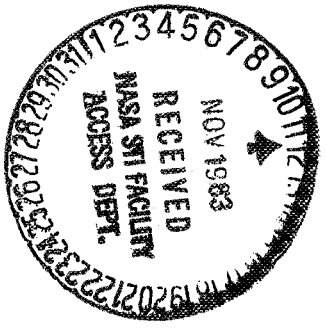
NASA Contractor Report 166065

Flight Service Evaluation of Kevlar-49 Epoxy Composite Panels in Wide-bodied Commercial Transport Aircraft

Ninth Annual Flight Service Report



R.H. Stone

LOCKHEED-CALIFORNIA COMPANY
BURBANK, CALIFORNIA

CONTRACT (NAS1-11621)
February 1983

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

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FOREWORD

This is the ninth annual flight service evaluation report on the condition of Kevlar-49 fairing panels installed on three L-1011s under NASA Contract NAS1-11621, "Flight Service Evaluation of Kevlar-49 Composite Panels in Wide-bodied Commercial Transport Aircraft." This report also includes an update of results from concurrent ground-based exposure tests on Kevlar-49 coupons being conducted by NASA-Langley. The manufacture and installation of these panels was completed in February 1973 and reported in NASA CR-112250 dated March 1973 (reference 1). The results of inspections after the first eight years of flight service were reported in references 2 through 9. The original 5-year flight service program was extended for an additional 5 years through 1983. Annual reports are being issued describing service performance after each year of service through the 10-year duration of the program.

This program is being administered by the Langley Research Center, National Aeronautics and Space Administration, with Mr. Benson Dexter of the Materials Division as the project Engineer. The program is being performed by the Lockheed-California Company with Robert H. Stone the Program Leader, assisted by personnel of the Product Support Branch.

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Ninth Annual Flight Service Report

R.H. Stone

Lockheed-California Company
Burbank, California

INTRODUCTION AND BACKGROUND

The subject program on flight service evaluation of Kevlar-49 fairings consists of fabrication, installation, and flight service evaluation of six secondary structural panels on each of three L-1011s. The three participating airlines are Eastern, TWA, and Air Canada. Fabrication and installation of the panels was completed in February 1973, with initiation of flight service occurring in early 1973 on all three aircraft.

In all of the prototype fairings Kevlar-49 fabric, comparable in fabric weave and thickness per ply to the baseline fiberglass, was substituted for the fiberglass on a ply-for-ply basis. This required no other design changes or development of new tooling for layup and cure, but still provided a savings in component mass of 25-30 percent. These six parts are as follows:

- A left-hand and right-hand set of large 152- by 170-cm (60- by 67-in.) sandwich wing-body fairing panels. The exterior skin is 0.05 cm (0.02 in.) thick with one ply of 181 style Kevlar-49 fabric and two plies of 120 style Kevlar-49 fabric. The interior skin is 0.04 cm (0.015 in.) thick with three plies of 120 style Kevlar-49 fabric. The honeycomb core is Nomex with 0.3 cm (1/8 in.) cells, and 0.05 gm/cm^3 (3.0 lb/cu ft) density. Overall panel thickness is 2.36 cm (0.93 in.), with a solid laminate edge 0.30 cm (0.12 in.) thick, built up of 181 style Kevlar-49 plies (figure 1).

- A left-hand and right-hand set of small 14- by 83-cm (5.5- by 32.5-in.) solid laminate underwing fillet panels. The laminate incorporates nine plies of 181 style Kevlar-49 fabric and is approximately 0.23 cm (0.09 in.) thick (figure 2).

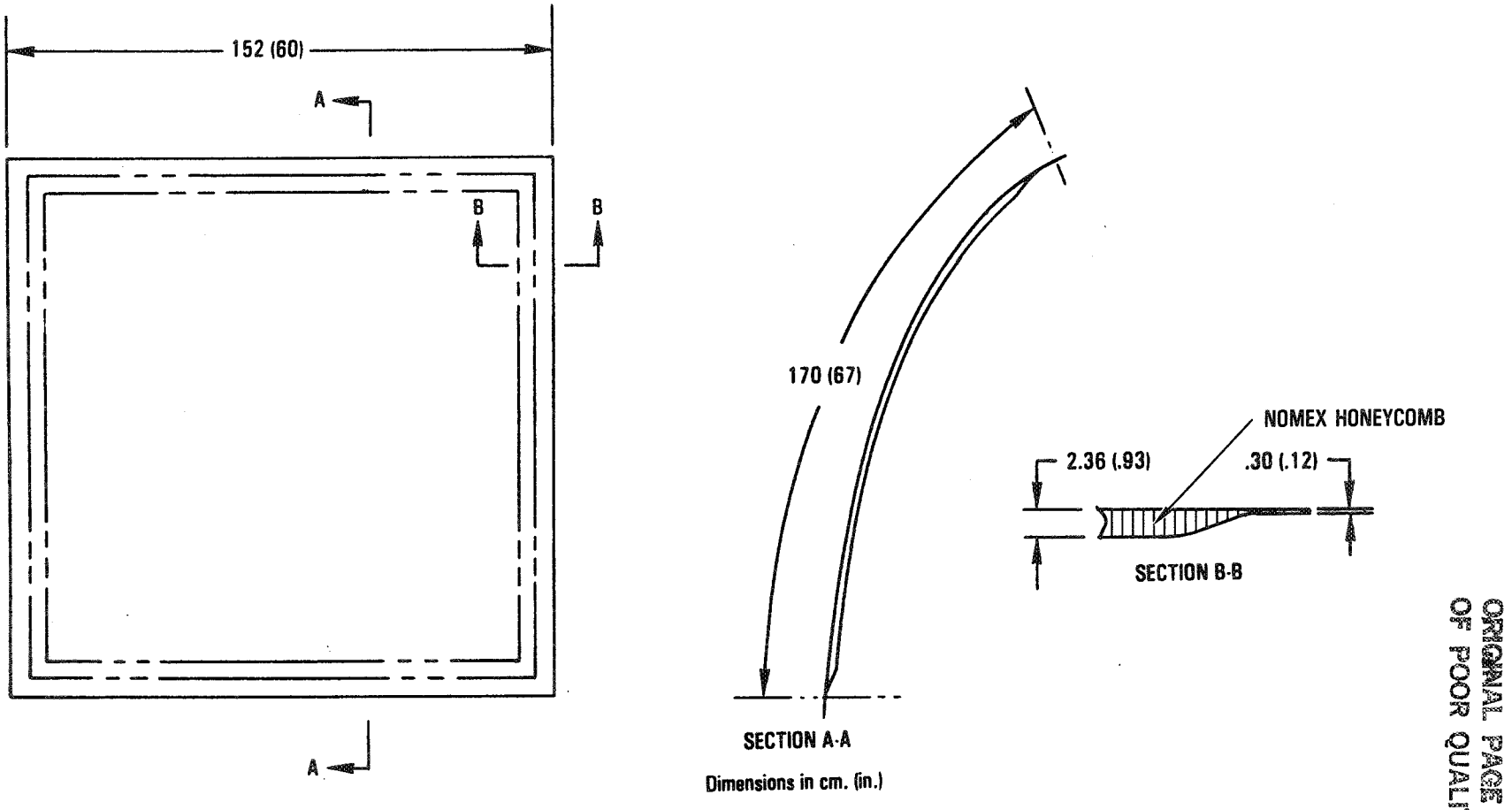

Figure 1. - Wing to body fairing panel.

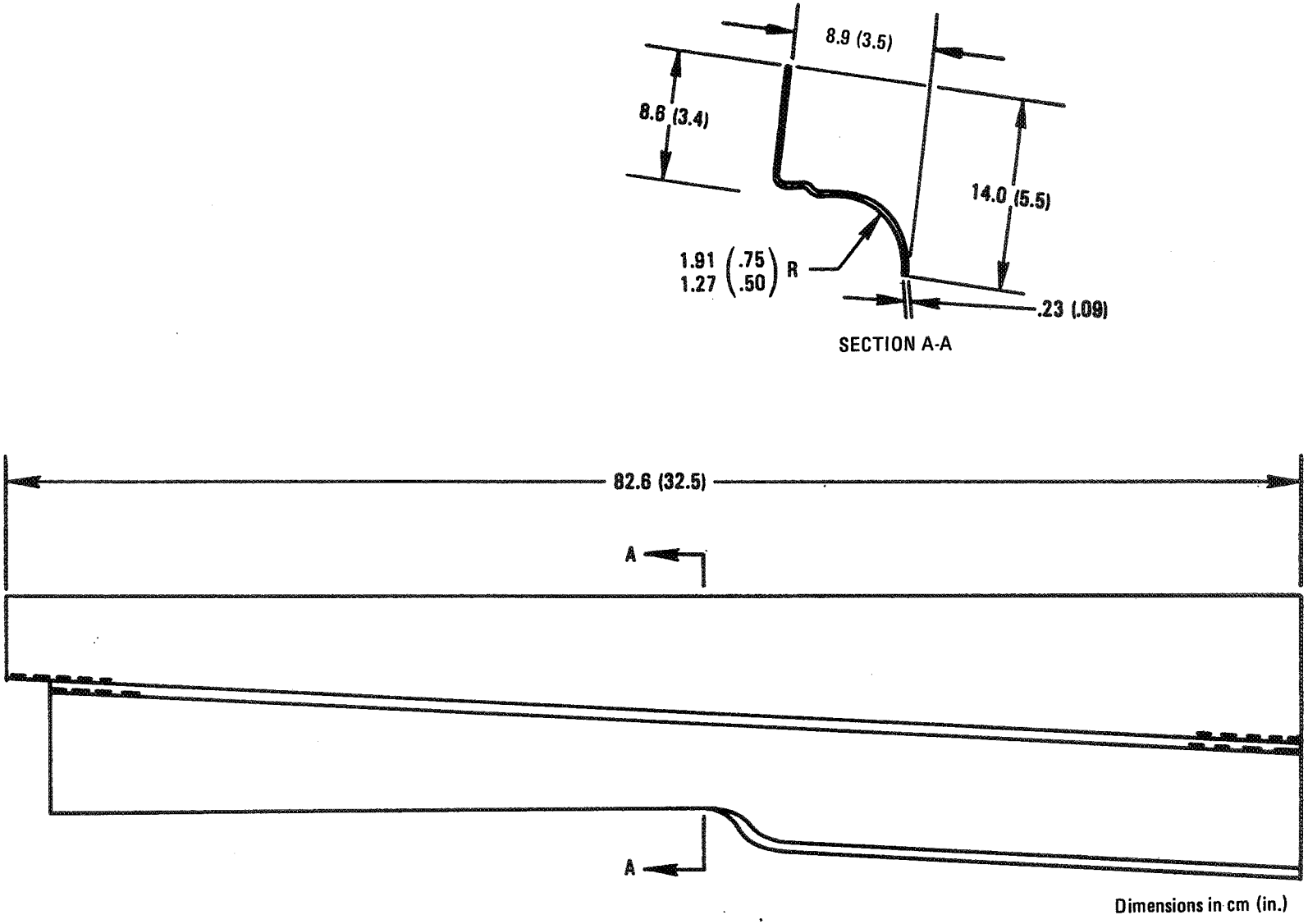

Figure 2. - Underwing fillet panel.

- A left-hand and right-hand set of aft engine sandwich fairings 76- by 208-cm (30- by 82-in.) approximately. The skins are 0.05 cm (0.02 in.) thick with one ply of 181 style Kevlar-49 fabric and two plies of 120 style Kevlar-49 fabric. The Nomex core is identical to that used in the wing-body fairing except for thickness, and the overall panel thickness is 0.64 cm (0.25 in.). The aft engine fairing has a solid laminate edge member 0.25 cm (0.10 in.) thick (figure 3).

The Kevlar-49 panels used the same resin system as the production fiberglass parts. A 121°C (250°F) curing, 82°C (180°F) service epoxy (Hexcel's F-155) was used in the wing-body fairing and underwing fillet panels; and a 177°C (350°F) curing, 149°C (300°F) service epoxy (Hexcel's F-161) was used in the aft engine fairings. Two fabric weave styles of Kevlar-49 were used. The Kevlar-49 style 181 is an 8-harness satin weave similar to the 181 fiberglass weave, 0.23 mm (9 mils) per cured ply and 0.17 kg/m^2 (5.0 oz/yd^2) dry mass. Kevlar-49 style 120 is a plain weave, 0.13 mm (5 mils) per cured ply and 0.6 kg/m^2 (1.8 oz/yd^2) dry mass. Both fabric styles incorporate light denier Kevlar-49 yarns, 380 denier for style 181, and 195 denier for style 120. The heavy denier yarns used in styles 281 and 285 Kevlar-49 fabric that are commonly used by the aircraft industry had not been developed at the time these parts were made.

All of the parts have an outer layer of flame-sprayed aluminum and topcoat applied according to standard production procedures used on the baseline fiberglass parts. The actual savings in component mass achieved by this direct substitution of Kevlar-49 for fiberglass averaged 26 percent for the six parts. Further details on Kevlar-49 part design and fabrication are given in NASA CR-112250 (reference 1), which is the final report of the fabrication and installation phases of the program.

The first annual inspection results are given in NASA CR-132647 (reference 2). The Air Canada and TWA panels were inspected at Lockheed in this case due to special circumstances, while Eastern personnel inspected the Eastern panels at their Miami Maintenance Base.

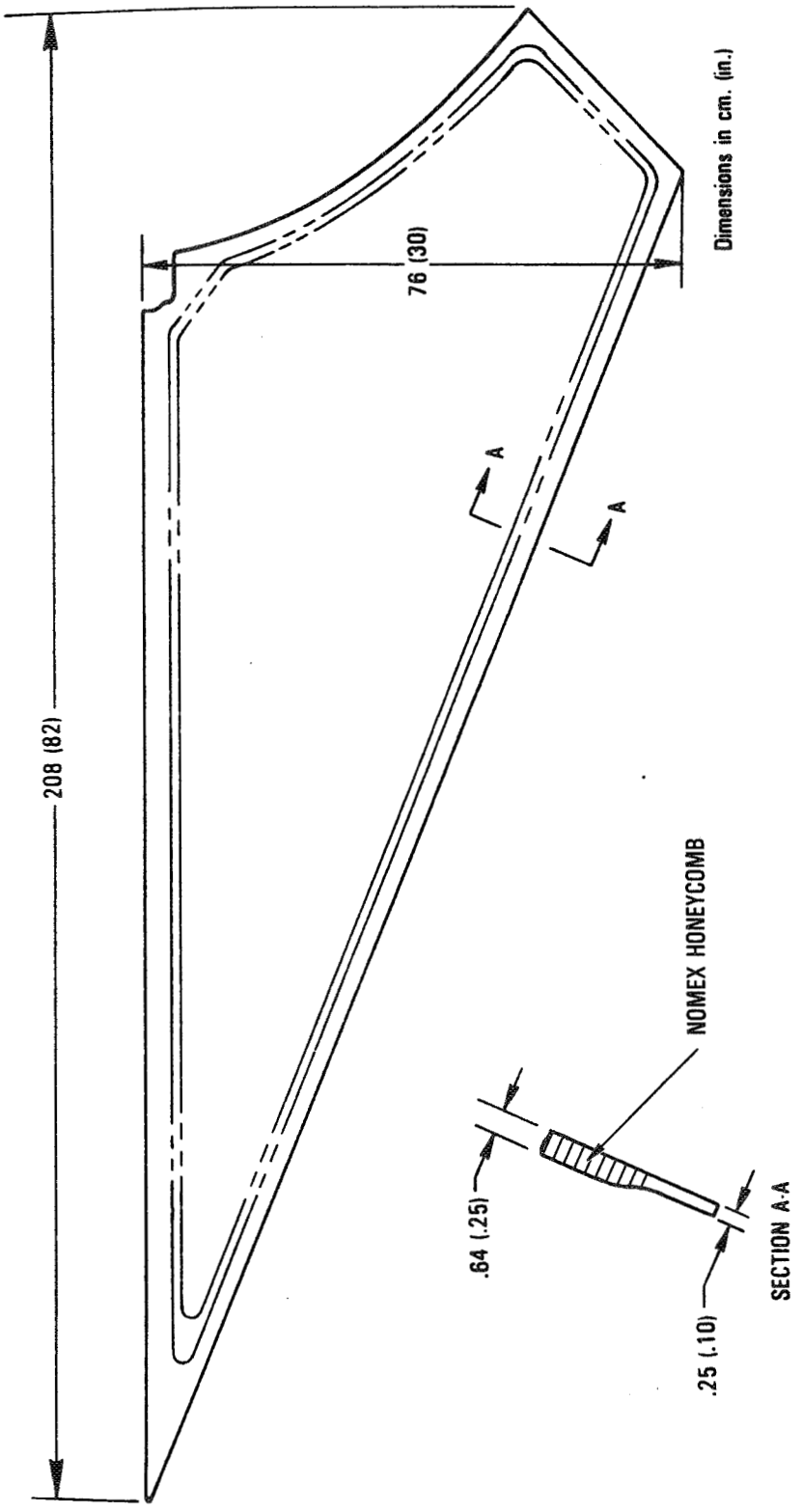

Figure 3. - Center engine fairing panel.

For the second annual inspection and all subsequent inspections, the program scope was expanded as follows to obtain more complete information and documentation of part conditions:

- A Lockheed Engineering representative is present for each annual inspection at the airlines' maintenance bases.
- Three of the six panels (one of each left-hand and right-hand set) are removed for thorough inspection, weighing, and inspection of fastener holes and interior surface conditions.
- The airlines provide reports to Lockheed on all incidences of damage and repair occurring in service.

The second through the eighth annual inspections were conducted in accordance with this expanded scope, and are reported in references 3-9, respectively.

As discussed in previous reports, the TWA panels were removed after approximately 1 year (2400 hours) of service, and reinstalled on a second TWA L-1011 for continuation of flight service testing. The reinstallation on TWA aircraft N31030 required some rework and repair of the panels, particularly in the case of the aft engine fairing panels, where relocation of all fastener holes was required. This rework activity is reported in detail in the Second Flight Service Report (reference 3). The aircraft on which these parts were installed was delivered to TWA in August 1975, and have since been inspected annually in accordance with the expanded program scope.

During 1977, a 5-year extension to the program was received from NASA for a total of 10 years of flight service of the Kevlar-49 fairings. This extension carried the program through 1983, and annual inspections of the three shipsets have taken place in accordance with the expanded program scope outlined above.

In 1978, Eastern disclosed plans to lease the aircraft with the Kevlar fairings to a foreign carrier, but stated a willingness to reinstall the

fairings onto a second Eastern aircraft. Removal of the panels took place in 1979 and was discussed in the Sixth Flight Service Report (reference 7). The panels were reinstalled onto Eastern Ship N313EA during 1980, and this activity was discussed in the Seventh Flight Service Report (reference 8).

The fairings being evaluated in this program are the earliest Kevlar-49 components placed in commercial airline flight service, predating production applications of Kevlar-49 on commercial transports by several years. These components are exposed to over 2000 flight hours per year of typical aircraft operating environments; and detailed monitoring of the fairings' performance in this program provides information on long-term durability, damage tolerance, chemical resistance, and mechanical properties. Kevlar-49 fibers are the only organic reinforcing fibers used in aircraft structures, and have certain characteristics, such as moisture pickup in the fiber and low resin/fiber bond, which were of concern initially. The resistance of Kevlar-49 composites to long-term service environment as verified by the 9 years of flight service in this program provides confidence in the use of Kevlar-49 for additional aircraft structural applications.

Concurrent with the flight service evaluation, Kevlar-49 test coupons are being subjected to long-term environmental exposures at various ground locations throughout the world, providing a variety of climatic conditions. The test coupons were fabricated using the same materials (Kevlar-49/F155 and Kevlar-49/F161) as the flight service fairings, and were fabricated at the same time and at the same facility (reference 1). The coupons are being tested after 1, 3, 5, 7, and 10 years of outdoor exposure to obtain data on moisture weight gain and residual mechanical properties. The results after 1-year and 3-year exposures are given in the Fourth Annual Flight Service Report (reference 5). Residual mechanical data after 5-year and 7-year exposures, plus moisture data after the 5-year exposure are given in the Eighth Annual Report (reference 9). This report provides the moisture weight gain data after 7-years of exposure. No additional mechanical property data are available at this time.

PANEL INSPECTIONS

The ninth annual inspection of the Air Canada fairings on Ship CF-TNB-502 (Serial No. 1021) took place on September 2, 1982 at the Montreal Maintenance Base. The left-hand wing-body fairing panel, the left-hand underwing fillet panel, and the right-hand aft engine fairing panel were removed for inspection, while the opposite set of panels were inspected on the aircraft. This was the opposite set to those removed in the previous inspection. The fairings at the date of inspection had accumulated 23,254 flight hours. In the 13 months since the previous inspection, the fairings had accumulated 2848 hours.

The inspection of the TWA fairings on Ship N31030 (Serial No. 1111) took place at TWA's Los Angeles Maintenance Base on September 20, 1982. The right-hand wing-body fairing panel, the right-hand underwing fillet panel, and the left-hand aft engine fairing panel were removed for inspection, while the opposite set of panels were inspected on the aircraft. These were the opposite parts to the wing-body and aft engine fairings removed in the previous inspection. The TWA right-hand underwing fillet is being removed at every inspection through the remainder of the program to obtain accurate mass determinations and detect any indication of continuing moisture pickup. Difficulty had been encountered in obtaining accurate mass determinations of the parts because of the lack of accurate balances at the airline maintenance bases. The proximity of TWA's base to the Lockheed plant made it feasible to bring in an accurate balance for the inspections. The sandwich panels are too large to weigh on this balance, but the underwing fillet can be readily weighed. This activity was initiated in 1978 on the right-hand part.

The TWA fairings had 21,884 flight hours on Ship 1111 as of the date of inspection. These fairings had been initially installed on Ship 1026, and accumulated 2404 flight hours on that ship prior to removal and reinstallation for a total of 24,288 flight hours. The parts had accumulated 3438 hours in the year since the previous inspection for an average utilization of 9.4 hours per day.

The inspection of the Eastern fairings on Ship N313EA (Serial 1020) took place at Eastern's Atlanta Maintenance Base on October 8, 1982. This was the second inspection after reinstallation of the fairings onto Ship N313EA in October 1980. The right-hand wing-body fairing panel and the right-hand aft engine fairing panel were removed for inspection while the opposite set of panels were inspected on the aircraft. This was the opposite set to those removed in the 1981 inspection. The two underwing fillet panels were misplaced by Eastern after removal from the original aircraft in 1979 and have not been found. These panels will be reinstalled if found, but are probably lost for the remainder of the program.

The fairings had accumulated 2523 flight hours on Ship N313EA in the year since their previous inspection, for a total of 5536 flight hours since their installation onto Ship N313EA in October 1980. The fairings had previously accumulated 17,718 flight hours on Ship N314EA for a total of 23,254 flight hours.

Inspection of these panels was by visual examination and coin tapping for delaminations and skin-core disbonds. The panels taken off the aircraft were cleaned to remove excessive dirt and residue. The panels were then inspected for the condition of the fastener holes and the inner surface, as well as the outer surface condition which was checked on all six parts.

The inspections were conducted with the participation of Lockheed Engineering, and with the assistance of airline maintenance personnel in removal and reinstallation of the panels. Photographs were taken of all panels and areas containing defects, damage, or other conditions of special interest. Photographs were provided by Air Canada in Montreal, by the Lockheed Photography Department at TWA in Los Angeles, and by a commercial photographer in Atlanta. Detail observations at the inspections are given in Appendices A, B and C.

DISCUSSION OF INSPECTION RESULTS

The Kevlar-49 panels continue to perform satisfactorily in service with no major damage or defects requiring corrective maintenance. Minor impact damage has occurred, with complete penetration of the skins in several instances. A few minor disbonds have also been noted, along with some incidences of fastener hole elongation. A general condition of fraying around fastener holes, resulting from the initial machining operation, has also been noted. The airlines do not regard these as serious occurrences as the fairings are lightly loaded nonstructural components which only take aerodynamic loads. Damage is therefore left unrepaired for an indefinite period or else given a cosmetic repair.

The incidences of new damage and damage growth noted in the 1982 inspections were:

1. Two new disbonds were noted on the inner surface of the Air Canada left-hand wing-body fairing, both relatively small and minor.

2. A deep gouge on the exterior surface of the TWA right-hand fairing, first noted in 1981, had a slight delaminated area around it which was not previously noted.

3. Two new disbonds were noted on the inner surface of the TWA right-hand wing-body fairing, both relatively small and minor.

4. A new crack was observed on the inner surface of the Eastern right-hand wing-body fairing with a slight associated delamination.

5. Three small, new disbond areas were observed on the exterior surface of the Eastern left-hand wing-body fairing.

The deep gouge and the crack (Items 2 and 4 above), as well as the cracks noted in previous inspections, are definitely the result of impact damage. The disbonds noted in this and previous inspections may have been caused by low-level impacts which did not produce a visible external crack. These cracks and disbonds have nearly all occurred on the wing-body fairings which are in an area more subject to ground-handling damage than the other parts. This is evidence that the disbonds are the result of low-level impact, but other possible

explanations are manufacturing defects and localized excessive heat application. These disbonds may be interply delaminations rather than skin-core disbonds or may be a combination of both; but this distinction cannot be made with coin tapping and visual inspection.

The incidence of damage on these prototype parts is probably greater than for standard production parts because of the increased handling during removal and reinstallation for the annual inspections. The inner skin damage on the wing-body fairings may have occurred during removal and reinstallation, but there is an access bay above these parts containing hydraulic lines, and the inner skin damage could have occurred during maintenance activity in this area.

Damage growth was noted in only one instance in the 1982 inspections, and this was a very minor occurrence. This lack of damage growth is a significant indication of acceptable damage tolerance for Kevlar-49 in these applications. In some cases the damage has remained unchanged in appearance or size for seven years.

While some of the minor damage observed to date has not been repaired, several repairs have been made to the Kevlar-49 parts, mostly on the exterior surfaces of the wing-body fairing sandwich panels. In previous inspections, repairs have been noted in which cracks were filled with a resin filler and in one case coated with conductive paint. Other patches consist of overlays of adhesive tape; in one case the patch has been identified as aluminum speed tape with an overcoat of paint. At least one repair of each type has been noted on the inner surface of the wing-body fairing panels. The only new repair noted in the 1982 inspections was a delaminated area on the exterior surface of the TWA right-hand wing-body fairing which had been filled with resin. This area is now detectable only as a slight surface depression.

In summary, the repair procedures used on the fairings have been cosmetic field repairs typical of the procedures used for noncritical fiberglass parts, and adaptable to either line station or maintenance base operations.

The other damage condition which has been typically observed on the Kevlar-49 panels has been fraying and elongation of fastener holes. These have been minor conditions in all instances, which have not required maintenance action or repair. Elongation of the fastener holes has occurred in a random distribution, and has been noted on the underwing fillet panels to a proportionally greater extent than the other parts. The condition is comparable to hole elongation on similar fiberglass panels which is a fairly common occurrence according to airline reports. The cause of elongation is concentrated or nonuniform bearing loads possibly resulting from installation problems or excessive hole clearances. There has been relatively little increase in the incidence or severity of this elongation, and in the 1982 inspections there was no significant increase in elongation over the previous inspections.

The fastener hole fraying appears to be a general occurrence on Kevlar-49 holes and edges where less than optimum machining procedures have been used. The fraying noted on these parts appears to be primarily the result of the initial machining operation, as this condition has remained essentially unchanged with increasing service life. These parts were fabricated in 1972 when development of Kevlar-49 machining techniques was in a very early stage, and the degree of fraying may therefore be more severe than for currently fabricated parts. In previous inspections, it has been observed that some of the aft engine fairings and underwing fillets have noticeably less fraying than others. This indicates that variations in machining techniques and operator skills at the time of installation was a significant factor in the degree of fraying. It has also been noted that the elongated holes in the underwing fillets generally have more fraying than the other holes, indicating that in-service loads can aggravate the initial fraying. There is no evidence that the frayed condition in any way affects part performance.

The fastener holes on the right-hand Eastern fairings were observed for the first time since their reinstallation which involved relocation of all fastener holes. The original fastener holes were filled, and new holes were drilled. These new fastener holes were observed to have a great amount of fuzz which creates the frayed appearance noted in other inspections. This

condition was much more pronounced than in any of the other Kevlar-49 parts (including the original fastener holes on the Eastern panels). As mentioned in the preceding paragraph, the frayed appearance is the result of the initial drilling operation. This condition therefore indicates that nonoptimum procedures and tools were used in the drilling of the relocated holes. Some holes were drilled partially through the chopped glass filled epoxy filler. These areas had no fuzz, but did have a greater incidence of elongation than has been noted for holes drilled through the Kevlar-49. No elongation was observed in any of the relocated holes drilled through the Kevlar-49. The frayed condition does not appear therefore to significantly affect performance of these parts. The fuzz was observed to be almost entirely on the inner surface.

The Kevlar-49 parts have not been affected to any discernible degree by exposure to Skydrol or other aircraft fluids, but the presence of Skydrol has been observed on all three components. The Skydrol appears to have attacked a vapor barrier coating on some of the aft engine fairings. Paint adhesion to the Kevlar-49 surfaces appears to be comparable to fiberglass parts, as would be expected.

The Kevlar-49 parts have been weighed on the occasions when they have been removed. The effects of paint loss, repainting, resealing, and repair have masked any mass change due to moisture pickup; and determination of mass changes has been hampered by the lack of suitable balances at the airline maintenance bases. A balance has been brought from Lockheed to the TWA base in Los Angeles for weighing of the small underwing fillet panel in the last four inspections. Accurate mass determinations have been obtained on the right-hand fillet (Appendix B), and the mass of this part will be monitored throughout the remainder of the program. Results to date show no significant weight change over two years; and the part apparently had reached moisture equilibrium by the time the weighings started in 1978, as would be expected.

while the disbonds may be the result of impact, heat or manufacturing defects. The fastener hole fraying appears to be primarily the result of the initial drilling and installation procedures, aggravated in a few instances by in-service loads; while the elongation is probably related to nonuniform bearing loads caused by installation mismatches or excessive hole clearances. The absence of crack growth, disbond growth or significantly increased hole elongation, and the random limited occurrence of the hole elongation indicates that Kevlar-49 is resistant to damage propagation under the relatively light loading conditions typical of fairings. The fastener hole fuzzing and frayed appearance is the only damage condition observed on the Kevlar-49 parts which is not also typical of similar fiberglass parts. The fuzzing has not increased in severity with increasing service life, and does not have any apparent effect on part performance.

The Kevlar-49 parts have been free of any defects which can be attributed to moisture or other environmental factors, and there has been no clear evidence of interply delaminations (as opposed to disbonds). These findings indicate that two properties of Kevlar-49 which have been of concern - the poor resin-fiber interface bond and the moisture pickup of the Kevlar-49 fibers - have not seriously affected part performance.

The repairs which have been performed on these parts are typical cosmetic repairs, such as resin filling of surface cracks and applications of tape over damage areas. This type of repair is typically performed on fiberglass secondary structures, and these observations indicate that Kevlar-49 parts can be repaired in the same manner as fiberglass parts.

In summary, Kevlar-49/epoxy appears to provide service life and structural performance for lightly loaded secondary structures equivalent to that of fiberglass/epoxy.

APPENDIX A

DETAIL OBSERVATIONS OF

KEVLAR-49 FAIRING PANELS -

AIR CANADA SHIP CF-TNB-502 (SERIAL 1021)

SEPTEMBER 1982

Three of the six fairing panels were removed for inspection: the left-hand wing-body fairing and underwing fillet panels, and the right-hand aft engine fairing. The other panels were inspected in place on the aircraft.

LEFT-HAND WING-BODY FAIRING

1. A deep gouge in the upper center area of the panel exterior, 0.4 by 0.6 cm (5/32 by 1/4 in.), had not changed in size or appearance since the previous inspection (figure A-1). This was first observed in 1978.

2. Several gouges, noted on the lower forward edge in previous inspections when the part was removed had not increased significantly in size. A few additional gouges were noted.

3. A repair of a 3.2 cm (1-1/4 in.) crack made between the 1977 and 1978 inspections was unchanged in appearance since the previous inspection, and was still obscured by overpainting

4. Two cracks on the inner surface had not changed in size or appearance since the previous inspection of the inner skin in 1980. One was a 0.8 cm (5/16 in.) crack in the upper forward area first observed in 1978; and the other was a 1.3 cm (1/2 in.) crack first observed in 1980 (figure A-2).

5. Two disbond or delamination areas were observed on the inner skin, neither of which had been previously observed. One was in the upper forward area, 1.3 by 0.4 cm (1/2 by 5/32 in.) in area, and had a visible white marking in the center indicative of a resin fracture zone. The other disbond was in the lower aft area and was 2.2 by 0.5 cm (7/8 by 3/16 in.) in area.

6. Slight fraying was observed on all fastener holes, with a greater degree of fraying noted on the aft and lower edges. Slight elongation

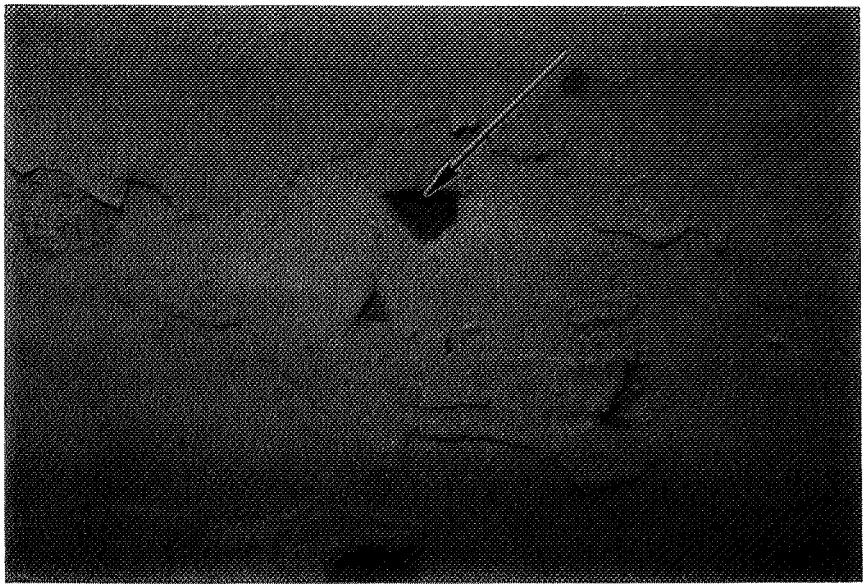

Figure A-1. - Air Canada left-hand wing-body fairing - deep gouge on exterior.

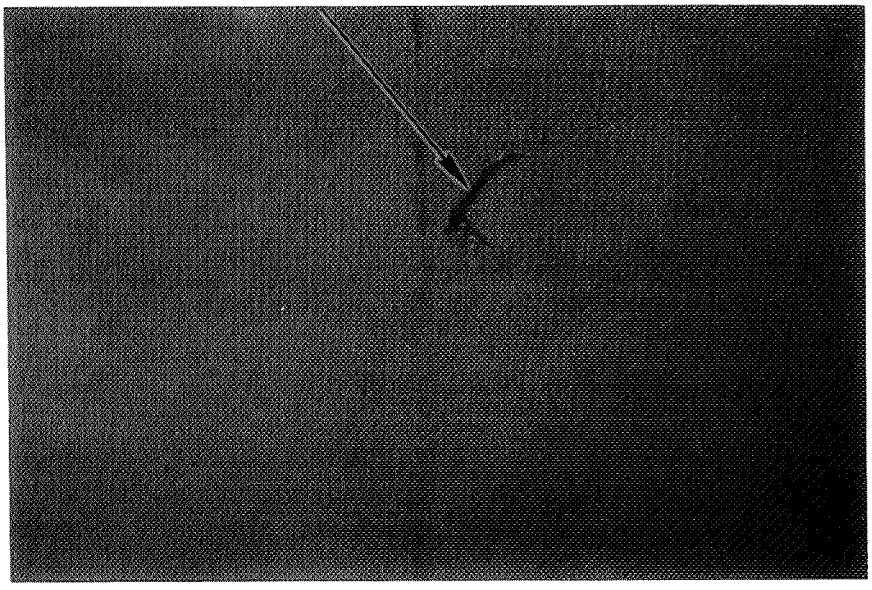

Figure A-2. - Air Canada left-hand wing-body fairing - 1.3 cm (1/2 in.) crack on inner skin.

was noted on several holes on the upper, aft, and lower edges. These included five holes elongated to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.) dimension, and four holes elongated to 0.6 cm (1/4 in.). The holes on the lower edge had the greatest degree of fraying along with a distinct fastener mark-off (figure A-3). These conditions have not changed significantly since the previous inspections.

LEFT-HAND UNDERWING FILLET

1. No surface damage or defects were noted, although there was extensive paint loss, particularly in the upper section where the Kevlar-49 was almost completely exposed. The location of this part protects it from ultraviolet exposure however.

2. Slight fraying was observed on the fastener holes, and several holes were observed to be frayed to a greater extent than the others (figure A-4). Most of the fastener holes had at least a slight degree of elongation. Five of these holes had a significant degree of elongation to 0.55 cm (7/32 in.), and three were elongated to 0.6 cm (1/4 in.) from the original 0.5 cm (3/16 in.) dimension. These conditions were basically unchanged since the previous inspection in 1980.

RIGHT-HAND AFT ENGINE FAIRING

1. No damage or defects were noted on either surface, but there was extensive paint loss indicating possible Skydrol exposure.

2. Two patch areas at the extreme forward and aft edges of the fairing were still unchanged in appearance since 1974 when they were originally observed. The patches are dark and fibrous, and may be some type of electrical tape overcoated with resin.

3. Slight fraying was observed on all fastener holes, but the degree of fraying on this component is less than other Kevlar-49 aft engine fairings. About one-third of the fastener holes are noticeably more frayed than the other holes (figure A-5).

4. Several holes had a slight amount of elongation. Three holes were elongated to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.) diameter, and one hole was noted to be a double hole with a maximum 0.7 cm (9/32 in.) dimension (figure A-6). This was out of approximately 110 fastener holes on the aft engine fairing, so the incidence of hole elongation was very minor.

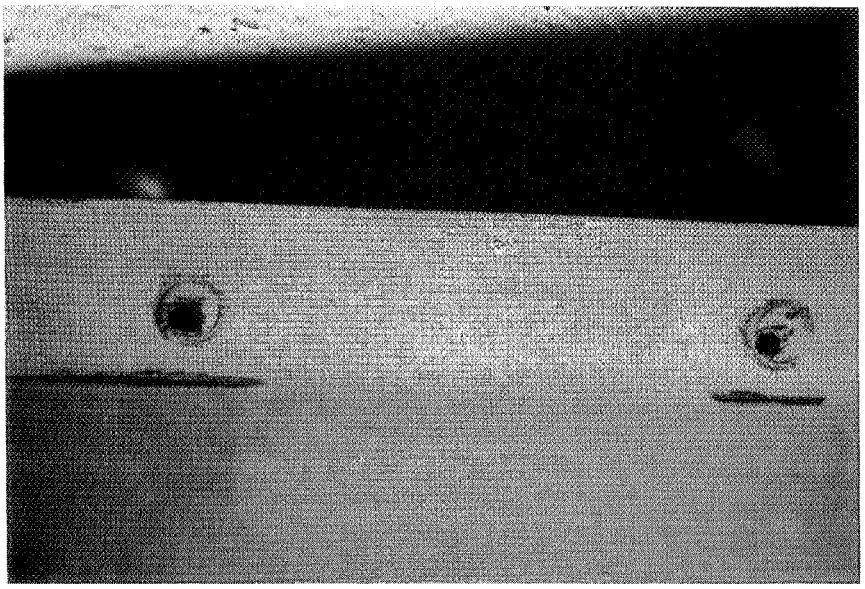

Figure A-3. - Air Canada left-hand wing-body fairing - frayed holes on lower edge with mark-off.

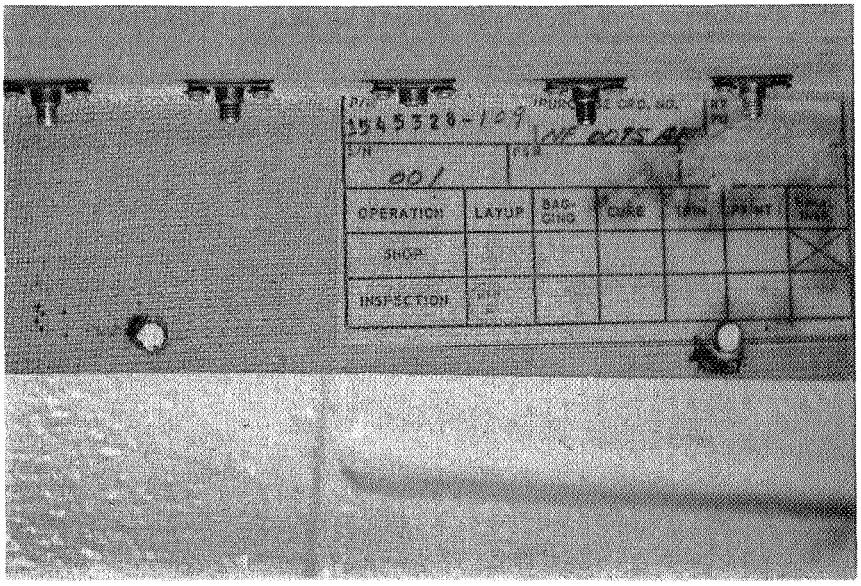

Figure A-4. - Air Canada left-hand underwing fillet - frayed and elongated fastener holes.

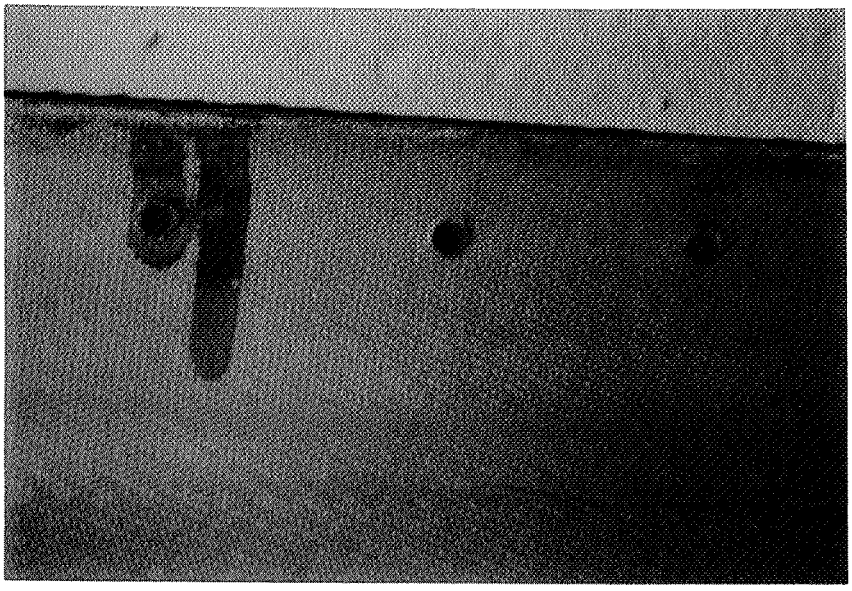

Figure A-5. - Air Canada right-hand aft engine fairing - frayed holes.

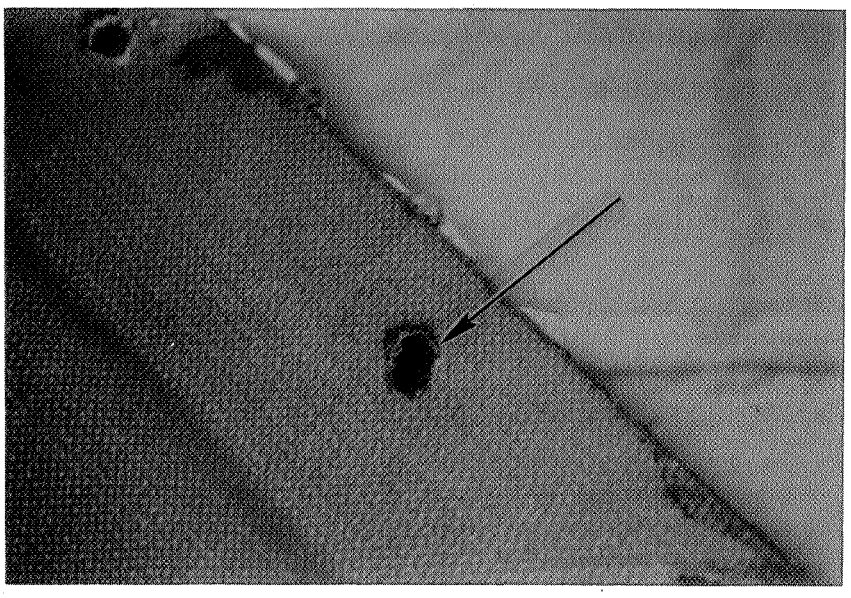

Figure A-6. - Air Canada right-hand aft engine fairing - badly elongated hole.

RIGHT-HAND WING-BODY FAIRING

1. Two cracks observed in previous inspections were again noted. A 0.6 cm (1/4 in.) crack in the forward center area, first observed in 1975, was unchanged in size; but an associated delamination area, 3.2 by 0.3 cm (1-1/4 by 1/8 in.), was observed for the first time. A 0.3 cm (1/8 in.) crack in the center area first observed in 1976 was unchanged.

2. A disbond in the upper aft area, first observed in 1981, was unchanged in appearance. There was no break in the skin, and the paint and flame spray were intact except for three small areas of paint loss. The disbond area was measured as 4.1 by 1.3 cm (1-5/8 by 1/2 in.).

RIGHT-HAND UNDERWING FILLET

1. No exterior damage or defects were noted. Extensive paint loss had been noted in previous inspections indicating possible Skydrol exposure, and the part had been repainted. A slight bulged appearance on the lower aft edge is indicative of a possible slight fastener hole mismatch which could account for the fastener hole elongation noted on these parts.

LEFT-HAND AFT ENGINE FAIRING

1. No exterior surface defects, damage or paint loss were noted.

APPENDIX B

DETAIL OBSERVATIONS OF

KEVLAR-49 FAIRING PANELS -

TWA SHIP N31030 (SERIAL 1111)

SEPTEMBER 1982

Three of the six fairings were removed for inspection: the right-hand wing-body fairing and underwing fillet panels and the left-hand aft engine fairing. The other panels were inspected in place on the aircraft. Mass determinations were made on the right-hand fillet panel.

RIGHT-HAND WING-BODY FAIRING

1. Two cracks were observed on the exterior surface: a deep gouge in the upper aft area first noted in 1981 (figure B-1), and a small 0.3 cm (1/8 in.) crack in the same area which was also first noted in 1981. The deep gouge was measured at 0.8 cm (5/16 in.) length with delamination extending about 0.3 cm (1/8 in.) beyond the crack. Repainting made visual comparisons with the 1981 inspection difficult.

2. Two other small cracks observed in previous inspections were not detected indicating they had been only in the paint.

3. A large teardrop shaped disbonded and crushed area, 11.4 by 2.5 cm (4-1/2 by 1 in.) had not changed in size or appearance since the previous inspection (figure B-2). This was first observed in 1977, and is in the lower forward area of the exterior surface at the probable location of a repair. A small depressed area in the lower forward area of the exterior surface, first observed in 1978, had not changed since the previous inspection. These may represent areas where some force has caused core crushing without skin penetration, and in the smaller area without a skin-core disbond.

4. A rectangular patch overlay 10 by 20 cm (4 by 8 in.) on the lower forward edge of the exterior surface was unchanged in appearance since the previous inspection. This was first observed in 1978, but no damage had been previously observed in that area.

5. Two slight depressed areas on the upper aft area of the inner skin 0.95 - 1.3 cm (3/8 - 1/2 in.) in diameter, first observed in 1980, had not increased in size. There were no associated delaminations.

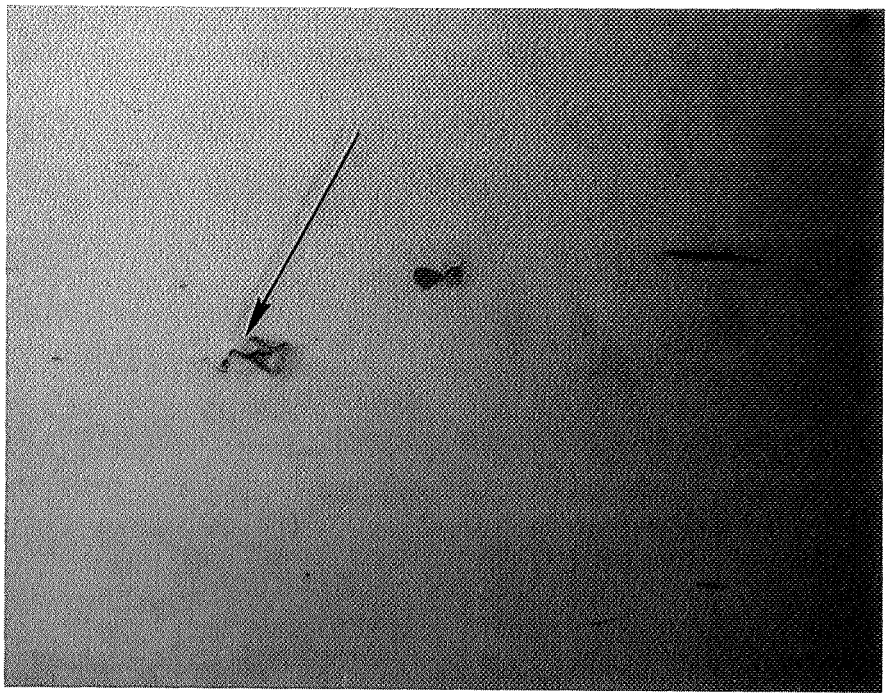

Figure B-1. - TWA right-hand wing-body fairing, gouge on exterior surface.

Figure B-2. - TWA right-hand wing-body fairing - disbonded and crushed area.

6. Two delaminations were observed in the upper forward area of the inner skin: one was 0.95 by 0.3 cm (3/8 by 1/8 in.) in area, and the other was 2.5 by 0.3 cm (1 by 1/8 in.) in area. These had not been observed previously.

7. Fraying was observed on most of the fastener holes to a slight degree (figure B-3). Fraying was more pronounced on the lower edge, and the five aft holes on the lower edge were very badly frayed.

8. Eight holes showed a significant degree of elongation, and all but one of these were on the aft and lower edges. Four holes were elongated to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.) diameter, and four were elongated to 0.6 cm (1/4 in.) diameter. Two of the elongated holes on the lower edge had been relocated at the time of reinstallation (reference 3), and the new holes had been drilled partially through a glass-filled resin filler. Fastener mark-off around the holes was noted to a slight degree on the upper, forward and aft edges; and to a significantly greater degree on the lower edge. This condition had not changed since previous inspections. One hole on the forward edge had two 0.3 cm (1/8 in.) diameter gouges evenly spaced above and below the hole on the inner surface. These had not been observed previously.

RIGHT-HAND UNDERWING FILLET

1. The panel mass was 670.4g (1.478 lb.). Previous mass determinations were 671.0g in the 1981 inspection, 664.0g in the 1980 inspection, 664.6g in 1979, and 663.75g in 1978. The changes in mass are due to paint loss and repainting.

2. No surface damage or defects were observed. Paint was chipped in the lower aft area exposing the Kevlar surface. This is an area not subject to ultraviolet exposure.

3. All of the fastener holes were at least slightly frayed (figure B-4), and eight of the twenty holes were badly frayed. Eight holes were elongated to a measurable degree: five holes to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.), and three holes elongated to 0.6 cm (1/4 in.). Some of the elongated holes were among the badly frayed holes, but the two conditions did not correlate exactly.

LEFT-HAND AFT ENGINE FAIRING

1. No damage or defects were observed on either surface. There were several areas of paint loss and flame spray loss on the exterior including a very large area in the lower aft corner. This surface had been repainted since the previous inspection in 1980, so the paint loss had occurred during the following 2-year period.

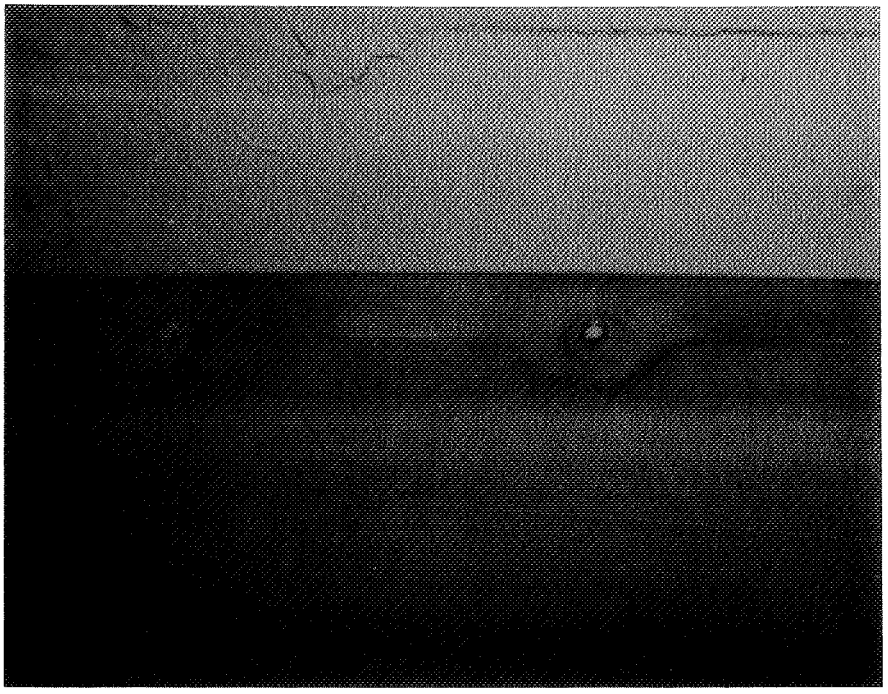

Figure B-3. - TWA right-hand wing-body fairing - typical slight fraying of fastener holes.

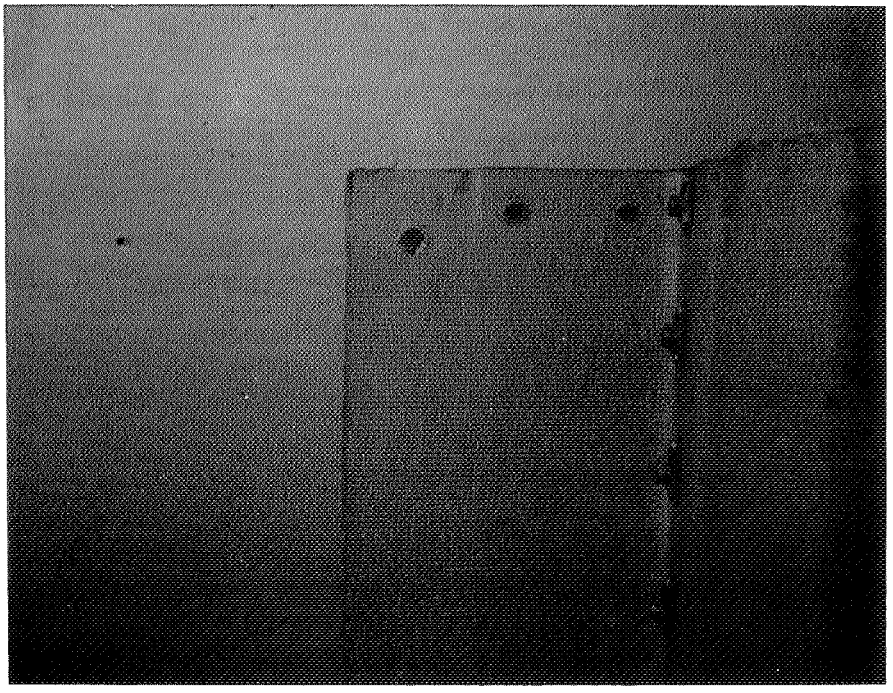

Figure B-4. - TWA right-hand underwing fillet - frayed fastener holes.

2. There was considerable degradation of the vapor barrier coating on the inner surface by Skydrol, particularly in the aft area (figure B-5).

3. The fastener holes showed very little fraying. All of the fastener holes were redrilled when this part was reinstalled (reference 2), and the drilling was performed after curing an outer layer of 120 fiberglass over both Kevlar-49 surfaces. The glass completely prevents the typical frayed condition of Kevlar-49 fastener holes.

4. A total of 29 fastener holes (1/4 of the total) were elongated to a significant degree. One hole was extremely elongated to 0.95 cm (3/8 in.) from the 0.5 cm (3/16 in.) diameter; two holes were elongated to 0.7 cm (9/32 in.); nine holes were elongated to 0.6 cm (1/4 in.) diameter, and the remaining 17 holes were elongated to 0.55 cm (7/32 in.) diameter. The distribution of these elongaged holes was random, and this condition was virtually unchanged since the previous inspection.

LEFT-HAND WING-BODY FAIRING

1. A tape patch repair of a deep gouge, first observed in 1980, was still in place with no changes in appearance since the previous inspection (figure B-6). There was some paint loss near the patch, but no delamination or evidence of damage growth.

2. Another repair, also observed in 1980, in which a 0.3 cm (1/8 in.) crack was filled with resin, was undetectable after repainting.

3. Two other cracks and an associated delamination were no longer detectable after repainting. These conditions were therefore only the result of loose paint.

4. An area of extensive paint loss along the forward edge was still present even though the panel had been repainted since the previous inspection. This indicates possible Skydrol exposure.

LEFT-HAND UNDERWING FILLET

1. There were no surface defects, damage areas, or paint loss. The lower aft edge was bulged in appearance incidating a possible slight mismatch of fastener holes. Two fasteners were missing.

RIGHT-HAND AFT ENGINE FAIRING

1. There was no visible damage to the exterior surface. There was some paint loss, and in a few small areas the flame spray was also missing, exposing the Kevlar-49 surface to ultraviolet.

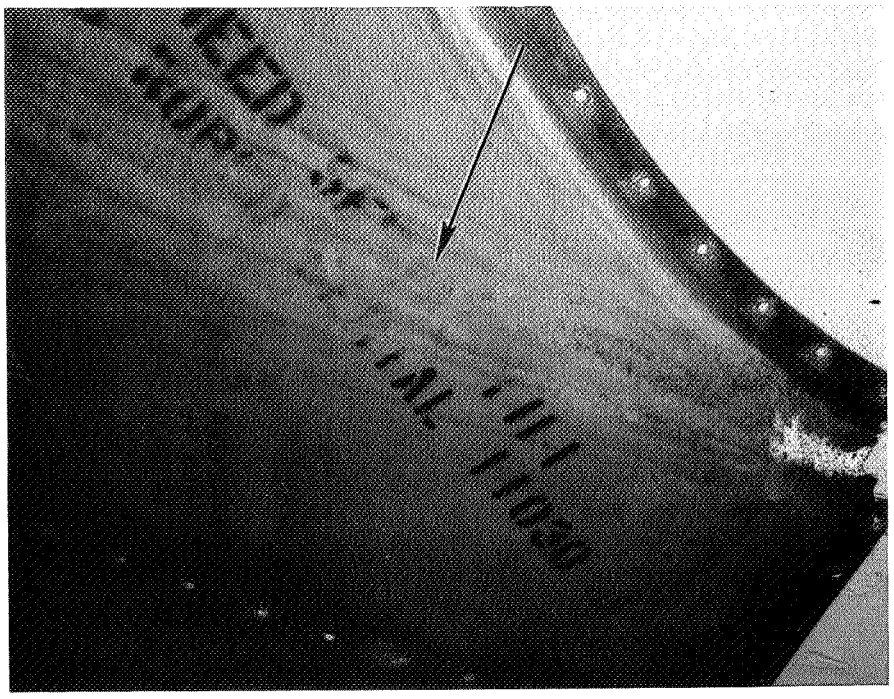

Figure B-5. - TWA left-hand aft engine fairing - Skydrol attack on vapor barrier

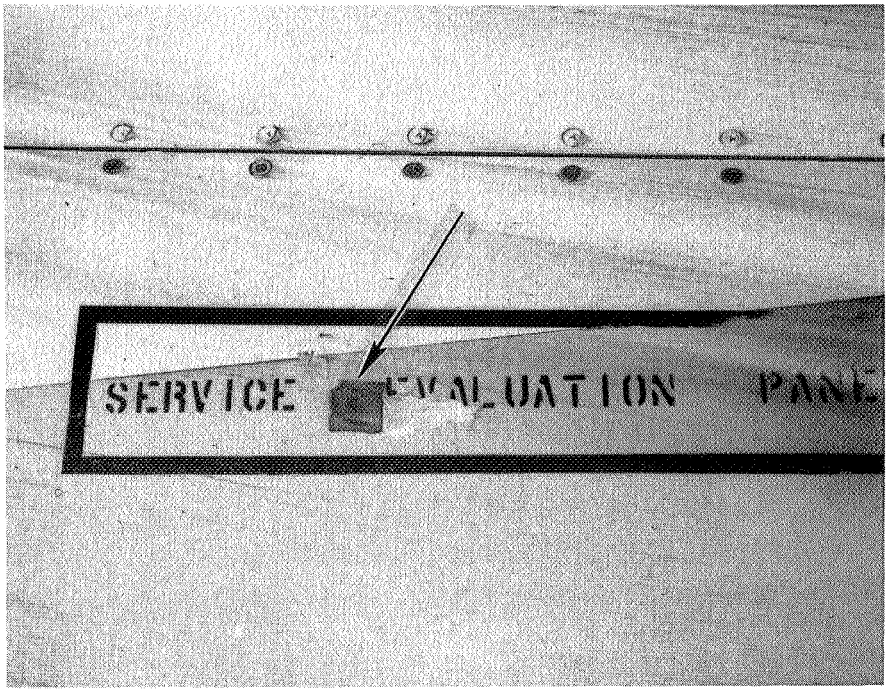

Figure B-6. - TWA left-hand wing-body fairing - tape patch repair.

APPENDIX C

DETAIL OBSERVATIONS OF

KEVLAR-49 FAIRING PANELS -

EASTERN SHIP N313EA (SERIAL 1020) -

OCTOBER 1982

Two of the remaining four fairings were removed for inspection: the right-hand wing-body fairing and aft engine fairing panels. The left-hand wing-body fairing was inspected on the aircraft. The two underwing fillet panels were misplaced after their removal from the original aircraft in 1979.

RIGHT-HAND WING-BODY FAIRING

1. Several exterior surface cracks observed in previous inspections had not propagated or changed in appearance, except they were somewhat obscured by repainting since the 1981 inspection:

   - A 1.3 cm (1/2 in.) crack in the forward edge between the fifth and sixth holes from the top first observed in 1976.

   - A 0.3 cm (1/8 in.) ding in the lower center area first observed in 1976.

   - A 0.3 cm (1/8 in.) crack in the aft center area first observed in 1975.

   - A 0.6 cm (1/4 in.) crack in the center area first observed in 1976.

   - A 0.8 cm (5/16 in.) crack in the upper forward area first observed in 1977.

2. Several small disbond or delaminated areas were noted on the exterior surface and had not increased in size since the 1981 inspection.

   - A disbond in the lower forward area 1.4 by 0.8 cm (9/16 by 5/16 in.), first noted in 1975 and previously observed as a 0.8 cm (5/16 in.) crack. It was probably filled during the repainting operation.

   - A disbond 2.5 by 1.6 cm (1 by 5/8 in.) in the upper aft area first observed in 1981.

   - A disbond 1.6 by 0.95 cm (5/8 by 3/8 in.) in the lower forward area first observed in 1981.

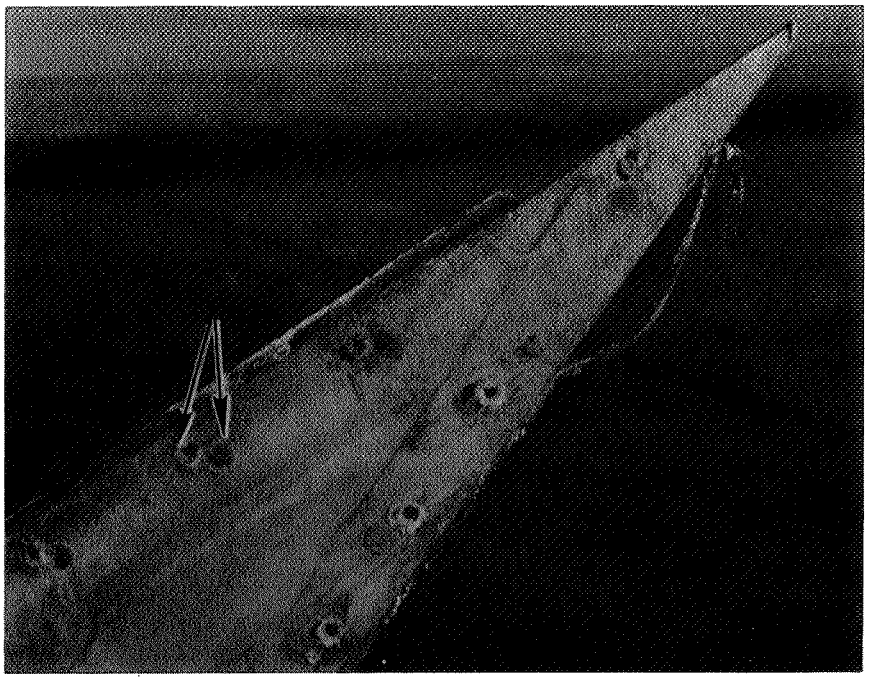

Figure C-3. - Eastern right-hand aft engine fairing - badly frayed holes after re-installation; filler in original holes.

3. A significant degree of elongation was observed in about 1/5 of the holes, principally at locations where the hole was drilled through the filler (which is chopped glass fiber filled epoxy) (figure C-4). Eleven holes were elongated to a maximum 0.55 cm (7/32 in.) dimension from the original 0.5 cm (3/16 in.); twelve holes were elongated to 0.6 cm (1/4 in.); and one hole was elongated very badly to 0.8 cm (5/16 in.).

LEFT-HAND WING-BODY FAIRING

1. A deep gouge and associated crack 2.5 cm (1 in.) in length in the upper forward area of the exterior surface was first observed in 1978. A repair consisting of a thixotropic resin filler forming a triangular patch approximately 12.9 cm^2 (2 $in.^2$) in area was observed in 1979. This repair has been painted over but is otherwise unchanged with no evidence of damage growth.

2. A speed tape patch first observed in 1975 on the exterior surface had been removed since the 1979 inspection, and presumably the damage had

APPENDIX C

DETAIL OBSERVATIONS OF

KEVLAR-49 FAIRING PANELS -

EASTERN SHIP N313EA (SERIAL 1020) -

OCTOBER 1982

Two of the remaining four fairings were removed for inspection: the right-hand wing-body fairing and aft engine fairing panels. The left-hand wing-body fairing was inspected on the aircraft. The two underwing fillet panels were misplaced after their removal from the original aircraft in 1979.

RIGHT-HAND WING-BODY FAIRING

1. Several exterior surface cracks observed in previous inspections had not propagated or changed in appearance, except they were somewhat obscured by repainting since the 1981 inspection:

   - A 1.3 cm (1/2 in.) crack in the forward edge between the fifth and sixth holes from the top first observed in 1976.

   - A 0.3 cm (1/8 in.) ding in the lower center area first observed in 1976.

   - A 0.3 cm (1/8 in.) crack in the aft center area first observed in 1975.

   - A 0.6 cm (1/4 in.) crack in the center area first observed in 1976.

   - A 0.8 cm (5/16 in.) crack in the upper forward area first observed in 1977.

2. Several small disbond or delaminated areas were noted on the exterior surface and had not increased in size since the 1981 inspection.

   - A disbond in the lower forward area 1.4 by 0.8 cm (9/16 by 5/16 in.), first noted in 1975 and previously observed as a 0.8 cm (5/16 in.) crack. It was probably filled during the repainting operation.

   - A disbond 2.5 by 1.6 cm (1 by 5/8 in.) in the upper aft area first observed in 1981.

   - A disbond 1.6 by 0.95 cm (5/8 by 3/8 in.) in the lower forward area first observed in 1981.

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3. Stone, R.H.; Flight Service Evaluation of Kevlar-49/Epoxy Composite Panels in Wide-Bodied Commercial Transport Aircraft - Second Annual Flight Service Report. NASA CR-132733, October 1975.

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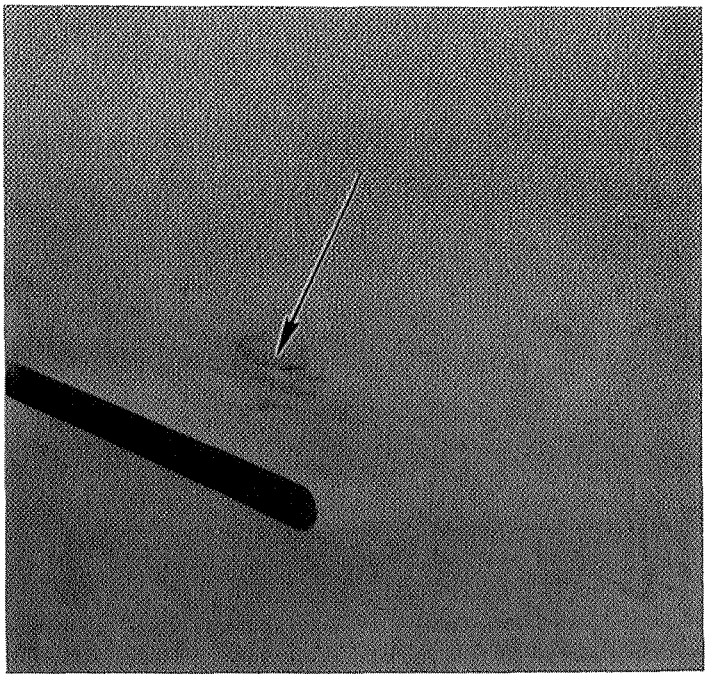

Figure C-1. - Eastern right-hand wing-body fairing - crack 2.5 cm (1 in.) long on inner surface.

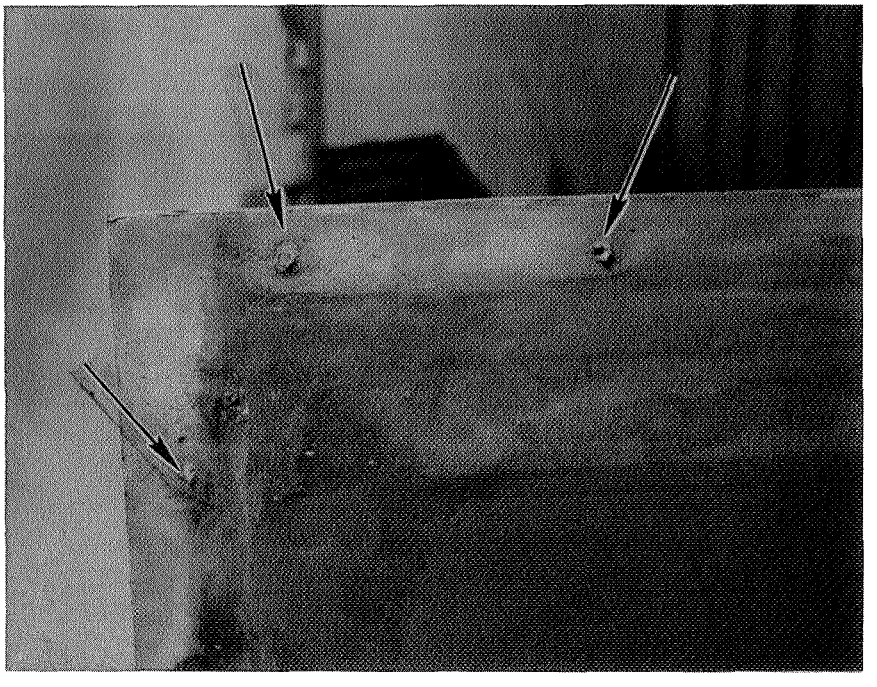

Figure C-2. - Eastern right-hand wing-body fairing - badly frayed holes.

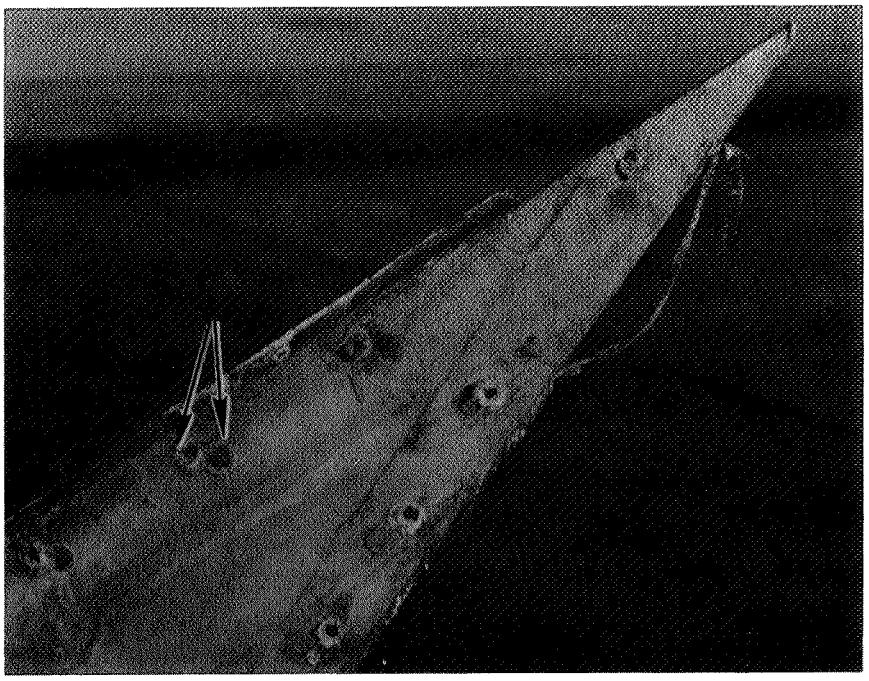

Figure C-3. - Eastern right-hand aft engine fairing - badly frayed holes after re-installation; filler in original holes.

3. A significant degree of elongation was observed in about 1/5 of the holes, principally at locations where the hole was drilled through the filler (which is chopped glass fiber filled epoxy) (figure C-4). Eleven holes were elongated to a maximum 0.55 cm (7/32 in.) dimension from the original 0.5 cm (3/16 in.); twelve holes were elongated to 0.6 cm (1/4 in.); and one hole was elongated very badly to 0.8 cm (5/16 in.).

LEFT-HAND WING-BODY FAIRING

1. A deep gouge and associated crack 2.5 cm (1 in.) in length in the upper forward area of the exterior surface was first observed in 1978. A repair consisting of a thixotropic resin filler forming a triangular patch approximately 12.9 cm^2 (2 $in.^2$) in area was observed in 1979. This repair has been painted over but is otherwise unchanged with no evidence of damage growth.

2. A speed tape patch first observed in 1975 on the exterior surface had been removed since the 1979 inspection, and presumably the damage had

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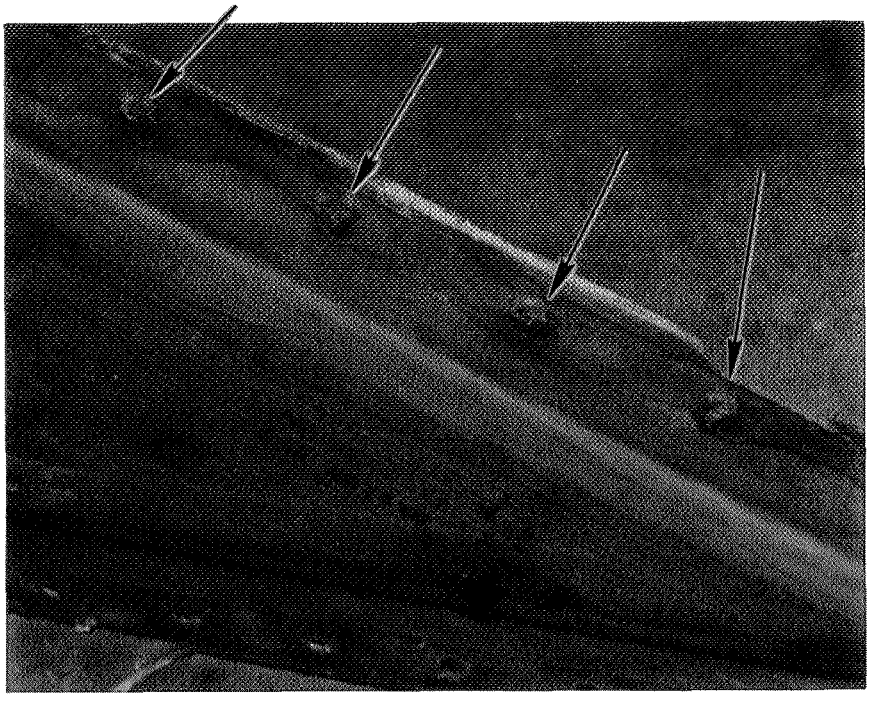

Figure C-4. - Eastern right-hand aft engine fairing - elongated holes partially drilled through filler.

been filled with resin. The precise location of the patch was never noted, but it probably was at the location of one of two disbonds or delaminations observed in the upper forward area. One is 1.6 by 1.9 cm (5/8 by 3/4 in.) in area, and the other is 1.3 by 1.6 cm (1/2 by 5/8 in.) in area.

3. A third delamination on the exterior had not been observed previously. This was in the lower forward area and was 3.2 by 0.95 cm (1-1/8 by 3/8 in.) in area.

4. Two depressed lines, first noted in 1981, had not changed in size or appearance. One is 6.35 cm (2-1/2 in.) long, with circular depressed areas 0.95 cm (3/8 in.) in diameter at either end; the other line is 8.9 cm (3-1/2 in.) long. There is no associated delamination.

LEFT-HAND AFT ENGINE FAIRING

1. There was no observation of this part due to lack of access on the aircraft.

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15. Supplementary Notes

Annual Flight Service Report. Technical Monitor, Benson Dexter, Materials Division, NASA/Langley Research Center, Hampton, Virginia

16. Abstract

Kevlar-49 fairing panels, installed as flight service components on three L-1011s, were inspected after 9 years of service. There are six Kevlar-49 panels on each aircraft: a left-hand and right-hand set of a wing-body sandwich fairing; a solid laminate under-wing fillet panel; and a 422 K (300°F) service aft engine fairing. The three L-1011s include one each in service with Eastern, Air Canada, and TWA. The fairings have accumulated a total of 70,000 hours, with one ship set having over 24,000 hours service. The inspections were conducted at the airlines' major maintenance bases with the participation of Lockheed Engineering.

The Kevlar-49 components were found to be performing satisfactorily in service with no major problems, or any condition requiring corrective action. The only defects noted were minor impact damage, a few minor disbonds and a minor degree of fastener hole fraying and elongation. These are for the most part comparable to damage noted on fiberglass fairings.

The service history to date indicates that Kevlar-49 epoxy composite materials have satisfactory service characteristics for use in aircraft secondary structure.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
COMPOSITES, KEVLAR-49, DURABILITY OF COMPOSITES, FLIGHT SERVICE EVALUATION	Unclassified - Unlimited STAR Category 24

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	35	

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