

AD-A058 002

LOCKHEED-CALIFORNIA CO BURBANK

F/G 11/6

COMPARISON OF ENGINEERING PROPERTIES OF 7050-T7E73 AND 7075-T65--ETC(U)

FEB 78 R W BRODIE, L BAKOW

N62269-77-C-0024

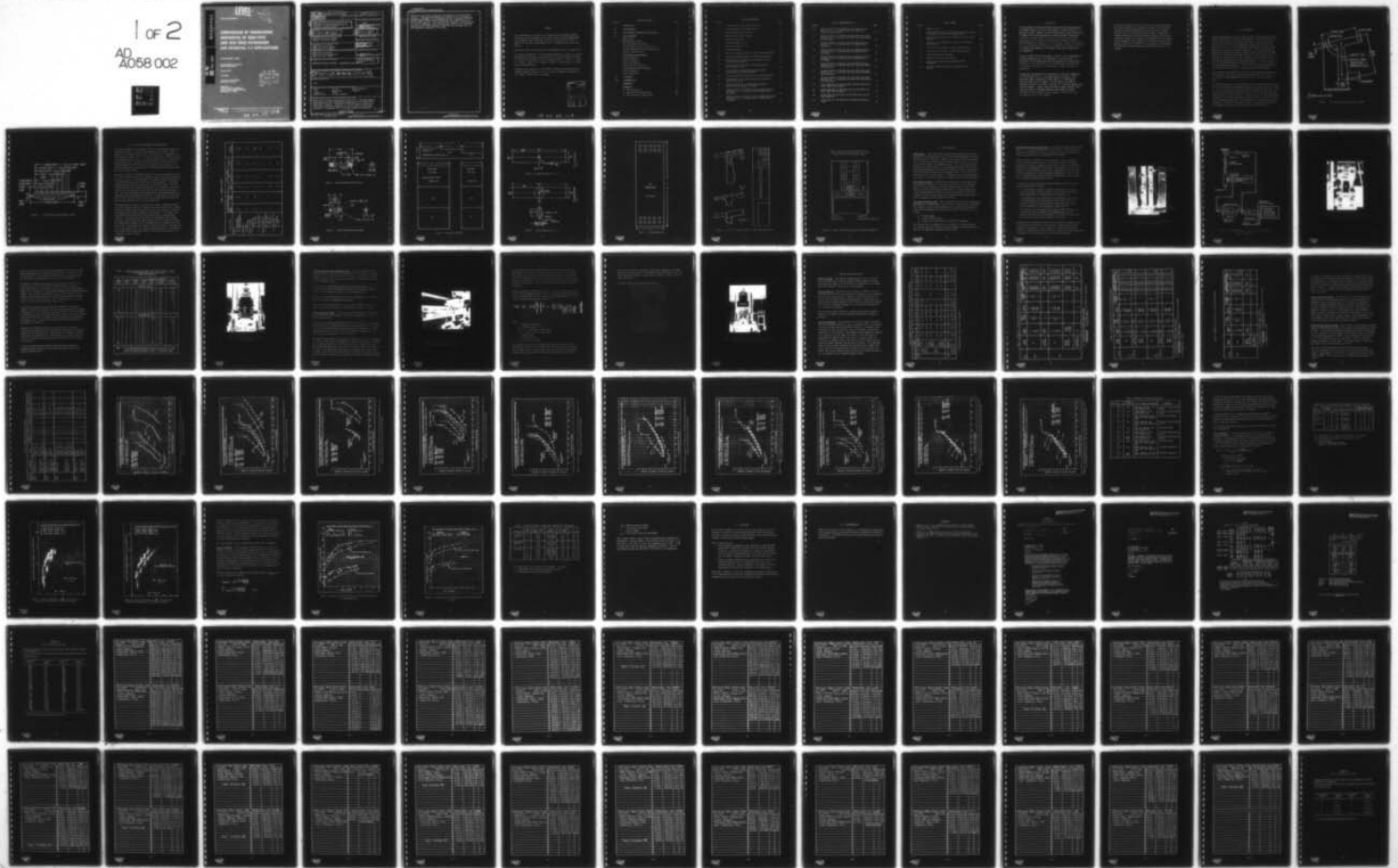
UNCLASSIFIED

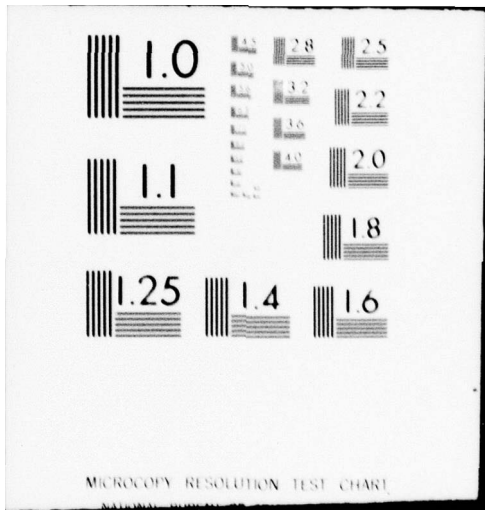
LR-28499

NADC-76269-30

NL

1 of 2
AD
A058 002





MICROCOPY RESOLUTION TEST CHART

LEVEL #

12 SC

Report NADC-76289-30

ADA058002

**COMPARISON OF ENGINEERING
PROPERTIES OF 7050-T7E73
AND 7075-T6510 EXTRUSIONS
FOR POTENTIAL P-3 APPLICATIONS**

Contract N62269-77-C-0024

Roy W. Brodie and Leon Bakow
Structures and Materials

February 1978

Final Report

Approved for Public Release
Distribution Unlimited

Prepared for
DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
Washington, D. C. 20361

DDC
RECEIVED
AUG 22 1978
RECEIVED

A

AD NO.
DDC FILE COPY



LOCKHEED-CALIFORNIA COMPANY • BURBANK
A DIVISION OF LOCKHEED CORPORATION

78 00 10 J±9

<p>18 19 REPORT DOCUMENTATION PAGE</p>		<p>READ INSTRUCTIONS BEFORE COMPLETING FORM</p>													
<p>1. AUTHOR(OR) NUMBER NADC-76269-30</p>		<p>2. GOVT ACCESSION NO.</p>													
<p>3. RECIPIENT'S CATALOG NUMBER</p>		<p>4. TITLE (and Subtitle)</p>													
<p>6. Comparison of Engineering Properties of 7050-T7E73 and 7075-T6510 Extrusions for Potential P-3 Applications.</p>		<p>5. TYPE OF REPORT & PERIOD COVERED FINAL</p>													
<p>7. AUTHOR(s) Roy W. Brodie Leon Bakow</p>		<p>6. PERFORMING ORG. REPORT NUMBER LR-28499</p>													
<p>8. AUTHOR(OR) NUMBER N62269-77-C-0024</p>		<p>7. CONTRACT OR GRANT NUMBER(s)</p>													
<p>9. PERFORMING ORGANIZATION NAME AND ADDRESS Lockheed-California Company Burbank, California 91503</p>		<p>10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A03V-3200/00HB/6F54591000</p>													
<p>11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy Naval Air Systems Command Washington, D. C. 20361</p>		<p>11. REPORT DATE Feb 78</p>													
<p>12. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Department of the Navy Naval Air Development Center Warminster, PA. 18974</p>		<p>12. NUMBER OF PAGES 11</p>													
<p>13. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED</p>		<p>13. SECURITY CLASS. (of this report) UNCLASSIFIED</p>													
<p>14. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Final Rept. 30 Nov 76 - 27 Feb 78</p>		<p>14a. DECLASSIFICATION/DOWNGRADING SCHEDULE</p>													
<p>15. SUPPLEMENTARY NOTES None</p>															
<p>16. KEY WORDS (Continue on reverse side if necessary and identify by block number)</p> <table border="0"> <tr> <td>7050</td> <td>Tensile</td> <td>Crack Propagation</td> </tr> <tr> <td>7075</td> <td>Exfoliation</td> <td>Toughness</td> </tr> <tr> <td>Aluminum</td> <td>Fatigue</td> <td></td> </tr> <tr> <td>Extruded Shapes</td> <td>Fracture Toughness</td> <td></td> </tr> </table>				7050	Tensile	Crack Propagation	7075	Exfoliation	Toughness	Aluminum	Fatigue		Extruded Shapes	Fracture Toughness	
7050	Tensile	Crack Propagation													
7075	Exfoliation	Toughness													
Aluminum	Fatigue														
Extruded Shapes	Fracture Toughness														
<p>17. ABSTRACT (Continue on reverse side if necessary and identify by block number)</p> <p>7050-T7E73 extrusion material was procured in P-3 wing spar cap and plank shapes for direct comparative testing with current 7075-T6510 production extrusions. Three lots of 7050-T7E73 were produced and processed in production facilities to be representative of actual part fabrication. Comparable 7075-T6 tensile strengths and improved</p> <p style="text-align: right;">(over)</p>															

209 970

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(cont)
→ exfoliation, and fatigue properties were obtained with the 7050-T7E73 material. Significant improvements were obtained in crack propagation in 40% R.H. and 98% R.H. environments where the crack growth threshold showed an 30% increase and the crack growth rate was 67% slower for the 7050-T7E73 material. The 7050-T7E73 also had a 60 to 70% improvement in fracture toughness at room temperature and -65°F over the 7075-T6510 material and the -65°F toughness of 7050-T7E73 was 30% higher than the room temperature toughness of 7075-T6510.

approx
mately

1473B

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This investigation was conducted by Lockheed-California Company, Burbank, California, for the Department of the Navy, Naval Air Systems Command/Naval Air Development Center under NADC Contract No. N62269-77-C-0024. Mr. E. Balmuth was the Navy Program Manager and S. J. Barber was the Contracting Officer.

This report covers work performed from 30 November 1976 to 27 February 1978.

The authors are grateful for the assistance provided by A. Chulick for tensile and exfoliation testing, D. Black for spectra fatigue and fracture testing, D. E. Pettit for assistance in fracture analysis and S. T. Chiu, C. T. Clark, S. T. Diggs, J. Ekvall, W. E. Krupp, W. Leuders, L. Silvas, and J. H. Wooley for their contributions.

The authors also appreciate the 7050-T7E73 information and data supplied by Aluminum Company of America, on a no cost basis, through the cooperation of A. S. Kuhns, P. Mehr, and R. B. Shepard.

ACCESSION No.	
NTIS	White Section <input checked="" type="checkbox"/>
DDC	Buff Section <input type="checkbox"/>
BRANDOWNER	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. NO. OR SPECIAL
A	



78 00 10 049

TABLE OF CONTENTS

Section		Page
I	INTRODUCTION	1
II	TEST MATERIALS	3
III	TEST SPECIMEN PREPARATION AND PROCESSING	6
IV	TEST PROCEDURES	14
	Tensile Test	14
	EXCO Exfoliation Tests	14
	Salt Spray Exfoliation Tests	14
	Flight-by-Flight Spectra Fatigue Tests	15
	Constant Amplitude Crack Propagation Tests	22
	Fracture Toughness Tests	22
V	TEST RESULTS AND DISCUSSION	27
	Chemical Analyses	27
	Tensile Properties	27
	Exfoliation Behavior	27
	Stress Corrosion Resistance	32
	Flight-by-Flight Spectra Fatigue	32
	Crack Propagation	45
	Fracture Toughness	49
VI	CONCLUSIONS	54
VII	RECOMMENDATIONS	55
	REFERENCES	56
	APPENDICES	
	A. Alcoa Information	A-1
	B. Spectra Fatigue Tabular Data	B-1
	C. Crack Propagation Tabular Data	C-1

LIST OF ILLUSTRATIONS

Figure		Page
1	P-3 Extruded Wing Spar Cap Shape, LS 9788	4
2	P-3 Extruded Wing Panel Shape, LS 9782	5
3	Smooth Standard Tensile Specimen	8
4	Smooth Subsize Tensile Specimen	8
5	Exfoliation Specimens	9
6	Fatigue Specimen, $K_t = 2.7$	10
7	Fatigue Specimen, $K_t = 4.0$	10
8	Toughness Specimen	11
9	Typical Test Specimen Layout for Wing Spar Cap Material	12
10	Typical Test Specimen Layout for Wing Plank Material	13
11	Spectra Fatigue Closed Loop Electro-Hydraulic Servo Controlled Test Machines	16
12	Block Diagram of Test Setup for Flight-by-Flight Spectra Fatigue Tests	17
13	Close-up View of Specimen Installation Showing Anti-Buckling Bar Support Assembly	18
14	Crack Propagation Test Set-Up of 16 Inch Wide Specimen	21
15	Close-Up View of Test Set-Up Showing Anti-Buckling Bars and Microscope	23
16	Typical Test Set-Up of -65°F Fracture Toughness Specimen Showing Chamber in Position	26
17	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 2.7$, Machine, Etch and Chemical Film Processing	34
18	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 2.7$, Machine, Etch and Chemical Film Processing	35

LIST OF ILLUSTRATIONS (Cont.)

Figure		Page
19	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 2.7$, Machine, Shot Peen, Etch and Chemical Film Processing	36
20	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 2.7$, Machine, Shot Peen, Etch and Chemical Film Processing	37
21	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 4.0$, Machine, Etch and Chemical Film Processing	38
22	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Etch and Chemical Film Processing	39
23	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Etch and Chemical Film Processing	40
24	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing	41
25	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing	42
26	Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing	43
27	Crack Growth Rate vs $\Delta\bar{K}$, 7075-T6510 and 7050-T7E73 Wing Plank, 98% Relative Humidity	47
28	Crack Growth Rate vs $\Delta\bar{K}$, 7075-T6510 and 7050-T7E73 Wing Plank, 40% Relative Humidity	48
29	R-Curve Data for 7075-T6510 and 7050-T7E73 Wing Plank at Room Temperature	50
30	R-Curve Data for 7075-T6510 and 7050-T7E73 Wing Plank at -65°F	51

LIST OF TABLES

Table		Page
1	Summary of Tests	7
2	Flight-by-Flight Fatigue Test Upper Surface Stress Spectra (P-3A Operational Mission Mix: SLEP, Part I)	20
3	Chemical Compositions of 7050-T7E73 and 7075-T6510 Test Materials	28
4	Properties of 7050-T7E73 and 7075-T6510 P-3 Wing Spar Cap Extrusions	29
5	Properties of 7050-T7E73 P-3 Wing Plank Extrusions	30
6	Properties of 7075-T6510 P-3 Wing Plank Extrusions	31
7	Spectra Fatigue Test Specimens	33
8	Comparison of Fatigue Test Results	44
9	List of Crack Propagation Specimens and Test Conditions	46
10	Fracture Toughness Specimen Test Conditions and Results	52

I. INTRODUCTION

The high strength 7000 series aluminum alloys have been used extensively in airframe construction due to their strength to weight ratios and low fabrication costs. However, the 7000 series alloys in their high strength T6 temper conditions are susceptible to stress corrosion cracking and exfoliation. An improvement of the stress corrosion and exfoliation resistance of the T6 conditions was obtained by reaging at higher (325 - 350°F) temperatures to produce T73 and T76 tempers. However, this improvement was accompanied by a reduction in strength which prevents 7075-T73 or T76 material from replacing 7075-T6 parts unless lower strengths can be accommodated.

Efforts to retain the static strength of 7075-T6, with an improvement in corrosion resistance led to the development of the 7050 alloy. In particular, 7050 extrusions have shown the potential for being a direct substitute for 7075-T6 extrusions on a strength basis while providing a significant improvement in the resistance to stress corrosion and exfoliation.

Lockheed has considered 7050-T76 extrusions as a potential replacement for the extruded 7075-T6 P-3 wing spar caps and wing skins. This potential caused considerable in-house testing to be performed on various extruded 7050-T76 shapes. The test results confirmed an improved combination of strength, corrosion resistance and toughness over the 7075 material. However, additional data on spectra fatigue, crack growth and fracture toughness properties were needed to provide information for performing structural analyses. The need for these data was the basis for this program.

During the development of the 7050 alloy, the T76 temper extrusions had typical properties which generally exceeded 7075-T6 minimums; however, the established guaranteed tensile and yield strength properties were 2 Ksi below the 7075-T6 minimums. Negotiations between Lockheed and the Aluminum Company of America (Alcoa) were conducted to obtain 7050 extrusions with guaranteed 7075-T6 minimum tensile properties. This resulted in a new temper currently designated as T7E73, which included the 510 stretcher level processing. The extruded 7050-T7E73 material was procured and tested in this program.

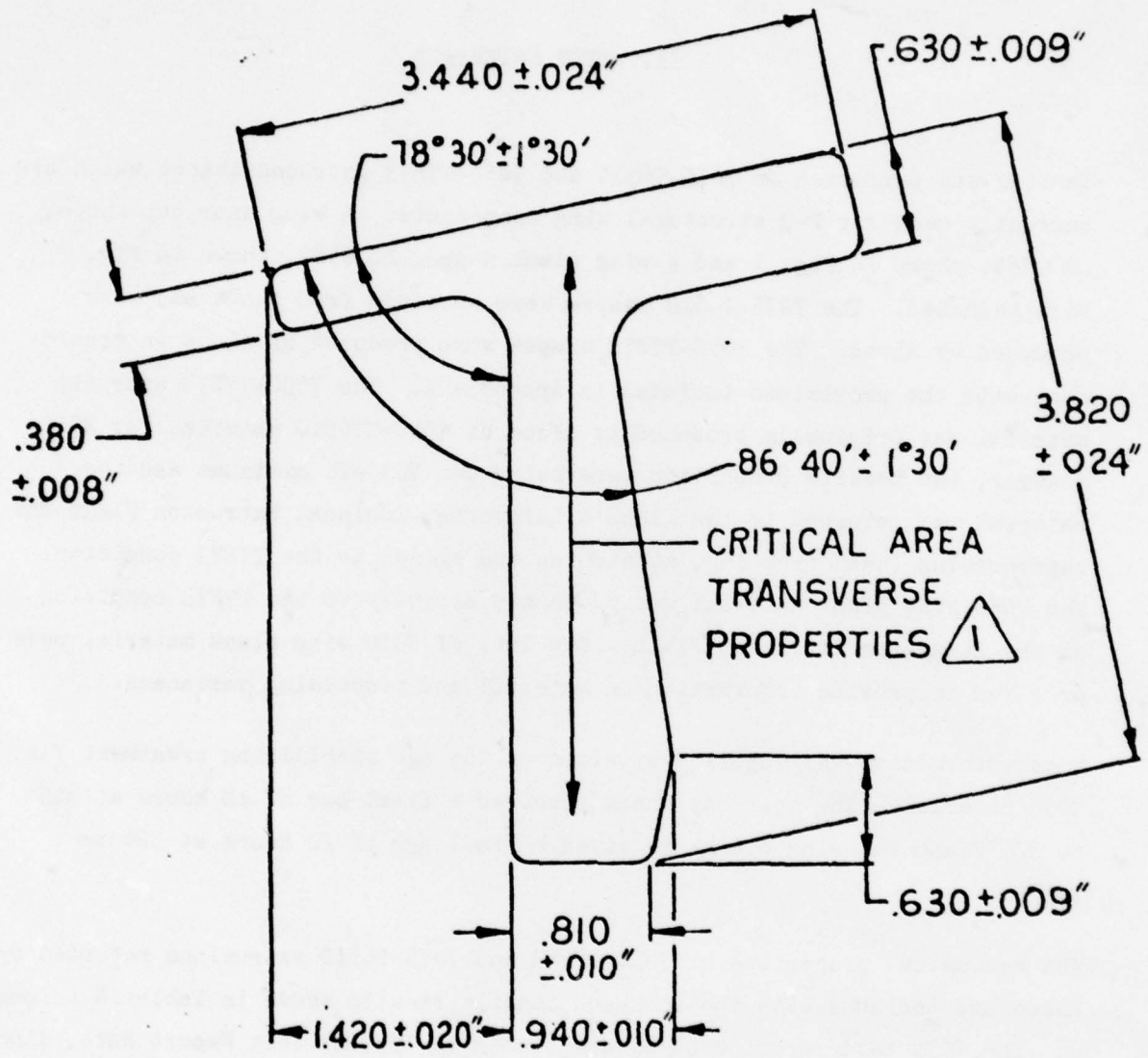


II. TEST MATERIALS

Testing was performed on 7075-T6510 and 7050-T7E73 extruded shapes which are currently used for P-3 structural wing components. A wing spar cap shape, LS 9788, shown in Fig. 1 and a wing plank shape, LS 9782, shown in Fig. 2 were selected. The 7075-T6510 shapes were obtained from stock and were produced by Alcoa. The 7050-T7E73 shapes were produced by Alcoa in accordance with the provisions included in Appendix A. The 7050-T7E73 spar cap material was originally produced by Alcoa as 7050-T76510 material for NADC. However, the tensile properties were below the 7075-T6 minimums and the material was returned to the Alcoa's Lafayette, Indiana, Extrusion Plant for reprocessing (heat treating, stretching and aging) to the T7E73 condition. The 7050 wing plank material was processed directly to the T7E73 condition at the Lafayette Extrusion Plant. Two lots of 7050 wing plank material were procured to provide information on material and processing variances.

Some information was supplied by Alcoa on the age stabilizing treatment for 7050 material. The spar cap shape received a final age of 18 hours at 315 to 325°F and the wing planks received a final age of 22 hours at 320 to 330°F.

The mechanical properties of 7050-T7E73 and 7075-T6510 extrusions reported by Alcoa are included with the Lockheed tensile results shown in Tables 4 through 6. The 7075 test report results are listed as Typical Test Report data, since stock is intermixed and the exact test report could not be matched with the pieces used for this test program. In addition to the 7050 test report data, pieces of the 7050-T7E73 wing plank extrusions were sent to Alcoa's Technical Center for additional testing. Data transmitted to Lockheed are contained in Appendix A. These results are also included in the appropriate tables with the Lockheed results and are identified as Alcoa Tech Center data.



△ PER LAC 04-551

Figure 1 P-3 Extruded Wing Spar Cap Shape, LS 9788



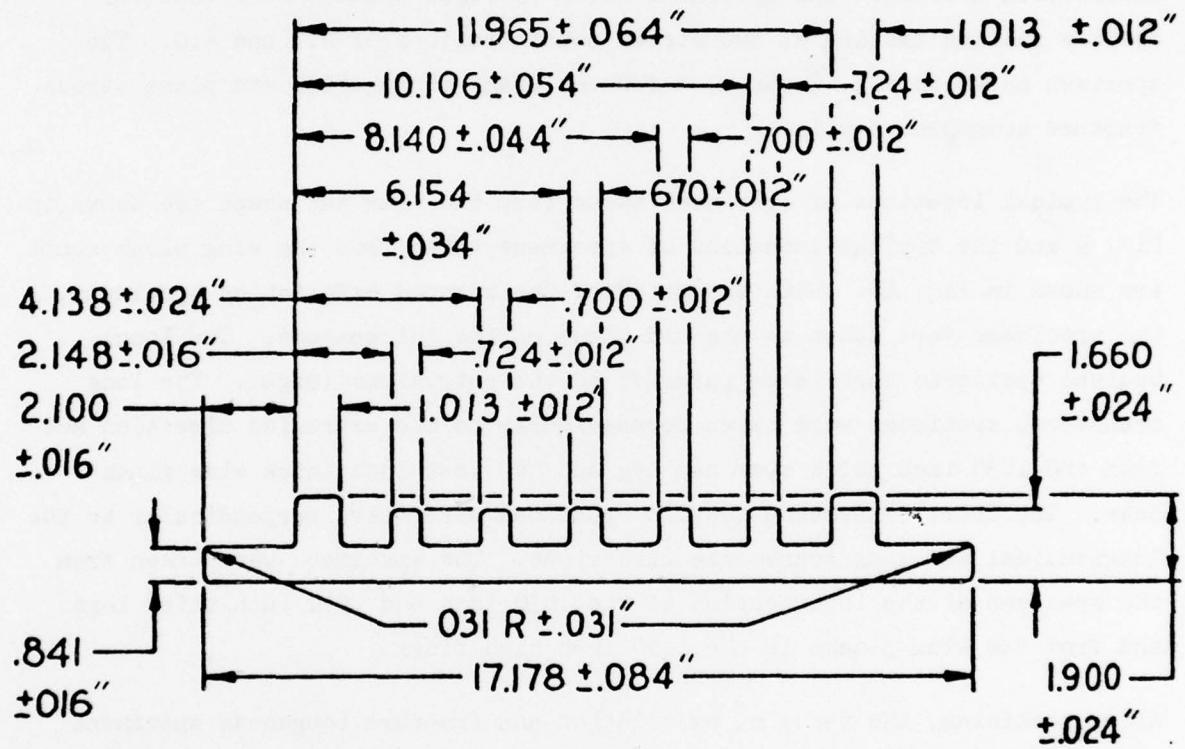


Figure 2 P-3 Extruded Wing Panel Shape, LS 9782

III. TEST SPECIMEN PREPARATION AND PROCESSING

The types and quantities of specimens tested for each material variable are summarized in Table 1. The specimen configurations are shown in Figs. 3 through 8. The specimen shown in Fig. 3 was used for the longitudinal and long transverse tensile tests. The specimen shown in Fig. 4 was used for the short transverse tensile tests. The specimens shown in Fig. 5 were used for exfoliation testing. The specimens shown in Figs. 6 and 7 were used for spectra fatigue testing at two stress concentrations of 2.7 and 4.0. The specimen shown in Fig. 8 was used for the crack propagation and plane stress fracture toughness testing.

The typical locations of specimens taken from the spar cap shape are shown in Fig. 9 and the typical locations of specimens taken from the wing plank shape are shown in Fig. 10. With exception of the stepped exfoliation specimens, the specimens were taken at the mid plane of the thicknesses. The longitudinal specimens were taken parallel to the extrusions length. The long transverse specimens were taken perpendicular to the extrusion direction and from the .630 inch thick spar cap leg and the .841 inch thick wing plank base. The short transverse tensile specimens were taken perpendicular to the longitudinal and long transverse directions. The specimens were taken from the spar cap at the intersection of the .630 inch and .940 inch thick legs and from the wing planks in the 1.90 inch high riser.

After machining, the tensile, exfoliation and fracture toughness specimens received no further processing. Subsequent processing of the spectra fatigue specimens included etching followed by chemical film treatment or saturation shot peening plus etching and chemical film treatment. The fatigue stress concentration notches were drilled and reamed after all processing was completed. This processing was performed in Lockheed-California Company production facilities with the same procedures as used to produce P-3 parts. The chemical film treatment was in accordance with LAC C-0498D(2) which meets MIL-C-5541A. The specimens were given an alkaline etch prior to the application of the chemical film. The saturation shot peening was in accordance with LAC C-1476C(4) which meets MIL-S-13165C. SAE 230 size shot was used at an intensity of 0.003 to 0.008A.



TABLE 1 - SUMMARY OF TESTS

Type of Test	P-3 Wing Spar Cap		P-3 Wing Plank			Total Specimens
	7075-T6510	7050 T7E73	7075 T6510	7050 T7E73 Lot A	7050 T7E73 Lot B	
Tensile						
a) Longitudinal	2	2	2	2	2	10
b) Long Transverse	2	2	2	2	2	10
c) Short Transverse	2	2	2	2	2	10
Exfoliation						
a) EXCO	1	1	1	1	1	5
b) Salt Spray	1	1	1	1	1	5
Spectra Fatigue						
a) Longitudinal	4	4	4	4	4	20
1) $K_t = 2.7$	4	4	4	4	4	20
2) $K_t = 4.0$						
b) Long Transverse	-	-	4	4	4	12
1) $K_t = 4.0$						
Fracture Properties						
a) Crack Propagation	-	-	2	1	1	4
to 2 a/w $\approx .35$						
1) Lab Air	-	-	2	1	1	4
2) Humid Air						
b) Plane Stress for			4	2	2	8
2 a/w $\approx .35$						
1) Room Temp	-	-	4	2	2	4
2) -65°F						

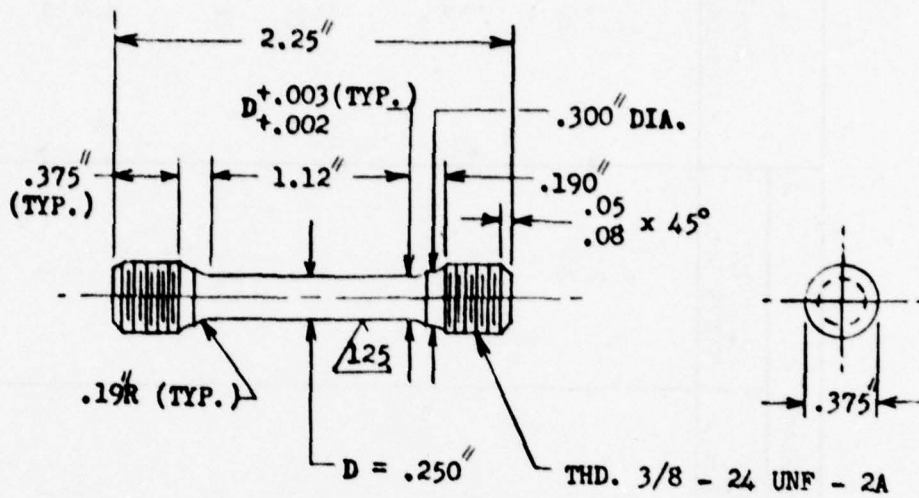


Figure 3 Smooth Standard Tensile Specimen

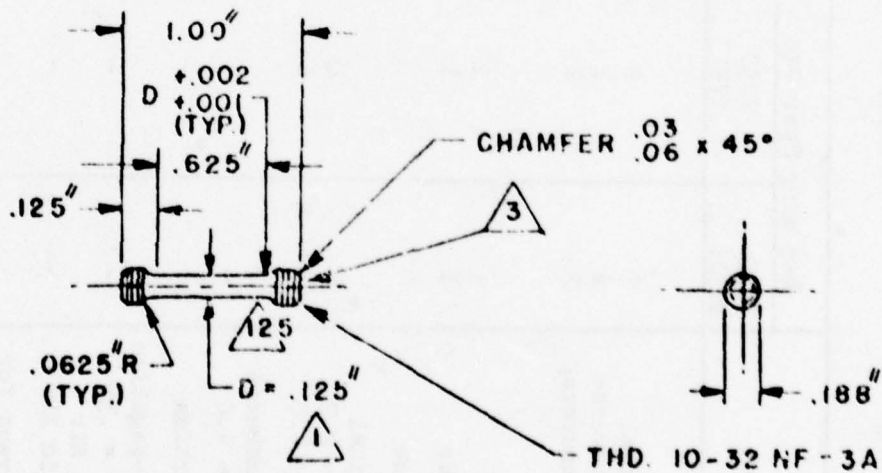


Figure 4 Smooth Subsize Tensile Specimen

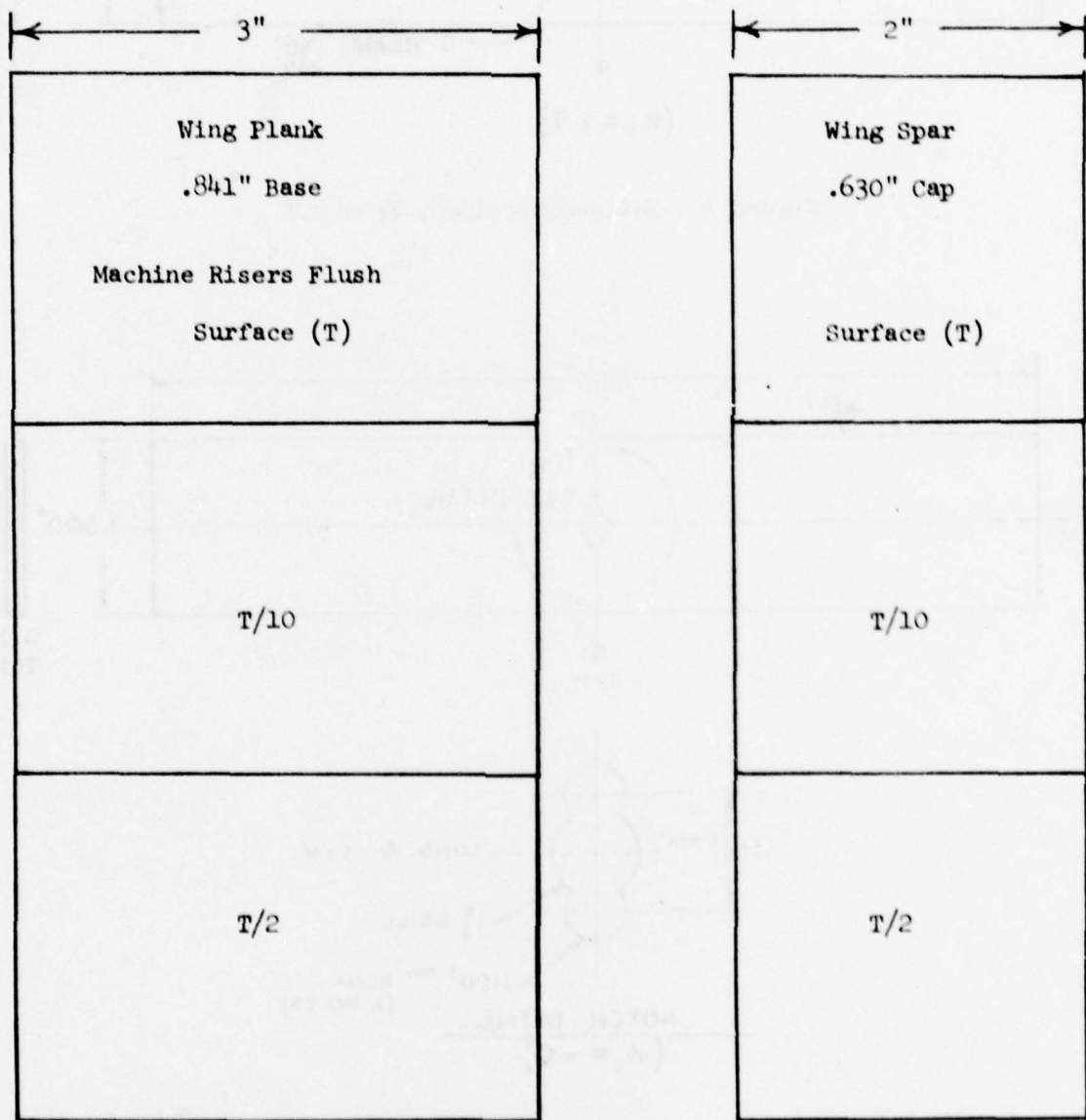
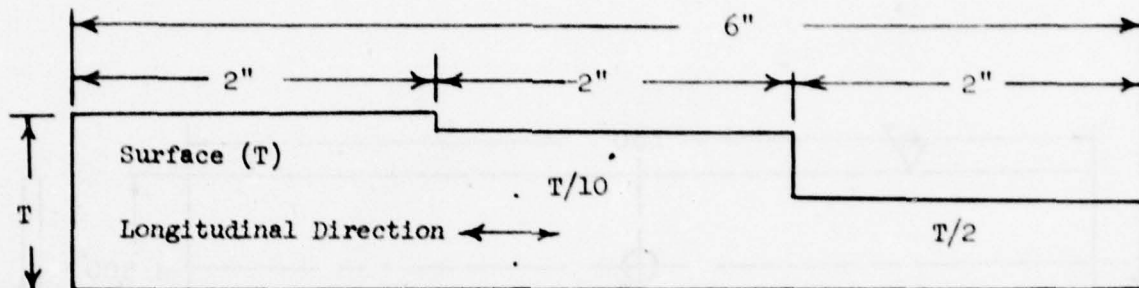


Figure 5 Exfoliation Specimens

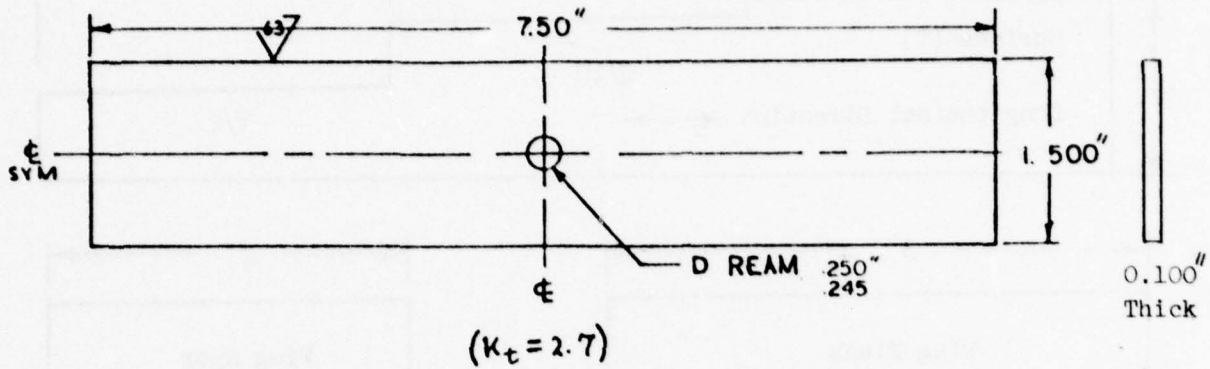


Figure 6 Fatigue Specimen, $K_t = 2.7$

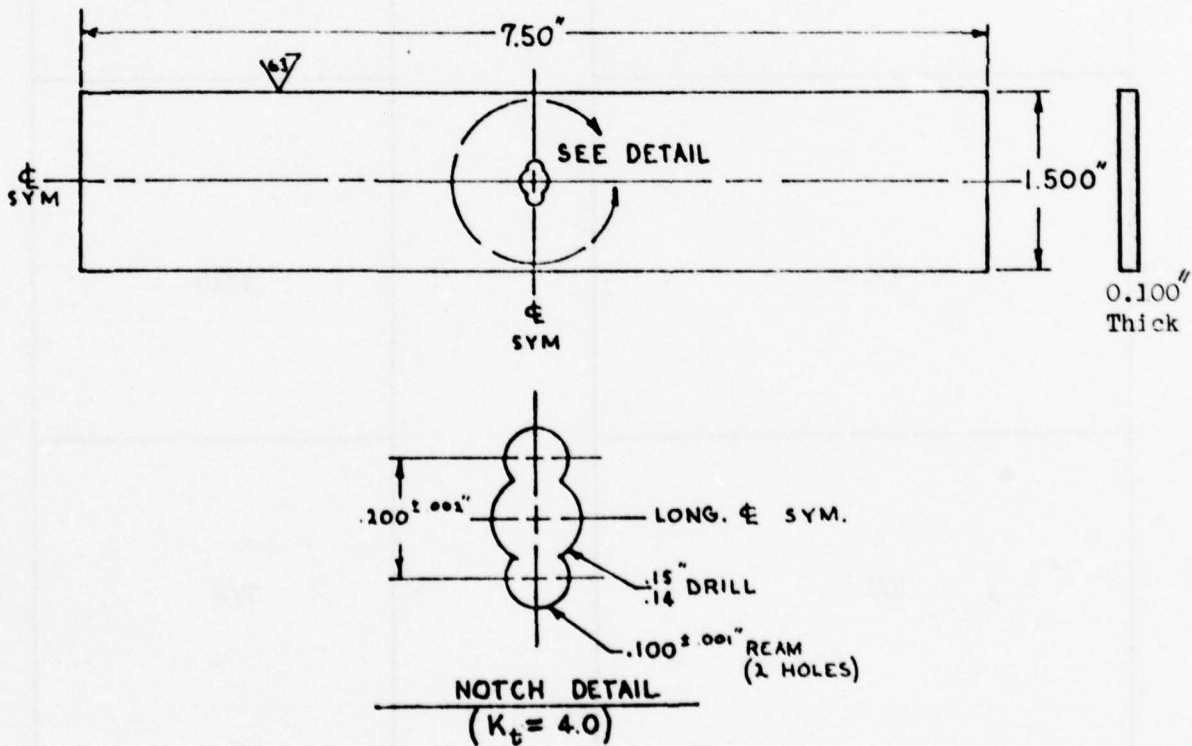


Figure 7 Fatigue Specimen, $K_t = 4.0$

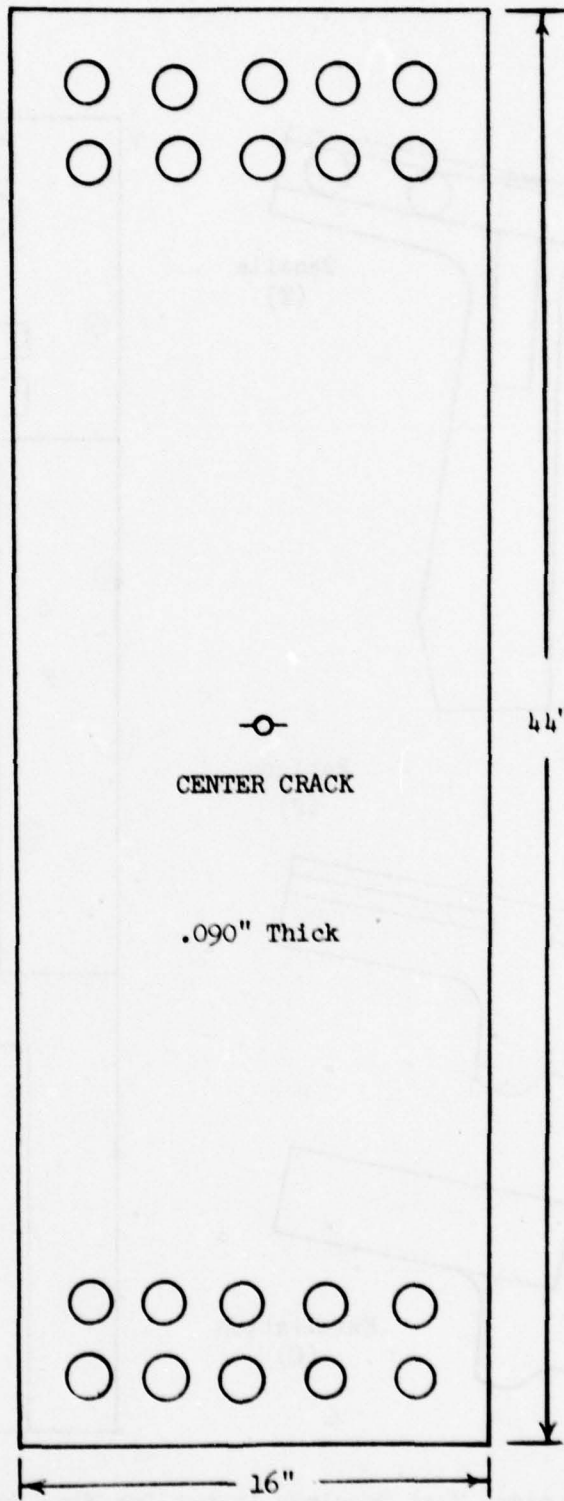


Figure 8 Toughness Specimen

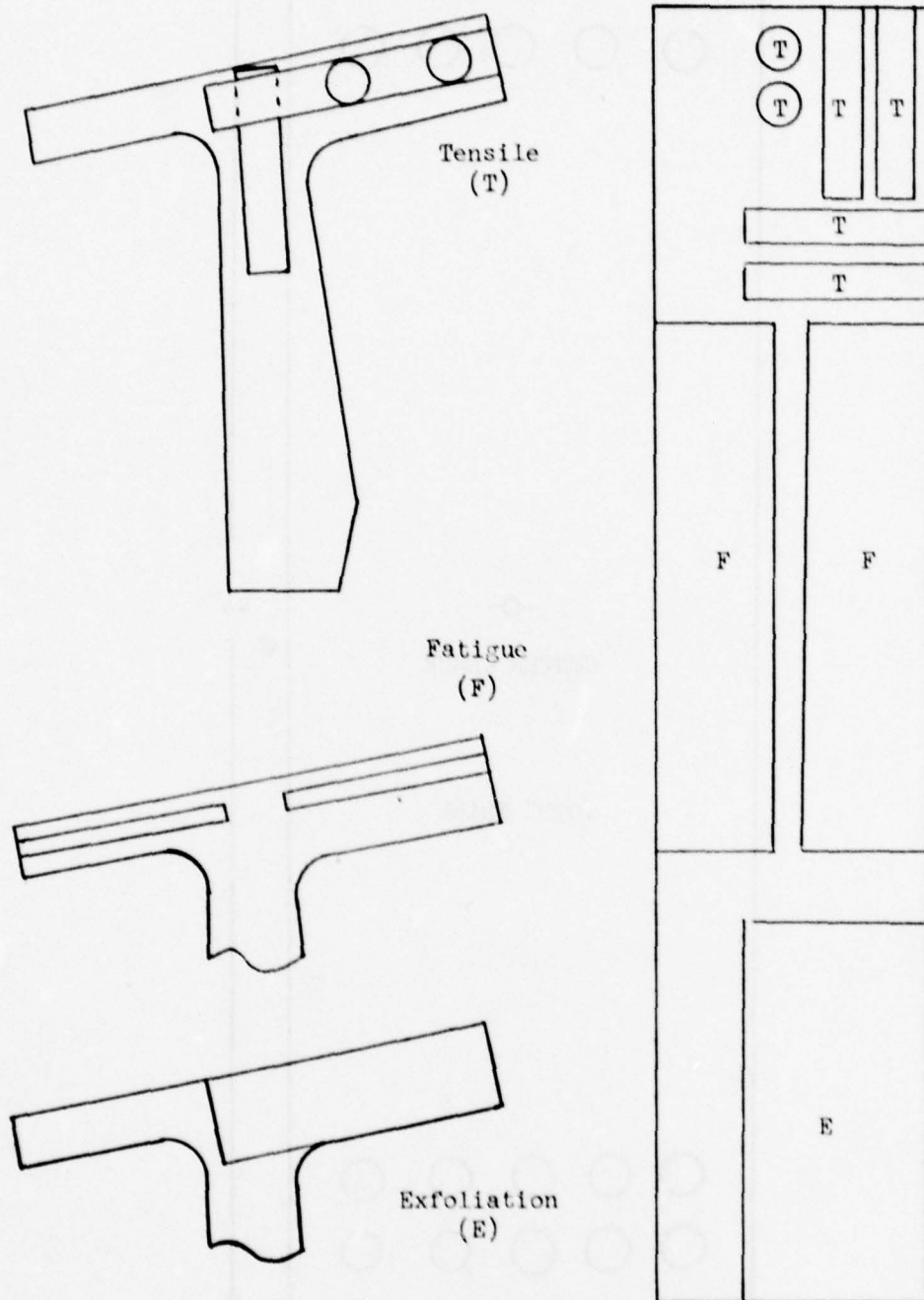
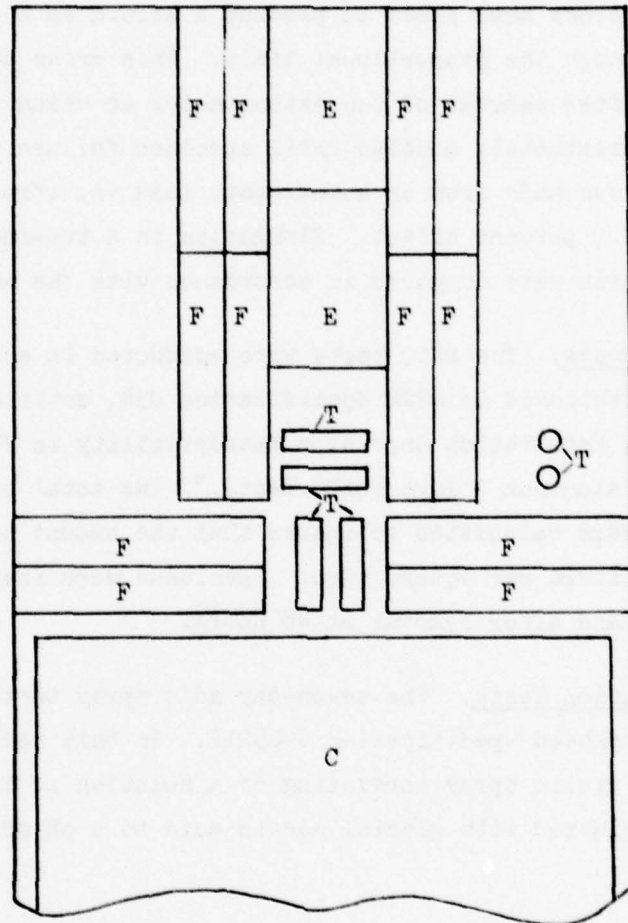


Figure 9 Typical Test Specimen Layout for Wing Spar Cap Material



Tensile (T)

Fatigue (F)

Exfoliation (E)

Crack Growth/Toughness (C)

Figure 10 Typical Test Specimen Layout for Wing Plank Material

IV. TEST PROCEDURES

Tensile Tests. Tensile tests were conducted in accordance with procedures established in ASTM Specification E8, entitled "Standard Methods of Tension Testing of Metallic Materials". Speed of testing was controlled by adjustment to a machine cross head speed to produce a strain rate of .005 in. per in. per minute through the proportional limit. This cross head speed was maintained until after removal of the extensometer at which time the cross head speed was approximately doubled until specimen failure. Determination of yield strength was made from an autographic load vs. strain curve and was specified as 0.2 percent offset. Elongation in a two-inch gauge length and reduction of area were computed in accordance with the ASTM procedures.

EXCO Exfoliation Tests. The EXCO tests were conducted in accordance with the procedures established in ASTM Specification G34, entitled "Standard Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper Containing Aluminum Alloys (EXCO Test)." The total surface areas of the specimens were calculated to insure that the amount of solution exceeded 50 milliliters per square inch. Specimens were inspected after 24 hours of exposure and after removal at 48 hours.

Salt Spray Exfoliation Tests. The seven-day salt spray test was conducted in accordance with Lockheed Specification C-0521F. In this test, the specimens were exposed to a cyclic spray consisting of a solution of five percent sodium chloride adjusted with glacial acetic acid to a pH of 3.0 to 3.1 as follows:

- a) 45 minute spray
- b) 2 hours of dry air purge
- c) 3 hours and 15 minute soak at 45-95% relative humidity

The six-hour cycle is repeated for a total period of 7 days (28 cycles). The specimens were then rinsed in water and immersed in concentrated nitric acid at room temperature followed by a water rinse.

Flight-by-Flight Spectra Fatigue Tests. The flight-by-flight spectra fatigue tests of 1.5 inch wide specimens were conducted on two ten thousand pound closed loop electrohydraulic servo controlled test machines which were designed and constructed by the Lockheed-California Company.

Figure 11 shows the installation of two specimens in the test machines, which are numbered channels 3 and 4 and are side-by-side to facilitate monitoring of incipient cracking and crack growth. Figure 12 schematically illustrates the arrangement of a test machine and magnetic tape load programmer. In the installation used in this program, the two machines were in parallel and were run by two independent programmers with only one tape deck. In these machines, loads can be controlled within a scale accuracy of ± 2 percent at frequencies up to 45 Hz.

As indicated in Figure 12 the loading system employed the following safeguards against specimen overload.

1. A load limiter was included to protect the specimens from spurious electrical signals as well as operator error by simply limiting the maximum amplitude of the signals to the pre-selected value.
2. A high-speed dump valve, located across the hydraulic lines between the servo valve and the servo jack protected the specimens from overload in the event of internal valve leakage from the hydraulic pressure reservoir to the high pressure side of the jack.
3. A high-speed relay was located within the servo valve amplifier. In the event the rate of increase in the command signal would have exceeded that which had been programmed, this relay would have locked the servo valve and opened the high-speed dump valve.

Specimens were restrained from buckling under compression loadings by using an anti-buckling bar support on the specimens. Figure 13 shows the bars installed on a specimen. Contact between the specimen and bar support assembly is through teflon and the assembly is installed by finger tightening to preclude any load being carried by the anti-buckling assembly.

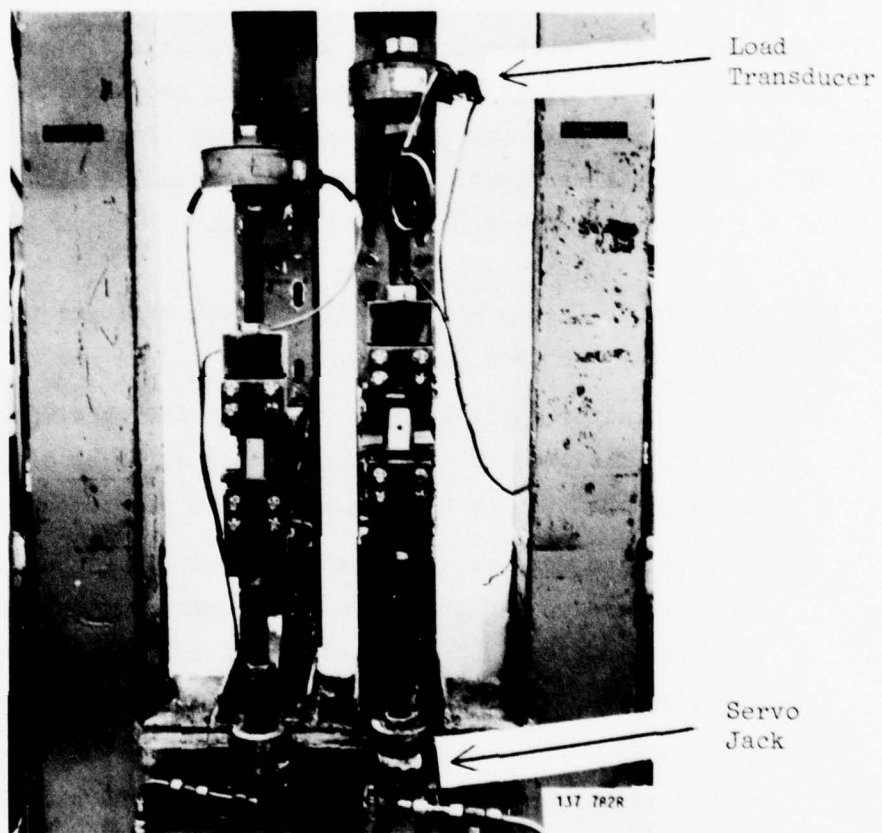


Figure 11 Spectra Fatigue Closed Loop Electro-Hydraulic
Servo Controlled Test Machines

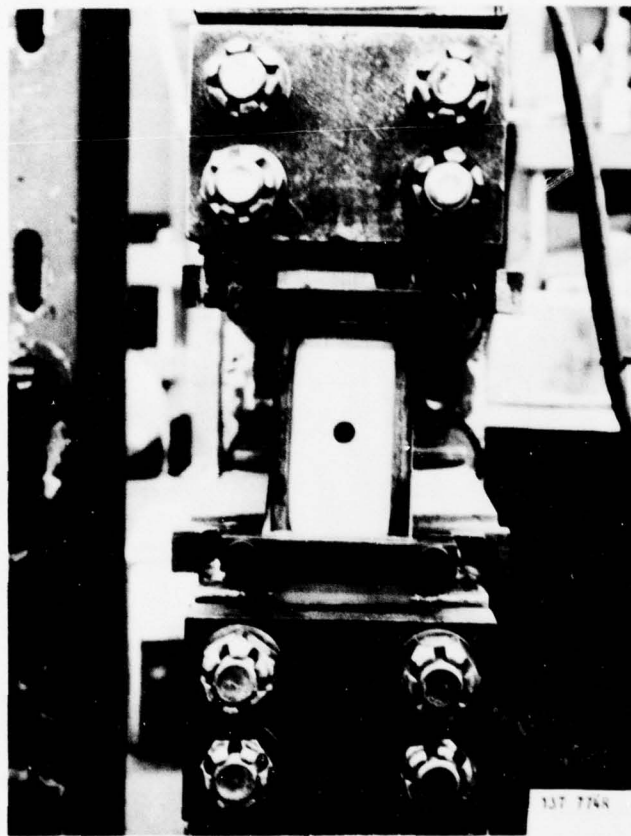


Figure 13 Close-up View of Specimen Installation Showing
Anti-Buckling Bar Support Assembly

During the testing, the specimens were examined at least every 1000 flights using a magnifying glass to detect incipient cracking. During the period of crack growth, a finely graduated ruler was read by a magnifying glass at intervals which were dependent upon the rate of crack growth.

The spectra of fatigue loadings used in this testing were derived from operational service loading records for the P-3A Fleet as a part of Contract N00019-76-A-001, Order No. KZ34, "Service Life Extension Program (SLEP) Part I", (Reference 1), which was performed at the Lockheed-California Company. This spectra is appropriate for use in this program, as it is basically the spectra to which the 7050-T7E73 material would be subjected if used in the P-3 series aircraft. Table 2 lists the gross area stress loads of the P-3A test spectra taken from Reference 1.

To preclude the fatigue test specimens being subjected to very large numbers of flights in the testing, the test spectra loadings were increased in magnitude by 15 to 30 percent to shorten the flights to crack initiation. In the tables and plots of the test data, this increase is noted as a stress factor (S.F.), by which all loadings in the spectra have been multiplied. For example, S.F. = 1.30 means all loadings have been multiplied by 1.30 (increased by 30 percent).

Specimens were generally selected for testing in pairs, one each of 7075-T6510 and 7050-T7E510 with the same stress concentration, processing, product form and grain direction. This procedure was adopted to minimize the effects of load variability. Additionally, each alloy pair was positioned in the test fixture to minimize any biasing effect due to position in the fixture.

All of the flight-by-flight spectra fatigue tests were conducted in laboratory ambient conditions at room temperature (R.T.) and $40 \pm 10\%$ relative humidity (R.H.).

TABLE 2 FLIGHT-BY-FLIGHT FATIGUE TEST UPPER SURFACE STRESS SPECTRA
(P-3A OPERATIONAL MISSION MIX: SLEP, PART I)
(GROSS AREA STRESSES)

MEAN STRESS (KSI)	± CYCLIC STRESS (KSI)	MAXIMUM STRESS (KSI)	MINIMUM STRESS (KSI)	NORMALIZED STRESSES		CYCLES* APPLIED IN 4000 FLTS.		
				MEAN 21.2	± CYCLIC 21.2			
TAXI AND LANDING								
3.8 ↑ ↓ 3.8	4	7.8	- 0.2	0.179 ↑ ↓ 0.179	0.189	17,500		
	5	8.8	- 1.2		0.236	14,000		
	6	9.8	- 2.2		0.283	4,400		
	7	10.8	- 3.2		0.330	1,100		
	8	11.8	- 4.2		0.377	340		
	9	12.8	- 5.2		0.425	100		
	10	13.8	- 6.2		0.472	38		
	11	14.8	- 7.2		0.519	13		
	12	15.6	- 8.2		0.566	5		
	13	16.8	- 9.2		0.613	4		
	MANEUVERS AND GUST							
	-7.2 ↑ ↓ -7.2	4	- 3.2		-11.2	-0.340 ↑ ↓ -0.340	0.189	17,500
		5	- 2.2		-12.2		0.236	3,500
6		- 1.2	-13.2	0.283	930			
7		- 0.2	-14.2	0.330	330			
8		+ 0.8	-15.2	0.377	130			
9		1.8	-16.2	0.425	65			
10		2.8	-17.2	0.472	24			
11		3.8	-18.2	0.519	10			
12		4.8	-19.2	0.566	6			
13		5.8	-20.2	0.613	4			
14		6.8	-21.2	0.660	4			
<p>NOTE: * 1000 flight random cycle tape made which is applied four times to get the specified number of cycles in this column in 4000 flights containing an average of about 15 cycles per flight.</p>								



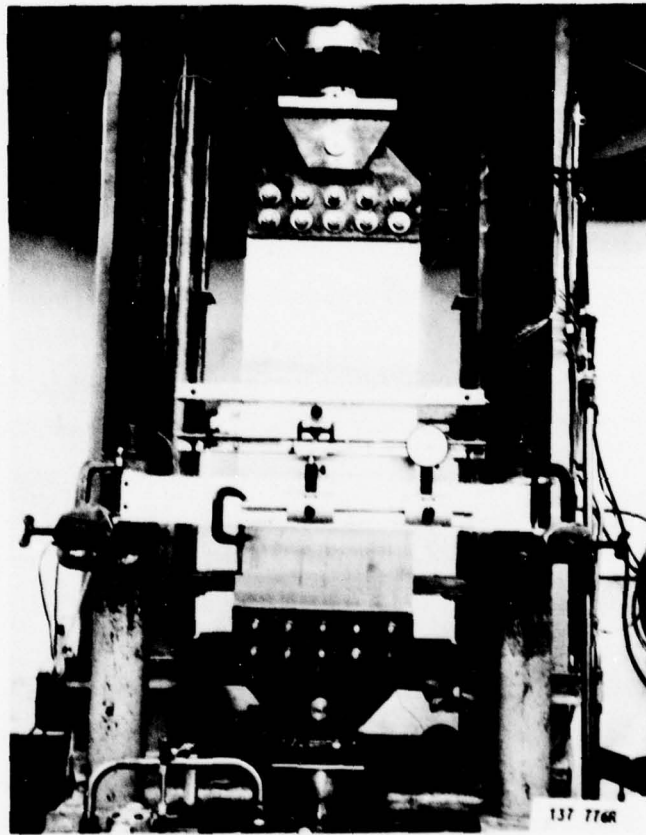


Figure 14 Crack Propagation Test Set-Up of
16 Inch Wide Specimen

Constant Amplitude Crack Propagation Tests. The crack propagation data were generated on closed-loop electro-hydraulic test machines at a loading frequency of 6 Hz. and a stress ratio of $R = +0.10$. Ambient air at $\approx 40\%$ relative humidity (R.H.) and moist air at $\approx 98\%$ R.H. environments were used at room temperature (R.T.).

To prevent out-of-loading-plane distortion of the test specimen in the vicinity of the crack, anti-buckling bars were attached approximately two inches above and below the crack as shown in Figs. 14 and 15.

Crack length readings were taken using optical techniques. Fig. 15 shows the 75 X10 micrometer microscope that was used.

Various gross stress levels were used to propagate cracking from the 2.0 inches long manufactured notch to crack lengths of 5.3 and 5.6 inches.

Fracture Toughness Tests. All fracture toughness (R-Curve) test procedures followed ASTM E 561-76T, entitled, "Tentative Recommended Practice for R-Curve Determination."

The fatigue precracking was conducted at 6 Hz in closed-loop electrohydraulic universal machines in laboratory air and at a stress ratio = $+0.1$. The maximum load was decreased so that a final value of ΔK of less than $20 \text{ ksi}\sqrt{\text{in}}$. was maintained for the last 0.5 inch of crack growth to assure that a flat initial crack was developed for the fracture test.

All static fracture tests were conducted in laboratory air at room temperature or -65°F in a closed-loop electrohydraulic universal test machine. A loading rate of approximately 50,000 pounds/minute was used. Antibuckling guides were located approximately one inch above and below the plane of the crack in all tests. Two displacement gages were used to measure crack opening displacement, one on each side of the specimen. The gages used were the clip-on double cantilever type described in ASTM E 399, entitled "Standard Test Method

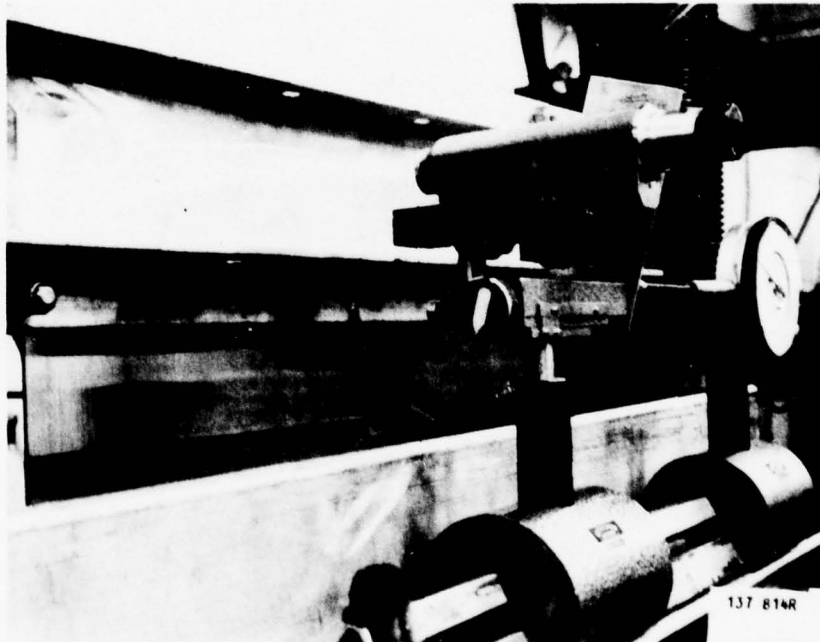


Figure 15 Close-Up View of Test Set-Up Showing
Anti-Buckling Bars and Microscope

for Plane-Strain Fracture Toughness of Metallic Materials." These gages were placed at the center of the crack between two gage mount blocks which were bonded to the specimen. The gage length was 0.20 inch. The outputs of the load transducer and the two compliance gages were fed directly into the Rye Canyon computer facility and computer-plotted results of load versus compliance were obtained. This test system has been described in detail in Reference 2 .

Average displacement measurements obtained from these two gages were used to determine the corresponding crack lengths. The translation from crack opening displacement (COD) to crack lengths was accomplished using the Liebowitz width corrected Irwin-Westergaard expression:

$$\frac{E (COD)}{SW} = \left[\frac{\pi c}{W} / \sin\left(\frac{\pi c}{W}\right) \right]^{\frac{1}{2}} \left\{ \frac{2Y}{W} \left[\frac{2W}{\pi Y} \cosh^{-1} \left(\frac{\cosh \frac{\pi Y}{W}}{\cos \frac{\pi c}{W}} \right) - \left[\frac{1 + \mu}{1 + \left(\frac{\sin \frac{\pi c}{W}}{\sinh \frac{\pi Y}{W}} \right)^2} \right]^{\frac{1}{2}} \right] + \mu \right\}$$

Where:

E = modulus of elasticity

μ = Poisson's Ratio

COD = $2v$ = crack opening displacement

c = 1/2 total effective crack length

S = gross stress

W = test panel width

Y = 1/2 span of COD gage

The equipment used for the room temperature tests was also used for the tests conducted at -65°F. The center crack area on the panel was enclosed and nitrogen gas from a liquid nitrogen tank was metered into the enclosed chamber under closely controlled and continuously monitored conditions,

utilizing monitoring and controlling thermocouples attached to the panel, and solenoid actuated valves. The temperature was stabilized at $-65 \pm 5^{\circ}\text{F}$ across the panel width for 5 minutes prior to testing. Figure 16 shows a -65°F test set-up.

Data reduction was conducted per ASTM E561-76T.

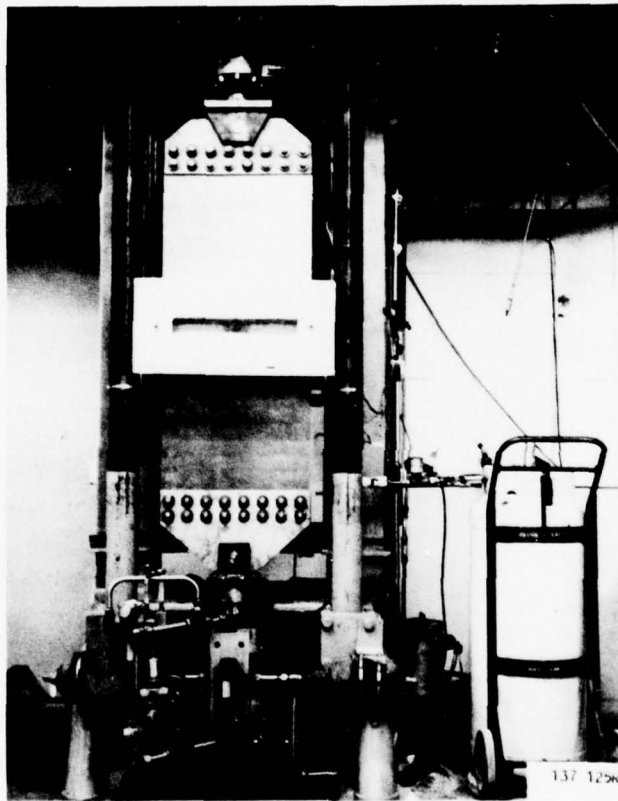


Figure 16 Typical Test Set-Up of -65°F Fracture Toughness Specimen Showing Chamber in Position

V. TEST RESULTS AND DISCUSSION

Chemical Analyses. The chemical analyses results, Table 3, show all the test material was within the required chemical composition limits. The analyses performed on the 7050-T7E73 wing plank material at Lockheed and Alcoa's Technical Center were in close agreement.

Tensile Properties. The tensile results, Tables 4 through 6, show the 7050-T7E73 and 7075-T6510 test material have comparable tensile properties. All the 7050 test values show a 5 percent or greater margin over the 7075-T6 extrusion specification minimum properties. Specifically, the longitudinal 7050-T7E73 properties exceed the 7075-T6 minimum requirements by 4 to 11 Ksi in tensile strength, 5 to 11 Ksi in yield strength and 3 to 7 percent in elongation.

Associated with tensile properties, corresponding Rockwell B hardness values were determined on the test material and reported in Tables 4 through 6.

Exfoliation Behavior. The exfoliation test results, Tables 4 through 6, show the 7050-T7E73 extrusions to have an acceptable level of exfoliation corrosion resistance and the 7075-T6510 extrusion to be almost as good. The behavior of the 7075 material in this test program is better than expected for the T6 condition. The Lockheed results represent a composite of the EXCO and 7 day salt spray test results. Some difficulty was encountered with EXCO testing in that one set of results showed the 7050-T7E73 wing planks to have an ED rating on the T/10 planes and upon retesting adjacent specimens only pitting was observed. The 7 day salt spray results were more consistent and less severe than the EXCO tests in that the 7050 wing planks had an EA rating on the T/10 plane. The results from Alcoa's Technical Center are the result of EXCO testing and are in agreement with the Lockheed composite rating.

TABLE 3 CHEMICAL COMPOSITIONS OF 7050-T7E73 AND 7075-T6510 TEST MATERIALS

ALLOY	SHAPE	DATA SOURCE	Zn	Mg	Cu	Fe	Si	Mn	Cr	Zr	Ti	OTHER
7050	All	Spec(1) Limits	5.7-6.7	1.9-2.6	2.0-2.6	0.15	0.12	0.10	0.04	.08-.15	0.06	0.05
	Spar	LAC	5.76	2.19	2.00	0.10	0.07	0.004	0	0.09	0.04	.001 Be
	Plank Lot A	LAC	6.48	2.36	2.01	0.082	0.06	0	0	0.09	0.05	.002 Be
		Alcoa Tech. Center	6.35	2.43	2.08	0.08	0.05	0	0.01	0.10	0.042	--
7075	Plank Lot B	LAC	6.58	2.38	2.03	0.085	0.07	0	0	0.10	0.05	.001 Be
		Alcoa Tech. Center	6.67	2.48	2.09	0.09	0.07	0	0	0.10	0.042	--
	All	Spec(1) Limits	5.1-6.1	2.1-2.9	1.2-1.9	0.35	0.25	0.30	0.18-0.35	0	0.20	0.05
	Spar	LAC	5.50	2.51	1.54	0.17	0.11	0.02	0.19	0	0.04	.002 Be
	Plank	LAC	5.13	2.45	1.34	0.17	0.10	0.01	0.23	0	0.04	--

(1) Maximum limits unless a range is specified

TABLE 4 PROPERTIES OF 7050-T7E73 AND 7075-T6510 P-3 WING SPAR CAP EXTRUSIONS

ALLOY	DATA SOURCE	GRAIN DIRECT.	ELECT. COND. (1) % IACS	EXFOL RATING (2)	ROCKWELL HARDNESS HRB	TENSILE PROPERTIES		
						TENSILE KSI	YIELD KSI	ELONG. % in 1"
7050	LAC	L	37.0 37.5	S P T/10 EA T/2 EA	91.0	91.2	85.4	12.0
		L				92.3	86.0	12.0
		LT				85.7	79.0	12.0
		LT				86.2	79.4	11.0
		ST				86.8	79.9	12.0
		ST				86.5	79.5	14.0
7075	ALCOA Test Rept.	L max	36.7	--	--	91.1	85.7	14.5
		L min				86.3	80.3	13.0
	LAC	L L LT LT ST ST	30.8 33.0	S P T/10 P T/2 EC	90.5	92.3	84.3	10.0
						95.4	88.4	10.0
						85.8	76.9	13.0
						84.6	75.8	10.0
						86.6	77.3	12.0
						87.3	77.6	12.0
	Typical Alcoa Test Rept.	L max L min LT max LT min	--	--	--	91.9	84.9	12.0
						91.1	83.9	12.0
						86.0	77.4	12.0
						85.3	77.4	12.0
LAC-04-551 (QQ-A-200/11)	L LT	-- --	-- --	-- --	81	72	7	
					73	63	4	

(1) % International Annealed Copper Standard

(2) Plane Evaluated S = Surface, T/10 = 1/10 plane, T/2 = mid plane
Exfol Rating Rating per ASTM G34

TABLE 5 PROPERTIES OF 7050-T7E73 P-3 WING PLANK EXTRUSIONS

ALLOY	DATA SOURCE	GRAIN DIRECT	ELECT. COND. (1) % IACS (1)	EXFOL RATING (2)	ROCKWELL HARDNESS HRB	TENSILE PROPERTIES			
						TENSILE KSI	YIELD KSI	ELONG. % in 1"	
7050 Lot A (H32482A1)	LAC	L	38.3 39.0	S P T/10 EA T/2 EB	88.0	87.2	78.6	14.0	
		L				86.8	77.9	13.0	
		LT				85.2	76.4	14.0	
		LT				85.6	77.0	13.0	
		ST				82.9	72.5	7.0(3)	
		ST				82.3	72.1	8.0(3)	
7050 Lot B (H32483A1)	Alcoa Test Rept	L max	38.6 38.9	-- --	-- --	86.1	77.7	14.5	
		L min				85.6	76.5	14.5	
		L				86.1 85.2 85.7 83.7 83.9 83.0	78.1	78.1	13.6
		L					77.4	77.4	14.3
		L					78.4	78.4	13.6
		LT					76.3	76.3	13.6
LT	76.1	76.1	14.3						
LT	75.3	75.3	12.1						
7050 Lot B (H32483A1)	LAC	L	38.3 39.0	S P T/10 EA T/2 EB	88.5	87.1	79.7	13.0	
		L				86.5	78.8	13.0	
		LT				85.1	76.7	12.0	
		LT				85.5	77.0	12.0	
		ST				82.3	72.5	7.0(3)	
		ST				81.9	73.1	4.0(3)	
7050 Lot B (H32483A1)	Alcoa Test Rept	L max	38.6 38.9	-- --	-- --	86.7	78.0	14.0	
		L min				84.9	76.5	13.0	
		L				85.1 84.9 85.2 84.1 83.4 83.4	77.3	77.3	13.6
		L					77.0	77.0	13.6
		L					77.4	77.4	14.3
		LT					76.0	76.0	14.3
LT	75.8	75.8	12.8						
LT	75.2	75.2	11.4						

(1) % International Annealed Copper Standard

(2) Plane Evaluated S = Surface, T/10 = 1/10 plane, T/2 = mid plane
Exfol Rating Rating per ASTM G34

(3) % Elongation in .5 inch

TABLE 6 PROPERTIES OF 7075-T6510 P-3 WING PLANK EXTRUSIONS

ALLOY	DATA SOURCE	GRAIN DIRECT	ELECT. COND (1) % IACS	EXFOL RATING (2)	ROCKWELL HARDNESS HRB	TENSILE PROPERTIES		
						TENSILE KSI	YIELD KSI	ELONG. % in 1"
7075	LAC	L	32.5 34.3	S P T/10 EA T/2 EC	89.0	87.5	77.0	9.0
		L				90.1	80.4	9.0
		LT				88.4	76.9	12.0
		LT				87.3	76.4	10.0
		ST				83.3	73.6	5.0(3)
		ST				85.0	74.0	5.0(3)
Typical Alcoa Test Rept	LAC-04-622 (QQ-A-200/11)	L max	--	--	--	89.8	82.0	12.5
		L min				88.3	80.8	12.0
		L				81	72	7

(1) % International Annealed Copper Standard

(2) Plane Evaluated S = Surface, T/10 = 1/10 plane, T/2 = mid plane
Exfol Rating Rating per ASTM G34

(3) % Elongation in .5 inch

In addition to exfoliation testing, the electrical conductivities of the test materials were measured, since conductivity is used to confirm proper age stabilization for acceptable corrosion resistance. The values, shown as percent International Annealed Copper Standard (% IACS) are presented in Tables 4 through 6. The 7050-T7E73 material had electrical conductivity values of 37.0 to 39.1% IACS and the 7075-T6510 material had values of 30.8 to 34.3% IACS.

Stress Corrosion Resistance. Although stress corrosion testing was not included as part of the Lockheed testing, stress corrosion testing was performed at Alcoa's Technical Center in accordance with ASTM G44-75 entitled "Standard Recommended Practice for Alternate Immersion Stress Corrosion Testing in 3.5% Sodium Chloride Solution." The results, in Appendix A, showed 0.75 inch "C" rings taken in the short transverse grain direction of 7050-T7E73 wing planks and stressed to 10, 15, 20, and 25 Ksi had no failure after 47 days of testing. Tensile specimens, 0.125 inch diameter, taken in the longitudinal grain direction and stress to 20 and 35 Ksi had no failure after 47 days of testing.

Flight-by-Flight Spectra Fatigue. Cross references of test specimen identifications, conditions and test data for the spectra fatigue specimens are shown in Table 7. The flight-by-flight spectra fatigue test results are shown in Figs. 17 through 26. In these figures, cracking which occurs on both sides of the stress concentration is added to the hole diameters (.250 inch for $K_t = 2.7$ and .300 inch for $K_t = 4.0$, Ref. Figs. 6 and 7) and the total lengths are plotted vs. flight hours. The average number of flight hours per flight for this service mission mix is five.

Basically, the flight-by-flight fatigue test data show that fatigue lives of 7050-T7E73 are as good or better than 7075-T6510 for small crack lengths of approximately .15 inches, for the products and conditions tested in this program. This is shown in Figs. 17 through 26, and compared in Table 8.

TABLE 7 SPECTRA FATIGUE TEST SPECIMENS

MATERIAL	PROCESSING	SHAPE	GRAIN DIRECTION	STRESS CONC.	NO. OF SPECIMENS	SPECIMEN IDENTIFICATION	CRACK GROWTH CURVES, FIG.		
7050-T7E73	Machine, Etch and Chem. Film	Spar Cap Plank, Lot A Plank, Lot B	L	2.7	2	5M21, 5M22	17		
			L	2.7	2	LA1, LA2	18		
			L	2.7	2	LB1, LB2	18		
	Machine, Shot Peen, Etch and Chem. Film	Spar Cap Plank, Lot A Plank, Lot B	L	2.7	2	5S21, 5S22	19		
			L	2.7	2	LA3, LA4	20		
			L	2.7	2	LB3, LB4	20		
7075-T6510	Machine, Etch and Chem. Film	Spar Cap Plank	L	2.7	2	7M21, 7M22	17		
			L	2.7	2	L1, L2	18		
	Machine, Shot Peen, Etch and Chem. Film	Spar Cap Plank	L	2.7	2	7S21, 7S22	19		
			L	2.7	2	L3, L4	20		
			7050-T7E73	Machine, Etch and Chem. Film	L	4.0	2	5M41, 5M42	21
					L	4.0	2	LA5, LA6	22
LT	4.0	2			LTA1, LTA2	23			
Machine, Shot Peen, Etch and Chem. Film	Spar Cap Plank, Lot A Plank, Lot B	L		4.0	2	LB5, LB6	22		
		LT		4.0	2	LTB1, LTB2	23		
		L		4.0	2	5S41, 5S42	24		
7075-T6510	Machine, Etch and Chem. Film	Spar Cap Plank	L	4.0	2	7M41, 7M42	21		
			L	4.0	2	L5, L6	22		
	Machine, Shot Peen, Etch and Chem. Film	Spar Cap Plank	LT	4.0	2	LT1, LT2	23		
			L	4.0	2	7S41, 7S42	24		
			L	4.0	2	L7, L8	25		
			LT	4.0	2	LT3, LT4	26		

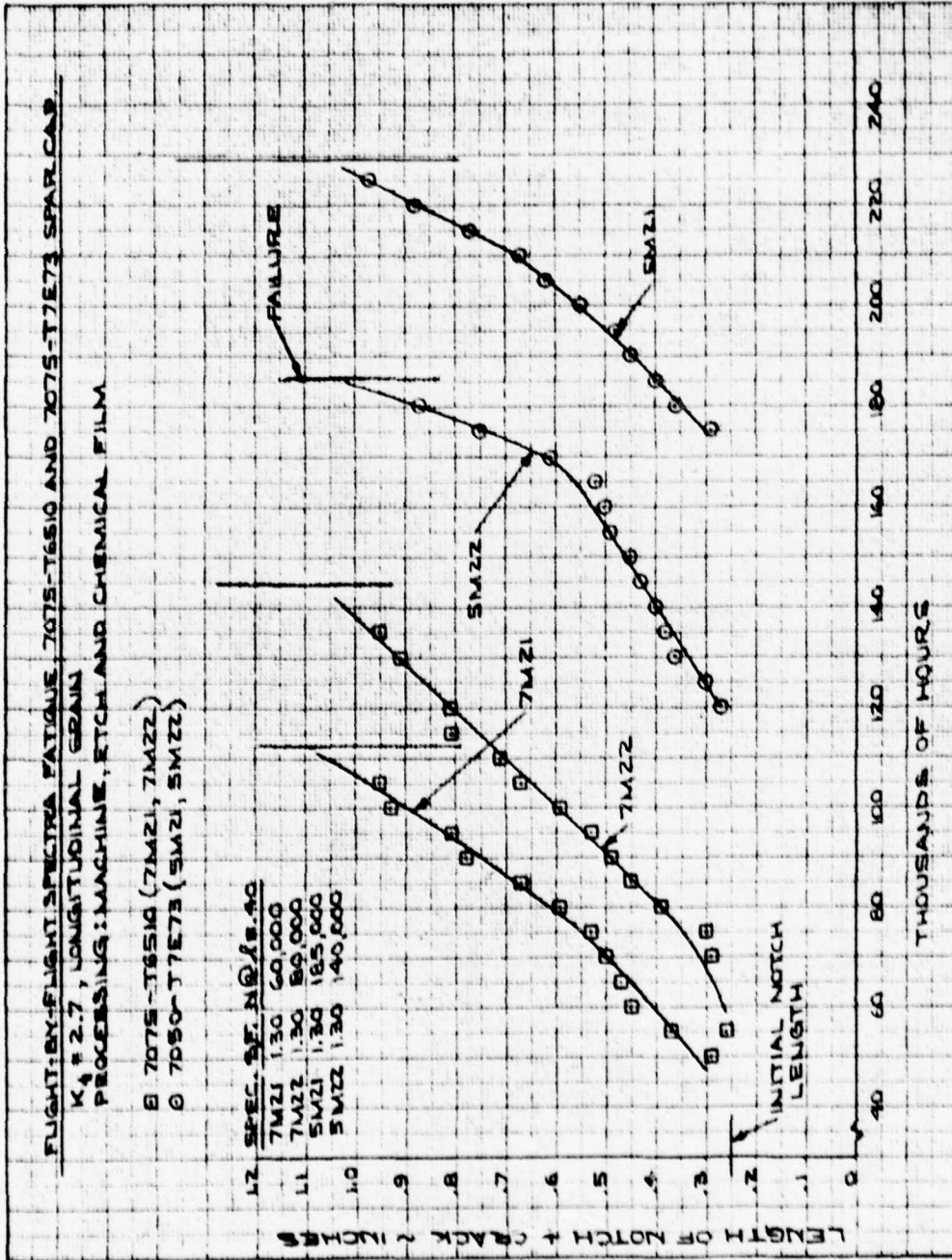


Figure 17 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t=2.7$, Machine, Etch and Chemical Film Processing

FLIGHT-BY-FLIGHT SPECIMEN FATIGUE, 7075-T6510 AND 7050-T7E73 PLANK

$K_t = 2.7$, LONGITUDINAL GRAIN

PROCESSING: MACHINE, ETCH AND CHEMICAL FILM

- 7075-T6510 (L1, L2)
- 7050-T7E73, LOT A (LAI, LAZ)
- 7050-T7E73, LOT B (LBI, LBZ)

SPEC.	S.F.	$NOP = 4.0$
L1	1.30	47,000
L2	1.30	60,000
LAI	1.30	58,000
LAZ	1.30	78,000
LBI	1.30	65,000
LBZ	1.30	96,000

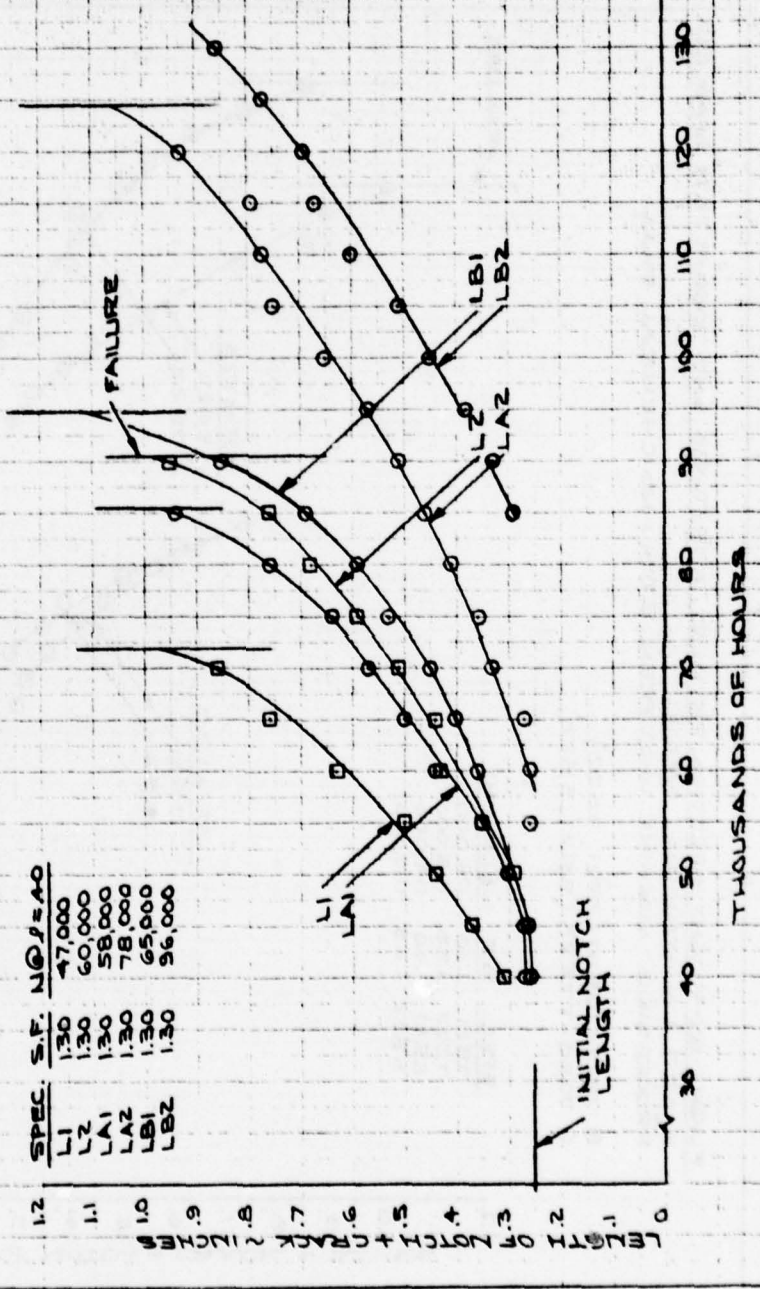


Figure 18 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 2.7$, Machine, Etch and Chemical Film Processing

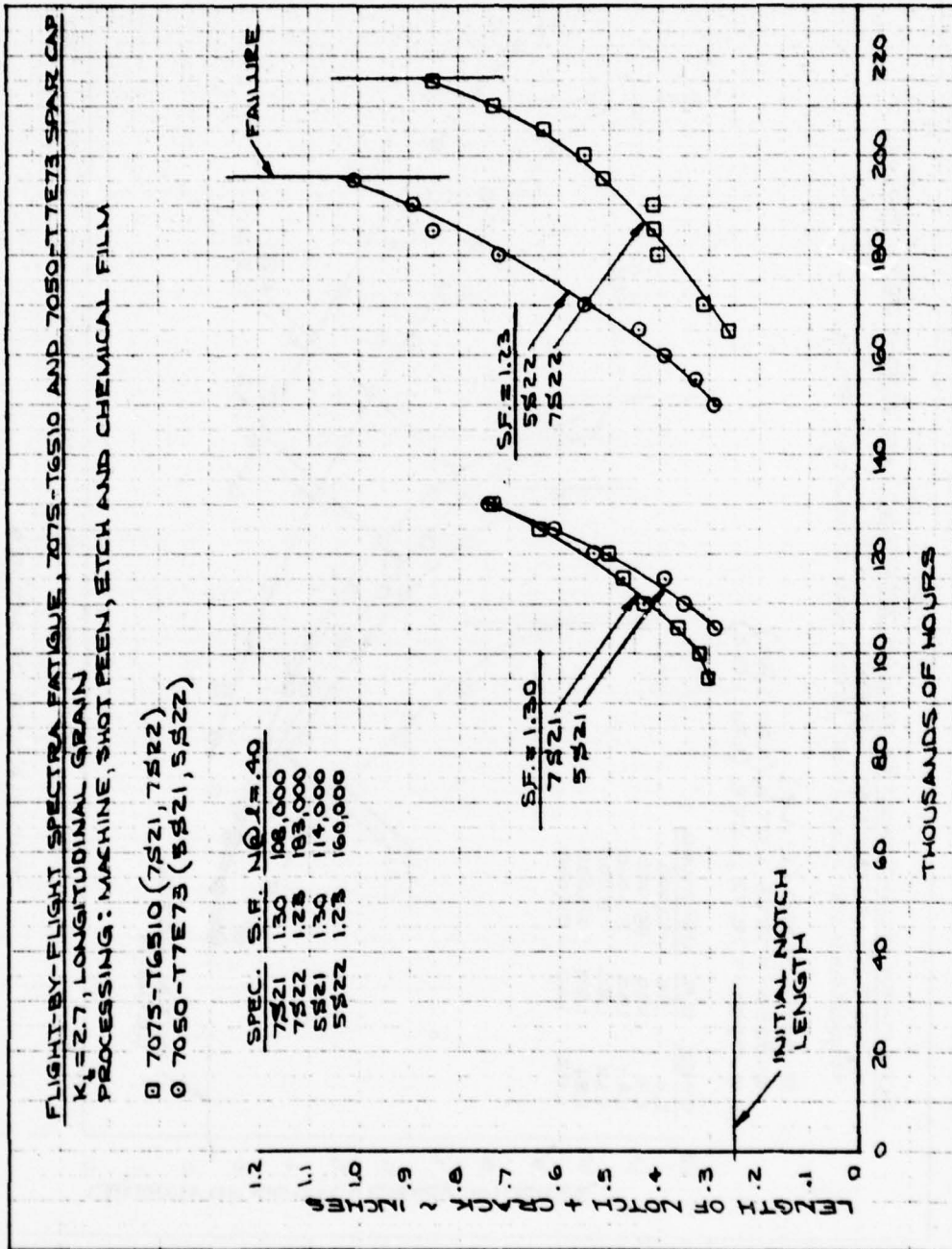


Figure 19 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 2.7$, Machine, Shot Peen, Etch and Chemical Film Processing

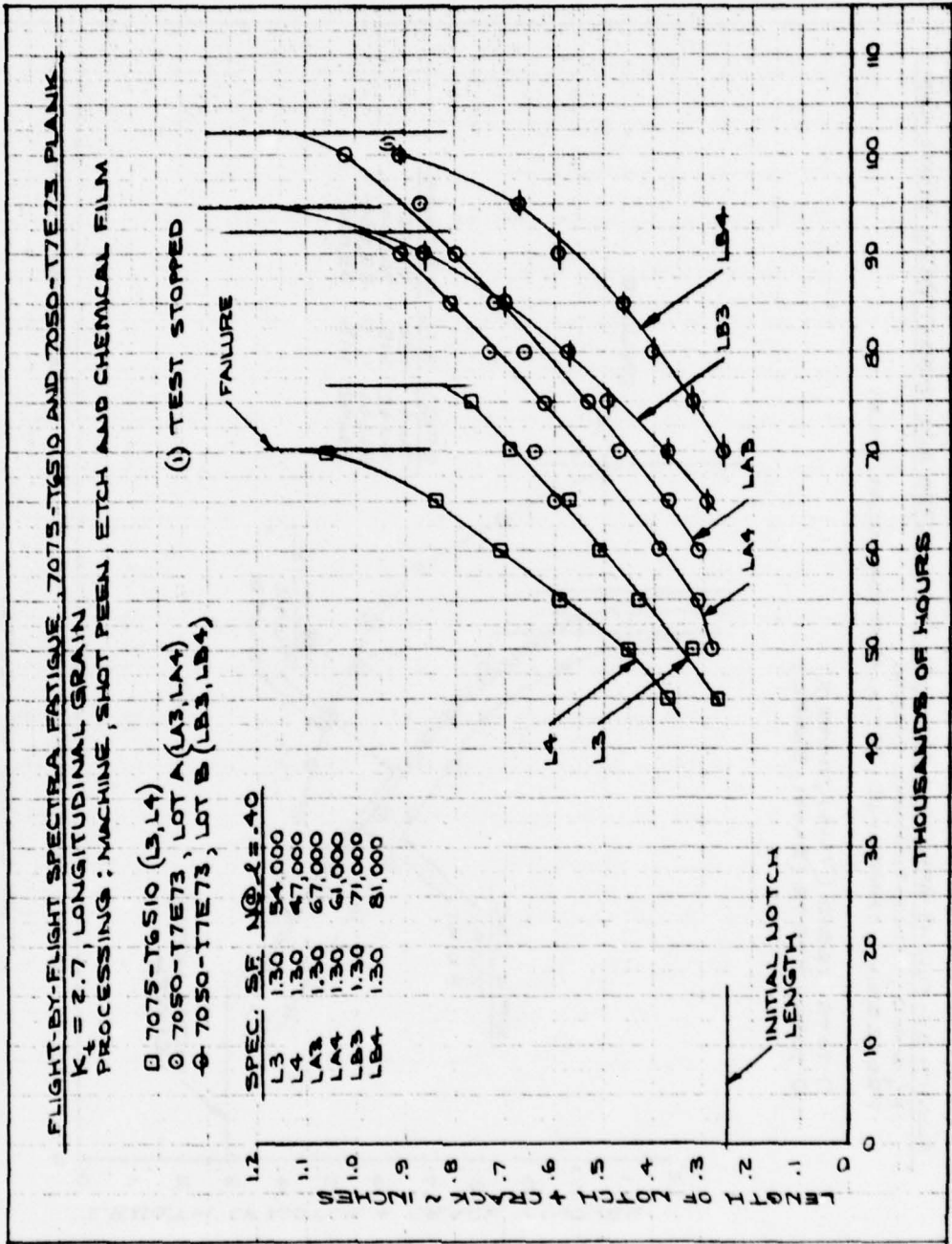


Figure 20 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 2.7$, Machine, Shot Peen, Etch and Chemical Film Processing

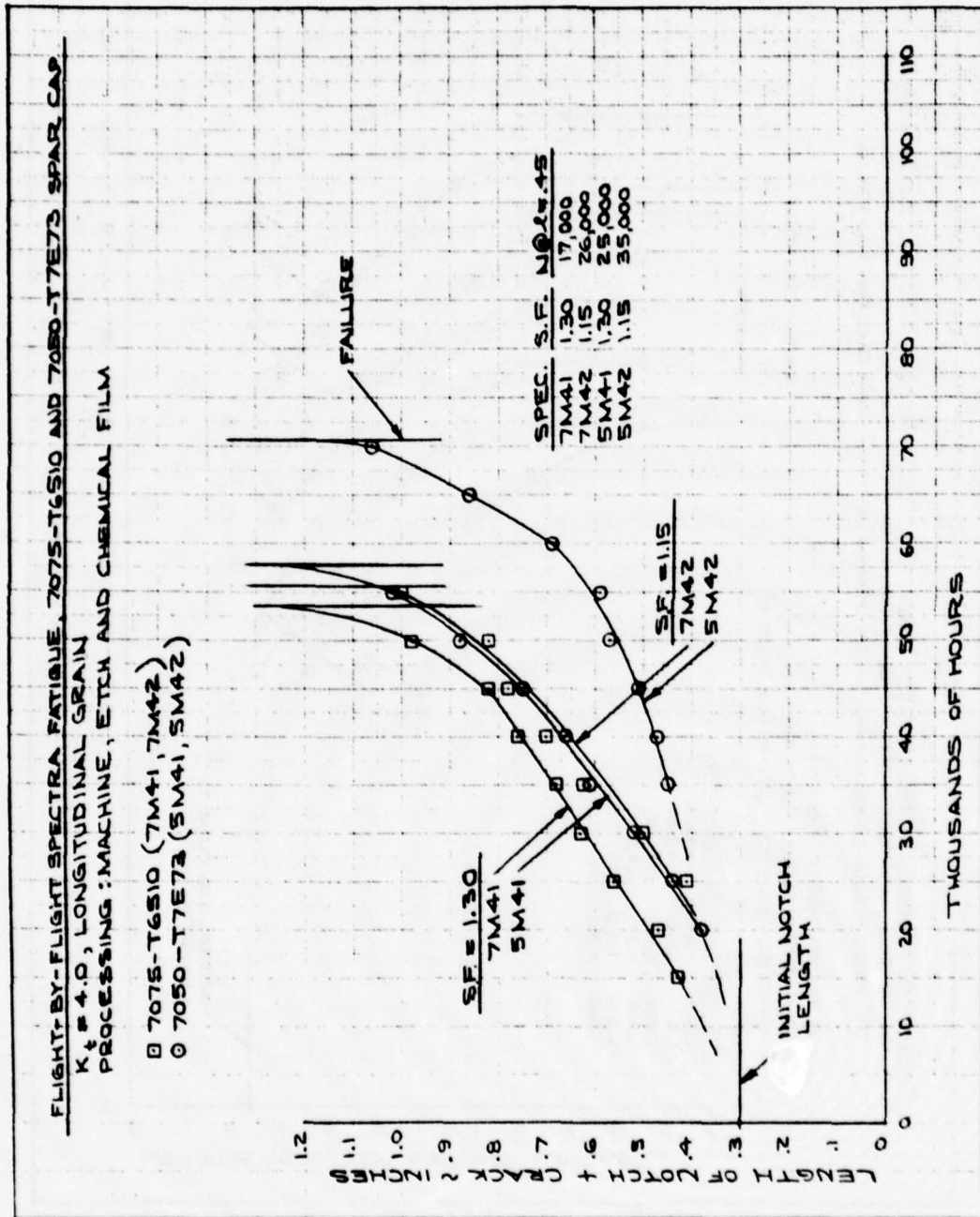


Figure 21 Fatigue Cracking of 7075-T6S10 and 7050-T7E73 Spar Cap Specimens, K_t=4.0, Machine, Etch and Chemical Film Processing

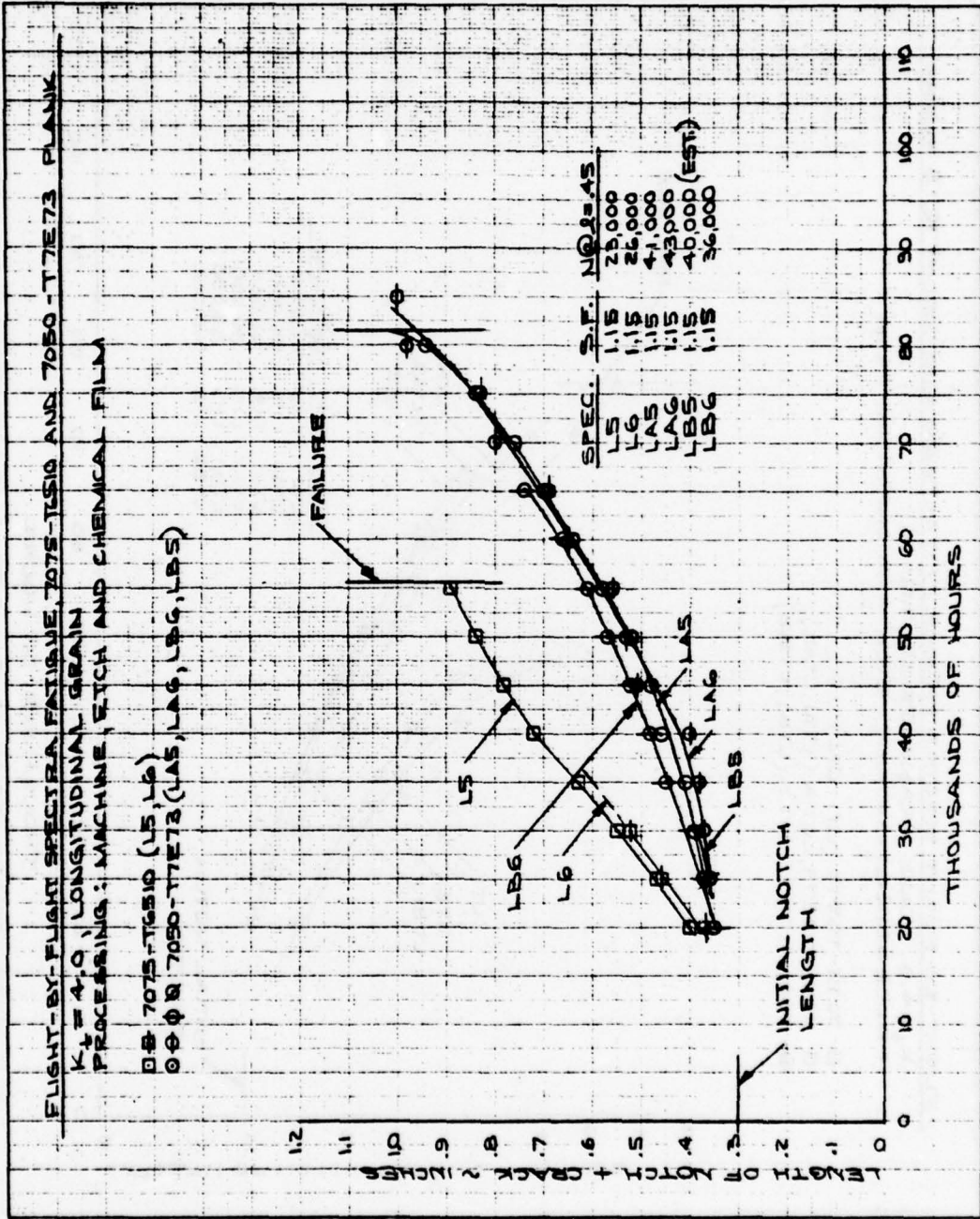


Figure 22 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Etch and Chemical Film Processing

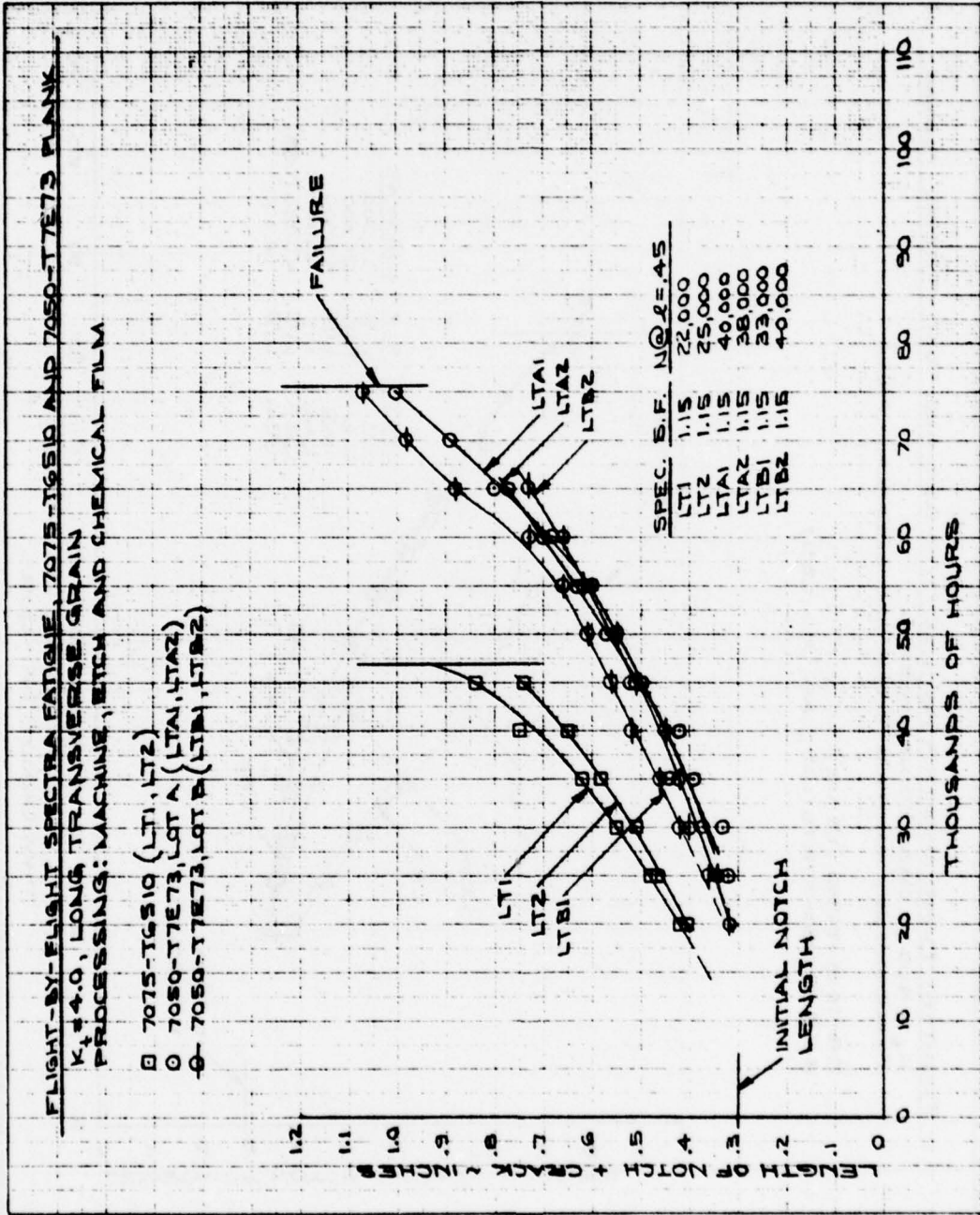


Figure 23 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, K_t = 4.0, Machine, Etch and Chemical Film Processing

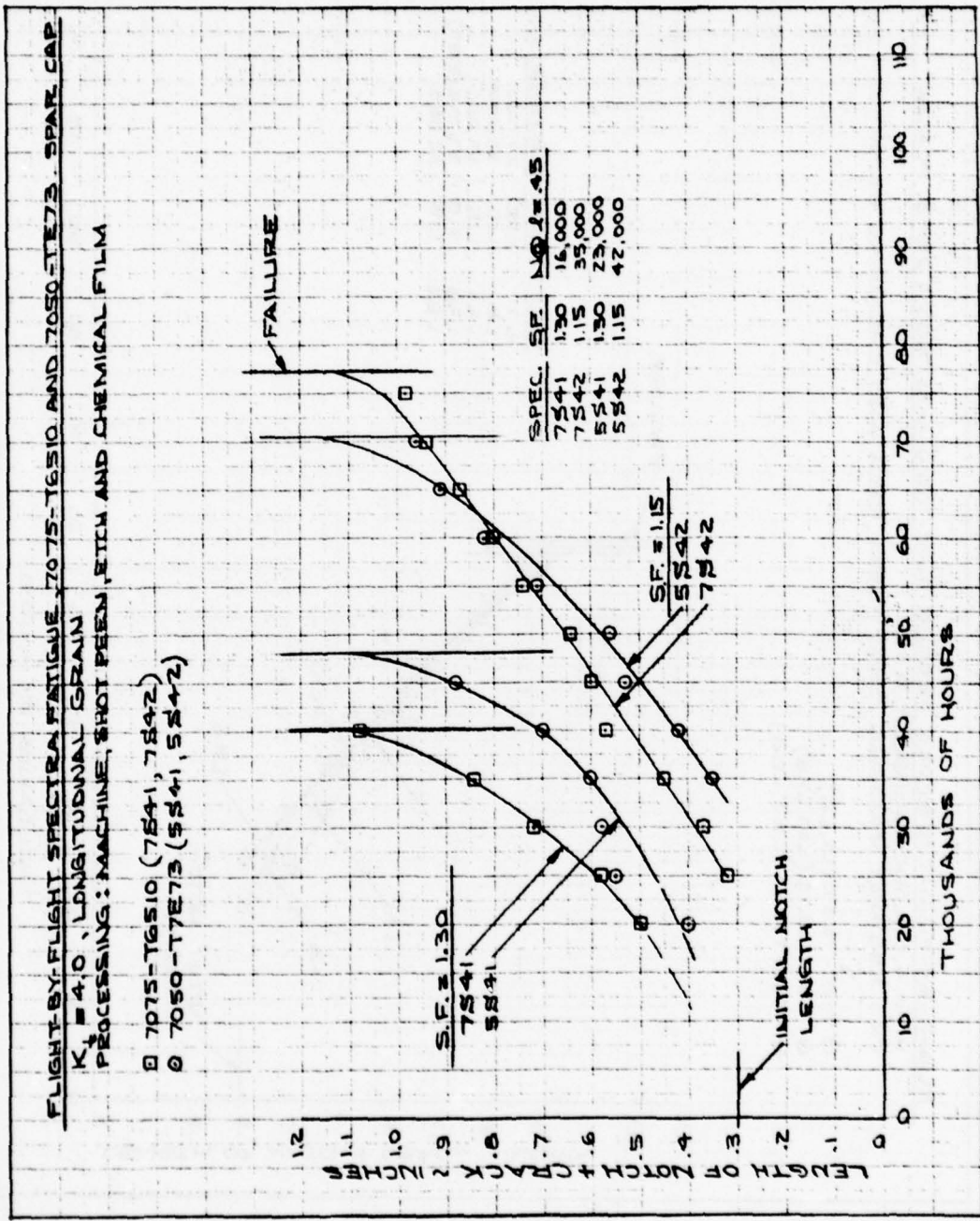


Figure 24 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Spar Cap Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing

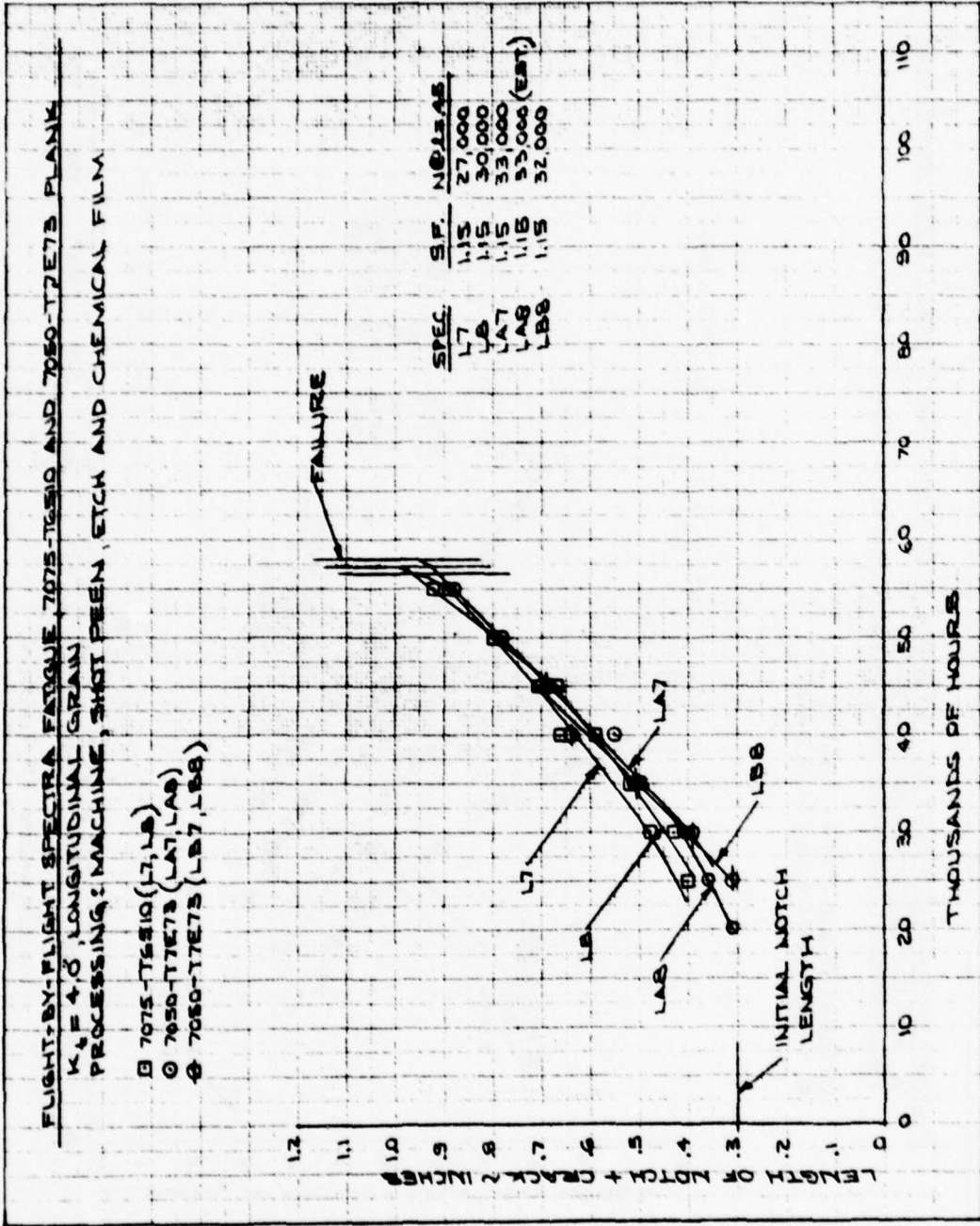


Figure 25 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing

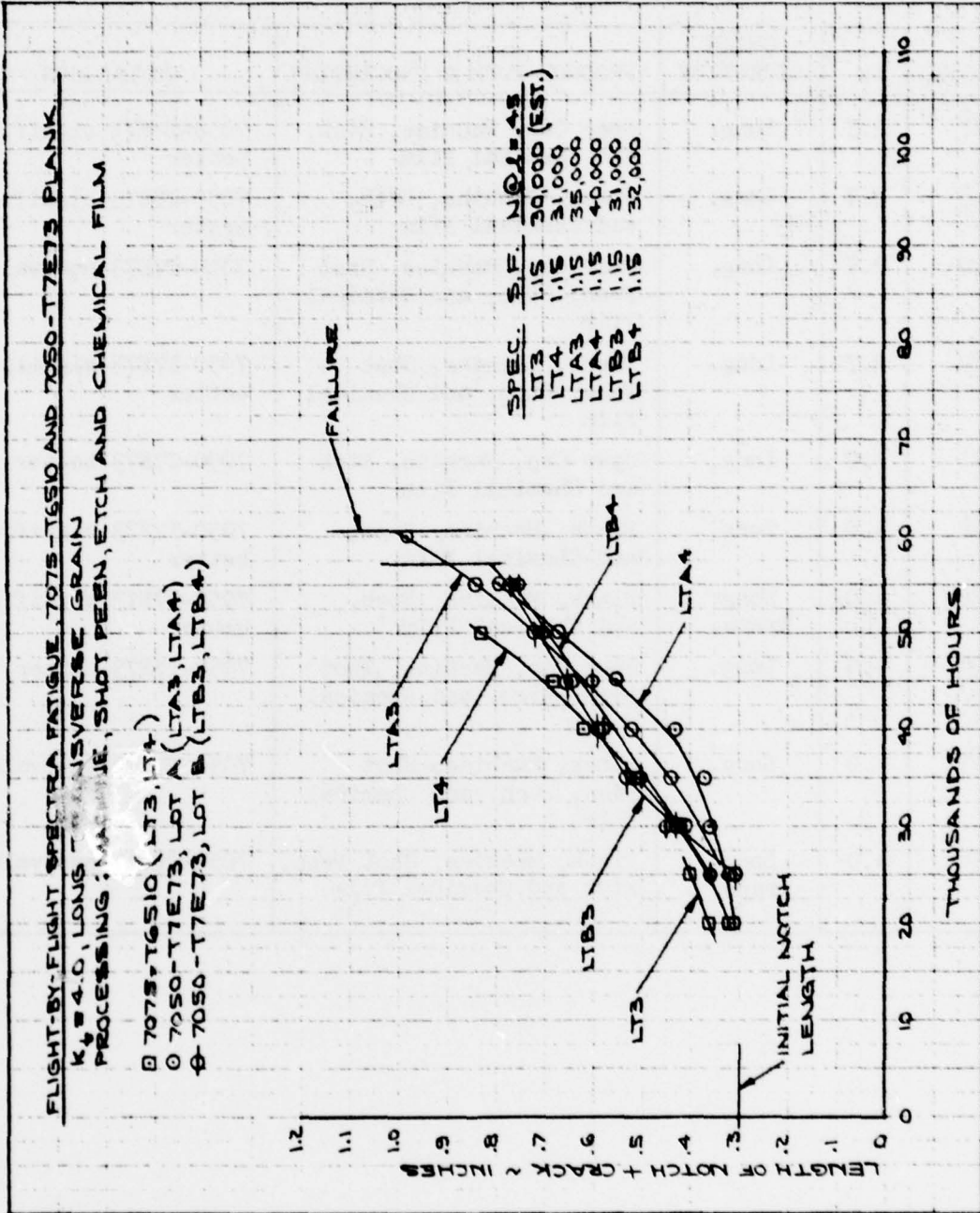


Figure 26 Fatigue Cracking of 7075-T6510 and 7050-T7E73 Wing Plank Specimens, $K_t = 4.0$, Machine, Shot Peen, Etch and Chemical Film Processing

TABLE 8 COMPARISON OF FATIGUE TEST RESULTS

FIGURE	K_t	GRAIN DIRECTION	PRODUCT FORM & PROCESSING	COMPARISON
17	2.7	Long.	Spar Cap, Machine, Etch, and Chemical Film	7050-T7E73 significantly better
18	2.7	Long.	Plank, Machine, Etch, and Chemical Film	7050-T7E73 significantly better
19	2.7	Long.	Spar Cap, Machine, Shot Peen, Etch, and Chemical Film	7050-T7E73 equivalent
20	2.7	Long.	Plank, Machine, Shot Peen, Etch, and Chemical Film	7050-T7E73 significantly better
21	4.0	Long.	Spar Cap, Machine, Etch and Chemical Film	7050-T7E73 better
22	4.0	Long.	Plank, Machine, Etch, and Chemical Film	7050-T7E73 significantly better
23	4.0	Long Trans.	Plank, Machine, Etch, and Chemical Film	7050-T7E73 significantly better
24	4.0	Long.	Spar Cap, Machine, Shot Peen, Etch, and Chemical Film	7050-T7E73 better
25	4.0	Long.	Plank, Machine, Shot Peen, Etch, and Chemical Film	7050-T7E73 equivalent
26	4.0	Long Trans.	Plank, Machine, Shot Peen, Etch and Chemical Film	7050-T7E73 equivalent

For spectra fatigue, magnitudes of all gross area stress levels in the loading spectra listed in Table 2 were increased by a fixed percentage to increase the severity of the spectra. This increase was effected to produce realistic test durations for the stress concentrations which were tested. The fixed percentage increases used in each test are expressed as a stress factor (S.F.) and are given in Figs. 17 through 26.

In examining Table 8, it is apparent that the fatigue improvement of 7050-T7E73 over the 7075-T6510 is more pronounced for the machine, etch and chemical film processing combination than for the processing combination which includes shot peening.

The flight-by-flight spectra fatigue test results are presented in tabular form in Appendix B.

Crack Propagation. The test specimen identification and test conditions are shown in Table 9. The constant amplitude crack propagation data generated in this program were reduced to crack growth rate (da/dN) using a Lockheed computer program and plotted in Figures 27 and 28 as a function of $\Delta\bar{K}$. The selection of $\Delta\bar{K}$ was made to facilitate the comparison with other similarly derived data. The expression for $\Delta\bar{K}$ is:

$$\Delta\bar{K} = (1 - R)^m S_{\max} \sqrt{\pi a \text{ SEC} \left(\frac{\pi a}{w} \right)}, \text{ where}$$

$\Delta\bar{K}$ is in units of ksi $\sqrt{\text{in.}}$.

R = Stress Ratio (S_{\min}/S_{\max})

= .1 for this program

m = .5

S_{\max} = Maximum gross area stress in ksi

a = 1/2 of the total crack length = 1/2 of the starter notch plus cracking on each side of notch

w = Width of panel.

TABLE 9 LIST OF CRACK PROPAGATION SPECIMENS⁽¹⁾ AND TEST CONDITIONS

MATERIAL ⁽²⁾	PANEL NUMBER	FREQUENCY	ENVIRONMENT ⁽³⁾	CRACK LENGTH, IN.	
				INITIAL	FINAL
7050-T7E73 Lot A	1	6 Hz.	Lab Air	2.0	5.6
	2	6 Hz.	Humid Air	2.0	5.3
7050-T7E73 Lot B	4	6 Hz.	Lab Air	2.0	5.3
	5	6 Hz.	Humid Air	2.0	5.3
7075-T6510	7	6 Hz.	Lab Air	2.0	5.3
	8	6 Hz.	Lab Air	2.0	5.3
	9	6 Hz.	Humid Air	2.0	5.3
	10	6 Hz.	Humid Air	2.0	5.3

(1) Panel width = 16.1 inches; Panel thickness = .09 inches

(2) Longitudinal grain direction, wing plank extrusion

(3) Room Temperature

Lab air \approx 40% relative humidity

Humid air \approx 98% relative humidity

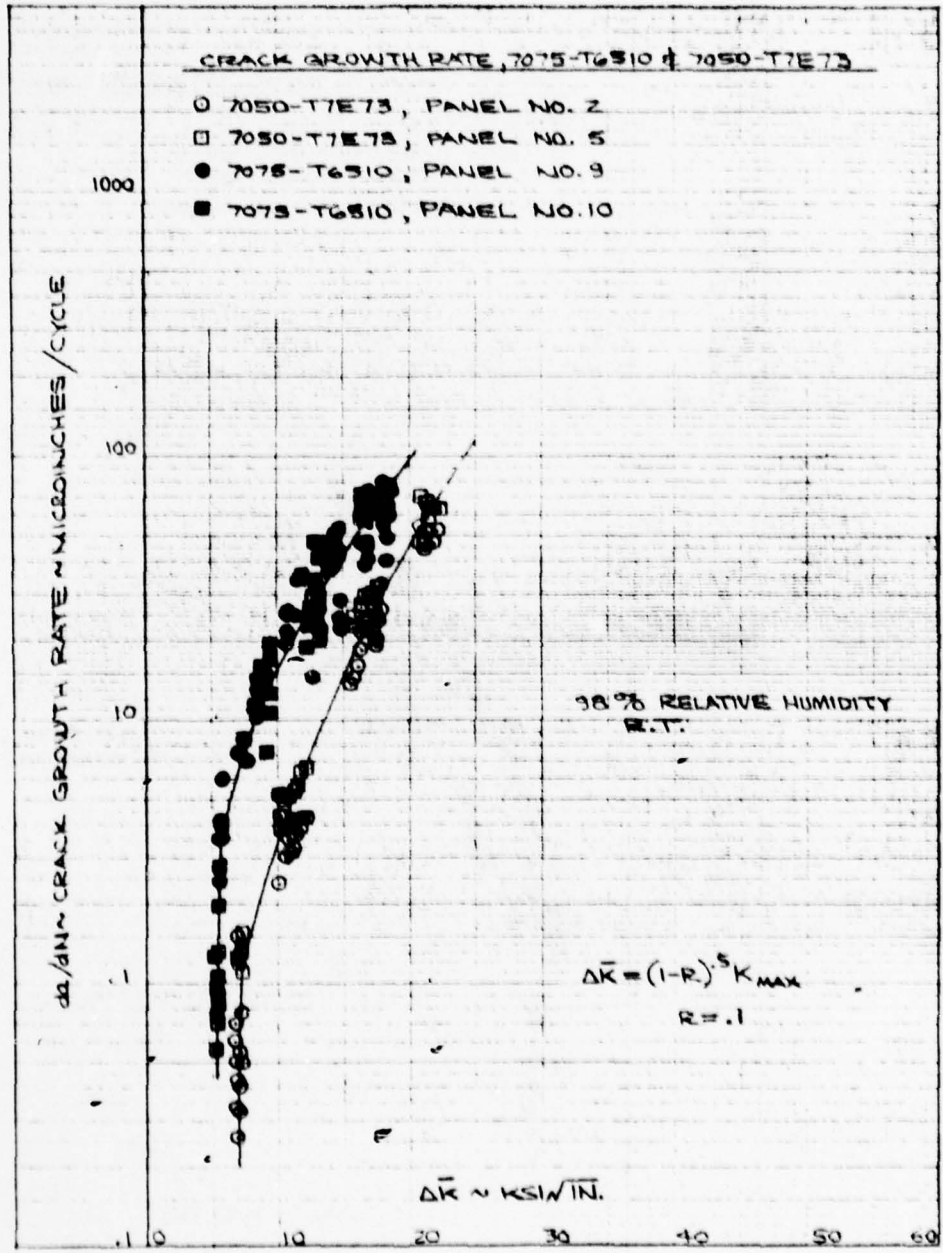


Figure 27 Crack Growth Rate vs $\Delta \bar{K}$, 7075-T6510 and 7050-T7E73 Wing Plank, 98% Relative Humidity

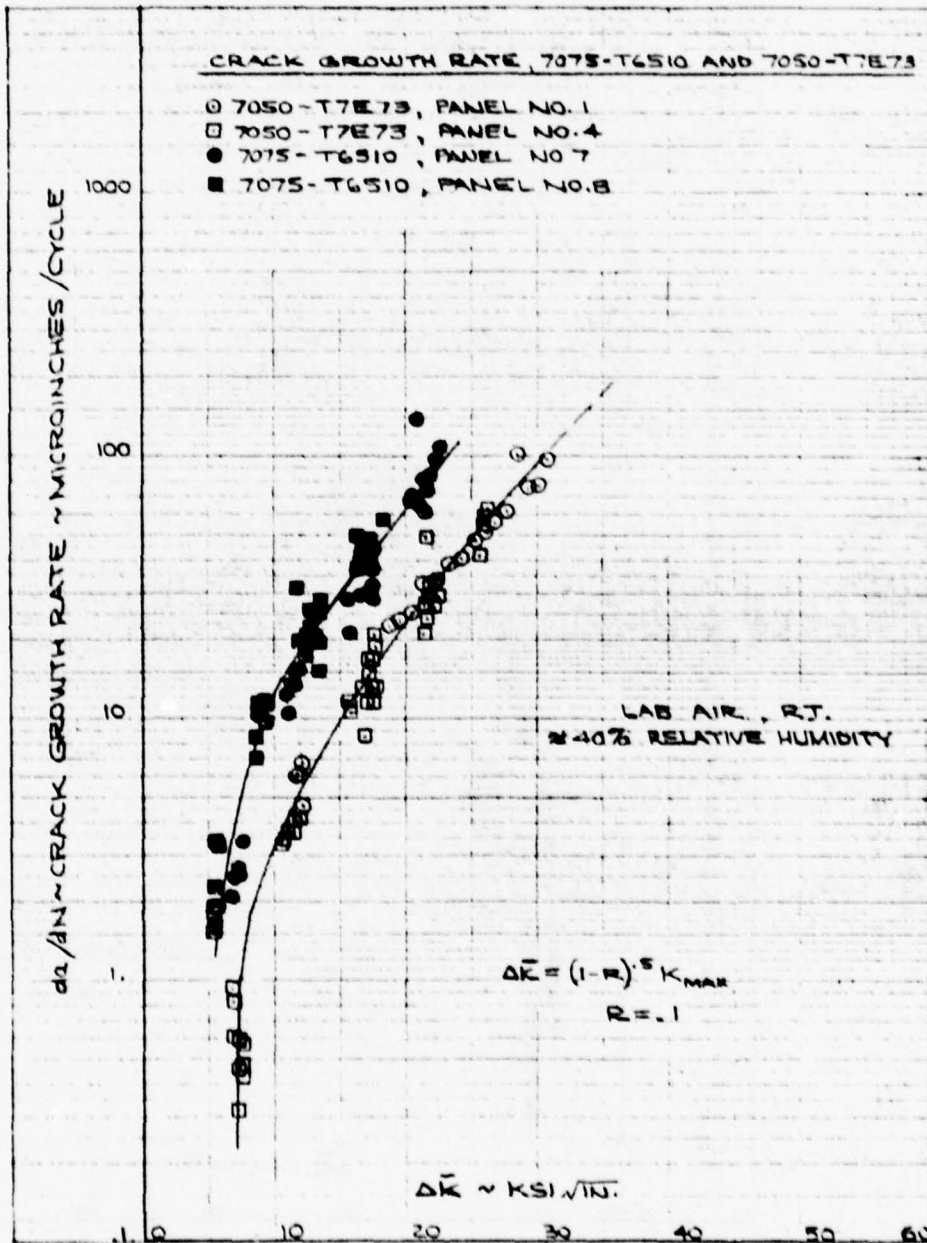


Figure 28 Crack Growth Rate vs $\Delta \bar{K}$, 7075-T6510 and 7050-T7E73 Wing Plank, 40% Relative Humidity

Figure 27 compares the crack growth rates for 7050-T7E73 and 7075-T6510 tested in a laboratory air environment. It shows that the crack propagation properties of the 7050-T7E73 are significantly better than those of the 7075-T6510, i.e., the indicated threshold $\Delta\bar{K}$ is approximately 30% higher for 7050-T7E73 and da/dN of 7050-T7E73 is approximately 33% of the 7075-T6510 values. Figure 28 discloses somewhat the same results, showing the 7050-T7E73 again significantly better in crack propagation properties in a 98% relative humidity environment.

The crack propagation data are presented in tabular form in Appendix C.

Fracture Toughness. The resistance-to-fracture curves (R - curves) are presented in Figs. 29 and 30 for room temperature and -65°F respectively. In Fig. 29, for the room temperature testing, an envelope has been drawn for each material to show the scatter bands. This illustrates that 7050-T7E73 has significantly higher fracture resistance than the 7075-T6510, with an increase of approximately 60 to 70 percent above the 7075-T6510 values. Similarly, the increase in fracture resistance for the 7050-T7E73 over the 7075-T6510 is of the order of 60 to 70 percent for a test temperature of -65°F , as shown in Figure 30.

Table 10 lists the test conditions and calculated values of K_{apparent} and K_{c} . The formulations used were:

$$K_{\text{apparent}} = S_{\text{max}} \sqrt{\pi c_i \text{SEC} \left(\frac{\pi c_i}{w} \right)}$$

and

$$K_{\text{c}} = S_{\text{max}} \sqrt{\pi c_{\text{cr}} \text{SEC} \left(\frac{\pi c_{\text{cr}}}{w} \right)} \quad \text{where,}$$

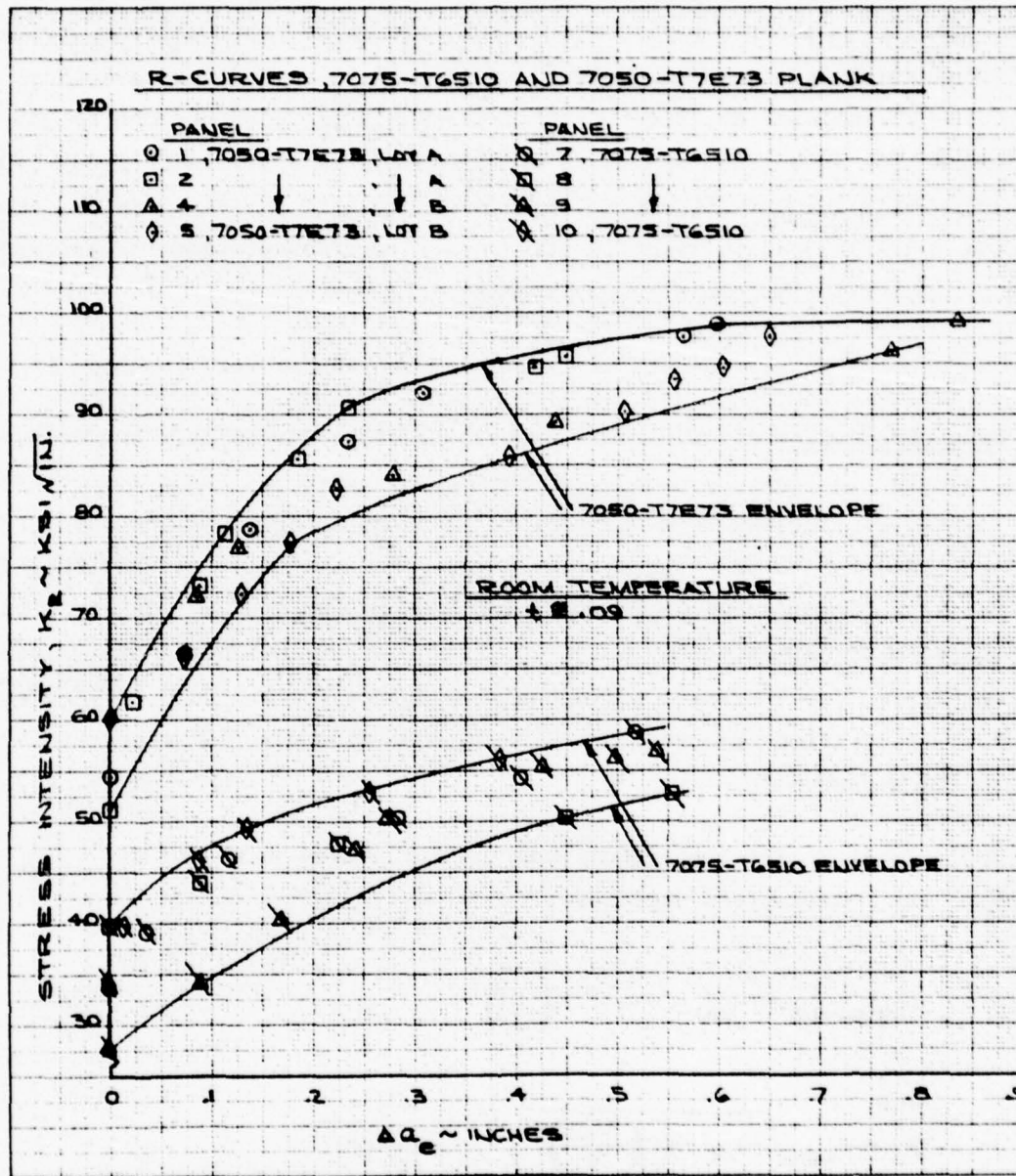


Figure 29 R-Curve Data For 7075-T6510 and 7050-T7E73 Wing Plank at Room Temperature

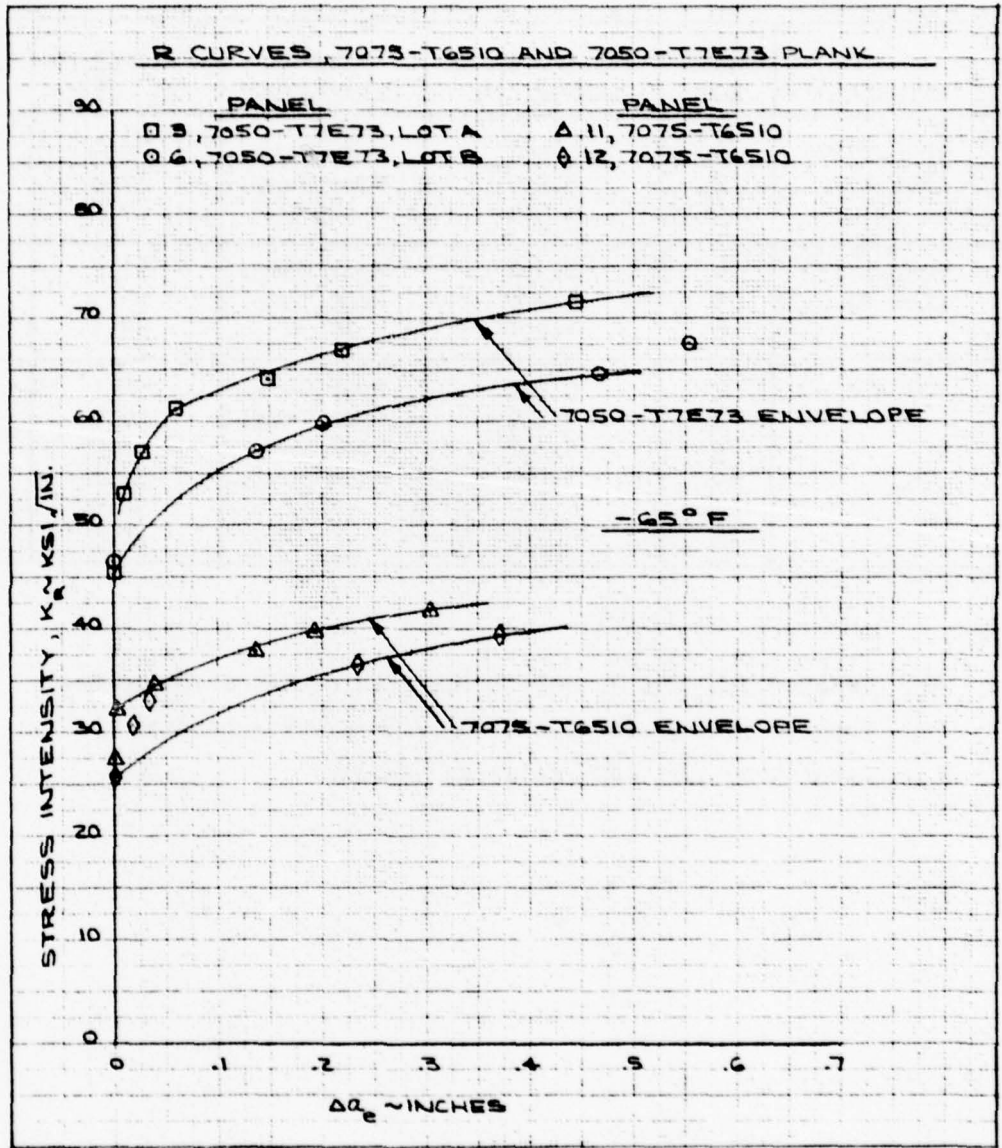


Figure 30 R-Curve Data For 7075-T6510 and 7050-T7E73 Wing Plank
at -65°F

TABLE 10 FRACTURE TOUGHNESS SPECIMEN TEST CONDITIONS⁽¹⁾ AND RESULTS

MATERIAL ⁽²⁾	PANEL NO.	INITIAL CRACK LENGTH, IN.	TEST ⁽³⁾ TEMPERATURE	K APPARENT KSI \sqrt{IN} .	K _c KSI \sqrt{IN} .
7050-T7E73 (Lot A)	1	5.601	Room Temp.	86.3	98.9
	2	5.297	Room Temp.	87.8	97.6
	3	5.301	-65°F	67.5	76.1
7050-T7E73 (Lot B)	4	5.304	Room Temp.	81.8	99.2
	5	5.292	Room Temp.	83.9	97.7
	6	5.298	-65°F	62.5	73.4
7075-T6510	7	5.317	Room Temp.	52.1	58.8
	8	5.297	Room Temp.	46.2	52.6
	9	5.302	Room Temp.	50.2	57.0
	10	5.295	Room Temp.	51.1	56.0
	11	5.30	-65°F	38.9	41.9
	12	5.303	-65°F	38.5	43.9

(1) Panel width = 16.1 inches; Panel thickness = .09 inches

(2) Longitudinal grain direction, wing plank extrusion

(3) Laboratory air \approx 40% relative humidity

S_{max} = Maximum gross area stress
 c_i = 1/2 initial crack length
 w = Width of panel
 c_{cr} = 1/2 critical effective crack length

The K_c values listed in Table 10 show a very significant improvement in the fracture toughness values of the 7050-T7E73 alloy over those of the 7075-T6510, in the order of 75% at room temperature and at -65°F. It may be noted, also, that the fracture toughness of 7050-T7E73 at -65°F is significantly higher than the value of 7075-T6510 at room temperature.

VI. CONCLUSIONS

The 7050-T7E73 extruded P-3 wing spar cap and plank shapes, produced and processed in production facilities have equivalent tensile and improved exfoliation resistance, stress corrosion resistance, and fatigue properties compared to identical 7075-T6510 extruded shapes.

Also, it was found that:

- o Crack propagation properties at room temperature of the 7050-T7E73 material were significantly improved over the 7075-T6510 material in lab air ($\approx 40\%$ R.H.) and humid air ($\approx 98\%$ R.H.) environments, with an increase of approximately 30% in the crack growth threshold and a decrease of approximately 67% in the crack growth rate.
- o Fracture toughness properties at room temperature and -65°F of the 7050-T7E73 material were 60 to 70% greater than those of the 7075-T6510 material. Fracture toughness of 7050-T7E73 at -65°F is approximately 30% higher than 7075-T6510 at room temperature.

Based upon a comparison of the above engineering properties, a substitution of the 7050-T7E73 for the 7075-T6510 extrusions would enhance the structural maintainability and durability of the P-3 series aircraft.

VII. RECOMMENDATIONS

Based upon the results of this program, it is recommended that appropriate material specifications and design allowables be established to permit the substitution of 7050-T7E73 extrusions for 7075-T6510 extrusions in the P-3 production aircraft.

REFERENCES

1. Rhodes, J. E., et al, "P-3A Service Life Extension Program (SLEP), Part I, Volume 2," LR 27982-2, Lockheed-California Company, Burbank, California, January 1977.
2. Pettit, D. E., "Experimental Techniques for Fracture Mechanics: Evaluation of Temperature Effects on R-Curve Behavior of Aluminum Sheet Materials," LR 28240, Lockheed-California Company, Burbank, California, December 1977.

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

APPENDIX A

Alcoa Information

Information and test data supplied by Aluminum Company of America are included in this Appendix.

ALUMINUM COMPANY OF AMERICA
1145 WILSHIRE BLVD., LOS ANGELES, CALIFORNIA 90017
(213) 481-1800
PAUL L. ADERVOTHO, JR., District Sales Manager



July 9, 1976

Lockheed California Company
P. O. Box 551
Burbank, California 91520

Attention: Mr. George Wald

Gentlemen:

During a recent meeting you asked Alcoa's intentions to provide 7050 extrusions at the same strength level as 7075-T6. Below are listed the fracture toughness, stress-corrosion cracking and exfoliation characteristics Alcoa would agree to for the P-3 family of integrally stiffened panels with the same minimum tensile properties of the 7075-T6511 extrusion. This material would be designed as a 7050-T7EXX with the experimental temper designation to be selected if and when Lockheed agrees to this proposal. The following properties would apply to the 7050-T7EXX temper:

1. Minimum tensile mechanical properties identical with those of the current 7075-T6511, integrally stiffened P-3 panels.
2. Minimum fracture toughness (L-T direction) 23.0 Ksi SQ. RT. IN.; (T/L direction) 21.0 Ksi SQ. RT. IN.
3. Exfoliation corrosion less than or equal to that pictured in Photograph B Figure 2 of ASTM G34-72 at the T/10 plane was tested in accordance with ASTM G34.
4. Stress corrosion cracking resistance, C-Ring specimens shall be capable of passing a 20-day alternate immersion test per ASTM G47-46 when stressed in the short transverse direction at 20% of the guaranteed longitudinal yield strength.

This information has been passed on to Mr. Ed Balmuth, Naval Air Systems Command, for his analysis. It is my understanding that he feels these characteristics are satisfactory for P-3 applications. Regardless, we look forward to Lockheed's response to this proposal.

Very truly yours,

A S Kuhns

A. S. Kuhns

mal 5/2



THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

ALUMINUM COMPANY OF AMERICA
1145 WILSHIRE BOULEVARD, LOS ANGELES, CALIFORNIA 90017
(213) 482-2630
PAUL L. ABERNETHY, JR., District Sales Manager

▼
ALCOA

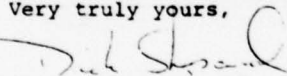
1977 December 16

Mr. Roy Brodie
Lockheed-California Company
P. O. Box 551
Burbank, California 91520

Dear Roy:

Attached is a summary of the mechanical property, fracture toughness, exfoliation and stress corrosion cracking tests conducted by the Alcoa Technical Center on the two lots of 7050-T7E73 wing planks, die no. 213562. I understand that you are interested in possibly attaching this data to your upcoming summary report. Please let me know if we can provide any additional information.

Very truly yours,



R. B. SHEPARD

mj 5/6

Attachment

A-2



THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

TABLE I.
PROPERTIES OF 7050-T7E73 EXTRUDED SHAPE # 213562

LOT NO	S NO	LOCATION IN EXTRUSION	TENSILE PROPERTIES T/2								ELECTRICAL CONDUCTIVITY % IACS		
			ENGLISH UNITS				S.I. UNITS				T/10	T/2	
			T.S. KSI	Y.S. KSI	EL. %40D	R.A. %	KC KSI/IN	T.S. MPa	Y.S. MPa	EL. %50 HR.4E			KC MPa/4E
LONGITUDINAL													
A38337		TESTED AT LAFAYETTE	85.6	76.5	14.5							38.6	38.9
		AUG.	86.1	77.7	14.2							38.9	38.8
			85.9	77.1	14.5								
H32482A1	488009	W/4	86.1	78.1	13.6	36	30.0	594	538	12.2	33.0		
		W/2	85.2	77.4	14.3	36		587	534	12.2		39.1	38.7
		3W/4	85.2	78.4	13.2	31	31.6	571	540	11.7	34.7		
		AUG.	85.7	78.0	13.8	35	30.8	591	548	12.0	33.8		
A38338		TESTED AT LAFAYETTE	86.6	78.0	14.0							38.6	38.9
			86.4	78.2	13.9							38.9	38.8
			85.7	77.2	14.8								
H32483A1	488010	W/4	85.1	77.3	13.6	37	29.4	537	533	12.2	32.3		
		W/2	84.9	77.0	14.6	37		535	531	12.2		38.9	38.5
		3W/4	85.2	77.4	14.2	37	29.2	547	534	12.2	32.1		
		AUG.	85.1	77.2	13.8	37	29.5	536	533	12.2	32.2		
LONG-TRANSVERSE													
H32482A1	488009	W/4	83.7	76.3	13.6	36		577	526	12.2			
		W/2	83.9	76.1	14.3	29		578	525	11.3			
		3W/4	83.0	75.2	13.1	30		572	519	11.1			
		AUG.	83.5	75.9	13.3	32		576	523	12.2			
H32483A1	488010	W/4	84.1	76.0	14.3	34		580	524	12.8			
		W/2	83.4	75.8	12.8	27		575	523	11.7			
		3W/4	83.2	75.2	11.4	31		572	518	11.7			
		AUG.	83.6	75.7	12.8	31		576	522	11.9			

ACCELERATED CORROSION TESTS - SPECIMENS FROM W/4 & 3W/4 LOCATIONS

LOT NO	S NO	STRESSED SPECIMENS EXPOSED TO 3.5% NaCl A.I. (ASTM G44-75)														
		EXFOLIATION EXCO TEST				LONGITUDINAL T.B.				SHORT-TRANSVERSE C-RINGS						
		24 HR.		48 HR.		21 MPa (35 KSI)		138 MPa (20 KSI)		172 MPa (25 KSI)		153 MPa (22 KSI)		103 MPa (15 KSI)		64 MPa (10 KSI)
		T/10	T/2	T/10	T/2	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	F/N ⁽¹⁾ DAYS	
H32482A1	488009	EA	EB	EA	EB	0/3	0K47	0/3	0K47	0/4	0K47	0/4	0K47	0/4	0K47	0/4
H32483A1	488010	EA	EB	EA	EB	0/3	0K47	0/3	0K47	0/4	0K47	0/4	0K47	0/4	0K47	0/4

COMPOSITION - WEIGHT PERCENT

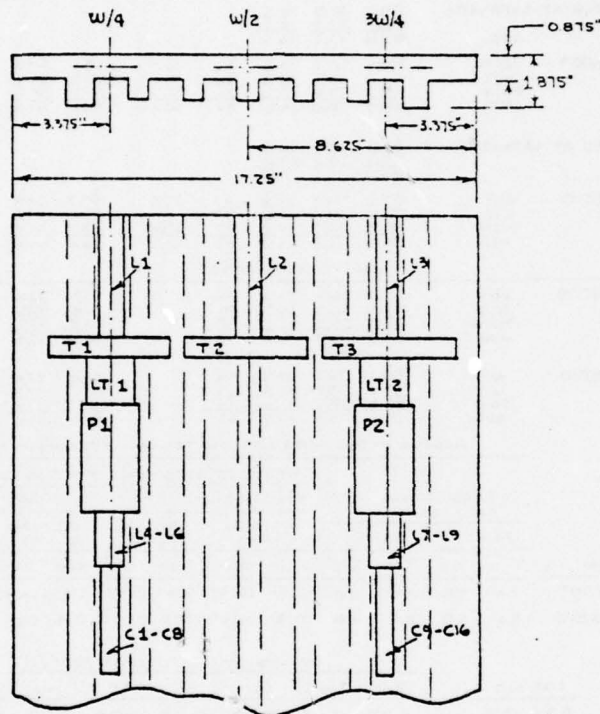
LOT NO	ZN	MG	CU	FE	SI	MN	CR	ZR	TI
A38337	6.35	2.43	2.08	0.08	0.05	0.00	0.01	0.10	0.042
A38338	6.67	2.48	2.09	0.09	0.07	0.00	0.00	0.10	0.040

NOTES

(1) F/N DENOTES NUMBER OF SPECIMENS FAILED OVER NUMBER OF SPECIMENS TESTED
 TENSILE TESTS: 0.357" ϕ LONGITUDINAL & LONG-TRANSVERSE TAPERED SEAT TENSILE SPECS
 FRACTURE TOUGHNESS TESTS: 0.75" THICK LT COMPACT TENSION FRACTURE TOUGHNESS SPECIMENS
 CORROSION TESTS: 0.125" ϕ LONGITUDINAL THREADED END TENSILE SPECIMENS & 0.75" ϕ SHORT-TRANSVERSE C-RINGS
 YIELD STRENGTH: 0.2% OFFSET
 M.T. NO. 083177C



THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC



- | | |
|--------------|--|
| L1-L3, T1-T3 | 0.357" ϕ TAPERED SEAT TENSILE SPECIMENS |
| L4-L9 | 0.125" ϕ THREADED END TENSILE SPECIMENS |
| LT1, LT2 | 0.75" THICK COMPACT TENSION FRACTURE TOUGHNESS SPECIMENS |
| C1-C16 | 0.75" ϕ SHORT-TRANSVERSE C-RINGS |
| P1-P2 | 2" x 4" PANELS FOR EXFOLIATION TESTS |

LOCATION OF SPECIMENS IN 7050-T7E73 EXTRUDE SECTION # 213562
S-488009, 488010

APPENDIX B
Spectra Fatigue Tabular Data

Tabular test data for flight-by-flight spectra fatigue tests are included in this Appendix.

The test data locations for the spectra fatigue specimens are shown in the following table:

Specimen ⁽¹⁾ No.	Location, Page	Specimen ⁽¹⁾ No.	Location, Page
5M21	B-2	LB5	B-18
5M22	B-2	LB6	B-19
LA1	B-3	LTB1	B-20
LA2	B-4	LTB2	B-21
LB1	B-5	5S41	B-22
LB2	B-6	5S42	B-13
5S21	B-7	LA7	B-20
5S22	B-8	LA8	B-23
LA3	B-9	LTA3	B-24
LA4	B-10	LTA4	B-27
LB3	B-11	LT3	B-18
LB4	B-11	LT4	B-19
7M21	B-5	LTB3	B-25
7M22	B-6	LTB4	B-21
L1	B-3	7M41	B-12
L2	B-4	7M42	B-26
7S21	B-7	L5	B-25
7S22	B-8	L6	B-23
L3	B-9	LT1	B-24
L4	B-10	LT2	B-17
5M41	B-12	7S41	B-22
5M42	B-13	7S42	B-26
LA5	B-14	L7	B-14
LA6	B-15	L8	B-15
LTA1	B-16	LB8	B-16
LTA2	B-17	LB7	Overloaded

(1) For test specimen description, see Table 7.

FATIGUE TEST DATA FOR SPECIMEN No. SMZ1				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		35,000	175,000	.04 .00
LONG. GRAIN		36,000	180,000	.08 .03
MACHINE, ETCH AND		37,000	185,000	.10 .05
CHEMICAL FILM		38,000	190,000	.14 .06
		39,000	195,000	.15 .08
		40,000	200,000	.18 .12
		41,000	205,000	.21 .16
		42,000	210,000	.24 .18
		43,000	215,000	.27 .25
		44,000	220,000	.33 .30
		45,000	225,000	.37 .35
		45,800	229,000	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. SMZZ				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		24,000	120,000	00 .02
LONG. GRAIN		25,000	125,000	00 .05
MACHINE, ETCH AND		26,000	130,000	00 .11
CHEMICAL FILM		27,000	135,000	00 .13
		28,000	140,000	00 .15
		29,000	145,000	00 .18
		30,000	150,000	00 .20
		31,000	155,000	00 .24
		32,000	160,000	00 .25
		33,000	165,000	00 .27
		34,000	170,000	00 .36
		35,000	175,000	.08 .42
		36,000	180,000	.14 .48
		37,109	185,545	FAILURE



FATIGUE TEST DATA FOR SPECIMEN NO. LA1				
$K_t = 2.7$ S.F. = 1.30	FLIGHTS	HOURS	CRACKING	
7050-T7E73 PLANK, LOT A	8,000	40,000	.01	.01
LONG. GRAIN	9,000	45,000	.01	.01
MACHINE, ETCH AND	10,000	50,000	.02	.03
CHEMICAL FILM	11,000	55,000	.04	.06
	12,000	60,000	.08	.11
	13,000	65,000	.10	.15
	14,000	70,000	.13	.19
	15,000	75,000	.16	.23
	16,000	80,000	.21	.30
	17,000	85,000	.23	.40
	17,109	85,545	FAILURE	

FATIGUE TEST DATA FOR SPECIMEN NO. LI				
$K_t = 2.7$ S.F. = 1.30	FLIGHTS	HOURS	CRACKING	
7075-T6510 PLANK	8,000	40,000	.04	.02
LONG. GRAIN	9,000	45,000	.06	.06
MACHINE, ETCH AND	10,000	50,000	.09	.10
CHEMICAL FILM	11,000	55,000	.12	.13
	12,000	60,000	.19	.19
	13,000	65,000	.25	.26
	14,000	70,000	.30	.31
	14,404	72,020	FAILURE	

FATIGUE TEST DATA FOR SPECIMEN No. LZ				
$K_t = 2.7$	SF. = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 PLANK		10,000	50,000	.04
LONG. GRAIN		11,000	55,000	.06 .04
MACHINE, ETCH AND		12,000	60,000	.10 .08
CHEMICAL FILM		13,000	65,000	.10 .09
		14,000	70,000	.14 .12
		15,000	75,000	.18 .16
		16,000	80,000	.22 .21
		17,000	85,000	.26 .25
		18,000	90,000	.36 .34
		18,109	90,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LAZ				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		11,000		.01 00
LONG. GRAIN		12,000		.01 00
MACHINE, ETCH AND		13,000		.02 00
CHEMICAL FILM		14,000		.04 .04
		15,000		.05 .06
		16,000		.07 .09
		17,000		.10 .11
		18,000		.12 .14
		19,000		.14 .18
		20,000		.18 .22
		21,000		.22 .28
		22,000		.24 .28
		23,000		.26 .28
		24,000		.30 .38
		24,871		FAILURE



FATIGUE TEST DATA FOR SPECIMEN No. LBI				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT B		8,000	40,000	00 .01
LONG. GRAIN		9,000	45,000	00 .01
MACHINE, ETCH AND		10,000	50,000	00 .05
CHEMICAL FILM		11,000	55,000	00 .10
		12,000	60,000	.01 .10
		13,000	65,000	.03 .12
		14,000	70,000	.06 .14
		15,000	75,000	.10 .18
		16,000	80,000	.14 .20
		17,000	85,000	.18 .26
		18,000	90,000	.26 .34
		18,980	94,900	FAILURE
FATIGUE TEST DATA FOR SPECIMEN No. 7M21				
$K_t = 2.7$	SF = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		10,000	50,000	.04 00
LONG. GRAIN		11,000	55,000	.10 .02
MACHINE, ETCH AND		12,000	60,000	.10 .10
CHEMICAL FILM		13,000	65,000	.11 .11
		14,000	70,000	.12 .13
		15,000	75,000	.14 .14
		16,000	80,000	.18 .16
		17,000	85,000	.22 .20
		18,000	90,000	.26 .27
		19,000	95,000	.28 .28
		20,000	100,000	.34 .34
		21,000	105,000	.36 .34
		22,473	112,365	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LB2				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT B		17,000	85,000	.04 00
LONG. GRAIN		18,000	90,000	.08 00
MACHINE, ETCH AND		19,000	95,000	.10 .03
CHEMICAL FILM		20,000	100,000	.14 .06
		21,000	105,000	.16 .10
		22,000	110,000	.20 .15
		23,000	115,000	.22 .20
		24,000	120,000	.24 .20
		25,000	125,000	.28 .24
		26,000	130,000	.34 .27
		27,000	135,000	.46 .28
		28,109	140,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. 7M22				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		11,000	55,000	00 .01
LONG. GRAIN		14,000	70,000	.01 .03
MACHINE, ETCH AND		15,000	75,000	.01 .04
CHEMICAL FILM		16,000	80,000	.06 .08
		17,000	85,000	.08 .12
		18,000	90,000	.10 .14
		19,000	95,000	.12 .16
		20,000	100,000	.16 .18
		21,000	105,000	.20 .22
		22,000	110,000	.22 .24
		23,000	115,000	.27 .29
		24,000	120,000	.28 .29
		26,000	130,000	.34 .32
		27,000	135,000	.36 .34
		28,921	144,605	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. 7S21				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		19,000	95,000	00 .05
LONG. GRAIN		20,000	100,000	00 .07
MACHINE, SHOT PEEN, ETCH		21,000	105,000	00 .11
AND CHEMICAL FILM		22,000	110,000	00 .18
		23,000	115,000	00 .22
		24,000	120,000	00 .25
		25,000	125,000	.07 .32
TEST STOPPED @		26,000	130,000	.12 .36

FATIGUE TEST DATA FOR SPECIMEN No. 5S21				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		21,000	105,000	00 .04
LONG. GRAIN		22,000	110,000	00 .10
MACHINE, SHOT PEEN, ETCH		23,000	115,000	00 .14
AND CHEMICAL FILM		24,000	120,000	.12 .16
		25,000	125,000	.16 .20
TEST STOPPED @		26,000	130,000	.22 .27



FATIGUE TEST DATA FOR SPECIMEN No. 5S22				
$K_t = 2.7$	S.F. = 1.23	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		30,000	150,000	.04 .00
LONG. GRAIN		31,000	155,000	.08 .00
MACHINE, SHOT PEEN, ETCH		32,000	160,000	.14 .00
AND CHEMICAL FILM		33,000	165,000	.18 .01
		34,000	170,000	.20 .10
		35,000	175,000	- -
		36,000	180,000	.29 .18
		37,000	185,000	.36 .24
		38,000	190,000	.38 .26
		39,000	195,000	.48 .28
		39,109	195,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. 7S22				
$K_t = 2.7$	S.F. = 1.23	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		33,000	165,000	.00 .01
LONG. GRAIN		34,000	170,000	.00 .06
MACHINE, SHOT PEEN, ETCH		36,000	180,000	.00 .15
AND CHEMICAL FILM		37,000	185,000	.00 .16
		38,000	190,000	.00 .16
		39,000	195,000	.00 .26
		40,000	200,000	.04 .26
		41,000	205,000	.06 .32
		42,000	210,000	.12 .36
		43,000	215,000	.18 .42
		43,109	215,545	FAILURE



FATIGUE TEST DATA FOR SPECIMEN No. L3				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 PLANK		9,000	45,000	.02 .00
LONG. GRAIN		10,000	50,000	.04 .03
MACHINE, SHOT PEEN, ETCH		11,000	55,000	.06 .12
AND CHEMICAL FILM		12,000	60,000	.10 .16
		13,000	65,000	.12 .20
		14,000	70,000	.18 .26
		15,000	75,000	.24 .28
		15,319	76,595	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LA3				
$K_t = 2.7$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		12,000	60,000	.00 .06
LONG. GRAIN		13,000	65,000	.03 .09
MACHINE, SHOT PEEN, ETCH		14,000	70,000	.10 .12
AND CHEMICAL FILM		15,000	75,000	.12 .16
		16,000	80,000	.17 .24
		17,000	85,000	.20 .27
		18,000	90,000	.26 .29
		19,000	95,000	.30 .32
		20,000	100,000	.40 .37
		20,428	102,140	FAILURE



FATIGUE TEST DATA FOR SPECIMEN No. 7M41				
$K_t = 4.0$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		3,000	15,000	.06 .07
LONG. GRAIN		4,000	20,000	.08 .09
MACHINE, ETCH AND		5,000	25,000	.14 .12
CHEMICAL FILM		6,000	30,000	.17 .16
		7,000	35,000	.20 .18
		8,000	40,000	.23 .23
		9,000	45,000	.24 .28
		10,000	50,000	.33 .35
		10,723	53,615	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. 5M41				
$K_t = 4.0$	S.F. = 1.30	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		4,000	20,000	.05 .03
LONG. GRAIN		5,000	25,000	.08 .06
MACHINE, ETCH AND		6,000	30,000	.12 .10
CHEMICAL FILM		7,000	35,000	.16 .15
		8,000	40,000	.18 .18
		9,000	45,000	.22 .23
		10,000	50,000	.30 .28
		11,000	55,000	.38 .34
		11,574	57,870	FAILURE



FATIGUE TEST DATA FOR SPECIMEN NO. 5S42				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		7,000	35,000	.03 .02
LONG. GRAIN		8,000	40,000	.07 .06
MACHINE, SHOT PEEN, ETCH		9,000	45,000	.12 .11
AND CHEMICAL FILM		10,000	50,000	.14 .12
		11,000	55,000	.21 .20
		12,000	60,000	.26 .26
		13,000	65,000	.31 .30
		14,000	70,000	.36 .30
		14,100	70,500	FAILURE

FATIGUE TEST DATA FOR SPECIMEN NO. 5M42				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 SPAR CAP		7,000	35,000	.07 .08
MACHINE, ETCH AND		8,000	40,000	.08 .08
CHEMICAL FILM		9,000	45,000	.10 .11
		10,000	50,000	.12 .15
		11,000	55,000	.13 .16
		12,000	60,000	.19 .20
		13,000	65,000	.26 .30
		14,000	70,000	.34 .42
		14,109	70,545	FAILURE



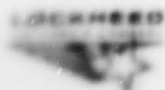
FATIGUE TEST DATA FOR SPECIMEN No. LA5				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		6,000	30,000	.05 .04
LONG. GRAIN		7,000	35,000	.06 .05
MACHINE, ETCH AND		8,000	40,000	.08 .08
CHEMICAL FILM		9,000	45,000	.09 .09
		10,000	50,000	.13 .09
		11,000	55,000	.16 .12
		12,000	60,000	.20 .14
		13,000	65,000	.24 .16
		14,000	70,000	.26 .20
		15,000	75,000	.32 .22
		16,000	80,000	.38 .26
		16,298	81,490	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. L7				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7075-T6510 PLANK		6,000	30,000	.08 .10
LONG. GRAIN		7,000	35,000	.08 .12
MACHINE, SHOT PEEN, ETCH		8,000	40,000	.18 .18
AND CHEMICAL FILM		9,000	45,000	.21 .20
		10,000	50,000	.26 .24
		11,000	55,000	.32 .27
		11,304	56,520	FAILURE



FATIGUE TEST DATA FOR SPECIMEN No. LB				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7075-T6510 PLANK		5,000	25,000	.03 .07
LONG. GRAIN		6,000	30,000	.03 .10
MACHINE, SHOT PEEN, ETCH		7,000	35,000	.10 .12
AND CHEMICAL FILM		8,000	40,000	.12 .17
		9,000	45,000	.15 .22
		10,000	50,000	.23 .27
		11,000	55,000	.29 .33
		11,470	57,350	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LAG				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		5,000	25,000	.04 .02
LONG. GRAIN		6,000	30,000	.04 .03
MACHINE, ETCH AND		7,000	35,000	.04 .04
CHEMICAL FILM		8,000	40,000	.06 .04
		9,000	45,000	.11 .10
		10,000	50,000	.12 .11
		11,000	55,000	.14 .12
		12,000	60,000	.23 .12
		13,000	65,000	.23 .16
		14,000	70,000	.27 .23
		15,000	75,000	.30 .23
		16,000	80,000	.38 .30
TEST STOPPED @		17,000	85,000	.40 .30



FATIGUE TEST DATA FOR SPECIMEN No. LTA1				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		6,000	30,000	.00 .03
LONG. TRANS. GRAIN		7,000	35,000	.06 .08
MACHINE, ETCH AND		8,000	40,000	.06 .09
CHEMICAL FILM		9,000	45,000	.10 .12
		10,000	50,000	.10 .15
		11,000	55,000	.14 .16
		12,000	60,000	.18 .20
		13,000	65,000	.24 .26
		14,000	70,000	.28 .31
		15,000	75,000	.34 .36
		15,109	75,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LBB				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT B		5,000	25,000	.00 .01
LONG. GRAIN		6,000	30,000	.02 .07
MACHINE, SHOT PEEN, ETCH		7,000	35,000	.10 .11
AND CHEMICAL FILM		8,000	40,000	.16 .18
		9,000	45,000	.18 .21
TEST STOPPED @		9,356	46,780	— —



FATIGUE TEST DATA FOR SPECIMEN NO. LTBI				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT B		5,000	25,000	.00 .02
LONG. TRANS. GRAIN		6,000	30,000	.06 .06
MACHINE, ETCH AND		7,000	35,000	.08 .08
CHEMICAL FILM		8,000	40,000	.12 .10
		9,000	45,000	.13 .13
		10,000	50,000	.15 .16
		11,000	55,000	.18 .18
		12,000	60,000	.22 .21
		13,000	65,000	.30 .28
		14,000	70,000	.35 .33
		15,000	75,000	.40 .37
		15,109	75,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN NO. LA7				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		6,000	30,000	.03 .06
LONG. GRAIN		7,000	35,000	.10 .10
MACHINE, SHOT PEEN, ETCH		8,000	40,000	.12 .13
AND CHEMICAL FILM		9,000	45,000	.20 .20
		10,000	50,000	.24 .24
		11,000	55,000	.27 .31
		11,600	58,000	FAILURE



FATIGUE TEST DATA FOR SPECIMEN No. LTA3				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7050-T7E73 PLANK, LOT A		5,000	25,000	.00 .02
LONG. TRANS. GRAIN		6,000	30,000	.05 .06
MACHINE, SHOT PEEN, ETCH		7,000	35,000	.06 .08
AND CHEMICAL FILM		8,000	40,000	.12 .10
		9,000	45,000	.18 .16
		10,000	50,000	.22 .20
		11,000	55,000	.30 .24
		12,000	60,000	.36 .32
		12,109	60,545	FAILURE

FATIGUE TEST DATA FOR SPECIMEN No. LTI				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7075-T6510 PLANK		4,000	20,000	.07 .05
LONG. TRANS. GRAIN		5,000	25,000	.09 .09
MACHINE, ETCH AND		6,000	30,000	.12 .13
CHEMICAL FILM		7,000	35,000	.16 .16
		8,000	40,000	.21 .24
		9,000	45,000	.24 .30
		9,383	46,915	FAILURE



FATIGUE TEST DATA FOR SPECIMEN NO. 7S4Z				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		5,000	25,000	.02 .00
MACHINE, SHOT PEEN, ETCH		6,000	30,000	.07 .02
AND CHEMICAL FILM		7,000	35,000	.10 .05
LONG. GRAIN		8,000	40,000	.18 .09
		9,000	45,000	.20 .10
		10,000	50,000	.20 .14
		11,000	55,000	.24 .20
		12,000	60,000	.27 .23
		13,000	65,000	.30 .27
		14,000	70,000	.34 .30
		15,000	75,000	.36 .32
		15,463	77,315.	FAILURE

FATIGUE TEST DATA FOR SPECIMEN NO. 7M4Z				
$K_t = 4.0$	S.F. = 1.15	FLIGHTS	HOURS	CRACKING
7075-T6510 SPAR CAP		4,000	20,000	.04 .03
LONG. GRAIN		5,000	25,000	.05 .06
MACHINE, ETCH AND		6,000	30,000	.10 .10
CHEMICAL FILM		7,000	35,000	.16 .16
		8,000	40,000	.20 .20
		9,000	45,000	.24 .24
		10,000	50,000	.26 .26
		11,000	55,000	.36 .34
		11,109	55,545	FAILURE



APPENDIX C
Crack Propagation Tabular Data

Tabular test data for constant amplitude crack propagation tests are included in this Appendix.

The test data locations for the crack propagation specimens are shown in the following table:

Specimen ⁽¹⁾ No.	Location, Page	Specimen ⁽¹⁾ No.	Location, Page
1	C-2	7	C-9 & 10
2	C-3 & 4	8	C-11 & 12
4	C-5 & 6	9	C-13 & 14
5	C-7 & 8	10	C-15 & 16

(1) For test specimen description, see Table 9.

AD-A058 002

LOCKHEED-CALIFORNIA CO BURBANK

F/G 11/6

COMPARISON OF ENGINEERING PROPERTIES OF 7050-T7E73 AND 7075-T65--ETC(U)

FEB 78 R W BRODIE, L BAKOW

N62269-77-C-0024

UNCLASSIFIED

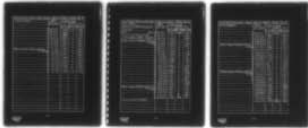
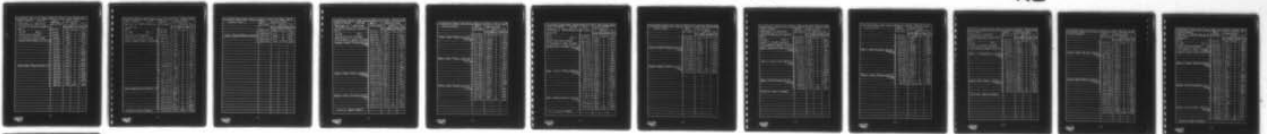
LR-28499

NADC-76269-30

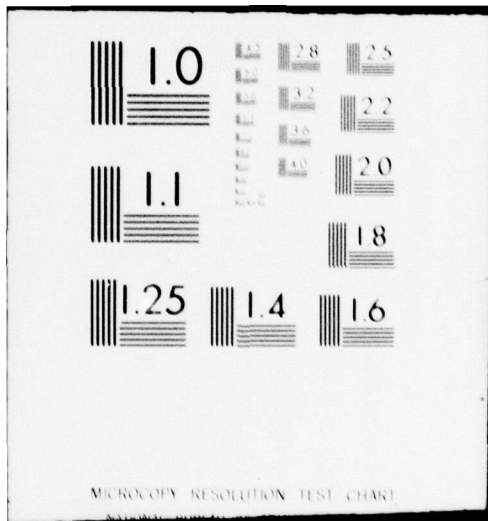
NL

2 of 2

AD
A058 002



END
DATE
FILMED
10-78
DDC



CONSTANT AMPLITUDE CRACK GROWTH DATA FOR PANEL NO. 2					
7050-T7E73	LOT A	ΣN	CRACKING		
TESTED IN 98% RELATIVE HUMIDITY		(CYCLES)	a_1	NOTCH	a_2
			(INCHES)	(INCHES)	(INCHES)
R.T.		40,000	.001	2.00	.012
6 HZ	R = .1	43,000	.026		.015
WIDTH = 16.09 INCHES		53,000	.035		.018
THICKNESS = .0945 INCHES		58,000	.042		.018
GROSS AREA STRESS = 4.0 KSI →		68,000	.042		.028
		73,000	.053		.032
		98,000	.064		.034
		113,000	.068		.040
		133,000	.073		.052
		150,000	.084		.052
		170,000	.097		.052
		190,000	.107		.062
		210,000	.127		.064
		259,000	.150		.081
		270,000	.158		.090
		275,000	.174		.101
		285,000	.194		.129
		292,000	.235		.149
		297,000	.265		.171
		304,000	.291		.189
		311,000	.320		.206
GROSS AREA STRESS = 5.50 KSI →		318,000	.340		.227
		325,000	.363		.247
		332,000	.389		.270
		339,000	.421		.291
		346,000	.445		.311
		353,000	.477		.337
		360,000	.501		.358
		367,000	.529		.383
(CONT'D NEXT PAGE)		374,000	.555	2.00	.408



CONSTANT AMPLITUDE CRACK GROWTH DATA, PANEL No. 4					
7050-T7E73	LOT B	ΣN	CRACKING		
TESTED IN LAB AIR		(CYCLES)	a_1	NOTCH	a_2
($\approx 40\%$ RELATIVE HUMIDITY)			(INCHES)	(INCHES)	(INCHES)
R.T.		15,000	.005	2.00	.009
6 Hz.	R=.1	30,000	.025		.017
WIDTH = 16.10 INCHES		50,000	.042		.033
THICKNESS = .0954 INCHES		80,000	.059		.053
GROSS AREA STRESS = 4.0 KSI		120,000	.087		.068
		170,000	.115		.072
		210,000	.145		.090
		260,000	.172		.110
		310,000	.203		.127
		374,000	.236		.156
		424,000	.265		.170
		470,000	.301		.187
		480,000	.335		.221
		490,000	.369		.254
		500,000	.403		.290
GROSS AREA STRESS = 5.5 KSI		510,000	.445		.321
		525,000	.500		.377
		540,000	.555		.431
		560,000	.637		.513
		572,000	.686		.564
		574,000	.709		.588
		579,000	.766		.644
		584,000	.810		.706
GROSS AREA STRESS = 70 KSI		589,000	.870		.768
		595,000	.940		.854
		601,000	1.022		.947
		606,000	1.097		1.038
		609,000	1.150	2.00	1.098
(CONT'D NEXT PAGE)					

CONSTANT AMPLITUDE CRACK GROWTH DATA, PANEL No.4				
(CONTINUED)	EN (CYCLES)	CRACKING		
		a ₁ (INCHES)	NOTCH (INCHES)	a ₂ (INCHES)
	609,300	1.156	2.00	1.109
GROSS AREA STRESS = 10.0 KSI	609,600	1.171		1.127
→	610,200	1.203		1.166
	610,800	1.239		1.206
	611,300	1.273		1.243
	611,800	1.282		1.255
	612,300	1.297		1.267
	612,800	1.321		1.292
	613,300	1.330		1.307
GROSS AREA STRESS = 8.0 KSI	613,800	1.346		1.321
→	614,800	1.376		1.349
	615,800	1.409		1.380
	616,800	1.433		1.409
	617,800	1.467		1.440
	618,800	1.495		1.470
	621,800	1.521		1.496
	623,800	1.548		1.519
	625,800	1.564		1.548
	626,800	1.587		1.558
GROSS AREA STRESS = 6.0 KSI	627,800	1.599		1.571
→	628,800	1.615		1.586
	629,800	1.628		1.599
	630,800	1.650		1.618
	631,800	1.662	↓	1.629
	632,300	1.670	2.00	1.634

CONSTANT AMPLITUDE CRACK GROWTH DATA FOR PANEL No.5				
7050-T7E73 LOT B	ΣN	CRACKING		
TESTED IN 98% RELATIVE HUMIDITY	(CYCLES)	a_1	NOTCH	a_2
		(INCHES)	(INCHES)	(INCHES)
R.T.	20,000	.017	2.00	.026
6Hz R=.1	30,000	.028		.039
WIDTH = 16.08 INCHES	45,000	.040		.064
THICKNESS = .096 INCHES	60,000	.052		.090
GROSS AREA STRESS = 4.0 KSI	70,000	.061		.107
	80,000	.071		.124
	90,000	.081		.136
	100,000	.092		.156
	102,000	.094		.167
	105,000	.108		.185
	114,000	.142		.220
	124,000	.180		.269
	134,000	.226		.324
GROSS AREA STRESS = 5.5 KSI	144,000	.267		.362
	154,000	.318		.412
	169,000	.395		.493
	184,000	.476		.575
	194,000	.545		.633
	200,000	.588		.668
	202,000	.639		.715
	204,000	.688		.757
	206,000	.746		.803
	208,000	.806		.851
GROSS AREA STRESS = 7.0 KSI	210,000	.864		.912
	212,000	.926		.967
	214,000	.987		1.026
	216,000	1.055	↓	1.088
	217,300	1.092	2.00	1.127
(CONT'D NEXT PAGE)				

CONSTANT AMPLITUDE CRACK GROWTH DATA, PANEL No. 9				
7075-T6510	ΣN	CRACKING		
TESTED IN 98% RELATIVE HUMIDITY	(CYCLES)	a_1	NOTCH	a_2
		(INCHES)	(INCHES)	(INCHES)
R.T.	10,000	.010	2.00	.023
6 HZ. R = .1	20,000	.114		.065
WIDTH = 16.10 INCHES	23,000	.142		.085
THICKNESS = .0865 INCHES	25,000	.163		.098
GROSS AREA STRESS = 4.0 KSI	30,000	.187		.109
	35,000	.200		.120
	40,000	.225		.134
	45,000	.244		.153
GROSS AREA STRESS = 3.0 KSI	50,000	.265		.167
	55,000	.292		.181
	60,000	.311		.198
	65,000	.330		.217
	70,000	.367		.240
	72,000	.382		.253
	75,000	.419		.282
	78,000	.452		.313
GROSS AREA STRESS = 4.0 KSI	81,000	.490		.343
	83,000	.512		.366
	85,000	.534		.385
	87,000	.563		.414
	88,000	.580		.423
	89,000	.600		.446
	90,000	.628		.468
	91,000	.647		.492
GROSS AREA STRESS = 5.0 KSI	92,000	.665		.513
	94,000	.718		.563
	96,000	.769		.613
	97,000	.805		.644
	97,900	.823	2.00	.670
(CONT'D NEXT PAGE)				

CONSTANT AMPLITUDE CRACK GROWTH DATA, PANEL No. 10				
7075-T6510	ΣN	CRACKING		
TESTED IN 98% RELATIVE	(CYCLES)	a ₁	NOTCH	a ₂
HUMIDITY		(INCHES)	(INCHES)	(INCHES)
R.T. R=.1	20,000	.009	1.968	.013
WIDTH = 16.08 INCHES	30,000	.016		.031
THICKNESS = .0856 INCHES	40,000	.018		.054
GROSS AREA STRESS = 3.0 KSI	50,000	.020		.069
	60,000	.023		.077
	70,000	.027		.092
	80,000	.027		.110
	90,000	.028		.124
	100,000	.028		.138
	110,000	.032		.151
	120,000	.038		.166
	140,000	.042		.195
	160,000	.056		.233
	180,000	.074		.293
	200,000	.086		.372
	215,000	.097		.444
	218,500	.152		.503
	220,000	.173		.527
	222,000	.201		.553
	224,000	.225		.588
GROSS AREA STRESS = 4.5 KSI	226,000	.251		.604
	228,000	.265		.620
	230,000	.290		.646
	232,000	.316		.688
	233,000	.334	1.968	.709
(CONT'D NEXT PAGE)				

CONSTANT AMPLITUDE CRACK GROWTH DATA, PANEL No. 10

(CONTINUED)	ΣN		CRACKING	
	(CYCLES)	a ₁	NOTCH	a ₂
		(INCHES)	(INCHES)	(INCHES)
	234,000	.360	1.968	.742
	235,000	.387		.783
	236,500	.437		.839
	238,000	.469		.893
GROSS AREA STRESS=5.5 KSI	239,500	.503		.956
→	241,000	.548		1.014
	242,500	.593		1.079
	243,000	.631		1.137
	245,000	.693		1.219
	246,800	.743		1.290
	247,300	.775		1.329
	248,000	.811		1.376
	249,000	.867		1.448
	250,000	.916		1.514
GROSS AREA STRESS=6.5 KSI	251,000	.976		1.574
→	252,000	1.045		1.645
	253,000	1.106		1.724
	254,000	1.188		1.797
	254,300	1.211		1.821
	256,300	1.238		1.856
	257,300	1.273		1.888
	258,300	1.298		1.922
	258,800	1.305		1.940
	259,300	1.326		1.960
	259,800	1.338	↓	1.977
	260,100	1.345	1.968	1.982

