ATTACHMENT 4

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

LAX-02-GA-201

FOWLER INC.

METALLURGICAL ANALYSIS
FAILURE ANALYSIS &
EXPERIMENTAL TESTING

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September 6, 2002

Mr. George Petterson
National Transportation Safety Board
Southwest Regional Office
1515 West 190th Street, Suite 555
Gardena, CA 90248-4916

Aircraft:	Lockheed C130A, S/N 56-538
Registration:	N130HP
Location:	Walker, CA
Date:	June 17, 2002
NTSB File No.:	LAX 02GA201

Dear Mr. Petterson:

A metallurgical evaluation of a section of lower wing panel from a Lockheed C130A has been conducted to determine the fracture mode and metallurgical properties. The C130A was engaged in fire fighting maneuvers when both wings experienced in-flight structural failure. Figure 1 shows an overall view of the lower wing panel in the center wing section (CWS) after retrieval from the crash site. The fractured end of the wing panel was sectioned at approximately CWS 41R as shown in Figure 2 (Figures 1 and 2 were provided for review and have been included in this report to show the condition of the lower panel from the center wing section). Figure 3 shows the sections of lower wing panel as they were received for examination at Fowler, Inc. According to information provided, the fracture occurred in the center wing section in the lower panel of the right wing at approximately wing station 53R. The lower wing panel between fuselage station (F.S.) 517.0 and 596.6 in the area of fracture consists of three skin panels and twelve stringers numbered 12 through 24 as shown in Figure 4 (without external doublers).

EXAMINATION

An examination was conducted of the lower wing panel visually and under the binocular microscope. The initial examination revealed the presence of crack arrest marks (striations) characteristic of fatigue crack growth. Fatigue is a progressive mechanism of crack growth that occurs due to cyclic stress of sufficient magnitude. Figure 5 shows the suspected area of fatigue crack propagation prior to cleaning. The fracture surface was cleaned in a soap solution with mild scrubbing using a nylon bristle brush, followed by an acetone rinse. The fracture surfaces were examined further under the binocular microscope. Figure 6 shows an illustration of the wing panels in the area of fatigue crack initiation and panel fracture. Clearly defined fatigue striations were observed to have initiated from two rivet holes where stringers 16 and 17 are attached to the lower wing skin center panel. Figure 7 shows a closer view of the region exhibiting fatigue crack initiation and propagation after cleaning.

The primary areas of fatigue crack initiation are at two adjacent holes in the skin where rivets attach stringers 16 and 17 and an external doubler to the lower skin panel at approximately center wing station 53R. An illustration of the area of primary fatigue initiation and growth is shown in Figure 8. Fatigue cracks initiated in the skin from both sides of the aft rivet hole for stringer 16 (Origin "A" shown in Figures 9a through 9c) and the forward rivet hole for stringer 17 (Origin "B" shown in Figures 10a through 10c) and grew outward from each rivet hole. The fatigue cracks at origin "A" initiated from the rivet hole surface adjacent to an indent on the forward side and appeared to have multiple origins from the hole surface on the aft side. The fatigue cracks at origin "B" initiated from the lower corner of the rivet hole on the forward side and appeared to have multiple origins from the hole surface on the aft side. The rivet hole surfaces contained shallow circumferential marks from drilling and residual sealant from installation of the external doubler. Fatigue cracks also initiated in the stringer flanges above the areas of primary initiation in the skin and propagated to the upper section of stringers 16 and 17 (see Figures 9c and 10c). The skin fatigue cracks that grew in the aft direction from stringer 16 and forward from stringer 17 eventually joined together resulting in one longer crack as indicated by the presence of black (aluminum) oxide caused by rubbing of the mating fracture surfaces in the area where the cracks joined. The length of fatigue crack growth based on the presence of striations on the fracture surface from each hole is listed in Table I. The aft crack from the skin hole at stringer 17 had multiple bands of fatigue crack growth separated by stable tearing of the skin. This crack grew into the rivet hole under the aft flange of stringer 17 and reinitiated on the opposite side of the hole. The aft most band of fatigue crack growth was under the forward flange of stringer 18 (see Figures 7 and 8). The other cracks from the primary fatigue origins also exhibited areas of stable tearing of the skin followed by crack arrest and continued fatigue crack growth. The total crack length based on the presence of fatigue striations for the forward end of the crack from stringer 16 and the aft end of the crack from stringer 17 was approximately 10.9 in. Assuming the crack grew to the forward edge of the center panel then the total crack length was 12.2 in. (see Figure 8). The lower skin thickness measured adjacent to the fatigue origins was 0.163 in. (with primer present).

The lower surface of the center panel skin had a rectangular shaped outline of sealant material extending aft 6.95 in. from the forward edge (Figure 11) and extending onto the forward skin panel. The sealant is from the installation of an external doubler riveted to the lower surface of the skin across the joint between the forward and center skin panels.

(Another external doubler spans the joint between the center and aft skin panels). The primary fatigue cracks have initiated in the center panel skin under the external doubler at two adjacent rivet holes along the inboard row of rivets used to attach the doubler. The fatigue crack would have to grow approximately 0.75 in. rearward of the forward rivet hole at stringer 17 in order to extend beyond the aft edge of the doubler. A small amount of fretting was present on the lower surface of the skin that mated with the external doubler at the rivet holes where fatigue crack initiation occurred. The upper surface of the stringer flange under the "bucked" end of the rivet did not exhibit fretting. The rivets adjacent to the primary fatigue origin areas did not exhibit evidence of being loose.

Examination of the fracture surface along the lower wing panel under the binocular microscope revealed the presence of eight additional areas of fatigue crack growth at various locations in the center panel of the lower wing skin and the adjacent edges of the forward and aft skin panels. Figure 6 illustrates the location of these additional fatigue cracks and Table I describes the location and size. The skin panels are joined together using a double row of Hi-Lok fasteners that extend through a wider flange on stringers 16 and 20 and the lower skin panel. The Hi-Lok fasteners along the aft edge of the forward panel sheared due to overload forces principally in an aft direction. The fasteners at stringer 20 joining the center and aft panels sheared due to overload forces. Also, rivets attaching stringers 12, 23 and 24 to the lower skin were sheared. The fasteners joining the forward beam cap and forward skin panel were sheared principally in an outboard direction. All sheared rivets occurred due to overload forces. The rear edge of the aft skin panel failed by an overstress fracture mechanism (see Figure 6 for location).

SCANNING ELECTRON MICROSCOPY

An examination of the area of crack initiation from primary fatigue origin "B" was conducted in the scanning electron microscope (SEM). Figure 12a shows an overall view of the skin fracture surface at primary fatigue origin "B" from the rivet hole at stringer 17. Clearly visible fatigue striations are present on the fracture surface. The fatigue crack initiated from the lower corner of the rivet hole. The origin area had been partially rubbed on both sides of the rivet hole eliminating identifiable fracture features (Figure 12b and 12c). Clearly defined fatigue striations are present along the fracture surface away from the hole edges (Figures 13a and 13b). A secondary fatigue origin in the stringer 17 flange above primary skin fatigue origin "B" was examined and found to have multiple small fatigue cracks initiating from the rivet hole and adjacent areas on the lower surface of the stringer (Figures 14a through 14c). The fatigue crack initiating in the skin from the forward side of the hole under the forward flange at stringer 16 (crack F2 in Figure 6) is shown in Figures 15a and 15b. The fatigue crack initiated from both sides of the Hi-Lok fastener hole. No indication of inter-granular fracture associated with stress corrosion cracking was found at the fatigue origin sites.

METALLURGICAL PROPERTIES

Sections were removed from the center skin panel and stringers 16 and 17 and submitted to an independent laboratory for chemical analysis. Table II shows the results of the chemical analysis which indicate that the skin and both stringers conform to the requirements for 7075 aluminum alloy. Conductivity and hardness measurements are reported in Table III. The results indicate that the alloy used for the skin and both stringers was heat treated to the T6 temper. Sections of the lower skin and both stringers were prepared for metallography. The skin microstructure is consistent with rolled 7075 aluminum heat treated to the T6 condition. Both stringer microstructures are consistent with extruded 7075 aluminum that has been heat treated to the T6 condition.

Best regards,

[redacted]

Gary J. Fowler, Ph.D.

/lp-3538

TABLE I

LOCATION OF FATIGUE CRACKS (See Figure 6)

Right Wing, Lower Skin Panel at STA 53R

Primary Origin "A"	Fatigue cracks initiated in the skin from both sides of the aft rivet hole where stringer 16 is attached to center panel, lower skin at STA 53R. Fatigue striations extended 2.2 in. forward of the hole and 0.75 in. rearward. Fatigue cracks also initiated in the stringer flange rivet hole and grew to the upper (thicker) section. See Figures 8 and 9c.
Primary Origin "B"	Fatigue cracks initiated in the skin from both sides of the forward rivet hole where stringer 17 is attached to center panel, lower skin at STA 53R. Fatigue striations extended 1.08 in. forward of the hole and 6.0 in. rearward. Fatigue cracks also initiated in the stringer flange rivet hole and grew to the upper (thicker) section. See Figures 8 and 10c.
F1*	Fatigue cracks initiated from both lower corners of skin fastener hole in forward panel where attaches to stringer 16. Crack grew forward 0.04 in. and rearward 0.27 in.
F2*	Fatigue cracks initiated in skin at both sides of fastener hole, forward flange stringer 16, and grew 0.05 in. forward and 0.13 in. rearward.
F3*	Fatigue cracks initiated at both sides of stringer fastener hole, in flange of stringer 16 and grew 0.15 in. forward and 0.10 in. rearward.
F4	Small fatigue cracks initiated from both sides of stringer 17 flange rivet hole (length approximately 0.02 in.)
F5	Small fatigue crack initiated at corner (approx. 0.02 in) in skin rivet hole under stringer 18.
F6	Small fatigue cracks initiated in stringer 18 from both sides of rivet hole and extended approximately 0.03 in.
F7*	Fatigue crack initiated from corner of fastener hole in center panel skin where joined to stringer 20 and extended rearward 0.08 in.
F8*	Fatigue crack initiated from corner of fastener hole in rear panel skin where joined to stringer 20 and extended rearward 0.10 in.

* Adjacent to skin joint where stringers 16 and 20 have wider flanges to span across both skin panels and are attached with Hi-Lok fasteners (see Figure 8 for illustration).

TABLE II

CHEMICAL ANALYSIS

Element	Lower Wing Skin Center Panel	Stringer 16	Stringer 17	Aluminum 7075 Min	Aluminum 7075 Max
Mg	2.32	2.27	2.24	2.10	2.90
Si	0.07	0.09	0.08	0.00	0.40
Ti	0.03	0.04	0.03	0.00	0.20
Mn	0.02	0.02	0.02	0.00	0.30
Fe	0.32	0.13	0.13	0.00	0.50
Cu	1.57	1.47	1.47	1.20	2.00
Zu	5.29	5.15	5.21	5.10	6.10
Cr	0.19	0.22	0.22	0.18	0.28
OE*	less than 0.05	less than 0.05	less than 0.05	0.00	0.05
OT**	less than 0.15	less than 0.15	less than 0.15	0.00	0.15
Al	Balance	Balance	Balance	Balance	Balance

* Other elements each
** Other elements total

All Samples conform to the requirements of 7075 Aluminum

TABLE III

CONDUCTIVITY AND HARDNESS DATA

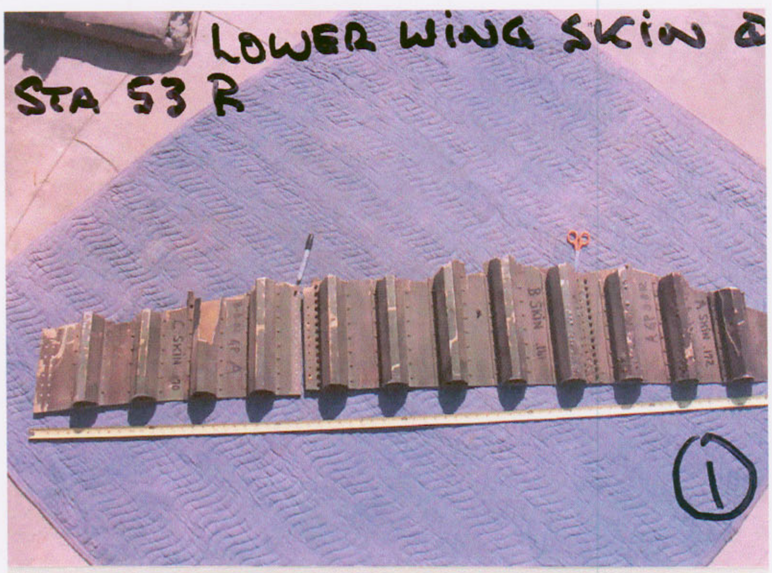
	Center Skin Panel	Stringer 16	Stringer 17
Conductivity* (% IACS)	30.0/30.7	33.5	33.0
Rockwell B**	91.0/91.5	91.0	91.5

* T6 temper specifics 30.5-36.0% IACS per Aerospace Material Specification (AMS) 2658.

** T6 temper specifics R_B 84 min. per AMS 2658.

Lower Panel of Center Wing Section

Figure 1



Piece Cut from Center Wing Section

Figure 2

Lower Wing Panel as Received at Fowler, Inc.

Figure 3

C130 CENTER WING PANELS

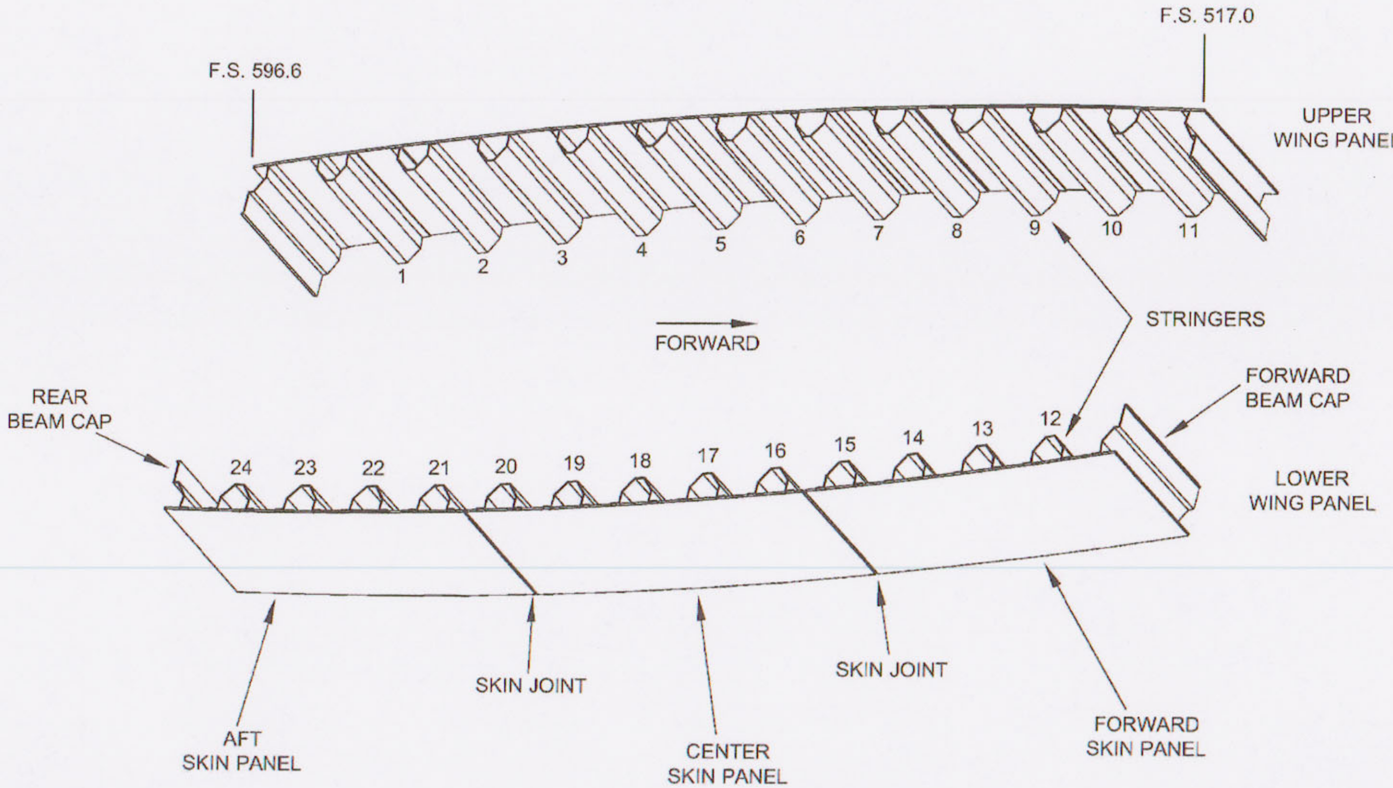


Figure 4

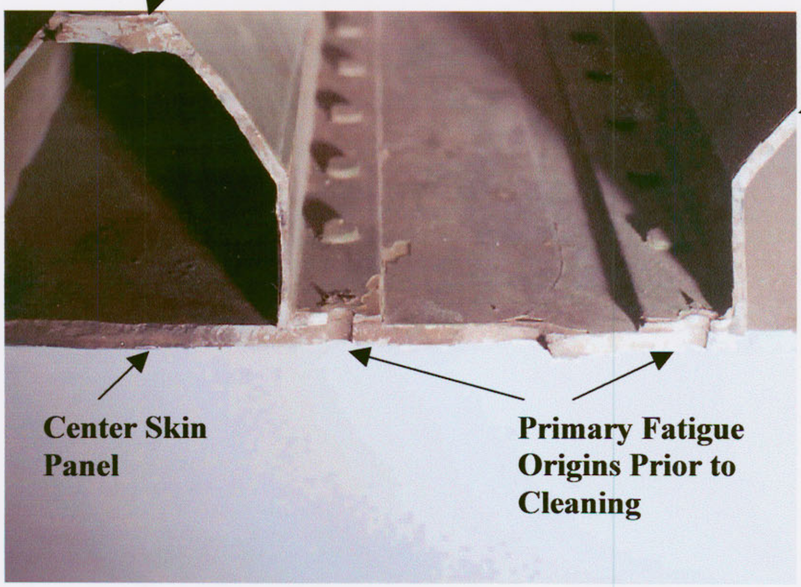
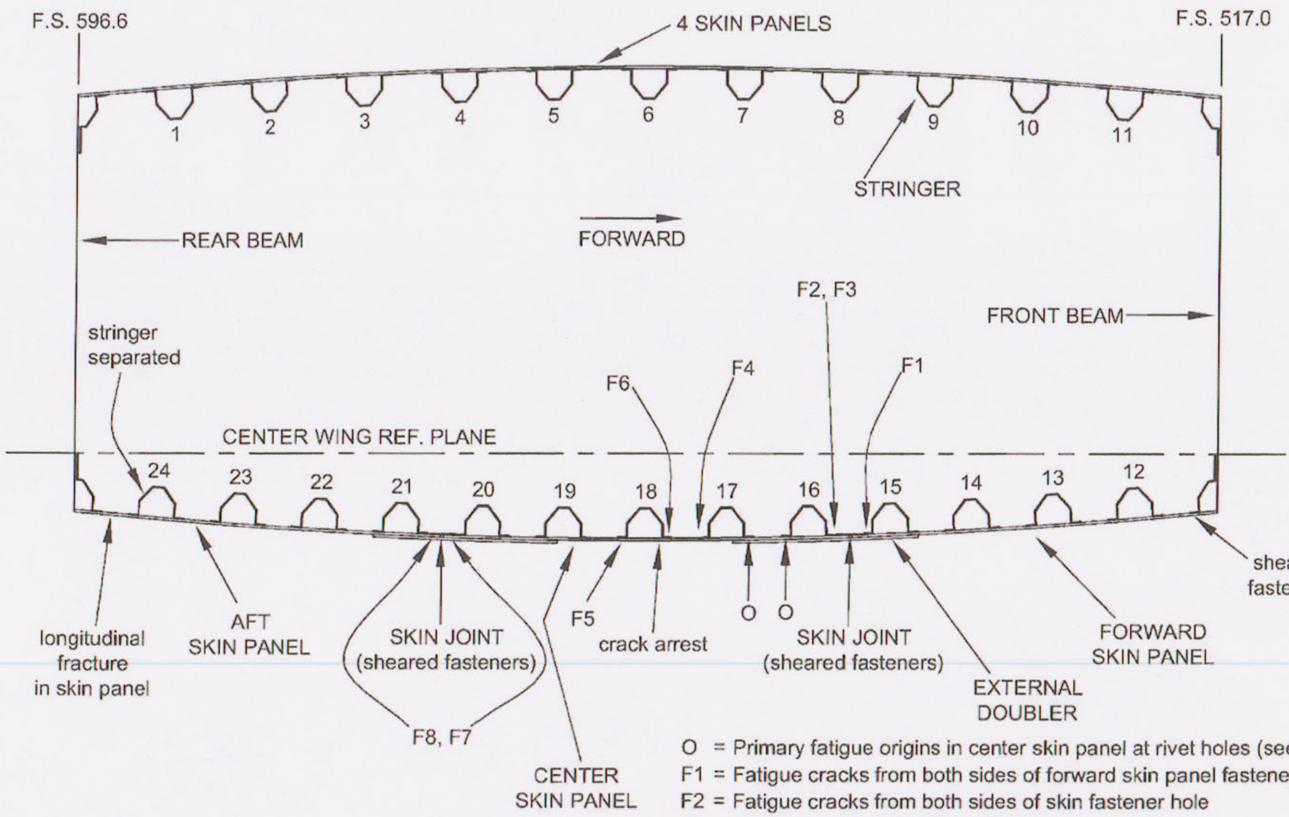

Stringer 17
Stringer 16
Center Skin Panel
Primary Fatigue Origins Prior to Cleaning

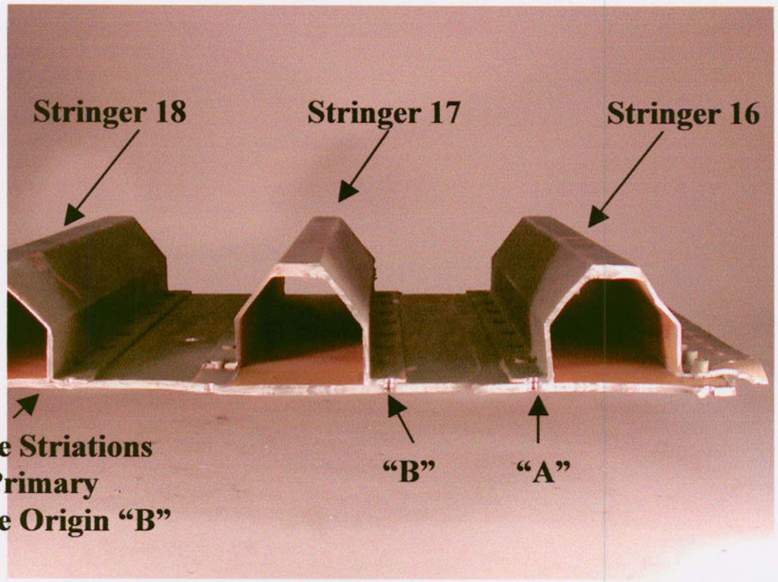
Figure 5

C130A RIGHT WING AT STA 53R
SHOWING LOCATION OF FATIGUE CRACKS



O = Primary fatigue origins in center skin panel at rivet holes (see Figure 8)
F1 = Fatigue cracks from both sides of forward skin panel fastener hole
F2 = Fatigue cracks from both sides of skin fastener hole
F3 = Fatigue cracks both sides of stringer fastener hole
F4 = Fatigue cracks from stringer rivet hole
F5 = Small corner crack in skin at rivet hole
F6 = Small cracks in stringer from rivet hole
F7 = Small crack from skin fastener hole
F8 = Small crack from fastener hole in aft skin panel

Figure 6



Center Skin Panel Showing Primary Fatigue Origins "A" and "B" (see Figure 8)

Figure 7

C130A RIGHT WING AT STA 53R
STRINGERS 18 - 15
SHOWING PRIMARY FATIGUE CRACK ORIGINS

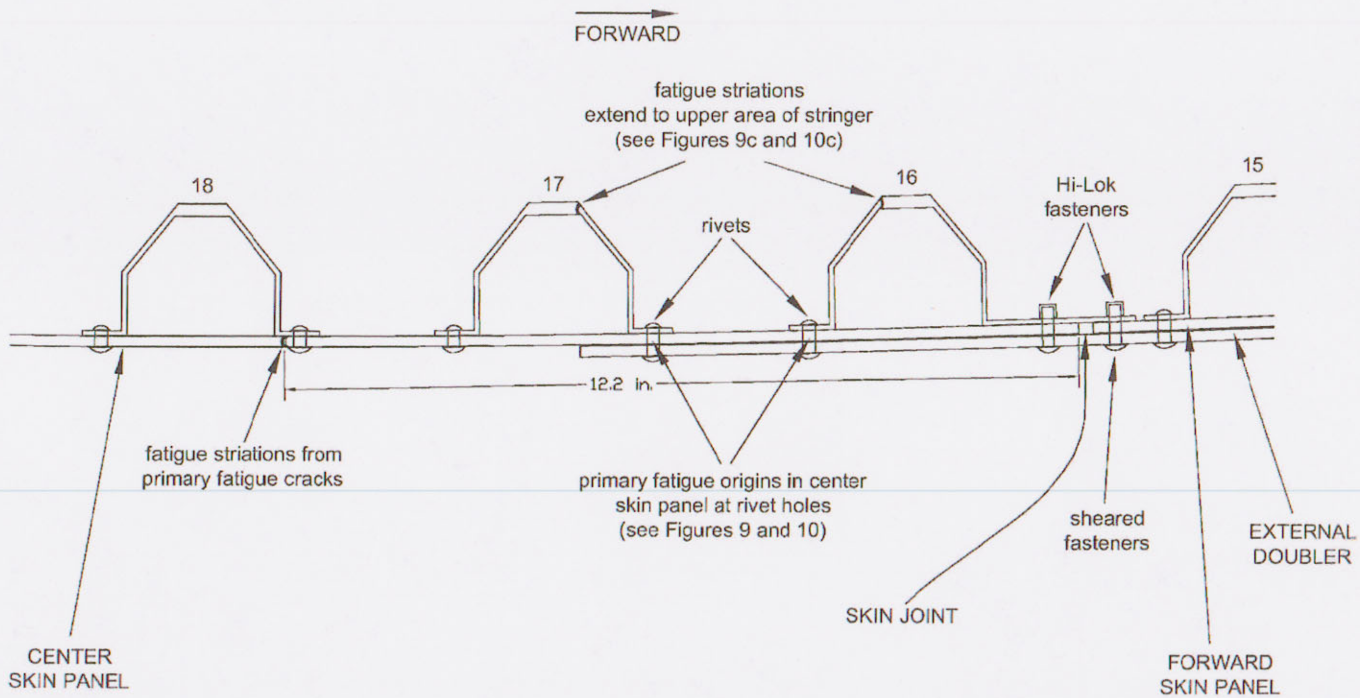
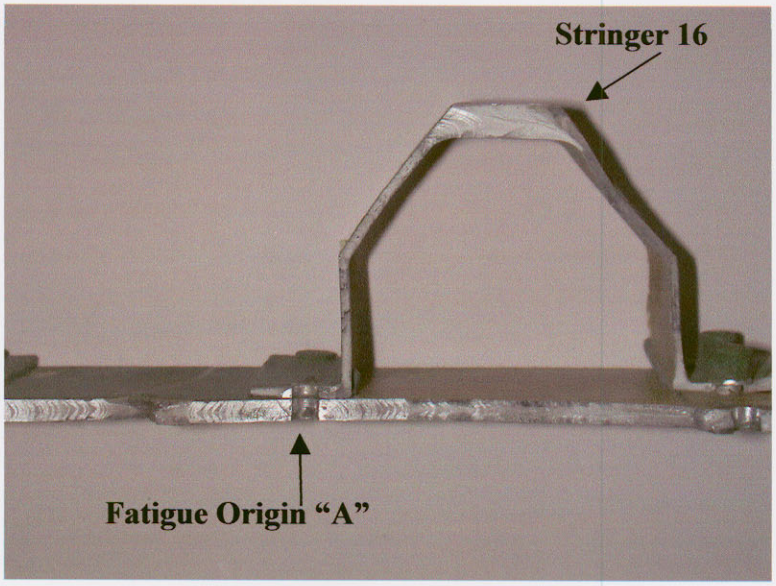
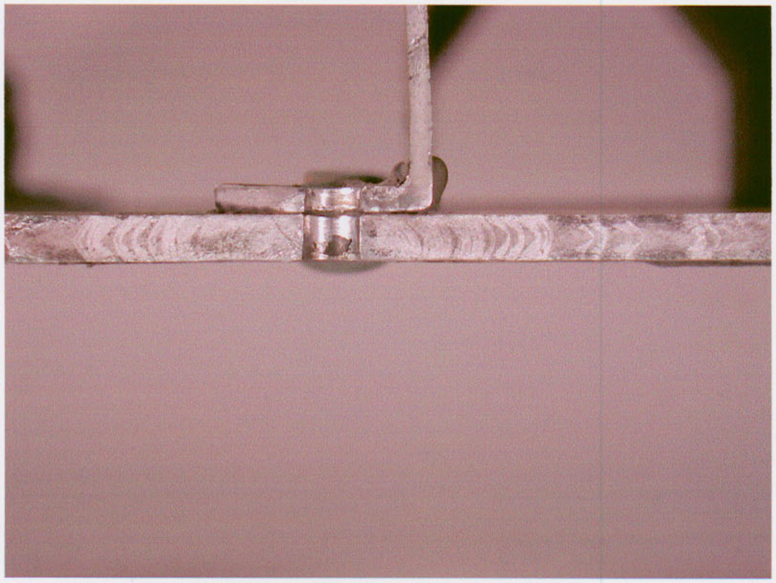


Figure 8



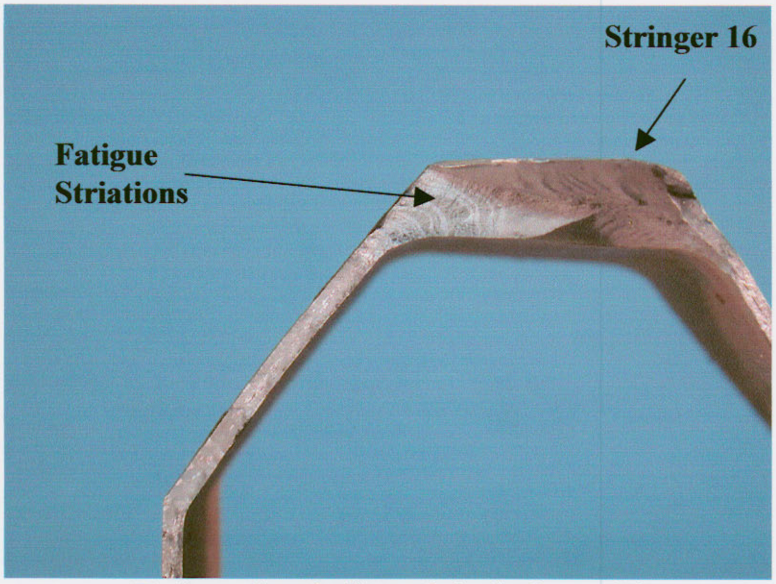
Primary Fatigue Origin "A"

Figure 9a



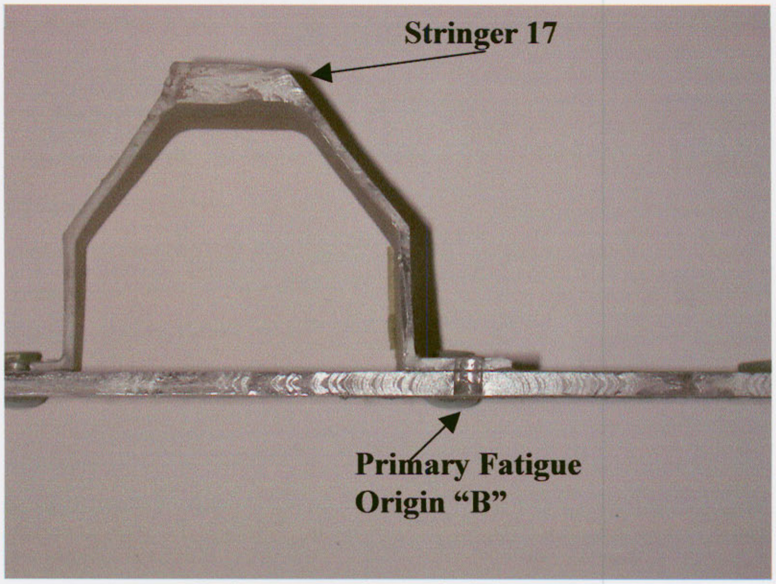
Primary Fatigue Origin "A"

Figure 9b



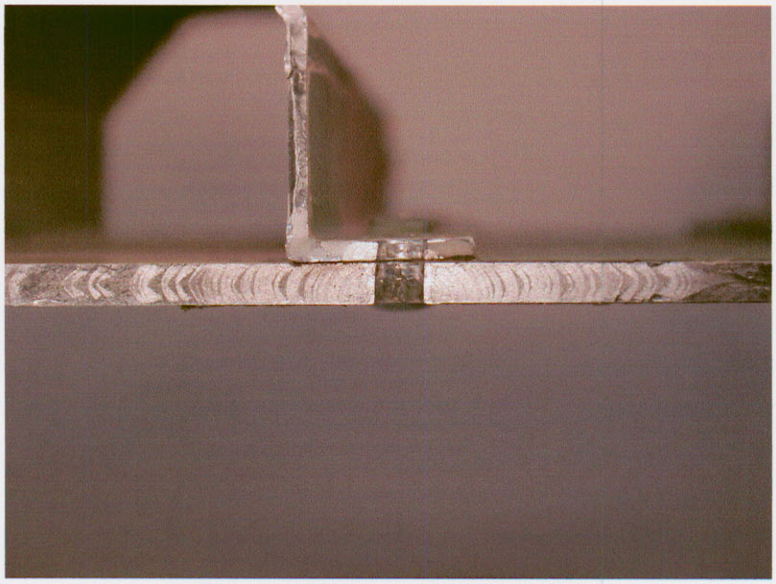
Fatigue Crack Growth in Stringer 16

Figure 9c



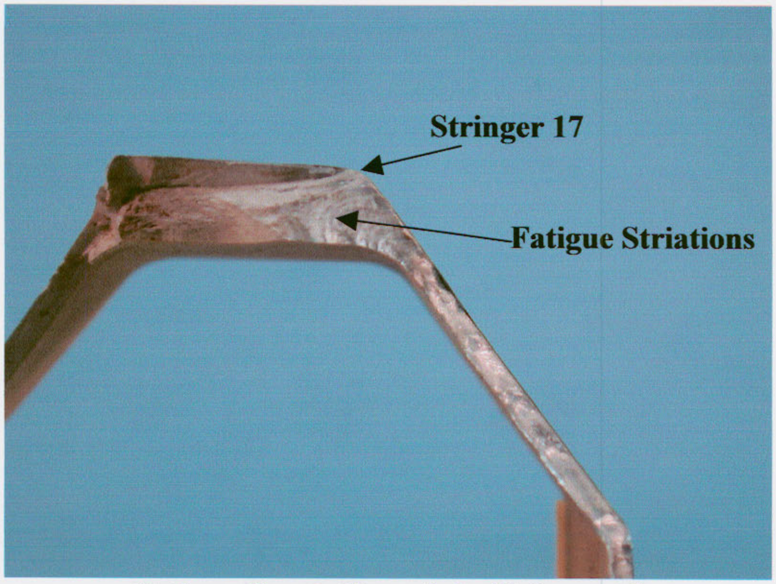
Primary Fatigue Origin "B"

Figure 10a



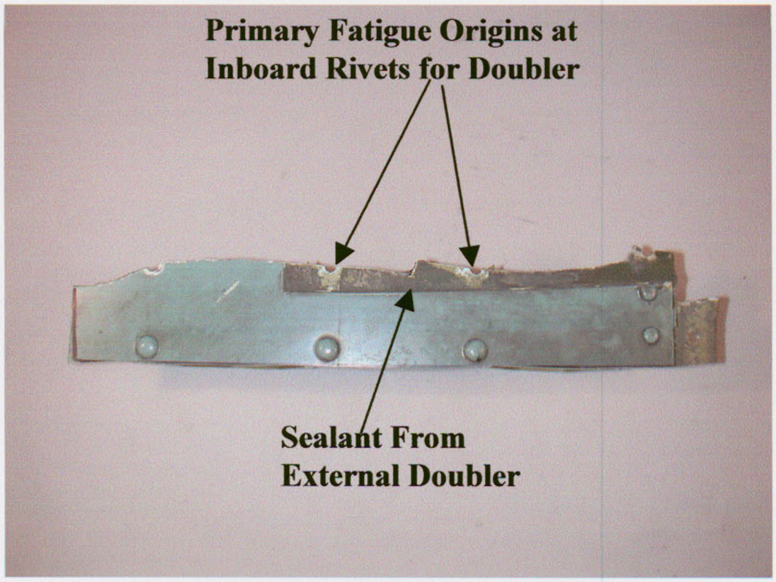
Primary Fatigue Origin "B"

Figure 10b



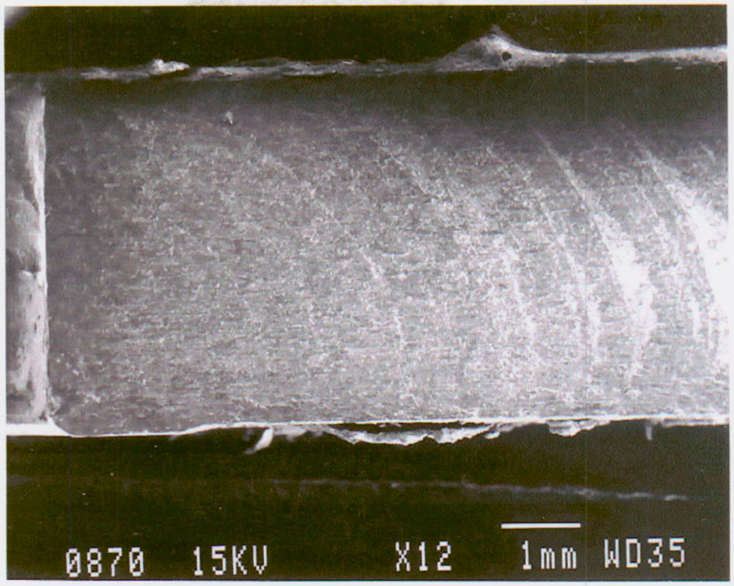
Fatigue Crack Growth in Stringer 17

Figure 10c



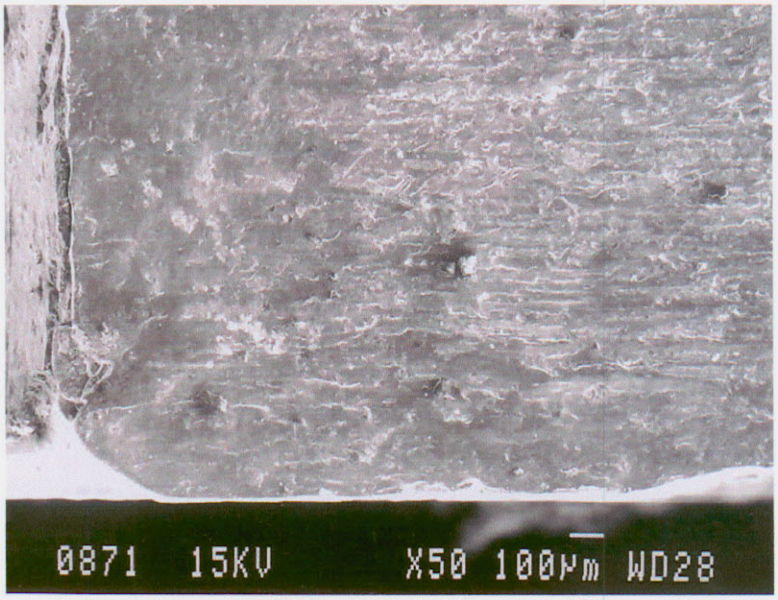
Lower Surface of Center Wing Panel

Figure 11



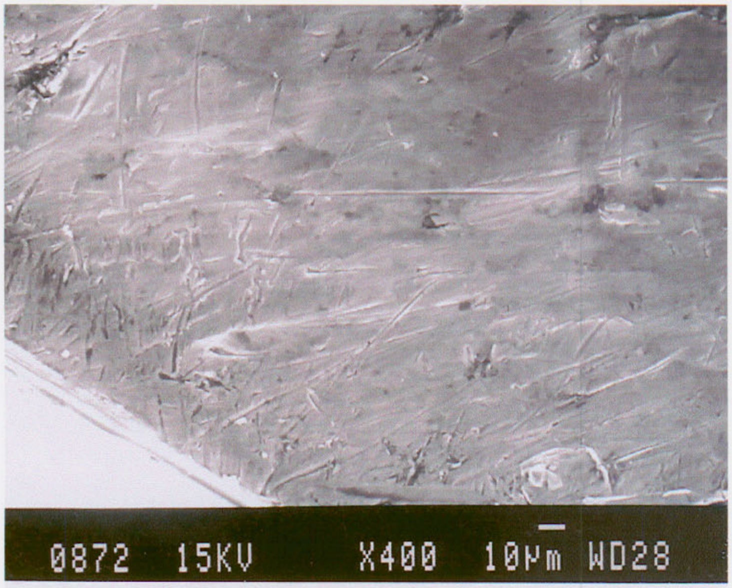
Primary Fatigue Origin "B", Forward Side of Rivet Hole

Figure 12a



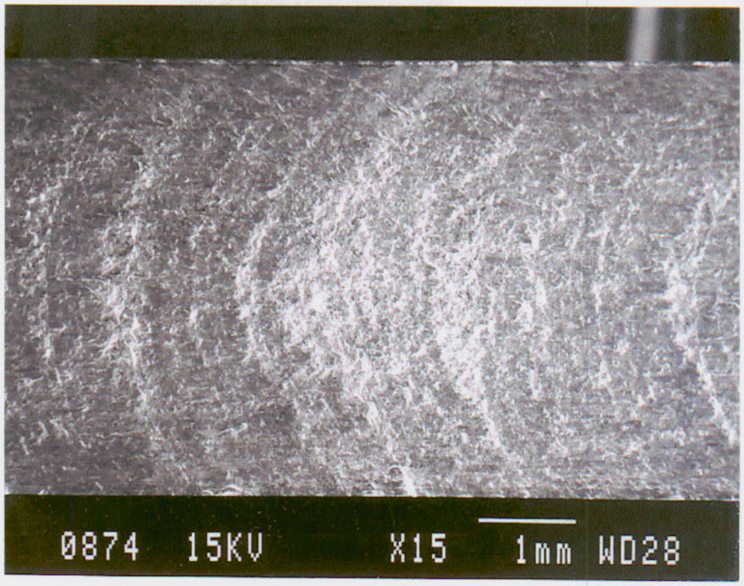
Lower Corner of Rivet Hole Shown in Figure 12a

Figure 12b



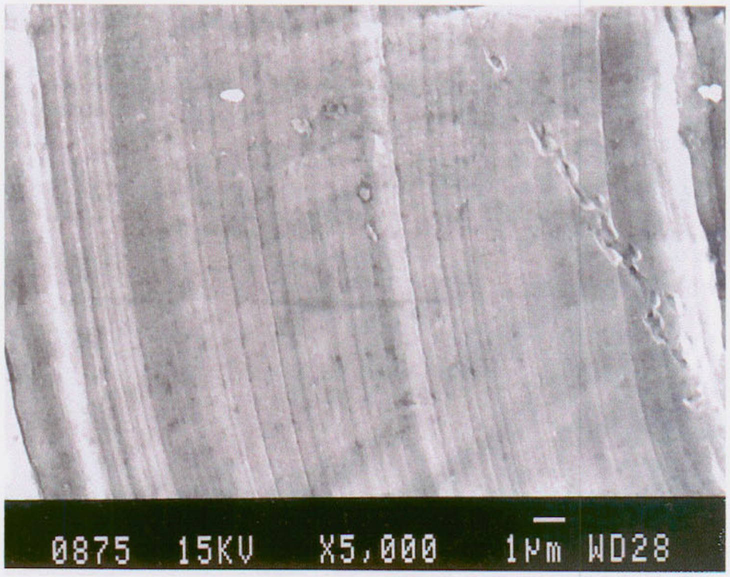
Closer View of Area in Lower Left of Figure 12b

Figure 12c

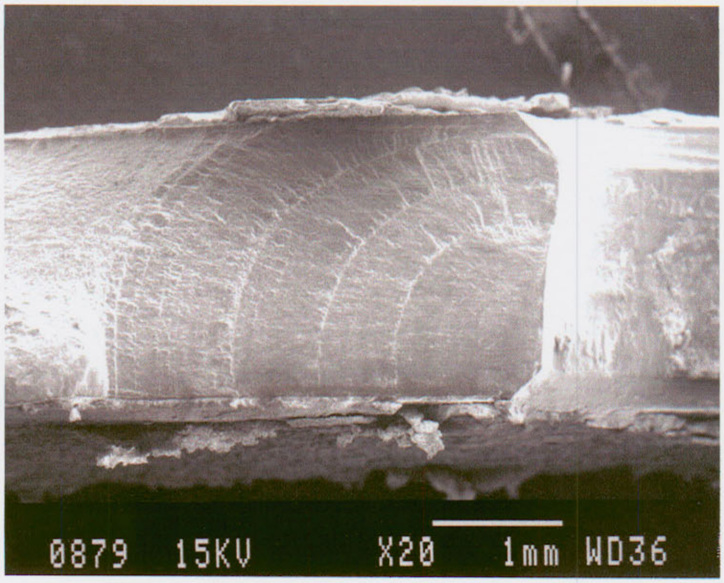


Fatigue Crack Growth in Center Skin Panel, Aft of Origin "B"

Figure 13a

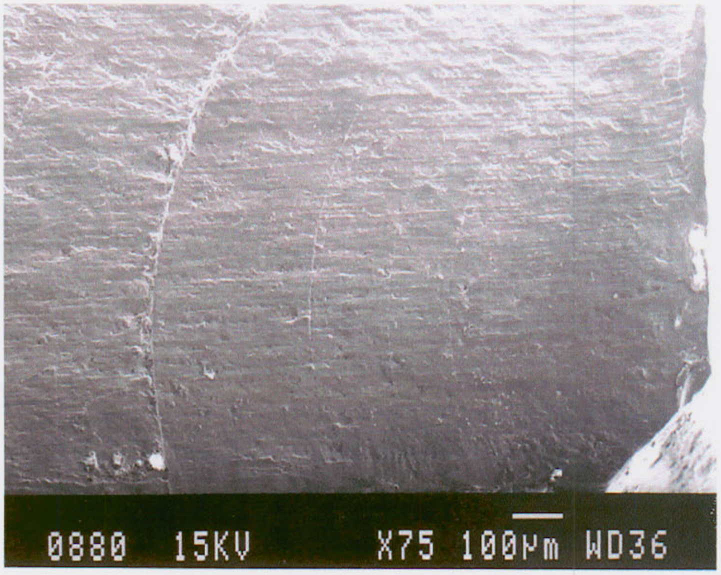


Fatigue Striations in Center of Figure 13a
Figure 13b



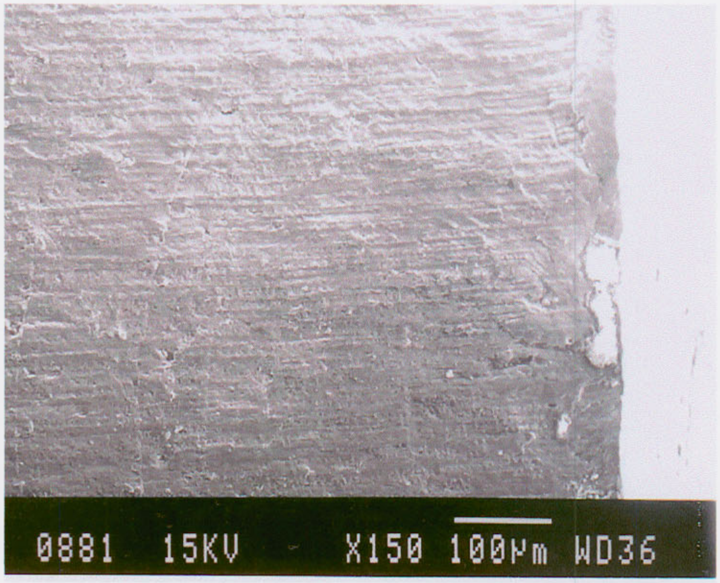
Fatigue Crack in Stringer 17 Above Primary Fatigue Origin "B"

Figure 14a



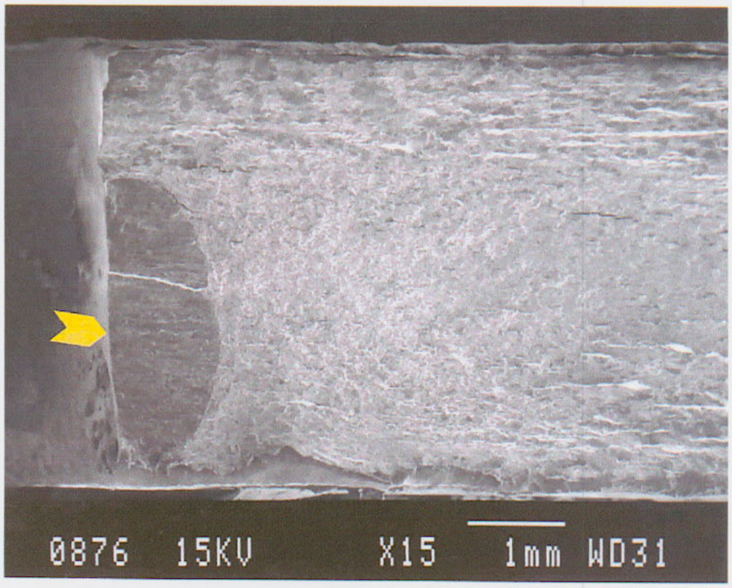
Closer View of Fracture Surface Adjacent to Rivet Hole

Figure 14b



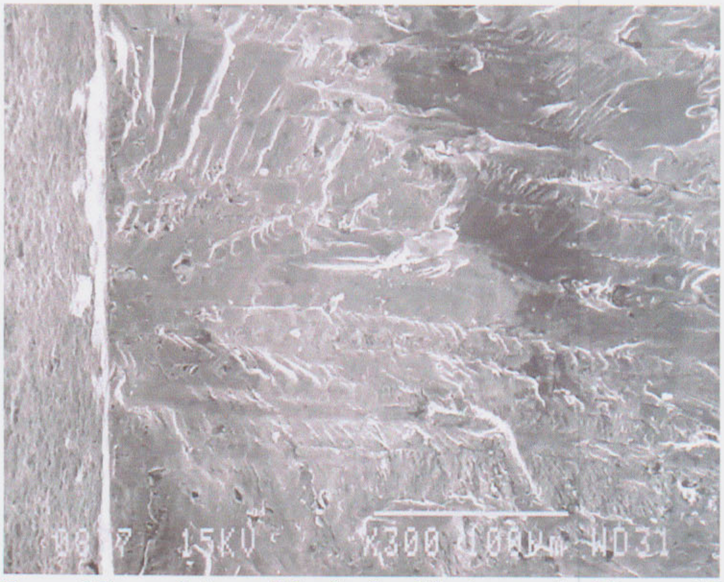
Closer View of Fracture Surface at Rivet Hole

Figure 14c



Fatigue Crack at F2 (See Figure 6), in Center Skin Panel

Figure 15a



Closer View of Area Marked with Arrow in Figure 15a

Figure 15b