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# FLIGHT SERVICE EVALUATION OF COMPOSITE COMPONENTS ON THE BELL HELICOPTER MODEL 206L

## SECOND ANNUAL FLIGHT SERVICE REPORT AUGUST 1983 THROUGH DECEMBER 1985

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# 1. SUMMARY

This is the second flight service report on the advanced composite components that have been in service on the 206L Long Ranger helicopters in the continental United States, Canada, and Alaska. The report covers the period from approximately 1 August 1983 to 1 January 1986. Previous reports (Reference 1 and 2) describe the design, fabrication, certification and first year of service.

Approximately 73,000 flight hours have accumulated on the components as of 1 January 1986. The high-time helicopter accumulated 5716 hours in the Gulf of Mexico.

Three ship sets of components and two-fifth of the exposure coupons were returned and tested. Neither the graphite/epoxy coupons nor the graphite/epoxy fin showed any structural degradation. However the Kevlar/epoxy coupons from the baggage door showed some strength degradation while the baggage door doubled in strength.

One of the graphite/epoxy fins had been hit by lightning and returned for tests. There was no apparent loss of strength or function. It was determined the fin could have been repaired and returned to service.

# 2. FIELD EXPERIENCES

The first parts were placed into service in 1981. In the Spring of 1986 five years of service will be reached for some of the ship sets in the program. On January 1, 1986, there has been approximately 73,000 hours flown with the components installed.

The high time helicopter has accumulated 5716 hours in the Gulf of Mexico. The hours accumulated as reported at the last field inspection in each geographic region is summarized in Table 2-1. The time of inspection varies from August to November.

TABLE 2-1. HOURS ACCUMULATED BY REGION

| Region | 1983 | 1984 | | 1985 | |
|---|---|---|---|---|---|
| | Total to Date | 1984 Hours | Hours to Date | 1985 Hours | Hours to Date |
| Gulf | 14674 | 13189 | 28493 | 8539 | 37032 |
| Northeast | 4223 | 2333 | 6556 | 1720 | 8276 |
| East Canada | 6087 | 3534 | 9621 | 6366 | 15987 |
| Western Desert | 1430 | 3021 | 4451 | 982 | 5433 |
| Alaska | 1509 | 2142 | 3651 | 2303 | 5954 |
| TOTAL | 27923 | 24849 | 52772 | 19910 | 72682 |

An inventory of the components is given in Table 2-2. Of the 160 components, 15 percent have been tested; 11 percent lost to crash; 21 percent are not installed; 53 percent are flying and one baggage door is not accounted for.

Table 2-2. Status of Components.

| Component | Tested | Lost To Crashes | Not Installed | Flying | Lost |
|---|---|---|---|---|---|
| Forward Fairing | 6 | 3 | 6 | 25 | 0 |
| Litter Door | 6 | 3 | 13 | 18 | 0 |
| Baggage Door | 6 | 7 | 7 | 19 | 1 |
| Vertical Fin | 6 | 5 | 7 | 22 | 0 |
| Total | 24 | 18 | 33 | 84 | 1 |

As a whole, the parts have been well received and have had few service problems. Service problems associated with each part are discussed below.

## 2.1 FORWARD FAIRING

The forward fairing has had the fewest service problems. Until the last set of inspections, the only service related problem was associated with the use of the fairing as an antenna base. Field operators had to bond a metal plate to the underside of the fairing for grounding.

The last field inspection revealed the first service problem with the fairing. Two helicopters operating in the Gulf of Mexico developed cracks inside the right-hand and left-hand latch location. Both ships have been in service since 1981. One had flown 4193 hours and the other had flown 5409 hours. Each helicopter averaged around 1200 hours per year. These are high time usage. The cracks were repaired by sanding the surface and applying a fiberglass patch. The parts were then returned to service. The two fairings with the cracks are two of the three helicopters with the most time on them. The helicopter with the greatest flight time is operating in the same environment. It has logged 5716 flight hours in about the same time frame. No problems have been identified with its fairing.

## 2.2 LITTER DOOR

The litter door has had very few problems with the composite material. However, it has had a major problem with hinges. The hinges were under-designed and broke in service. New hinges have been manufactured and most of the doors are back in service. Currently, there are ten doors that are at operator's facilities waiting to be re-installed.

Other normal service problems have occurred. Two ships have had the window broken and replaced. Another door has a slight separation at a lower corner. Finally, another door had some cracks in the paint around the hinges. Besides the broken hinges, the doors have encountered only normal service problems, all of which were handled at the operator's normal repair facility.

## 2.3 BAGGAGE DOOR

Of the four components, the baggage door has the poorest record of service. The adhesive used in the Kevlar doors has not maintained its integrity. There were several cases of a large number of voids in the door. One reason that added to the problem was the fact that the outside face sheet was co-cured with nomex core. There was very little adhesive present between the nomex core and the fuse sheet. This left a poor bond between the outside skin and the core. Figure 2-1 is a picture of a door that was struck under "normal operating environment" in the New York City area. Figure 2-2 shows cracks in the laminate. A close examination of the door yielded large areas of disbond between the outer face and the core. This door is of the same manufacturing lot that was tested after one year of service. The previous report said the door failed prematurely and it might be due to the year of service. It is believed, now, that it was due strictly to a poor resin and

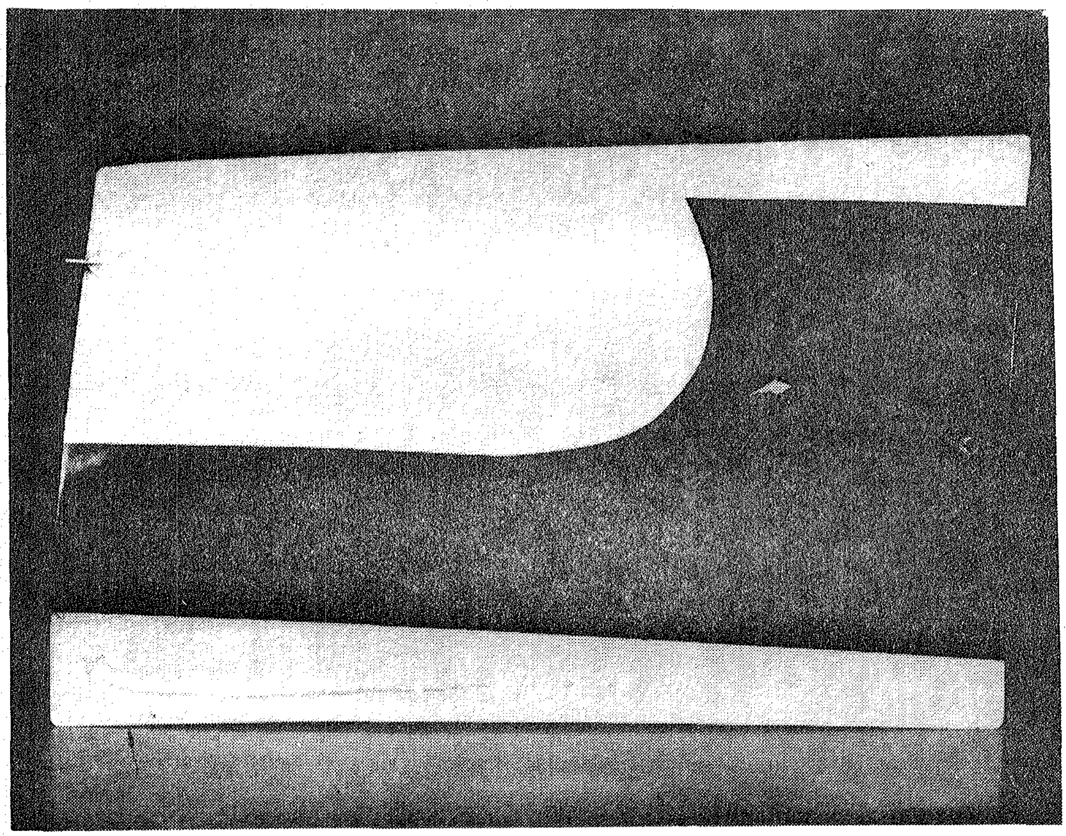


Figure 2-1. Baggage door struck during "normal operating environment" in the New York City area.

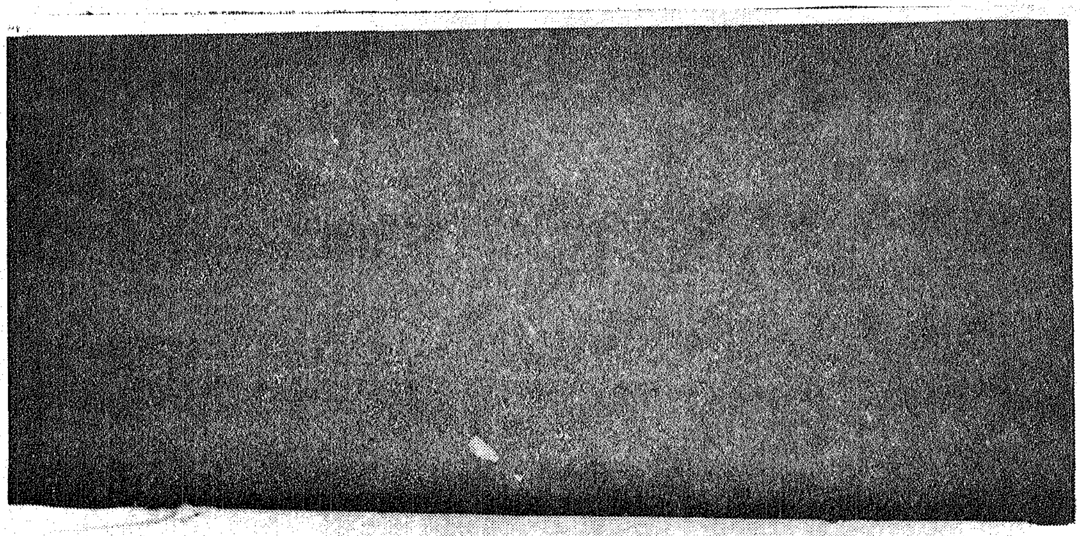


Figure 2-2. Cracks in the laminate of the baggage door.

poor construction. Figure 2-3 is a 100X photo of a cross section of the laminate through the door. There are large areas of voids indicated on the photographs.

Another baggage door was returned due to delaminations between the core and the exterior skin. It is shown in Figure 2-4. A repair at the operator's facility was attempted by identifying the voids, and then using a grinding wheel to remove the skin. The technician was then going to repair the door with a fiberglass patch. After he had frayed the skin, he discovered other areas of disbond. He then marked the zones and sent it back to Bell. Figure 2-5 shows the voids on the composite door.

A baggage door was destroyed in a hard landing when a helicopter rolled into a ravine. Figures 2-6 and 2-7 show the damaged baggage door.

The other service problem with the door has more to do with design. The unsupported corners of the door are cracking. This is an aesthetic problem rather than a function problem. The corners do not break off. Instead, they hinge along the crack.

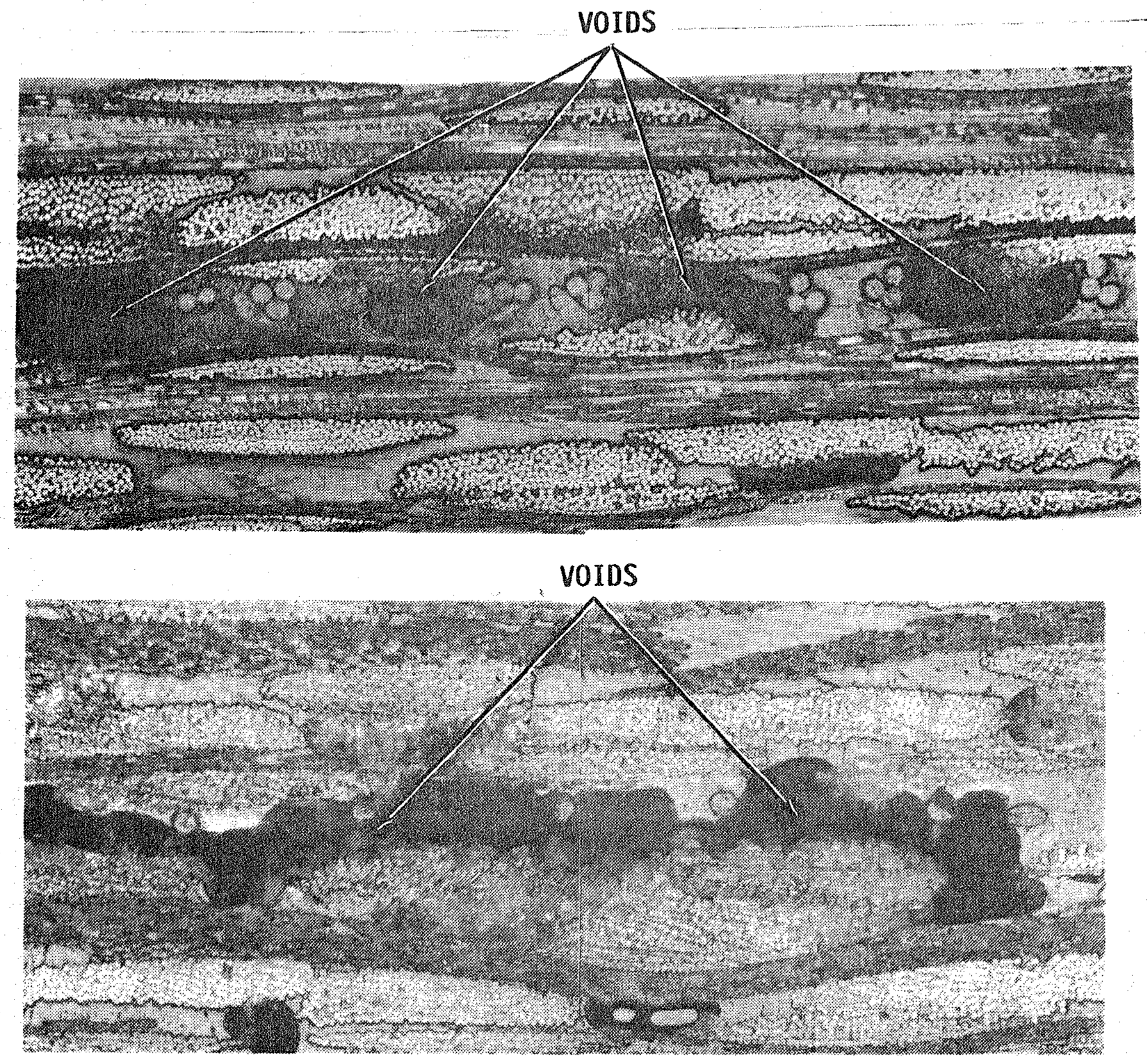



Figure 2-3. 100x magnification of a cross section of the laminate through the door.

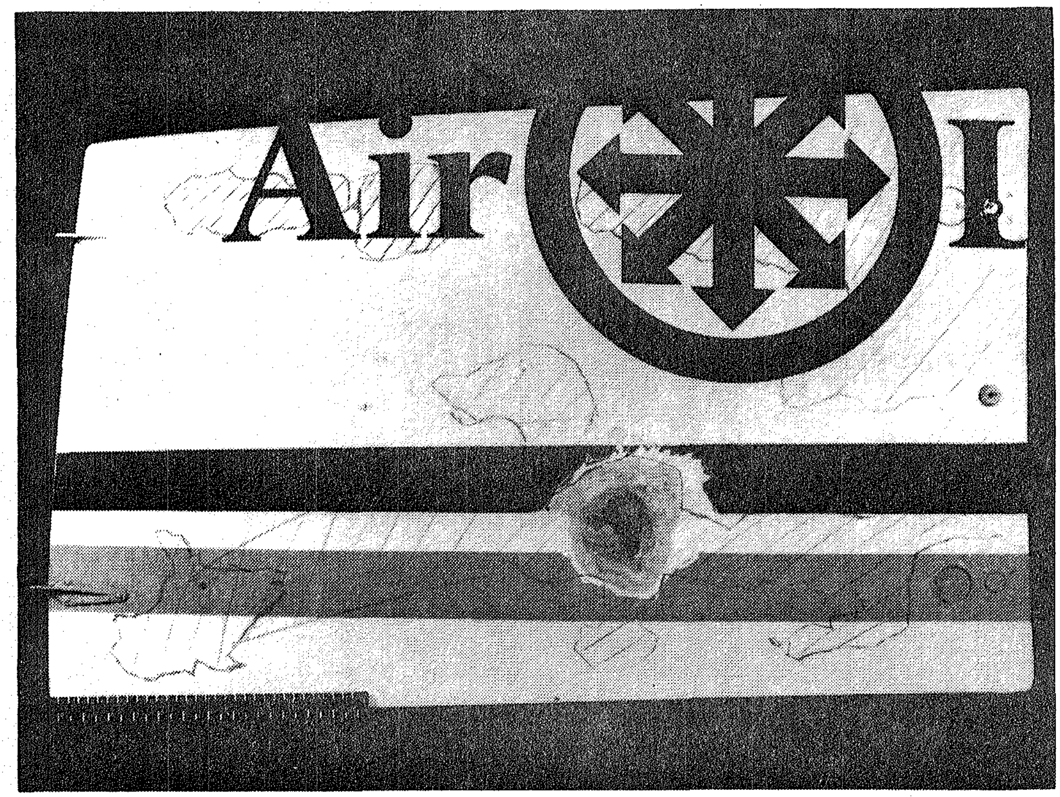



Figure 2-4. Baggage door returned due to delaminations.

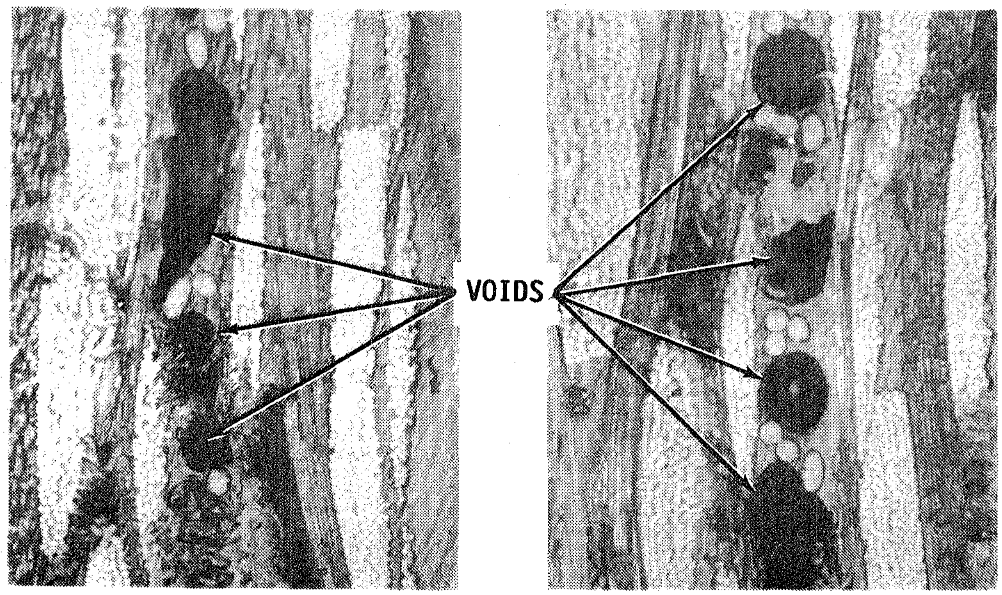
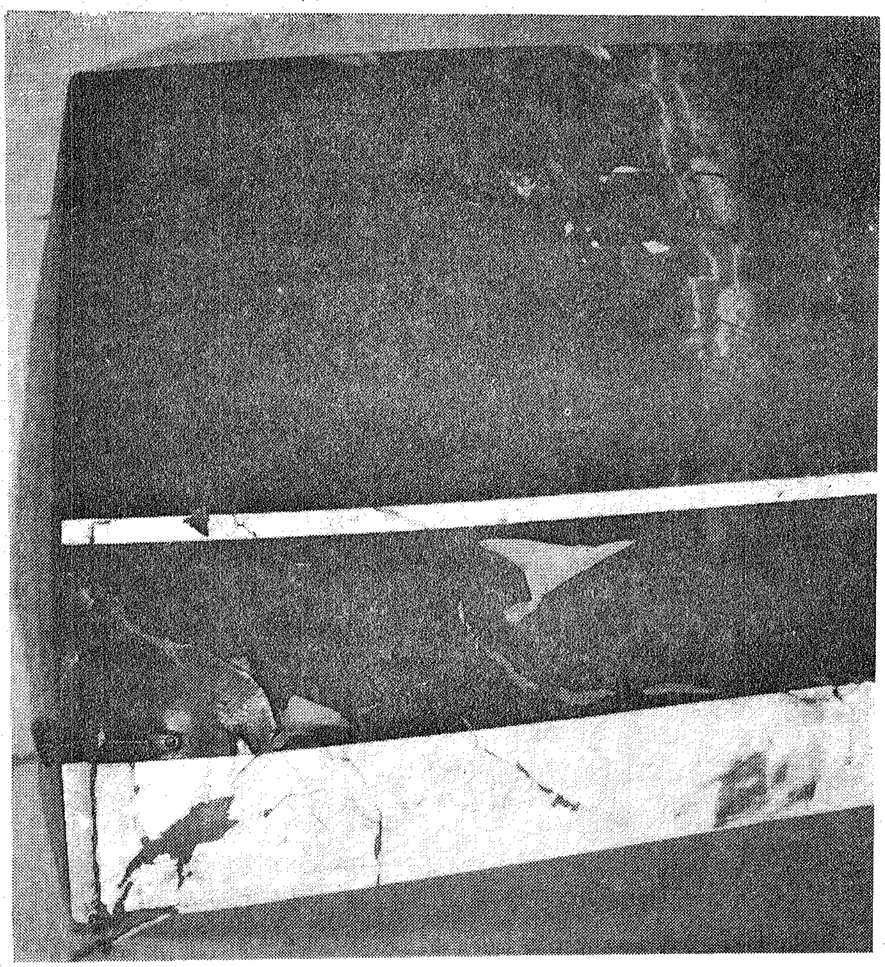



Figure 2-5. Voids on the composite door.



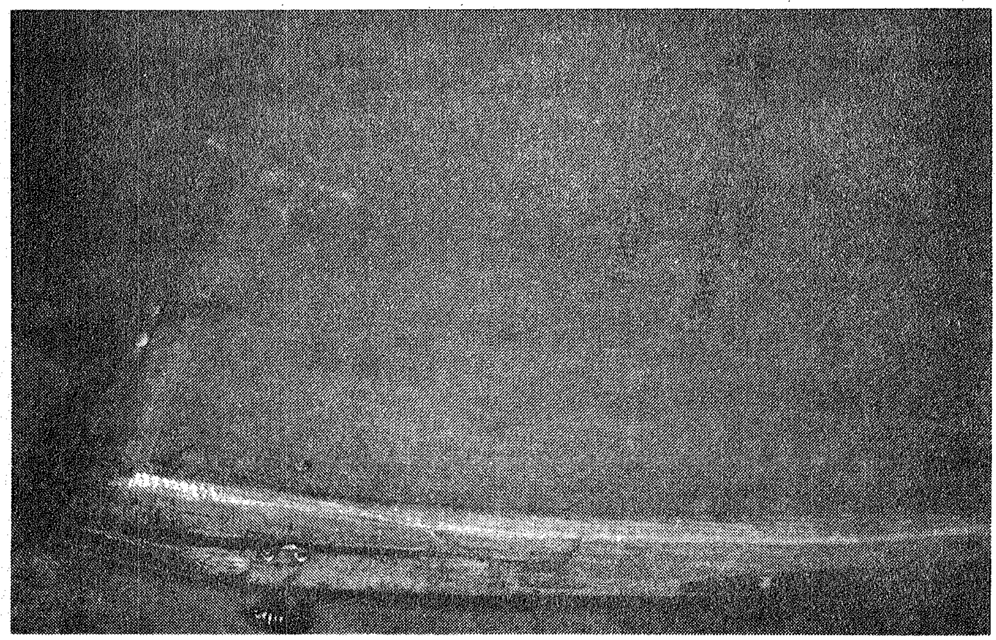


Figure 2-6. Baggage door damaged due to a hard landing.

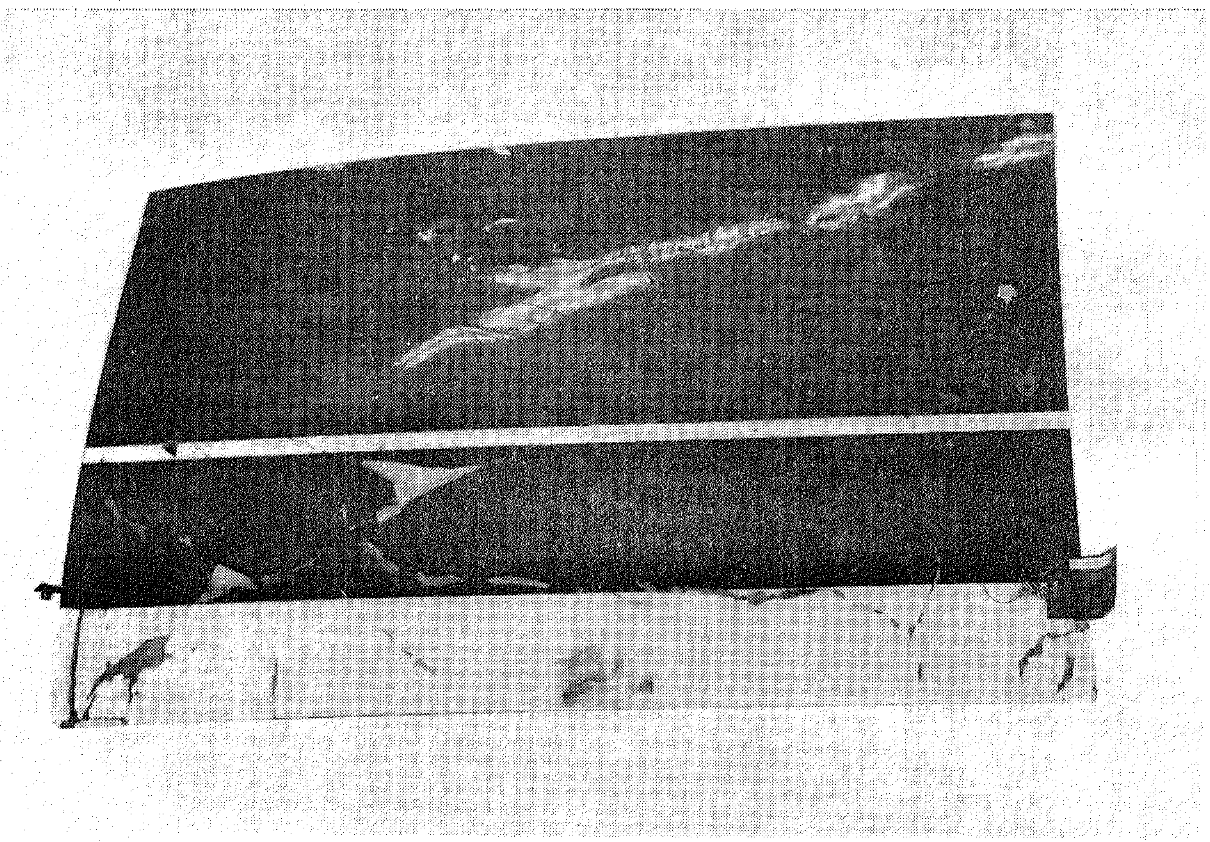


Figure 2-7. Damage to baggage door caused by a hard landing.

## 2.4 VERTICAL FIN

The graphite vertical fin has excellent service experience. Its only problem has been non-structural. The fin is used for ground handling the helicopter. Cracks appeared on the leading edge of the fin which is made of unsupported two ply Kevlar. Though it was first thought to be cracked laminates, it was determined to be only cracked paint.

One fin was destroyed in the same hard landing mentioned in Section 2.3 when a helicopter rolled into a ravine. Figures 2-8 and 2-9 show the damage to the fin. The forward fairing and litter door were undamaged.

Two other fins were hit by lightning. One was repaired with a titanium patch and is still flying. The second was sent back for testing and is discussed in Section 5. In both cases, the lightning protection performed as designed.

One of the biggest service problems in the Gulf of Mexico is corrosion. PHI and Air Logistics start patching corroded metal fins after 1 1/2 to 2 years. By six years in service, the leading edge, trailing edge, and other parts have been rebuilt. The graphite fins have up to five years without a single maintenance problem. This is a tremendous cost reduction item.

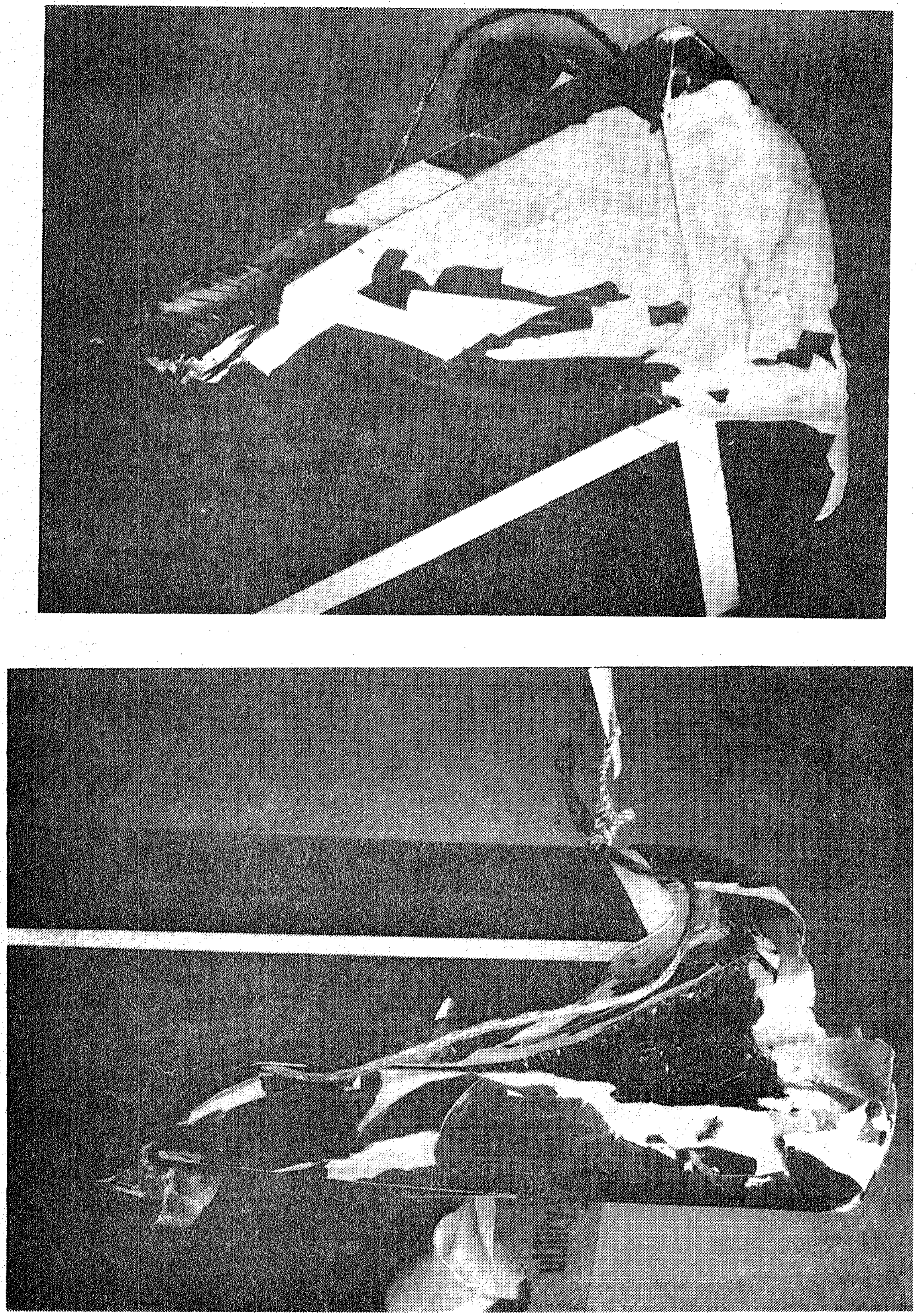


Figure 2-8. Fin damaged during hard landing.

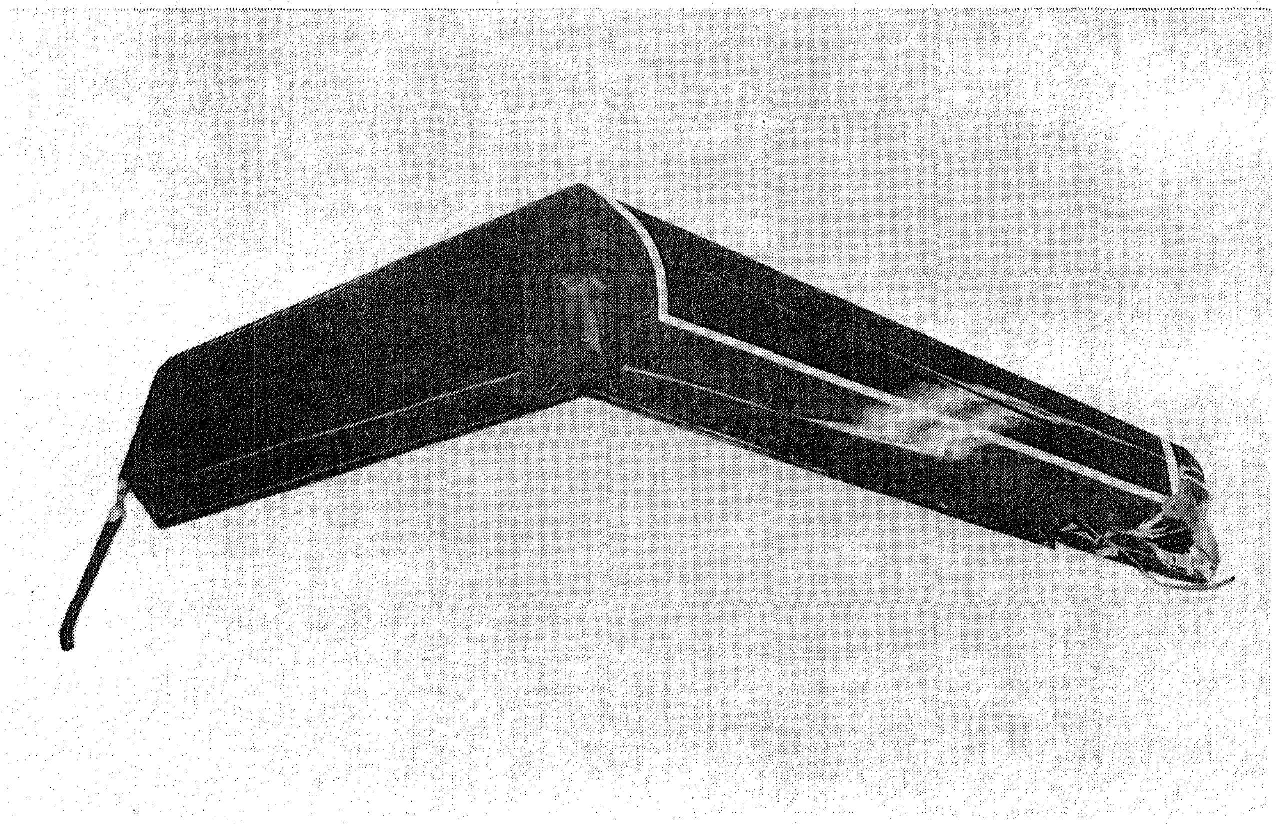


Figure 2-9. Damage to fin caused by a hard landing.

# 3. EXPOSURE COUPONS

Laminates were fabricated representing the material from each of the components. Tension, compression, and short beam shear coupons were fabricated. These specimens were painted with a polyurethane paint (DuPont IMIRON) which is used on the flight service helicopters. The remaining specimens were left unpainted to determine the weathering effects on bare composites. The results presented are only for the painted specimens. The geometry of these specimens is given in Figure 3-1. The specimens were assembled on exposure racks and placed in different environments for exposure. At the end of one and three years, a panel containing a sample of the exposure coupons was tested to determine the residual strength of the coupons. An exposure rack and the geographic locations of the racks are shown in Figures 3-2 and 3-3.

The testing for the three-year exposure has been completed. After the panels were removed from the racks at Cameron, LA. and the offshore oil platform in the Gulf of Mexico, a hurricane destroyed both installations. As a result, the three year data will be the last data from the humid, salt environment.

The average baseline strengths for the fabricated exposure specimens are given in Table 3-1. As a whole, the results of three years of ground exposure indicates that all the material systems exhibit good strength retention. The Kevlar-49/LRF-277 (baggage door) had the greatest degradation in the matrix dominated failure, while all systems did not show a significant reduction in tensile strength.

The results of the exposure coupons are fully documented in Reference 3. This report uses some of the data presented in Reference 3.

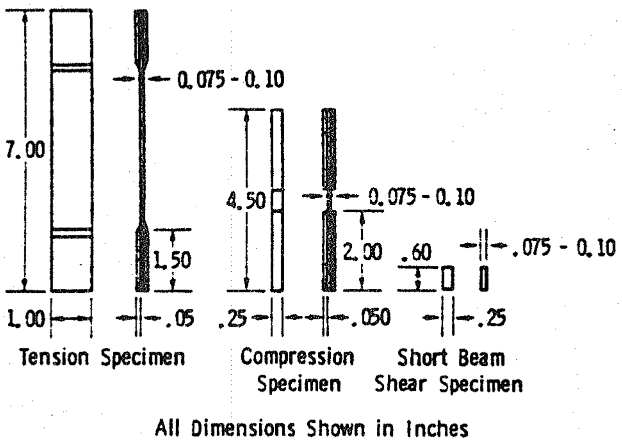



Figure 3-1. Geometry of painted specimens.

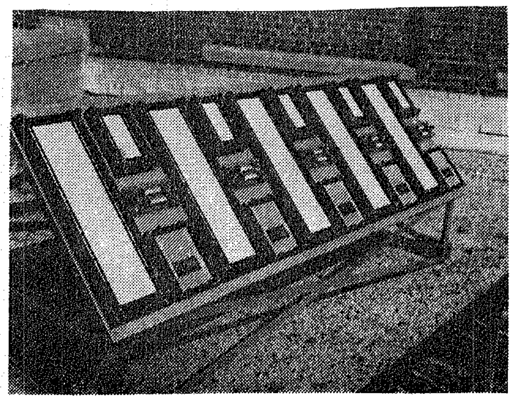


Figure 3-2. Environmental exposure rack with specimens installed.

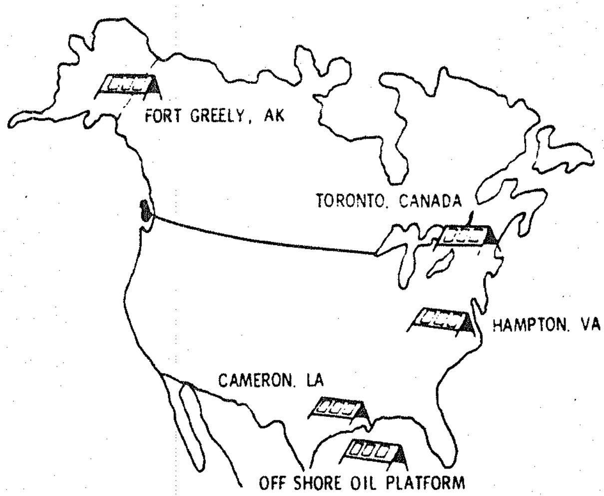



Figure 3-3. Location of environmental exposure racks.

TABLE 3-1. AVERAGE BASELINE STRENGTH FOR THE FABRICATED EXPOSURE SPECIMENS

| Material System | Strength (PSI) | | | | | |
|---|---|---|---|---|---|---|
| | Short Beam Shear | | Compression | | Tension | |
| | Mean | SD* | Mean | SD* | Mean | SD* |
| Kevlar-49/F-185 | 6018 | 197 | 20176 | 489 | 57363 | 2448 |
| Kevlar-49/LRF-277 | 3873 | 119 | 22363 | 909 | 83658 | 2198 |
| Kevlar 49/CE-306 | 5277 | 258 | 18265 | 337 | 61090 | 2917 |
| T300/E-788 | 11222 | 285 | 126343 | 4025 | 126478 | 4209 |

*SD - Standard Deviation

## 3.1 COMPRESSION

The average residual compression strengths for painted specimens after three years of exposure are shown in Figure 3-4. Data from all five geographic locations are averaged and presented as a percentage of the baseline strength. All the material systems exhibit fairly good strength retention in compression. The Kevlar-49/LRF-277 (baggage door) had the greatest strength degradation. Its strength retention was 88% of the baseline after three years of exposure. The effects of environment on the residual compression strength for each material are shown in Figures 3-5 through 3-8. The data represent a comparison of the average compression strength after exposure as compared to the average baseline strength for each laminate.

## 3.2 SHORT BEAM SHEAR

The average residual short beam shear strength data for the painted specimens with three years of exposure are shown in Figure 3-9. The Kevlar-49/LRF-277 (baggage door) had the lowest short beam shear strength retention. It was

91% after three years of exposure. The other laminates have a residaual strength greater than 95% of baseline. The effects of the environments are given in Figures 3-10 through 3-13.

## 3.3 TENSION

The tension specimen did not show any significant reduction in strength from three years of exposure. Figure 3-14 shows the average residual strength for the tension coupons. The effects of the environments are given in Figures 3-15 through 3-18.

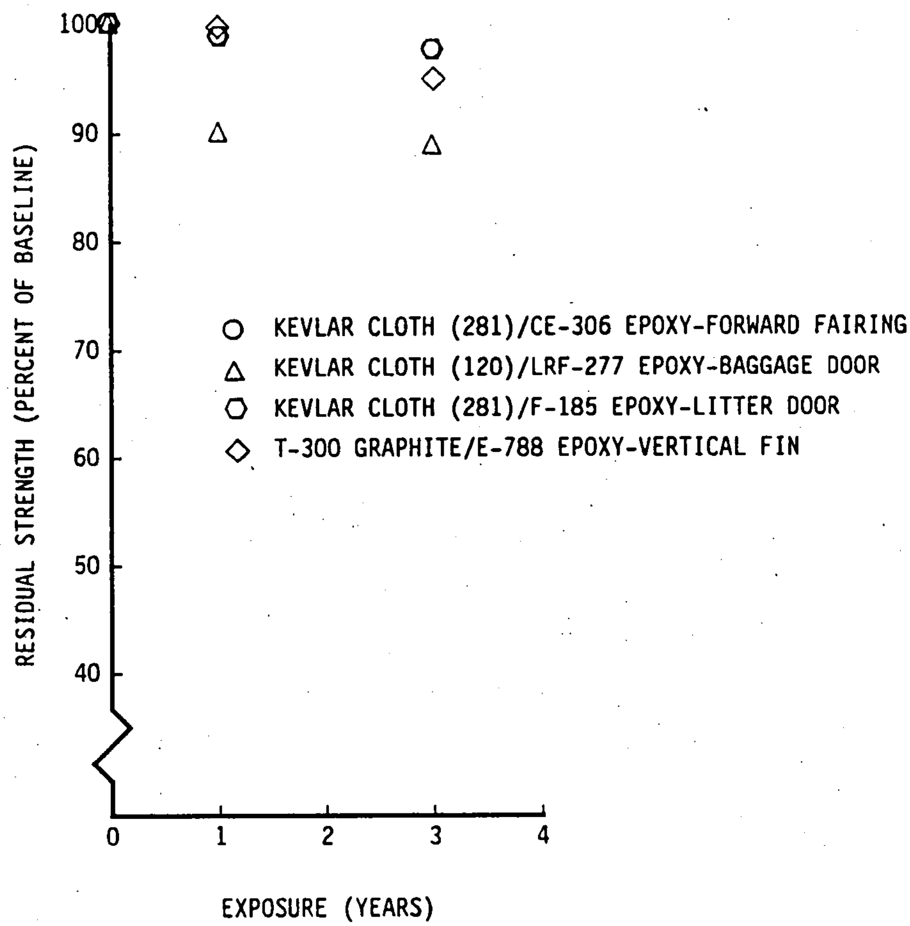



Figure 3-4. Average residual compression strength for painted specimens after three years of exposure.

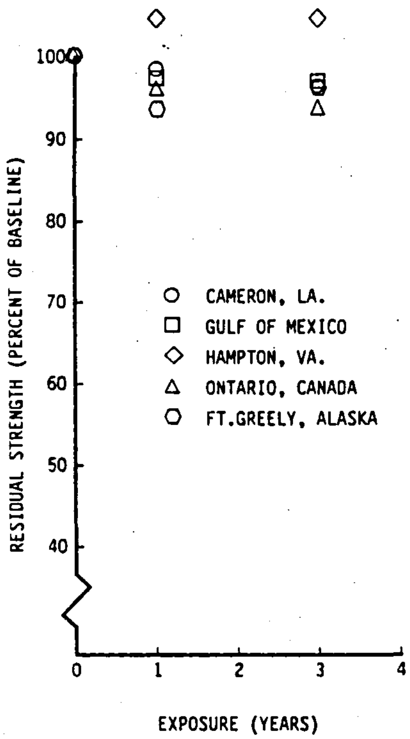



Figure 3-5. Residual compression strength for specimens made of Kevlar-49/CE-306 epoxy.

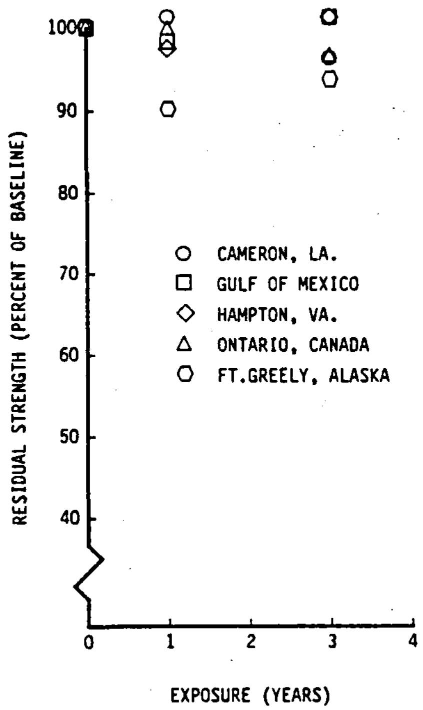



Figure 3-6. Residual compression strength for specimens made of Kevlar-49/F-185 epoxy.

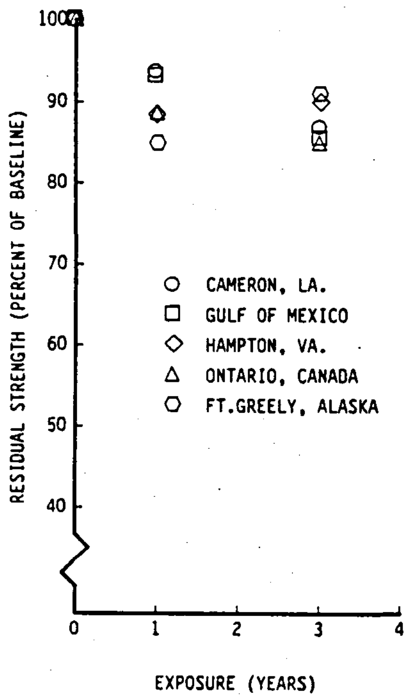



Figure 3-7. Residual compression strength for specimens made of Kevlar-49/LRF-277 epoxy.

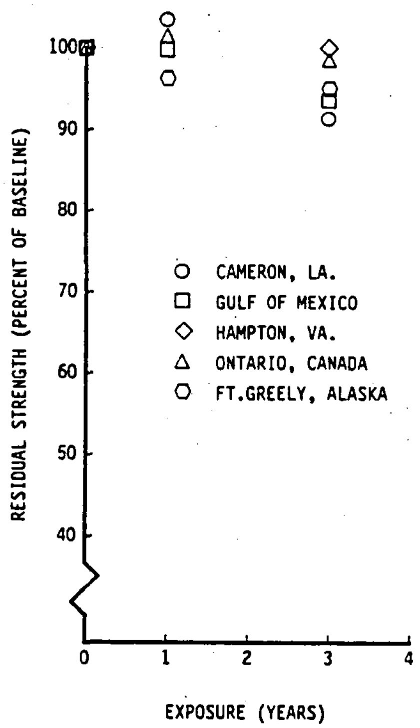



Figure 3-8. Residual compression strength for specimens made of T-300 Graphite/E-788 epoxy.

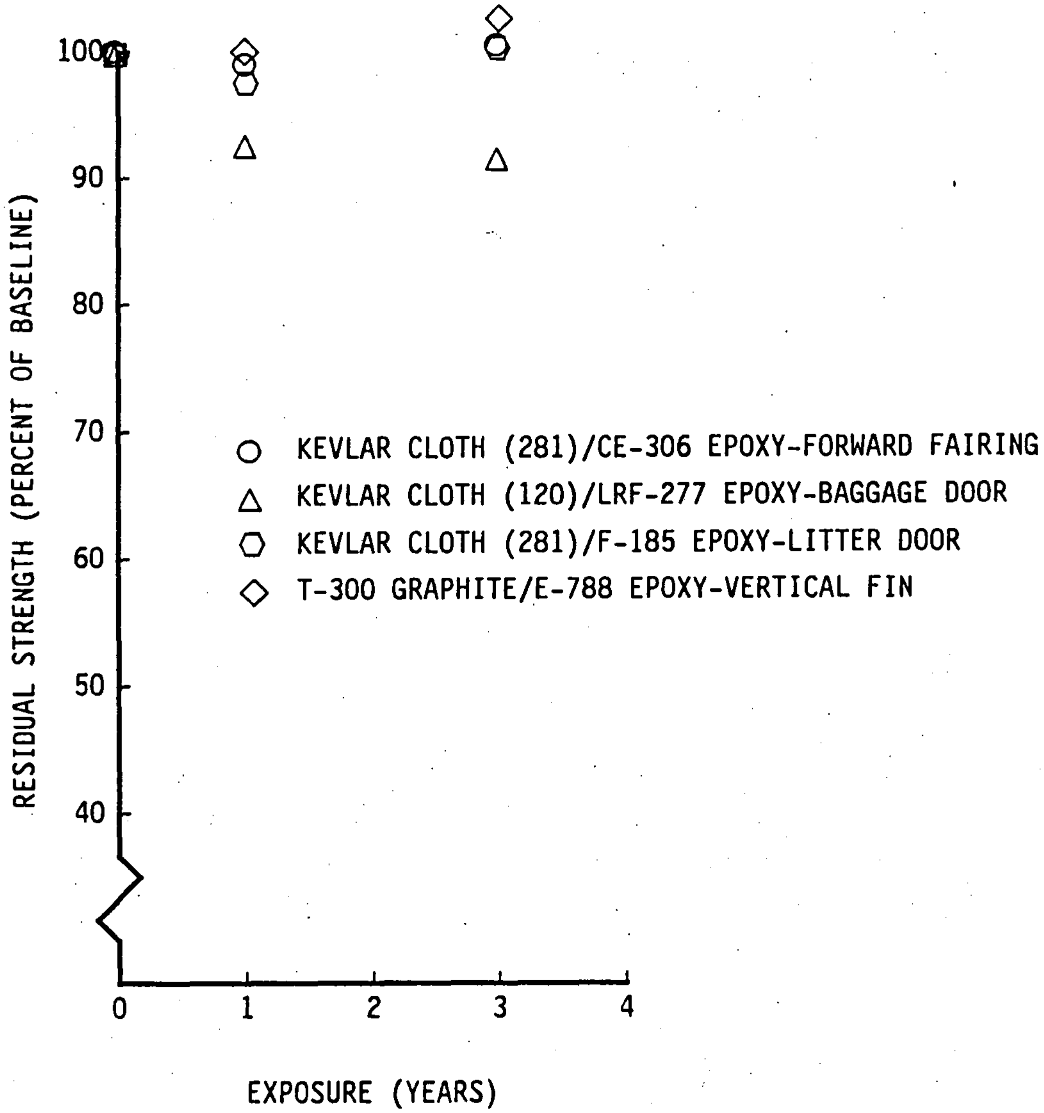



Figure 3-9. Average residual short beam shear strength data.

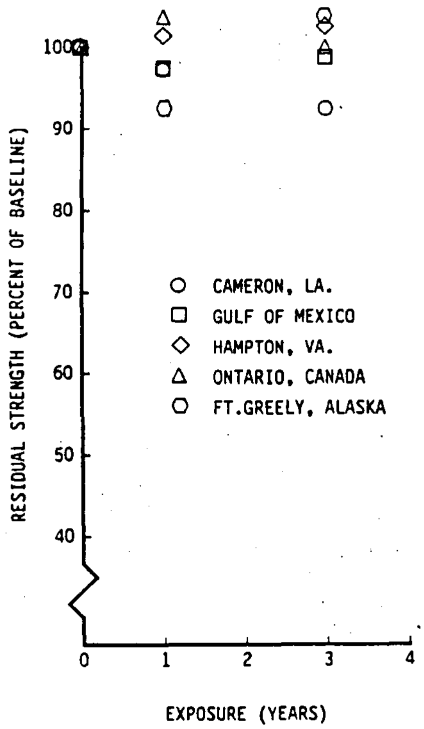



Figure 3-10. Residual short beam shear strength for specimens made of Kevlar-49/CE-306 epoxy.

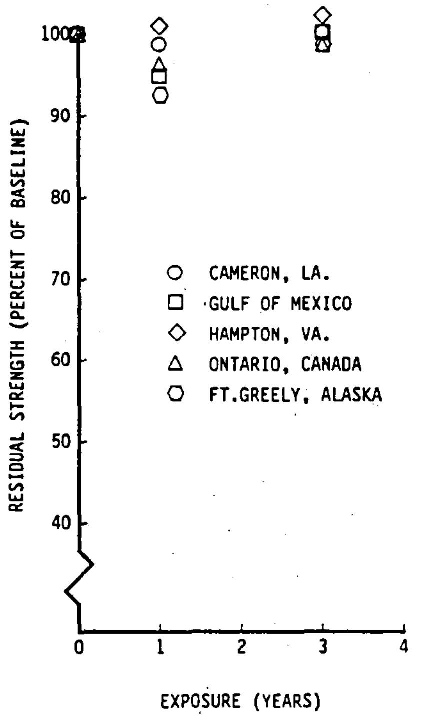



Figure 3-11. Residual short beam shear strength for specimens made of Kevlar-49/F-185 epoxy.

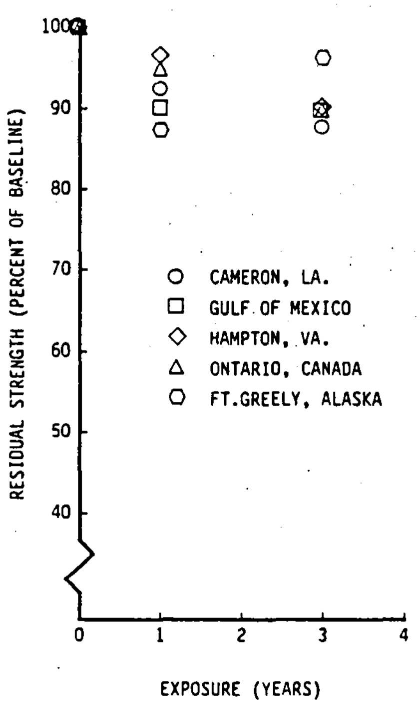



Figure 3-12. Residual short beam shear strength for specimens made of Kevlar-49/LRF-277 epoxy.

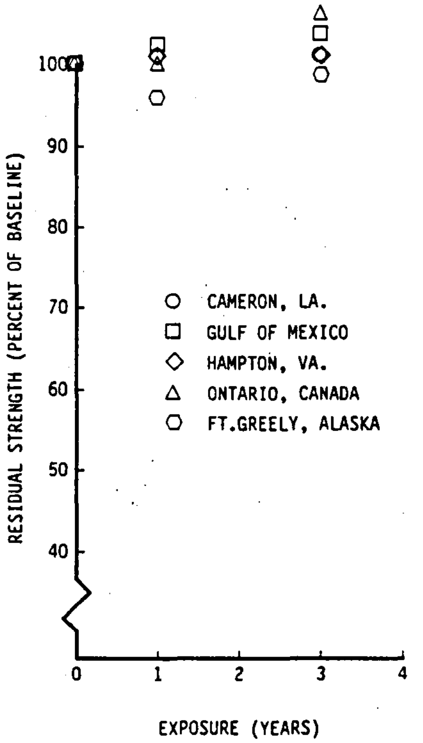



Figure 3-13. Residual short beam shear strength for specimens made of T-300 Graphite/E-788 epoxy.

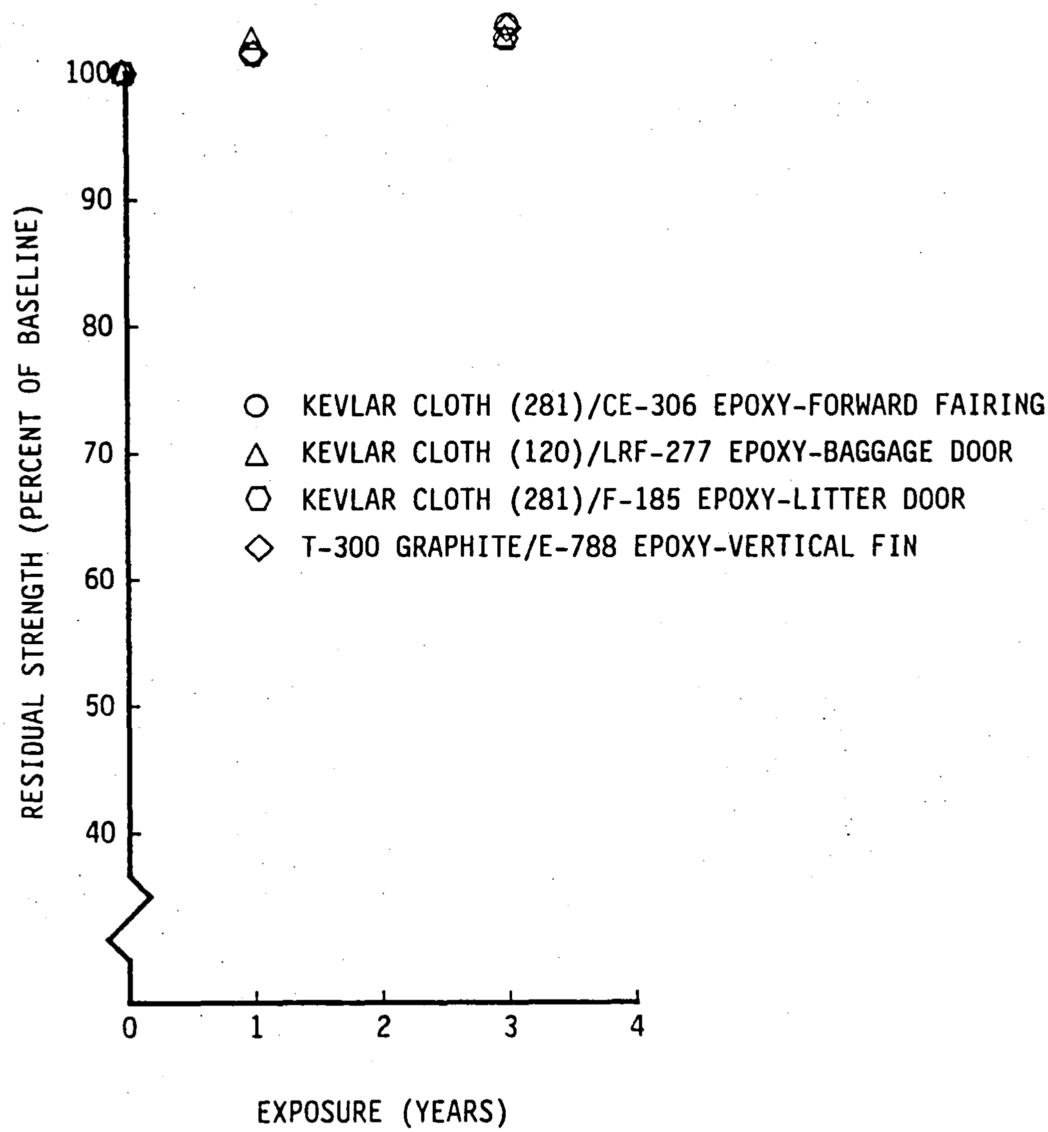



Figure 3-14. Average residual strength for tension coupons.

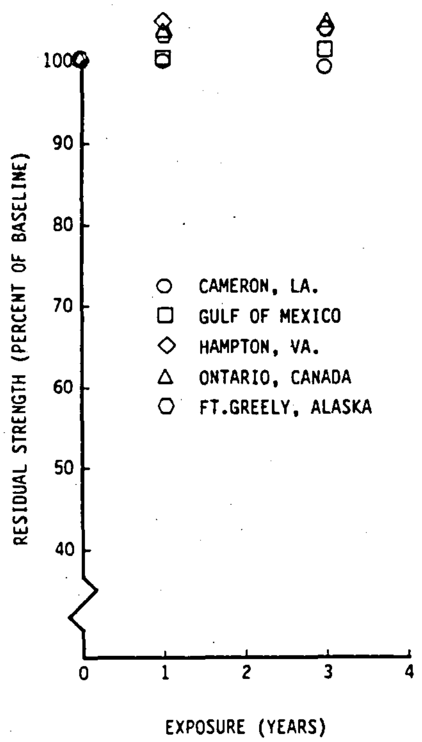



Figure 3-15. Residual tension strength for specimens made of Kevlar-49/CE-306 epoxy.

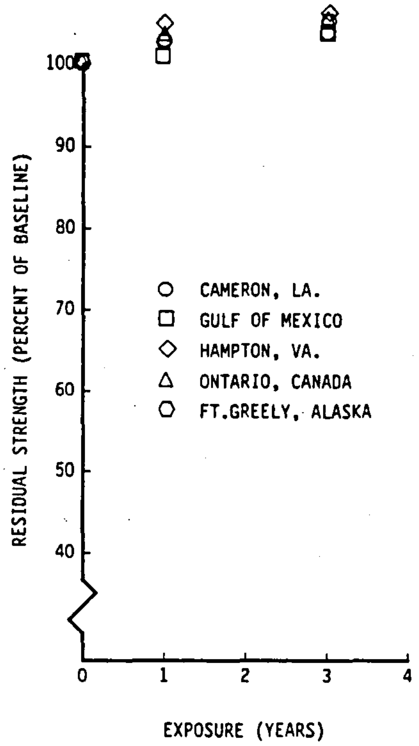



Figure 3-16. Residual tension strength for specimens made of Kevlar-49/F-185 epoxy.

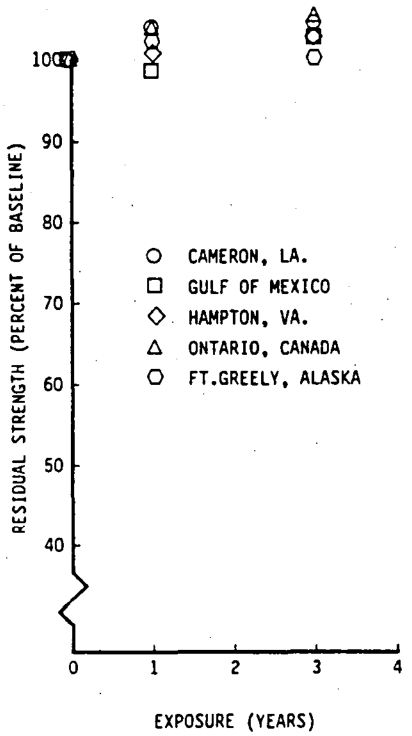



Figure 3-17. Residual tension strength for specimens made of Kevlar-49/LRF-277 epoxy.

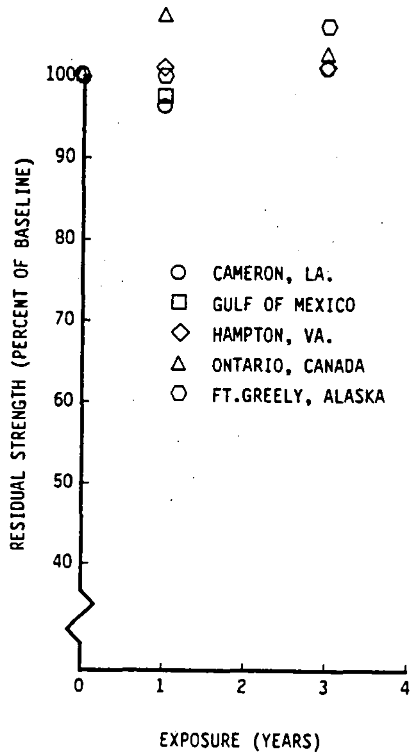



Figure 3-18. Residual tension strength for specimens made of T-300 Graphite/E-788 epoxy.

# 4. COMPONENT TESTS

Three ship sets were retrieved from service for the three year test of the components. The locations and times of the components are given in Table 4-1.

TABLE 4-1. COMPONENTS TESTED AFTER THREE YEARS OF SERVICE

| GEOGRAPHIC ZONE | SERIAL NUMBER | OPERATOR | START OF SERVICE | END OF SERVICE | TIME | FLYING HOURS |
|---|---|---|---|---|---|---|
| Gulf of Mexico | 45378 | Air Logistics | 2/82 | 11/84 | 34 mo | 3387 |
| East Canada | 45028 | Heli-Voyageur | 4/82 | 11/84 | 32 mo | 1160 |
| Alaska | 45115 | ERA | 5/82 | 10/84 | 29 mo | 668 |
| NY City (Lightning Strike) | 45450 | Island Helicopters | 9/81 | 9/84 | 36 mo | 2661 |

The components were instrumented and tested in the same fixtures used in the certification tests. Both deflection and strength data were taken. Where multiple load cases were used in the certification, only the loads associated with air pressure were used since the tests were taken to failure.

The vertical fin on the ERA helicopter had previously been returned to Bell. Therefore, only two fins were included for test at this time. A third fin was tested in conjunction with a lightning strike investigation. This gave three vertical fins for testing.

## 4.1 TEST SETUP

The tests of the components were conducted at the mechanical lab at Bell Helicopter. Each component was loaded to failure. Deflection was measured up to limit load using dial indicators. The limit design loads are given in Table 4-2. Both doors were supported at their hinge and latch points, then loaded with water bags to represent an even pressure. The forward fairing was mounted in a sealed box and a vacuum was drawn representing the aerodynamic pressure. The vertical fin was mounted at the tailboom attach points and evenly loaded with shot bags. Each component went well beyond the design limit load.

TABLE 4-2. DESIGN LOADS FOR FLIGHT SERVICE COMPONENTS

| | BAGGAGE DOOR | LITTER DOOR | FWD FAIRING | VERTICAL FIN |
|---|---|---|---|---|
| Limit | 0.33 PSI | 0.20 PSI +<br>53.0 lb Upper Hinge<br>140.0 lb Lower Hinge | 0.20 PSI | 0.50 PSI |
| Ultimate | 0.50 PSI | 0.30 PSI<br>79.5 lb Upper Hinge<br>210.0 lb Lower Hinge | 0.30 PSI | 0.75 PSI |
| Knockdown Factor | 1.39 | 1.94 | 1.62 | 1.40 |
| Required* Strength | 0.70 | 0.58 PSI<br>154.0 lb Upper Hinge<br>407.0 lb Lower Hinge | 0.49 PSI | 1.05 PSI |

*Required Strength = Ultimate x Knockdown Factor

## 4.2 DEFLECTIONS

Deflection data was taken for the test specimen using dial indicators. The deflection data was taken up to limit load.

### 4.2.1 Forward Fairing

The deflection for the forward fairing was measured in the center of the fairing, 14.5 inches forward of the back of the fairing. The load deflection data is given in Figure 4-1. The solid curve was developed at the time of certification, prior to service. The current results are given as the symbolized points.

The test was conducted by sealing the fairing in an aluminum box and drawing a vacuum. It was very hard maintaining dimensional stability of the deflection gage during the test. This is the reason for the test of the East Canada fairing being softer than the other parts. Failure occurred when a crack began at the aft latch locations then propogated forward parallel to the edge of the fairing. This failure mode was consistent in all tests.

### 4.2.2 Litter Door

Deflections were taken at two locations for the litter door. The locations are shown in Figure 4-2. Location one data tracks the original curve while location two (the larger post) shows a softening of the door. The load deflection curves are given in Figure 4-2. The litter door failure was initiated on the major door post failing as a simply supported beam. After the post breaks, the entire door folds in the middle. This failure was characteristic in all tests.

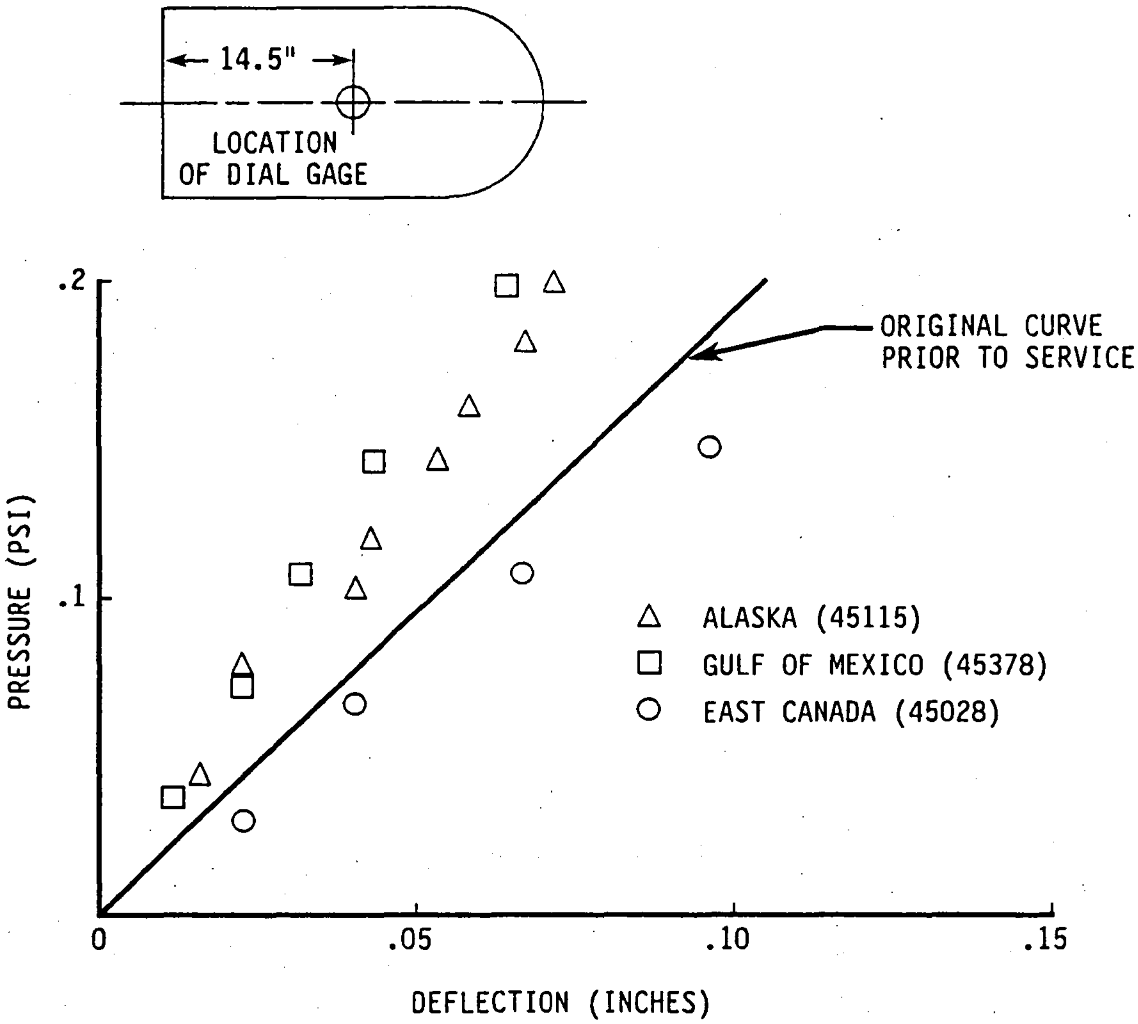



Figure 4-1. Load deflection curve of forward fairing after three years of service.

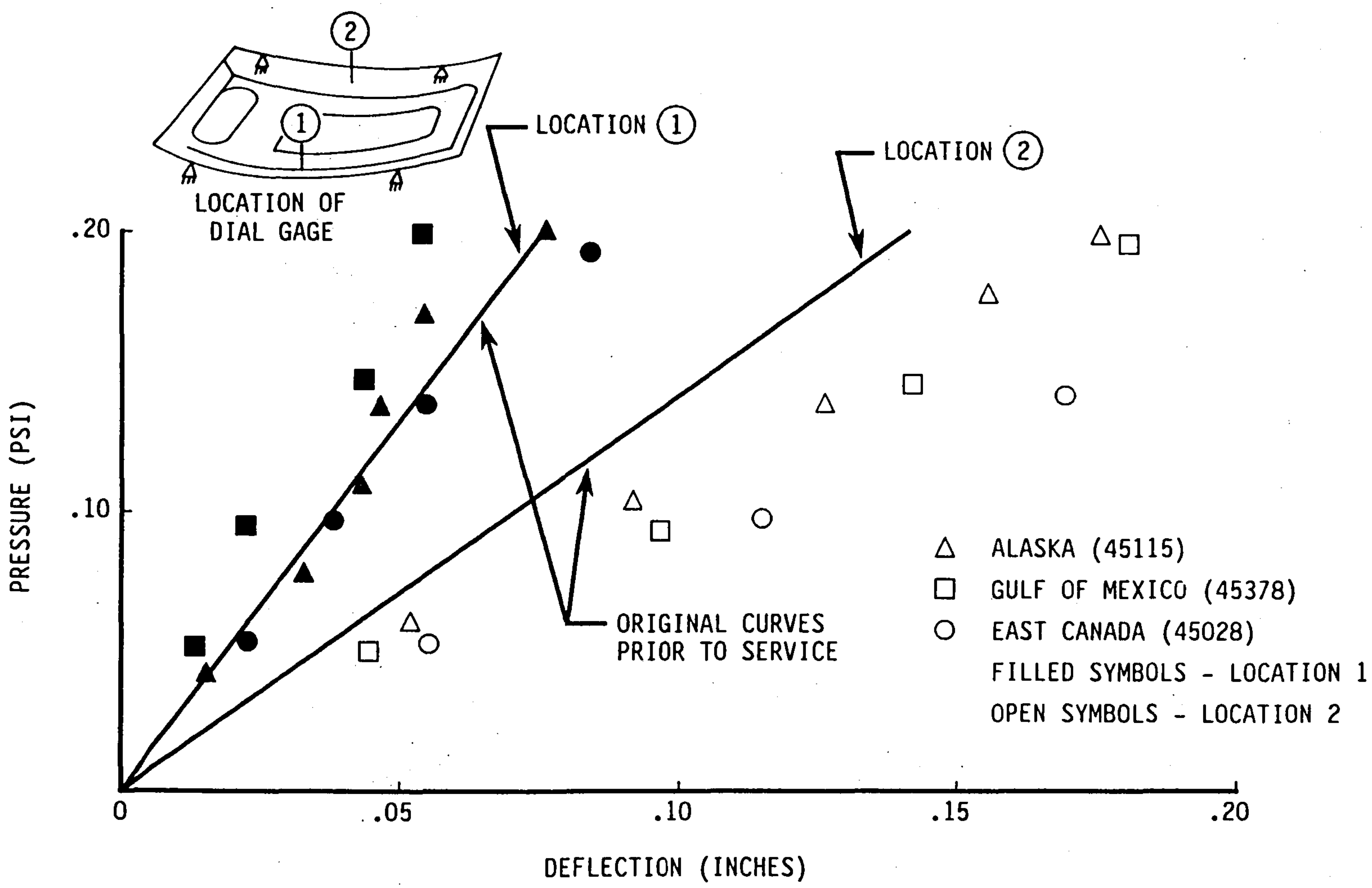


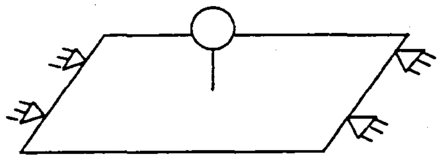

Figure 4-2. Load deflection curve of litter door after three years of service.

### 4.2.3 Baggage Door

All tests of the baggage door failed as a simply supported beam, folding in the middle, where the moment is the highest. The deflection data for the baggage door was measured in the geometric center of the door. All three geographic areas plot within a tight scatter. They show a stiffening of the door. Examination of the material of the door shows an "evaporation" of the resin thus yielding a stiffening of the door. The load deflection curve of the baggage door is given in Figure 4-3.

### 4.2.4 Vertical Fin

There was no deflection data developed at the time of certification of the vertical fin. Therefore, the data given has no basis to compare. Since there was no fin from the Alaskan ship set, the lightning strike fin was substituted in the set. The results of the lightning strike will be discussed in Section 5. The load deflection curve for the vertical fin is given in Figure 4-4. All fins failed on the upper part near the root of the fin. It was a classic cantilever beam failure, breaking at the maximum moment section.



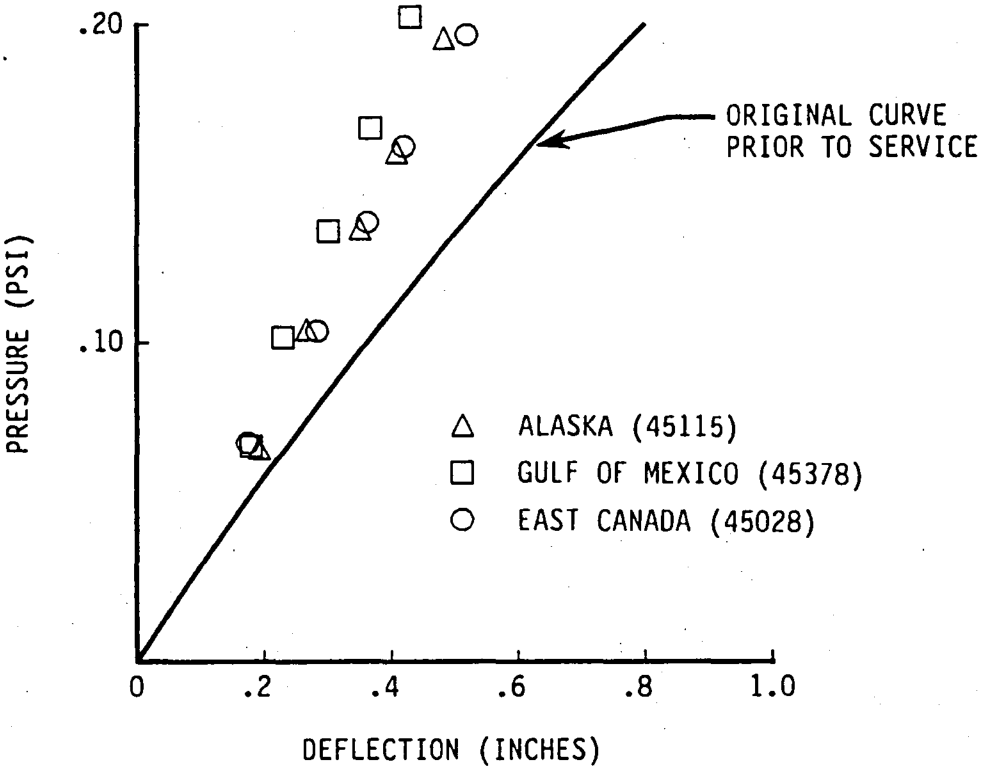




Figure 4-3. Load deflection curve of baggage door after three years of service.

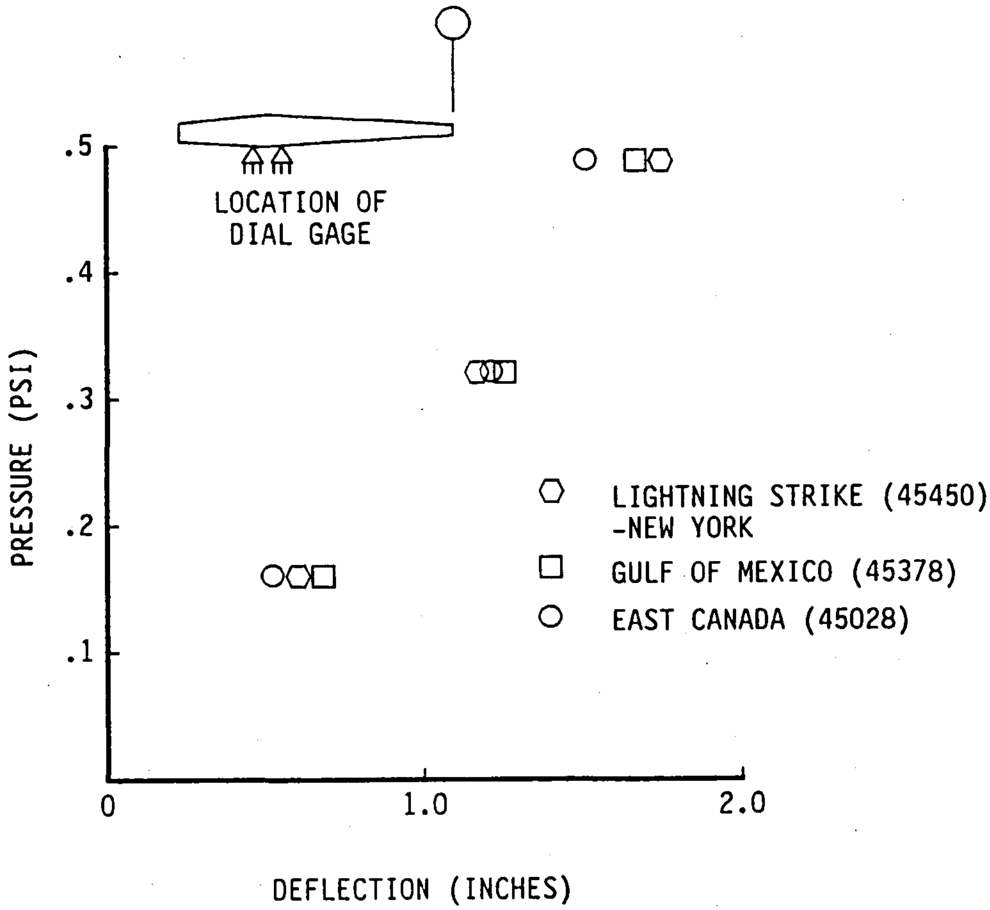



Figure 4-4. Load deflection curve of vertical fin after three years of service.

## 4.3 STRENGTH

Each specimen was tested to failure at room temperature. Each specimen had been environmentally conditioned by having three years of service testing. Table 4-3 summarizes the results of the component tests. As mentioned previously, there was no fin from Alaska, so the lightning struck fin was substituted.

TABLE 4-3. SUMMARY COMPONENT STRENGTH TEST COMPARED TO PRE SERVICE TEST RESULTS

| COMPONENT | AFTER SERVICE TESTS | | MEAN |
|---|---|---|---|
| | LOCATION | FAILING LOAD | |
| Baggage Door | Alaska<br>Gulf of Mexico<br>East Canada | 1.387 PSI<br>1.385 PSI<br>1.573 PSI | 1.448 PSI |
| Litter Door | Alaska<br>Gulf of Mexico<br>East Canada | 0.473 PSI<br>0.606 PSI<br>0.878 PSI | 0.652 PSI |
| Fwd Fairing | Alaska<br>Gulf of Mexico<br>East Canada | 2.686 PSI<br>2.339 PSI<br>2.470 PSI | 2.498 PSI |
| Vertical Fin | New York City<br>Gulf of Mexico<br>East Canada | 1.226 PSI<br>1.118 PSI<br>1.370 PSI | 1.238 PSI |

Table 4-4 summarizes the average strength of each component and compares it to the preservice testing.

TABLE 4-4. COMPARISON OF PRESERVICE TO AFTER SERVICE MEAN STRENGTHS

| COMPONENT | PRESERVICE TEST (PSI) | AFTER SERVICE TEST (PSI) | AFTER/PRE |
|---|---|---|---|
| Baggage Door | 0.700 | 1.448 | 2.07 |
| Litter Door | 0.622 | 0.652 | 1.05 |
| Fwd Fairing | 3.130 | 2.498 | 0.80 |
| Vertical Fin | 1.455 | 1.238 | 0.85 |

The Mean and Standard Deviations from the preservice tests were normalized and are presented in Table 4-5 along with the ratio of after service test to preservice test. With the exception of the baggage door, the average of all other components fell within the scatter of the preservice data. As shown in Table 4-5, the standard deviation of the component test varied from 6.6 percent of the mean for the vertical fin to 14.1 percent of the mean for the forward fairing. The scatter in the data and the small amounts of data is such that it is difficult to attribute the reduction in strength to service. The ratio of afterservice test to preservice test is less than three standard deviations from the mean.

TABLE 4-5. NORMALIZED PRESERVICE TESTING COMPARED WITH AFTER SERVICE TESTING

| COMPONENT | PRESERVICE RESULTS | | | | AFTER/PRE |
|---|---|---|---|---|---|
| | MEAN | STANDARD DEVIATION $\sigma$ | M-3$\sigma$ | M+3$\sigma$ | |
| Baggage Door | 1.0 | 0.121 | 0.637 | 1.363 | 2.07 |
| Litter Door | 1.0 | 0.072 | 0.784 | 1.216 | 1.05 |
| Fwd Fairing | 1.0 | 0.141 | 0.577 | 1.423 | 0.80 |
| Vertical Fin | 1.0 | 0.066 | 0.800 | 1.198 | 0.85 |

The increased strength of the composite baggage door follows the trend of the deflection test where its stiffness increased 60%. The resin had dried out resulting in a much more brittle laminate. It should be noted that while the strength and stiffness of the baggage door has increased, its service behavior was the worst, primarily due to the large void areas and brittleness of the laminate.

It is also interesting that the coupon test did not reflect the same results as did the component test. This causes the conclusion to be drawn that there is something associated with the design or geometry that results in the coupon data not supporting the component tests.

# 5. LIGHTNING DAMAGED FIN

On September 7, 1984 during normal 100 hour inspection of Island Helicopter's 206L Serial Number 45450, delamination was found on the upper left side of the vertical fin. The fin was removed from service that day and shipped back to Bell Helicopter for inspection.

An inspection of the fin did not show any laminate delamination, but rather a peeling of the paint and a corrosion of the wire mesh used for lightning protection. Closer examination showed evidence that an electrical charge had been transmitted through the fin and exited at the fin to tailboom attachment locations. It was determined at that time that the fin had been struck by lightning.

The operator reviewed the helicopter's log and found one occurrence where the helicopter had been moored overnight at New York City's Thirty-Fourth Street Heliport due to bad weather. This occurred several months prior to the 100 hour inspection. It was determined that the helicopter was struck by lightning while static on the ground and flew for six months after the strike. Pictures of the fin are shown in Figures 5-1, 5-2, and 5-3.

To determine the complete effect of the damage, several tests, both non-destructive and destructive, were conducted. They were: 1) test for delamination using non-destructive tests, 2) destructive stiffness and strength tests, 3) chemical tests of the corroded wire mesh and heat blistered areas of paint, 4) metallurgical tests of the fasteners, and 5) scanning electron microsope tests of the skin to compare the damage to undamaged areas. All tests were performed at Bell Helicopter.

## 5.1 NON-DESTRUCTIVE TESTS

Using an S-1A Sondiactor, delaminations in the carbon skin and rebonds were studied. No detectable delaminations in the damaged or undamaged area were found.

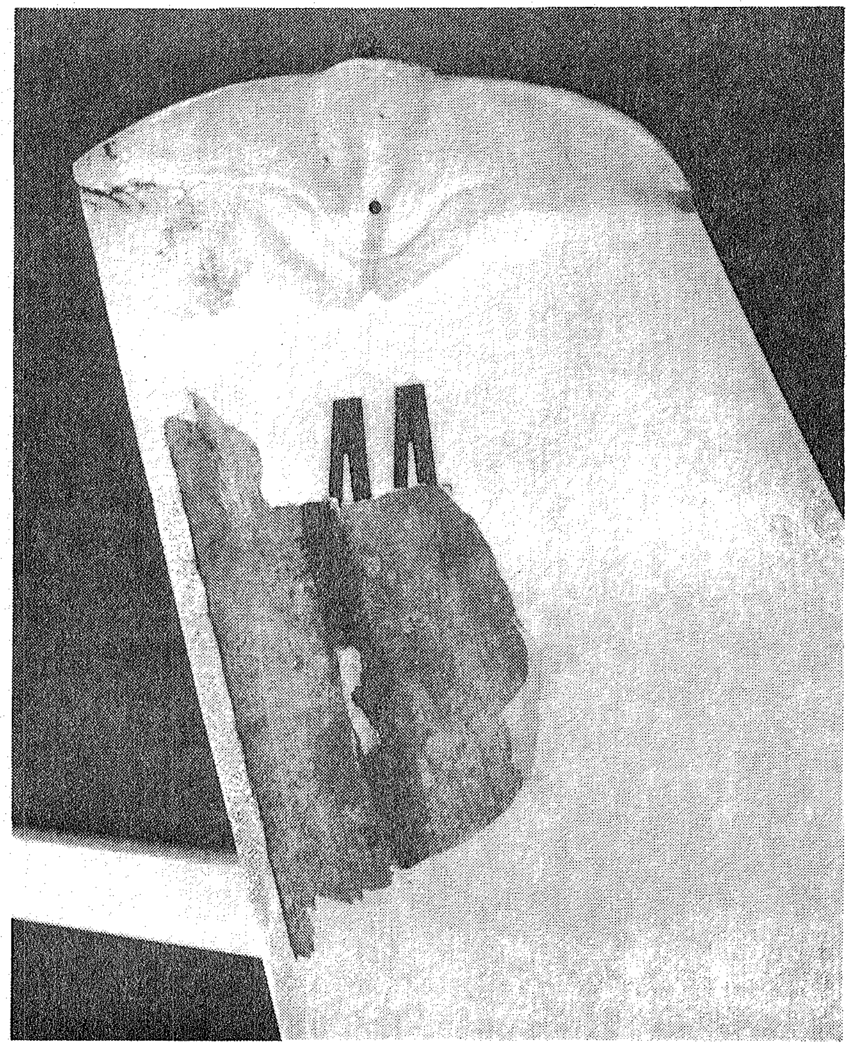


Figure 5-1. Corrosion on the wire mesh on the fin struck by lightning.

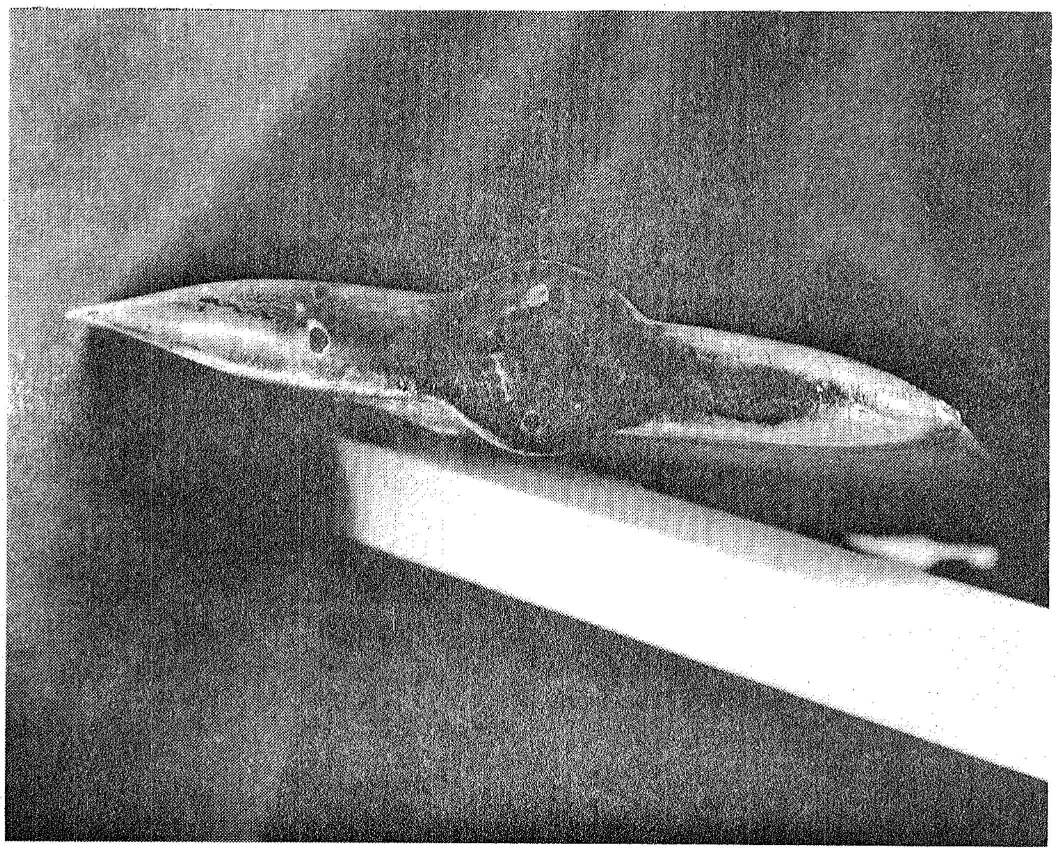


Figure 5-2. Charred top of fin struck by lightning.

PITTING

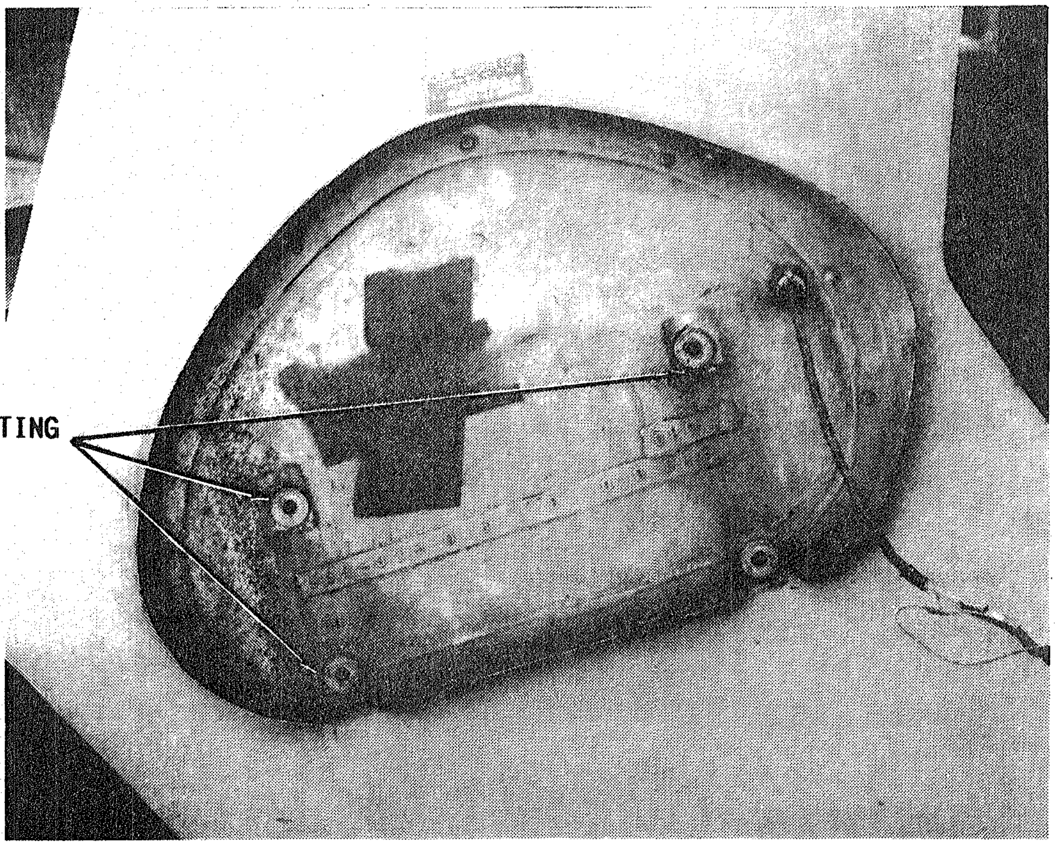


Figure 5-3. Tailboom attachment fittings of fin struck by lightning.

## 5.2 DESTRUCTIVE TESTS

As reported in Section 4, the lightning damaged fin showed no effects on its stiffness or strength. Figure 5-4 shows the deflection measurements compared with the average of the other fins.

It was shown in Section 4 that the difference in the average strength of the fin could not be attributed to its service. Therefore, all the tests of the fin were used to form a statistical sample. Excluding the lightning damaged fin, eight fins have been tested to failure. The results are given in Table 5-1.

TABLE 5-1. STRENGTH SUMMARY OF ALL TESTED FINS

| ALL FINS | MEAN $\delta$ | LOAD (PSI) |
|---|---|---|
| Tested Prior | MEAN | 1.400 |
| to Lightning | $\sigma$ | 0.139 |
| Damaged Fin | $M-3\sigma$ | 0.983 |
| Damaged Fin | | 1.226 |

The strength of the damaged fin is only 1.25 standard deviations away from the mean of the sample. Therefore, there is no strength degradation attributable to the lightning damage.

## 5.3 CHEMICAL TESTS

Tests were conducted on an area six inches down from the top of the vertical fin and three-quarters of an inch up from the trailing edge. The tests concluded the area received a high heat, based on the heavy blistering of the paint finish. The area also exhibited heavy corrosion due to the aluminum wire mesh (lightning protection) being applied directly to the graphite laminate. There was a design error. A layer of FM1000 adhesive was

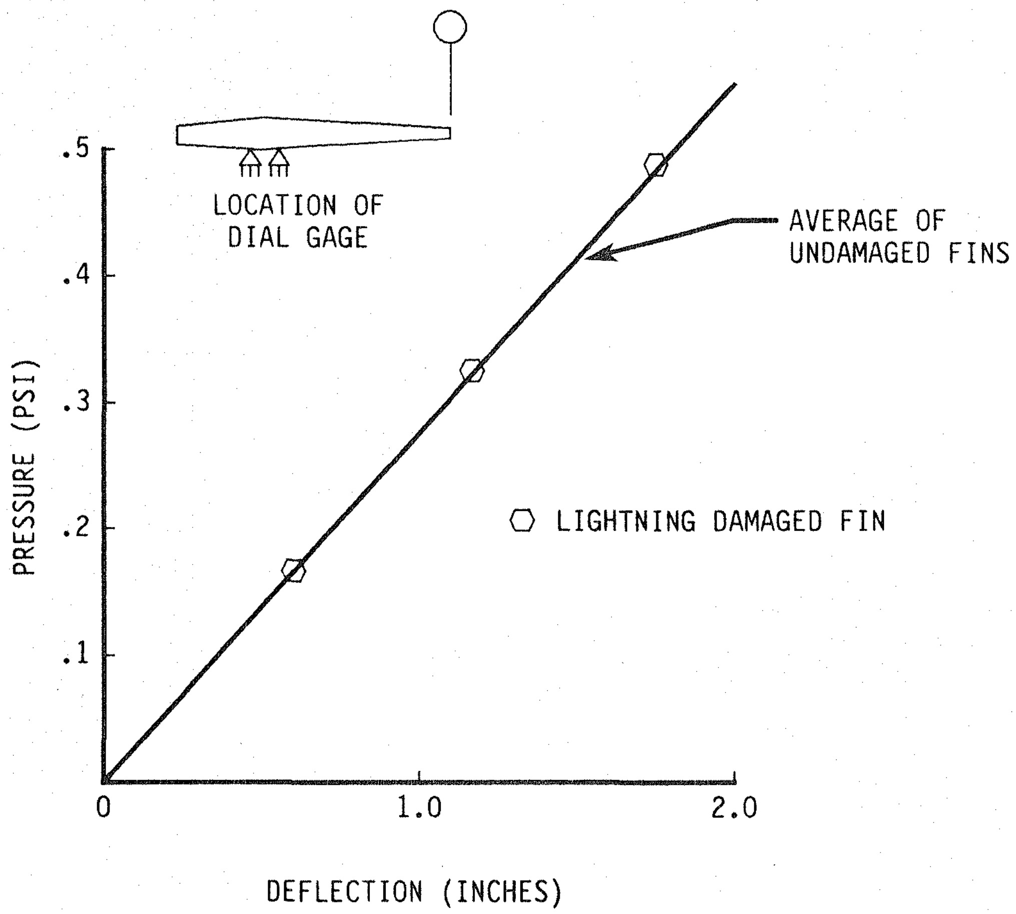



Figure 5-4. Deflection of the lightning damaged fin.

to separate the wire mesh and the graphite. Instead, the adhesive was applied on the outside of the mesh between the mesh and the paint. Had the FM1000 been correctly applied, the corrosion might not have occurred and the fin could have been easily repaired.

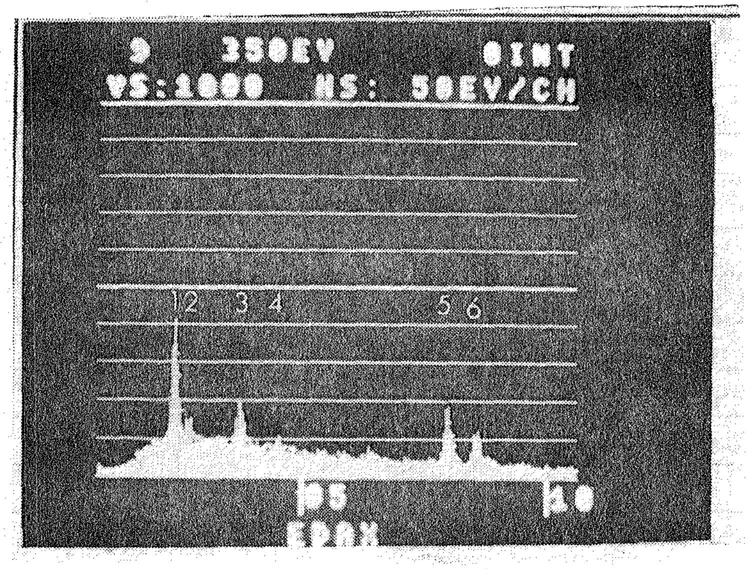
## 5.4 METALLURGICAL TEST

The fasteners were examined and the pitting was determined to be caused from electric arcing. No other effects or degradation were found with the fasteners.

## 5.5 ELECTRON MICROSCOPE

The effects of the lightning strike on the graphite was studied using an energy dispersive x-ray analyser (EdaX). Figure 5-5 shows the results of the EdaX scan on the damaged and undamaged specimen. Based on the EdaX results in Table 5-2, there is no basic difference in material.

A. Undamaged Area




B. Damaged Area

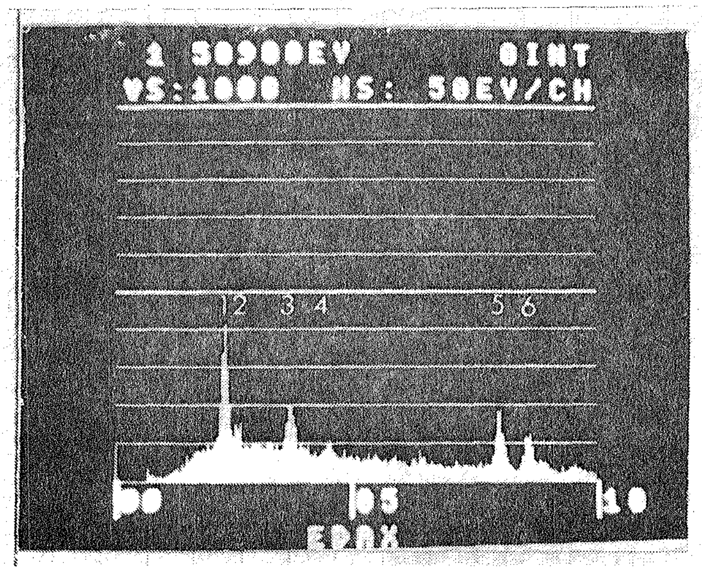



Figure 5-5. Results of EdaX scan on the damaged and undamaged specimen.

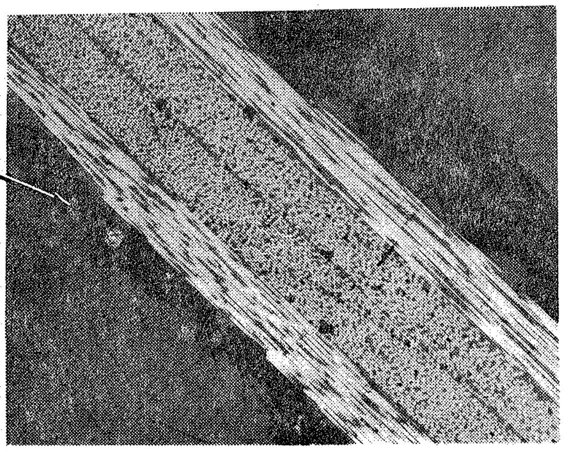
TABLE 5-2. RESULTS OF EDAX OF THE DAMAGED AND UNDAMAGED AREA

| PEAK | ENERGY KEV | IDENTIFY |
|---|---|---|
| 1 | 2.35 | Sulfer |
| 2 | 2.65 | Chlorine |
| 3 | 3.75 | Calcium |
| 4 | 4.50 | Titanium |
| 5 | 8.05 | Copper |
| 6 | 8.65 | Zinc |

Figure 5-6 shows a 100X photograph of a cross section of the damaged and undamaged laminate. The laminates were of a different orientation and number of plys. The only degradation noticable on the photographs is the wire mesh which had corroded.

CORROSION

A. Damaged Area 100x



B. Undamaged Area 100x

Figure 5-6. <u>100X magnification of a cross section of the damaged and undamaged specimen</u>.

## 6. CONCLUSIONS

1. As of 1 January 1986, a total of 73,000 hours of flight service on the four components had been flown. The high-time helicopter accumulated 5716 hours.

2. The service experience showed the forward fairing and vertical fin had very little service problems. The hinges on the litter door are still a problem and the baggage door does not stand-up well to ground conditions.

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

4. After three years service, the test of the components indicated a strength retention of 80 percent and 85 percent for the forward fairing and vertical fin, respectively. Although there is not very much data, it is within the three standard deviations of the preservice test results. Therefore, it is difficult to attribute the lower strength to service. The litter door tested slightly higher than the preservice tests and the baggage door doubled its strength.

5. The baggage door increased stiffness by 60 percent and average strength by 107 percent. But its service problems were greater than the other components. Large voids were found in the resin and the laminates became very brittle. This is due to "evaporation" of the resin from the laminate.

6. A graphite fin was struck by lightning and flew for several months after the incident. The lightning protection functioned as designed. All

tests, both destructive and non-destructive, showed only minor damage to the fin. It was determined to be repairable and could have returned to service.

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15. Supplementary Notes

Langley Technical Monitor: D. J. Baker
Technical Summary Report

16. Abstract

This is the second annual report on the flight service components for the Bell Model 206L JetRanger helicopter. The components have been placed in service in the Continental United States, Canada, and Alaska. The report covers the period from 1 August 1983 to 1 January 1986. The status of 34 sets of components is discussed in this report. Approximately 73,000 flight hours were accumulated on the components as of 1 January 1986. The results of three years exposure on the coupon tests are given with the test results of the component tests. A vertical fin had been struck by lightning and the results of its examination and tests are included.

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