1668	4500	107.8
-047		.2501	.1704	4445	104.3
-048		.2507	.1702	4110	96.3
				Average...	102.8
1-049	3-year outdoor	0.2511	0.1712	4555	106.0
-050		.2504	.1705	4570	107.0
-051		.2500	.1719	3715	86.4
				Average...	99.8
1-052	5-year outdoor	0.2500	0.1714	4160	97.1
-053		.2503	.1733	4175	96.2
-054		.2498	.1715	3040	71.0
				Average...	88.1
1-055	7-year outdoor	0.2507	0.1701	4660	109.3
-056		.2505	.1705	4933	115.5
-057		.2496	.1692	4625	109.5
				Average...	111.4

TABLE XIX.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-058 -059 -060	10-year outdoor	0.2512 .2515 .2504	0.1796 .1747 .1756	4135 4525 4510	91.6 103.0 102.6
				Average...	99.1

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-016 -017 -018	1-year outdoor	0.2481 .2508 .2531	0.1459 .1717 .1683	3450 4280 3690	95.3 99.4 86.6
				Average...	93.8
1-019 -020 -021	3-year outdoor	0.2510 .2502 .2501	0.1746 .1669 .1703	3900 4295 4320	89.0 102.8 101.4
				Average...	97.7
1-022 -023 -024	5-year outdoor	0.2503 .2500 .2499	0.1694 .1745 .1696	4155 3050 3195	98.0 69.9 75.4
				Average...	81.1
1-025 -026 -027	7-year outdoor	0.2520 .2510 .2513	0.1787 .1779 .1752	3920 4227 3985	87.0 94.7 90.5
				Average...	90.7
1-028 -029 -030	10-year outdoor	0.2508 .2509 .2527	0.1773 .1795 .1697	4590 4360 4305	103.2 96.8 100.4
				Average...	100.1

C-2

TABLE XIX.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
1-061	1-year outdoor	0.2498	0.1685	4440	105.5
-062		.2500	.1683	3760	89.4
-063		.2505	.1705	4875	114.1
				Average...	103.0
1-064	3-year outdoor	0.2502	0.1711	4160	97.2
-065		.2503	.1692	4020	94.9
-066		.2507	.1748	4610	105.2
				Average...	99.1
1-067	5-year outdoor	0.2481	0.1613	4035	100.8
-068		.2499	.1664	4580	110.1
-069		.2515	.1718	3900	90.3
				Average...	100.4
1-071	7-year outdoor	.2502	.1685	4220	100.1
-072		.2514	.1735	3995	91.6
				Average...	95.8
1-075	10-year outdoor	0.2501	0.1693	4490	106.0

TABLE XX.- COMPRESSION STRENGTH OF UNPAINTED T300/2544 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-076	1-year outdoor	0.2519	0.1378	5030	144.9
-077		.2514	.1354	4520	132.8
-078		.2492	.1455	5470	150.9
				Average...	142.9
2-082	3-year outdoor	0.2519	0.1407	5100	143.9
-083		.2512	.1413	4815	135.7
-084		.2514	.1303	4455	136.0
				Average...	138.5
2-079	5-year outdoor	0.2516	0.1280	4640	144.1
-080		.2518	.1456	4735	129.2
-081		.2513	.1333	4445	132.7
				Average...	135.3
2-085	7-year outdoor	0.2509	0.1366	4855	141.7
-086		.2513	.1305	4418	134.7
-087		.2507	.1480	5218	140.6
				Average...	139.0
2-088	10-year outdoor	0.2504	0.1303	4605	141.1
-089		.2513	.1391	4720	135.0
-090		.2526	.1482	4880	130.4
				Average...	135.5
2-111	10-year office storage	0.2511	0.1398	5150	146.7
-112		.2511	.1406	5130	145.3
-113		.2523	.1378	4190	120.5
-114		.2523	.1497	5305	140.5
-115		.2497	.1225	4115	134.5
-116		.2516	.1388	5070	145.2
-117		.2507	.1223	4685	152.8
-118		.2537	.1442	5530	151.2
-119		.2529	.1314	4080	122.8
-120		.2513	.1426	5185	144.7
				Average...	140.4

TABLE XX.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-001 -002 -003	1-year outdoor	0.2507 .2510 .2538	0.1425 .1324 .1428	5395 No test 5370	151.0 - 148.2
				Average...	149.6
2-004 -005 -006	3-year outdoor	0.2529 .2517 .2515	0.1332 .1287 .1232	5015 4920 4780	148.9 151.9 154.3
				Average...	151.7
2-007 -008 -009	5-year outdoor	0.2522 .2510 .2514	0.1429 .1439 .1398	4425 4530 4525	122.8 125.4 128.7
				Average...	125.7
2-010 -011 -012	7-year outdoor	0.2503 .2509 .2487	0.1464 .1296 .1455	5205 5024 5250	142.0 154.5 145.1
				Average...	147.2
2-013 -014 -015	10-year outdoor	0.2518 .2504 .2506	0.1427 .1403 .1437	5060 4470 4200	140.8 127.2 116.6
				Average...	128.2

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-031 -032 -033	1-year outdoor	0.2503 .2506 .2523	0.1281 .1410 .1317	4705 4430 5240	146.7 125.4 157.7
				Average...	143.3
2-035 -036	3-year outdoor	0.2511 .2513	0.1382 .1420	4760 3505	137.2 98.2
				Average...	117.7

TABLE XX.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-037	5-year outdoor	0.2513	0.1398	4900	139.5
-038		.2527	.1323	4950	148.1
-039		.2507	.1443	5000	138.2
				Average...	141.9
2-040	7-year outdoor	0.2520	0.1361	5238	152.7
-041		.2510	.1383	5055	145.6
-042		.2512	.1382	5550	159.9
				Average...	152.7
2-043	10-year outdoor	0.2520	0.1447	4810	131.9
-044		.2520	.1231	4220	136.0
-045		.2506	.1244	4640	148.8
				Average...	138.9

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-046	1-year outdoor	0.2513	0.1383	4995	143.7
-047		.2521	.1407	5230	147.4
-048		.2530	.1316	5120	153.8
				Average...	148.3
2-049	3-year outdoor	0.2511	0.1326	4799	144.1
-050		.2531	.1414	5065	141.5
-051		.2509	.1399	5010	142.7
				Average...	142.8
2-052	5-year outdoor	0.2500	0.1468	5000	136.2
-053		.2525	.1406	4800	135.2
-054		.2503	.1302	4500	138.1
				Average...	136.5
2-055	7-year outdoor	0.2509	0.1399	5177	147.5
-056		.2510	.1409	No test	-
-057		.2508	.1406	5672	160.9
				Average...	154.2

TABLE XX.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-058	10-year	0.2505	0.1391	4505	129.3
-059	outdoor	.2497	.1447	5175	143.2
-060		.2534	.1406	5100	143.1
				Average...	138.6

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-016	1-year	0.2530	0.1419	4245	118.2
-017	outdoor	.2510	.1398	4265	121.5
-018		.2499	.1379	4710	136.7
				Average...	125.5
2-019	3-year	0.2510	0.1400	4665	132.8
-020	outdoor	.2533	.1379	4260	122.0
-021		.2434	.1386	4040	119.8
				Average...	124.8
2-022	5-year	0.2509	0.1385	3810	109.6
-023	outdoor	.2525	.1463	4140	112.1
-024		.2519	.1425	3820	106.4
				Average...	109.4
2-025	7-year	0.2523	0.1422	5045	140.6
-026	outdoor	.2526	.1312	4610	139.1
-027		.2530	.1322	5195	155.3
				Average...	145.0
2-028	10-year	0.2508	0.1388	4200	120.7
-029	outdoor	.2536	.1388	4220	119.9
-030		.2520	.1364	4245	123.5
				Average...	121.3

TABLE XX.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
2-061	1-year outdoor	0.2510	0.1398	4620	131.7
-062		.2506	.1231	4795	155.4
-063		.2506	.1404	4800	136.4
				Average...	141.2
2-064	3-year outdoor	0.2515	0.1414	3800	106.9
-065		.2509	.1432	4120	114.7
-066		.2509	.1228	4910	159.4
				Average...	127.0
2-067	5-year outdoor	0.2512	0.1406	4705	133.2
-068		.2511	.1395	4835	138.0
-069		.2505	.1438	4110	114.1
				Average...	128.4
2-070	7-year outdoor	0.2514	0.1422	4990	139.6
2-073	10-year outdoor	0.2501	0.1253	4955	158.1
-074		.2511	.1427	4465	124.6
-075		.2523	.1384	4385	125.6
				Average...	136.1

TABLE XXI.- COMPRESSION STRENGTH OF UNPAINTED AS/3501 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-076	1-year outdoor	0.2514	0.1174	4775	161.8
-077		.2505	.1165	4175	143.1
-078		.2517	.1204	4545	150.0
				Average...	151.6
3-082	3-year outdoor	0.2534	0.1167	3920	132.6
-083		.2537	.1213	4505	146.4
-084		.2538	.1224	4895	157.6
				Average...	145.5
3-079	5-year outdoor	0.2535	0.1187	4810	159.9
-080		.2536	.1198	4450	146.5
-081		.2522	.1206	4735	155.7
				Average...	154.0
3-085	7-year outdoor	0.2510	0.1192	5030	168.1
-086		.2497	.1234	4525	146.9
-087		.2517	.1226	4835	156.7
				Average...	157.2
3-088	10-year outdoor	0.2539	0.1161	4600	156.0
-089		.2538	.1192	4675	154.5
-090		.2530	.1198	4955	163.5
				Average...	158.0
3-111	10-year office storage	0.2539	0.1193	4640	153.2
-112		.2540	.1212	4525	147.0
-113		.2535	.1246	5000	158.3
-114		.2540	.1225	5250	168.7
-115		.2517	.1220	5085	165.6
-116		.2511	.1241	4515	144.9
-117		.2515	.1216	4725	154.5
-118		.2542	.1213	5040	163.5
-119		.2536	.1240	4905	156.0
-120		.2515	.1158	4145	142.3
				Average...	155.4

TABLE XXI.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-001	1-year outdoor	0.2530	0.1210	5030	164.3
-002		.2514	.1222	4925	160.3
-003		.2507	.1149	4490	155.9
				Average...	160.2
3-004	3-year outdoor	0.2511	0.1176	4820	163.2
-005		.2542	.1226	4795	153.9
-006		.2535	.1163	4050	137.4
				Average...	151.5
3-007	5-year outdoor	0.2532	0.1180	4325	144.8
-008		.2527	.1167	3540	120.0
-009		.2513	.1234	3970	128.0
				Average...	130.9
3-010	7-year outdoor	0.2510	0.1225	5630	183.1
-011		.2517	.1198	3915	129.8
-012		.2537	.1181	4550	151.9
				Average...	154.9
3-013	10-year outdoor	0.2539	0.1196	4600	151.5
-014		.2522	.1221	5000	162.4
-015		.2539	.1197	5200	171.1
				Average...	161.7

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-031	1-year outdoor	0.2538	0.1247	4880	154.2
-032		.2518	.1208	4610	151.6
-033		.2523	.1187	4915	164.1
				Average...	156.6
3-034	3-year outdoor	0.2530	0.1158	4280	146.1
-035		.2515	.1172	4030	136.7
-036		.2516	.1195	4555	151.5
				Average...	144.8

TABLE XXI.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-037	5-year outdoor	0.2523	0.1183	4750	159.1
-038		.2534	.1204	4750	155.7
-039		.2539	.1159	4280	145.4
				Average...	153.4
3-040	7-year outdoor	0.2520	0.1193	4930	164.0
-041		.2521	.1215	5035	164.4
-042		.2519	.1161	4675	159.9
				Average...	162.7
3-043	10-year outdoor	0.2531	0.1175	4620	155.4
-044		.2514	.1248	5425	172.9
-045		.2538	.1195	3315	109.3
				Average...	145.9

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-046	1-year outdoor	0.2525	0.1194	4970	164.9
-047		.2513	.1200	5630	186.7
-048		.2517	.1201	4735	156.6
				Average...	169.4
3-049	3-year outdoor	0.2523	0.1220	4765	154.8
-050		.2514	.1185	4815	161.6
-051		.2523	.1227	4745	153.3
				Average...	156.6
3-052	5-year outdoor	0.2537	0.1150	4600	157.7
-053		.2539	.1203	4525	148.1
-054		.2508	.1208	4800	158.4
				Average...	154.7
3-055	7-year outdoor	0.2515	0.1207	5105	168.2
-056		.2534	.1201	5052	166.0
-057		.2517	.1161	4625	158.3
				Average...	164.1

TABLE XXI.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-058	10-year outdoor	0.2506	0.1210	4535	149.6
-059		.2542	.1248	4740	149.4
-060		.2518	.1164	4815	164.3
				Average...	154.4

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-016	1-year outdoor	0.2530	0.1253	4365	137.7
-017		.2506	.1202	4520	150.1
-018		.2514	.1234	4605	148.4
				Average...	145.4
3-019	3-year outdoor	0.2510	0.1203	4315	142.9
-020		.2534	.1249	4250	134.3
-021		.2518	.1239	4285	137.3
				Average...	138.2
3-022	5-year outdoor	0.2509	0.1162	3525	120.9
-023		.2516	.1174	3410	115.4
-024		.2516	.1225	3685	119.6
				Average...	118.6
3-025	7-year outdoor	0.2513	0.1162	4810	164.7
-026		.2512	.1196	4590	152.8
-027		.2529	.1165	4898	166.2
				Average...	161.2
3-028	10-year outdoor	0.2536	0.1198	5650	186.0
-029		.2514	.1200	5505	182.5
-030		.2531	.1172	5340	180.0
				Average...	182.8

TABLE XXI.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
3-061 -062 -063	1-year outdoor	0.2514 .2526 .2543	0.1236 .1188 .1189	4350 4775 4755	140.0 159.1 157.3
				Average...	152.1
3-064 -065 -066	3-year outdoor	0.2537 .2509 .2525	0.1248 .1224 .1206	5160 5060 5080	163.0 164.8 166.8
				Average...	164.9
3-067 -068 -069	5-year outdoor	0.2516 .2529 .2511	0.1225 .1158 .1236	4200 4295 4945	136.3 146.7 159.3
				Average...	147.4
3-070 -071 -072	7-year outdoor	0.2537 .2516 .2513	0.1156 .1209 .1195	4080 4895 4640	139.1 160.9 154.5
				Average...	151.5
3-073 -074 -075	10-year outdoor	0.2515 .2537 .2537	0.1212 .1206 .1213	4955 4465 4385	162.6 145.9 142.5
				Average...	150.3

TABLE XXII.- COMPRESSION STRENGTH OF UNPAINTED K-49/F-155 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-076	1-year outdoor	0.2545	0.0503	263	20.5
-077		.2485	.0501	280	22.5
-078		.2499	.0504	273	21.7
				Average...	21.6
4-082	3-year outdoor	0.2533	0.0505	246	19.2
-083		.2504	.0503	248	19.7
-084		.2515	.0504	243	19.2
				Average...	19.4
4-079	5-year outdoor	0.2505	0.0507	214	16.8
-080		.2534	.0503	217	17.0
-081		.2494	.0503	215	17.1
				Average...	17.0
4-085	7-year outdoor	0.2540	0.0505	234	18.2
-086		.2499	.0508	231	18.2
-087		.2485	.0503	218	17.4
				Average...	18.0
4-088	10-year outdoor	0.2539	0.0503	219	17.1
-089		.2482	.0504	205	16.4
-090		.2540	.0504	197	15.4
				Average...	16.3
4-096	10-year office storage	0.2482	0.0499	270	21.8
-097		.2494	.0501	276	22.1
-098		.2490	.0505	264	21.0
-099		.2543	.0505	275	21.5
-100		.2408	.0501	259	21.5
				Average...	21.6

TABLE XXII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-001 -002 -003	1-year outdoor	0.2544 .2484 .2520	0.0483 .0506 .0504	282 259 276	23.0 20.6 21.7
				Average...	21.8
4-004 -005 -006	3-year outdoor	0.2489 .2492 .2521	0.0508 .0501 .0500	250 237 248	19.8 19.0 19.7
				Average...	19.5
4-007 -008 -009	5-year outdoor	0.2528 .2510 .2537	0.0502 .0505 .0507	224 220 230	17.7 17.4 17.9
				Average...	17.6
4-010 -011 -012	7-year outdoor	0.2539 .2500 .2481	0.0509 .0498 .0500	262 253 234	20.3 20.3 18.9
				Average...	19.8
4-013 -014 -015	10-year outdoor	0.2502 .2503 .2483	0.0505 .0506 .0503	226 220 192	17.9 17.4 15.4
				Average...	16.9

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-031 -032 -033	1-year outdoor	0.2506 .2491 .2499	0.0505 .0503 .0506	266 268 272	21.0 21.4 21.5
				Average...	21.3
4-034 -035 -036	3-year outdoor	0.2502 .2514 .2499	0.0503 .0501 .0504	235 239 221	18.7 19.0 17.5
				Average...	18.4

TABLE XXII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-037	5-year outdoor	0.2534	0.0499	202	16.0
-038		.2506	.0502	213	16.9
-039		.2485	.0502	215	17.2
				Average...	16.7
4-040	7-year outdoor	0.2519	0.0499	230	18.3
-041		.2530	.0498	242	19.2
-042		.2497	.0498	224	18.0
				Average...	18.5
4-043	10-year outdoor	0.2502	0.0506	181	14.3
-044		.2485	.0511	179	14.1
-045		.2496	.0502	194	15.5
				Average...	14.6

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-046	1-year outdoor	0.2485	0.0511	262	20.6
-047		.2538	.0503	260	20.4
-048		.2481	.0505	254	20.3
				Average...	20.4
4-049	3-year outdoor	0.2494	0.0506	257	20.4
-050		.2489	.0503	257	20.5
-051		.2533	.0504	253	19.8
				Average...	20.2
4-052	5-year outdoor	0.2547	0.0504	237	18.5
-053		.2532	.0508	236	18.3
-054		.2493	.0500	237	19.0
				Average...	18.6
4-055	7-year outdoor	0.2494	0.0504	248	19.7
-056		.2486	.0503	255	20.4
-057		.2549	.0502	250	19.5
				Average...	19.9

TABLE XXII.- CONTINUED

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-058	10-year outdoor	0.2494	0.0505	219	17.4
-059		.2537	.0504	223	17.4
-060		.2544	.0501	229	18.0
				Average...	17.6

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-016	1-year outdoor	0.2538	0.0504	261	20.4
-017		.2479	.0504	254	20.3
-018		.2522	.0502	267	21.1
				Average...	20.6
4-019	3-year outdoor	0.2501	0.0500	231	18.5
-020		.2494	.0503	222	17.7
-021		.2546	.0499	233	18.3
				Average...	18.2
4-022	5-year outdoor	0.2538	0.0502	222	17.4
-023		.2514	.0495	216	17.4
-024		.2505	.0499	226	18.1
				Average...	17.6
4-025	7-year outdoor	0.2503	0.0499	225	18.0
-026		.2536	.0500	252	19.9
-027		.2505	.0500	237	18.9
				Average...	18.9
4-028	10-year outdoor	0.2496	0.0502	203	16.2
-029		.2573	.0502	187	14.5
-030		.2481	.0486	191	15.8
				Average...	15.5

TABLE XXII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
4-061 -062 -063	1-year outdoor	0.2544 .2534 .2546	0.0509 .0502 .0502	226 236 231	17.5 18.6 18.1
				Average...	18.0
4-064 -065 -066	3-year outdoor	0.2533 .2494 .2498	0.0503 .0505 .0507	254 263 272	19.9 20.9 21.5
				Average...	20.8
4-067 -068 -069	5-year outdoor	0.2529 .2496 .2533	0.0501 .0500 .0503	No test 213 221	- 17.1 17.3
				Average...	17.2
4-070 -071 -072	7-year outdoor	0.2545 .2485 .2544	0.0505 .0494 .0506	No test 206 206	- 16.8 16.0
				Average...	16.4
4-073 -074 -075	10-year outdoor	(Specimens were damaged during exposure)			

TABLE XXIII.- COMPRESSION STRENGTH OF UNPAINTED K-49/F-161 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-076	1-year outdoor	0.2489	0.0490	239	19.6
-077		.2502	.0491	239	19.5
-078		.2491	.0491	250	20.4
				Average...	19.8
5-082	3-year outdoor	0.2479	0.0492	214	17.5
-083		.2515	.0491	209	16.9
-084		.2483	.0494	233	19.0
				Average...	17.8
5-079	5-year outdoor	0.2504	0.0490	194	15.8
-080		.2501	.0495	201	16.2
-081		.2488	.0494	179	14.6
				Average...	15.5
5-085	7-year outdoor	0.2453	0.0495	223	18.4
-086		.2556	.0493	214	17.0
-087		.2504	.0490	197	16.1
				Average...	17.1
5-088	10-year outdoor	0.2506	0.0500	176	14.0
-089		.2541	.0491	198	15.9
-090		.2554	.0490	189	15.1
				Average...	15.0
5-096	10-year office storage	0.2522	0.0494	231	18.6
-098		.2488	.0499	251	20.2
-099		.2498	.0488	231	18.9
-100		.2478	.0488	227	18.8
-101		.2488	.0490	234	19.2
				Average...	19.2

TABLE XXIII.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-001	1-year outdoor	0.2469	0.0490	248	20.5
-002		.2525	.0492	262	21.1
-003		.2489	.0489	228	18.7
				Average...	20.1
5-004	3-year outdoor	0.2531	0.0492	229	18.4
-005		.2501	.0491	222	18.1
-006		.2465	.0494	219	18.0
				Average...	18.2
5-007	5-year outdoor	0.2502	0.0490	211	17.2
-008		.2501	.0491	199	16.2
-009		.2463	.0487	191	15.9
				Average...	16.4
5-010	7-year outdoor	0.2502	0.0493	214	17.3
-011		.2491	.0491	220	18.0
-012		.2503	.0490	242	19.7
				Average...	18.4
5-013	10-year outdoor	0.2508	0.0489	216	17.6
-014		.2507	.0494	213	17.2
-015		.2483	.0487	180	14.9
				Average...	16.6

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-031	1-year outdoor	0.2515	0.0491	232	18.8
-032		.2513	.0492	266	21.5
-033		.2508	.0496	256	20.6
				Average...	20.3
5-034	3-year outdoor	0.2504	0.0494	228	18.4
-035		.2490	.0496	231	18.7
-036		.2481	.0498	192	15.5
				Average...	17.6

TABLE XXIII.- CONTINUED

(c) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-037	5-year outdoor	0.2461	0.0491	185	15.3
-038		.2509	.0490	193	15.7
-039		.2496	.0491	183	14.9
				Average...	15.3
5-040	7-year outdoor	0.2518	0.0503	224	17.7
-041		.2486	.0487	212	17.5
-042		.2522	.0493	217	17.5
				Average...	17.5
5-043	10-year outdoor	0.2517	0.0495	174	14.0
-045		.2481	.0489	176	14.5
				Average...	14.2

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-046	1-year outdoor	0.2493	0.0493	253	20.6
-047		.2465	.0495	230	18.8
-048		.2507	.0489	226	18.4
				Average...	19.3
5-049	3-year outdoor	0.2505	0.0505	208	16.4
-050		.2510	.0493	209	16.9
-051		.2484	.0489	221	18.2
				Average...	17.2
5-052	5-year outdoor	0.2507	0.0493	199	16.1
-053		.2495	.0491	224	18.3
-054		.2508	.0492	185	15.0
				Average...	16.5

(d) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-055	7-year outdoor	0.2477	0.0486	218	18.1
-056		.2479	.0487	208	17.2
-057		.2480	.0488	210	17.4
				Average...	17.6
5-058	10-year outdoor	0.2477	0.0491	206	16.9
-059		.2504	.0486	207	17.0
-060		.2455	.0490	209	17.4
				Average...	17.1

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-016	1-year outdoor	0.2434	0.0492	241	20.1
-017		.2457	.0491	242	20.1
-018		.2474	.0489	227	18.8
				Average...	19.6
5-019	3-year outdoor	0.2511	0.0501	211	16.8
-020		.2475	.0492	223	18.3
-021		.2490	.0488	212	17.4
				Average...	17.5
5-022	5-year outdoor	0.2509	0.0496	202	16.2
-023		.2523	.0489	190	15.4
-024		.2509	.0489	187	15.2
				Average...	15.6
5-025	7-year outdoor	0.2488	0.0491	205	16.8
-026		.2513	.0493	218	17.6
-027		.2494	.0493	215	17.5
				Average...	17.3
5-028	10-year outdoor	0.2504	0.0495	186	15.0
-029		.2487	.0494	203	16.5
-030		.2522	.0492	174	14.0
				Average...	15.2

TABLE XXIII.- CONCLUDED

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
5-061	1-year outdoor	0.2506	0.0493	203	16.4
-062		.2524	.0498	224	17.8
-063		.2508	.0500	194	15.5
				Average...	16.6
5-064	3-year outdoor	0.2500	0.0485	230	19.0
-065		.2505	.0490	242	19.7
-066		.2509	.0493	223	18.0
				Average...	18.9
5-067	5-year outdoor	0.2493	0.0496	Damaged	-
-068		.2539	.0489	221	17.8
-069		.2528	.0488	207	16.8
				Average...	17.3
5-070	7-year outdoor	0.2467	0.0492	187	15.4
-071		.2531	.0505	197	15.4
-072		.2483	.0491	165	13.5
				Average...	14.8
5-073	10-year outdoor	0.2500	0.0494	218	17.7
-074		.2510	.0510	192	15.0
-075		.2520	.0494	196	15.7
				Average...	16.1

TABLE XXIV.- COMPRESSION STRENGTH OF UNPAINTED T300/P1700 AFTER ENVIRONMENTAL EXPOSURE

(a) Exposed at NASA Langley - Hampton, VA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-082	1.7-year outdoor	0.2513	0.1233	1440	46.5
-083		.2529	.1351	1930	56.5
-084		.2530	.1350	1685	49.3
				Average...	50.8
6-079	3.7-year outdoor	0.2510	0.1402	1675	47.6
-080		.2501	.1432	1835	51.2
-081		.2513	.1257	1525	48.3
				Average...	49.0
6-085	5.7-year outdoor	0.2497	0.1257	1820	58.0
-086		.2508	.1324	1649	49.7
-087		.2527	.1351	1535	45.0
				Average...	50.9
6-088	8.8-year outdoor	0.2518	0.1355	1950	57.2
-089		.2525	.1343	1985	58.5
-090		.2529	.1344	2100	61.8
				Average...	59.2
6-001	10-year office storage	0.2523	0.1188	1550	51.7
-002		.2518	.1292	1890	58.1
-003		.2516	.1377	2000	57.7
-016		.2515	.1434	2200	61.0
-017		.2515	.1429	2040	56.8
-018		.2515	.1432	1975	54.8
-046		.2513	.1429	2050	57.1
-047		.2501	.1448	2030	56.1
-048		.2514	.1451	1940	53.2
-112		.2532	.1351	1762	51.5
-113		.2497	.1348	1941	57.7
-114		.2528	.1352	1820	53.2
-115		.2527	.1353	1720	50.3
-116		.2521	.1348	1757	51.7
-117		.2524	.1326	1997	59.7
-118		.2515	.1282	1745	54.1
-119		.2497	.1187	1355	45.7
-120		.2505	.1207	1495	49.4
				Average...	54.4

TABLE XXIV.- CONTINUED

(b) Exposed at San Diego, CA

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-004 -005 -006	1.7-year outdoor	0.2524 .2516 .2512	0.1416 .1432 .1432	2145 2105 1950	60.0 58.4 54.2
				Average...	57.6
6-007 -008 -009	3.7-year outdoor	0.2520 .2510 .2521	0.1431 .1429 .1423	1500 1420 1515	41.6 39.6 42.2
				Average...	41.1
6-010 -011 -012	5.7-year outdoor	0.2519 .2522 .2519	0.1427 .1431 .1434	2155 2105 2130	60.0 58.3 59.0
				Average...	59.1
6-013 -014 -015	8.8-year outdoor	0.2517 .2507 .2511	0.1441 .1442 .1439	2010 1860 1905	55.4 51.5 52.7
				Average...	53.2

(c) Exposed at Honolulu, HI

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-037 -038 -039	3.7-year outdoor	0.2515 .2513 .2498	0.1430 .1396 .1321	2100 1925 1830	58.4 54.9 55.5
				Average...	56.2
6-040 -041	5.7-year outdoor	0.2514 .2518	0.1242 .1211	1435 1595	46.0 52.3
				Average...	49.2
6-043 -044 -045	8.8-year outdoor	0.2510 .2513 .2512	0.1240 .1338 .1399	1560 1640 1930	50.1 48.8 54.9
				Average...	51.3

TABLE XXIV.- CONTINUED

(d) Exposed at Frankfurt, W. Germany

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-049	1.7-year outdoor	0.2512	0.1451	1675	46.0
-050		.2511	.1439	2050	56.7
-051		.2517	.1429	2230	62.0
				Average...	54.9
6-052	3.7-year outdoor	0.2521	0.1428	2025	56.3
-053		.2511	.1421	1961	55.0
-054		.2519	.1419	1920	53.7
				Average...	55.0
6-055	5.7-year outdoor	0.2528	0.1418	2015	56.2
-056		.2518	.1419	2023	56.6
-057		.2516	.1420	2073	58.0
				Average...	57.0
6-058	8.8-year outdoor	0.2517	0.1420	1885	52.7
-059		.2510	.1418	1990	55.9
-060		.2511	.1417	1965	55.2
				Average...	54.6

(e) Exposed at Wellington, N. Zealand

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-019	1.7-year outdoor	0.2511	0.1434	2080	57.8
-020		.2519	.1431	1925	53.4
-021		.2526	.1429	2065	57.2
				Average...	56.1
6-022	3.7-year outdoor	0.2521	0.1435	2065	57.1
-023		.2520	.1431	1425	39.5
-024		.2518	.1432	1530	42.4
				Average...	46.3
6-025	5.7-year outdoor	0.2518	0.1438	2160	59.7
-026		.2526	.1439	1980	54.5
-027		.2525	.1438	2177	60.0
				Average...	58.0

TABLE XXIV.- CONCLUDED

(e) CONCLUDED

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-028	8.8-year outdoor	0.2523	0.1429	1730	48.0
-029		.2519	.1426	2090	58.2
-030		.2525	.1422	2005	55.8
				Average...	54.0

(f) Exposed at São Paulo, Brazil

Specimen number	Exposure condition	Width, in.	Thickness, in.	Maximum load, lbf.	Failure stress, ksi
6-061	1-year outdoor	0.2527	0.1415	1775	49.6
-062		.2508	.1414	1970	55.6
-063		.2493	.1414	2005	56.9
				Average...	54.0
6-064	2.5-year outdoor	0.2518	0.1421	1935	54.1
-065		.2518	.1421	2015	56.3
-066		.2511	.1425	2052	57.3
				Average...	55.9
6-067	4.5-year outdoor	0.2509	0.1429	2080	58.0
-068		.2515	.1432	1910	53.0
-069		.2512	.1435	1745	48.4
				Average...	53.2
6-070	5.7-year outdoor	0.2510	0.1439	1720	47.6
-071		.2514	.1438	1785	49.4
				Average...	48.5
6-073	9.5-year outdoor	0.2518	0.1434	1985	55.0
-074		.2510	.1432	1820	50.6
-075		.2495	.1436	1930	53.9
				Average...	53.2

TABLE XXV.- EFFECT OF FLIGHT SERVICE ON BELL 206L COMPOSITE COMPONENTS

Flight service region	Service time, months	Flight hours	Component Strength, psi			
			Litter door	Baggage door	Forward fairing	Vertical fin
Gulf of Mexico	12 34	879 3387	0.88 0.61	0.91 1.39	1.80 2.34	1.80 1.12
East Canada	14 32	870 1160	0.85 0.88	0.50 1.57	2.50 2.47	1.60 1.37
Northeast U.S.A.	22 34	1413 2661	0.97 -	0.31 -	1.89 -	1.51 1.23
Alaska	29	668	0.47	1.39	2.69	-
Baseline Strength		High Low Average*	0.67 0.63 0.65	0.80 0.63 0.70	3.40 2.20 3.13	1.57 1.35 1.46
Design Strength**			0.58	0.70	0.49	1.05

*Average test results from five components selected from production.

**Required strength for as-fabricated components (including environmental factor).

TABLE XXVI. NASA COMPOSITE STRUCTURES FLIGHT SERVICE SUMMARY

Aircraft component	Total components		Start of flight service	Cumulative flight hours	
				High time aircraft	Total component
L-1011 Fairing panels	18	(15)	January 1973	37,950	587,940
737 Spoiler	108	(54)	July 1973	37,370	2,350,000
C-130 Center wing box	2	(2)	October 1974	8,210	16,280
DC-10 Aft pylon skin	3	(2)	August 1975	31,810	80,880
DC-10 Upper aft rudder	15	(12)	April 1976	37,740	336,090
727 Elevator	10	(8)	March 1980	20,760	175,570
L-1011 Aileron	8	(8)	March 1982	15,510	117,360
737 Horizontal stab.	10	(10)	March 1984	7,580	68,600
S-76 Tail rotors and horizontal stab.	14	(3)	February 1979	5,500	51,300
206L Fairing, doors, and vertical fin	160	(84)	March 1981	6,900	310,000
CH-53 Cargo ramp skin	1	(1)	May 1981	1,500	1,500
Grand total	349	(199)			4,095,520

( ) Still in service

November 1986

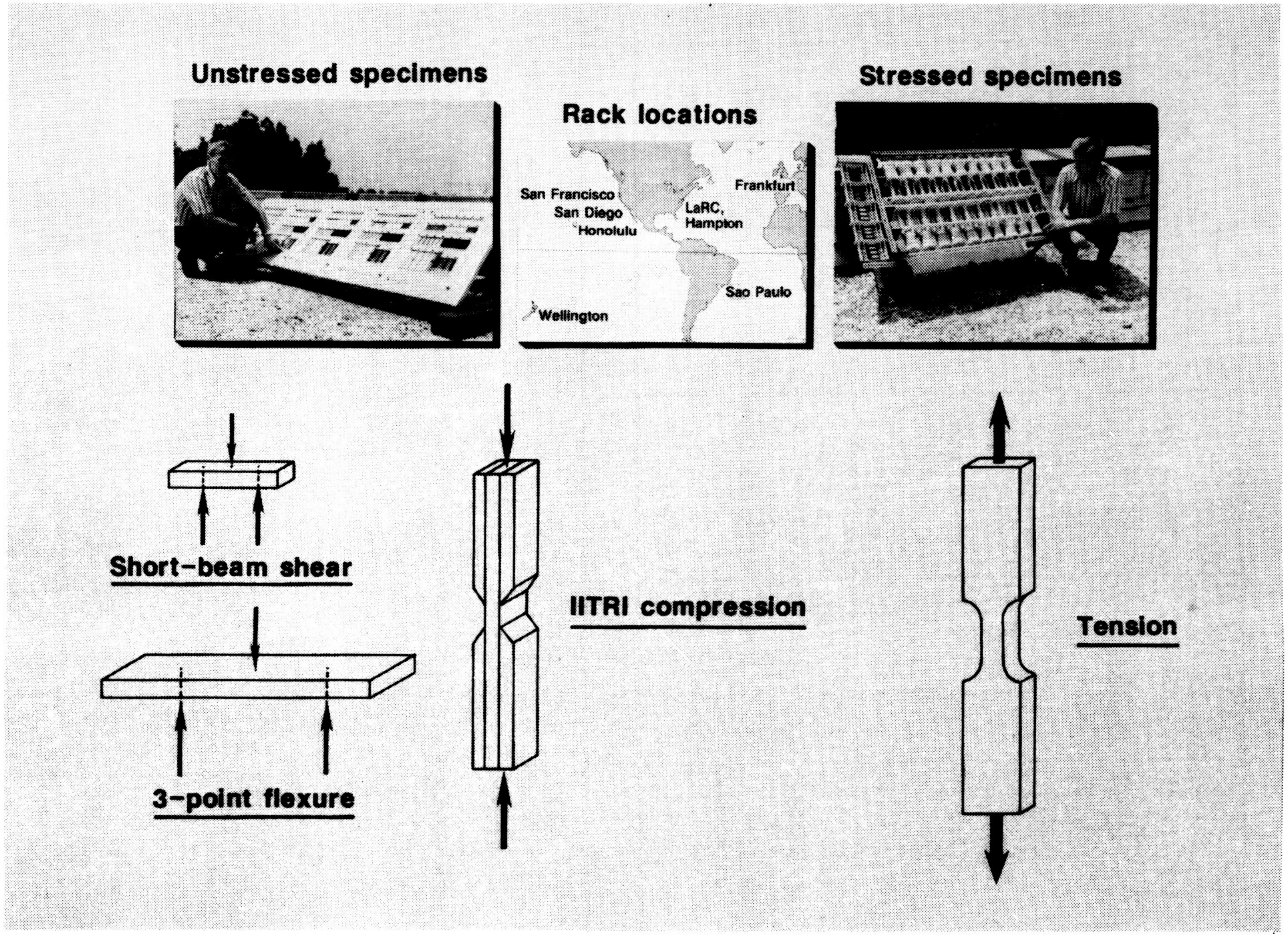

Figure 1. Exposure location and specimen types.

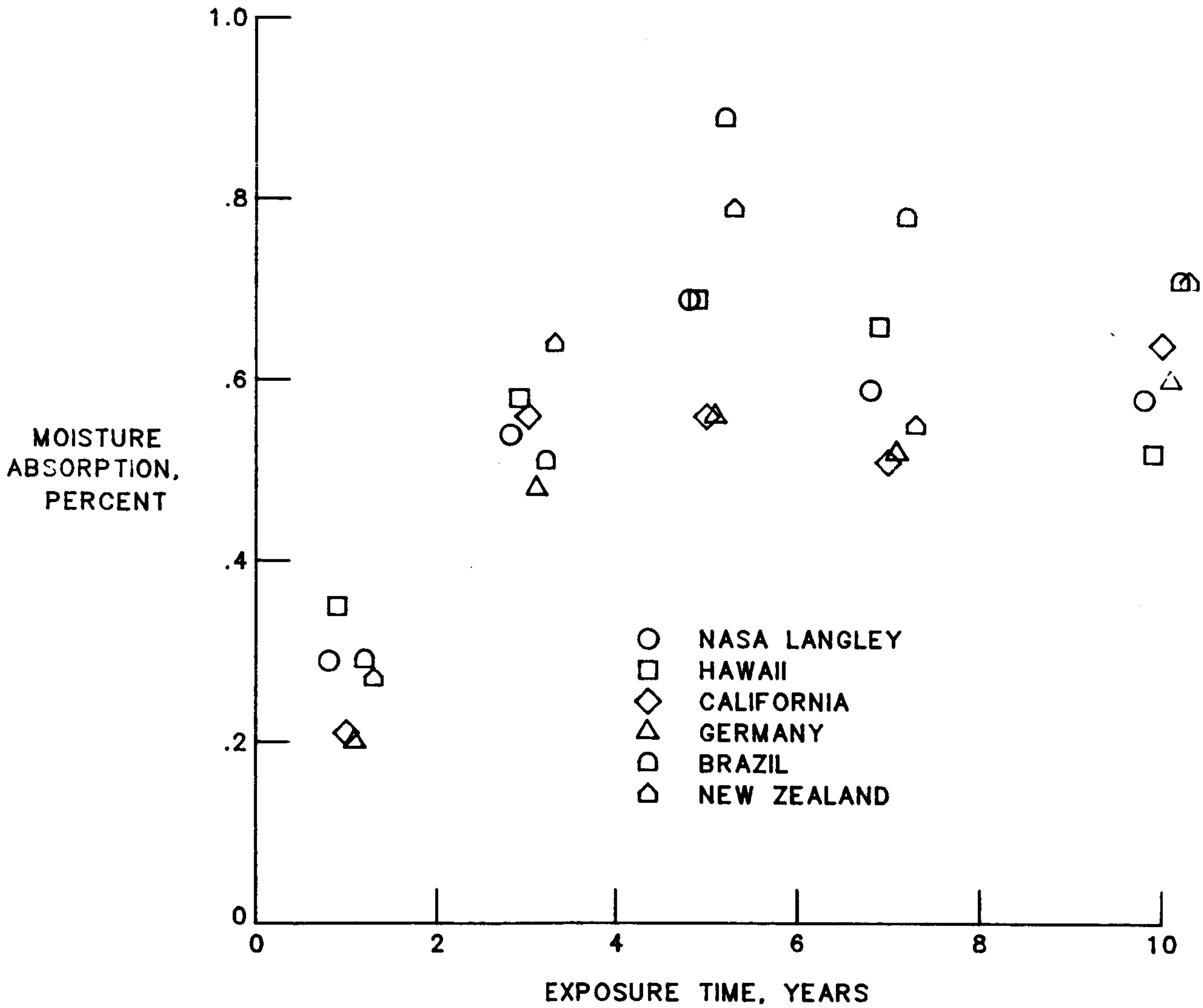

Figure 2. Moisture absorption of T300/5209 graphite/epoxy.

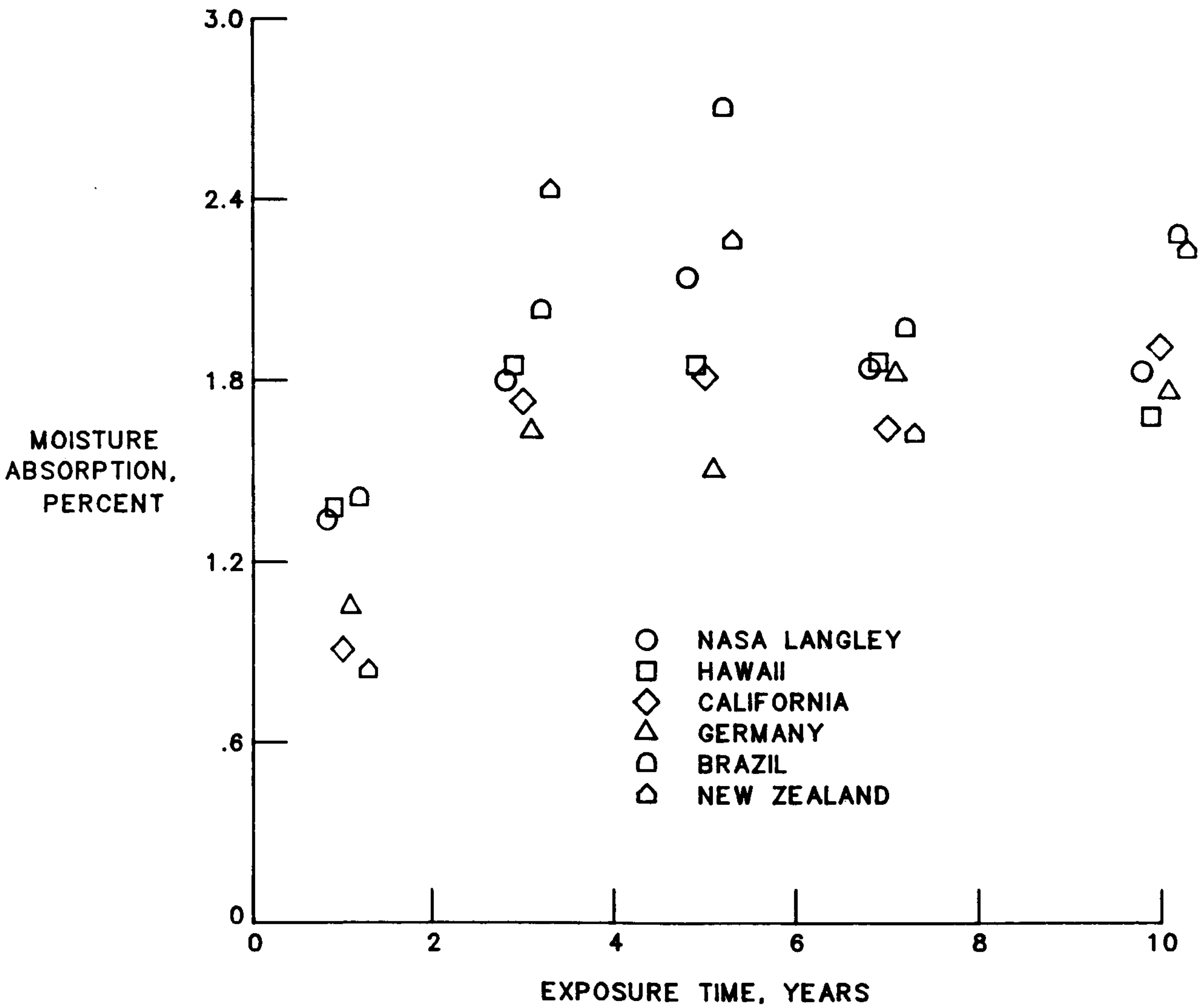

Figure 3. Moisture absorption of T300/2544 graphite/epoxy.

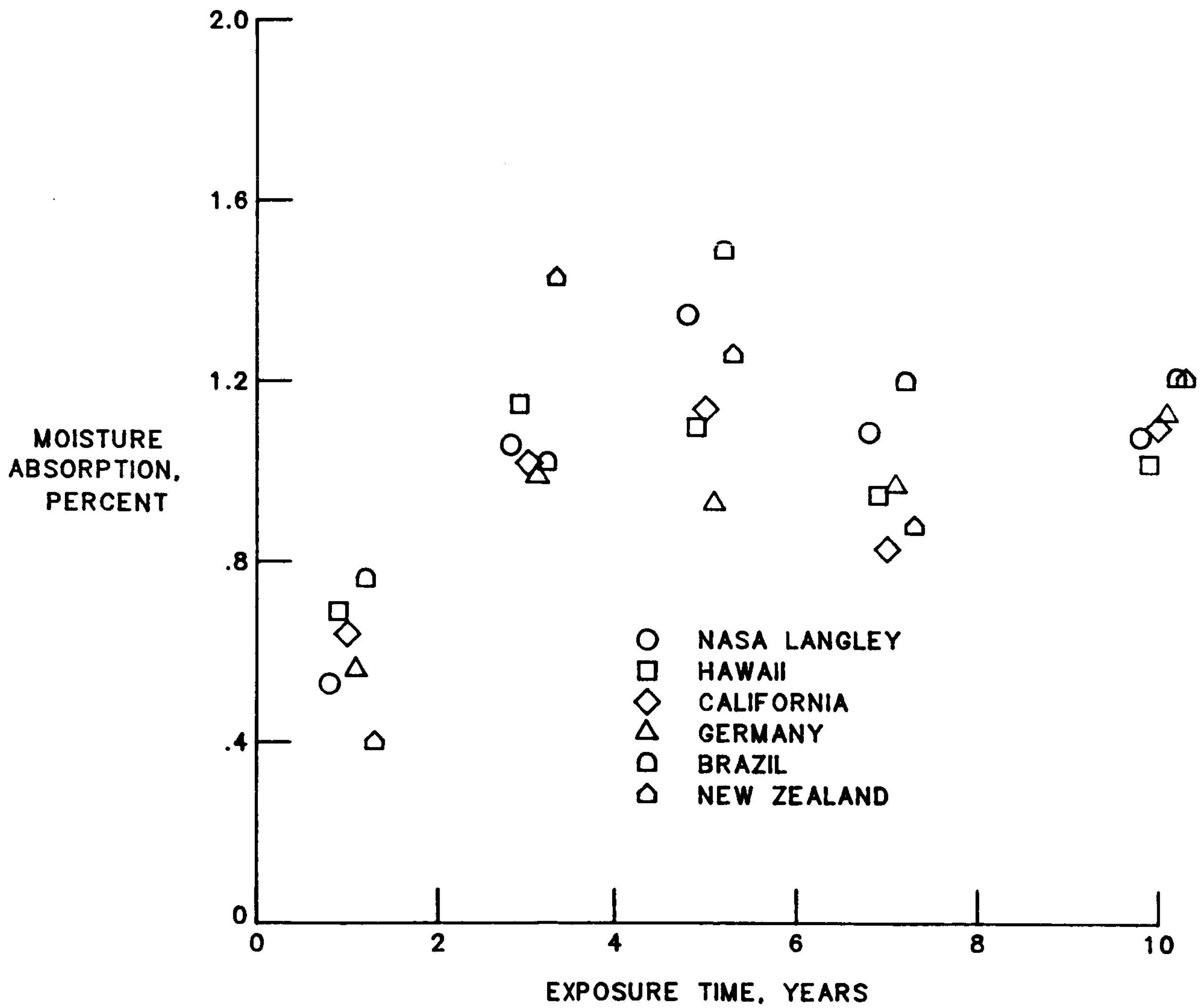

Figure 4. Moisture absorption of AS/3501 graphite/epoxy.

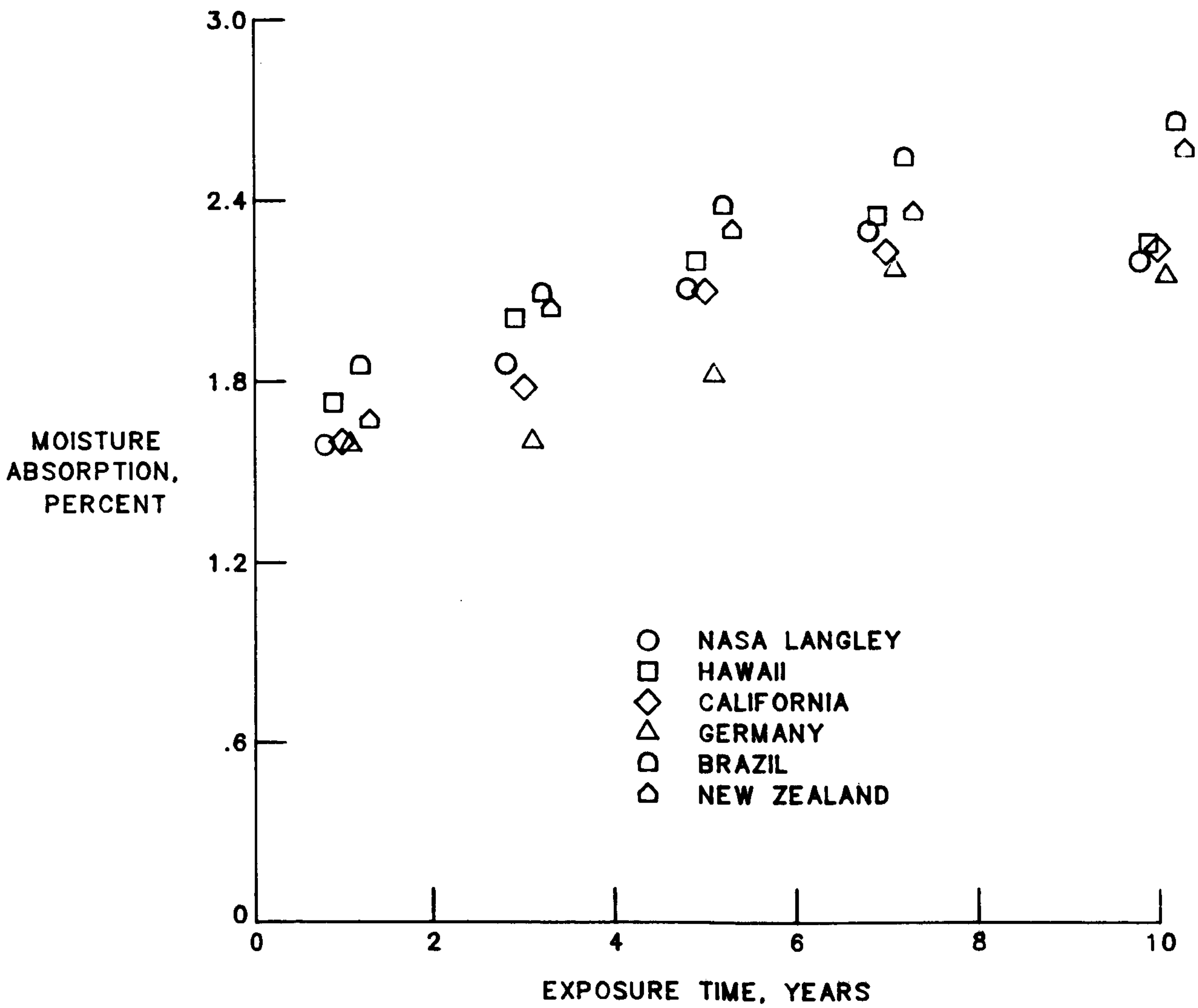

Figure 5. Moisture absorption of Kevlar-49/F-155.

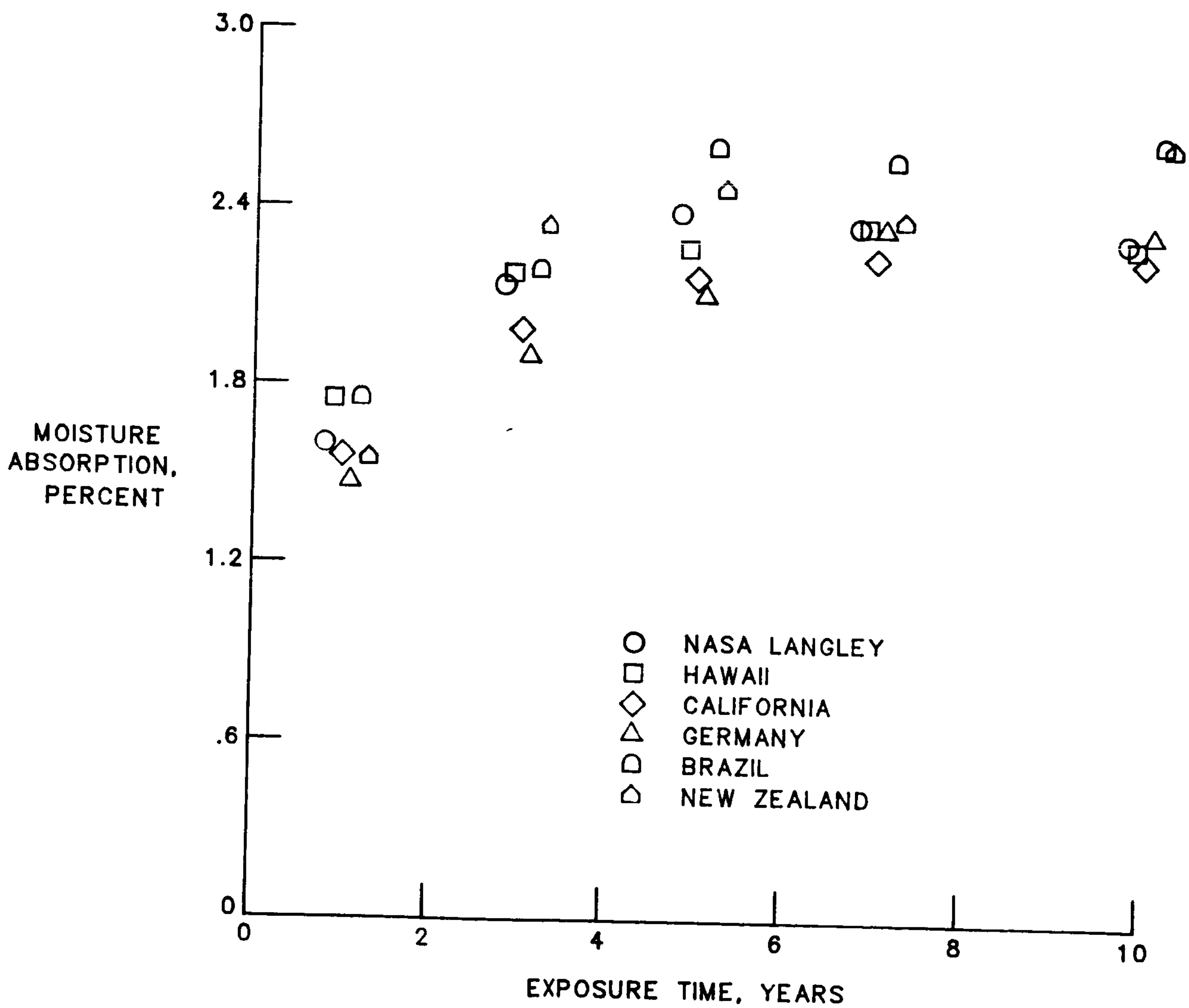

Figure 6. Moisture absorption of Kevlar-49/F-161.

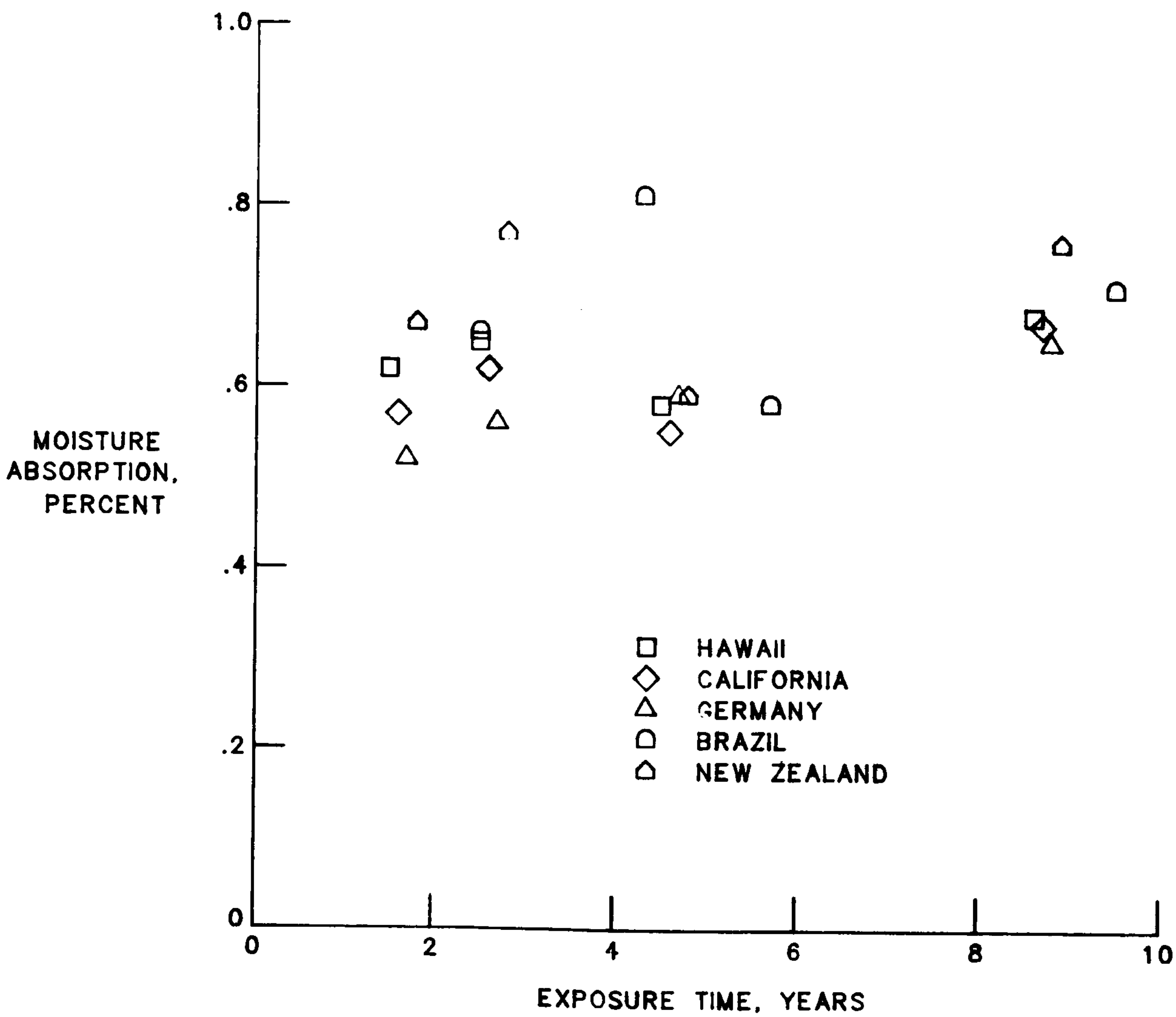

Figure 7. Moisture absorption of T300/5208 graphite/epoxy.

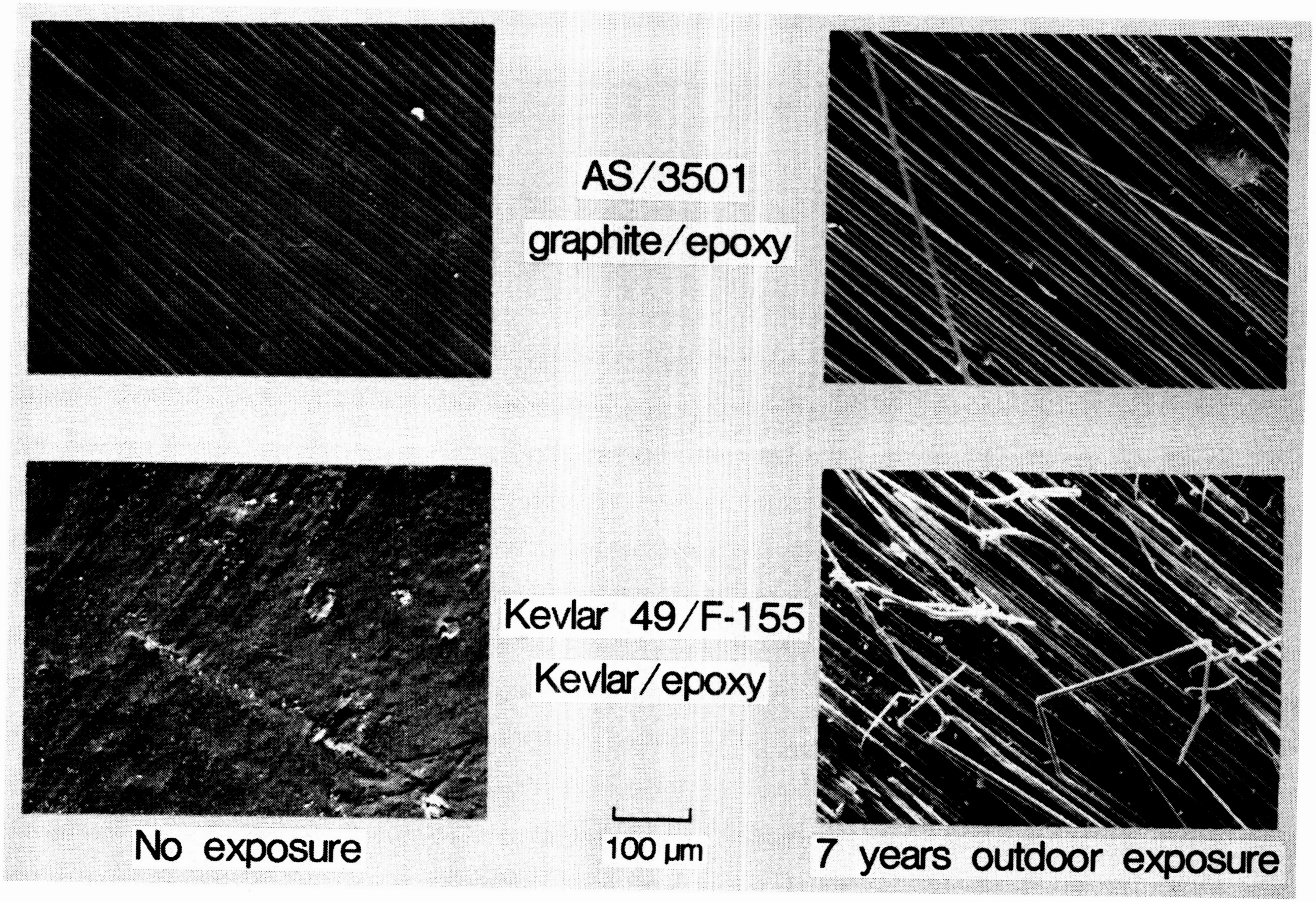

Figure 8. Ultraviolet radiation effects on unpainted composite materials.

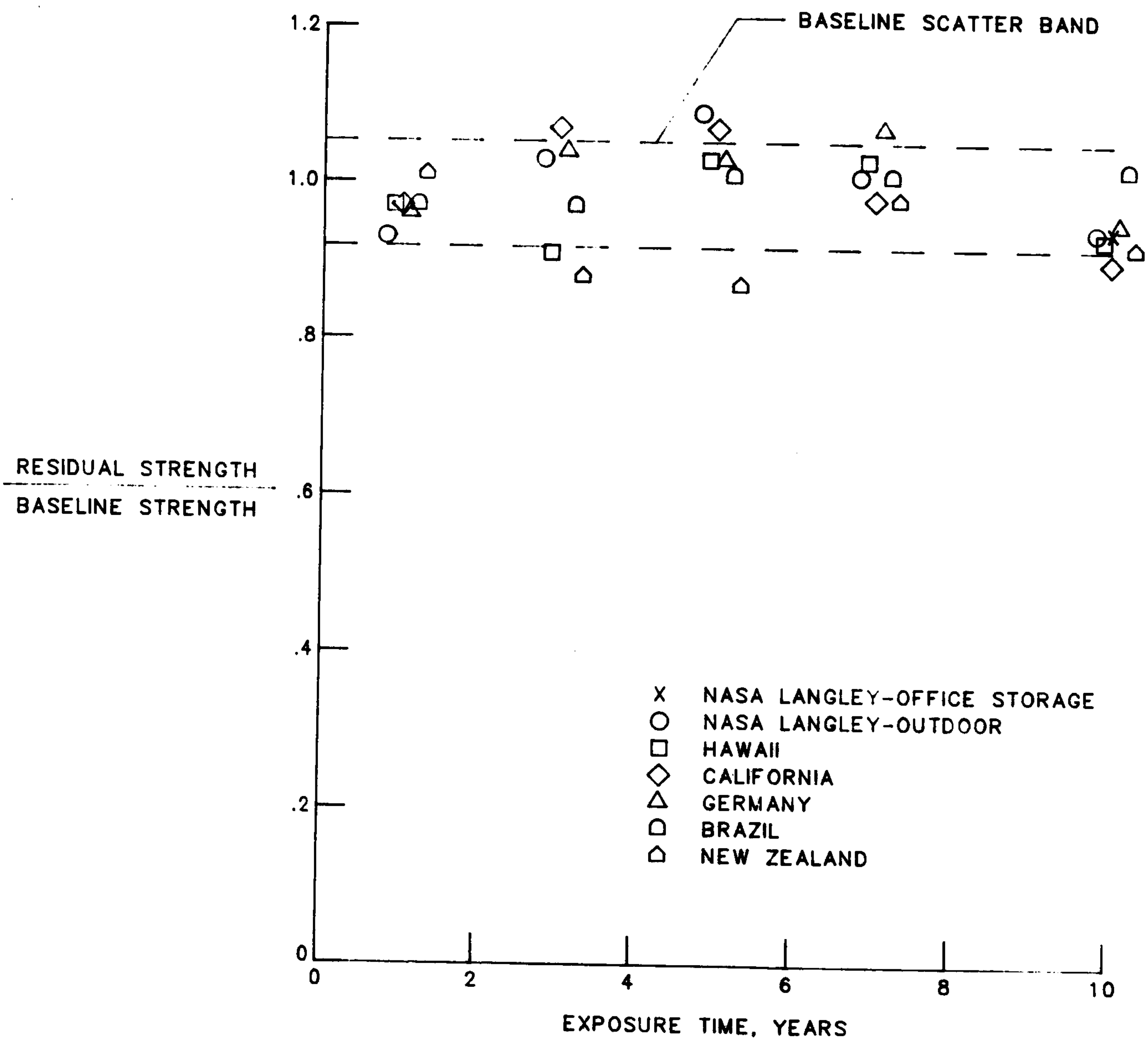

Figure 9. Flexural strength of T300/5209 graphite/epoxy.

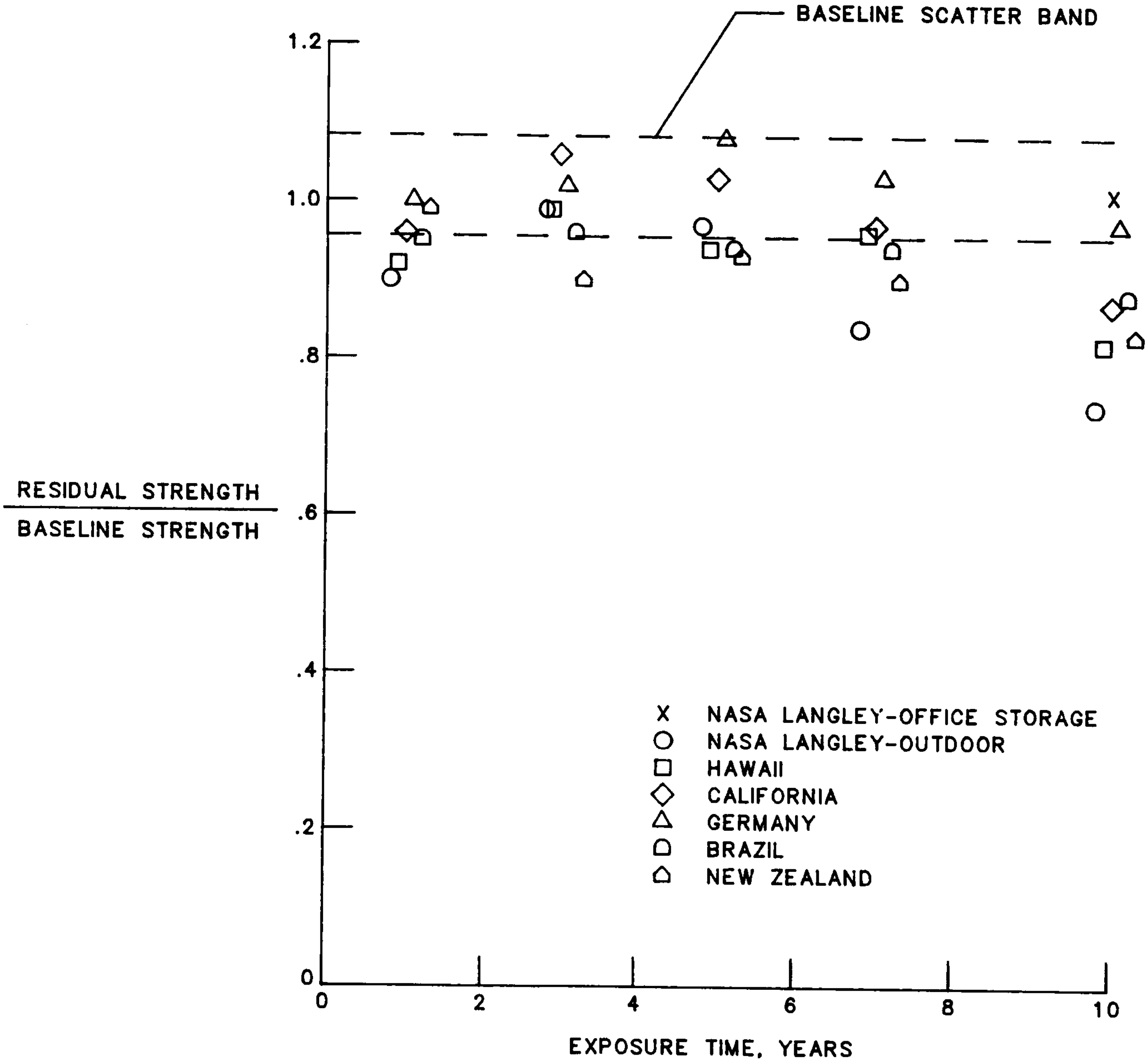

Figure 10. Flexural strength of T300/2544 graphite/epoxy.

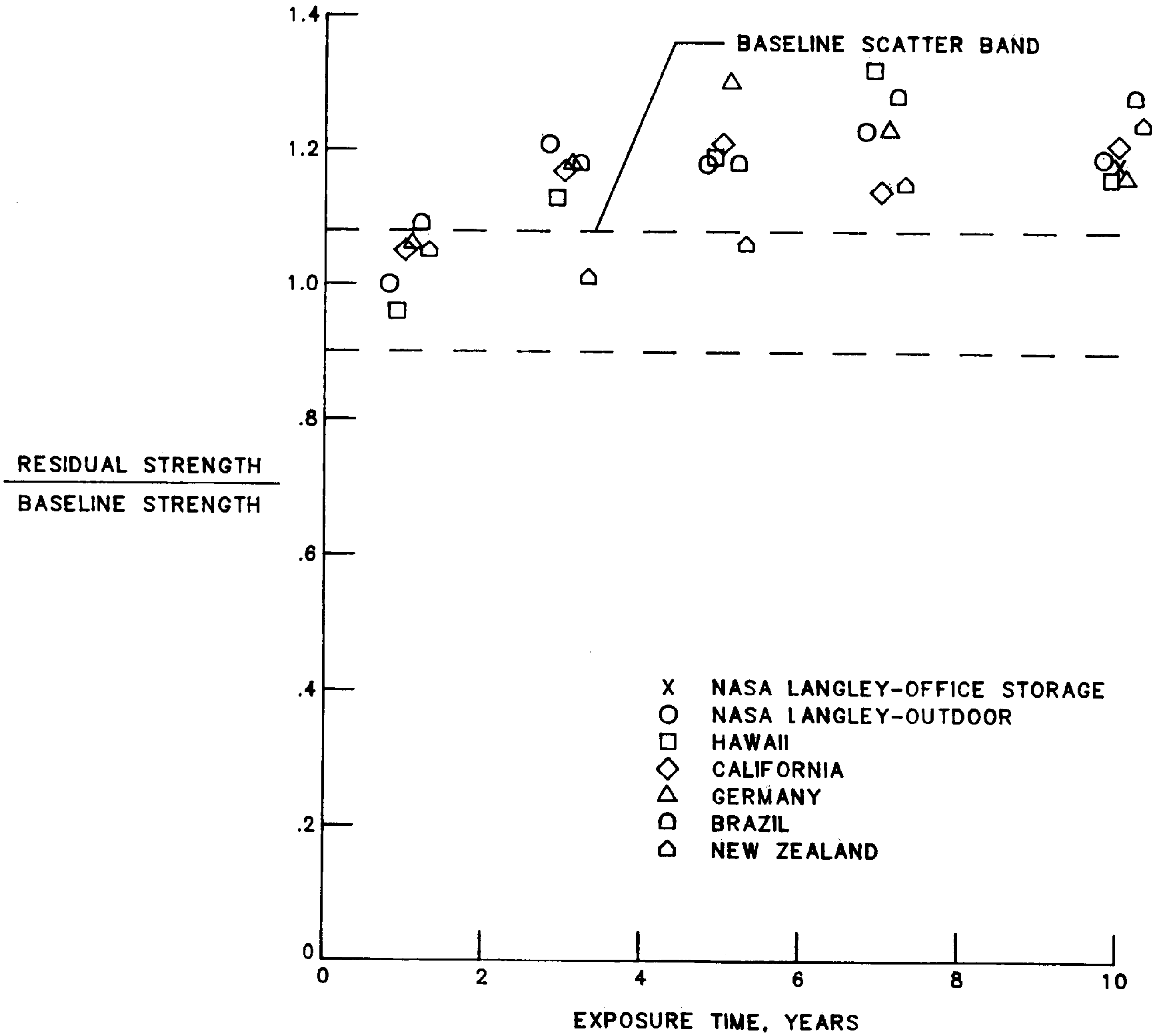

Figure 11. Flexural strength of AS/3501 graphite/epoxy.

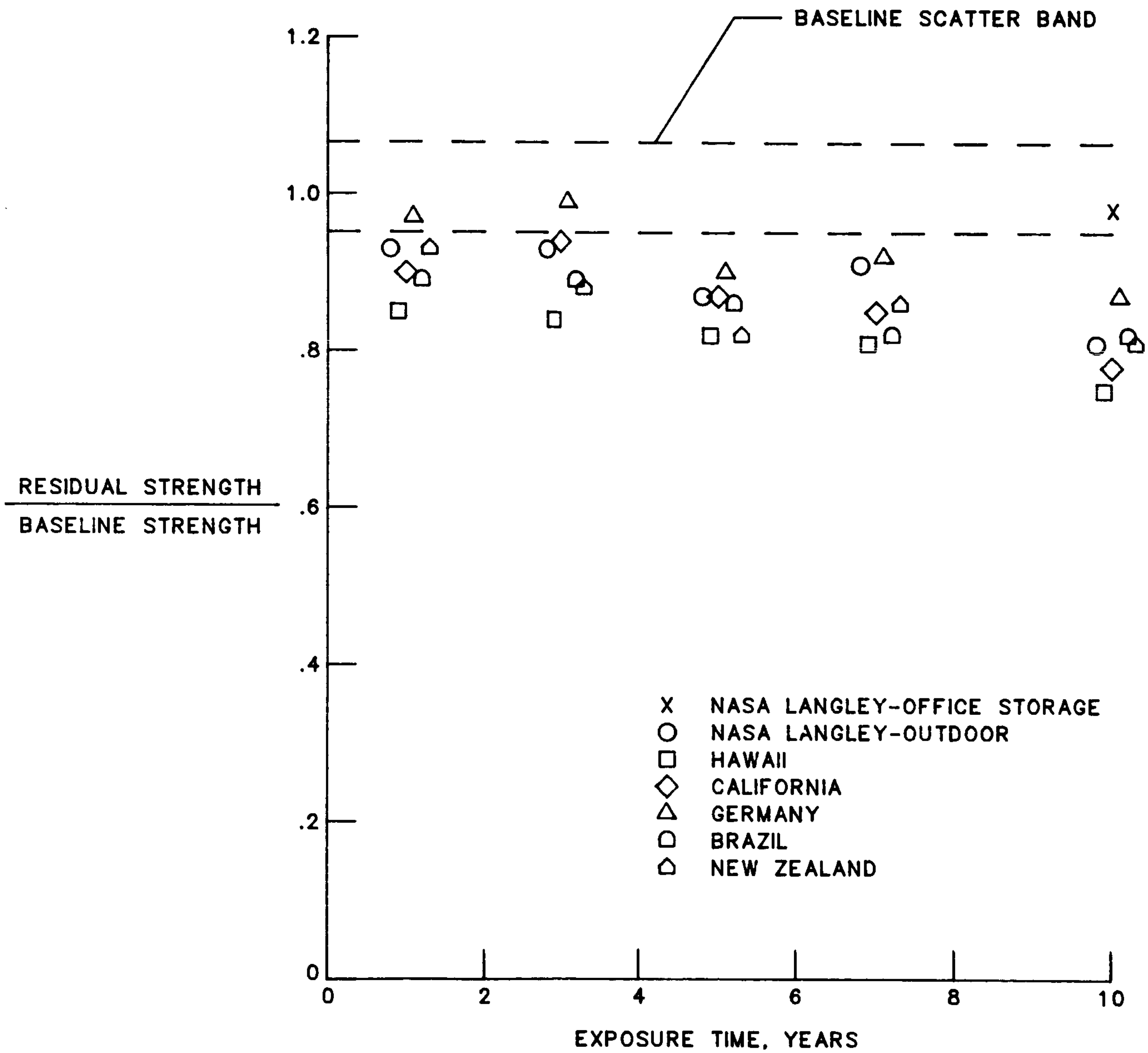

Figure 12. Flexural strength of Kevlar-49/F-155.

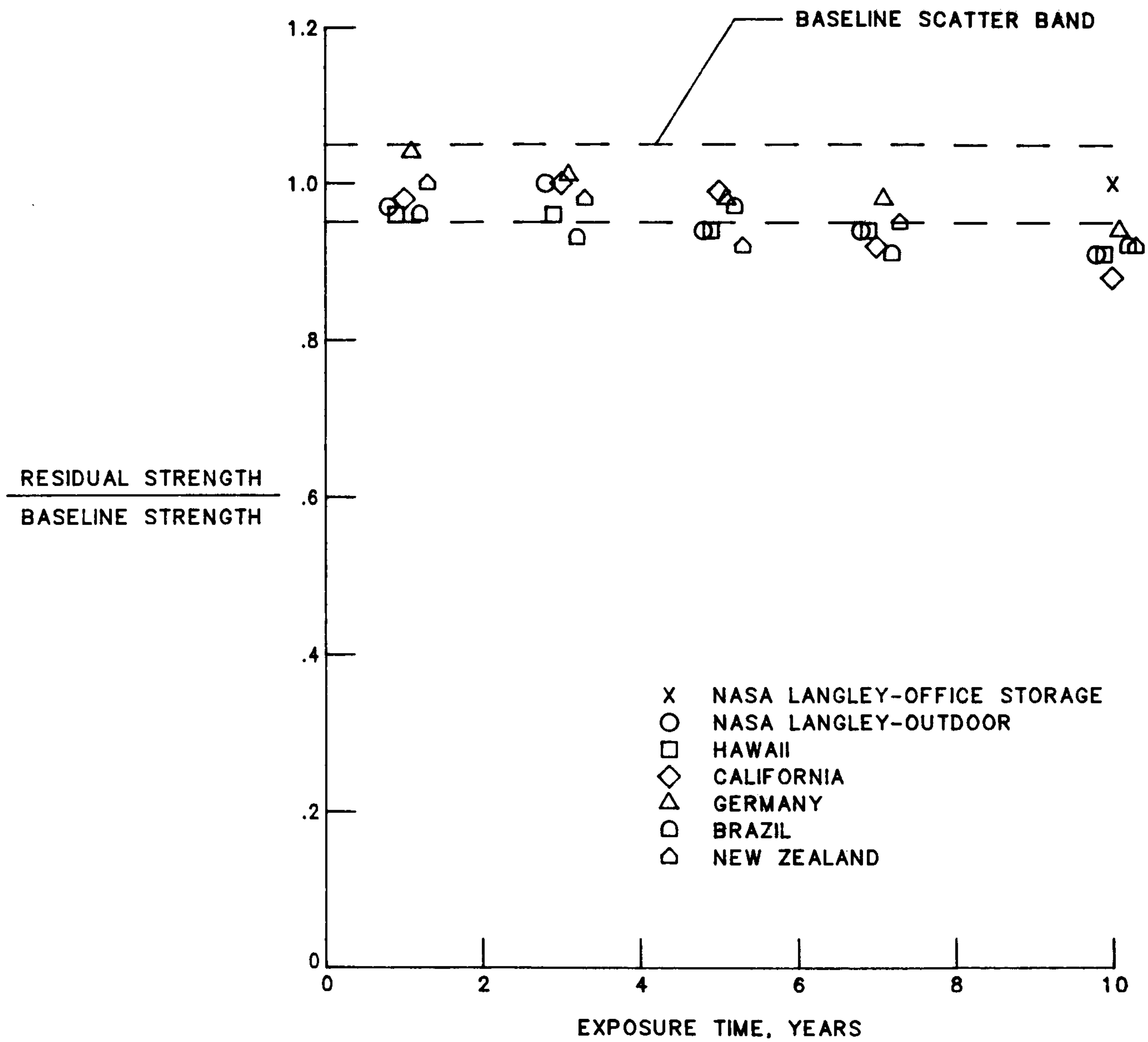

Figure 13. Flexural strength of Kevlar-49/F-161.

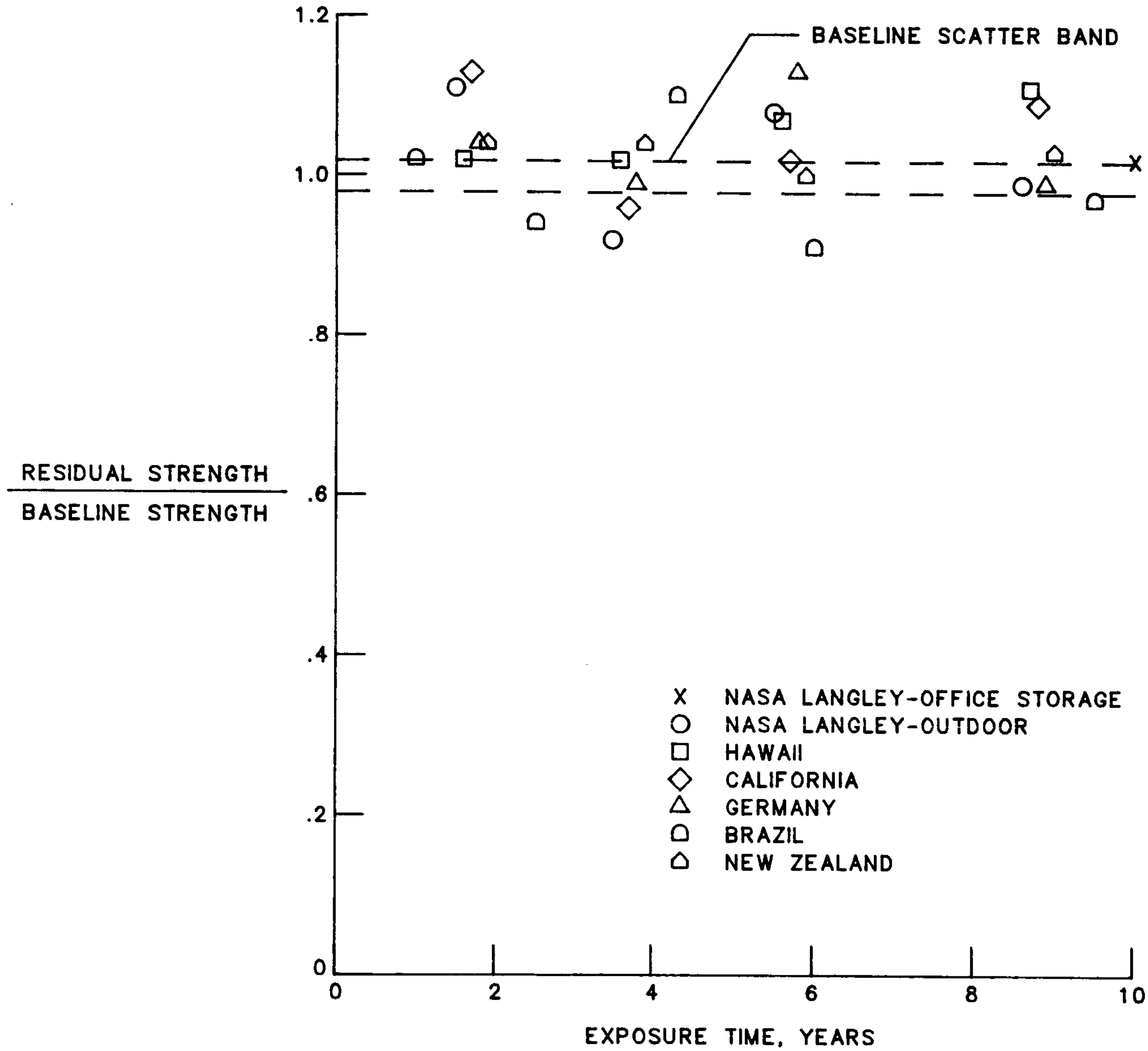

Figure 14. Flexural strength of T300/P1700 graphite/polysulfone.

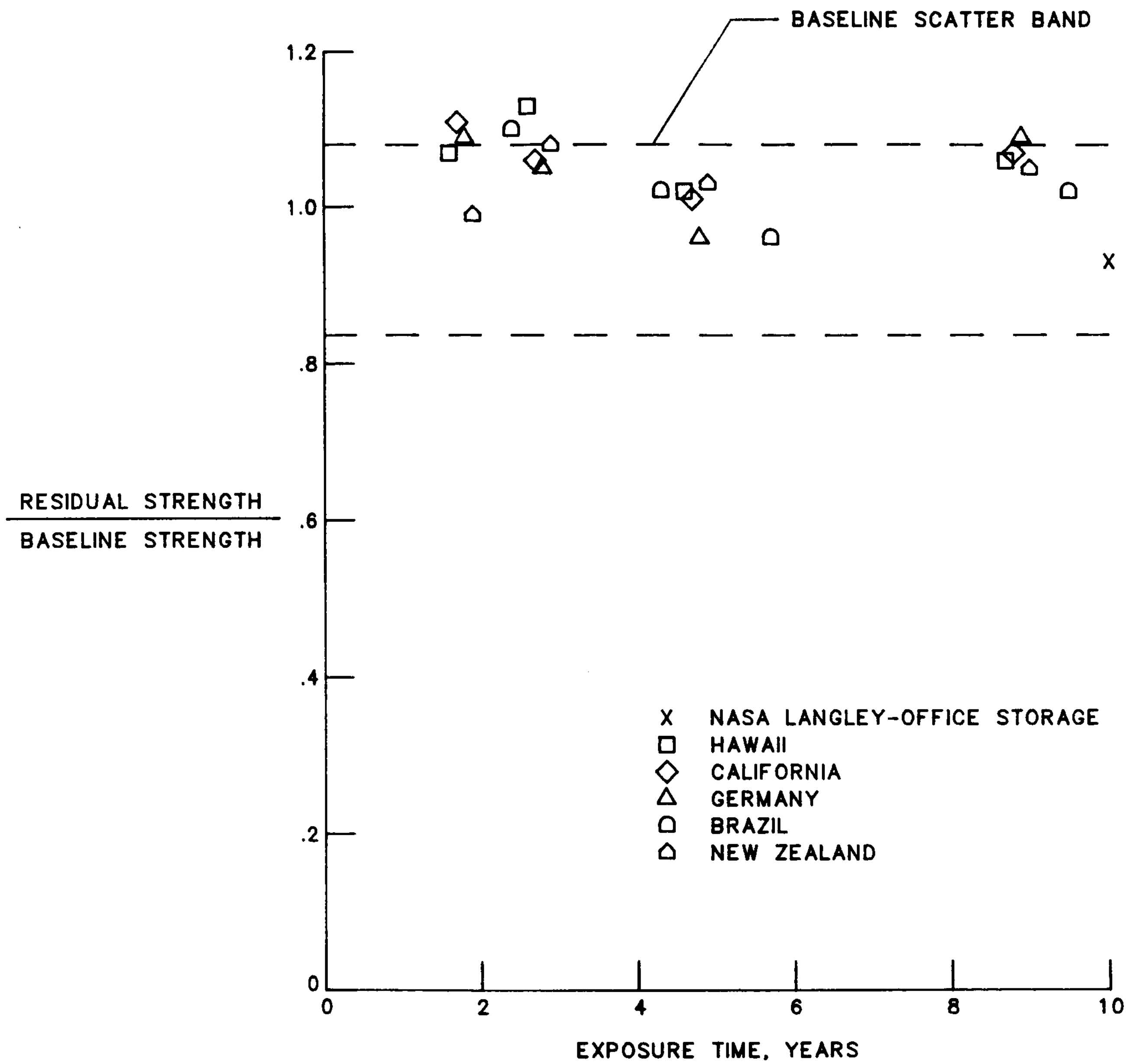

Figure 15. Flexural strength of T300/5208 graphite/epoxy.

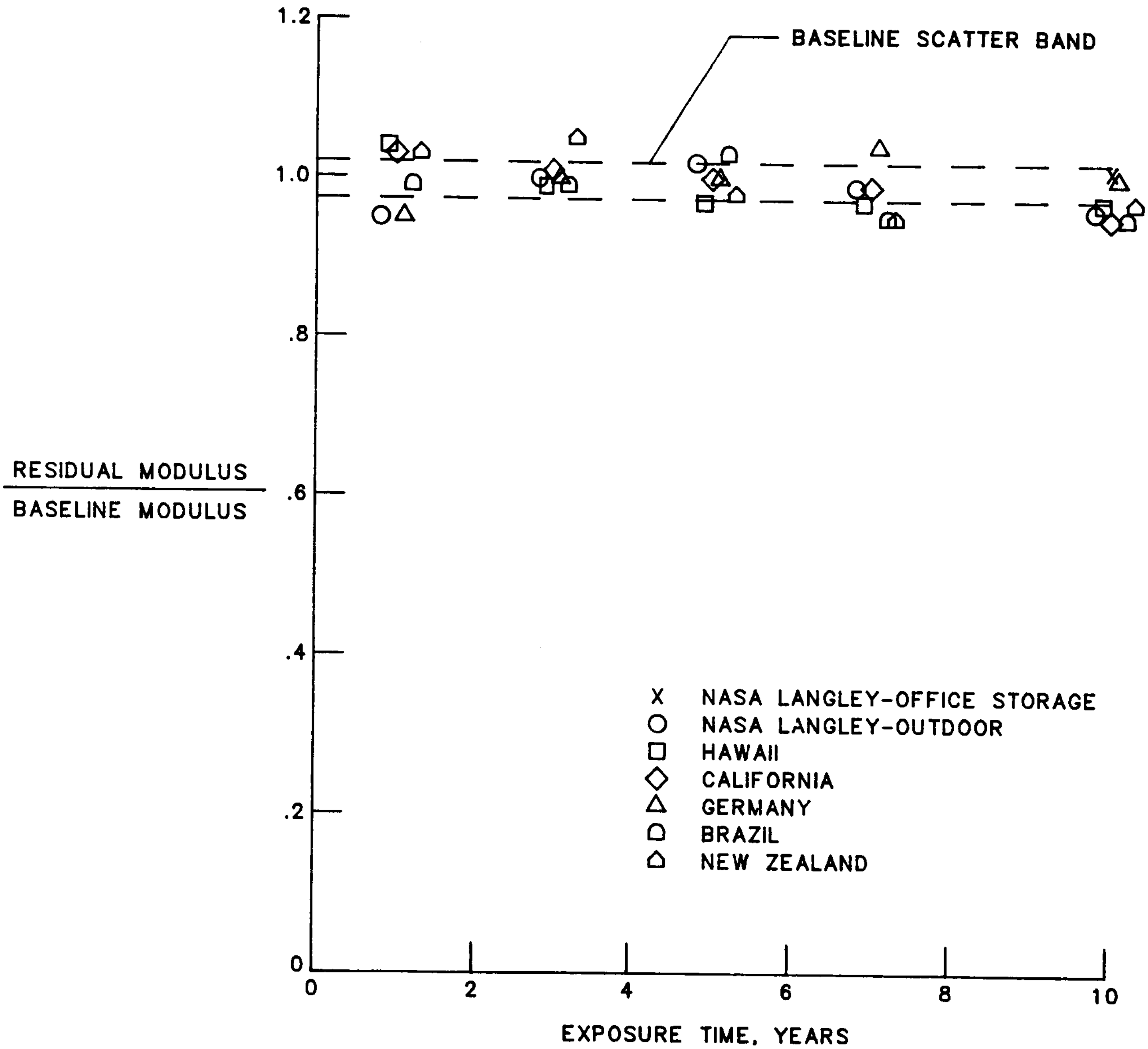

Figure 16. Flexural modulus of T300/5209 graphite/epoxy.

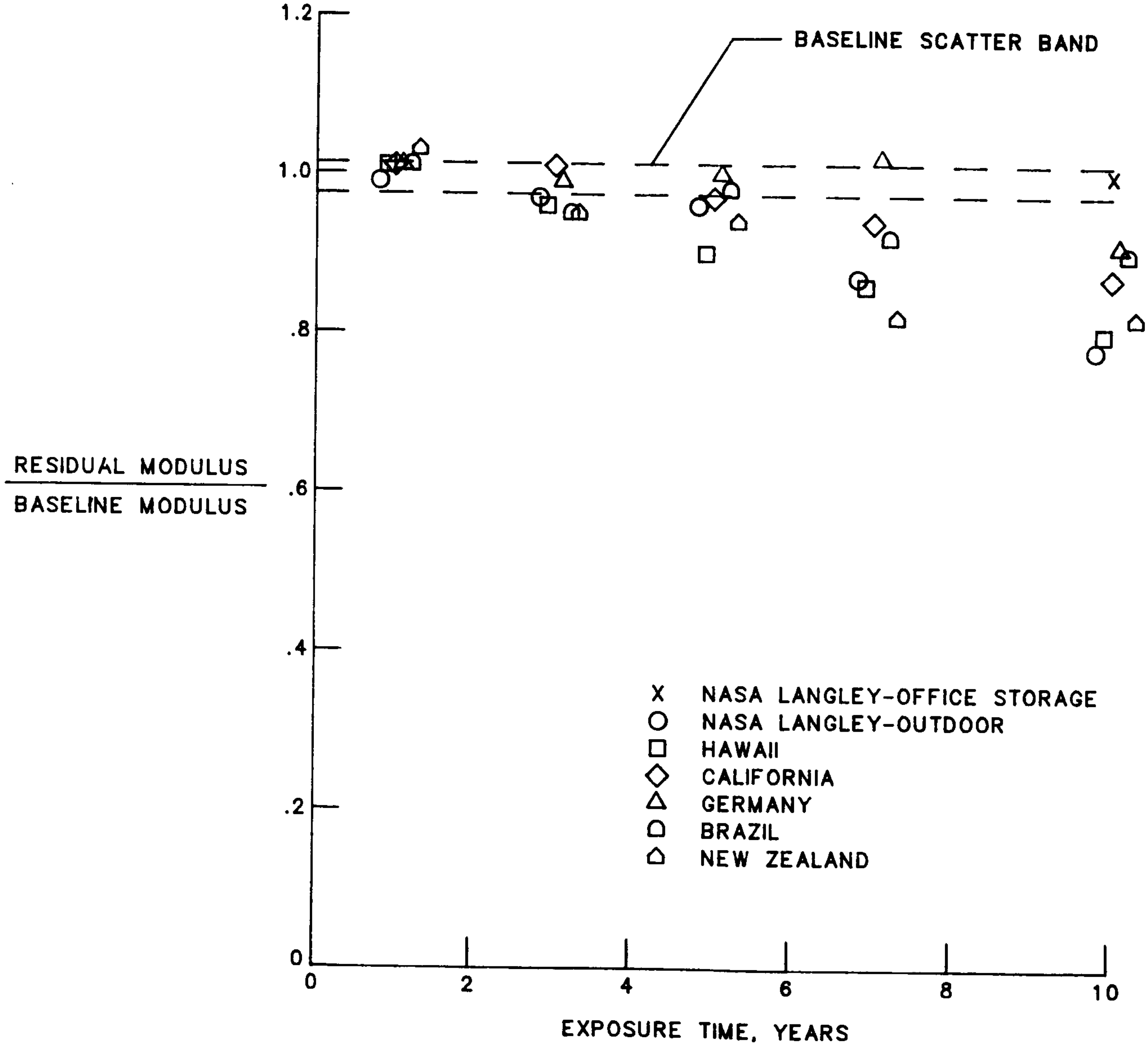

Figure 17. Flexural modulus of T300/2544 graphite/epoxy.

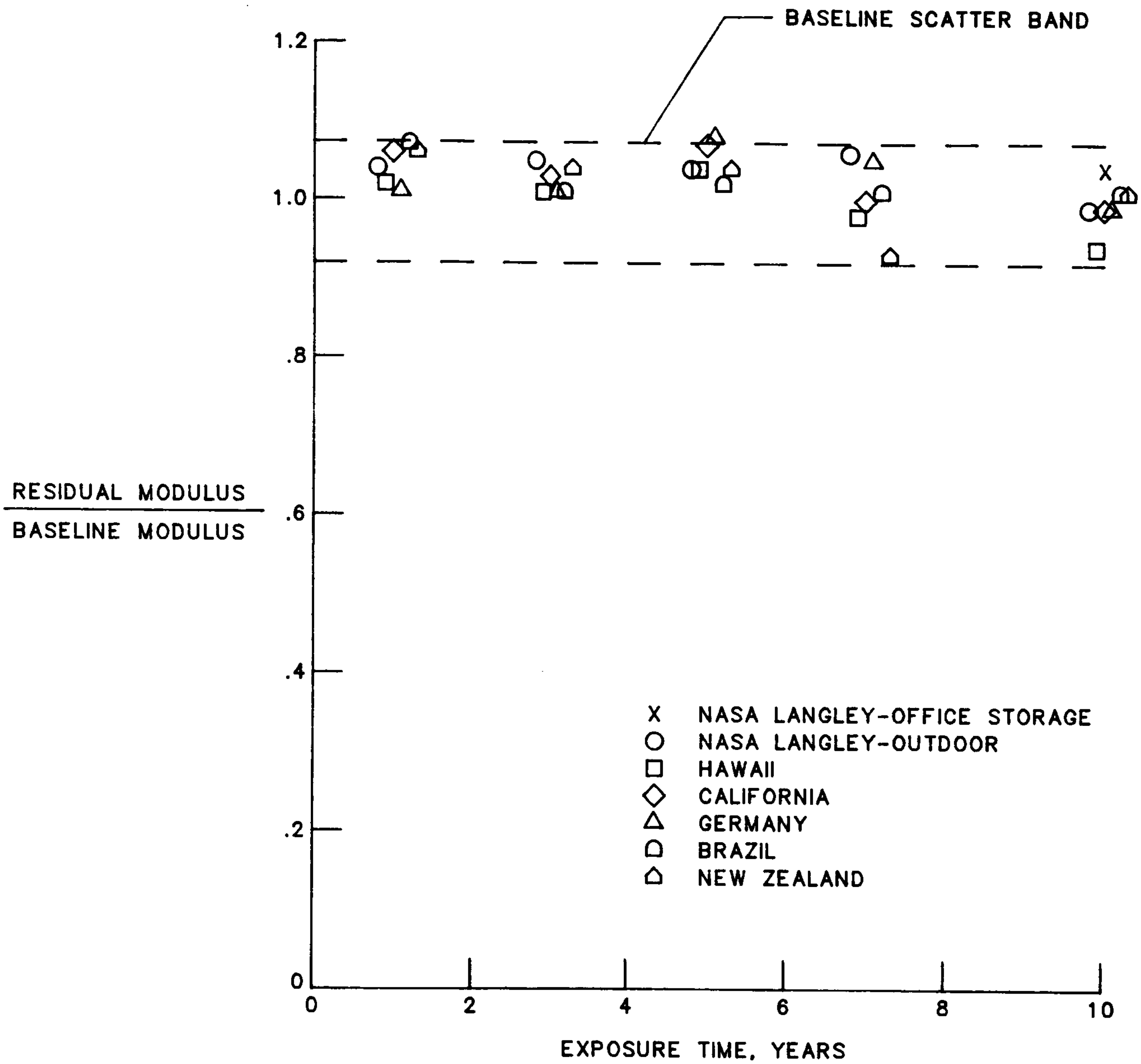

Figure 18. Flexural modulus of AS/3501 graphite/epoxy.

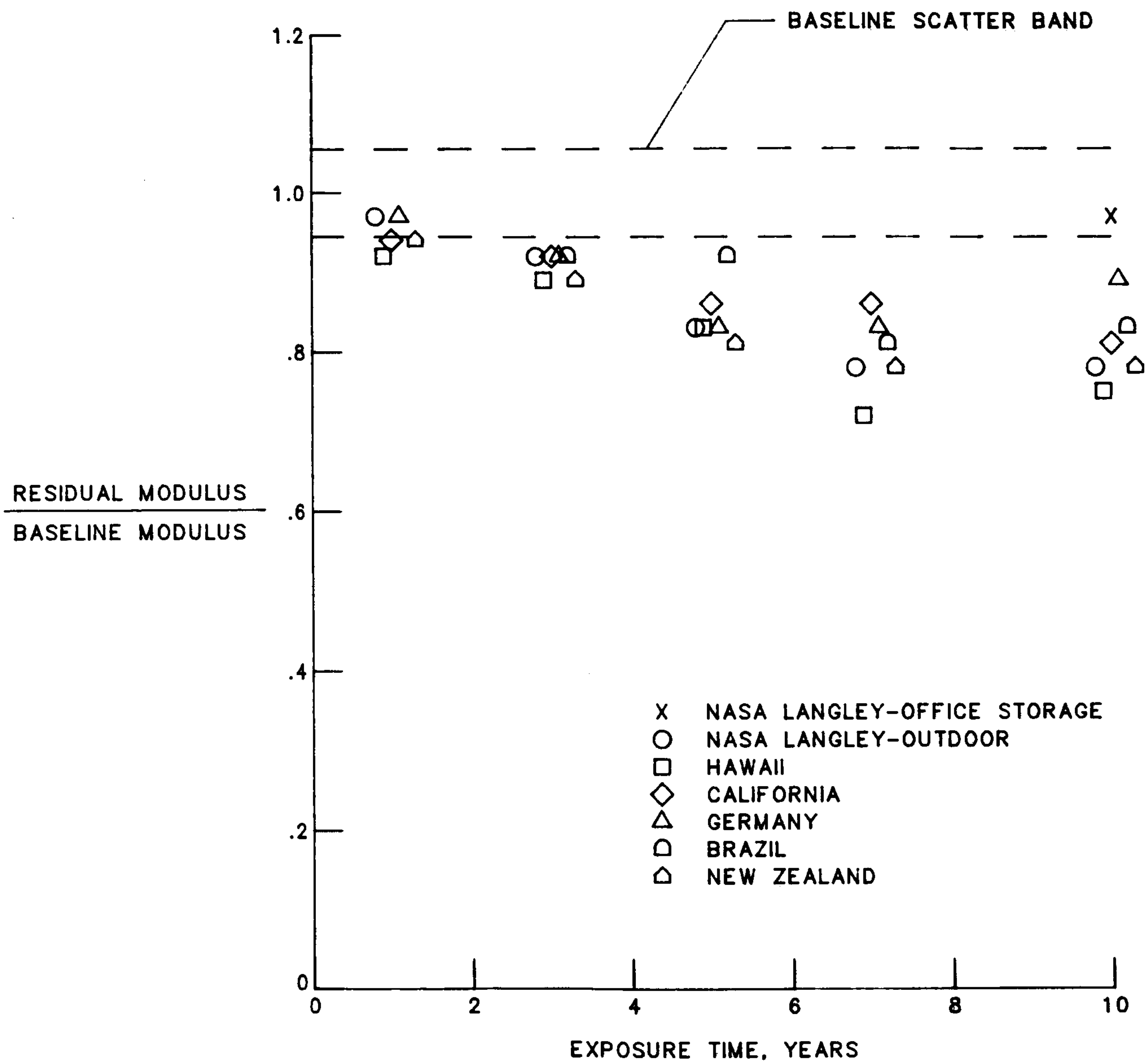

Figure 19. Flexural modulus of Kevlar-49/F-155.

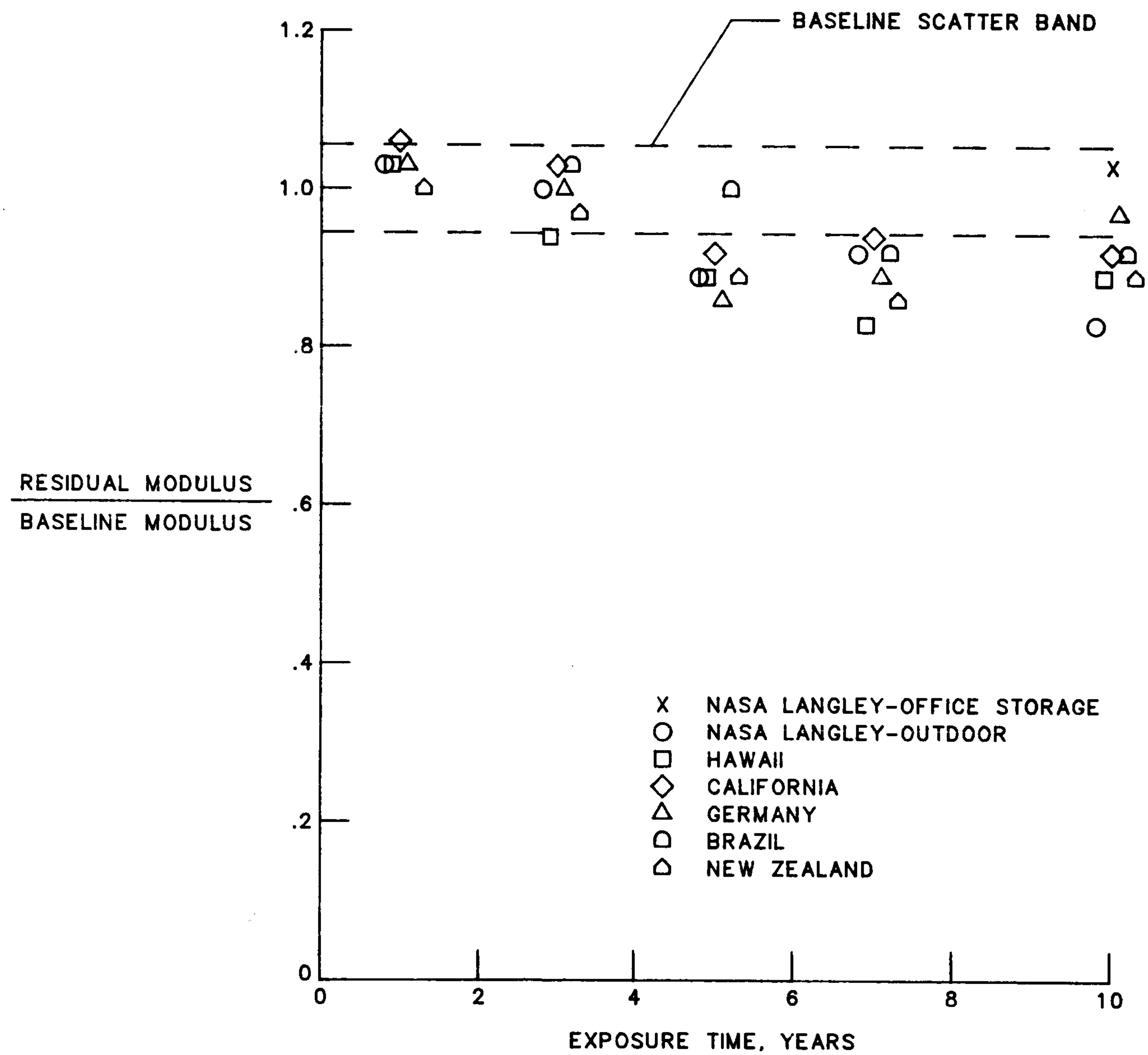

Figure 20. Flexural modulus of Kevlar-49/F-161.

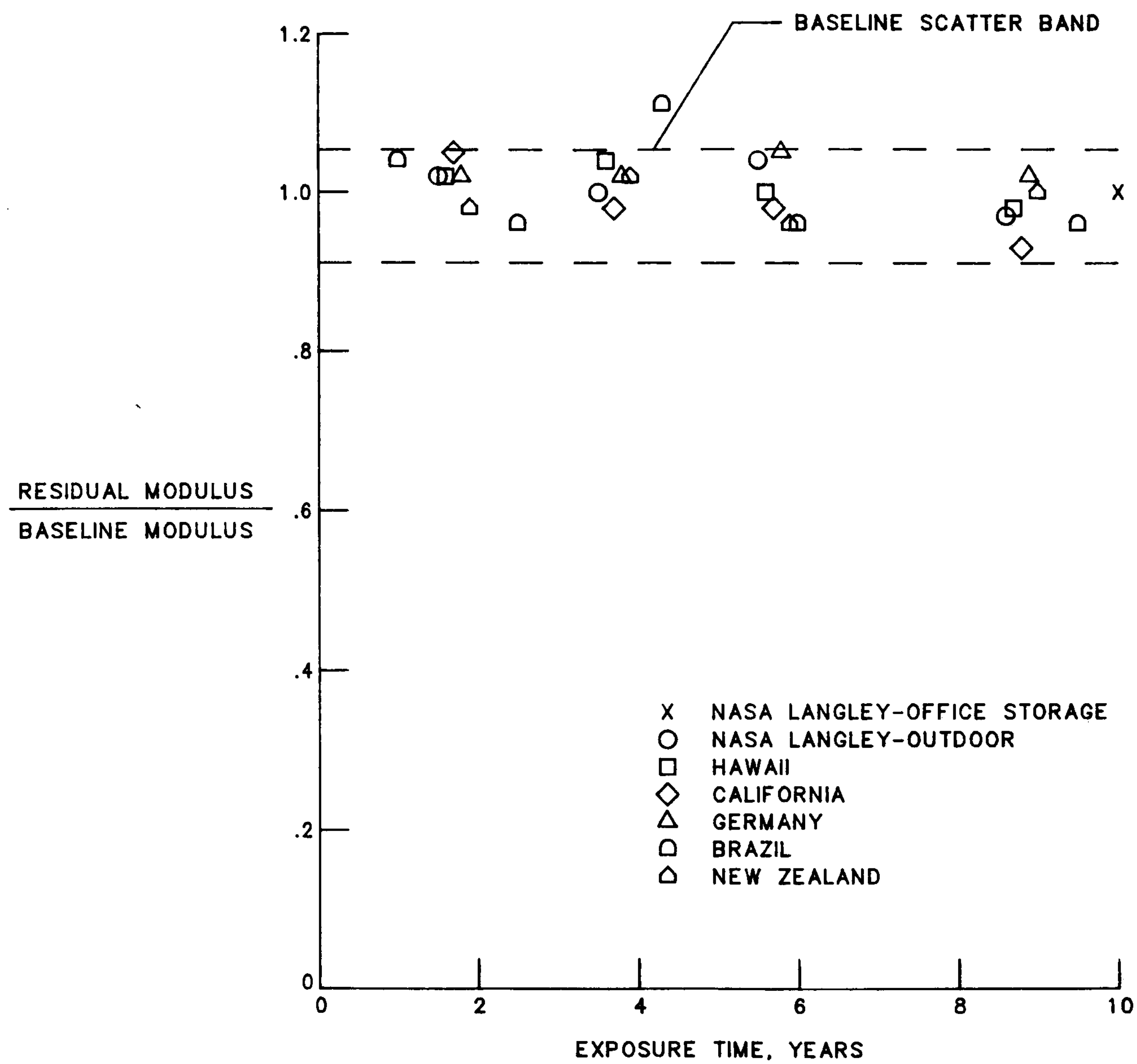

Figure 21. Flexural modulus of T300/P1700 graphite/polysulfone.

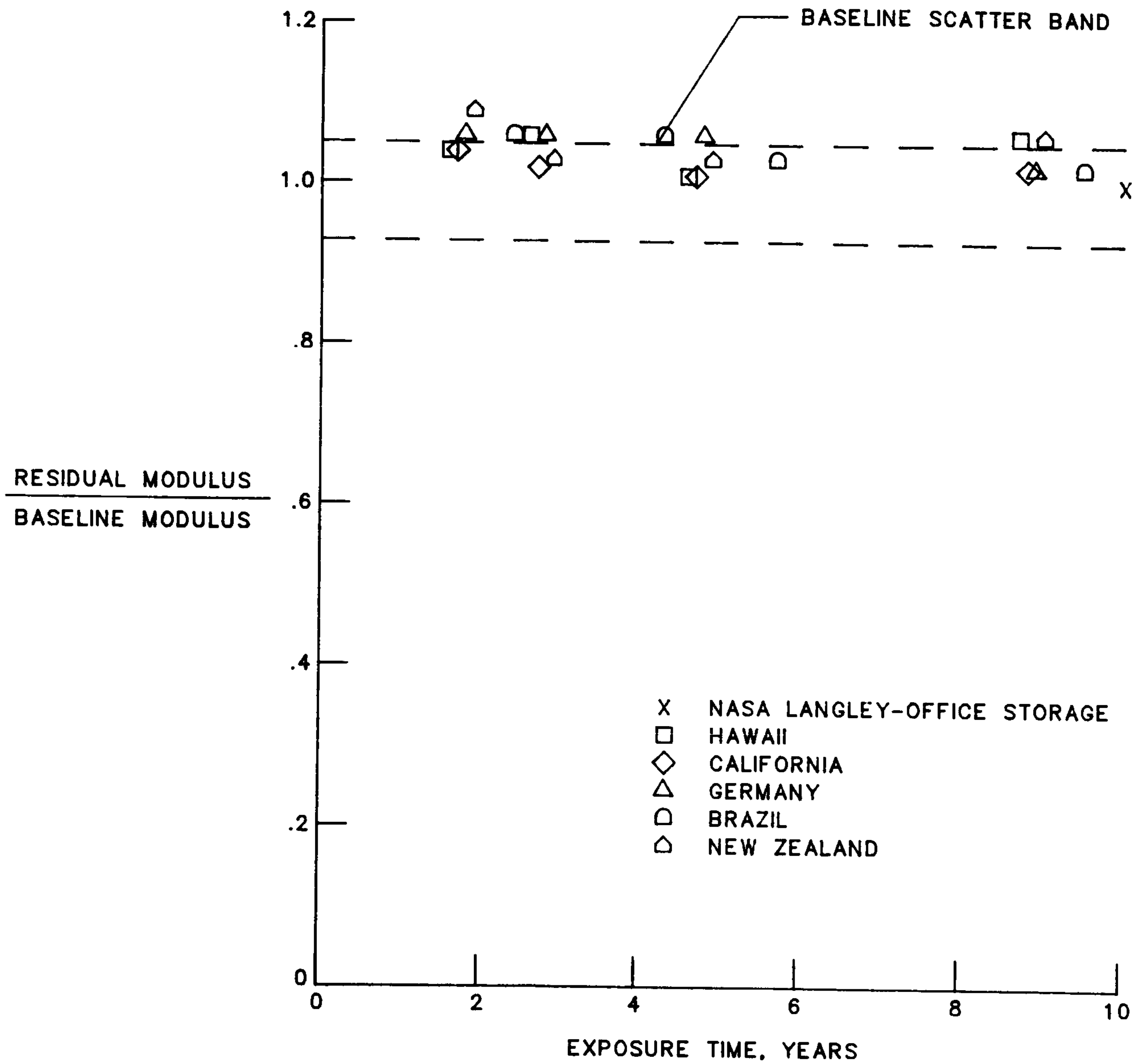

Figure 22. Flexural modulus of T300/5208 graphite/epoxy.

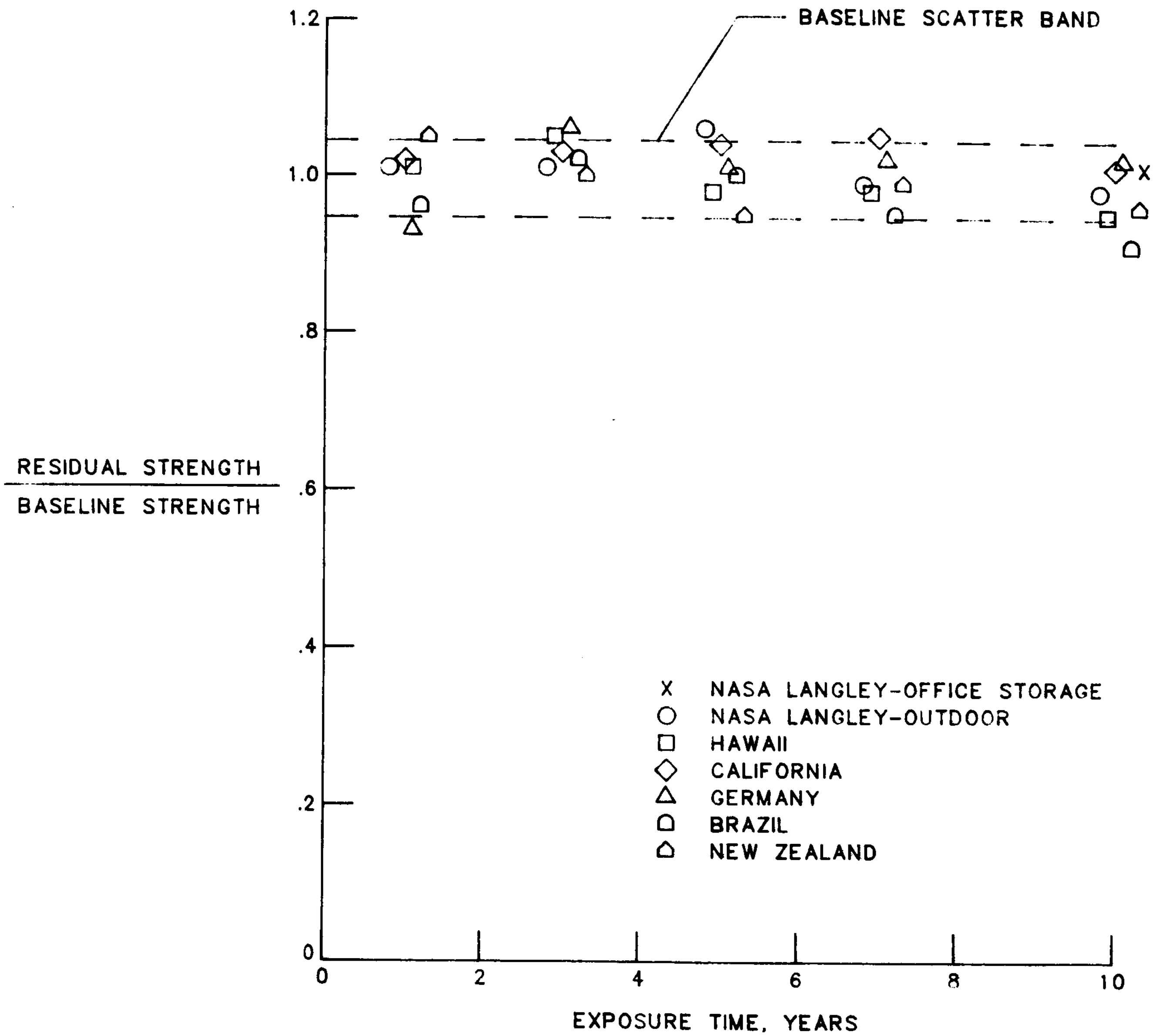

Figure 23. Short-beam shear strength of T300/5209 graphite/epoxy.

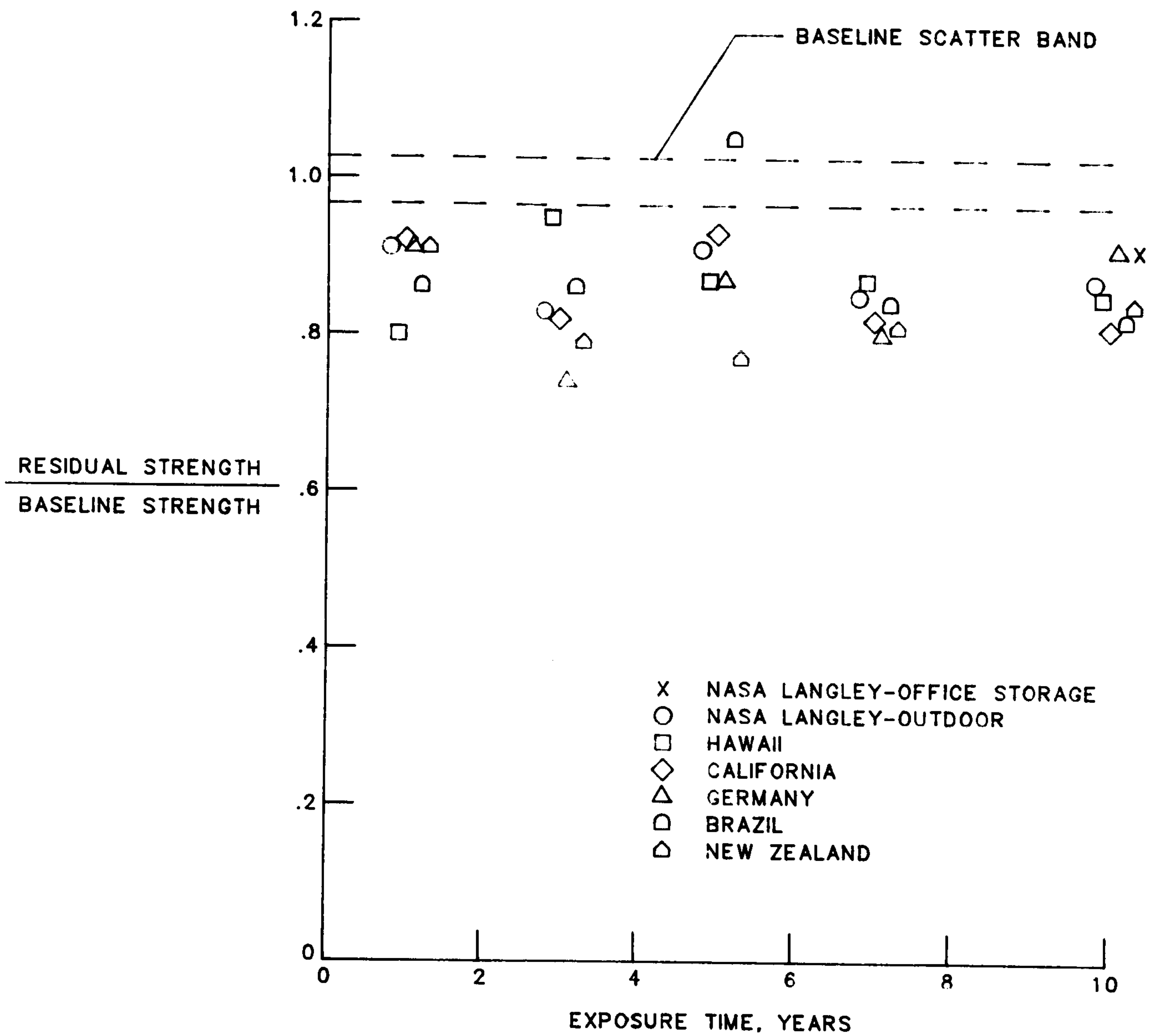

Figure 24. Short-beam shear strength of T300/2544 graphite/epoxy.

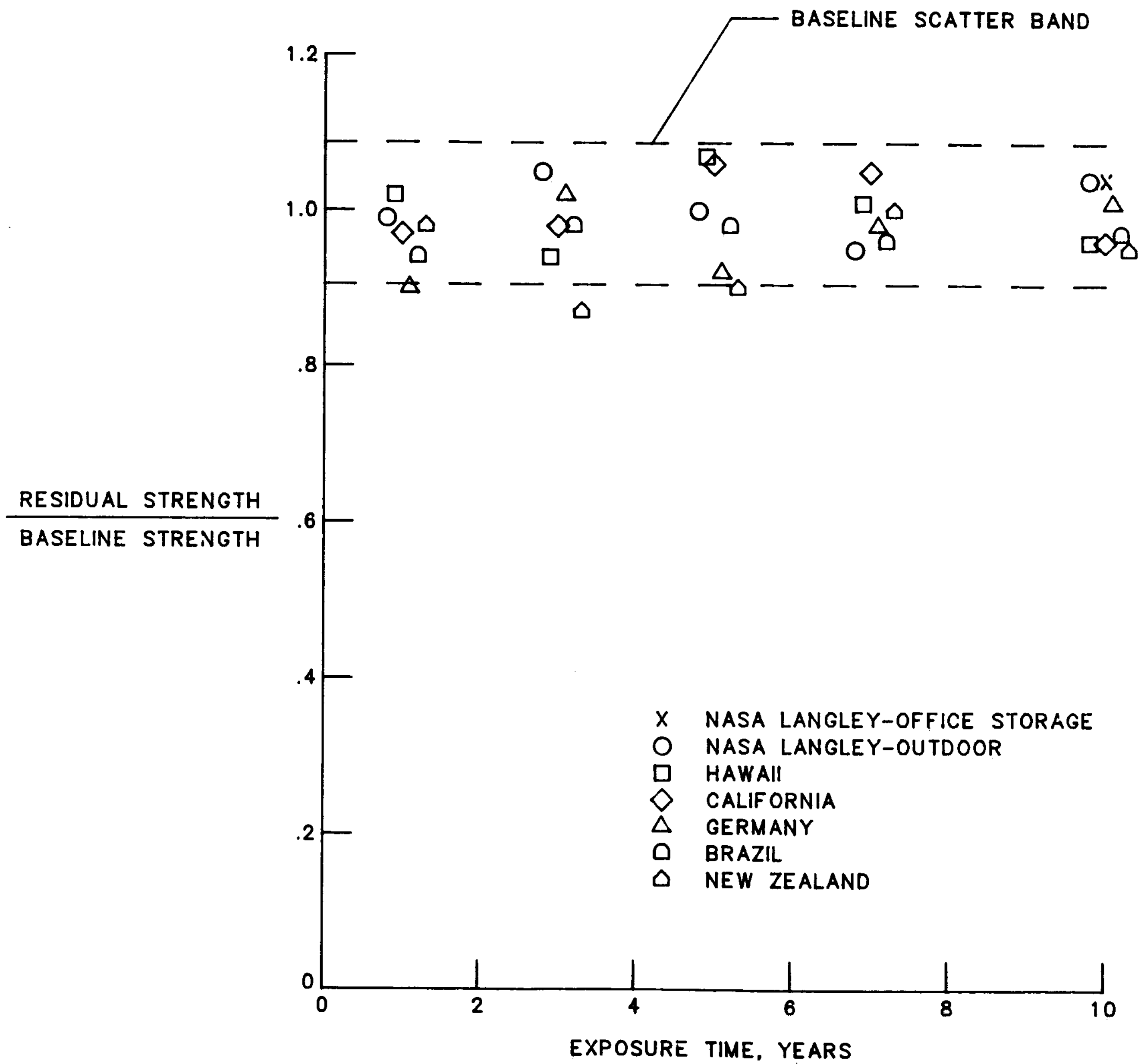

Figure 25. Short-beam shear strength of AS/3501 graphite/epoxy.

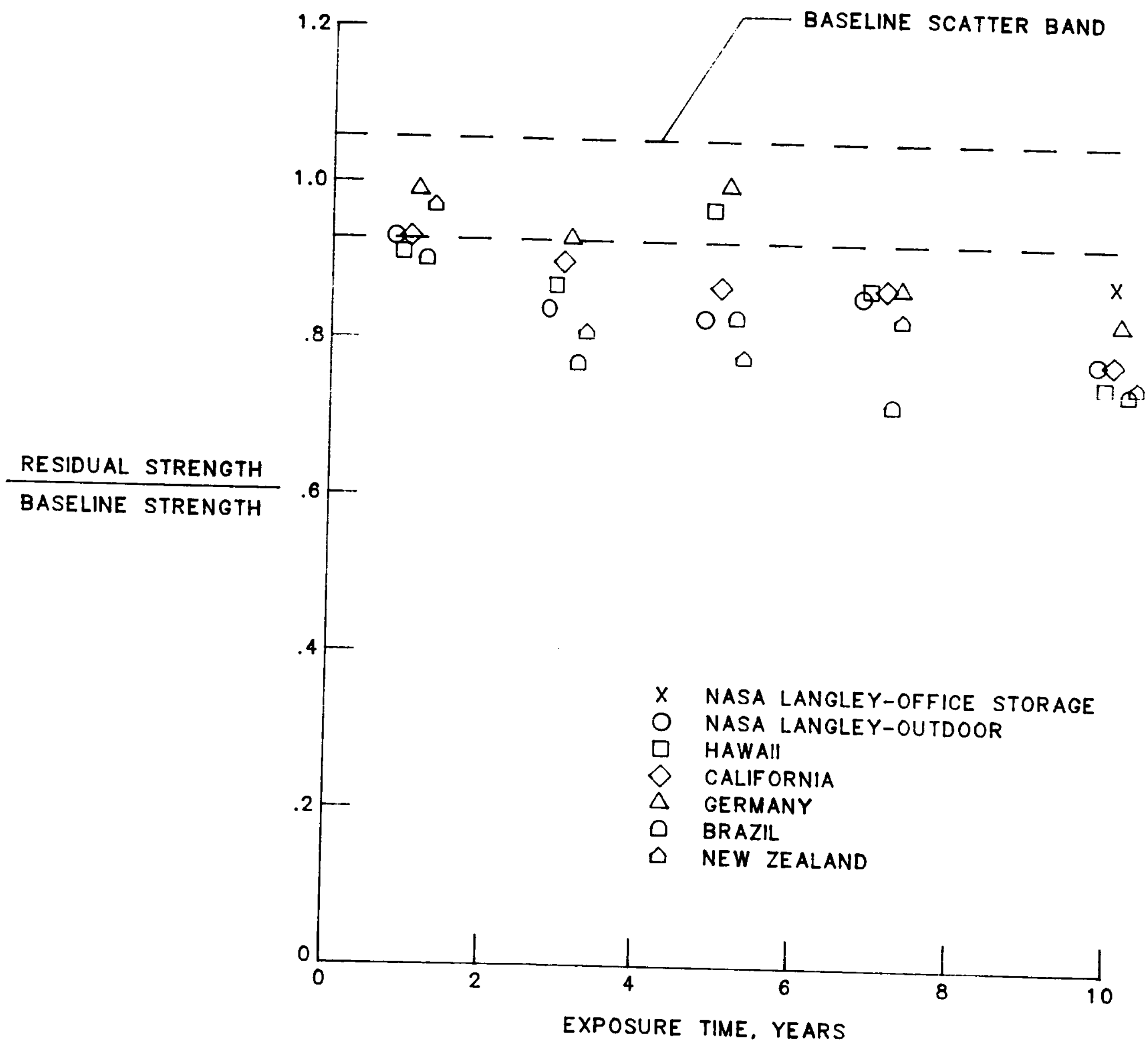

Figure 26. Short-beam shear strength of Kevlar-49/F-155.

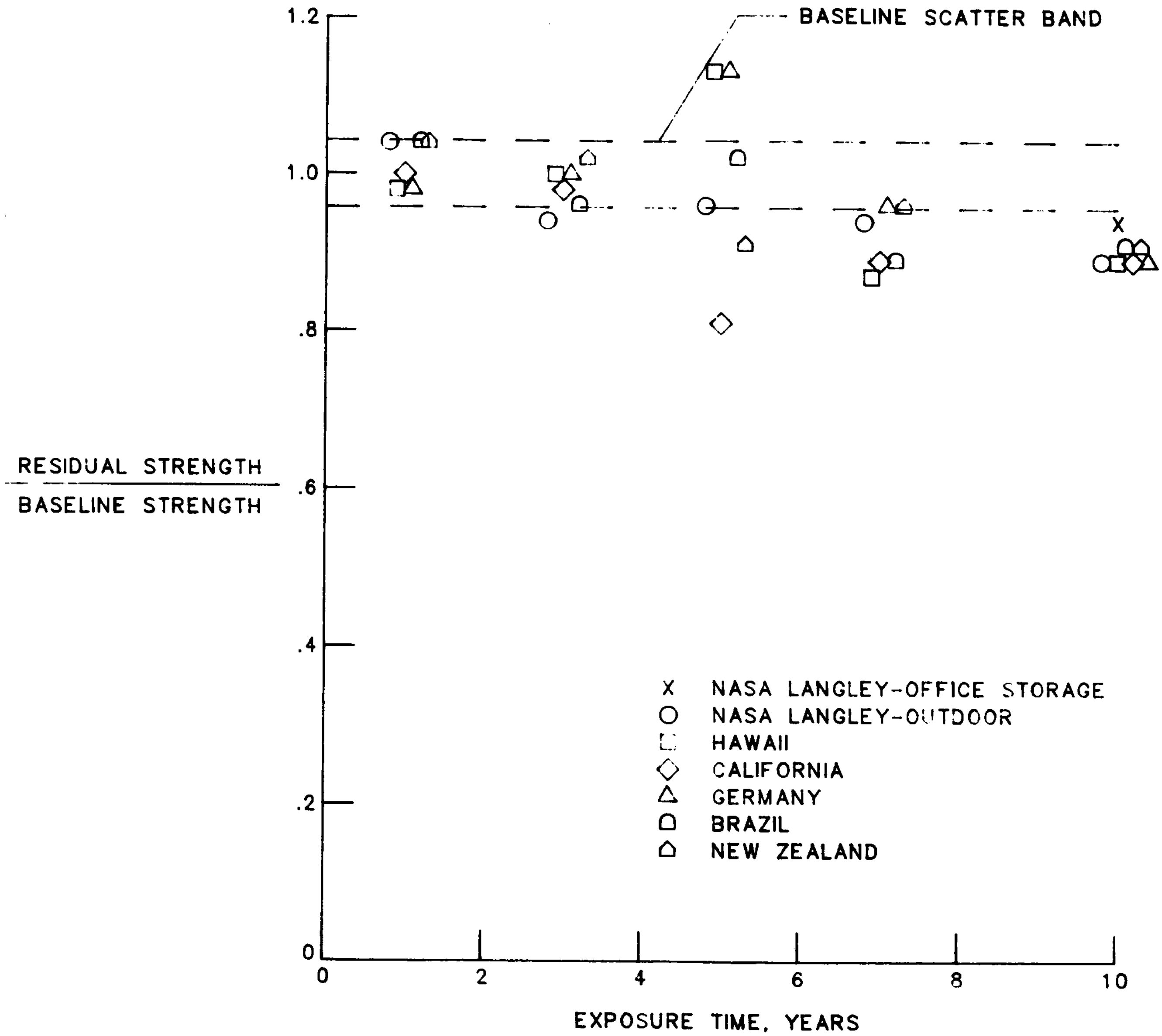

Figure 27. Short-beam shear strength of Kevlar-49/F-161.

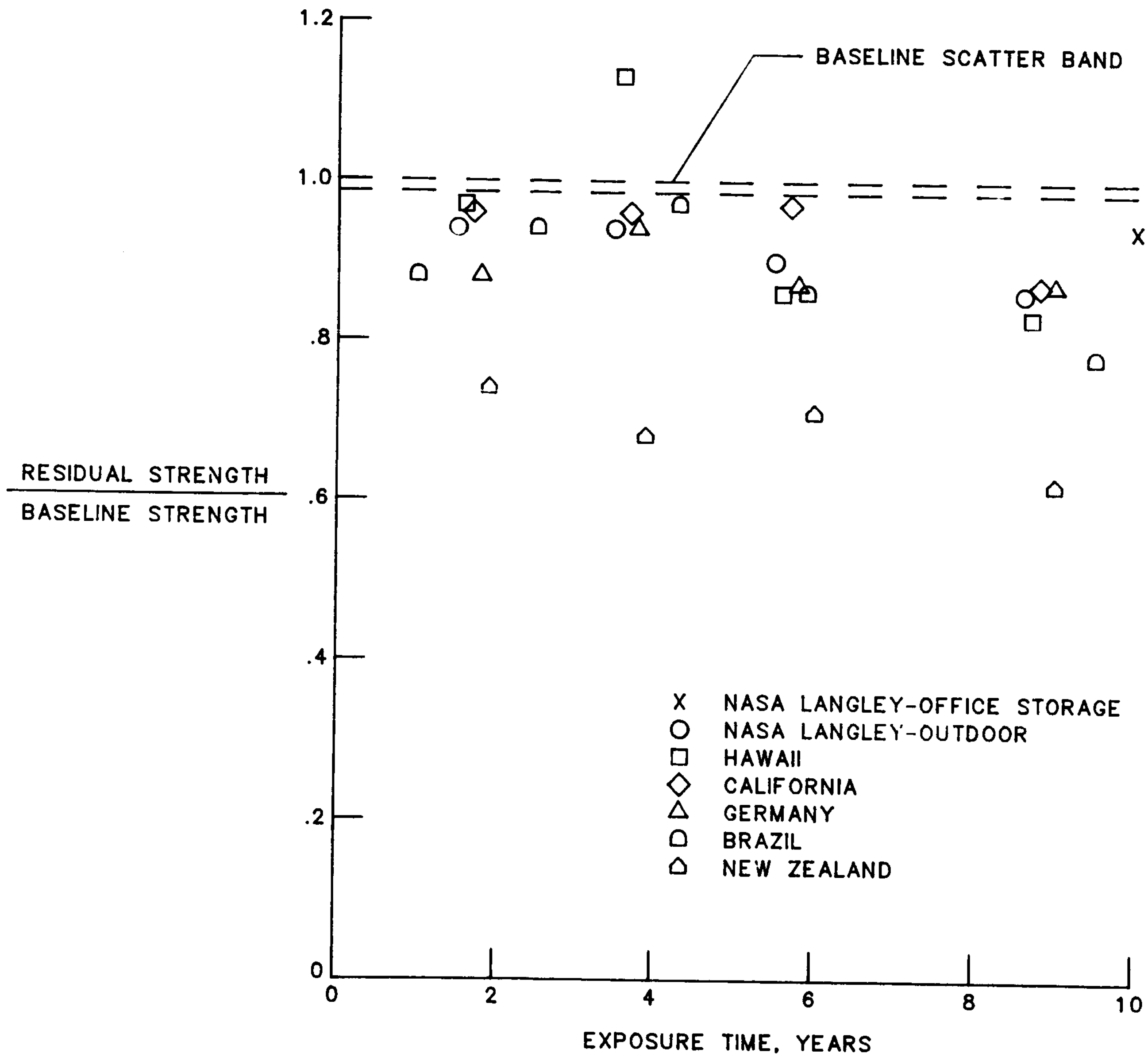

Figure 28. Short-beam shear strength of T300/P1700 graphite/polysulfone.

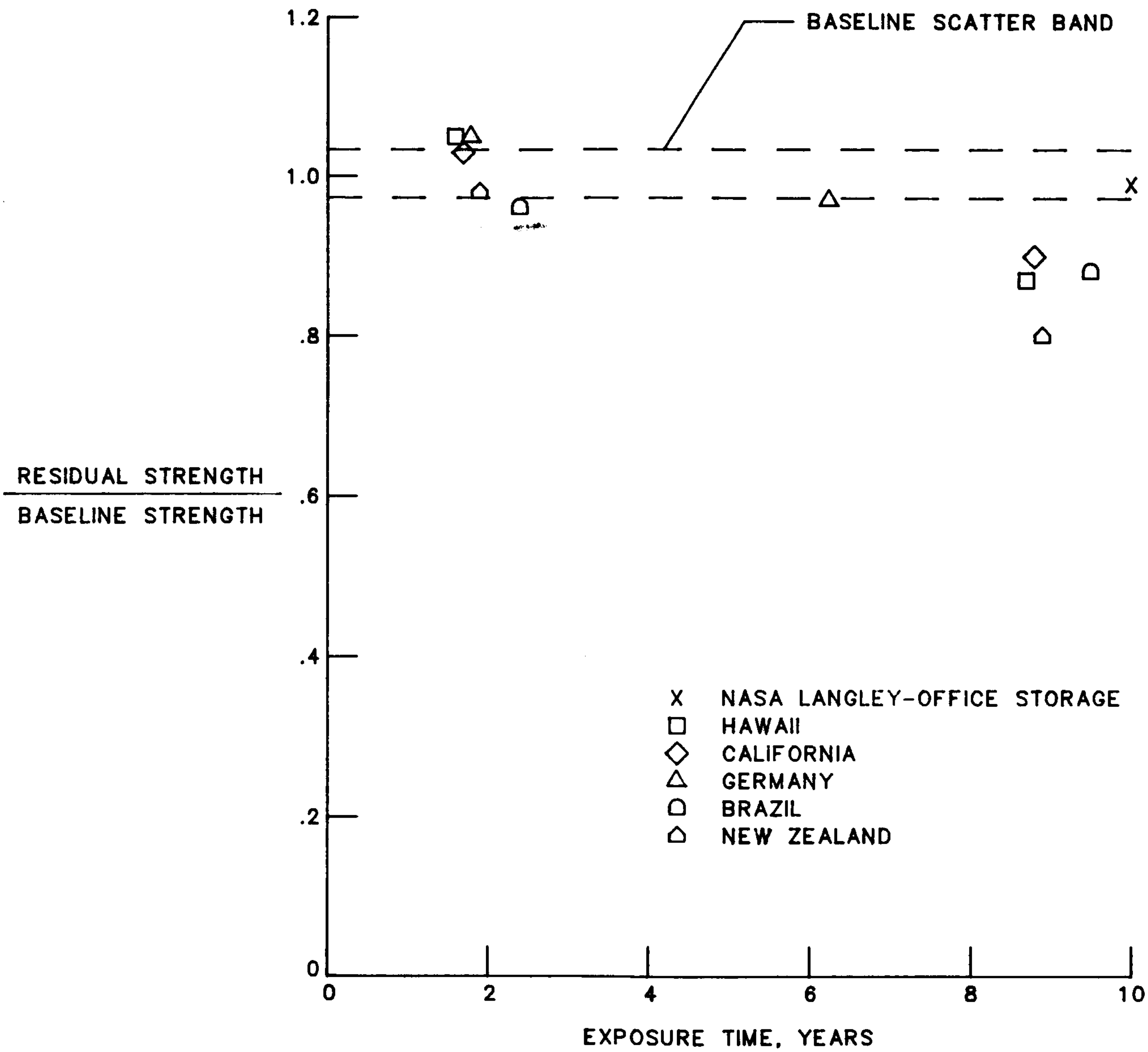

Figure 29. Short-beam shear strength of T300/5208 graphite/epoxy.

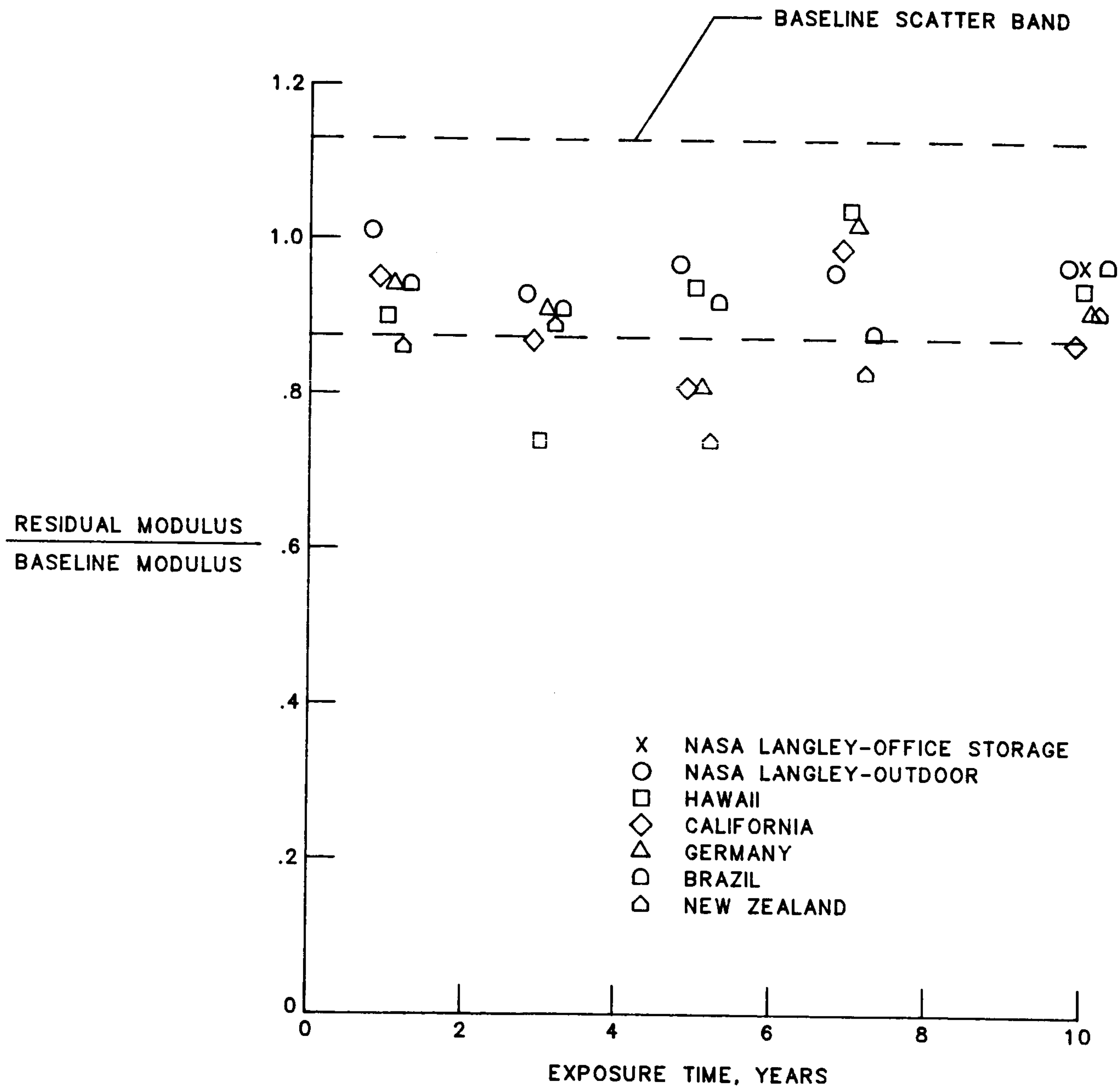

Figure 30. Compression strength of T300/5209 graphite/epoxy.

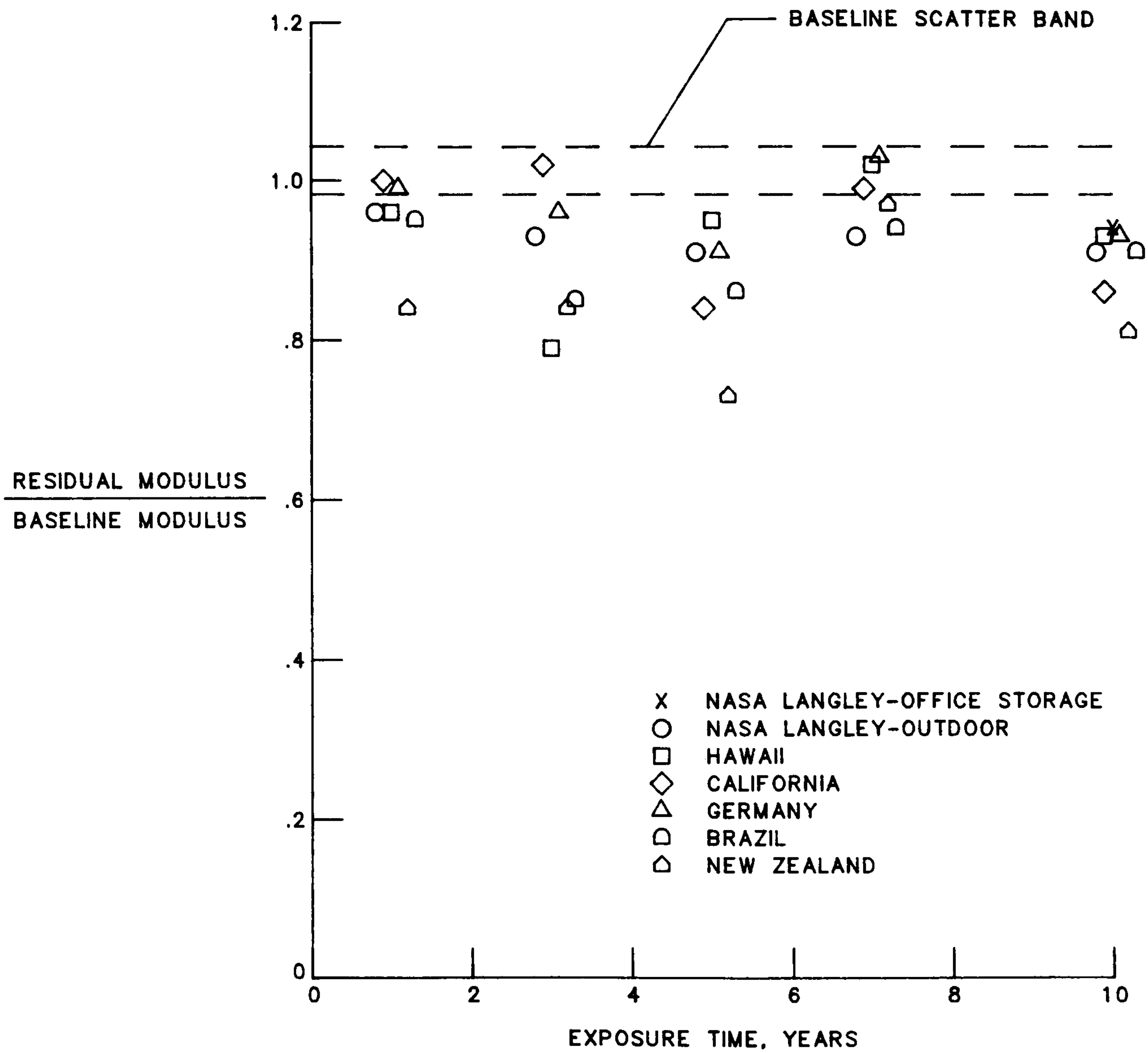

Figure 31. Compression strength of T300/2544 graphite/epoxy.

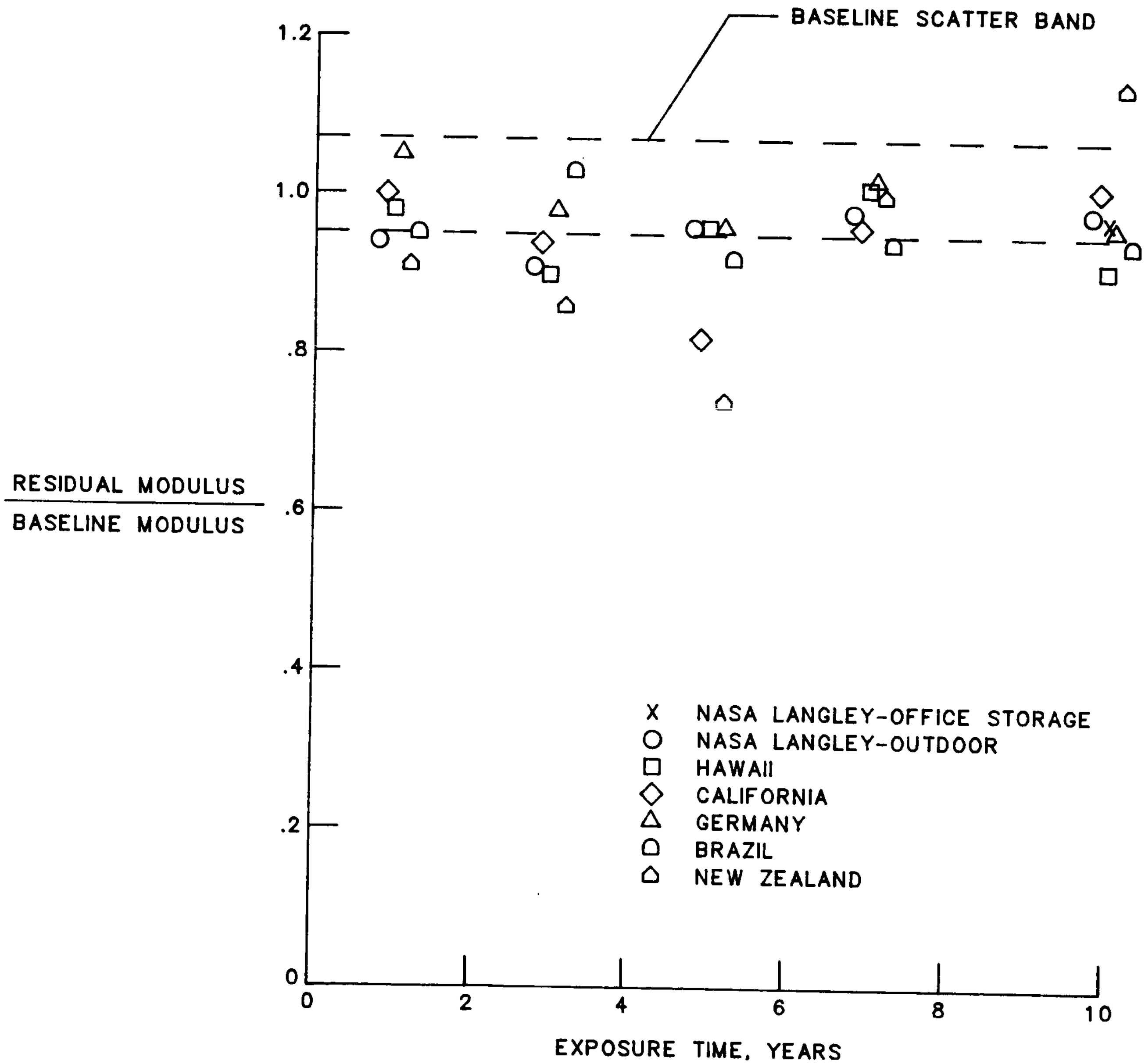

Figure 32. Compression strength of AS/3501 graphite/epoxy.

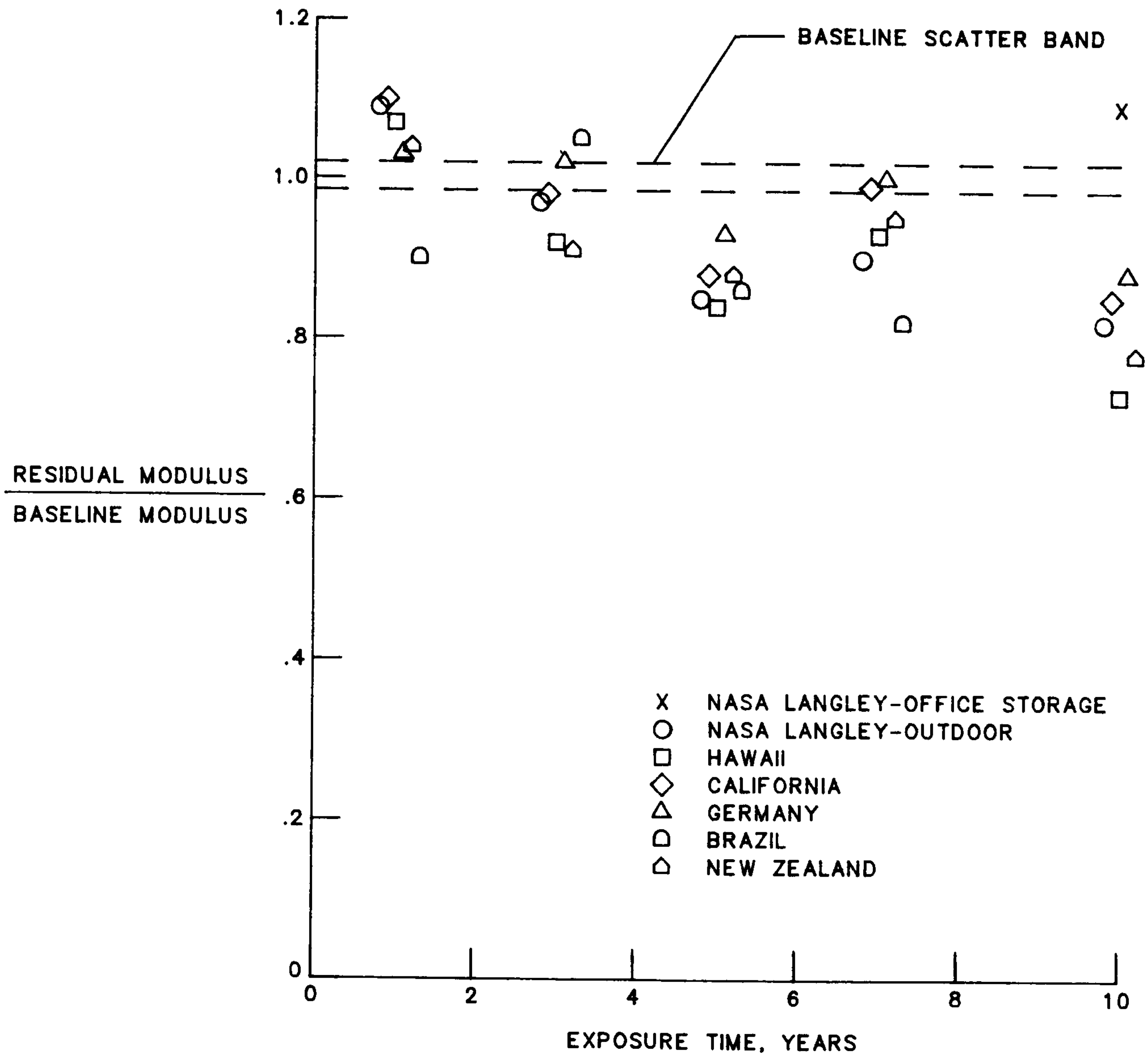

Figure 33. Compression strength of Kevlar-49/F-161.

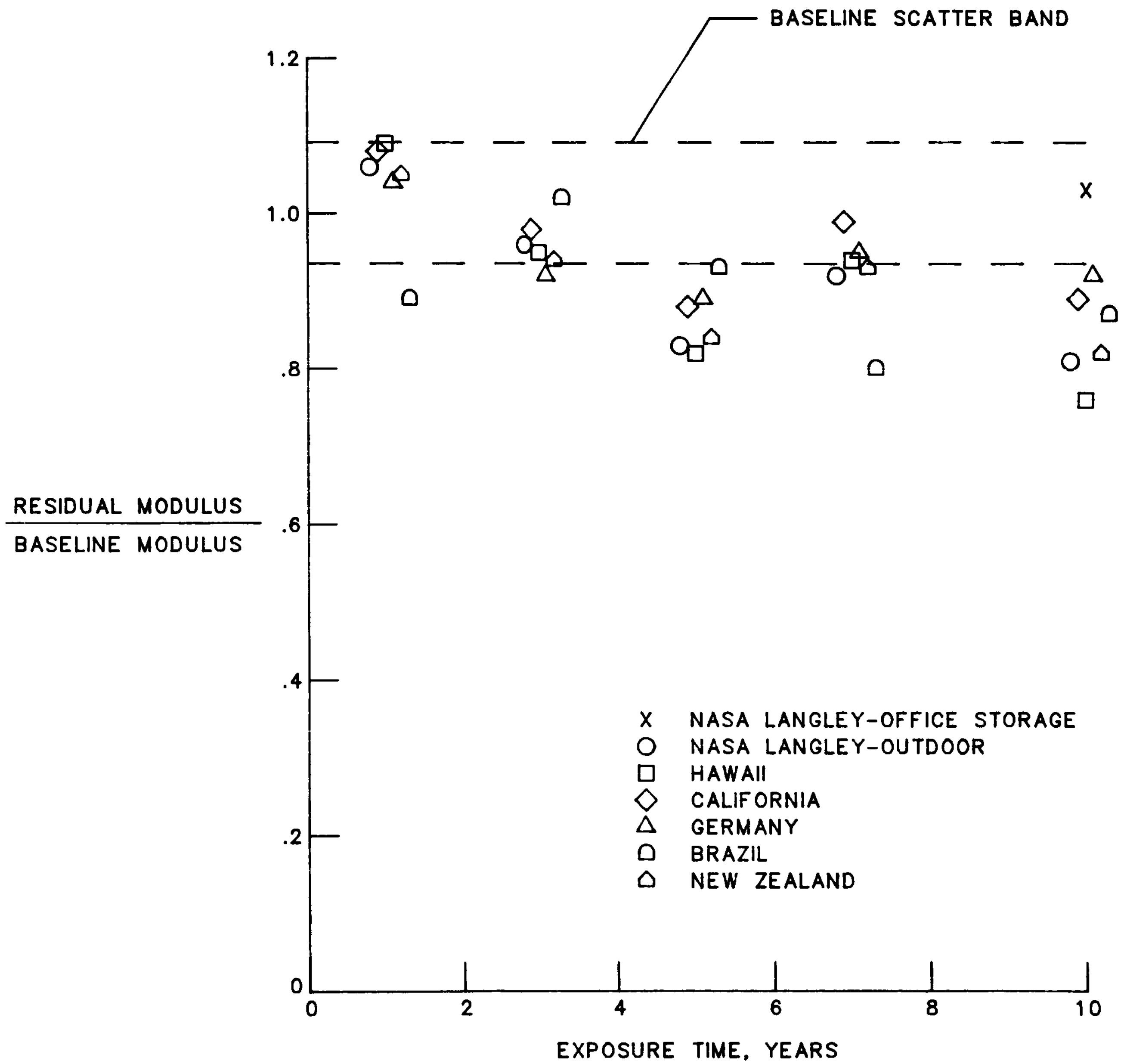

Figure 34. Compression strength of Kevlar-49/F-161.

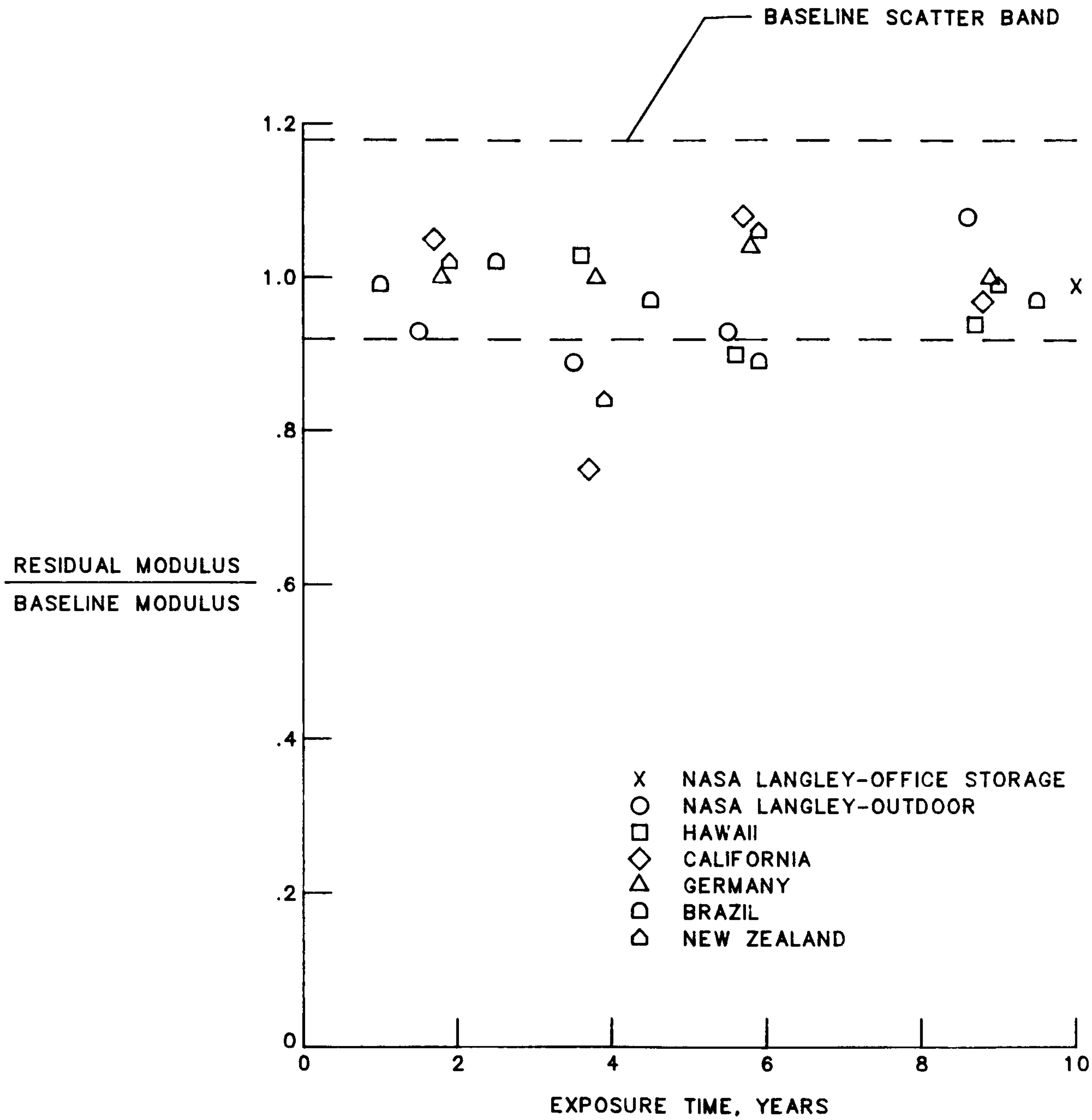

Figure 35. Compression strength of T300/P1700 graphite/polysulfone.

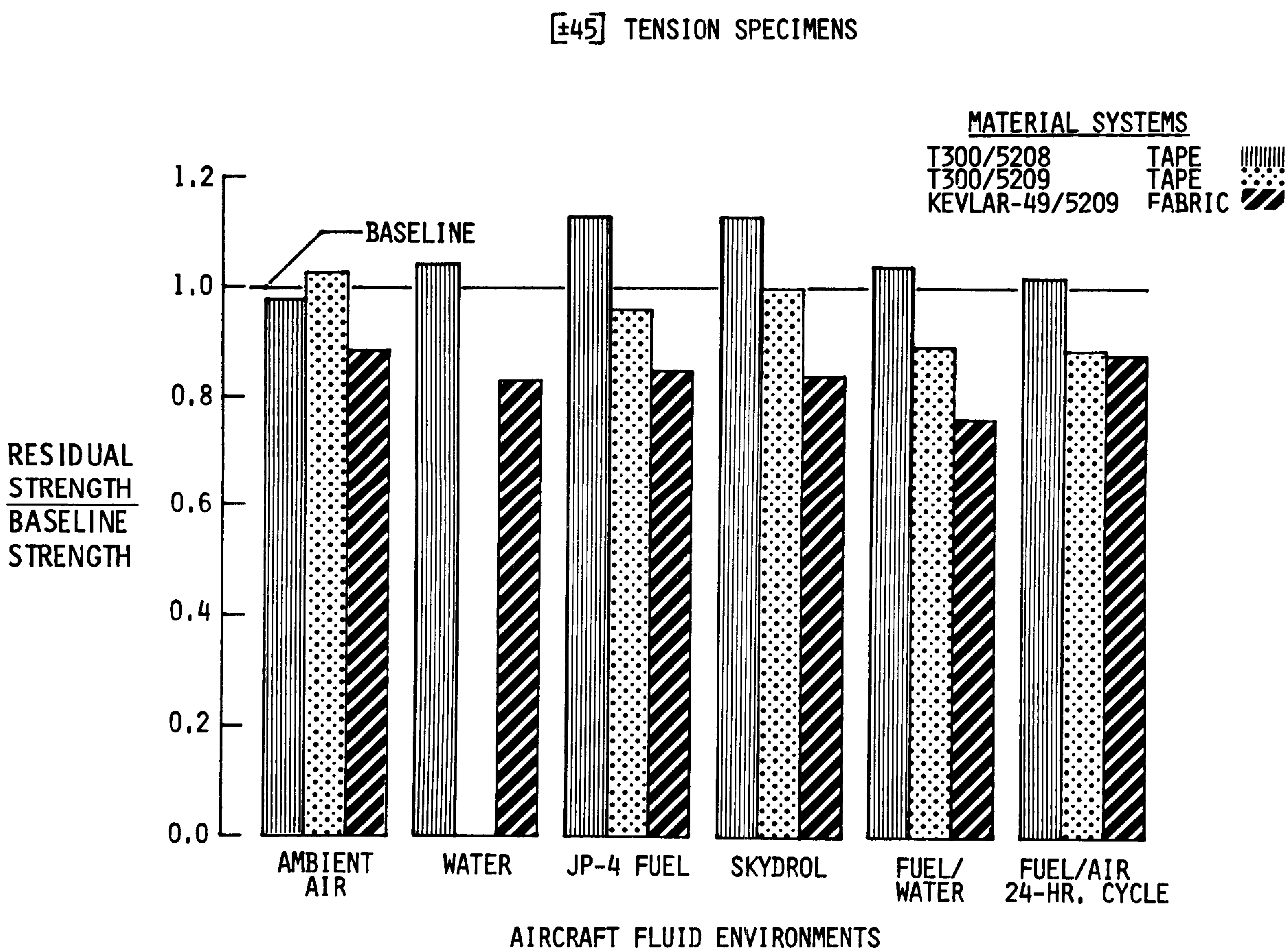

Figure 36. Effect of aircraft fluids and fuels on tensile strength of composite materials after 5 years of exposure.

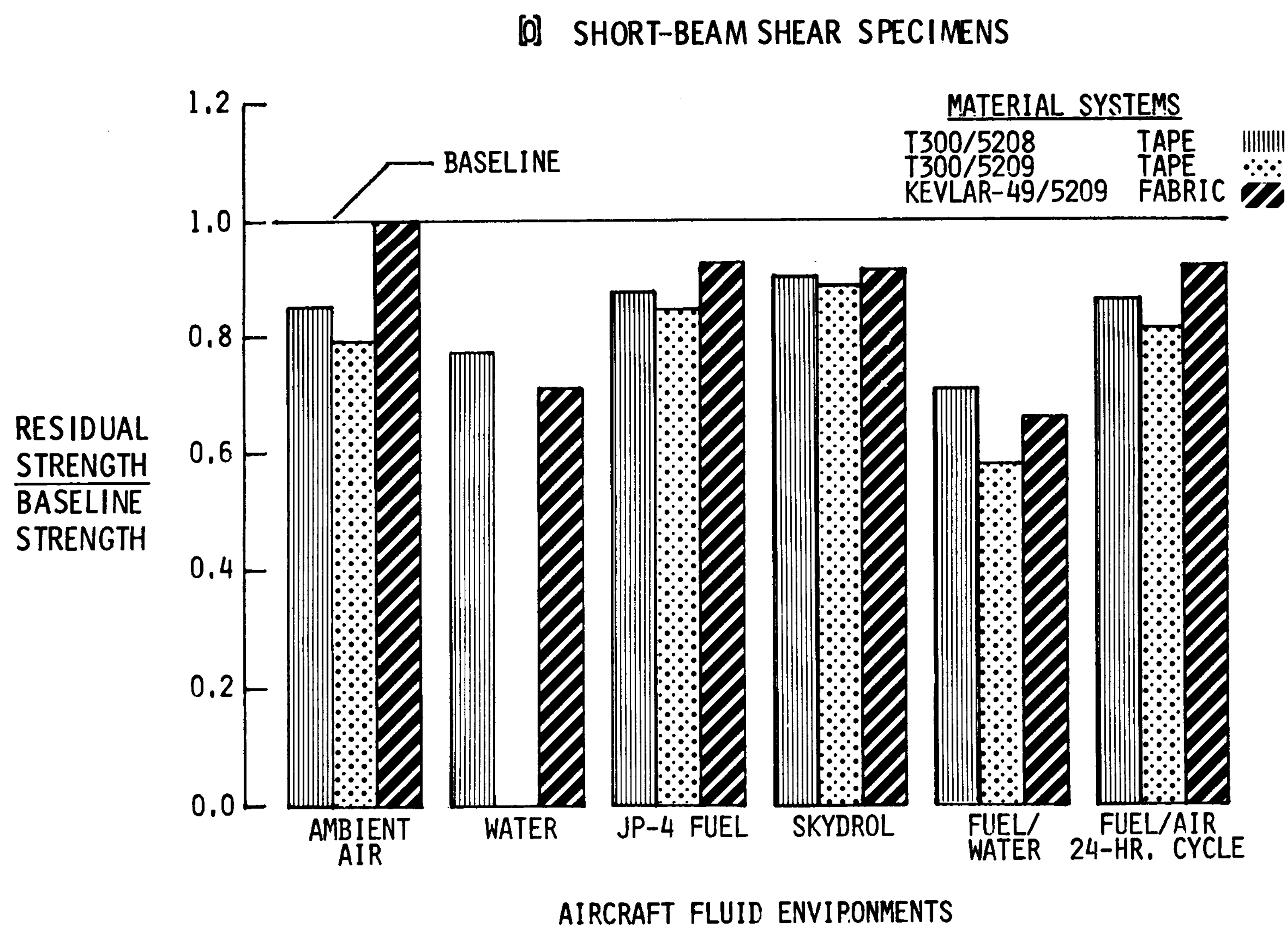

Figure 37. Effect of aircraft fluids and fuels on short-beam shear strength of composite materials after 5 years of exposure.

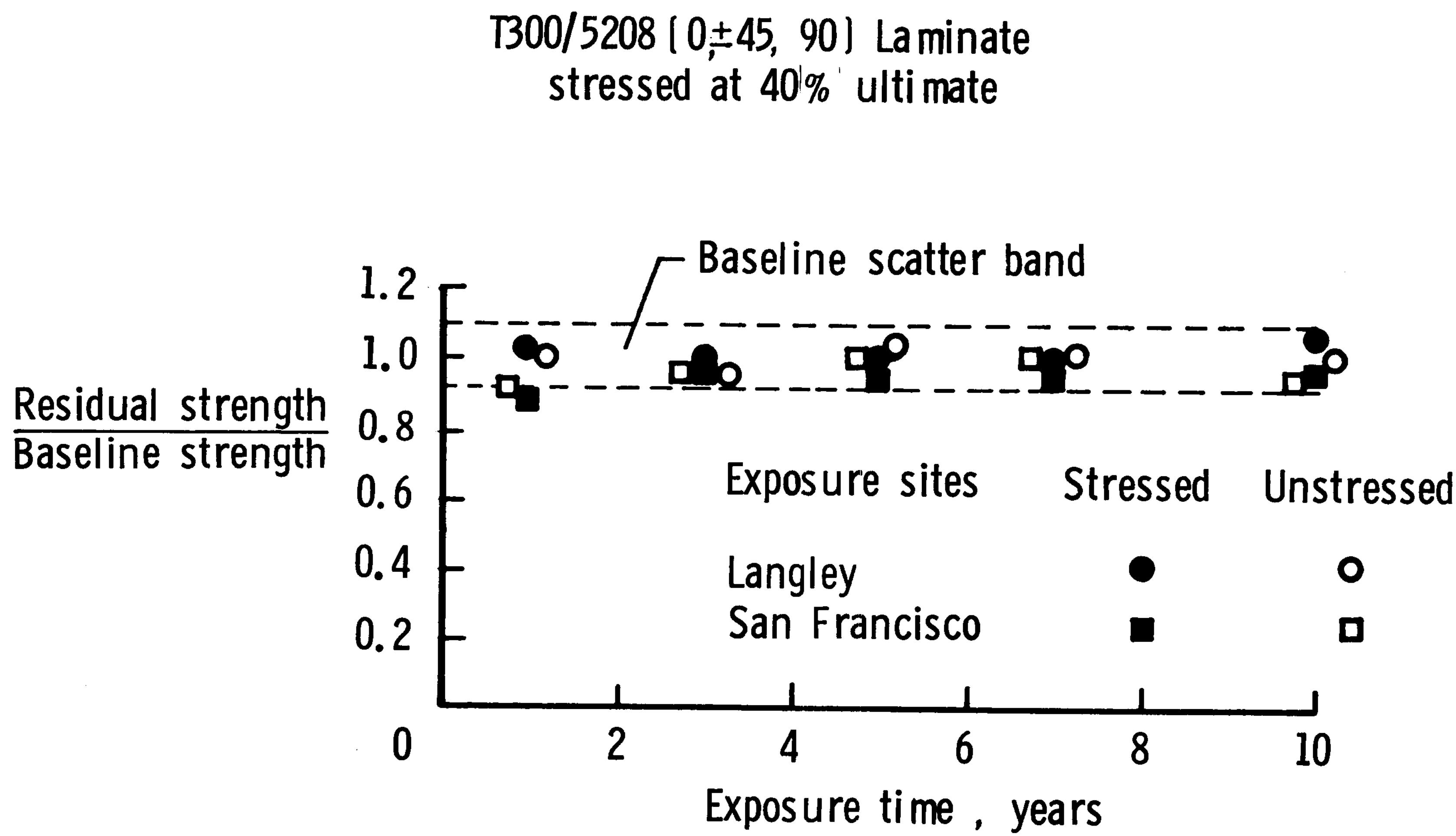

Figure 38. Effect of 10 years of sustained-stress on tensile strength of T300/5208 graphite/epoxy.

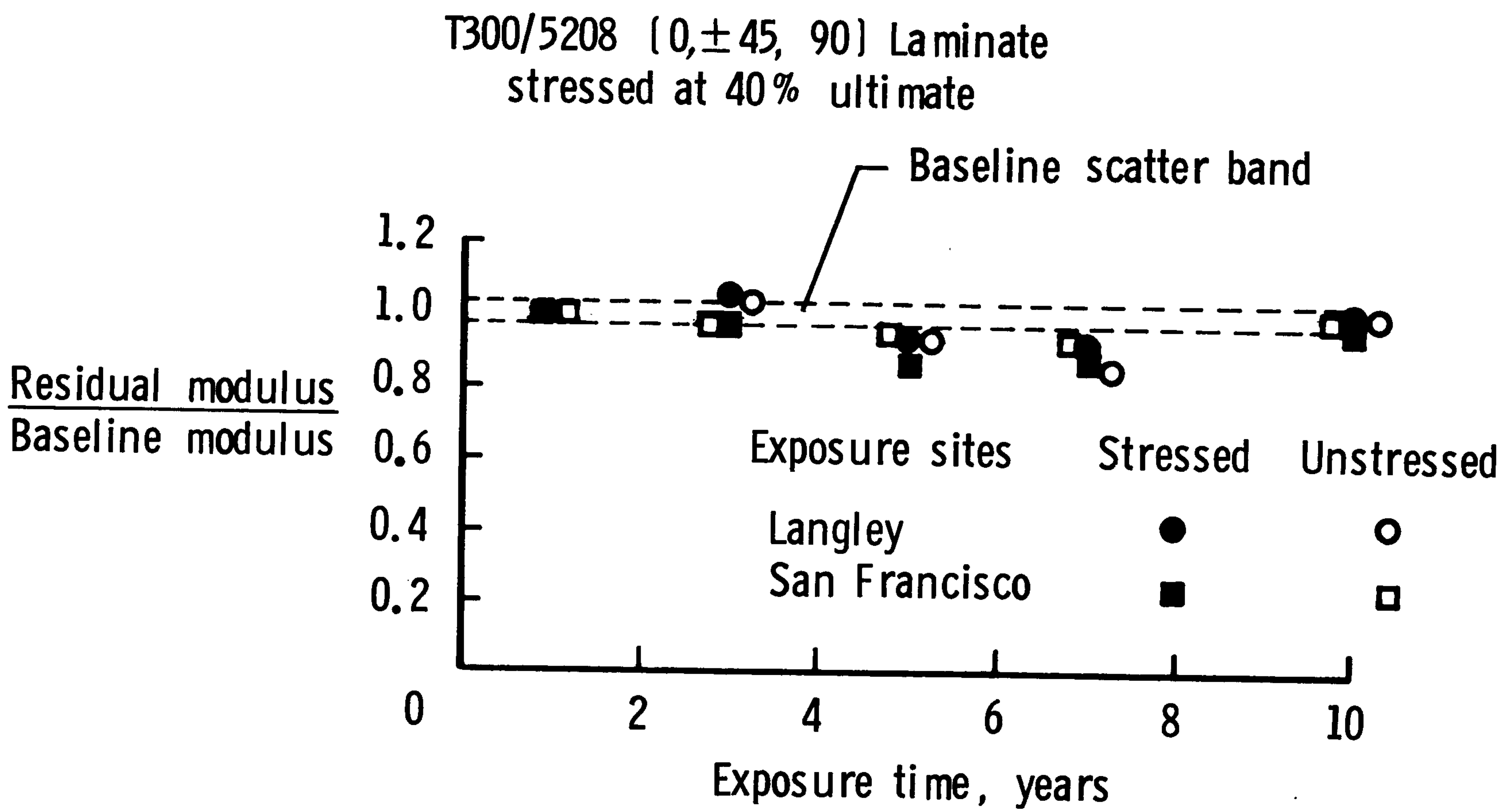

Figure 39. Effect of 10 years of sustained-stress on tensile modulus of T300/5208 graphite/epoxy.

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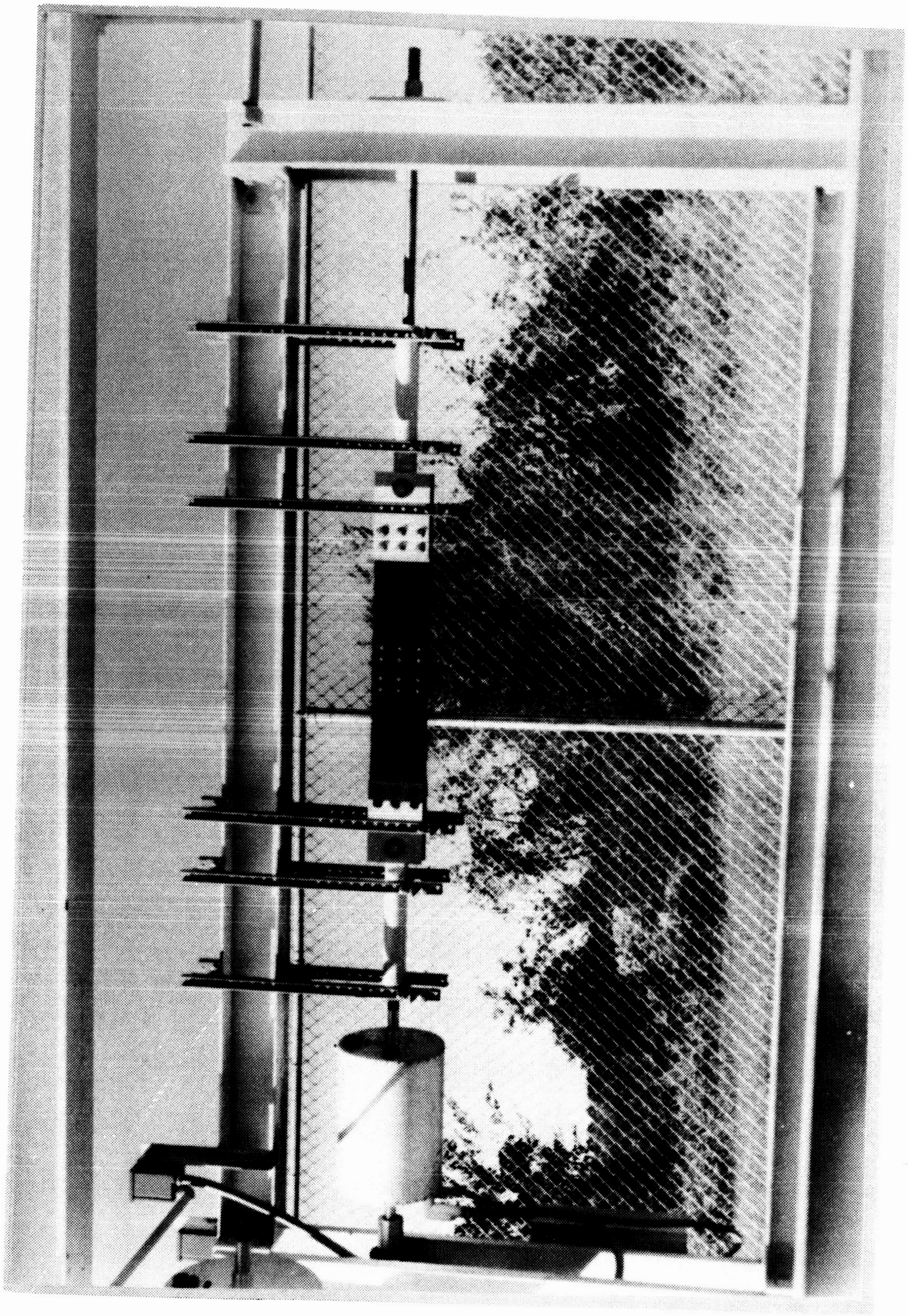

Figure 40. Loading apparatus for sustained-stress exposure of composite bolted joints.

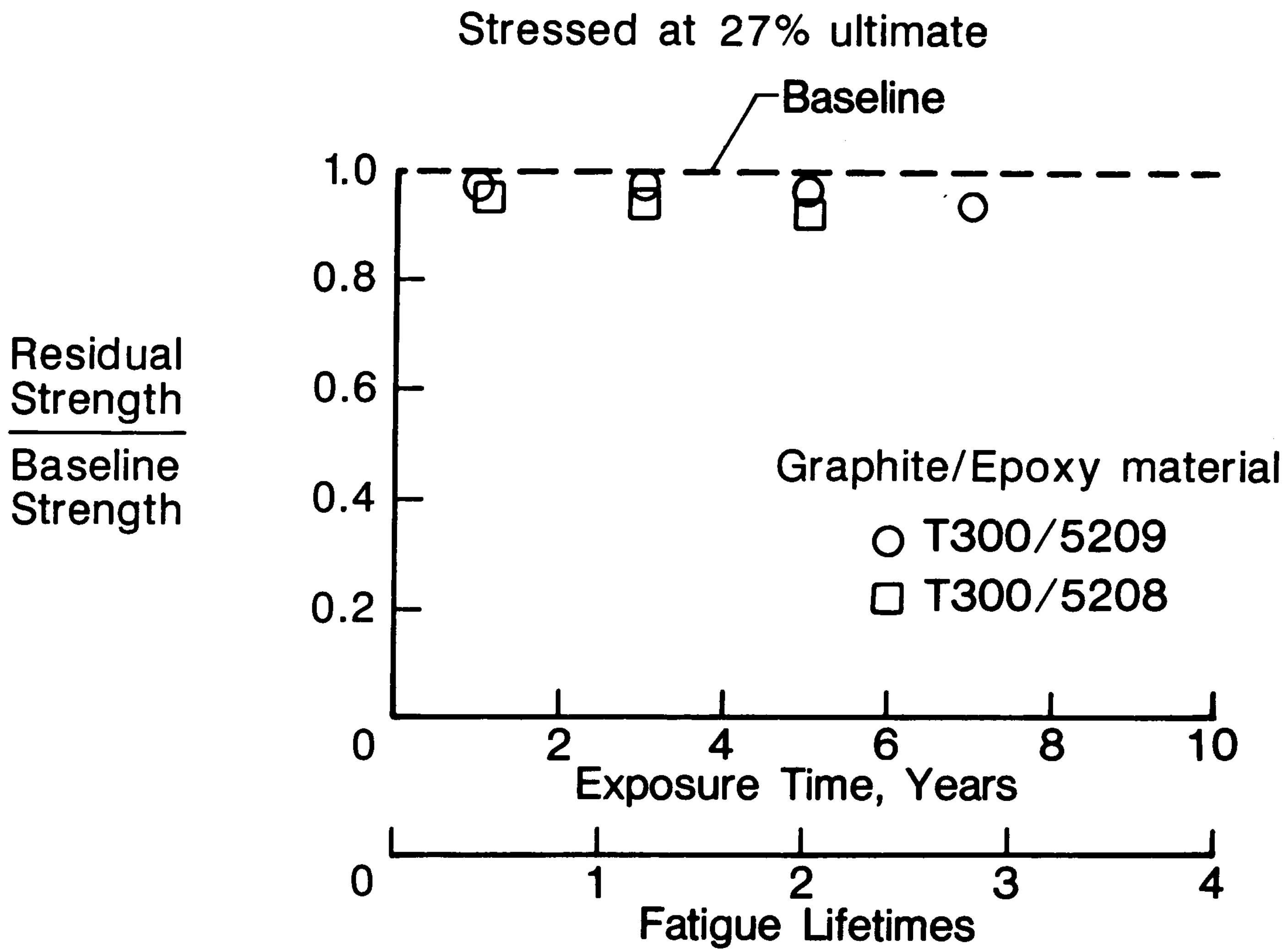

Figure 41. Effect of sustained-stress on tensile strength of composite bolted joints.

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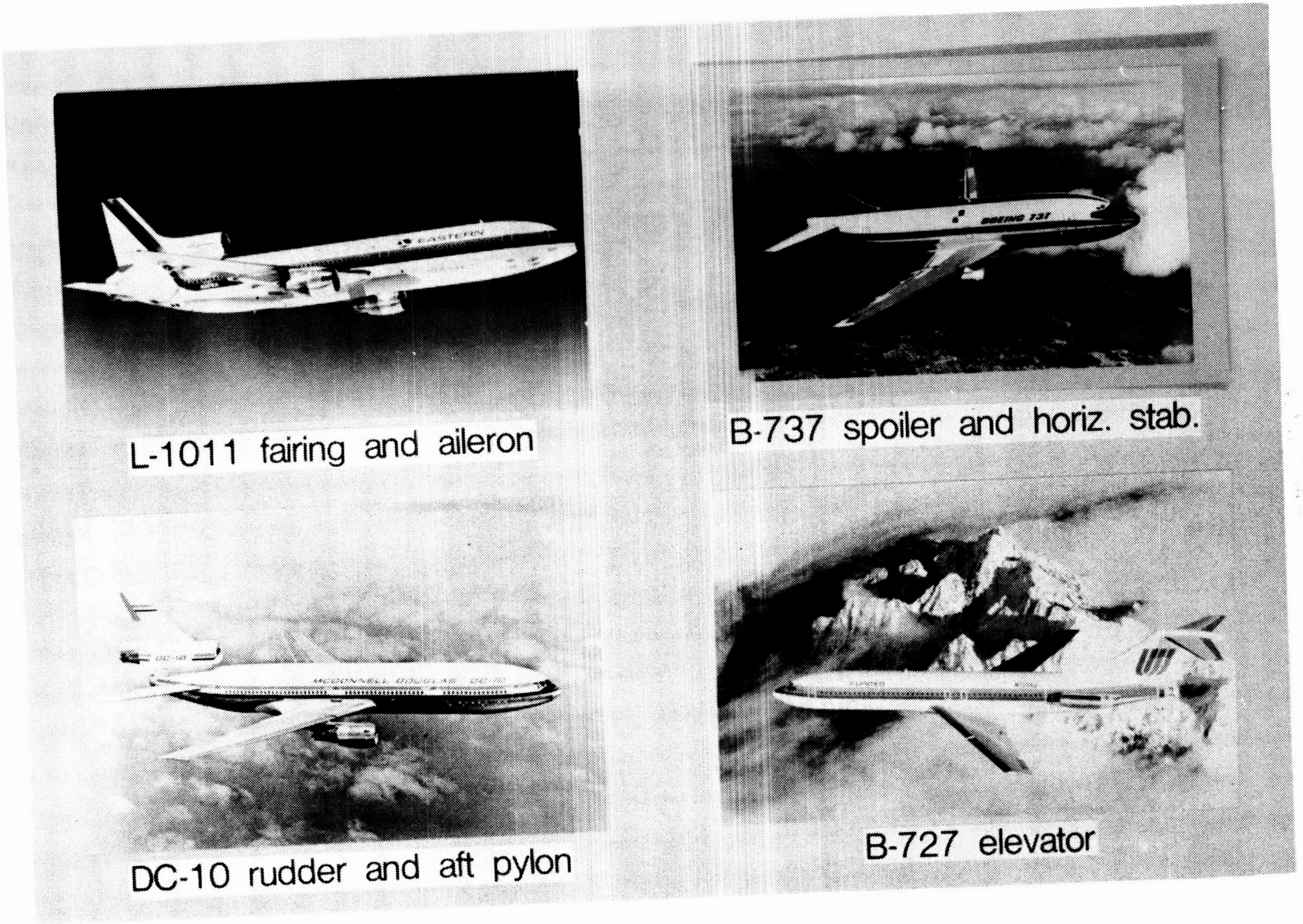

Figure 42. Flight service composite components on transport aircraft.

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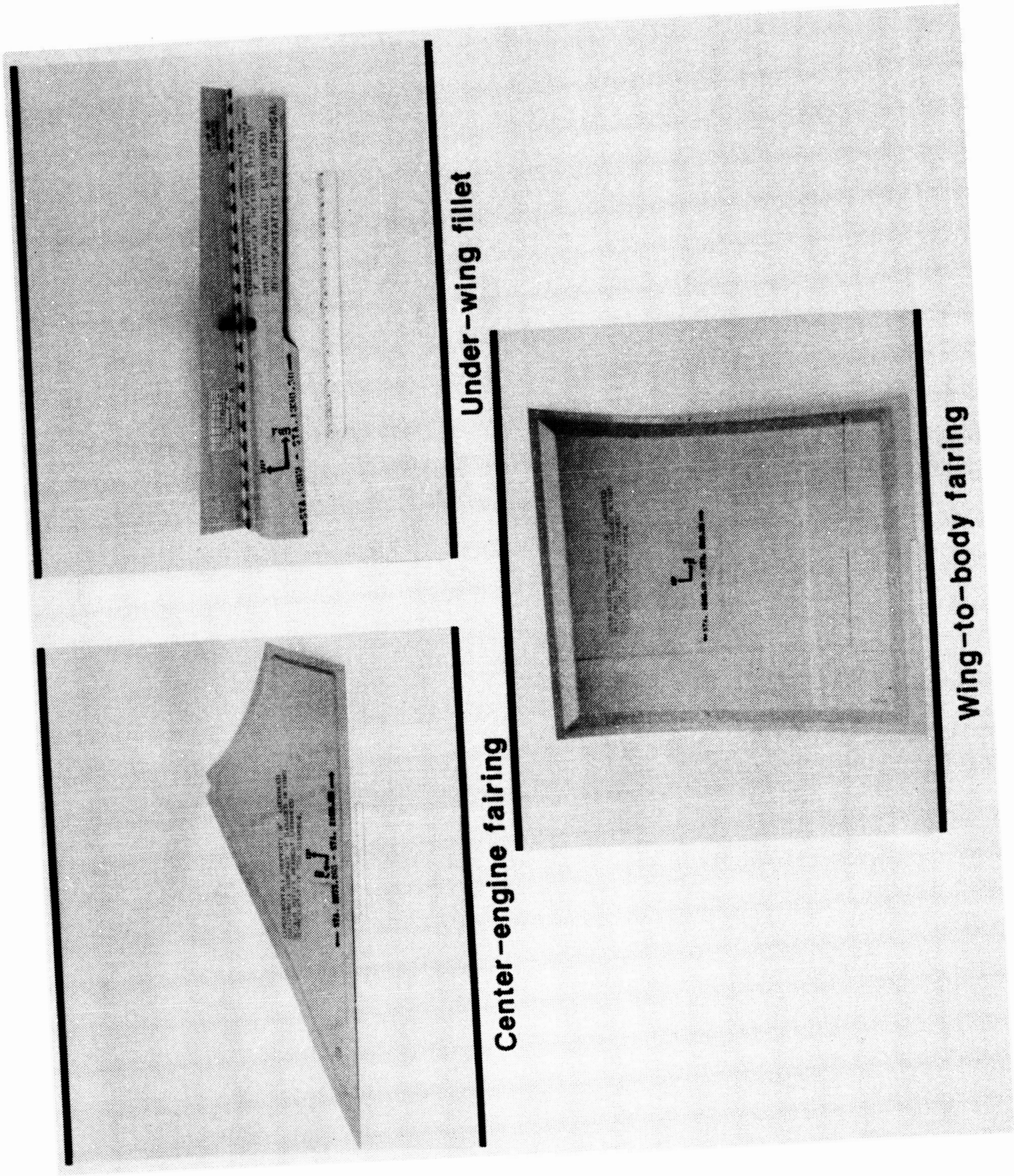

Figure 43. L-1011 Kevlar-49/epoxy fairings.

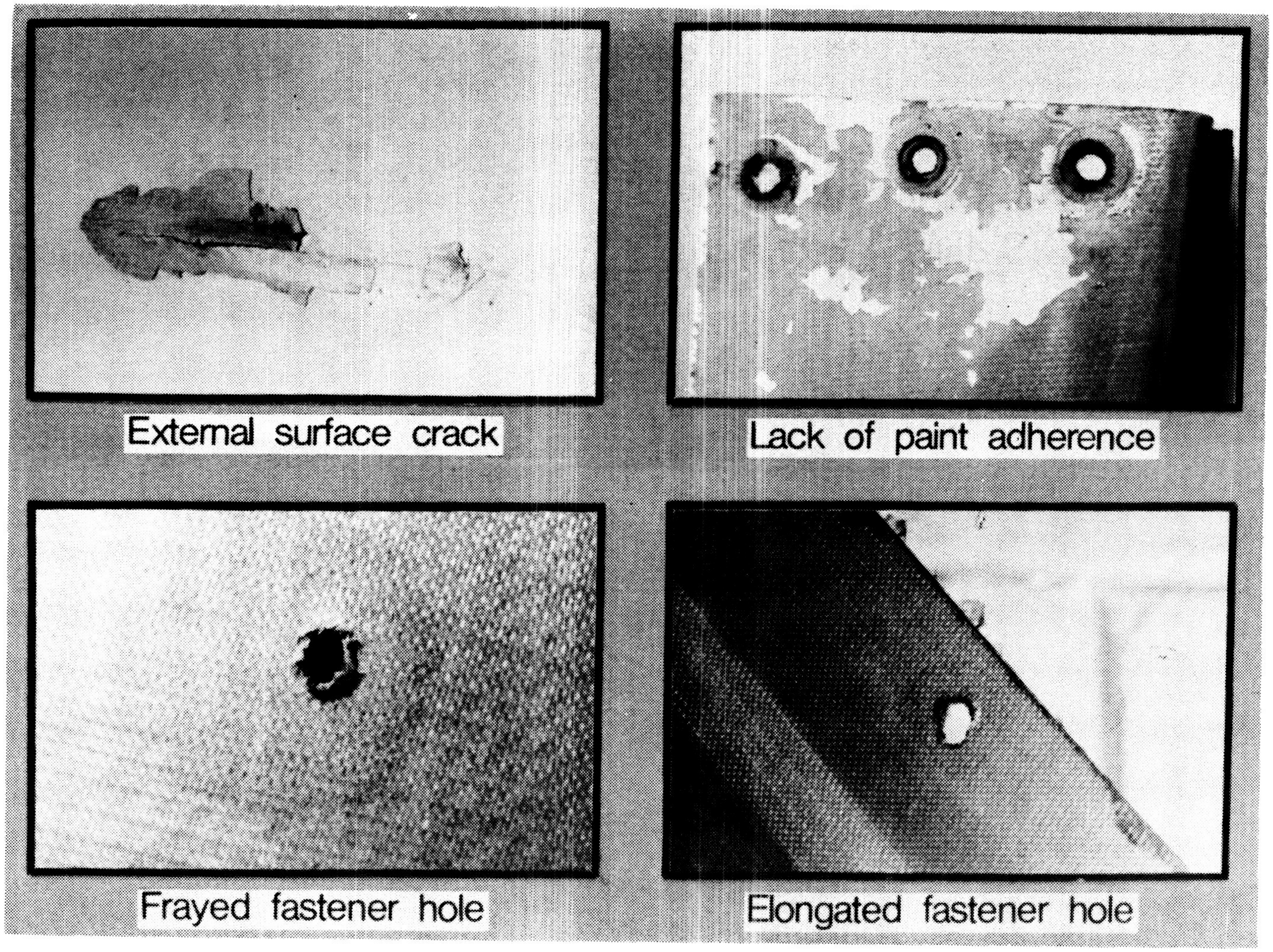

Figure 44. Typical in-service conditions of L-1011 Kevlar-49/epoxy fairings.

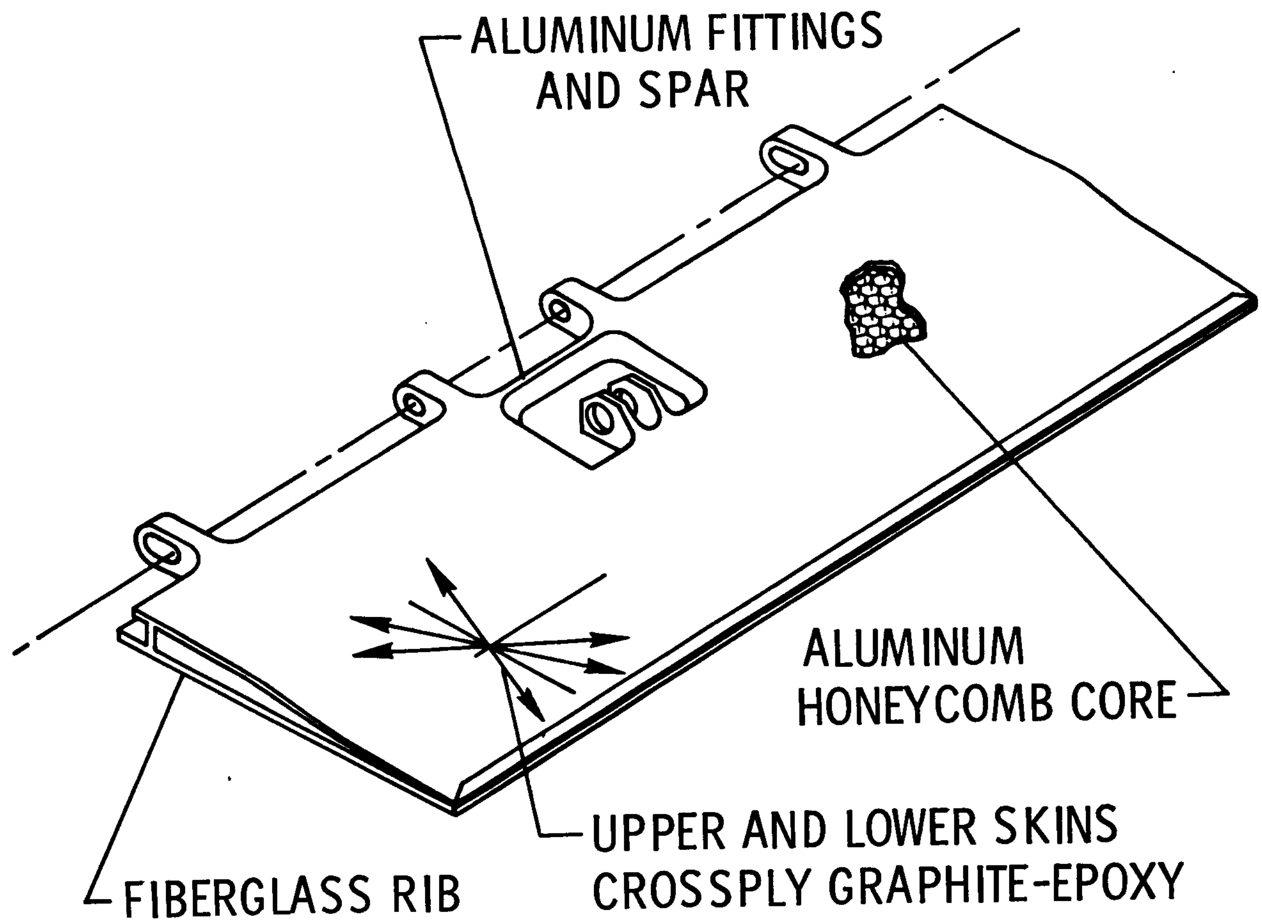

Figure 45. Configuration of B-737 graphite/epoxy spoiler.

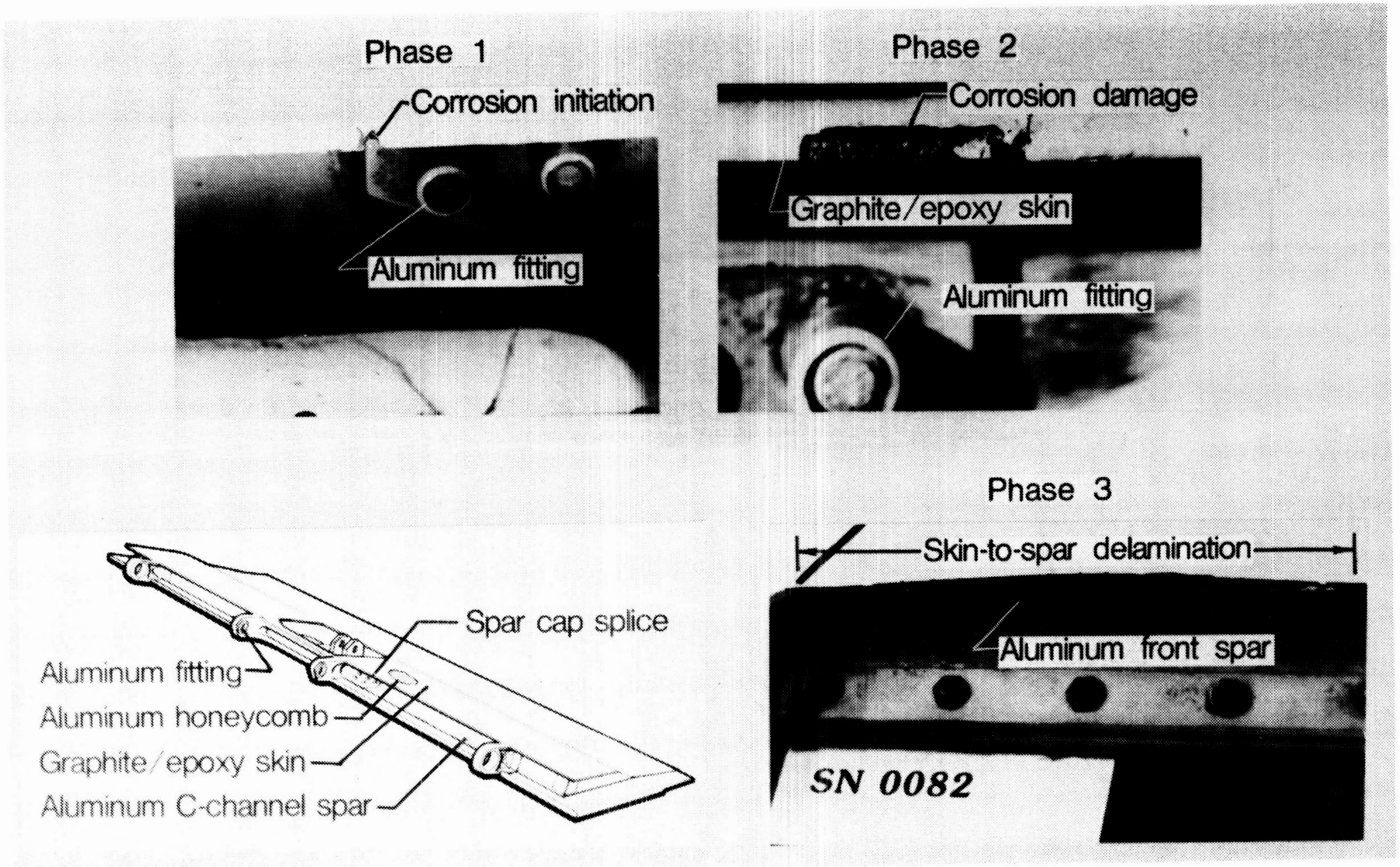

Figure 46. Corrosion damage to B-737 graphite/epoxy spoiler.

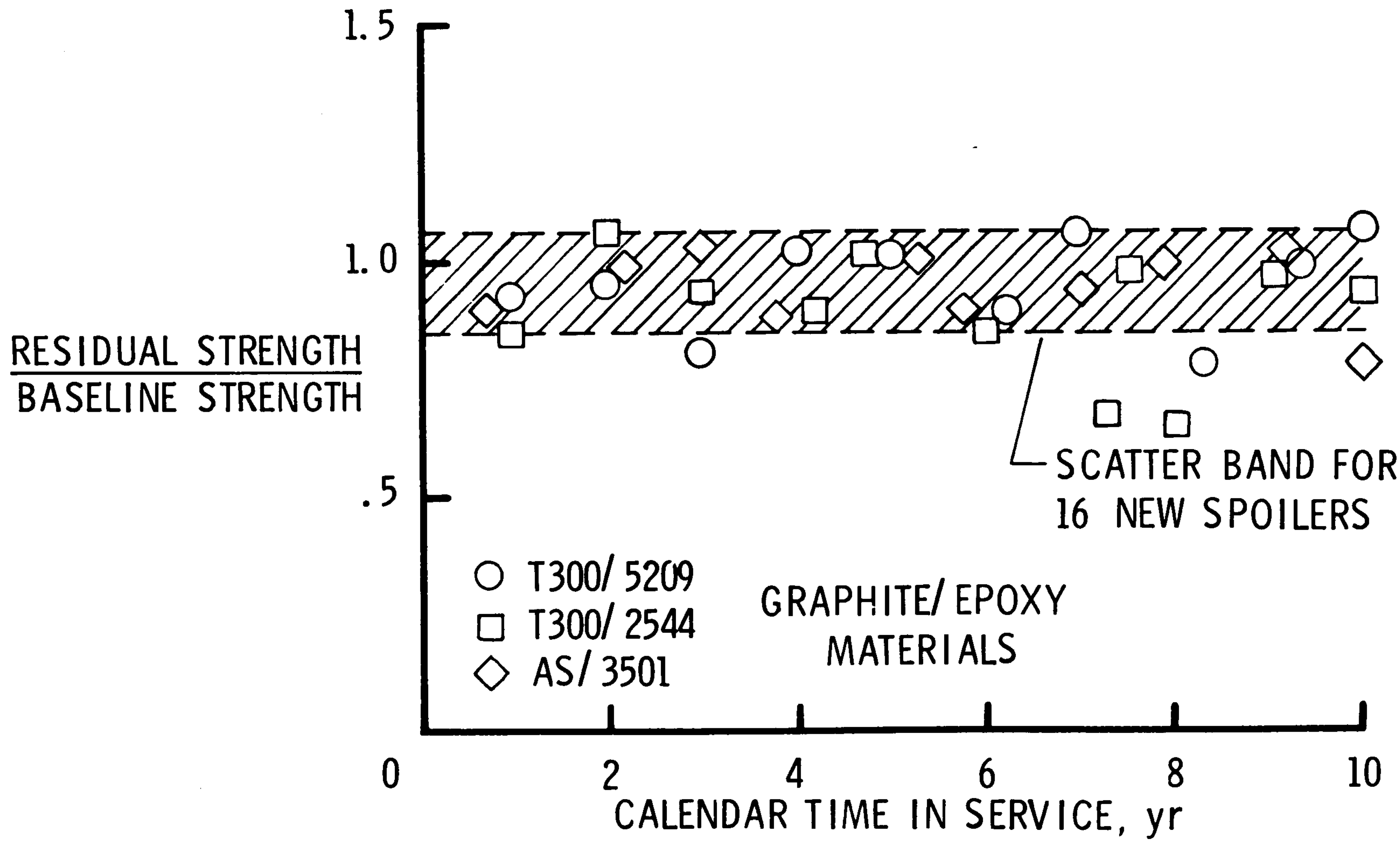

Figure 47. Residual strength of B-737 graphite/epoxy spoilers.

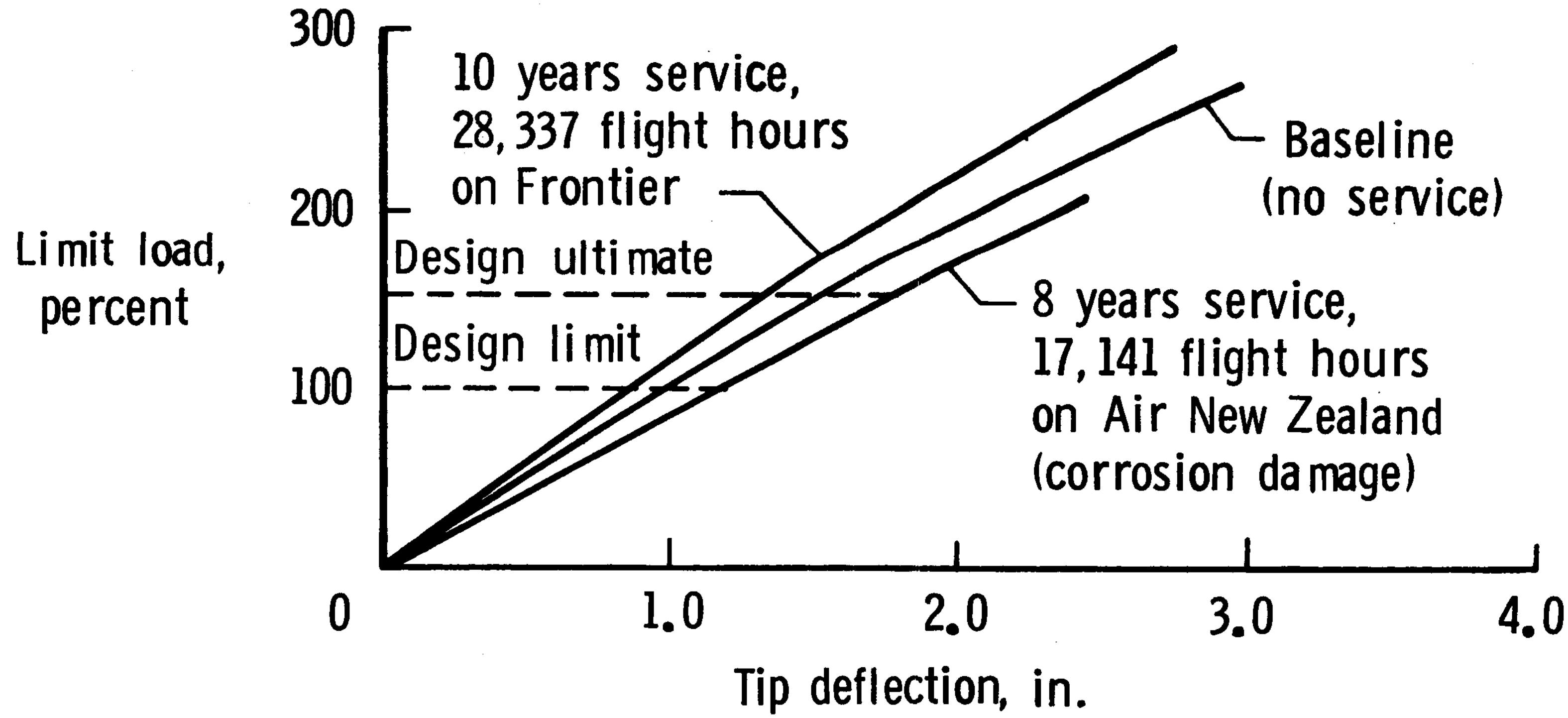

Figure 48. Load-deflection response of T300/5209 graphite/epoxy spoilers.

9 YEARS SERVICE

GRAPHITE/EPOXY	MOISTURE CONTENT, PERCENT	AIRLINE
T300/5209	0.59	LUFTHANSA
T300/2544	0.90	PIEDMONT
AS/3501	0.86	PIEDMONT

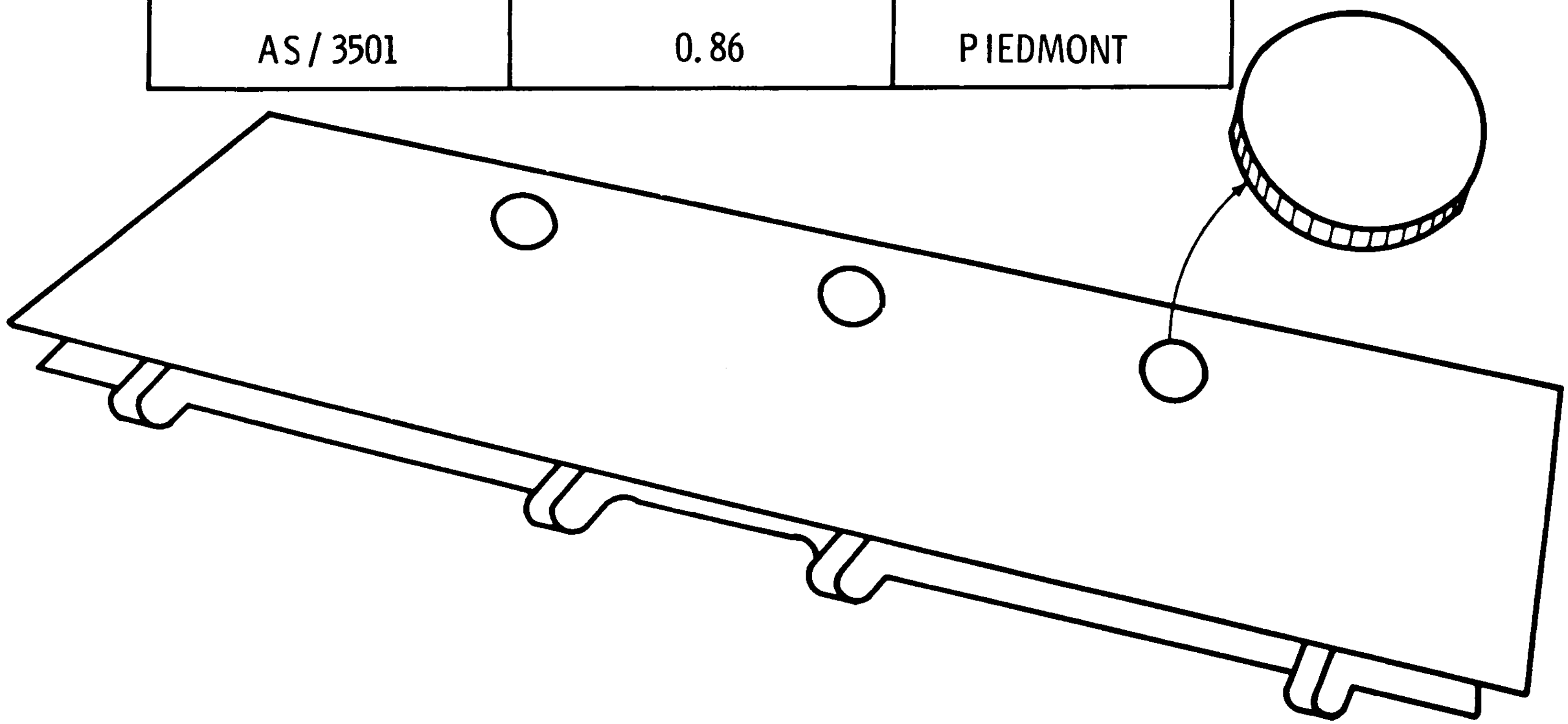

Figure 49. Moisture absorption of graphite/epoxy spoilers.

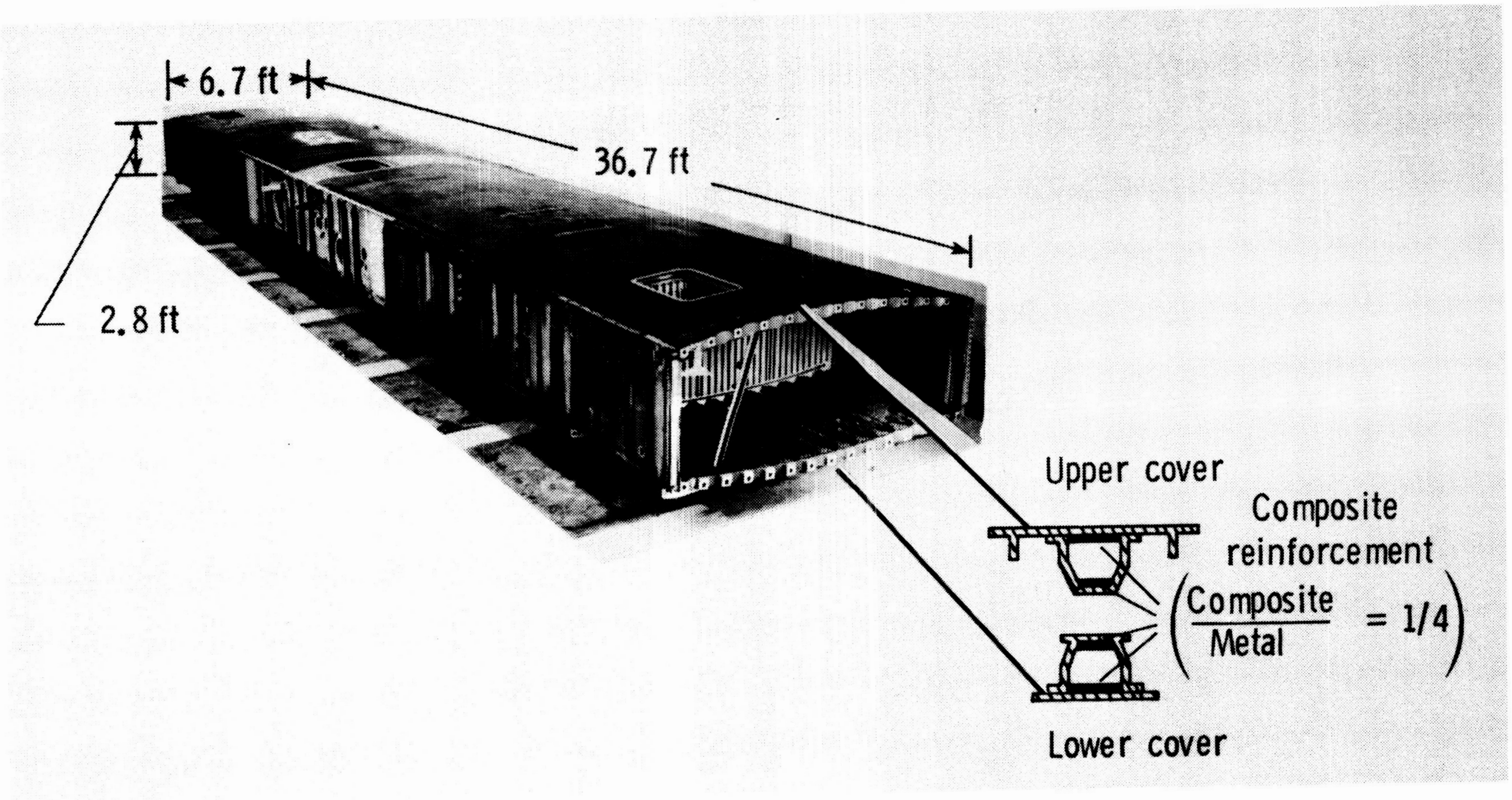

Figure 50. Configuration of C-130 boron/epoxy reinforced center-wing box.

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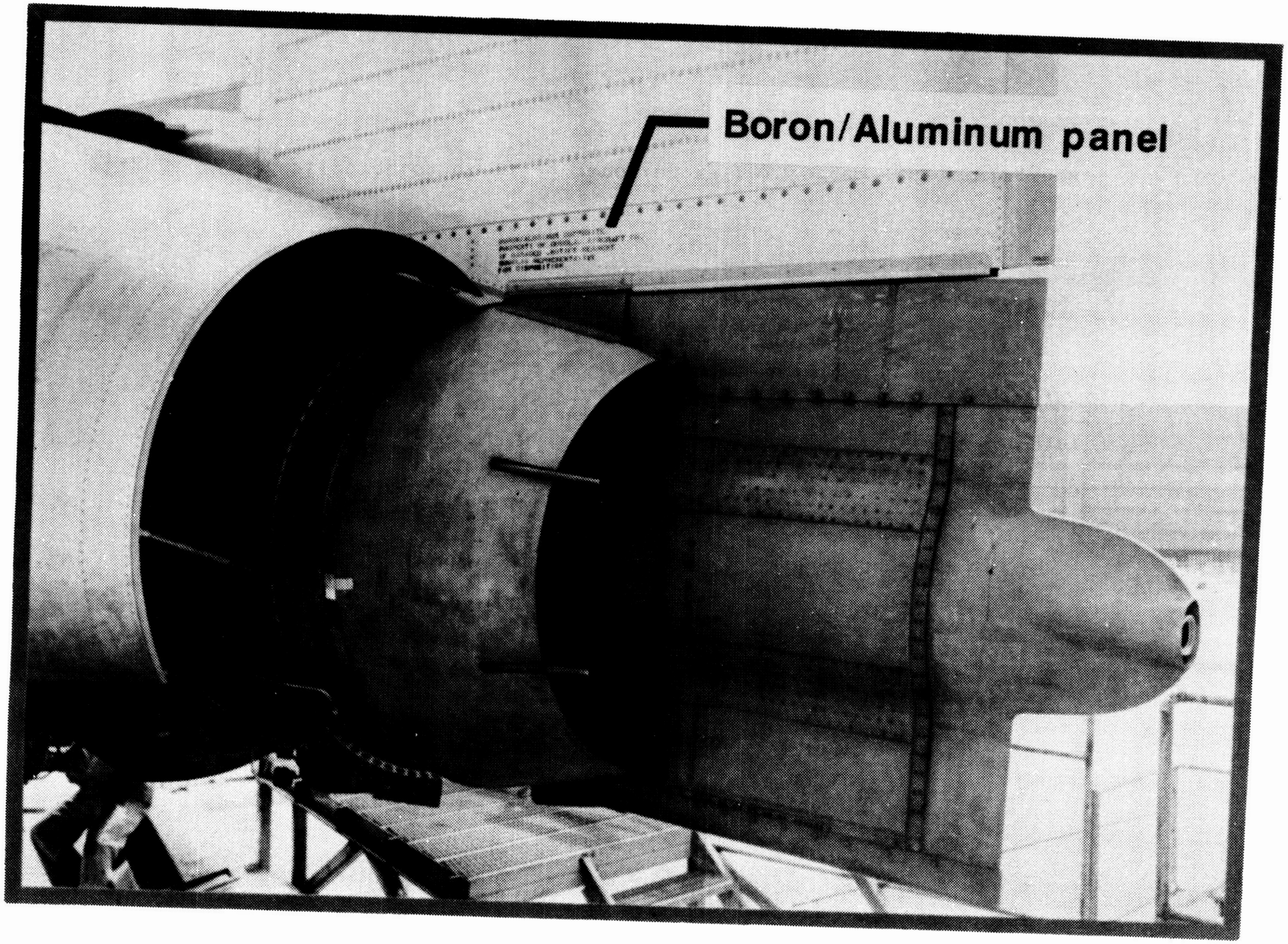

Figure 51. Configuration and location of DC-10 boron/aluminum aft pylon skin panel.

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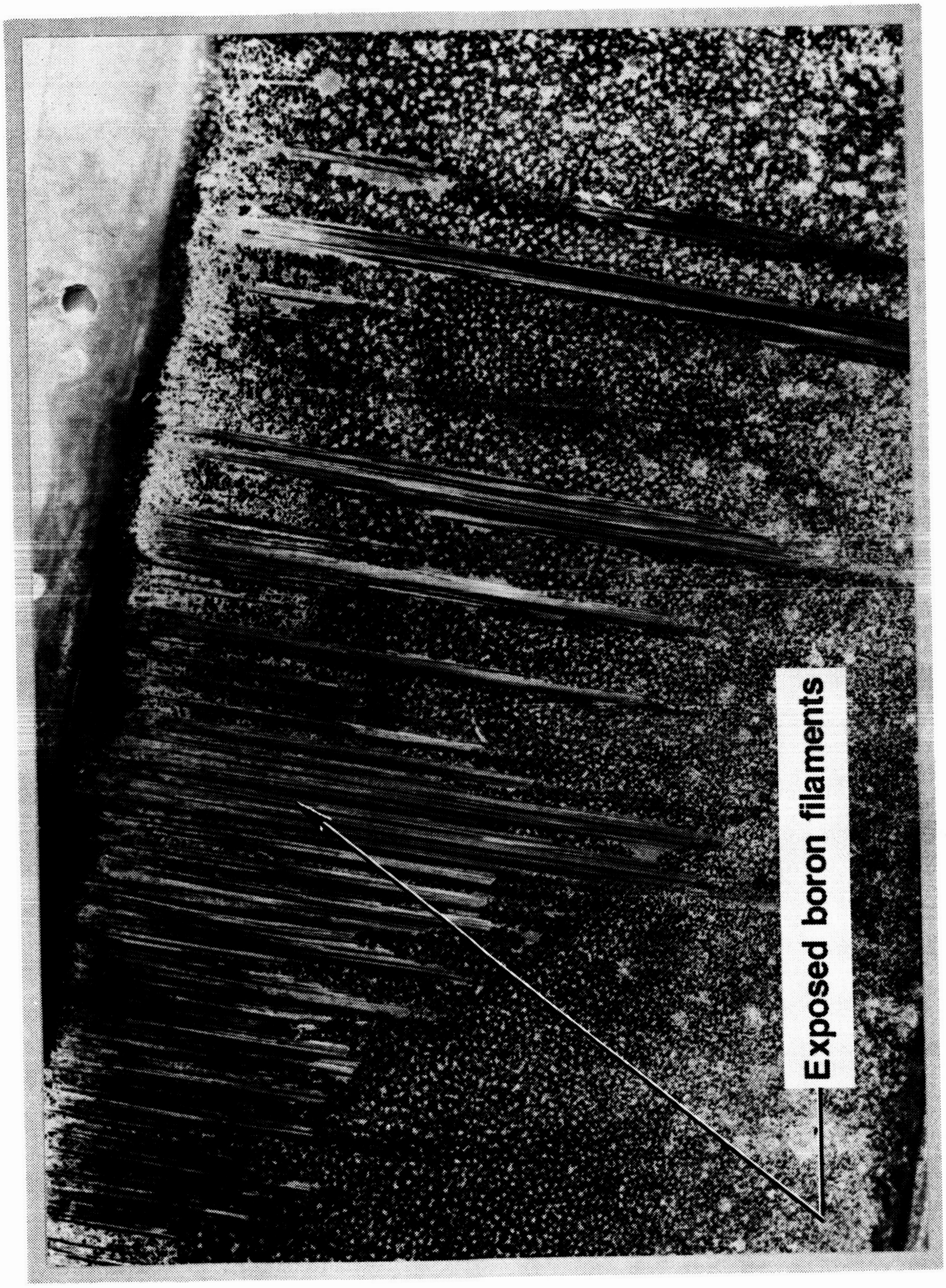

Figure 52. Corrosion damage to DC-10 boron/aluminum aft pylon skin panel.

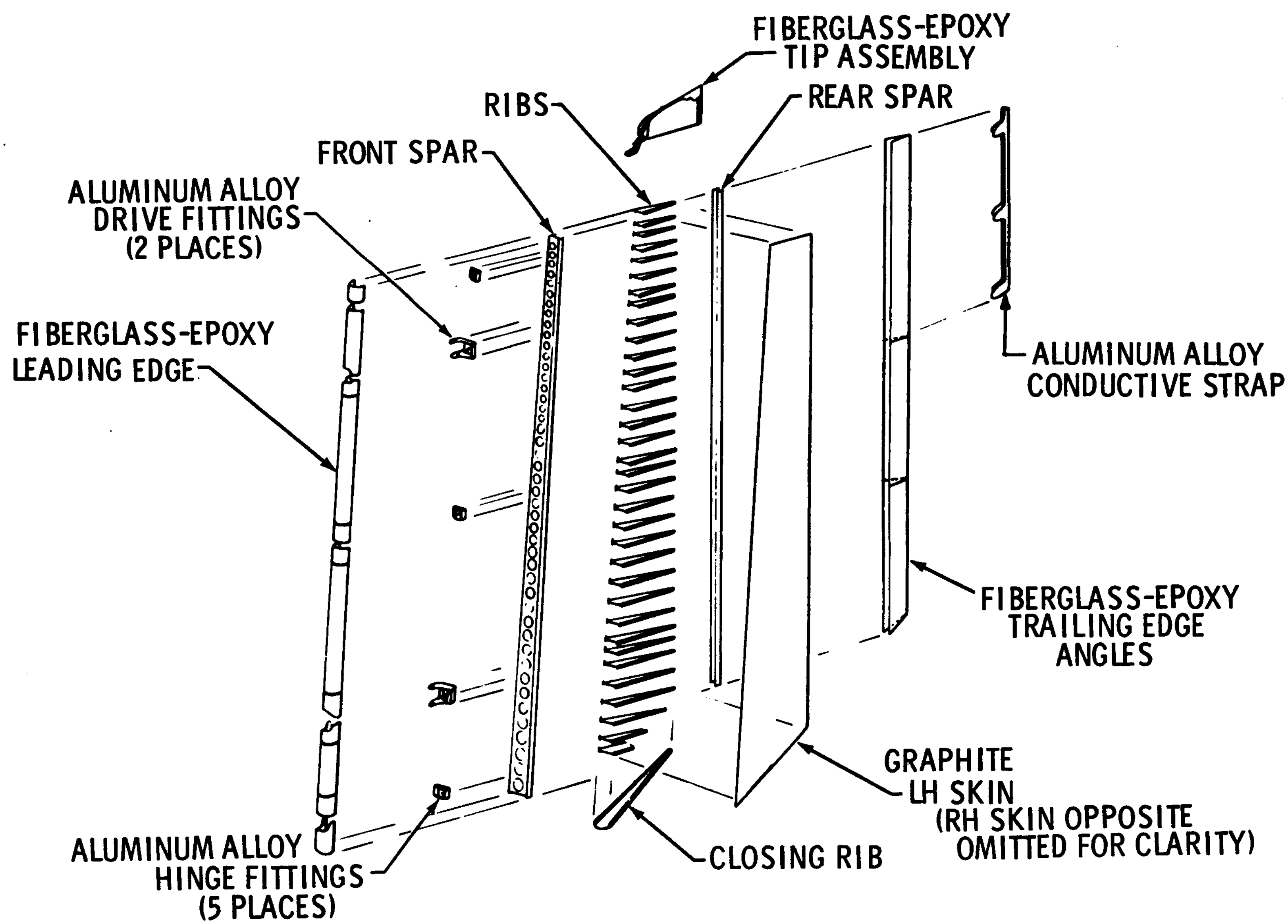

Figure 53. Configuration of DC-10 graphite/epoxy upper aft rudder.

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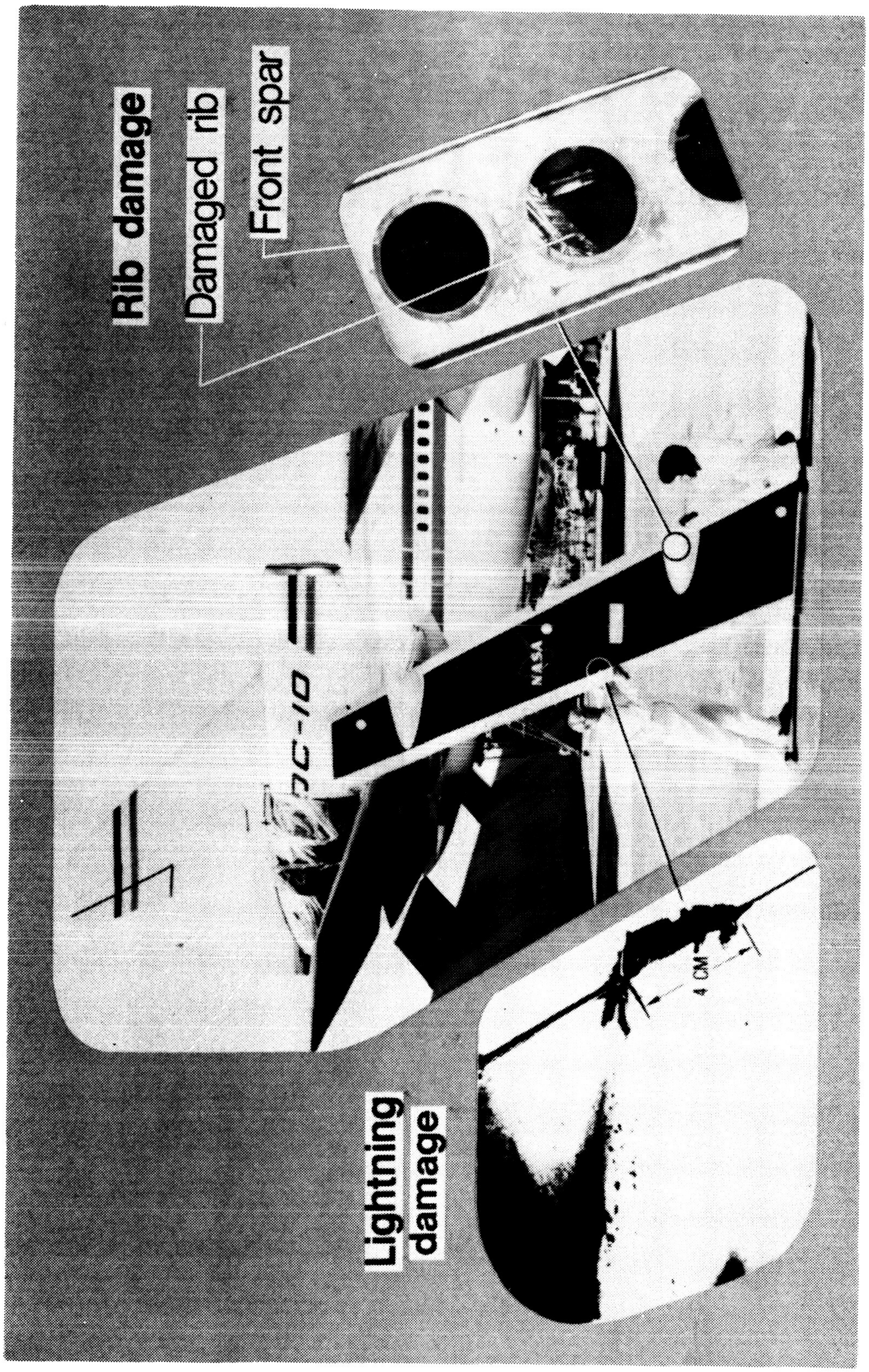

Figure 54. DC-10 graphite/epoxy rudder damage.

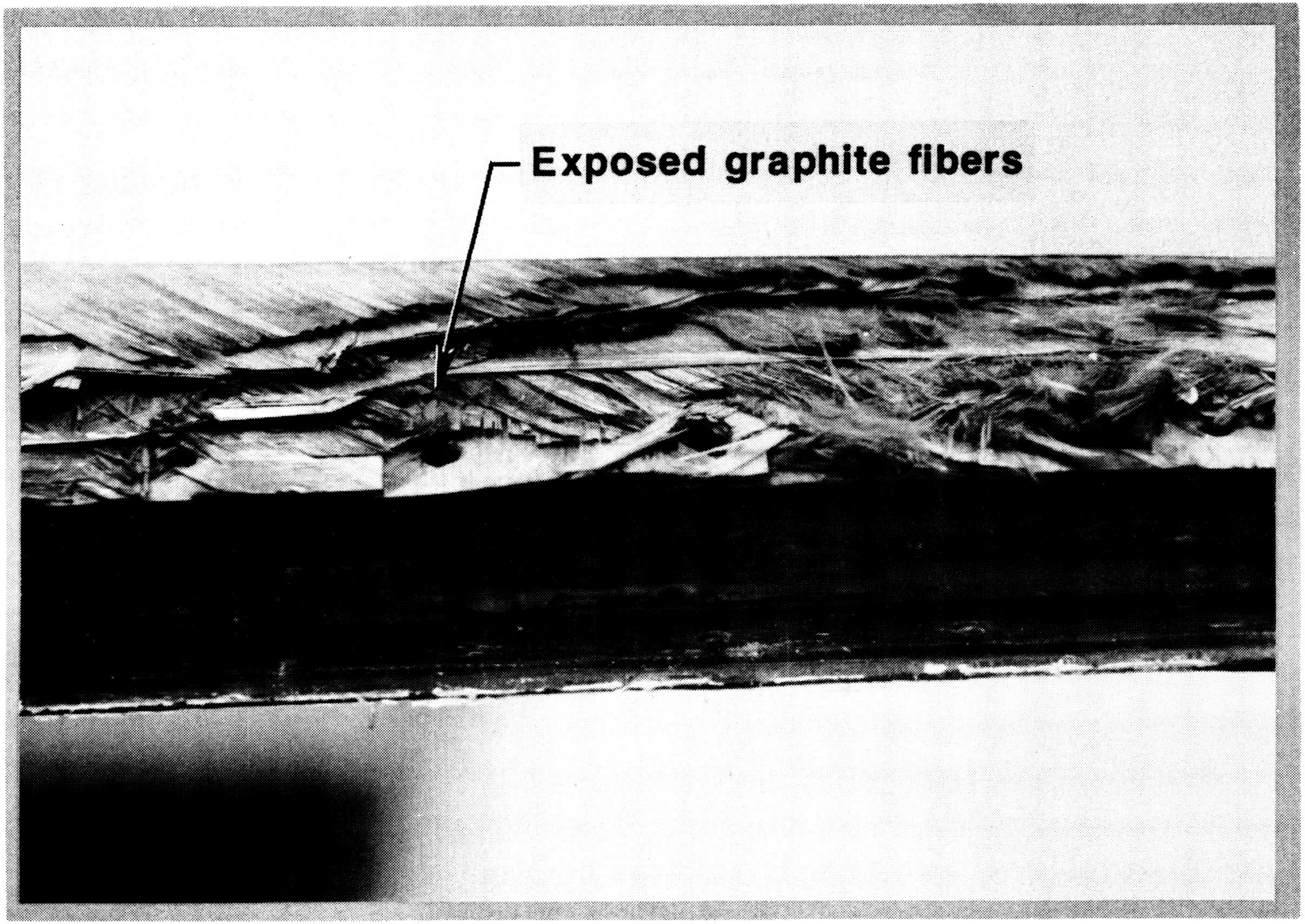

Figure 55. Lightning strike damage to DC-10 graphite/epoxy rudder.

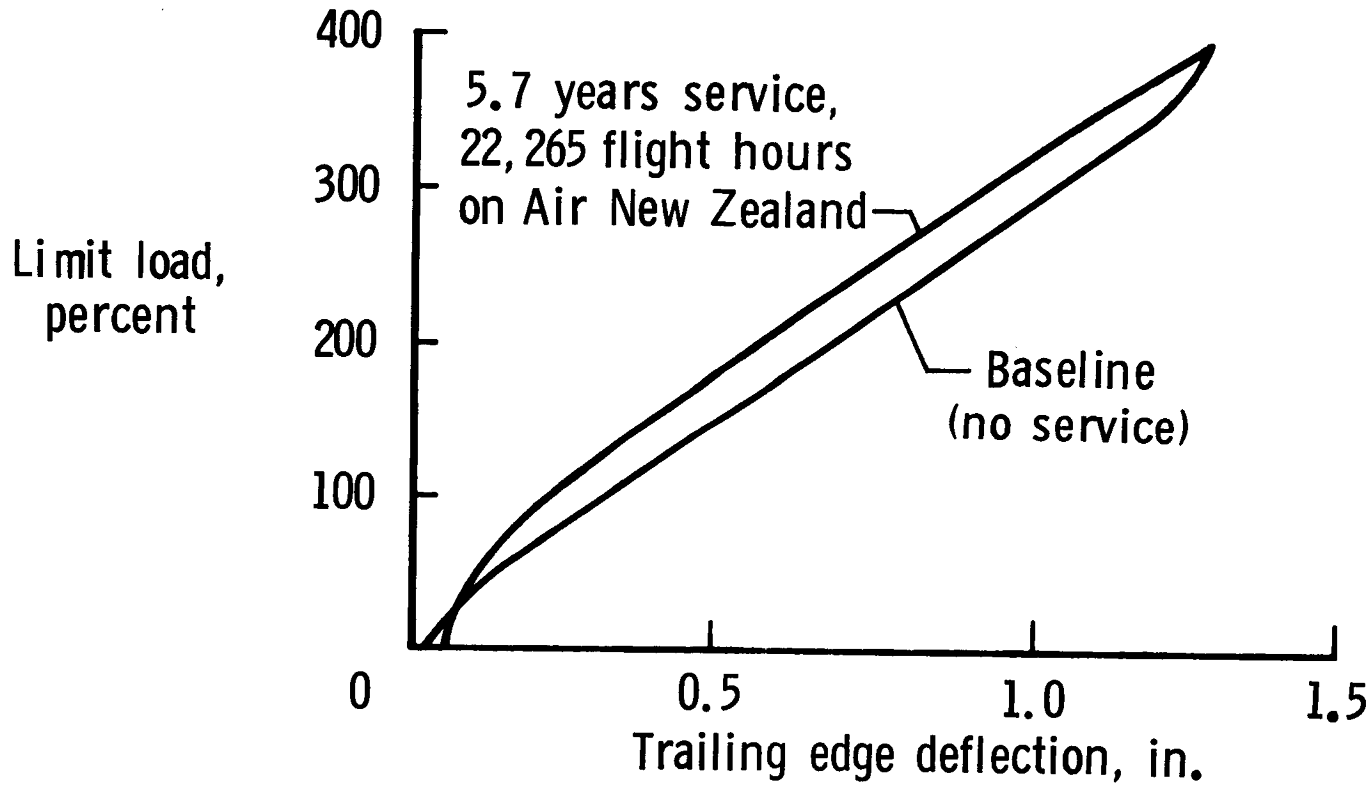

Figure 56. Load-deflection response of DC-10 graphite/epoxy rudder.

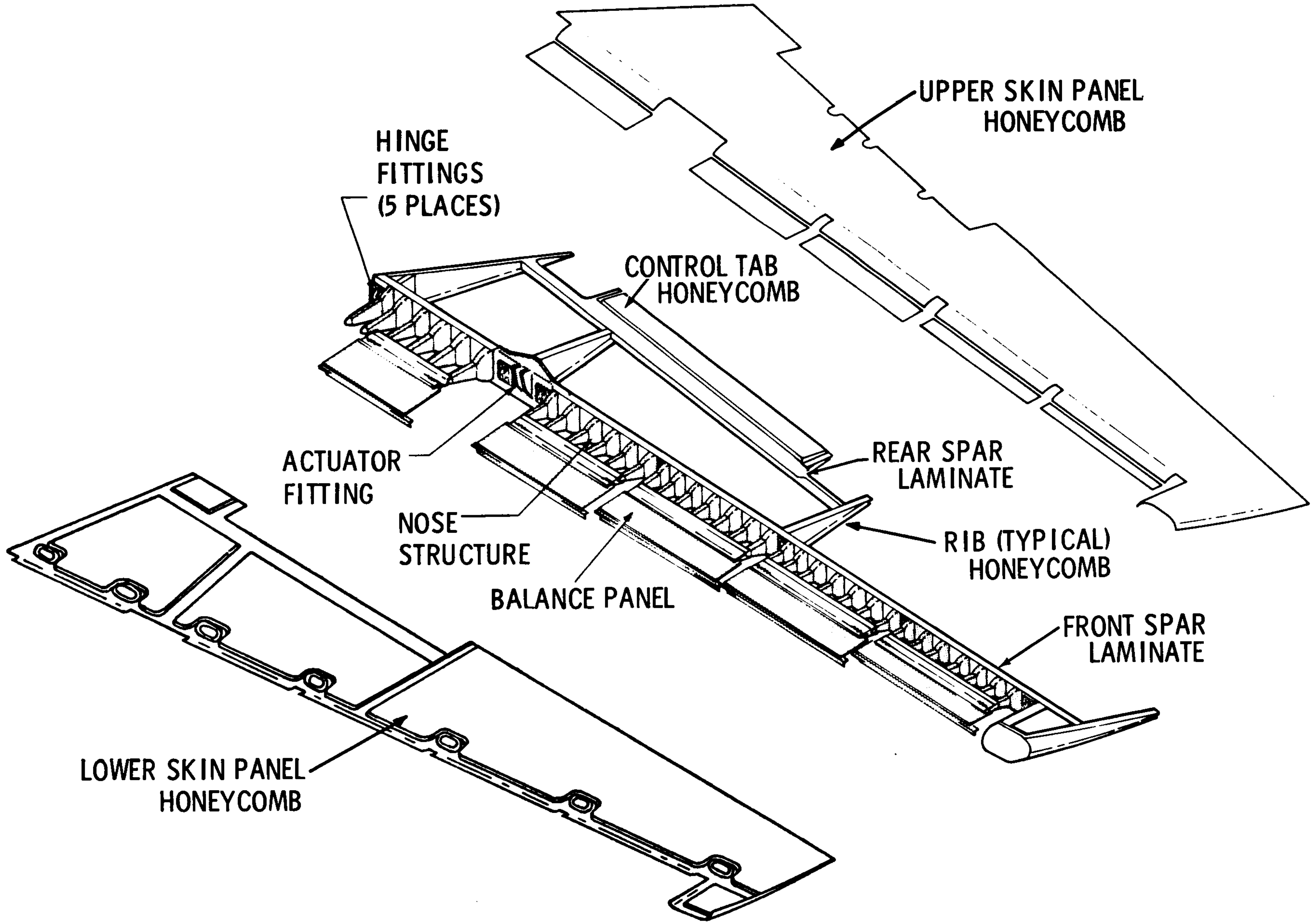

Figure 57. Configuration of B-727 graphite/epoxy elevator.

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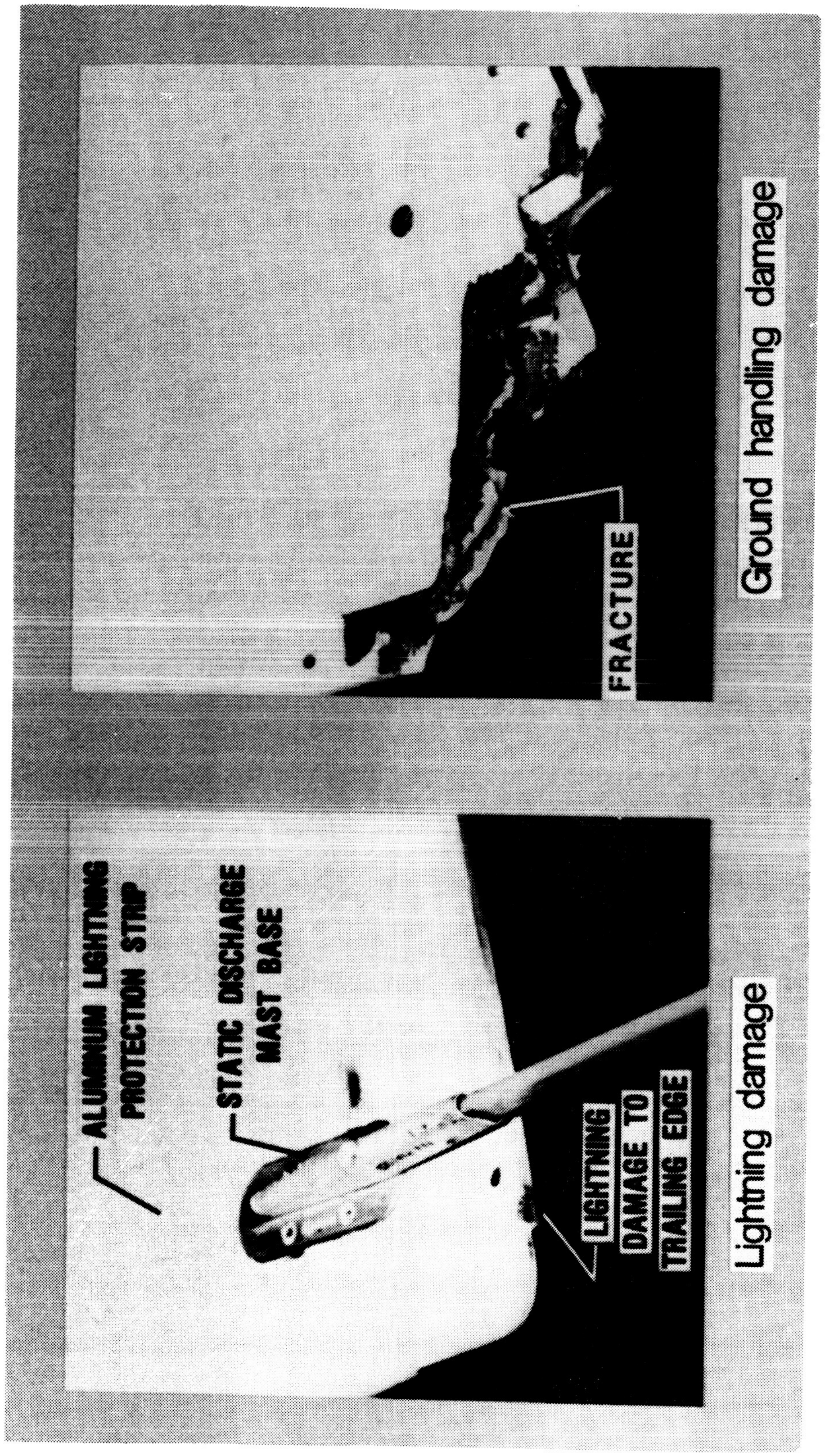

Figure 58. B-727 graphite/epoxy elevator damage.

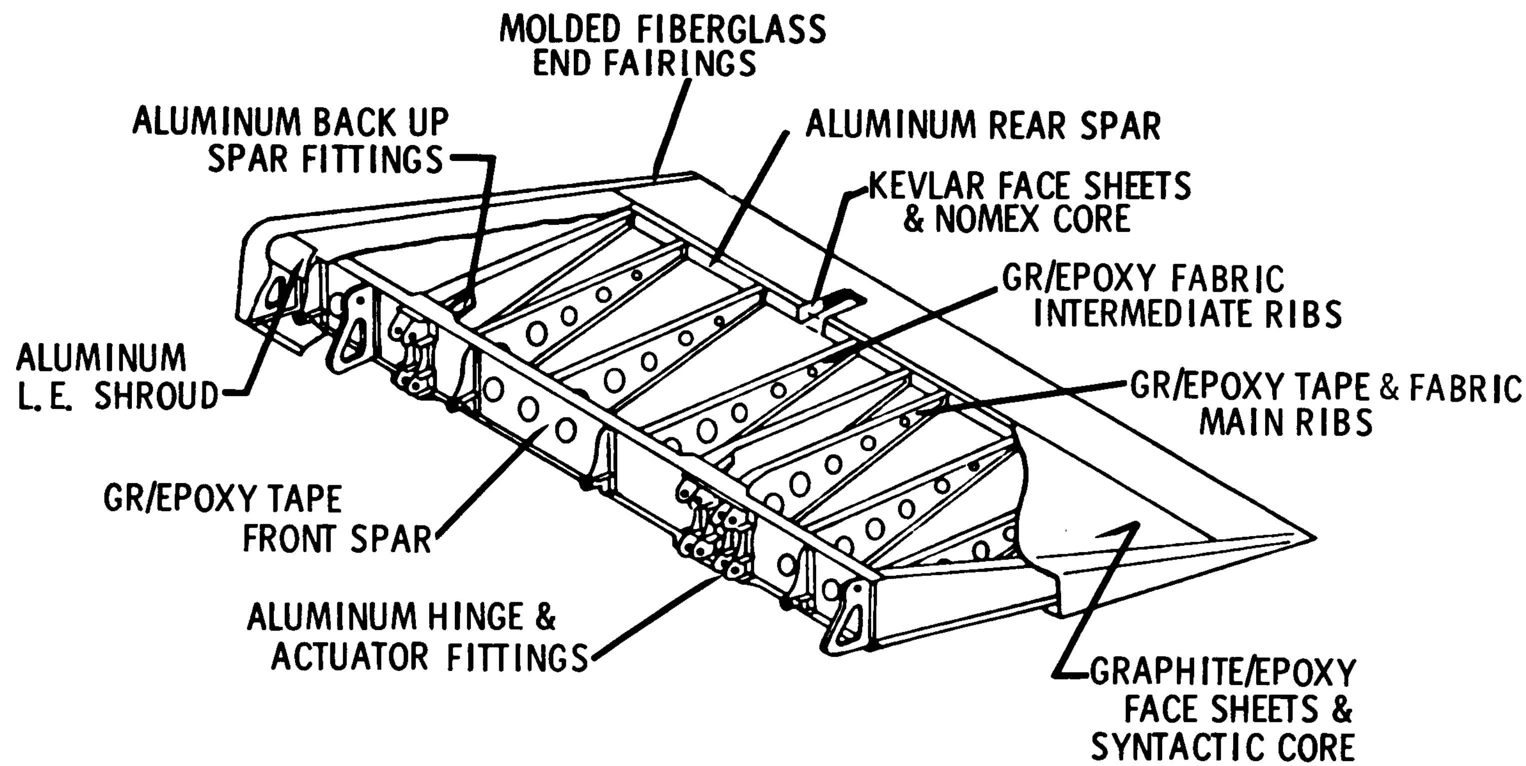

Figure 59. Configuration of L-1011 graphite/epoxy aileron.

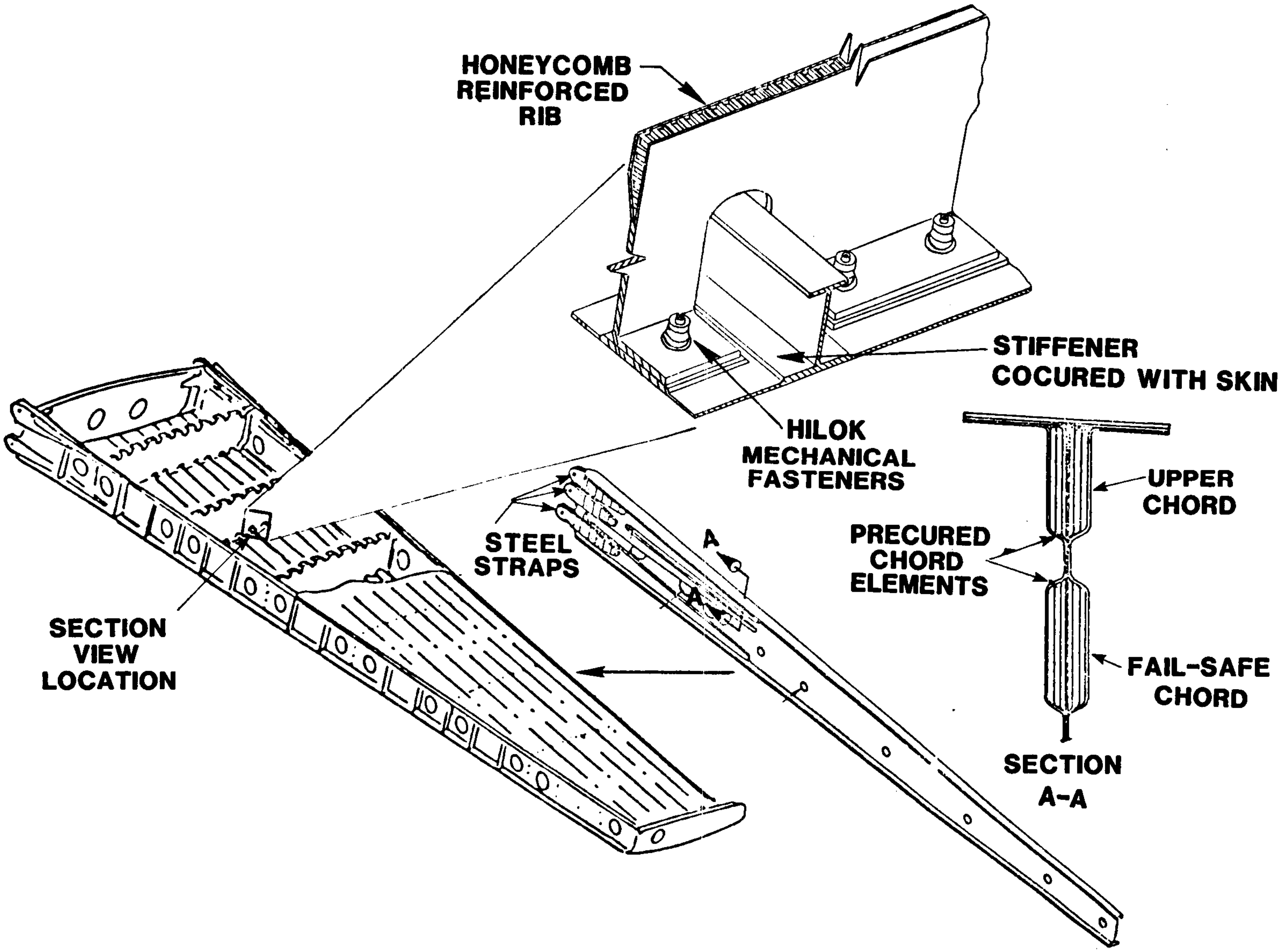

Figure 60. Configuration of B-737 graphite/epoxy horizontal stabilizer.

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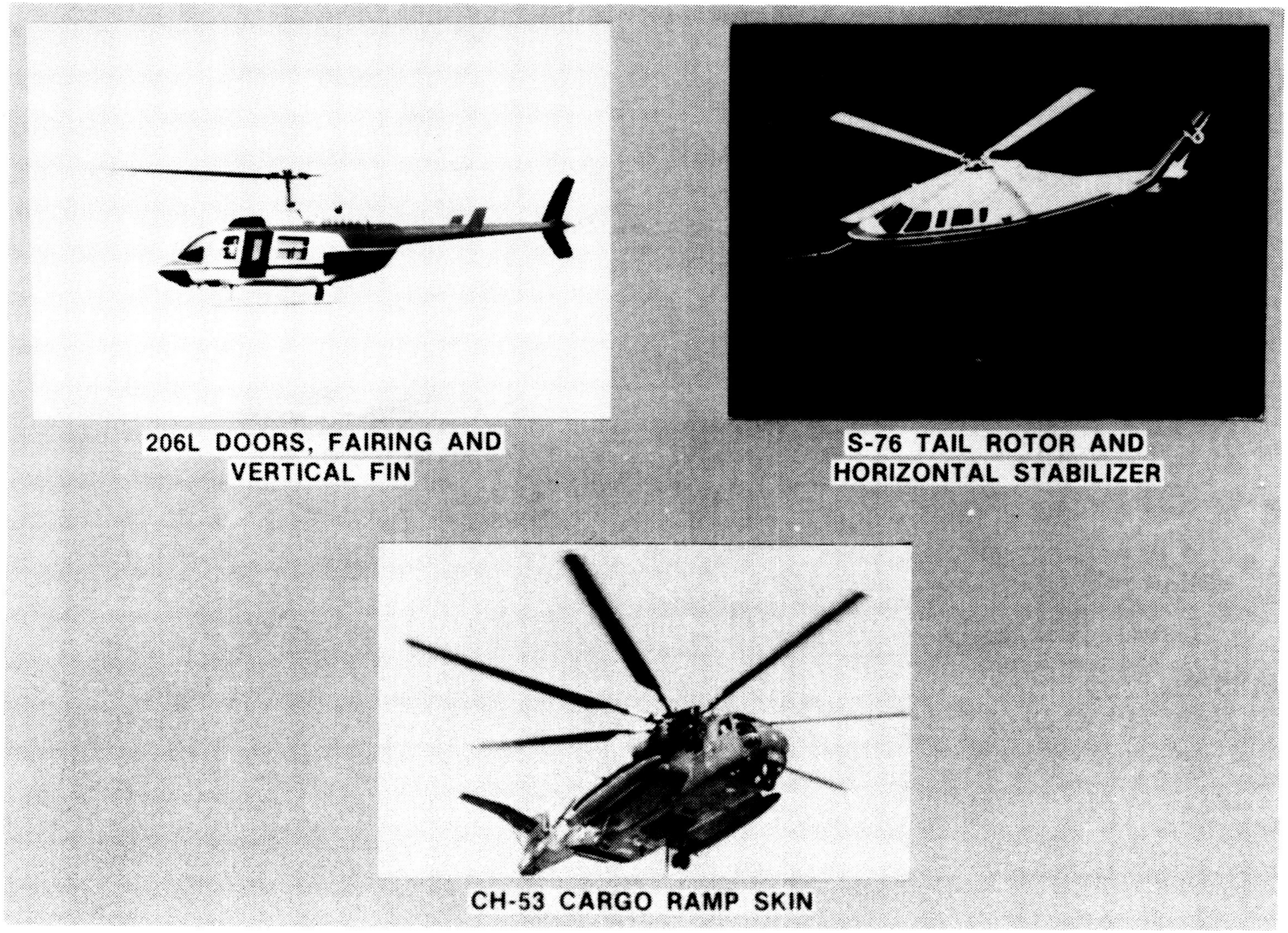

Figure 61. Flight service composite components on helicopters.

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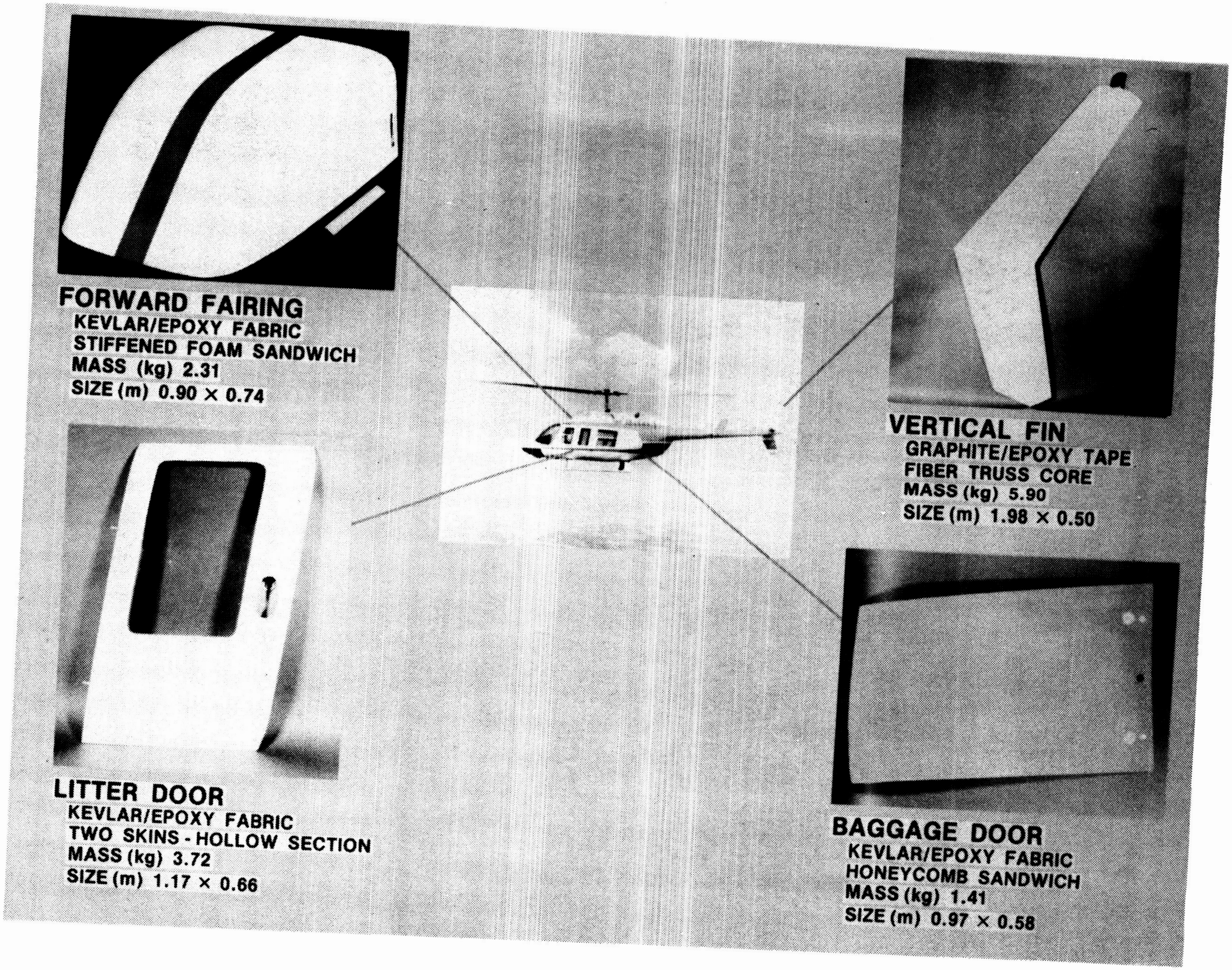

Figure 62. Bell 206L composite components.

Figure 63. Sikorsky S-76 composite components.

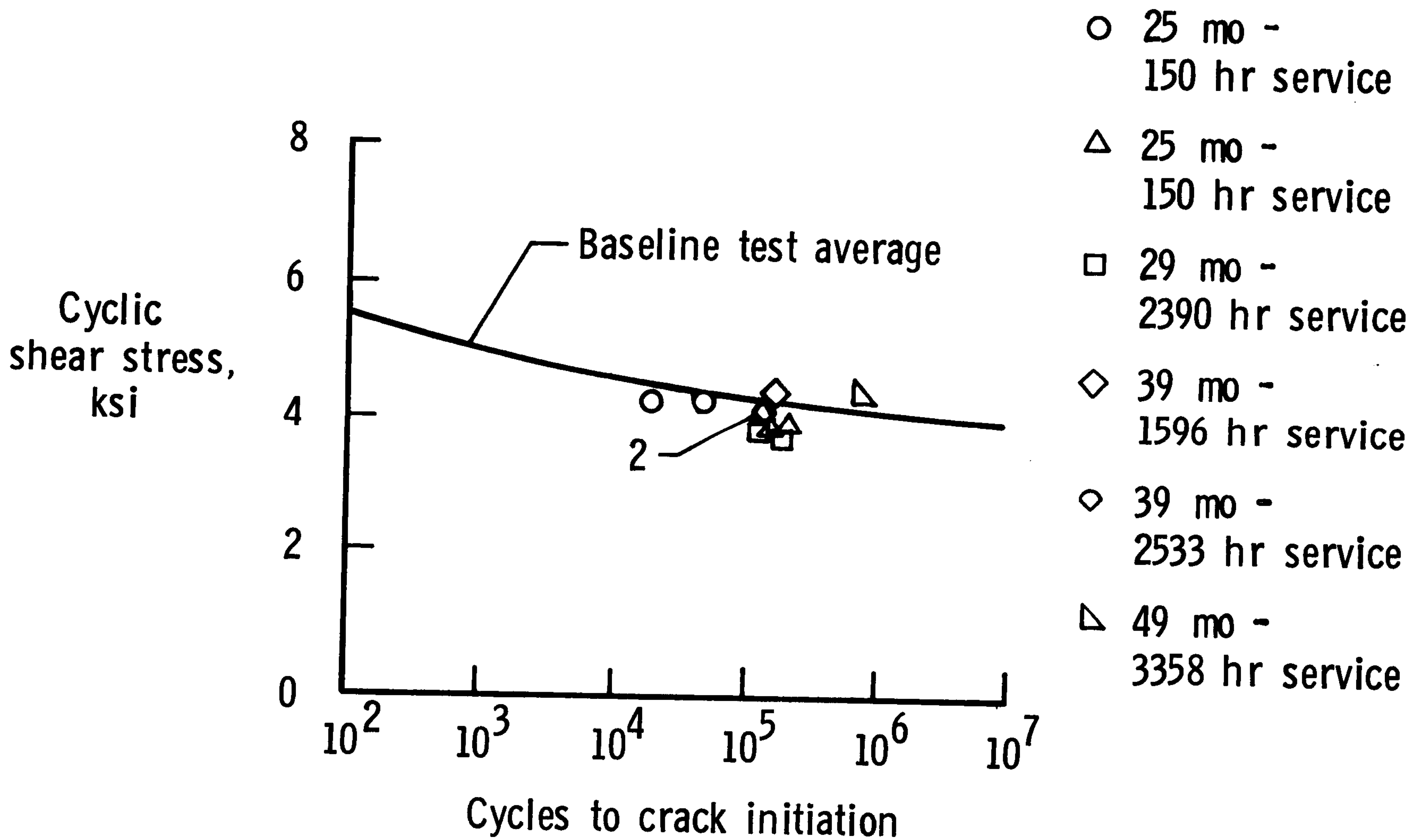

Figure 64. Effect of service environment on S-76 graphite/epoxy tail rotor spars.

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16. Abstract

This paper presents results of a NASA-Langley sponsored research program to establish the long-term effects of realistic flight environments and ground-based exposure on advanced composite materials. The effects of moisture, ultraviolet radiation, aircraft fuels and fluids, sustained stress, and fatigue loading are reported. Residual strength and stiffness as a function of exposure time and exposure location are reported for seven different material systems after 10 years of worldwide outdoor exposure. Flight service results of over 300 composite components installed on rotorcraft and transport aircraft are included. Over 4 million total component flight hours have been accumulated on various aircraft since initiation of flight service in 1973. Service performance, maintenance characteristics, and residual strength of numerous composite components installed on commercial and military aircraft are reported as a function of flight hours and years in service. Residual strength test results of graphite/epoxy spoilers with 10 years of worldwide service and over 28,000 flight hours are reported.

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