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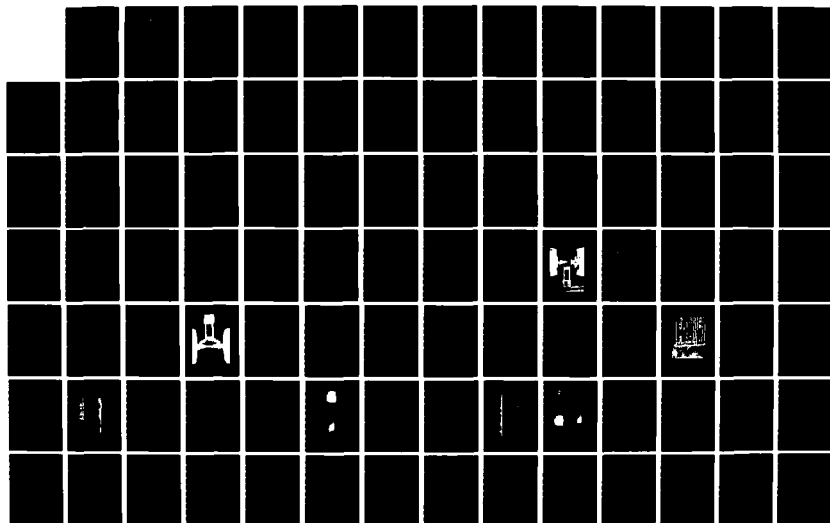
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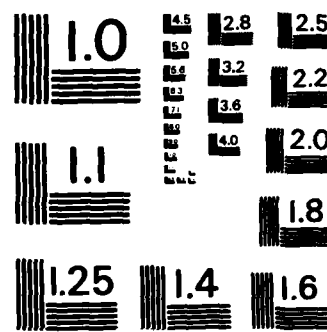
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REPORT NO. NADC-83126-60 (VOL. IV)



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**DEVELOPMENT OF FATIGUE AND CRACK PROPAGATION
DESIGN & ANALYSIS METHODOLOGY IN A CORROSIVE
ENVIRONMENT FOR TYPICAL MECHANICALLY-FASTENED JOINTS**

VOLUME IV — PHASE II TEST AND FRACTOGRAPHIC RESULTS

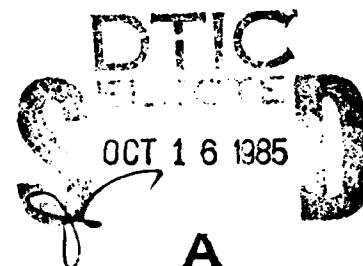
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FOR PERIOD SEPTEMBER 1982 - OCTOBER 1984



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Prepared for
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DEPARTMENT OF THE NAVY
Warminster, PA 18974

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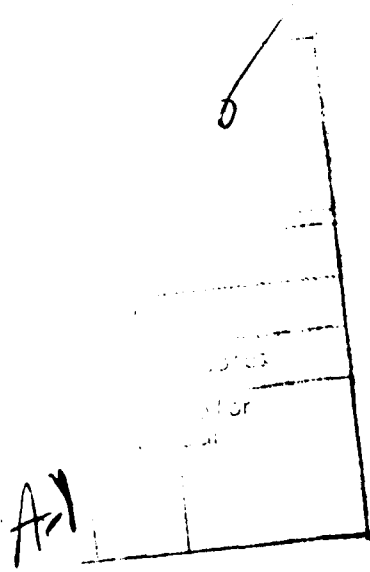
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains the test results and raw fractographic data acquired under Phase II of the corrosion fatigue program for mechanically-fastened joints. The results presented in this Volume (IV) are evaluated in Volume III. Variables included in the Phase II test program were material (7075-T7651 and Ti-6Al-4V), environment (dry air and 3.5% NaCl), load spectra (F-16 400 Hr. and F-18 300 Hr.), type loading (strain-controlled, constant amplitude,		

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> spectrum), stress level (a base-line stress; three alternate stresses), specimen conditioning (none; preconditioned), loading frequency (four loading rates), specimen type (strain controlled, compact tension and dog-bone); and bolt load transfer (0%, 20%, 40%). Most of the results ~~herein~~ are for 7075-T7651 aluminum alloy dog-bone specimens. These results were used to evaluate the corrosion fatigue analysis methodology for crack initiation and crack propagation in Volume II. Ti-6Al-4V alloy results ~~herein~~ are limited to un-notched strain controlled tests. Further titanium research conducted under Phase II, including experimental results and evaluations, is documented in Volume V. Vol. 5. Research

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FOREWORD

This program was conducted by General Dynamics, Fort Worth Division (GD/FWD), with Lehigh University (Dr. R. P. Wei) as a subcontractor/consultant. This report (Vol. IV) documents the test and fractographic results obtained by General Dynamics under Phase II of the "Development of Fatigue and Crack Propagation Design and Analysis Methodology in a Corrosive Environment for Typical Mechanically-Fastened Joints" program (NADC Contract N6226-81-C-0268). The program was sponsored by the Naval Air Development Center, Warminster, PA, with Mr. P. Kozel as the project engineer. Dr. S. D. Manning of General Dynamics, Fort Worth Division, was the Program Manager/Principal Investigator and Dr. R. P. Wei of Leigh University was a co-investigator.

Several General Dynamics personnel supported the Phase II test program. D. E. Gordon coordinated the overall testing effort, procured specimens, performed the strain-controlled and the constant amplitude tests, eddy current inspections and fractographic evaluations. S. B. Kirschner coordinated the dog-bone specimen spectrum tests and per-

formed fractographic evaluations and data analyses. Dog-bone specimen spectrum tests and specimen dimensional checks were performed by R. O. Nay. Corrosion fatigue testing support was provided by F. C. Nordquist, J. W. Hagemayer and H. C. Hoffman. Dr. R. P. Wei of Lehigh University also assisted in setting up the test plan and provided valuable technical support.

The following reports (NADC-83126-60-) were also prepared under the Phase II effort:

- o Volume III - Phase II Documentation
- o Volume V - Corrosion Fatigue Cracking Response of
Beta Annealed Ti-6Al-4V Alloy in 3.5%
NaCl Solution

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S E C T I O N I

I N T R O D U C T I O N

This report documents the test and fractographic results acquired by General Dynamics under Phase II of the corrosion fatigue test program. The test matrix, test setup, test procedures, specimen details, data acquisition methods, etc., are described herein. Raw fractographic results and supporting details are also presented. However, the conclusions and recommendations for the Phase II test program, including the evaluation of the test/fractographic results are presented in Volume III [1].

Most of the test and fractographic results presented herein are for the 7075-T7651 aluminum alloy. Results are also presented for strain-controlled specimens made from Ti-6Al-4V alloy. However, the Ti-6Al-4V alloy test results and evaluations that were conducted by Lehigh University as a part of the basic titanium research effort under Phase II are documented in Volume V [2].

A brief overview of the corrosion fatigue program for mechanically-fastened joints is given in Section II. The

corrosion fatigue (CF) test program for the Phase II effort is described in Section III. In Section IV, testing procedures and data acquisition methods, including fractography, are described. Strain-controlled test results for the 7075-T7651 aluminum alloy and the beta-annealed Ti-6Al-4V alloy are presented in Appendices A and B, respectively. Constant amplitude test results for dog-bone specimens of 7075-T7651 aluminum alloy are presented in Appendix C. Dog-bone specimen spectrum fatigue test results and applicable fractographic data are presented for Tasks 4, 5 and 6 in Appendices D, E and F, respectively.

S E C T I O N I I

C O R R O S I O N F A T I G U E P R O G R A M
O V E R V I E W

The purpose of this section is to review the overall objectives of the corrosion fatigue program for mechanically-fastened joints and to put the results of this Volume (IV) into perspective.

The main objectives of this program were to:

1. Develop and verify an analytical methodology for predicting the TTCI and crack propagation life of mechanically-fastened joints in a corrosive environment.
2. Develop corrosion fatigue test/data-acquisition methods and guidelines for acquiring statistically-valid data needed to implement the analytical methodology.
3. Study the effects of various factors on the corrosion fatigue behavior of mechanically-fastened joints.

The Phase I effort, documented in Volumes I and II [3,4], was concerned with three tasks as follows:

- o Task 1 - Methodology and Data State-of-the-Art Assessment
- o Task 2 - Methodology Development
- o Task 3 - Test Plan Development

In Phase I the existing corrosion fatigue analysis methods were reviewed, the effects of various variables (i.e., stress level, R-ratio, loading frequency, environment hold-time, etc.) on TTCI and crack growth were experimentally investigated and evaluated for two different materials (7075-T7651 aluminum alloy and beta-annealed 6Al-4V Ti alloy), and a test plan was developed for the Phase II effort. The most suitable corrosion fatigue analysis methods for predicting the TTCI and crack propagation for mechanically-fastened joints were recommended in Phase I for evaluation in Phase II. Constant amplitude corrosion fatigue data were acquired under the Phase I effort.

The Phase II effort, data acquisition and methodology evaluation, included three tasks:

- o Task 4 - Experimental Methodology Development and Evaluation
- o Task 5 - Acquisition of Data for Prediction of Environmentally-Assisted Crack Growth in Aircraft Joints
- o Task 6 - Prediction Methodology Evaluation and Verification

The objectives of the Phase II effort were to: (1) develop and evaluate suitable experimental methods and specimens for acquiring corrosion fatigue data for mechanically-fastened joints, (2) acquire corrosion fatigue data needed to implement the predictive methods recommended under Phase I, (3) evaluate the effectiveness of the CF analysis methodology for predicting the fatigue life of mechanically-fastened joints under spectrum loading, and (4) evaluate the effects of various factors (e.g., loading frequency, R-ratio, stress level, load transfer, load spectra) on the TTCI and crack propagation in mechanically-fastened joints.

In Phase I it was found that the corrosion fatigue behavior of the Ti-6Al-4V alloy was very complex [3]. For this reason, the Phase II effort was mainly concerned with the demonstration and evaluation of the corrosion fatigue

methodology for 7075-T7651 aluminum alloy. In Phase II, the Ti-6Al-4V alloy investigations were limited to the development of a better understanding of the corrosion fatigue crack growth mechanisms and the effects of loading frequency were emphasized [2].

This volume (IV) documents the Phase II experimental test program conducted and includes the raw test and fractographic results. Phase II test/fractographic results presented in this Volume (IV) are evaluated in Volume III [1] and the conclusions and recommendations are also presented.

S E C T I O N I I I

P H A S E I I T E S T P R O G R A M

3.1 INTRODUCTION

The purpose of this section is to describe what was tested under Phase II of the corrosion fatigue program for mechanically-fastened joints and to discuss overall test objectives. Detailed test procedures and methods for acquiring the experimental results are discussed in Section IV. A preliminary test plan for the Phase II effort was developed under Phase I and it is described in Volume I [3]. The preliminary test plan was periodically adjusted during the course of the Phase II effort so that future tests could build on the Phase II test results and needs.

3.2 PHASE II TEST OBJECTIVES

The main objectives of the Phase II test program were to:

1. Develop and evaluate suitable experimental methods and specimens for acquiring corrosion fatigue data for mechanically fastened joints (Task 4).

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2. Acquire statistically-valid corrosion fatigue data needed to implement and "tune" the corrosion fatigue analysis methodology for spectrum loading applications (Task 5).

3. Provide statistically-valid experimental data for evaluating the effects of various factors (e.g., loading frequency, R-ratio, stress level, load spectra, and percent bolt load transfer) on the time-to-crack-initiation (TTCI) and time-to-failure (TTF) in fastener holes (Task 5).

4. Provide key experimental results for Ti-6Al-4V alloy for developing a better understanding of basic mechanism and the effects of loading frequency on fatigue crack growth (Task 5).

5. Provide corrosion fatigue test results for crack initiation and crack growth in fastener holes that can be used to evaluate the accuracy of analytical methodology described in Volume I [3] (Task 6).

3.3 TEST PROGRAM PHILOSOPHY

The corrosion fatigue behavior of mechanically-fastened joints is complex. Therefore, the following philosophy was reflected in the Phase II test program:

- o Minimize the number of test variables to isolate the effects of corrosion fatigue.
- o Use test replications to acquire statistically-valid data.
- o Consider the most fundamental elements of a mechanically-fastened joint (i.e., single hole, straight bore, protruding head fastener and fastener load transfer).
- o Develop a better understanding of the corrosion fatigue behavior of straight-bore holes - with and without: fasteners and load transfer through the fasteners.
- o Due to the complexity of corrosion fatigue, state-of-the-art analytical corrosion fatigue methodology should be developed and verified in progressive steps with increasing structural complexities. Develop

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understanding and data for simple joints before considering more complex joints.

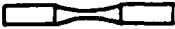
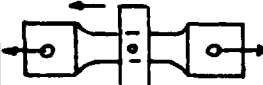
- o Build on the test data and understandings from the Phase I effort.
- o Develop and verify the corrosion fatigue analytical methodology for 7075-T7651 aluminum alloy.
- o Develop a better understanding of the corrosion fatigue mechanisms for Ti-6Al-4V alloy [2].

3.4 TEST MATRIX AND DATA SET DESIGNATIONS

This section describes what was tested in Phase II. Key test variables reflected in the test program and testing rationale are also discussed in this section. However, detailed testing procedures and data acquisition methods are discussed in Section IV.

The Phase II corrosion fatigue program test matrix included 253 test specimens as noted in Table 1. Specimen details are shown in Figs. 1-3. A summary of the test variables used in Phase II is shown in Table 2.

TABLE 1 TEST SPECIMEN MATRIX FOR PHASE II

SPECIMEN		MATERIAL	NO. OF SPECIMEN			
CONFIGURATION	TYPE		TASK 4	TASK 5	TASK 6	Σ
 (Fig. 1)	S-C	7074-T7651	5	45	0	50
		Ti-6Al-4V	1	29	0	30
 (Fig. 2)	CT	Ti-6Al-4V	0	9*	0	9*
 (Fig. 3)	NLT	7075-T7651	23	90	3	116
 (Fig. 3)	LT	7075-T7651	2	3	43	48
Σ			31	176	46	253

NOTES:

Task 4 - Experimental Methodology Development & Evaluation

Task 5 - Acquisition of Data for Prediction of Environmentally-Assisted Crack Growth in Aircraft Joints

Task 6 - Prediction Methodology Evaluation and Verification

S-C - Strain-controlled

CT - Compact Tension

NLT - No Load Transfer (through the fastener)

LT - Load Transfer (through the fastener)

* Results are documented and evaluated in Volume V [2].

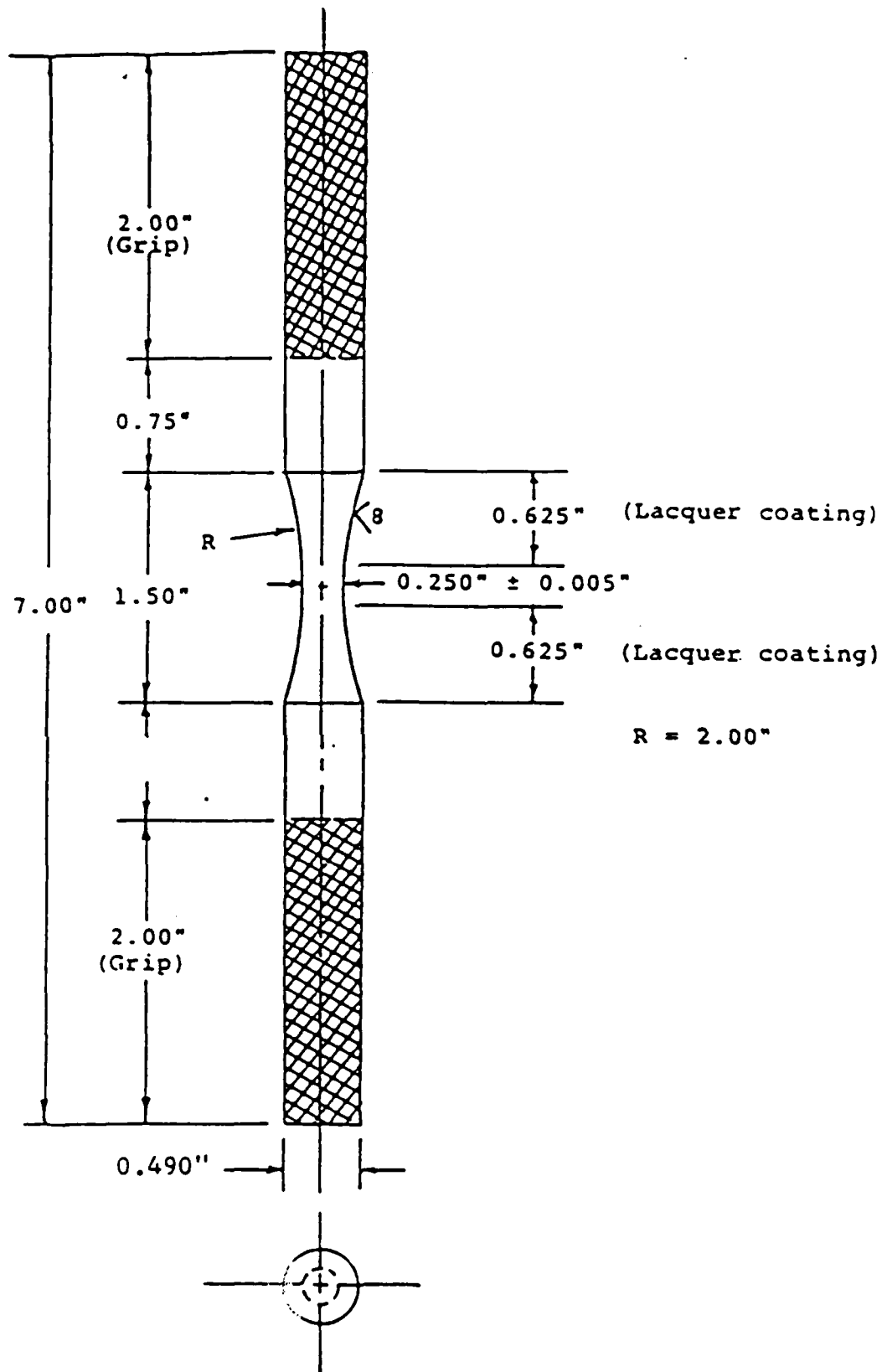


Fig. 1 Strain-Controlled Specimen

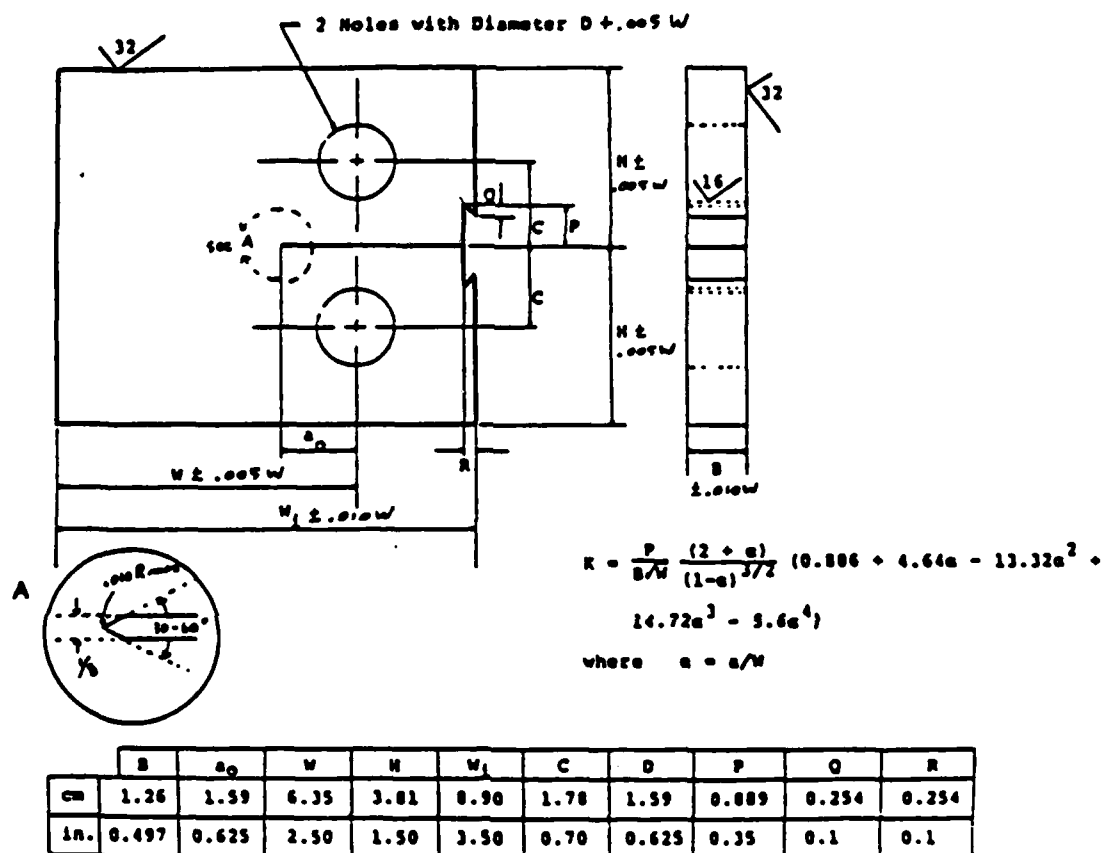


Fig. 2 Compact Tension Specimen for Beta-Annealed Ti-6Al-4V Alloy

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TABLE 2 PHASE II TEST VARIABLES

MATERIAL	- o 7075-T7651 ALUMINUM ALLOY - o Ti-6Al-4V ALLOY
ENVIRONMENT	- o DRY AIR - o 3.5% NaCl SOLUTION
TYPE LOADING	- o STRAIN-CONTROLLED - o CONSTANT AMPLITUDE - o SPECTRUM
LOAD SPECTRA	- o F-16 400 HR. (HI-LO BLOCKS) - o F-18 300 HR. (RANDOMIZED) - o F-18 300 HR. (HI-LO BLOCKS)
LOADING FREQUENCY AND HOLD TIME	- o CONSTANT AMPLITUDE (0.3 Hz TO 20 Hz) - o SPECTRUM (FAST, SLOW, X-SLOW) - o HOLD TIME (0 s TO 2.33 s)
TEST SPECIMENS	- o UN-NOTCHED AXIAL (STRAIN-CONTROL) - o COMPACT TENSION - o DOG-BONE WITH CENTER HOLE
FASTENER HOLE	- o OPEN (W/O BOLT) - o WITH BOLT
BOLT HOLE FINISH	o POLISHED
BOLT TYPE	o STEEL PROTRUDING HEAD (CAD-PLATED) (e.g., NAS 6207)
BOLT LOAD TRANSFER	- o 0% LT - o 20% LT - o 40% LT
STRESS LEVEL	- o BASELINE STRESS - o OTHER
SPECIMEN PRECONDITIONING	- o NONE - o PRETEST AND PRESOAK IN 3.5% NaCl

Test plans for Tasks 4, 5 and 6 are shown in Tables 3-7. For tracking purposes, tests are defined by I.D. number and by data set. The total number of specimens tested under each data set and other testing details are shown in Tables 3-7.

3.4.1 Coding System for Tests

A coding system was devised to concisely describe the key test variables used in Tables 3-7 and to facilitate test identifications. The coding system used in this report is shown and illustrated in Table 8.

In Tables 3-7 tests are also identified by "data set number" so that test specimens can be grouped and identified by the applicable data set number. This system is used throughout this report.

3.4.2 Materials

Two materials were used for the Phase II testing: 7075-T7651 aluminum alloy and Beta-annealed Ti-6Al-4V. These materials are of particular interest because several Navy aircraft in service include these materials in the airframe and such materials are susceptible to corrosion fatigue. The 7075-T7651 aluminum alloy material was supplied as 0.50-inch plate. The Ti-6Al-4V material was in the form of 0.875-inch thick plate. These materials were

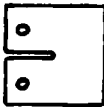
TABLE 3 EXPERIMENTAL METHODOLOGY DEVELOPMENT AND EVALUATION TESTS (TASK 4)

SPECIMEN	SPECTRUM	MATERIAL	TEST I.D.	DATA SET NO.	SPECIMEN DETAILS			ENVIRONMENT		FREQUENCY		NO. SPECIMENS TESTED
					X LT	BOLT?	PC?	DRY	3.5%NaCl	FAST	SLOW	
 (Fig. 3)	F-16 400 HR	7075-T7651	A-34/S/D A-34/F/W A-34/S/W A-32/S/D A-32/F/W A-32/S/W A-30/F/D A-30/S/D A-30/F/W A-30/20/S/W A-30/20/F/W A-28/F/W/B A-28/F/W/B/PC A-28/S/W/B/PC	41	0	No	No	X	-	-	X	1
				42				-	X	X	-	1
				43				-	X	-	X	3
				44				X	-	-	X	3
				45				-	X	X	-	1
				46				-	X	-	X	3
				47				-	X	-	X	2
				48				X	-	-	X	1
				49				X	-	-	X	3
				50	20	Yes		-	X	-	-	1
				54	20	Yes		-	X	X	-	1
				51	0	Yes		-	X	X	-	1
				52	†			-	X	X	-	2
				53	0			-	X	-	X	2
 (Fig. 1)	CONSTANT AMPLITUDE (R = -1) (STRAIN CONTROLLED)	T1-6Al-4V	SC 1A	71	STRAIN SURVEY TESTS							5
				81								1
				31								

TABLE 4 STRAIN-CONTROLLED TESTS FOR TASK 5

LOADING	MATERIAL	TEST I.D.	DATA SET NO.	ENVIRONMENT		FREQUENCY	NO. SPECIMENS TESTED
				DRY	3.5% NaCl		
Constant Amplitude (R=-1)	7075-T7651	SC/D/A	72	X	-	VARIABLE	22
	7075-T7651	SC/W/A	73	-	X	VARIABLE	23
	Ti-6Al-4V	SC/D/T	82	X	-	VARIABLE	18
	Ti-6Al-4V	SC/D/T	83	-	X	VARIABLE	11
							74

TABLE 5 Ti-6Al-4V ALLOY CRACK GROWTH TESTS FOR TASK 5

SPECIMEN	MATERIAL	ENVIRONMENT	K LEVEL			NO. SPECIMEN TESTED
			LOW	MED	HIGH	
	Ti-6Al-4V	Oxygen (Ref.)	X	-	-	2
			-	X	-	2
			-	-	X	2
		3.5% NaCl	X	-	-	1
			-	X	-	1
			-	-	X	1
						9

Notes: 1. Ref. Volume I [3] for tests in vacuum.

2. Ref. Volume V [2] for testing details and results.

TABLE 6 DOG-BONE SPECIMEN TESTS FOR TASK 5

SPECIMEN	SPECTRUM	MATERIAL	TEST I.D.	DATA SET NO.	SPECIMEN DETAILS				ENVIRONMENT		FREQUENCY			NO. SPECIMENS TESTED	
					% LT	BOLT?	PC?	DRY	3.5% NaCl	FAST	SLOW	X SLOW			
 (Fig. 3)	CONSTANT AMPLITUDE	7075-T7651 7075-T7651	CA/F/D/PC CA/F/W/PC	61 62	0 0	NO NO	YES YES	X -	- X	X X	- -	- -	3 4		
	P-16 400 HR. (BLOCK)	7075-T7651	A-28/F/D	1	0	NO	NO	NO	X	-	X	-	-	4	
			A-28/S/D	2	0	NO	NO	NO	X	-	-	X	-	4	
			A-28/F/W	3	0	NO	NO	NO	-	X	-	X	-	4	
			A-28/S/W	4	0	NO	NO	NO	-	X	-	-	-	6	
			A-28/F/W	5	0	NO	NO	NO	-	-	-	-	X	3	
			A-28/F/D/PC	6	0	NO	YES	YES	X	-	X	-	-	3	
			A-28/S/D/PC	7	0	NO	NO	NO	X	-	-	X	-	3	
			A-28/F/W/PC	8	0	NO	NO	YES	-	X	-	X	-	3	
			A-28/S/W/PC	9	0	NO	NO	YES	-	X	-	-	-	4	
			A-28/F/D/B	10	0	YES	NO	NO	X	-	X	-	-	3	
			A-28/F/W/B	11	0	NO	NO	NO	-	X	-	-	-	4	
			A-28/S/W/B	12	0	NO	NO	NO	-	X	-	X	-	2	
			A-28/F/D/B/PC	13	0	YES	YES	YES	X	-	X	-	-	3	
			A-28/F/W/B/PC	14	0	YES	YES	YES	-	X	-	X	-	3	
	P-18 300 HR. (RANDOM)	7075-T7651	B-28/F/D	21	0	NO	NO	NO	X	-	X	-	-	3	
			B-28/S/D	22	0	NO	NO	NO	X	-	-	X	-	3	
			B-28/F/W	23	0	NO	NO	NO	-	X	-	-	-	4	
			B-28/S/W	24	0	NO	NO	NO	-	X	-	X	-	4	
			B-28/F/D/PC	25	0	NO	YES	YES	X	-	X	-	-	3	
			B-28/S/D/PC	26	0	NO	NO	NO	X	-	-	X	-	3	
			B-28/F/W/PC	27	0	NO	NO	YES	-	X	-	-	-	4	
			B-28/S/W/PC	28	0	NO	YES	YES	-	X	-	X	-	4	
	P-18 300 HR. (BLOCK)	7075-T7651 7075-T7651	C-28/F/D	33	0	NO	NO	NO	X	-	X	-	-	3	
			C-28/F/W	34	0	NO	NO	NO	-	X	-	-	-	3	
	P-16 400 HR. (BLOCK)		A-28/20/F/W/PC	37	20	YES	YES	YES	-	X	X	-	-	2	
			A-28/20/S/W/PC	38	20	YES	YES	YES	-	X	-	X	-	1	
															93

TABLE 7 DOG-BONE SPECIMEN TESTS FOR TASK 6

SPECIMEN	SPECTRUM	MATERIAL	TEST I.D.	DATA SET NO.	SPECIMEN DETAILS		ENVIRONMENT		FREQUENCY		NO. SPECIMENS TESTED
					z LT	PC?	DRY	3.5% NaCl	FAST	SLOW	
	CONSTANT AMPLITUDE	7075-T7651	CA-23/20/F/D	63	20	NO	X	-	6 Hz	-	1
			CA-17/20/F/D	64	20		X	-		-	3
			CA-17/20/F/W	65	20		-	X			3
		7075-T7651	CA-17/40/F/D	66	40		X	-			2
			CA-17/40/F/W	67	40	NO	-	X			3
	F-16 400 HR. (BLOCK)	7075-T7651	A-28/20/F/D	15	20	NO	X	-	X	-	3
			A-28/20/F/W	16	20		-	X	X	-	2
			A-28/20/S/D	17	20		X	-	-	X	1
		7075-T7651	A-28/20/S/W	18	20		-	X	-	-	2
			A-28/40/F/D	19	40		X	-	X	-	3
			A-28/40/F/W	20	40	NO	-	X	X	-	3
	F-18 300 HR. (RANDOM)	7075-T7651	B-28/20/F/D	30	20	NO	X	-	X	-	4
			B-28/20/F/W	29	20		-	X	X	-	4
		7075-T7651	B-28/40/F/D	31	40		X	-	X	-	3
			B-28/40/F/W	32	40	NO	-	X	X	-	3
	F-18 300 HR. (BLOCK)	7075-T7651	C-28/40/F/D	35	40	NO	X	-	X	-	3
			C-28/40/F/W	36	40	NO	-	X	X	-	3
(Fig. 3)											46

TABLE 8 CODING SYSTEM FOR DESCRIBING TESTS

ITEM	CODE
Type Test or Spectrum	- o CA = Constant Amplitude Test - o SC = Strain-Controlled Test - o A = F-16 400 Hr. (Hi-Lo Block) - o B = F-18 300 Hr. (Random) - o C = F-18 300 Hr. (Hi-Lo Block)
Stress Level (ksi, gross)	o 28, 30, 32, 34 ksi
% Bolt Load Transfer	o 20 or 40 (Follows stress level if applicable)
Spectrum Loading Frequency	- o F = Fast (8000 flt hrs/2 days) - o S = Slow (8000 flt hrs/16 days) - o Δ = XSlow (8000 flt hrs/90 days)
Environment	- o D = Dry Air @ R.T. - o W = 3.5% NaCl Solution @ R.T.
Bolt in Hole	o B = Bolt in Hole (Noted for 0% LT Tests)
Preconditioning	o PC = Specimen Preconditioned (Pretested and Soaked in 3.5% NaCl Solution)

Examples:

- (1) A-28/F/W = F-16 400 Hr. Spectrum; 28 ksi
(gross) stress on test section;
fast loading frequency; 3.5%
NaCl environment
- (2) A-28/20/S/D/B/PC = F-16 400 Hr. Spectrum; 28 ksi
(gross) stress on test section;
20% bolt load transfer; slow
loading frequency; dry air; bolt
in hole; specimen preconditioned

from the same plates used for the Phase I testing. Material properties for these materials are presented in Volume I [3].

The 7075-T7651 aluminum alloy was emphasized in the Phase II test program and the test results were used to evaluate the corrosion fatigue methodology under Task 6.

The corrosion fatigue behavior of the Ti-6Al-4V alloy was found to be very complex in the Phase I effort [3]. Therefore, the Phase II experimental effort for this alloy was mainly concerned with developing a better understanding of the corrosion fatigue mechanisms and, in particular, the effects of loading frequency on crack growth. Test results for the strain-controlled specimens are presented in this report and the compact tension test results and evaluations, are presented in Volume V [2].

3.4.3 Test Specimen Design

Three specimen designs were used in the Phase II investigations. The test specimen details are shown in Figs. 1 - 3. Types of tests conducted with these specimens are shown in Table 1.

The hour-glass specimens shown in Fig. 1 is commonly used in strain-controlled experiments, where large strain

amplitudes are required. This specimen geometry is less susceptible to buckling than the commonly used longitudinal specimen. In our experiments, we felt that the NDI detectability of small cracks would be improved by using the hour-glass design specimen at low strain amplitudes also. All strain-controlled tests in both 7075-T7651 aluminum alloy and beta-annealed Ti-6Al-4V were conducted with the particular specimen geometry shown in Fig. 1.

All Ti-6Al-4V crack growth investigations conducted in Phase II were accomplished with the compact tension specimen shown in Fig. 2. This is the identical specimen design that was used for Ti-6Al-4V crack growth investigations in Phase I [3].

All of the constant amplitude and spectrum loaded stress controlled tests were conducted on the dog-bone specimen shown in Fig. 3. The same specimen design was used for both no-load transfer and load-transfer testing. Considerable experience has been obtained on this specimen design from previous investigations [5-7].

To minimize the effects of fastener hole quality (e.g., scratches in the bore) fatigue crack initiation, all fastener holes in the dog-bone test specimen were polished. Also, all steel fasteners were cad-plated to minimize the corrosive effects between dissimilar metals.

Most dog-bone specimens had a nominal hole diameter of 7/16 inch and a few specimen had a hole diameter of 1/2 inch. Specimen dimensions in the test section and hole diameters were measured and results were recorded.

A 7/16 inch diameter fastener hole was typically used so that the same dog-bone specimen design could be used for both no-load transfer tests as well as for 20% and 40% load transfer tests.

3.4.4 Environments

Specimens were tested in both dry air and 3.5% NaCl solution at room temperature. Several specimens tested in Tasks 4 and 5 were preconditioned (pretested and presoaked in 3.5% NaCl). Test chambers used for obtaining these environments plus the preconditioning procedure are discussed in Section IV.

3.4.5 Type Loading

The Phase II tests included three different types of loading: (1) strain-controlled, (2) constant amplitude and (3) spectrum. Strain-controlled tests were performed with un-notched specimens (Fig. 1) to acquire the data needed to implement the strain-life approach for making time-to-

crack-initiation predictions for loaded and unloaded fastener holes. Constant amplitude tests were performed using both compact tension specimens (Fig. 2) and dog-bone specimens (Fig. 3). Spectrum tests were also performed using dog-bone specimens.

3.4.6 Load Spectra

Corrosion fatigue tests were performed using three different load spectra: (1) F-16 400 Hour (Hi-Lo Blocks), (2) F-18 300 Hour (Randomized) and (3) F-18 300 Hour (Hi-Lo Blocks). Details of these test spectra are discussed in Section 4.6.

Dog-bone specimens of 7075-T7651 aluminum alloy were fatigue tested using the F-16 400 hour block spectrum to acquire experimental results for "tuning" corrosion fatigue analysis predictions for the time-to-crack-initiation (TTCI) and time-to-failure (TTF) in fastener holes.

Fatigue tests were also performed under Task 6 using dog-bone specimens and two variations of the F-18 300 hour spectrum. These tests provided results for evaluating the corrosion fatigue analysis predictive methodology for the time-to-crack-initiation and crack propagation for mechanically-fastened joints.

3.4.7 Loading Frequency

Tests were performed using different loading frequencies (ref. Tables 3-7) so that the possible effects of frequency and environment exposure time on the time-to-crack-initiation and crack growth could be assessed for the two alloys considered. Particular emphasis was placed on acquiring dog-bone specimen (7075-T7651) fatigue test results for three different loading frequencies: (1) Fast = flight hours/2 days, (2) slow = 8000 flight hours/16 days and (3) x slow = 8000 flight hours/90 days.

3.4.8 Bolt Load Transfer

Three different load transfers were used: (1) 0% both with and without a fastener in hole, (2) 20% load transfer, and (3) 40% load transfer. The percent bolt load transfer is defined as the percentage of the total input load to the dog-bone specimen (Fig. 3) reacted by the single bolt in the test section. The test setup used to obtain the 20% and 40% load transfers is described in Section 4.5.

All bolts were loaded in double shear to minimize the effects of bending and to focus attention on key variables: environment, load spectra, stress level, loading frequency and % bolt load transfer.

3.4.9 Stress Levels

Dog-bone specimens were fatigue tested at four different stress levels in Task 4, including 34 ksi, 32 ksi, 30 ksi and 28 ksi (gross). Task 4 was mainly concerned with developing and evaluating the experimental and corrosion fatigue data acquisition methods that would be used to conduct the fatigue tests under Task 5. Another objective of Task 4 was to determine a suitable baseline stress level that would be used for the corrosion fatigue tests of Tasks 5 and 6. After testing several dog-bone specimens at different stress levels, we selected a baseline stress of 28 ksi (gross). We selected a stress level that would assure fatigue cracking in a reasonable test and environmental exposure time.

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S E C T I O N I V

T E S T I N G D E T A I L S A N D D A T A A C Q U I S I T I O N P R O C E D U R E S

4.1 INTRODUCTION

The purpose of this section is to describe and discuss the essential elements of the Phase II test program (e.g., test specimen preparation test setups test spectra, and testing procedures). Also, the data acquisition procedures are discussed, including eddy current techniques, fractographic analysis methods and data extrapolations. Test results are presented in Appendix A-F.

4.2 SPECIMEN PREPARATION FOR TESTING

4.2.1 Strain - Controlled

Strain-controlled specimens (hour-glass type) shown in Fig. 1 were manufactured for both 7075-T7651 aluminum alloy and beta-annealed Ti-6Al-4V alloy. Specimens for the aluminum alloy and for the titanium alloy were machined from plate stock 0.50 inch and 0.875 inch thick, respectively.

After machining, all specimens were mechanically polished

in the hour-glass area to obtain a surface finish of 8 μ inch r.m.s. or better. All polishing was conducted parallel to the longitudinal axis of the specimen. Specimens were polished to help minimize the effects of manufacturing defects, such as small surface scratches, on the test results. Residual stresses were produced by the surface polishing. However, this result was considered more acceptable than the surface scratches for the test objectives intended.

4.2.2 Dog-Bone Specimen

All dog-bone specimens tested in Phase II were machined from 7075-T7651 aluminum alloy, 0.50 inch thick plate material. Specimen details are shown in Fig. 3.

After machining, a straight-bore center hole was drilled using the modified Winslow spacematic drill. This automatic drill unit maintains rotation during retraction to minimize surface scratches caused by the drilling operation.

Fastener holes were drilled per General Dynamics fastener installation standard M198 [8]. Standard hole diameters for the dog-bone specimens are shown in Table 9.

After drilling, the center hole in each specimen was mechanically polished using a split mandrel and metallographic polishing paper to obtain better than an 8 μ inch r.m.s.

TABLE 9 STANDARD HOLE DIAMETERS

Nominal Hole Dia. (Inch)	Hole Diameter (Inch)	
	Min	Max
1/4	0.2500	0.2540
7/16	0.4375	0.4425
1/2	0.5000	0.5050

Ref. General Dynamics Standard M198 [8].

surface finish. The purpose of the polishing was to minimize the effects of fastener hole quality on the fatigue test results. Also, we wanted to obtain test results that would be compatible as close as possible with the smooth un-notched strain-controlled data acquired.

After polishing the center hole of each specimen, the hole diameter, width and thickness of each specimen in the test section were measured. Results are recorded on the fractographic data sheets for each specimen in Appendices D-F.

4.2.3 Preconditioning

Selected dog-bone specimens from Tasks 4 and 5 were preconditioned as follows:

1. One block of the F-16 400 hour block spectrum was applied to the test specimen in lab air at a maximum spectrum stress of 28 ksi (i.e., peak load in spectrum produces 28 ksi stress on gross section of test specimen).

2. The specimen was then soaked in a 3.5% NaCl solution at room temperature for 72 hours.

3. Specimens were then cleaned and dried using the procedure described in AGARD report 695 [9].

4. If the preconditioned specimens were not fatigue tested immediately, they were stored at room temperature in a plastic bag with desiccant until tested.

Specimen preconditioning was considered to complement the AGARD program effort [9] and to further evaluate the effects and of preconditioning on the time-to-crack-initiation and crack growth in fastener holes.

4.2.4 Fastener Type and Installation

Dog-bone specimens were fatigue tested with or without fasteners installed in the center hole. All fasteners used were cad-plated steel with a protruding head. NAS-6207 (7/16" dia.) and NAS-6208 (1/2" dia.) bolts were used where applicable. The standard minimum and maximum fastener diameter after cad-plating are 0.4360"/0.4370" and 0.4985"/0.4995" for the NAS-6207 and NAS 6208 bolts, respectively.

Some dog-bone specimens were tested with a NAS bolt and mating nut installed in the center hole with no-load transferred through the bolt (i.e., 0% LT). In this case a steel washer was used under the nut and the nut was installed "finger-tight".

4.3 ENVIRONMENTAL CHAMBERS

Two different environments were considered in the Phase II testing: dry air and 3.5% NaCl solution both at room temperature. Three basic environmental chamber designs were used to simulate the environment for the strain-controlled tests, for the no-load transfer dog-bone specimen tests and for the load transfer dog-bone tests. The environmental chamber designs used and the environment simulation procedures for the Phase II test program are described and discussed in the following subsections.

The salt water solution for the Phase II tests was prepared by dissolving reagent grade NaCl in triply-distilled water. The average solution pH was about 6.5 over the duration of each test. All Phase II salt water tests were performed in a constant immersion environment with periodic changing of the 3.5% NaCl solution to keep the solution fresh.

4.3.1 Strain-Controlled Tests

The environmental chamber for both dry air and 3.5% NaCl solution consisted of tygon tubing with an inside and outside diameter of 1/2 inch and 3/4 inch, respectively. A short piece of tubing, less than 2.00" in length, was first slipped over the strain-controlled specimen (Fig. 1) in the test section. The tubing was short enough to prevent any interference with the extensometer device. The tubing was

sealed at both ends with polysulfide sealant after mounting. The mounted environmental chamber is shown in Fig. 4. For the dry air tests, desiccant was poured into the container before sealing the top. In the 3.5% NaCl solution experiments the salt water solution was added at an opening near the top of the chamber after the container had been sealed.

4.3.2 No-Load Transfer Dog-Bone Tests

Details of the environmental chamber used for the no-load transfer tests are shown in Fig. 5. This type of chamber was successfully used in the Phase I test program [3]. A chamber was mounted to each side of the dog-bone specimen over the center hole of the test section. The two chambers were clamped together to seal them against the specimen. The environmental chamber system described above was used for both constant amplitude and spectrum fatigue tests in Phase II.

The hole in the chamber allowed access for eddy current detection probes during testing to monitor fatigue crack initiation. A cork was placed in the hole when the chamber was in use. Environmental chambers were also used for dry air environment tests by placing desiccant crystals in the chamber.

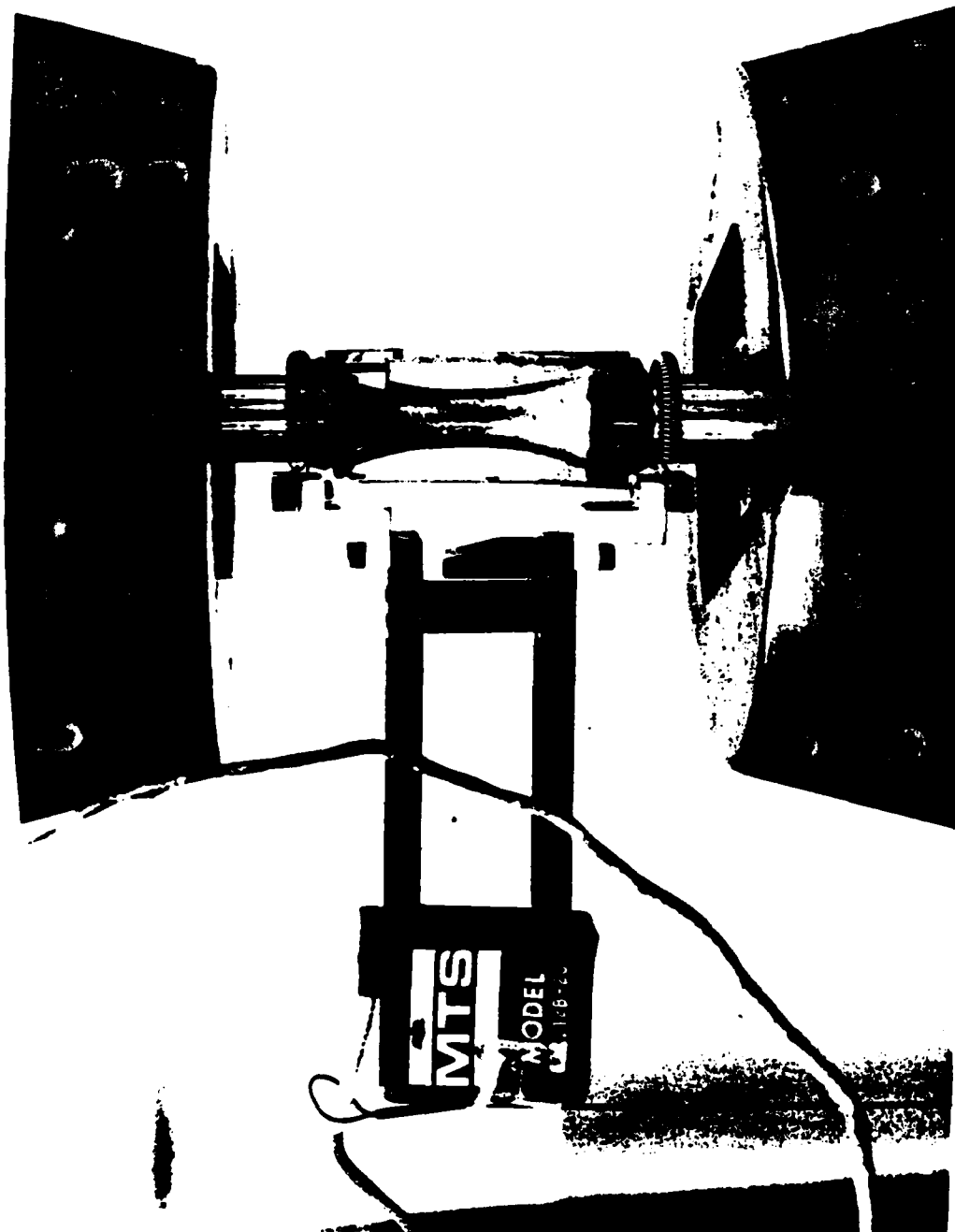


Fig. 4 Environmental Chamber and Test Setup for Strain-Controlled Tests

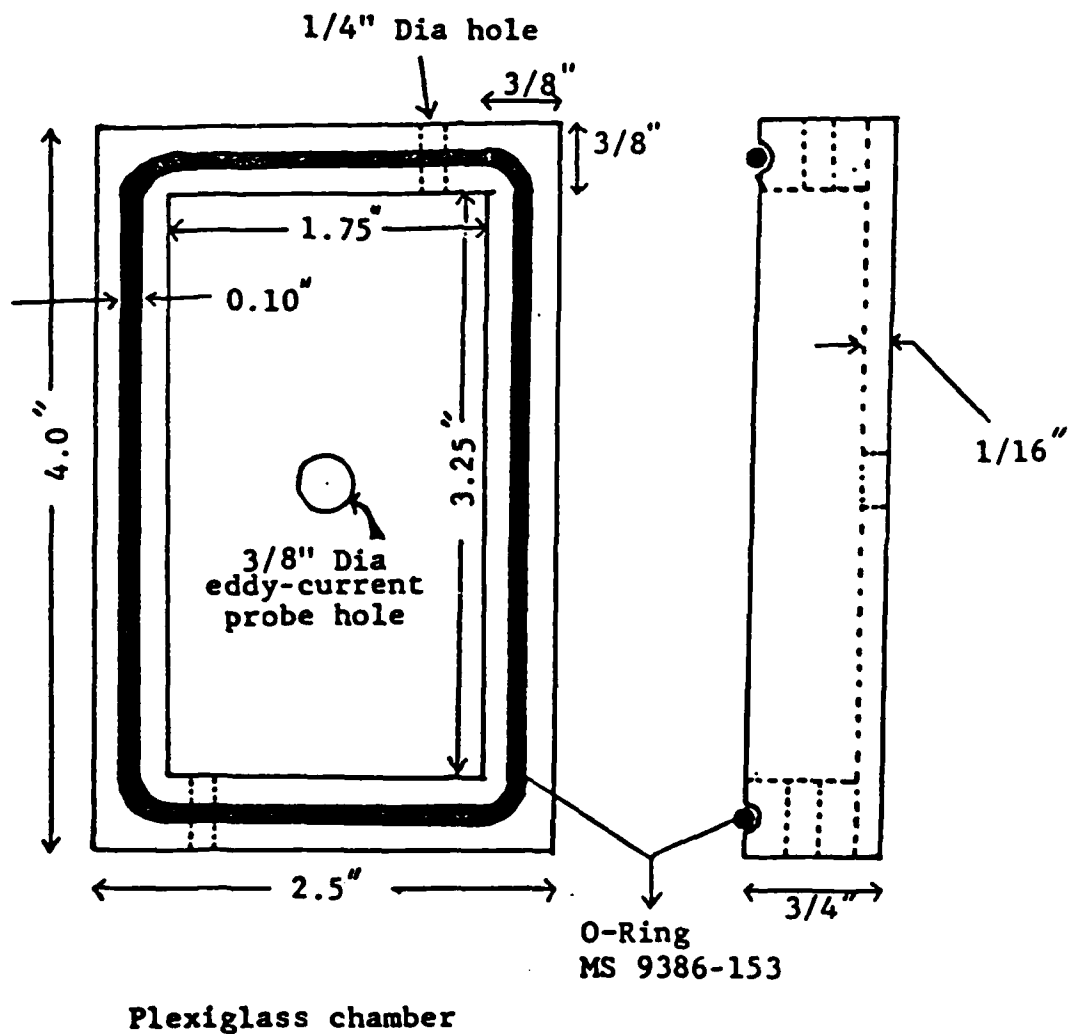


Fig. 5 Environmental Chamber Used for NO - Load Transfer Dog-Bone Tests

4.3.3 Load Transfer Dog-Bone Tests

The environmental chamber was an integral part of the loading bars used to transmit the ram loading directly to the bolt in the dog-bone specimen. Two loading bars, with the test specimen in the middle, were bolted together with a single 7/16" diameter steel bolt (clad plated) with a washer under the nut. An environmental chamber was formed in each loading bar by a counterbore (1.50" diameter and 0.10" deep) on the side facing the test specimen. A sealing groove with a rubber "O" ring surrounded the counterbore to seal the environmental chamber. A small torque was applied to the nut -- just enough to seal the environmental chambers against the surface of the test specimen. The loading bar assembly and details of the chamber are shown in Fig. 6.

Desiccant crystals were placed in the chambers to simulate a dry air environment. A 3.5% NaCl solution was added to the environmental chambers to simulate a salt water environment. Provisions were made in the chamber for draining the solution and for adding a fresh solution without disassembling the two loading bars.

4.4 STRAIN-CONTROLLED TESTS

Strain-controlled experimental procedures were developed in three stages: (1) calibrate strain-controlled specimen and ram loading, (2) evaluate environmental simulation methods, and (3) verify the time-to-crack-initiation (TTCI) acquisition method. Elements of the experimental methodology development

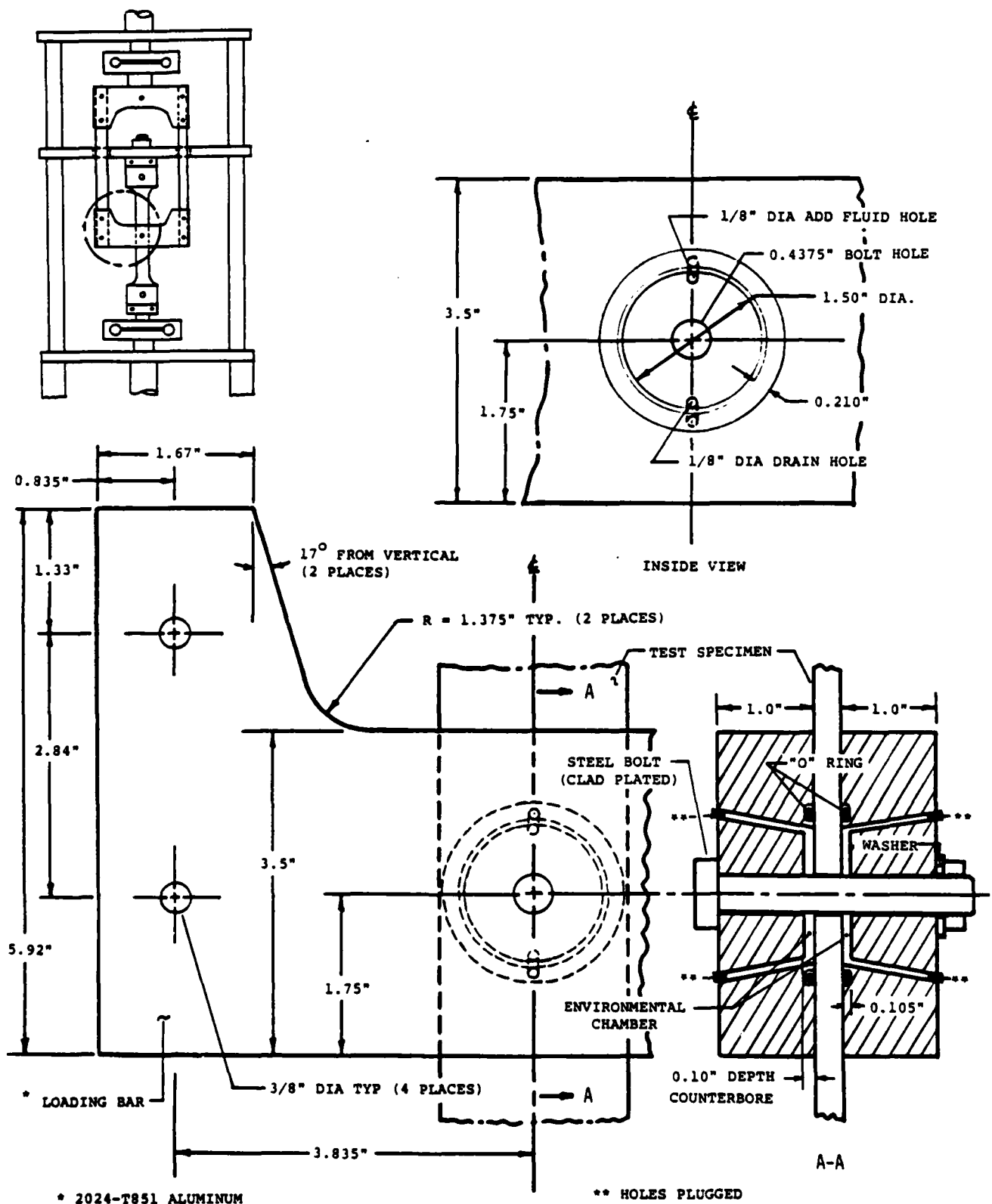


Fig. 6 Details of Integral Environmental Chamber Used In Loading Bar for Bolt Load Transfer Tests

are described in Fig. 7.

Experimental procedures were developed and verified for acquiring strain-controlled fatigue crack initiation data in dry air and in a 3.5% NaCl solution. Strain-controlled tests were conducted on fifty 7075-T7651 aluminum specimens and thirty beta-annealed Ti-6Al-4V alloy specimens as part of Tasks 4 and 5 (see Tables 1, 3 & 4). The experimental procedures used to acquire the crack initiation data are described in this section.

A total of 30 strain-controlled experiments were conducted on the beta-annealed Ti-6Al-4V alloy. Since the same experimental procedures developed for the aluminum alloy worked equally well for the titanium alloy, only one titanium specimen was needed for Task 4 (ref. Tables 1, 3 and 4). This specimen was used to conduct a strain survey. Crack initiation data was obtained for 29 test specimens.

4.4.1 Experimental Procedures

Total strain-controlled fatigue tests were performed on a closed loop hydraulic MTS machine (MTS Model 810.13, 22 kip capacity) controlled by fully reversed ($R' = \epsilon_{\min} / \epsilon_{\max} = -1$) sinusoidal strain amplitude waves. This system was used in conjunction with a 406.11 controller, 436.11 Control unit, Model 436.11 FG functional generator, 6 GPM hydraulic supply

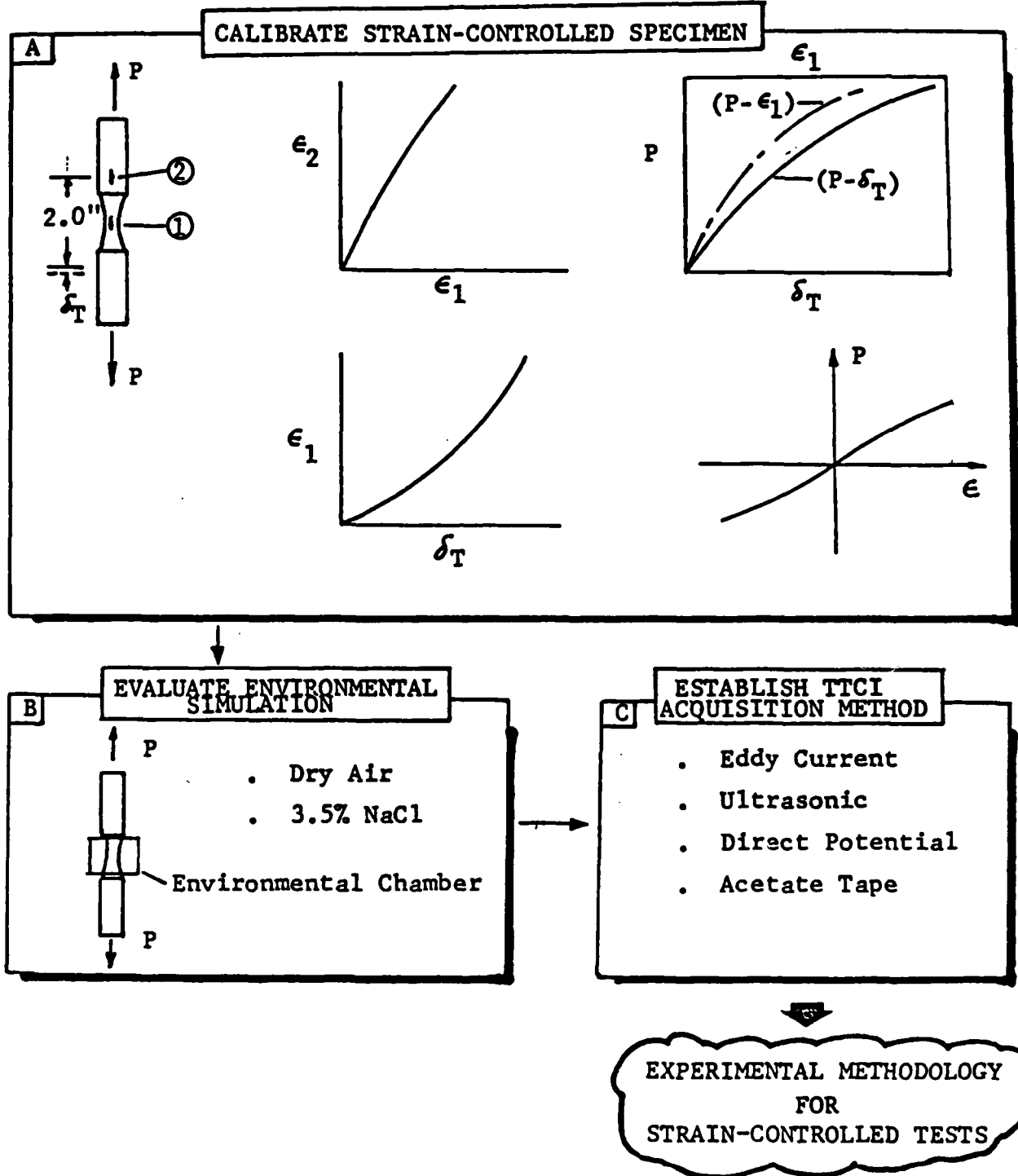


Fig.7 Elements of Strain-Controlled Experimental Methodology Development

and a digital indicator Model 430.41. Hydraulically operated grips (Model 641.92) were used. These grips are self-aligning to relieve possible bending stresses in the test specimens.

The aligning grips assured that the test machine axis was coincident with the specimen axis. For test specimens with strain gages, alignment was checked by observing the strain gage readings after the specimen was installed under zero applied load. Only very small strains were observed after installation in the test machine.

Normally, diametrical strain measurements are made on the hour-glass specimen. However, since many of the tests were conducted in a 3.5% NaCl environment, a two-inch gage length extensometer was mounted outside of the environmental chamber (Fig. 4). Extensometer voltage output (axial deformation) was measured as a function of axial strain in the reduced section of the specimen. These measurements were made by correlating extensometer voltage readings to strain gage readings for strain gages mounted axially in the minimum area section of the test coupon. Calibration curves based on these measurements are presented in Appendix A.

Strain surveys and strain-controlled specimen calibration tests were conducted to experimentally determine the relationship between ram load, axial strain and axial deformation (over 2.00" gage length). The test setup is shown

in Fig. 8. Four axial strain gages and an extensometer were mounted on the calibration specimen as shown in Fig. 9.

The instrumented specimen shown in Fig. 8 was statically loaded in tension and compression using a selected range of loads. Strain and extensometer measurements were taken at selected load levels. Typical results are presented in Appendix A for the 7075-T7651 aluminum alloy.

Calibration curves for 7075-T7651 aluminum alloy and Ti-6Al-4V alloy, respectively, were used to select extensometer voltages to obtain a specified strain value in the Task 5 experiments. The shape of the calibration curves were similar for both beta-annealed Ti-6Al-4V and 7075-T7651 aluminum alloys.

The environmental chamber used and simulation procedures for both dry air and 3.5% NaCl solution are described in Section 4.3.1.

In our experiments, most specimens were tested at a maximum total strain amplitude greater than .7% and at a test frequency of .5 Hz. This frequency was low enough to plot stress-strain hysteresis loops using the x-y recorder. For the long-life fatigue specimens, the frequency was increased to 2 Hz and 5 Hz to allow a large number of cycles to be accumulated in a reasonable period of time. During these

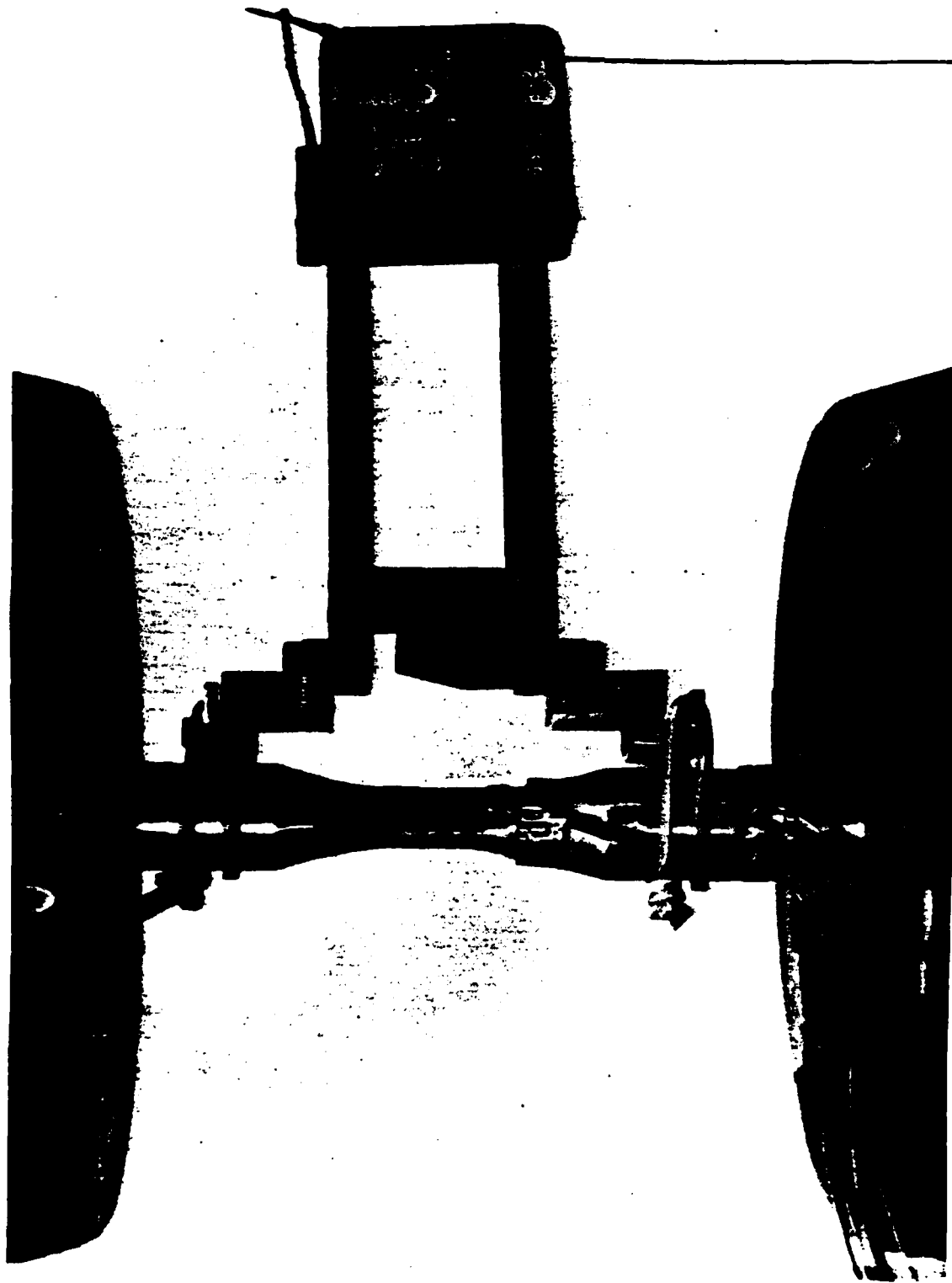


Fig. 8 Setup for Strain Surveys Using Strain-Controlled Specimen

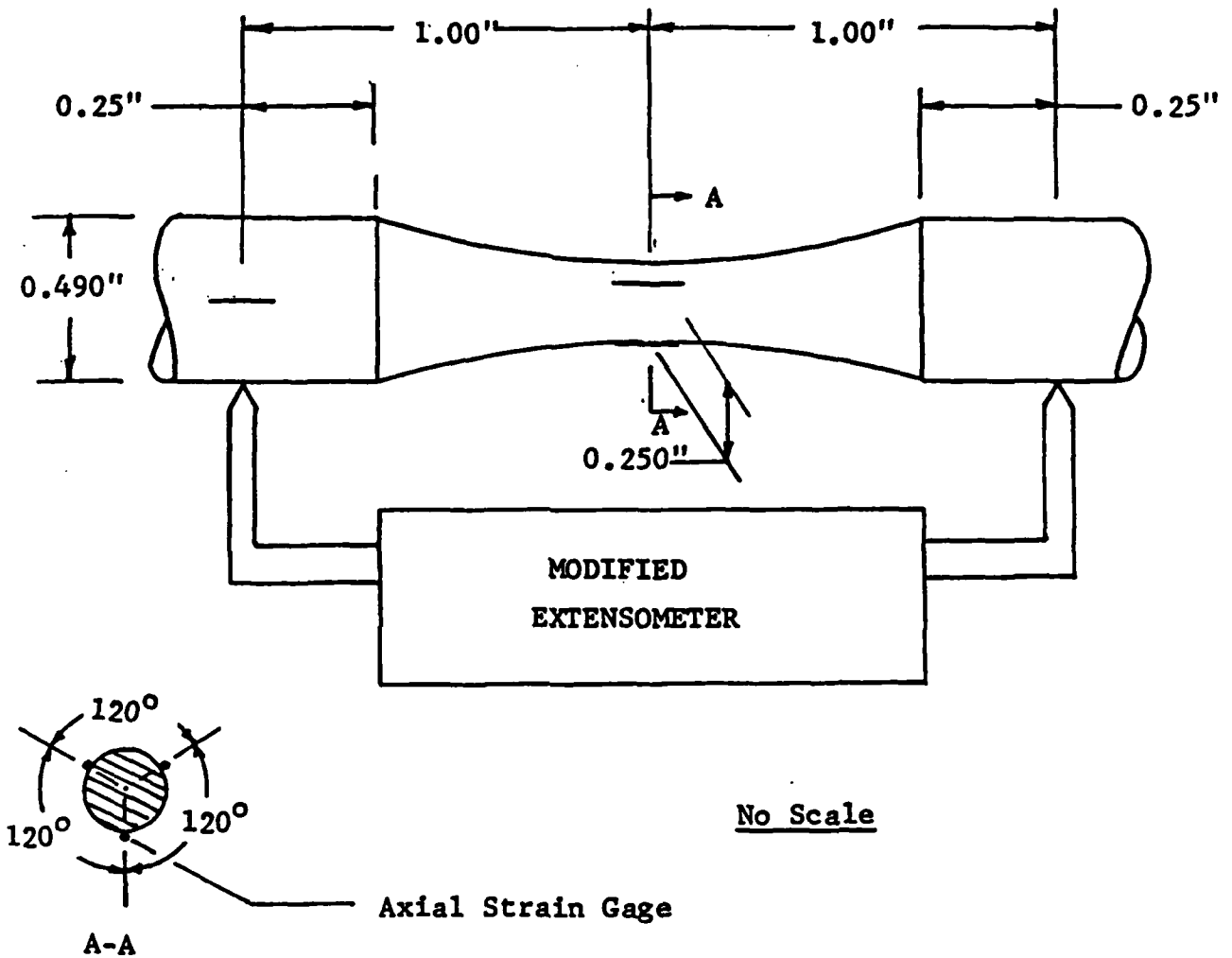


Fig. 9 Strain Gage Locations for Strain-Controlled Specimen

tests, test frequencies were lowered to .5 Hz at fixed intervals to make x-y plots. A few specimens were tested at several different frequencies corresponding to one strain amplitude value to investigate the effect of frequency on fatigue crack initiation.

During the constant strain tests, individual stress-strain hysteresis loops were recorded on a Moseley Model 7000A x-y recorder. All recordings were made at frequencies less than 1 Hz. An example fo the type of traces obtained are shown in Fig. 10. After recording the first few cycles, traces were obtained at periodic intervals, until testing ceased.

From the slopes of the stress-strain hysteresis loops, the elastic strain amplitude, $\Delta\epsilon_e/2$, and plastic strain amplitude, $\Delta\epsilon_p/2$, could be determined. This technique is also illustrated in Fig. 10.

The area enclosed by the hysteresis loops was measured using a polar planimeter. Using this technique, areas could be measured to the nearest 0.01 square inch.

Continuous load-time and strain-time records were obtained with a Gould Brush 2200 two-channel strip chart recorder. Typical traces are shown in Fig. 11.

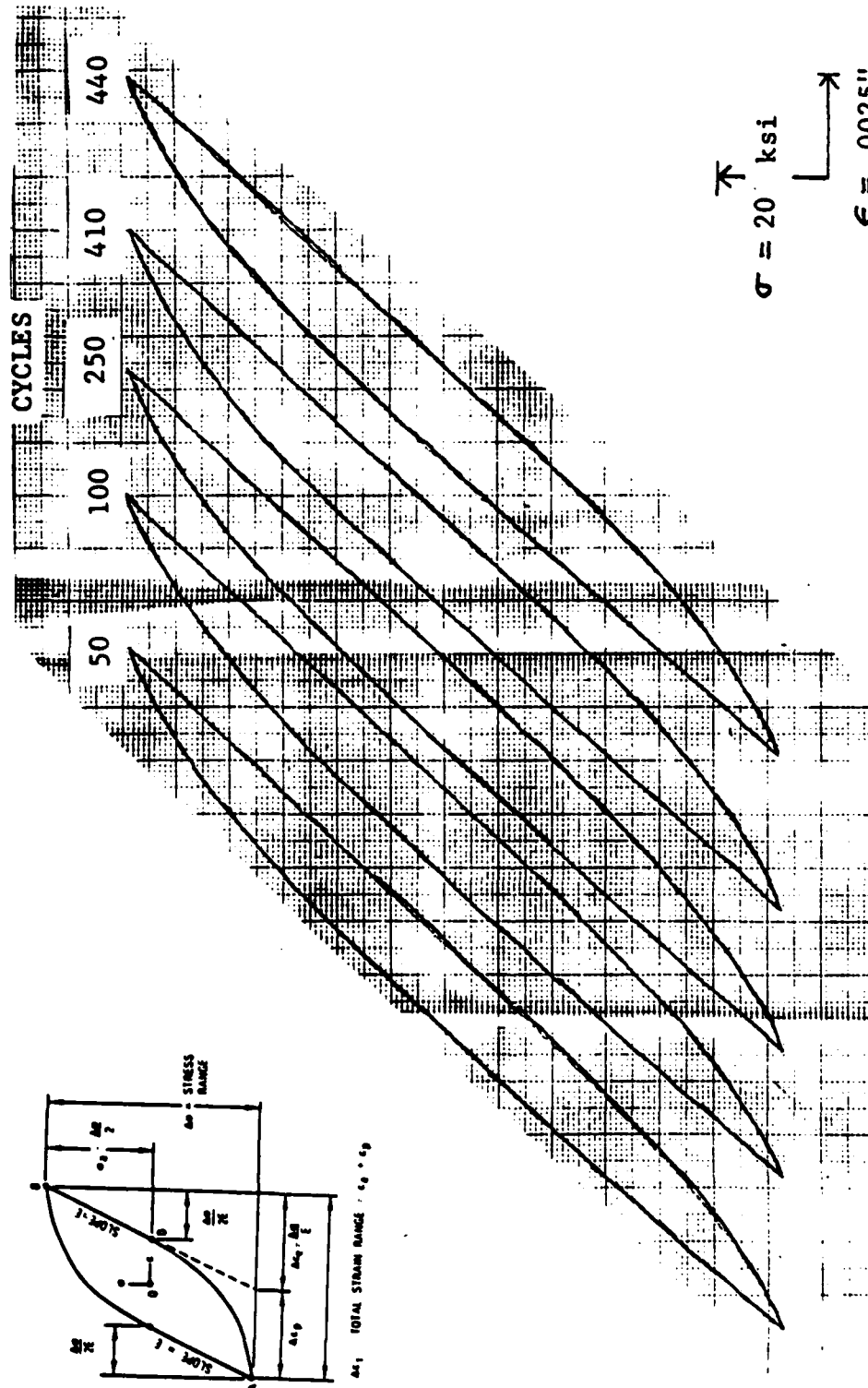


Fig. 10 Typical Stress-Strain Hysteresis Loops Recorded on a Moseley Model 7000A x-y Recorder

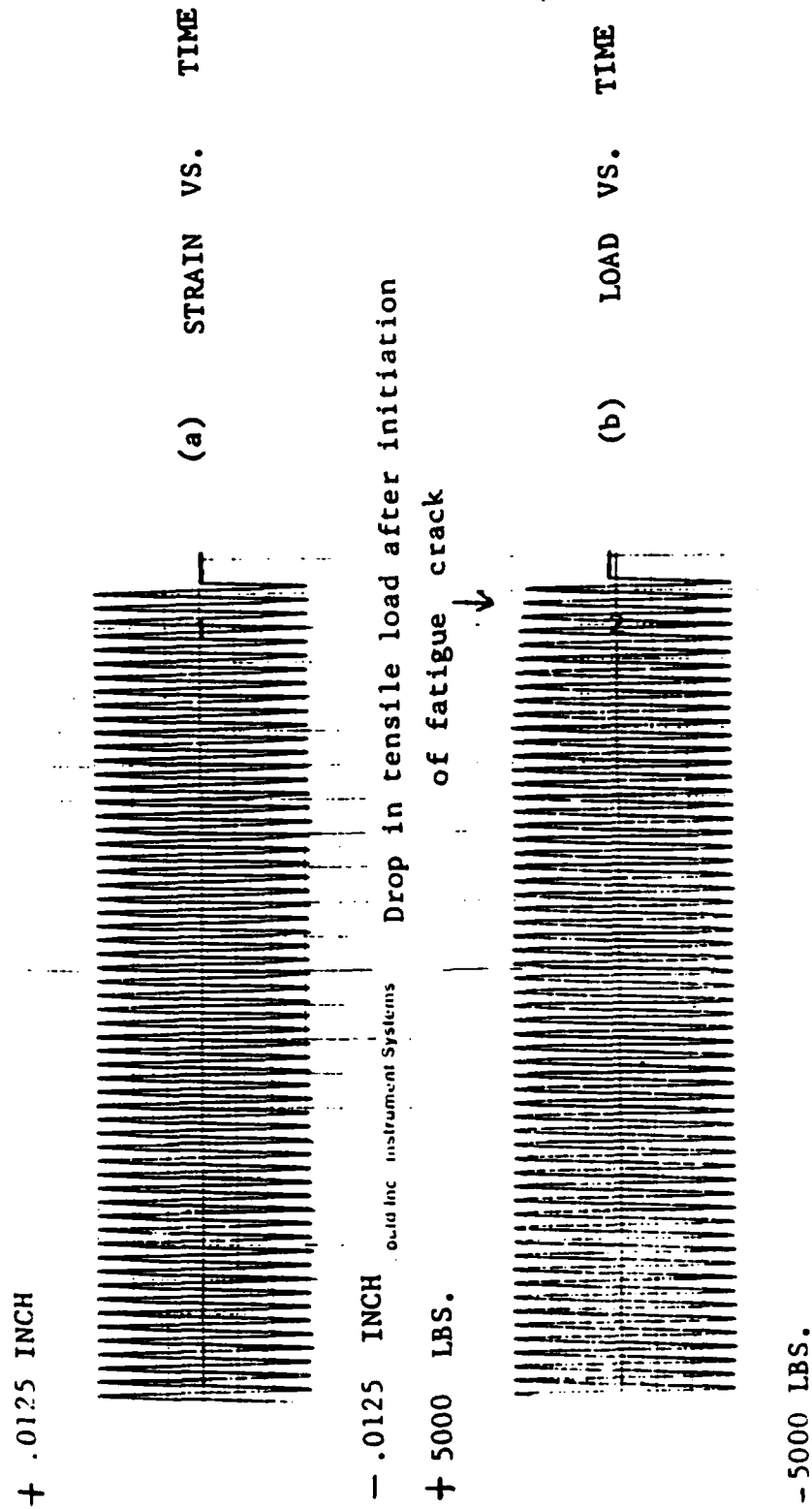


Fig. 11 Typical Load-Time and Strain-Time Traces Obtained with a Gould Brush 2200 Two-Channel Strip Chart Recorder

4.4.2 NDI Monitoring for Crack Detection

Early monitoring of experimental methodology specimens was accomplished with eddy current techniques. These techniques, used in fastener hole inspections, are described in Volume I [3]. For surface inspection, an eddy current pencil probe (NDT Product Engineering, MP-20 micro-probe) was used to inspect for early fatigue cracks in the reduced section of the specimen. Since scanning had to be performed manually instead of automatically, there was some loss of sensitivity. This monitoring was compared to crack detection as observed from the decrease in maximum tensile load with cycling. The decrease in the maximum tensile load, due to load shedding, was found to be more sensitive than eddy current techniques for determining macroscopic crack initiation. Therefore, the load shedding technique was used to determine the TTCI for Tests under Task 5 (Ref. Table 4) for both 7075-T7651 aluminum alloy and beta-annealed Ti-6Al-4V.

In the 7075-T7651 aluminum alloy material, after the first few cycles, the maximum tensile stress remained relatively constant until a fatigue crack was initiated. A calibration curve was established between the decrease in maximum tensile stress and crack depth. After tensile load decreases of different percentages were observed during fatigue testing, specimens were then overloaded in tension to failure. Fatigue crack sizes were then measured. The results are

presented in Appendices A and B. Cycles to crack initiation for test specimens in Task 5 were defined in terms of cycles completed before a 2% drop in maximum tensile stress occurred.

Cyclic softening occurred in the beta-annealed Ti-6Al-4V alloy at higher strain amplitudes. Both the maximum tensile stress and compressive stress decreased as a function of cycling. The percentage decrease in maximum compressive stress was used to measure cyclic softening occurring and thus allowing the effects of "load shedding" and cyclic softening to be separated in the measurements of maximum tensile stress. The onset of a 0.010 inch deep fatigue crack was defined as the number of cycles when the maximum tensile stress showed a 2% greater decrease than the maximum compressive stress.

4.5 DOG-BONE SPECIMEN TESTS

Dog-bone specimens with a center hole were tested in three basic configurations: (1) open hole, (2) bolt in hole but no bolt load transfer and (3) load transferred directly through the bolt to the specimen. All dog-bone specimens tested in Phase II had the same basic specimen design shown in Fig. 3. Details of the dog-bone fatigue tests performed, including test setup, experimental procedures, etc., are described below.

All spectrum fatigue and constant amplitude

stress-controlled tests were performed on servo-controlled hydraulically-actuated load frames. The test setup used for the no bolt load transfer tests is shown in Fig. 12. This setup was used for both constant amplitude and spectrum fatigue tests. Details of the environmental chamber are described in Section 4.3.2.

Specimens for the spectrum fatigue tests were run continuously until failure or to a specified time. Occasional stops were made for testing adjustments, measurements or equipment maintenance/repair.

The test setup for the bolt load transfer tests is shown in Fig. 13. A loading bar with an integral environmental chamber was used to transfer the ram load to the bolt in the center hole of the dog-bone test specimens. Two independent but synchronized rams were used to load the test specimen. One ram applied load directly through the lug and of the specimen while the other ram applied loads directly to the loading bar as shown in Fig. 13. The environmental chamber used is described in Section 4.3.3.

The percentage of load transfer (LT) through the bolt is defined as a percentage of the total applied ram load to the specimen lug end. We used two different percentages of LT for the load transfer tests, i.e., 20% LT and 40% LT.

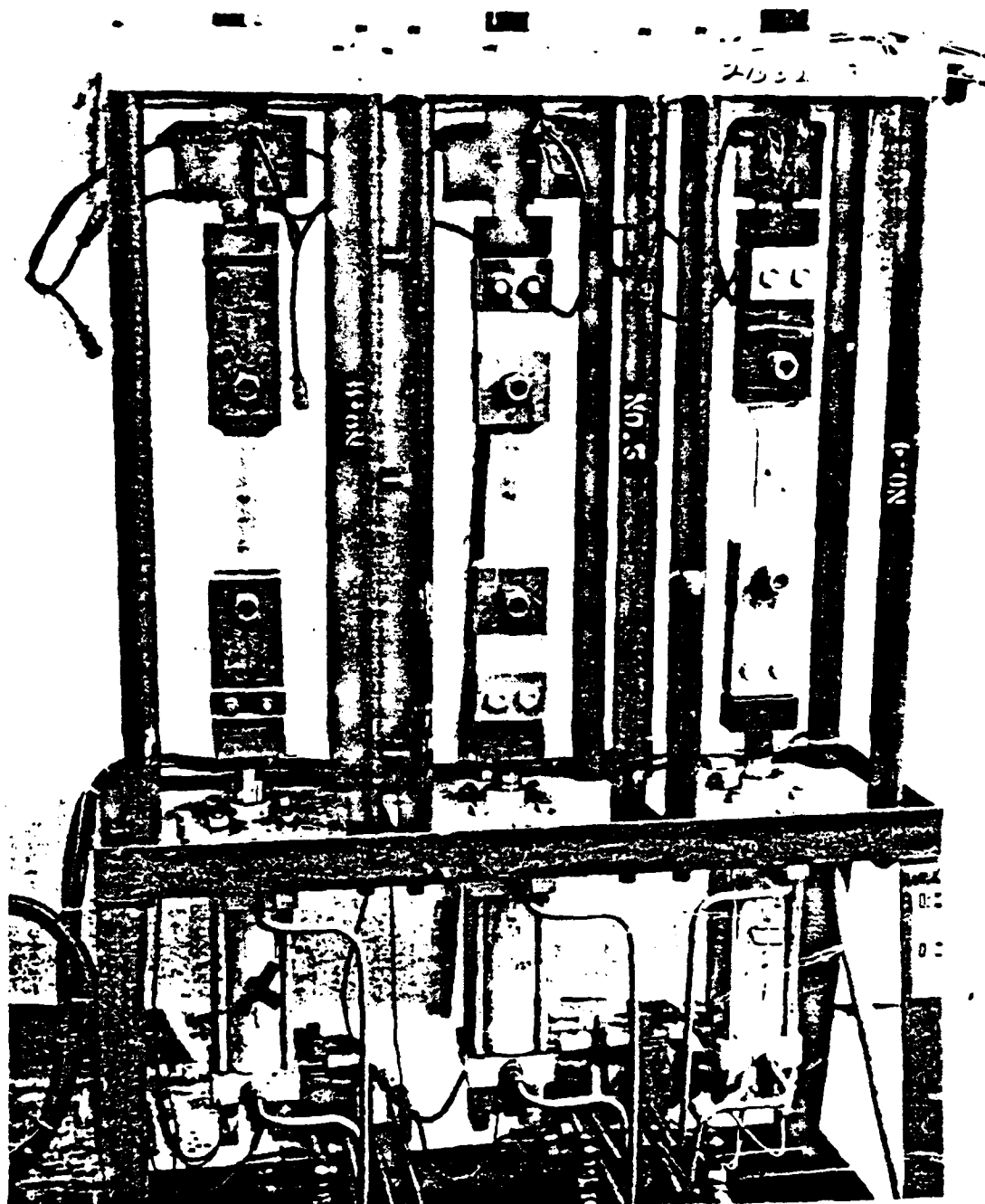


Fig. 12 Test Setup for No-Bolt Load Transfer
Dog-Bone Specimen Tests

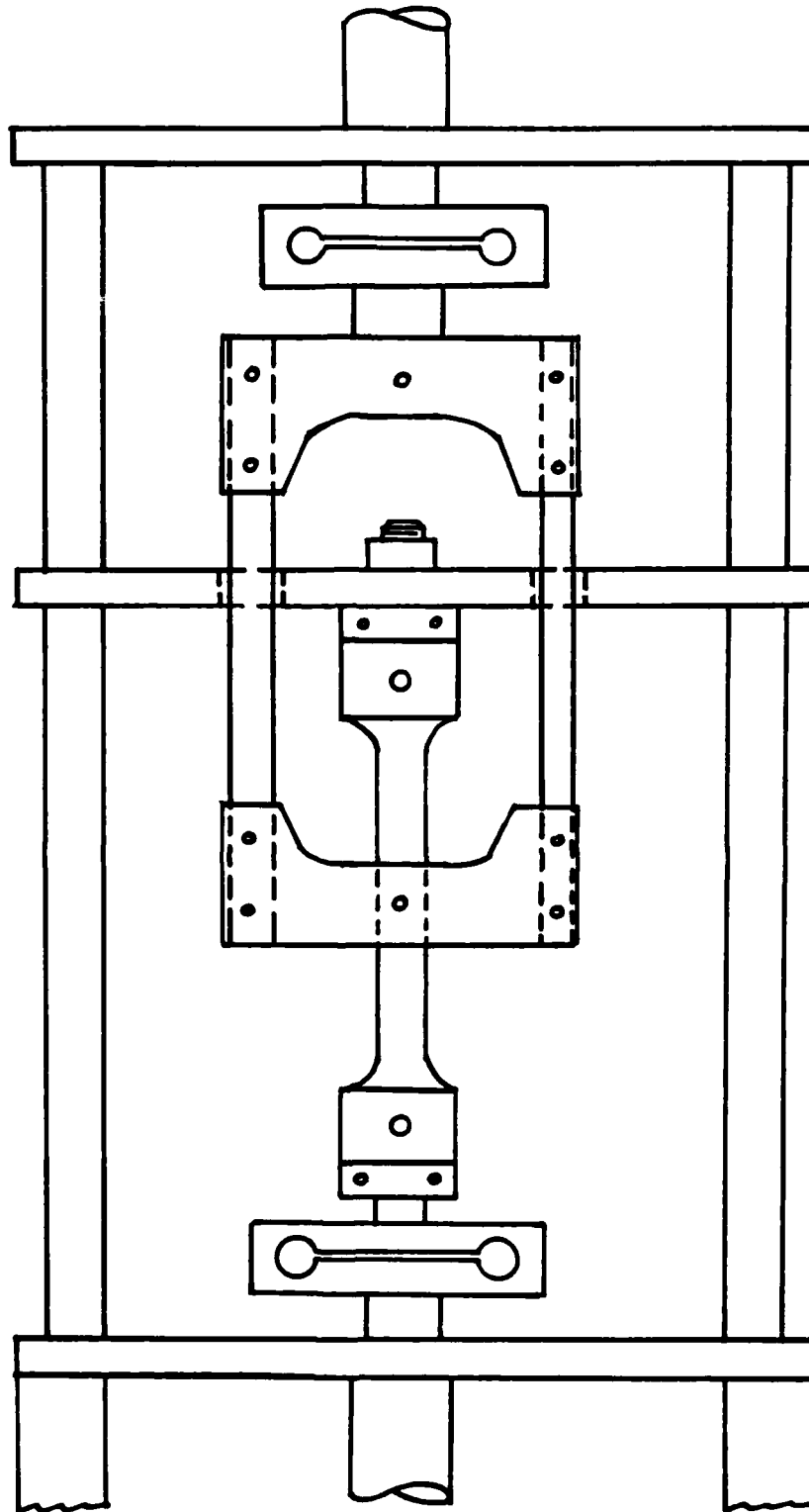


Fig. 13 Test Setup for Bolt Load Transfer Dog-Bone Specimen Tests

A special hardware interface was used for all dog-bone tests to continuously monitor each load frame and to assure proper load control. This system provided a permanent record of test events.

Eddy current measurements were periodically made in the center hole of the test specimen for all constant amplitude tests. Spot check measurements were also made during the spectrum fatigue tests to determine the time to initiate a crack size of 0.01" in the fastener hole. The eddy current probe was inserted directly into the fastener hole without disassembling the environmental chamber. For the no-load transfer tests the cork in the hole at the side of the environmental chamber was removed to permit eddy current measurements to be made. In the case of the bolt load transfer tests, the bolt through the loading bar and environmental chamber was removed to make eddy current measurements.

The eddy current technique, described in Volume I [3] provided backup information on the TCI for the spectrum fatigue tests. This technique was used to complement the fractography - particularly for those tests when the 3.5% NaCl environment might affect the fatigue markings on the fracture surface.

4.6 TEST SPECTRA

Three test spectra were considered in the Phase II testing of 7075-T7651 aluminum alloy dog-bone specimens: (1) F-16 400 hour (hi-lo block), (2) F-18 300 hour (random) and (3) F-18 300 hour (hi-lo block).

The F-16 400 hour (hi-lo block) spectrum used for the Phase II testing is a wing-root bending spectrum. This preliminary development spectrum has been used extensively at the General Dynamics, Fort Worth Division for F-16 development tests and other structural research programs [5-7]. We selected this spectrum for use in the Phase II effort because this spectrum marks well fractographically and we have considerable experience in reading the fractographic data. The F-16 400 hour (hi-lo block) spectrum is referred to herein as spectrum "A".

Samples of the load history for the F-16 400 hour spectrum are shown in Fig. 14. A breakdown of the load history by load points for the F-16 400 hour and F-18 300 hour test spectra are compared in Table 11.

The F-18 300 hour spectrum, supplied by the Naval Air Development Center (Warminster, PA) for this program, is a modified wing spectrum. This spectrum was modified for Phase II testing purposes as follows. The maximum compressive load in

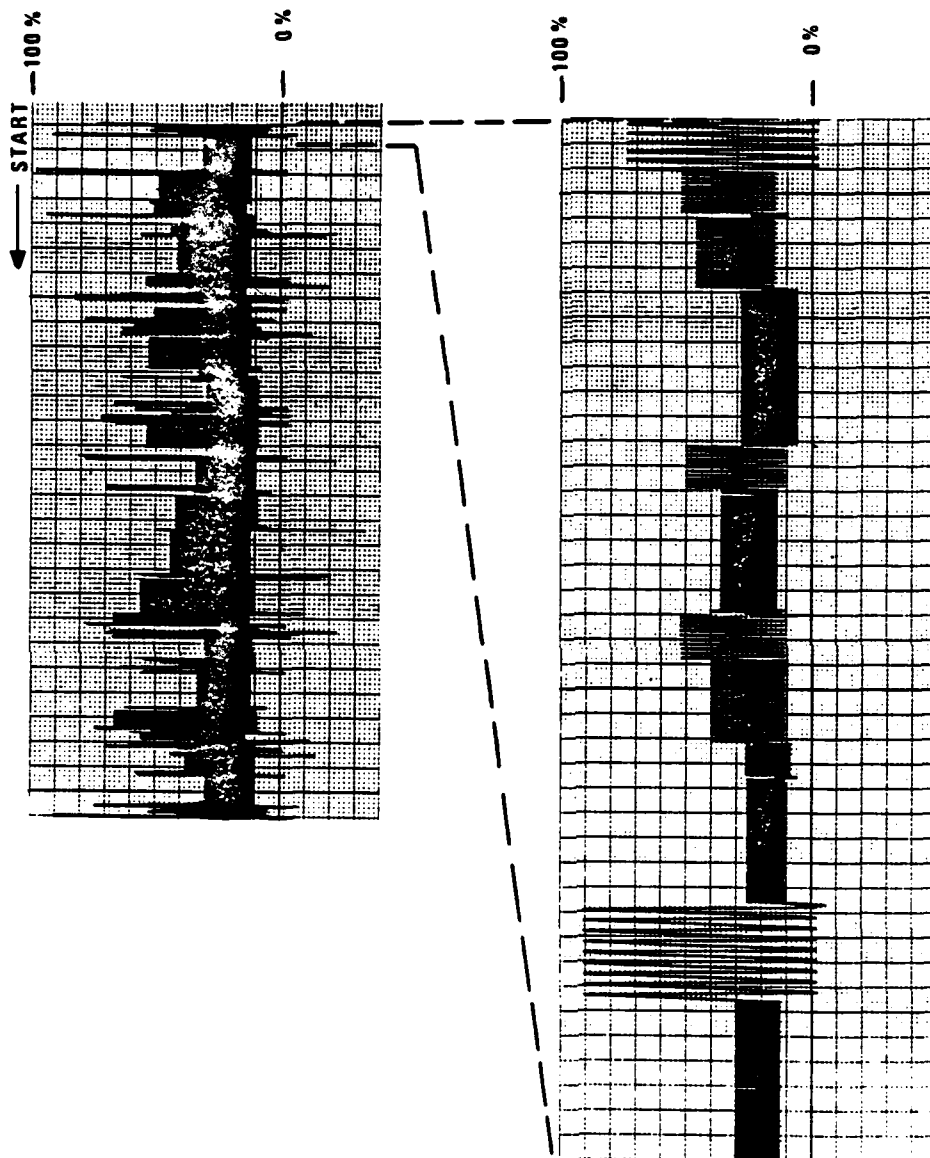


Fig. 14 Samples of the Load History for the F-16 400 Hr. Spectrum

Table 10 Breakdown of Load Points by 5% Intervals for the
F-16 400 Hr Block Spectrum

Range in Percent		Spectrum Johns II 400 Hr. F-16 765747 LP Total (8000 Flt Hrs) Load Pts. in Range
Min	Max	
-30.1	-35.0	60
-25.1	-30.0	0
-20.1	-25.0	60
-15.1	-20.0	80
-10.1	-15.0	200
-5.1	-10.0	440
-0.1	-5.0	3684
0 at zero	0	10187
0.1	5.0	2880
5.1	10.0	59360
10.1	15.0	312566
15.1	20.0	920
20.1	25.0	3780
25.1	30.0	81300
30.1	35.0	100222
35.1	40.0	39024
40.1	45.0	66050
45.1	50.0	16526
50.1	55.0	35585
55.1	60.0	18770
60.1	65.0	1700
65.1	70.0	8980
70.1	75.0	1950
75.1	80.0	551
80.1	85.0	640
85.1	90.0	0
90.1	95.0	208
95.1	100.0	24

TABLE 11 COMPARISONS OF F-16 400 HOUR AND
F-18 300 HOUR TEST SPECTRA

Spectrum I.D.	No. Flt. Hrs. Per Block	Service Life (Flt Hrs)	No. Load Points for		
			Block	Flt Hrs	Service Life
F-16 400 Hr	400	8000	38287	95.718	765747
F-18 300 Hr	300	6000	3137	10.457	62740

Note: The maximum gross stress on test specimen cross section scaled to maximum load in each spectra.

the spectrum was limited to the same percentage of the maximum tension load as that for the F-16 400 hour spectrum (i.e., 35% of maximum tension load). This modification of the F-18 300 hour spectrum was made so that the dog-bone specimens could be fatigue tested in load frames without special lateral support required.

Two variations of the F-18 300 hour spectrum were considered: (1) loads randomized for each 300 hour block and (2) loads ordered in the same sequence for each 300 hour block (hi-lo). The first spectrum variation is referred to herein as the "F-18 300 hour (randomized)" spectrum or spectrum "B" and the second variation is referred to as the "F-18 300 hour (Hi-lo block)" spectrum or spectrum "C". The hi-lo block version of the F-18 300 hour spectrum was formatted the same way as the F-16 400 hour (hi-lo block) spectrum.

Strip chart printouts of the load history for spectrum B and C are shown in Fig. 15 and 16, respectively.

4.7 FRACTOGRAPHIC ANALYSIS

4.7.1 General Procedure

Dog-bone fatigue specimens were prepared for fractographic evaluation as follows. Unbroken specimens were first broken open to display the fracture surface. All

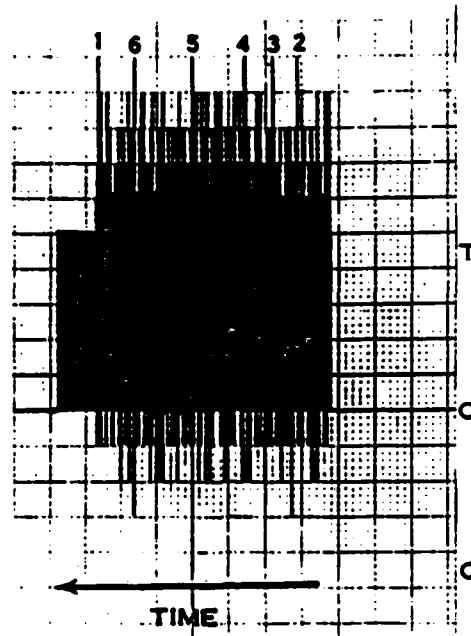


Fig. 15 Strip Chart Trace of Load History for
F-18 300 Hour (Random) Spectrum ("B")

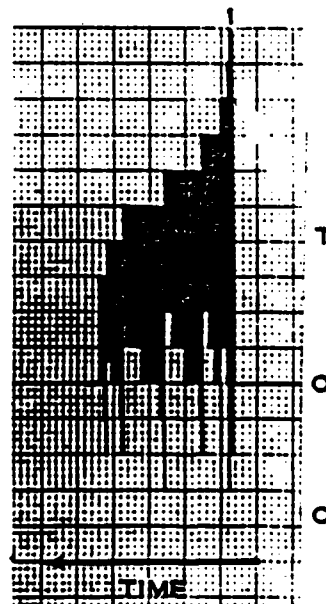


Fig. 16 Strip Chart Trace of Load History for
F-18 300 Hour (Block) Spectrum ("C")

fracture surfaces were then cleaned to prepare the specimens for fractographic analysis. All shear lips were ground off without damaging the fracture surface. Specimens were then cleaned ultrasonically in acetone. A cellulose-acetate tape was softened using acetone and then pressed firmly against the fracture surface to remove surface dirt or residue. This cleaning process was repeated several times for best results.

After thoroughly cleaning the fracture surface, the fracture specimen was then mounted onto the microscope stage using a piece of clay to hold it in place. A fractographic evaluation was performed then for the largest fatigue crack in each fastener hole. The final size of the fatigue crack on each size of the fastener hole was measured and results were recorded on the fractographic data sheets (e.g., ref. Appendices D-F).

Fractographic evaluation were made using an X, Y micrometer stage with a bench stereo microscope at magnifications of 15X to 120X. The number of load points at specimen failure were translated into the bench marks at failure using the applicable load spectra. Fractographic measurements were then taken at the end of each block back to a minimum crack size of 0.010", where possible. In some cases, fractographic measurements could not be traced to the desired minimum crack size due to poor surface markings for

the smaller crack sizes. The fractography provided the means for defining the time-to-crack-initiation (TTCF) for $a_0 = 0.01"$ in the fastener holes.

Crack size versus time measurements and other pertinent details were recorded on the fractographic data sheets. This includes, in most cases, a photograph of the fracture surface, specimen dimensions, crack origins, peculiarities, number of load points at failure, etc.

Sample fractographic surfaces are shown in Fig. 17 with crack growth markers corresponding to loads $\geq 80\%$ of the maximum load in the F-16 400 hour spectrum ("A"). Similarly, sample fractographic surfaces with crack growth markers corresponding to loads $\geq 90\%$ of the maximum spectrum load are shown in Figs. 18(a) and 18(b) for the F-18 300 hour (random) spectrum ("B") and the F-18 300 hour (block) spectrum ("C"), respectively.

4.7.2 Crack Initiation Origins

Following fatigue testing, each failed specimen was carefully examined to determine, if possible, the primary origin of failure. Many specimens had multiple crack origins making failure analysis difficult.

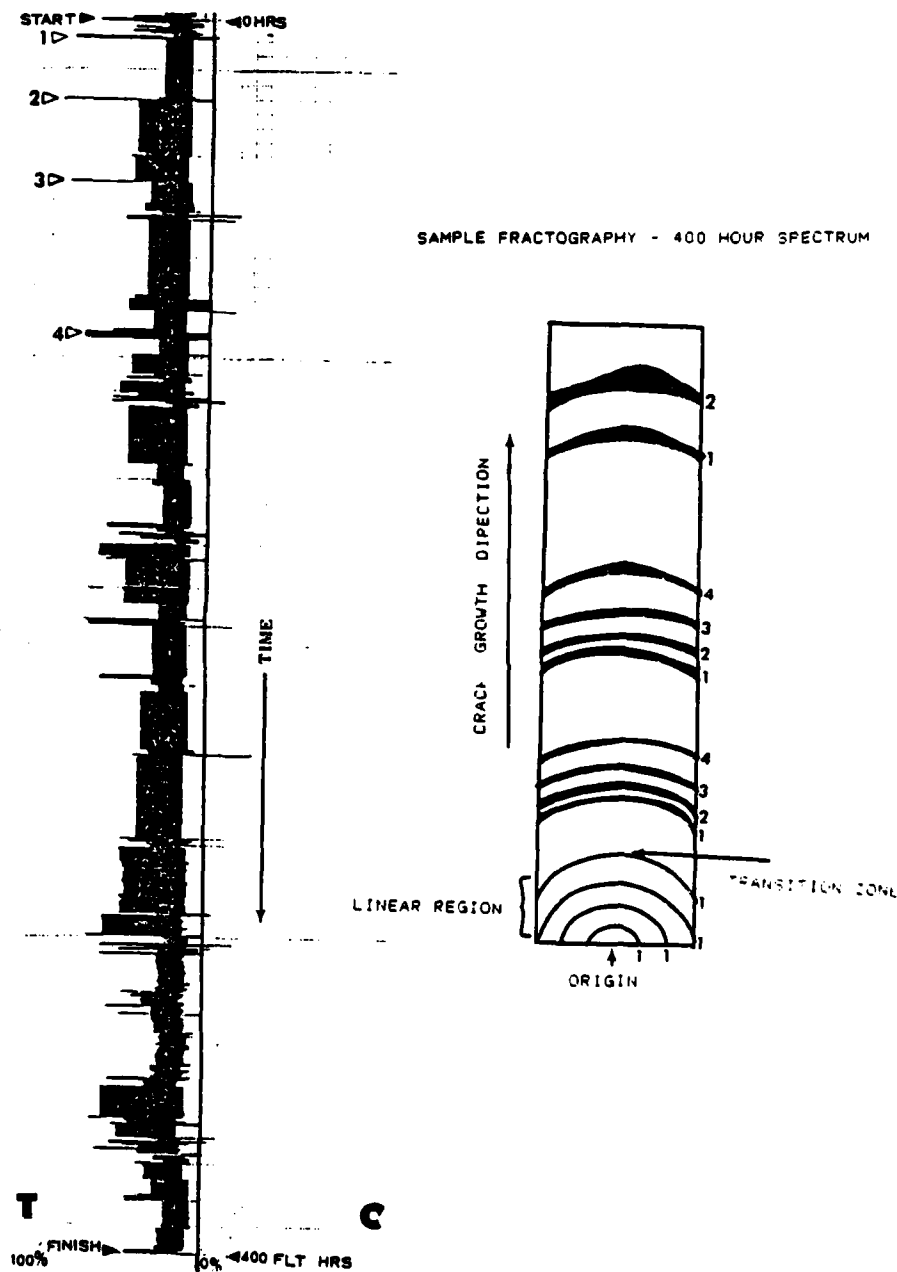


Fig. 17 Sample Crack Growth Markers Corresponding to 80% + Loads for F-16 400 Hours Spectrum ("A")

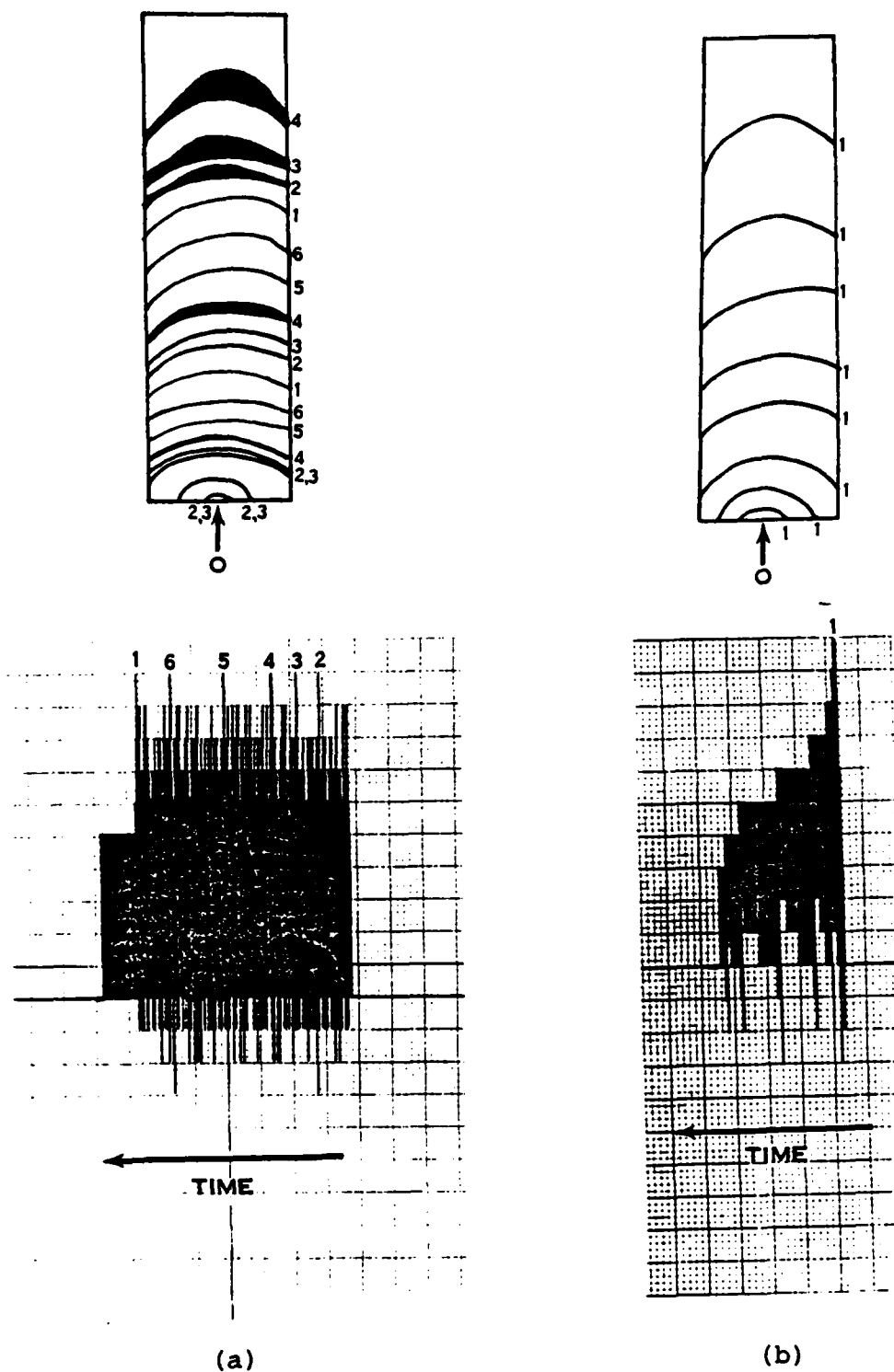


Fig. 18 Sample Crack Growth Markers Corresponding to 90% + Loads for F-18 300 Hour Spectrum:
 (a) Random Spectrum ("B"); (b) Block Spectrum ("C")

Fatigue crack origins were cataloged as follows: B = bore of hole, C = corner of hole, S = surface away from hole and I = internal flaw. Results are presented in Appendices D-F.

4.8 EXTRAPOLATION OF FRACTOGRAPHIC RESULTS

In some cases, the fractography could not be reliably read down to the selected reference crack size for time-to-crack-initiation (i.e., $a_0 = 0.010"$) for the dog-bone specimens. In such cases, the fractographic results were extrapolated to estimate the time-to-crack initiation (TTCI).

Three different extrapolation methods were considered to estimate the TTCI for $a_0 = 0.01"$: (1) linear extrapolation, (2) least squares fit of power law and (3) least squares fit of exponential function. Extrapolations were estimated for each of the three methods and the results were compared for consistency.

Linear extrapolations were based on the two smallest consecutive crack sizes that could be fractographically read. Extrapolations based on the assumed power law and exponential functions were determined using a least squares fit form of

Eqs. 1 and 2 to the three smallest consecutive crack sizes shown on the fractographic data sheet, respectively.

$$a(t) = At^B \quad (1)$$

$$a(t) = \hat{a}(0) \exp (Qt) \quad (2)$$

In Eqs. 1 and 2, $a(t)$ is the crack size at any time t ; A , B , $a(0)$ and Q are empirical constants. The applicable constants were determined using the least square fit form of Eqs. 1 and 2 given by Eqs. 3 and 4, respectively.

$$\underbrace{\ln a(t)}_Y = \underbrace{\ln a}_b + \underbrace{B}_m \underbrace{\ln t}_X \quad (3)$$

$$\underbrace{\ln a(t)}_Y = \underbrace{\ln \hat{a}(0)}_{b'} + \underbrace{Qt}_{mX} \quad (4)$$

A P P E N D I X A
STRAIN-CONTROLLED TEST RESULTS FOR
7075-T7651 ALUMINUM ALLOY

A.1 INTRODUCTION

Raw test results for Tasks 4 and 5 are presented in this Appendix. These results are evaluated and discussed in Volume III [1].

A.2 TASK 4 TEST RESULTS

Task 4 was concerned with the development of experimental methodology for requiring strain-controlled data for dry air and 3.5% NaCl environments. The strain-controlled data is needed to implement the strain life approach for making time-to-crack-initiation (TTCI) predictions for mechanically-fastened joints. Details of the strain life approach are discussed in Volumes I [3] and III [1]. Results from the Task 4 effort are presented herein.

A.2.1 Stress Strain Hysteresis

Typical behavior of the stress-strain hysteresis plots are shown in Fig. A1. A slight drop in the maximum tensile and compressive stresses occurred during the first few cycles followed by stable behavior after approximately 25 cycles.

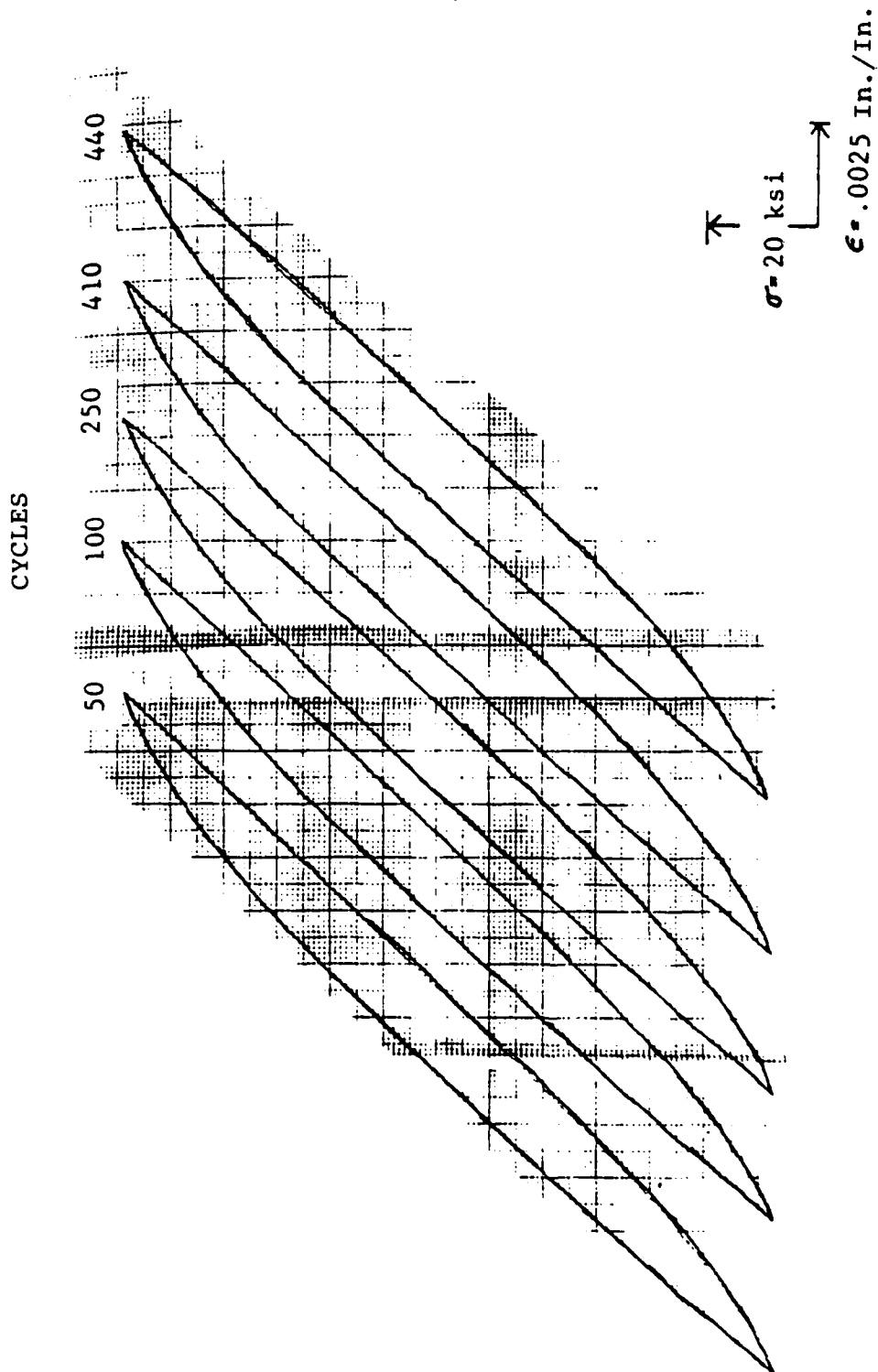


Fig. A1 Stress-Strain Hysteresis Loops During Fatigue Cycling .

A.2.2 Strain Survey

Strain surveys were performed to experimentally quantify the relationship between ram load, axial strain and axial deformation (over 2.00" gage length). Four axial strain gages and an extensometer were mounted on the calibration specimen as shown in Figs. 9 and 10.

Strain survey results are presented in Table A1. Axial load versus axial strain results are plotted in Fig. A2. In Fig. A3 the axial load versus axial deformation is plotted. The relationship between strain at the neck-down area and the constant diameter area is shown in Fig. A4. The axial load versus axial strain relationship obtained is plotted in Fig. A5.

A.2.3 Specimen Calibration and Load Shedding Results

Plots for the maximum tensile load versus number of cycles and the maximum tensile stress versus number of cycles are shown in Figs. A6 and A7, respectively. Results are shown in Fig. A6 for three specimens immersed in 3.5% NaCl solution. In Fig. A7, results are plotted for specimens have total strain amplitudes ranging from $\Delta\epsilon_{T/2} = 0.65\%$ to $\Delta\epsilon_{T/2} = 1.70\%$. In general, very little change in compressive or tensile loads was observed until a

Table A1 Strain Survey Results for Strain-Controlled Specimen

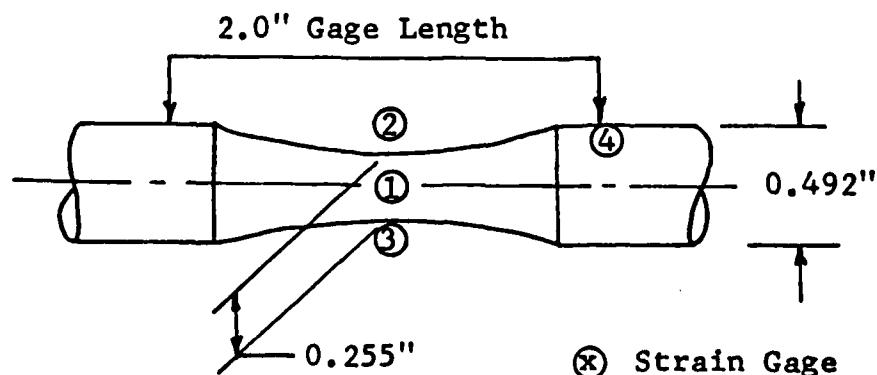
Load	P/A ₁	Extensometer Volts**	In	ε ₁	ε ₂	ε ₃	Ave. ε ₁₋₃	ε ₄	Ave. ε ₁₋₃ /ε ₄
				$\xrightarrow{\quad} 10^3 \text{ in/in} \xrightarrow{\quad}$					
0	0	-	-	0	0	0	0	0	0
80	1567	-	-	.147	.154	.146	.149	.044	3.386
120	2351	.06	.0003	.218	.228	.215	.220	.065	3.385
200	3918	.10	.0005	.369	.389	.370	.376	.110	3.418
300	5877	.15	.00075	.551	.582	.555	.563	.164	3.433
500	9795	.23	.00115	.920	.966	.920	.935	.273	3.425
700	13713	.32	.0016	1.294	1.364	1.302	1.320	.388	3.402
1000	19591	.45	.00225	1.845	1.942	1.854	1.880	.552	3.406
1200	23509	.54	.0027	2.221	2.338	2.230	2.263	.663	3.413
1400	27427	.63	.00315	2.594	2.726	2.599	2.639	.773	3.414
1600	31345	.72	.0036	2.977	3.129	2.987	3.031	.885	3.425
1800	35263	.82	.0041	3.360	3.527	3.370	3.415	.996	3.429
2000	39181	.91	.00455	3.746	3.931	3.756	3.811	-	-
0	0	-	-	-	-	-	-	-	-
1000	19591	.46	.0023	1.900	1.995	1.897	1.931	.574	3.364
2000	39181	.92	.0046	3.803	3.987	3.821	3.870	1.131	3.422
2200	43099	1.02	.0051	4.190	4.386	4.200	4.259	1.236	3.446
2400	47018	1.11	.00555	4.582	4.791	4.598	4.657	1.348	3.455
2600	50936	1.21	.00605	5.016	5.234	5.056	5.102	1.466	3.480
2800	54854	1.30	.0065	5.513	5.684	5.608	5.602	1.572	3.564
3000	58772	1.40	.0070	6.115*	6.194*	6.330*	6.213	1.694	3.668
3100	60731	1.46	.0073	6.560	6.514	6.909	6.661	1.745	3.817
3200	62690	1.80	.0090	12.089	11.532	12.205	11.942	1.819	6.565
0	0	.28	.0014	5.633	4.752	5.719	5.368	.042	127.80

Notes: * Creep Observed

Extensometer Readings: 20 Volts = 0.10"

** ± 0.02 Volts

$$A_1 = 0.785(0.255)^2 = 0.05104 \text{ in.}^2$$



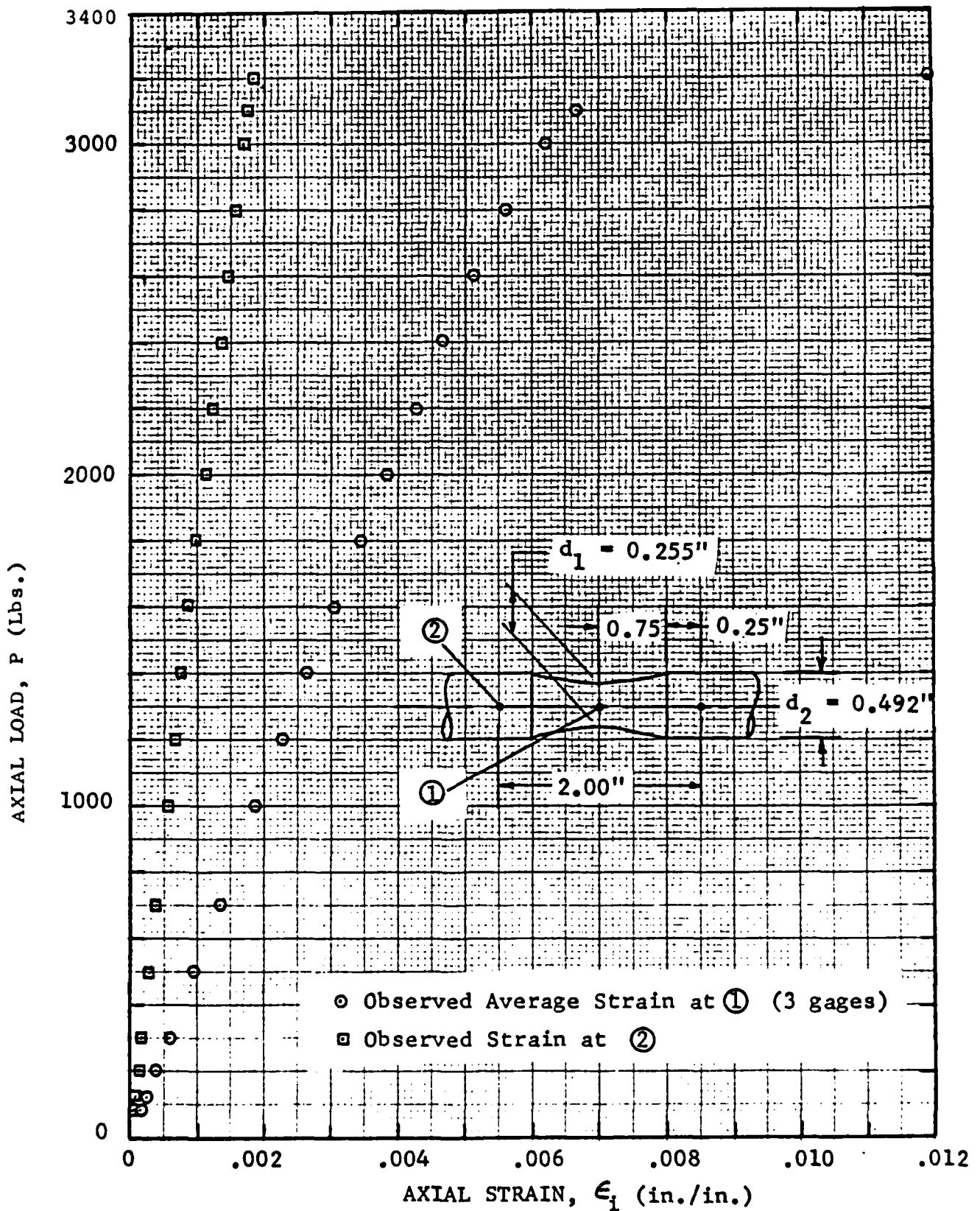


Fig. A2 Axial Strain Versus Axial Load For Strain-Controlled Specimen (7075-T7651)

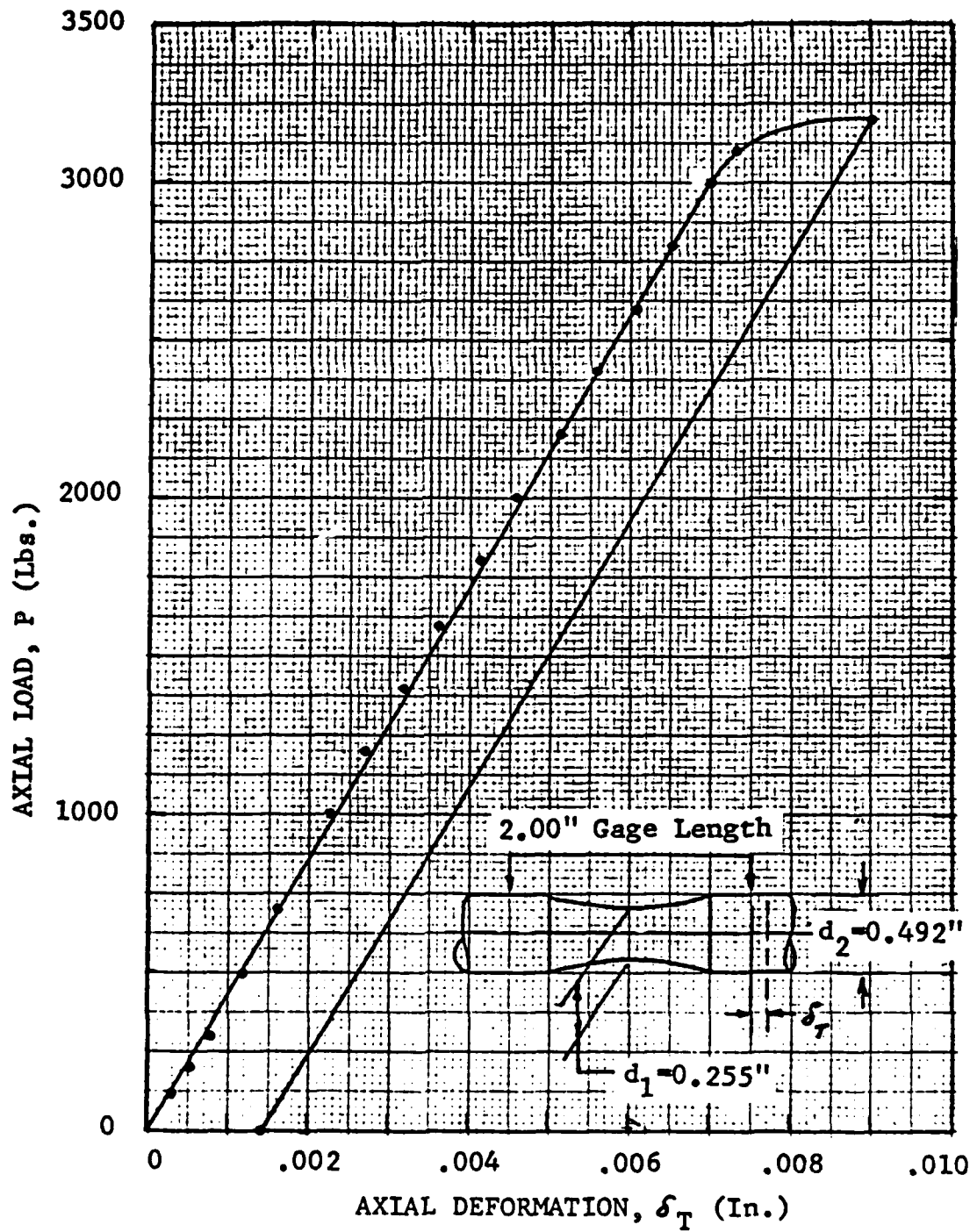


Fig. A3 Axial Deformation Versus Axial Load For Strain-Controlled Specimen (7075-T7651)

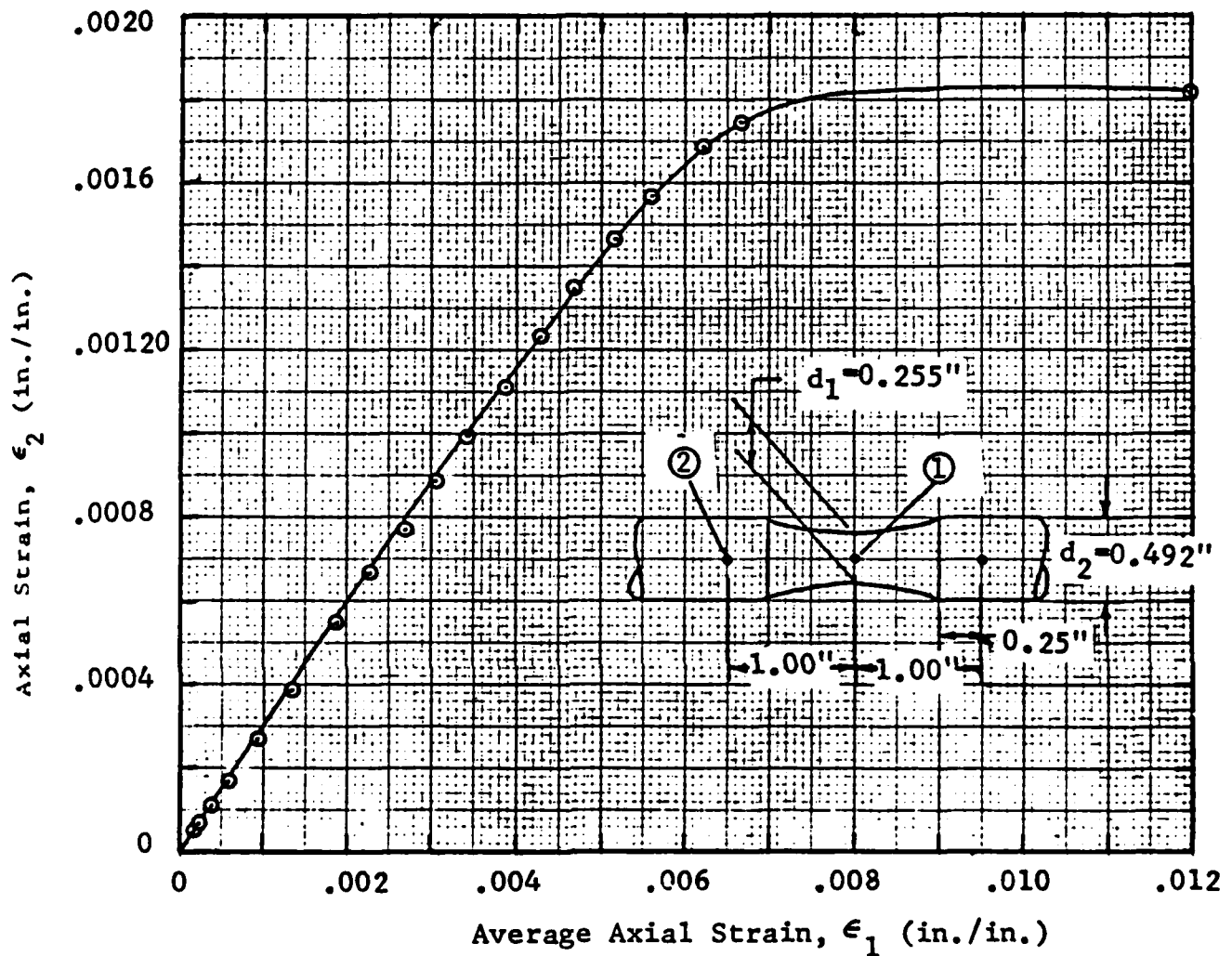


Fig. A4 Axial Strain Relationships For Strain-Controlled Specimen (7075-T7651)

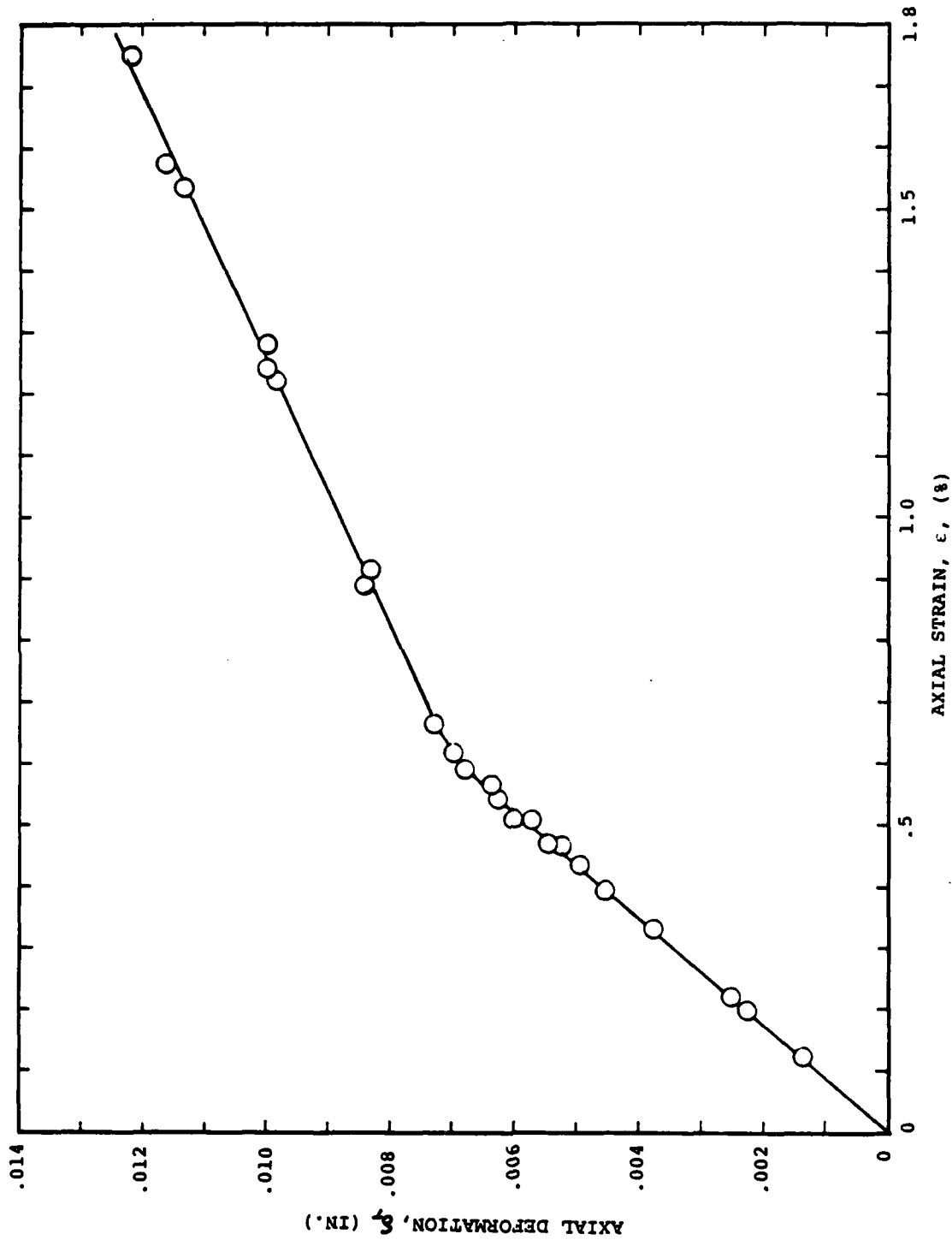


Fig. A5 Axial Deformation Versus Axial/Strain
for Strain-Controlled Specimens (7075-T7651
Aluminum)

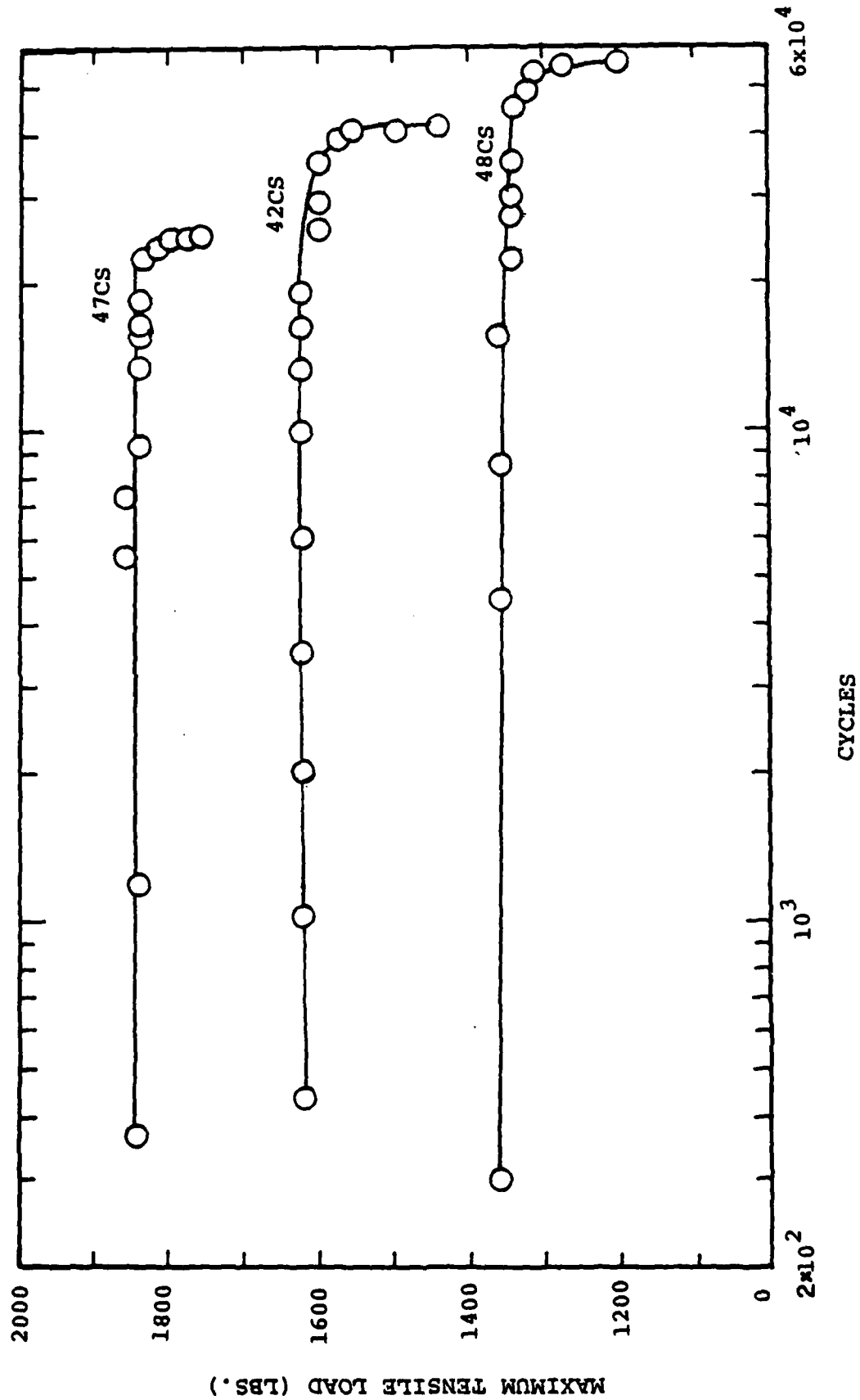
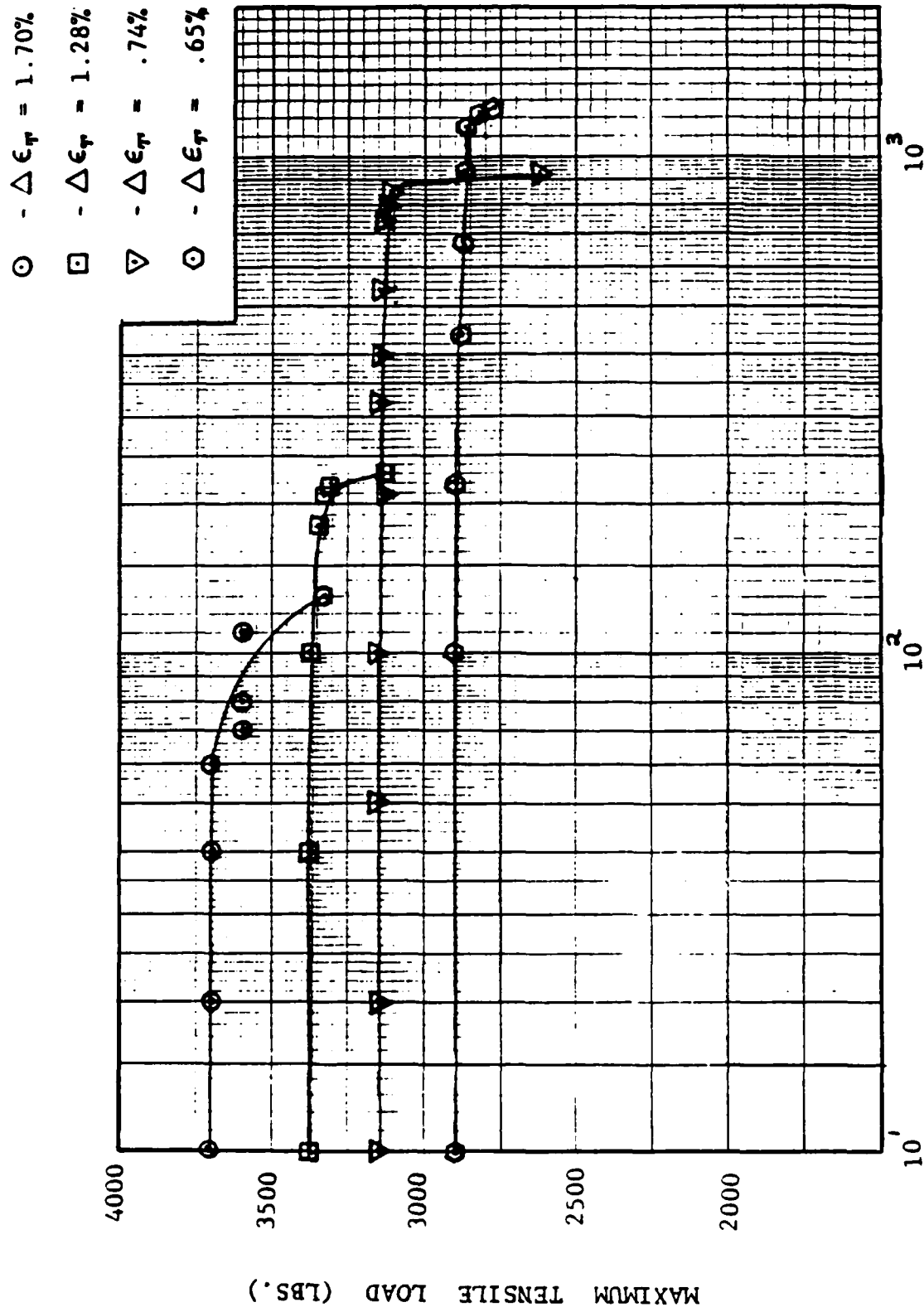


Fig. A6 Maximum Tensile Load as a Function of Fatigue Cycling
(Specimens 47CS, 42CS, and 48CS; 7075-T7651 Aluminum)



CYCLES

Fig. A7 Maximum Tensile Load As A Function Of Fatigue Cycling For Four Different Total Strain Levels

fatigue crack had initiated. Compressive and tensile loads were relatively stable for both low and high strain amplitude specimens until crack initiation occurred (Fig. A7). Once a fatigue crack had formed, the tensile load dropped rapidly while the compressive load stayed relatively constant. The fatigue crack allows a crack opening displacement to meet the required strain limit with a smaller tensile load. In compression, larger loads were required to strain the material to the required value. Little difference was observed in the behavior of specimens tested at different total strain levels.

A calibration curve was established between the decrease in maximum tensile stress and crack depth. After tensile stress decreases of different percentages were observed, specimens were loaded to failure. Fatigue crack sizes were then measured. The results of these tests are shown in Fig. A8. Cycles to crack initiation for test coupons in Task 5 were defined in terms of cycles completed before a 2% drop in maximum tensile stress occurred. From Fig. A8, a 2% decrease corresponds to a 0.010 inch fatigue crack. This is the same crack size used to define the number of cycles to initiate a crack depth of 0.010", Ni, for the stress-controlled tests of Phase I [3].

A.3 TASK 5 TEST RESULTS

Using the experimental procedures developed and evaluated under Task 4, the required strain-controlled data for Task 5 was

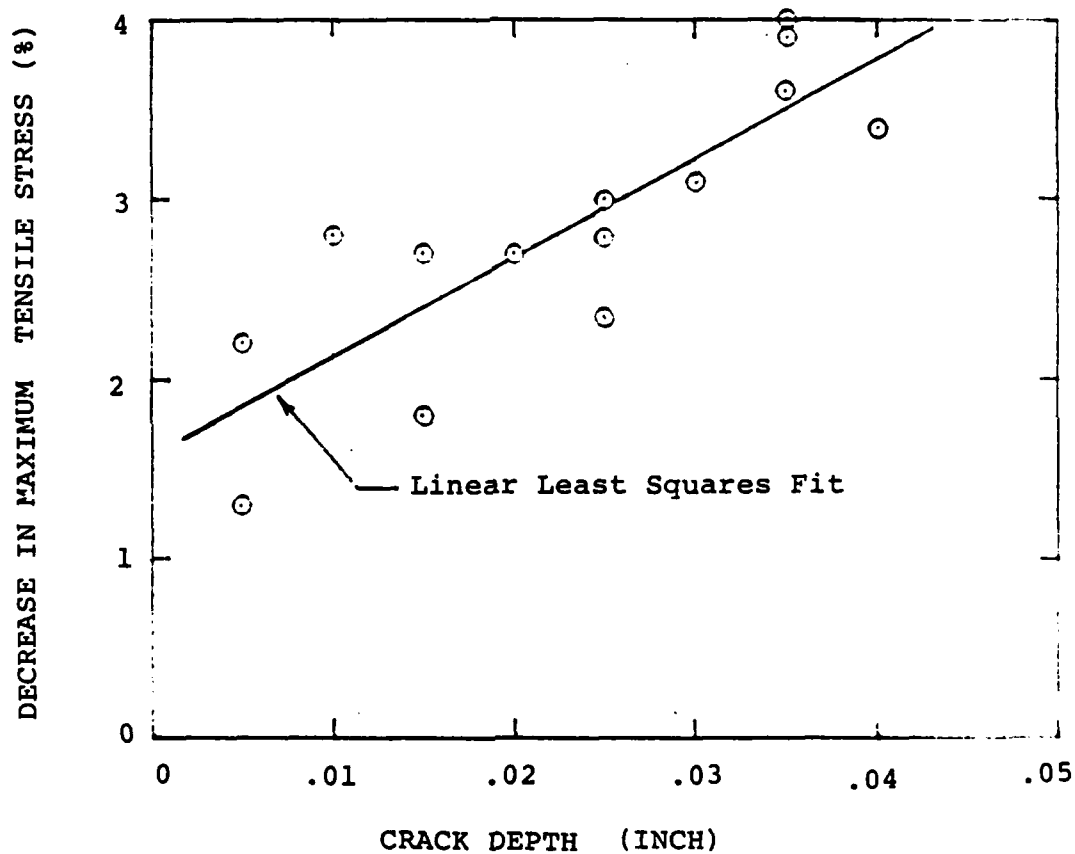


Fig. A8 Decrease in Maximum Tensile Stress as a Function of Crack Size in Strain-Controlled Specimens (7075-T7651 Aluminum)

obtained. The experimental data acquired under Task 5 provided the information needed to make time-to-crack-initiation predictions for mechanically-fastened joints under Task 6. Results presented herein are evaluated in Volume III [1].

Strain-controlled results for Task 5 are shown in Tables A2 and A3 for dry air/lab air and for 3.5% NaCl environments, respectively. Results are presented for: strain amplitude (total, elastic and plastic), area under the hysteresis loop, load frequency, and 2Ni cycles to initiate a crack depth of 0.010 inch.

A plot of cyclic strain versus initiation life in 7075-T7651 aluminum is shown in Fig. A9 for dry air and a 3.5% NaCl environment.

The possible effect of test frequency on crack initiation in a 3.5% NaCl environment was examined. Most of these studies were conducted at lower strain amplitudes where the test coupons were exposed to a salt water environment longer. Four frequencies were used: .1 Hz, .5 Hz, 2.0 Hz, and 5.0 Hz. Test results are shown in Fig. A10 and results are evaluated in Volume III [1].

Table A2 Strain-Controlled Test Results for 7075-T7651
Aluminum in Dry Air and Lab Air Environments

Specimen No.	Total Strain Amp (%)	Total Elastic Strain Amp (%)	Total Plastic Strain Amp (%)	Area under Hysteresis Loop (In ²)	Freq. (Hz.)	ZN ₁ (cycles)	Environmental Condition
40CS	.37	.370	-	-	.5	183,200	Dry Air
12CS	.42	.420	-	-	.2	57,660	Dry Air
6CS	.42	.420	-	-	.2	55,400	Lab Air
39CS	.50	.496	-	-	.5	23,600	Dry Air
29CS	.51	.510	-	-	.5	18,800	"
31CS	.53	.530	-	-	.2	14,000	"
20CS	.52	.520	-	-	.2	13,600	"
7CS	.60	.594	.006	.25	.5	8,380	"
37CS	.67	.658	.012	.45	.5	3,820	"
43CS	.71	.680	.030	1.45	.5	1,760	"
17CS	.74	.690	.050	2.30	.5	1,800	"
21CS	.89	.786	.104	3.64	.5	920	"
46CS	.90	.803	.097	3.92	.5	860	"
51CS	.90	.788	.112	4.04	.1	860	"
28CS	.98	.802	.178	6.69	.5	700	"
13CS	1.04	.860	.180	5.20	.5	680	"
18CS	1.28	1.003	.272	9.80	.5	420	"
8CS	1.14	.907	.233	8.82	.5	420	"
4CS	1.35	.955	.395	10.90	.5	300	Lab Air
24CS	1.63	1.117	.513	16.88	.5	200	Dry Air
19CS	1.70	1.164	.596	18.78	.5	220	Lab Air
52CS	2.02	1.210	.810	24.63	.5	110	Dry Air

Table A3 Strain-Controlled Test Results for 7075-T7651
Aluminum in 3.5% NaCl Solution

Specimen No.	Total Strain Amp. (%)	Total Elastic Strain Amp (%)	Total Plastic Strain Amp (%)	Area under Hysteresis Loop (in ²)	Freq. (Hz)	2N ₁ (cycles)	Environmental Condition
49CS	.27	.270	-	-	5	213,000	3.5% NaCl
48CS	.29	.290	-	-	5	109,060	"
42CS	.31	.310	-	-	5	81,120	"
38CS	.33	.330	-	-	2	66,700	"
47CS	.37	.370	-	-	5	49,260	"
34CS	.38	.380	-	-	2	43,680	"
30CS	.37	.370	-	-	2	33,660	"
11CS	.43	.430	-	-	2	38,100	"
15CS	.43	.430	-	-	.5	22,080	"
35CS	.45	.450	-	-	2	16,740	"
22CS	.52	.520	-	-	2	9,740	"
32CS	.52	.519	.001	.05	.5	9,160	"
33CS	.53	.527	.003	.12	5	7,020	"
9CS	.59	.583	.007	.22	.5	3,820	"
16CS	.65	.635	.015	.52	2	2,280	"
44CS	.66	.631	.029	1.15	.5	1,380	"
36CS	.86	.792	.068	2.72	.5	850	"
45CS	.90	.795	.105	4.12	.1	640	"
23CS	.89	.786	.104	3.61	.5	580	"
14CS	.98	.818	.162	5.93	.5	480	"
10CS	1.25	.950	.300	9.82	.5	300	"
26CS	1.63	1.136	.490	16.98	.5	140	"
41CS	2.02	1.220	.800	24.58	.5	88	"

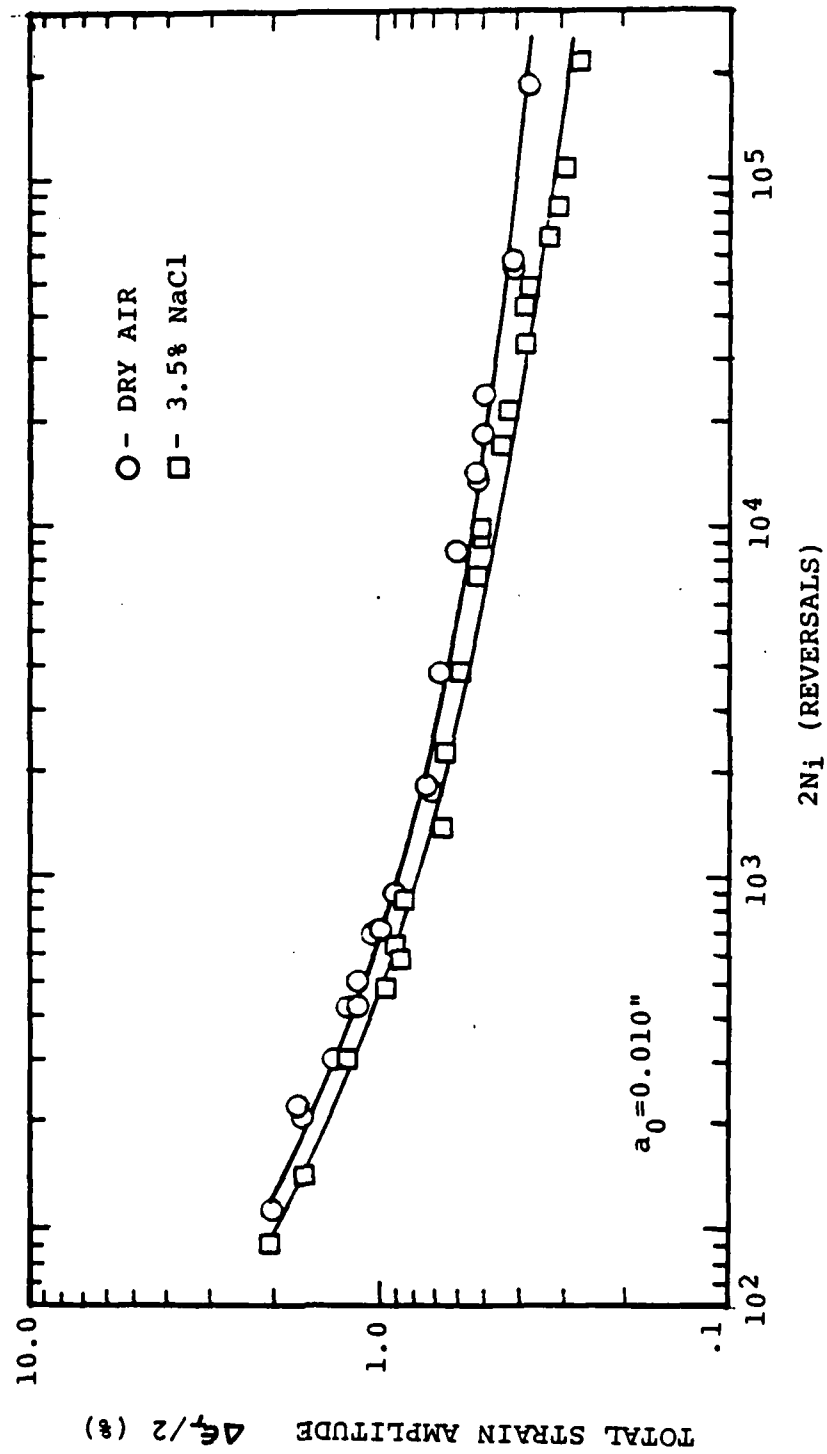


Fig. A9 Total Strain Amplitude Versus Reversals to Crack Initiation for 7075-T7651 Aluminum in Both Dry Air and 3.5% NaCl Environments

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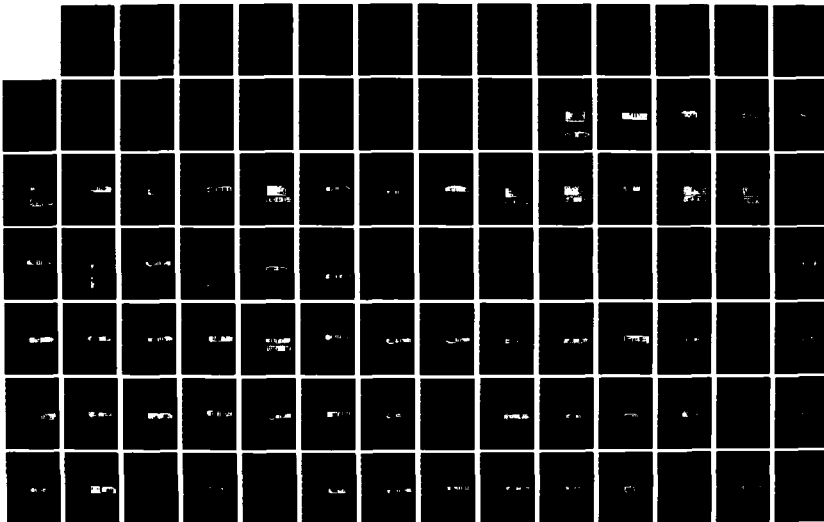
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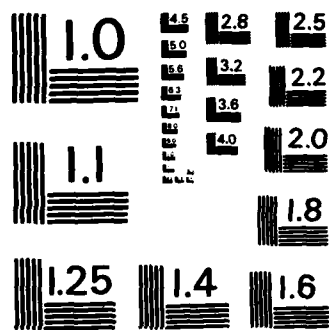
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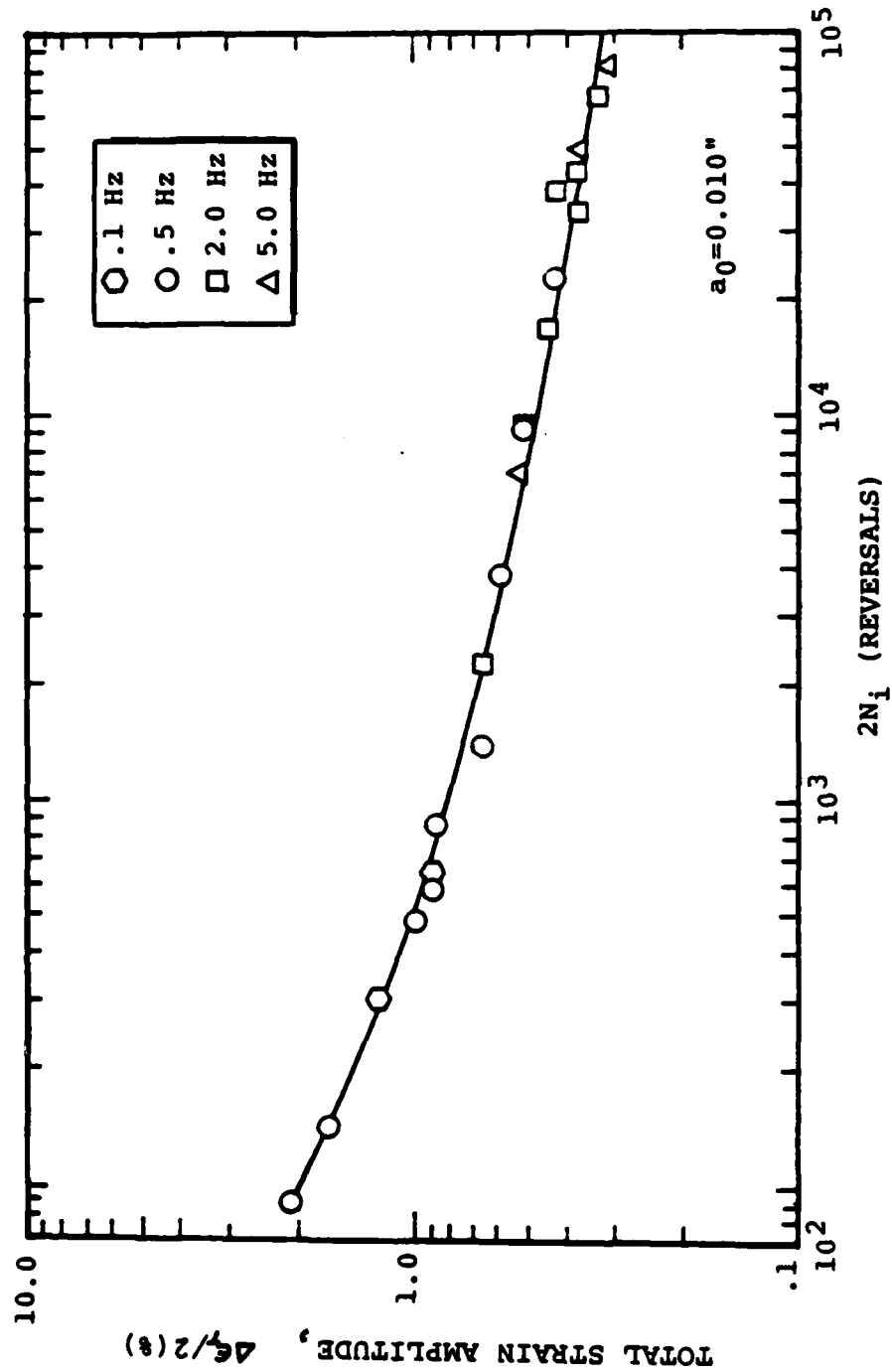


Fig. A10 Total Strain Amplitude Versus Reversals to Crack Initiation for 7075-T7651 Aluminum in a 3.5% NaCl Environment for Different Loading Frequencies

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A P P E N D I X B

STRAIN-CONTROLLED TEST RESULTS FOR
BETA-ANNEALED TI-6AL-4V ALLOY

B.1 INTRODUCTION

Raw test results for Tasks 4 and 5 are presented in this Appendix. These results are evaluated and discussed in Volume III [1].

B.2 TASK 4 TEST RESULTS

Typical stress-strain hysteresis plots are shown in Figure B1. Monotonic and cyclic stress-strain properties for this material and basic material properties are given in Volume I [3].

Both the maximum tensile and compressive stresses decreased with cycling with the largest decrease during the first few cycles (Fig. B1). The decrease in the maximum tensile and compressive stresses with cycling was accompanied by an increase in the width of the hysteresis stress-strain plots (increase in plastic strain increment) and also the area enclosed by the hysteresis loop (increase in plastic work).

The strain-controlled specimens (Fig. 1) for this material were calibrated using the same procedure developed for the 7075-T7651 aluminum alloy. Extensometer voltage output (axial

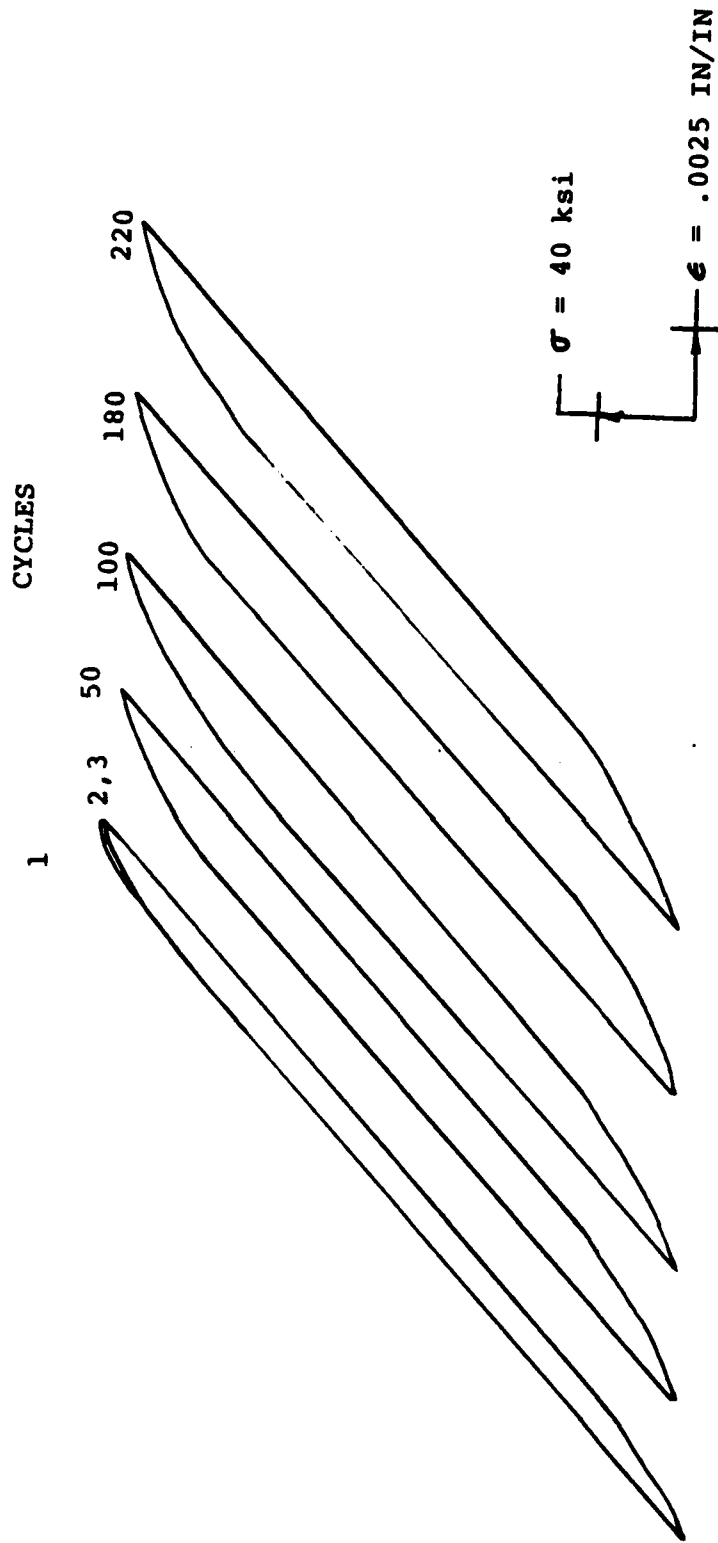


Fig. B1 Stress-Strain Hysteresis Loops During
Fatigue Cycling for Beta-Annealed
Ti-6Al-4V ($\Delta\epsilon/2 = 1.06\%$)

deformation) was measured as a function of axial strain in the reduced section of the specimen. These measurements were made by correlating extensometer voltage readings to strain gage readings for strain gages mounted axially in the minimum area section of the test specimen. A calibration curve based on these measurements is shown in Figure B2. This calibration curve was used to select extensometer voltages to obtain a specified strain value for the Task 5 experiments.

B.3 TASK 5 TEST RESULTS

Strain-controlled results for Task 5 are presented in Table B1 for lab air, dry air and 3.5% NaCl solution environments. The $2N_i$ reversals are for a crack depth of 0.010 inch. N_i was defined as the number of cycles in which a 2% decrease was observed in the maximum tensile stress compared to the maximum compressive stress.

The total strain amplitude versus $2N_i$ reversals to crack initiation ($a_0 = 0.010$ inch) is plotted in Figure B3 for lab air, dry air and 3.5% NaCl environments.

The effect of test frequency on crack initiation in both dry air and 3.5% NaCl environment were examined. Results are plotted in Fig. B4.

The change in the plastic strain amplitude versus $2N_i$ reversals to initiate a crack depth of 0.010 inch was

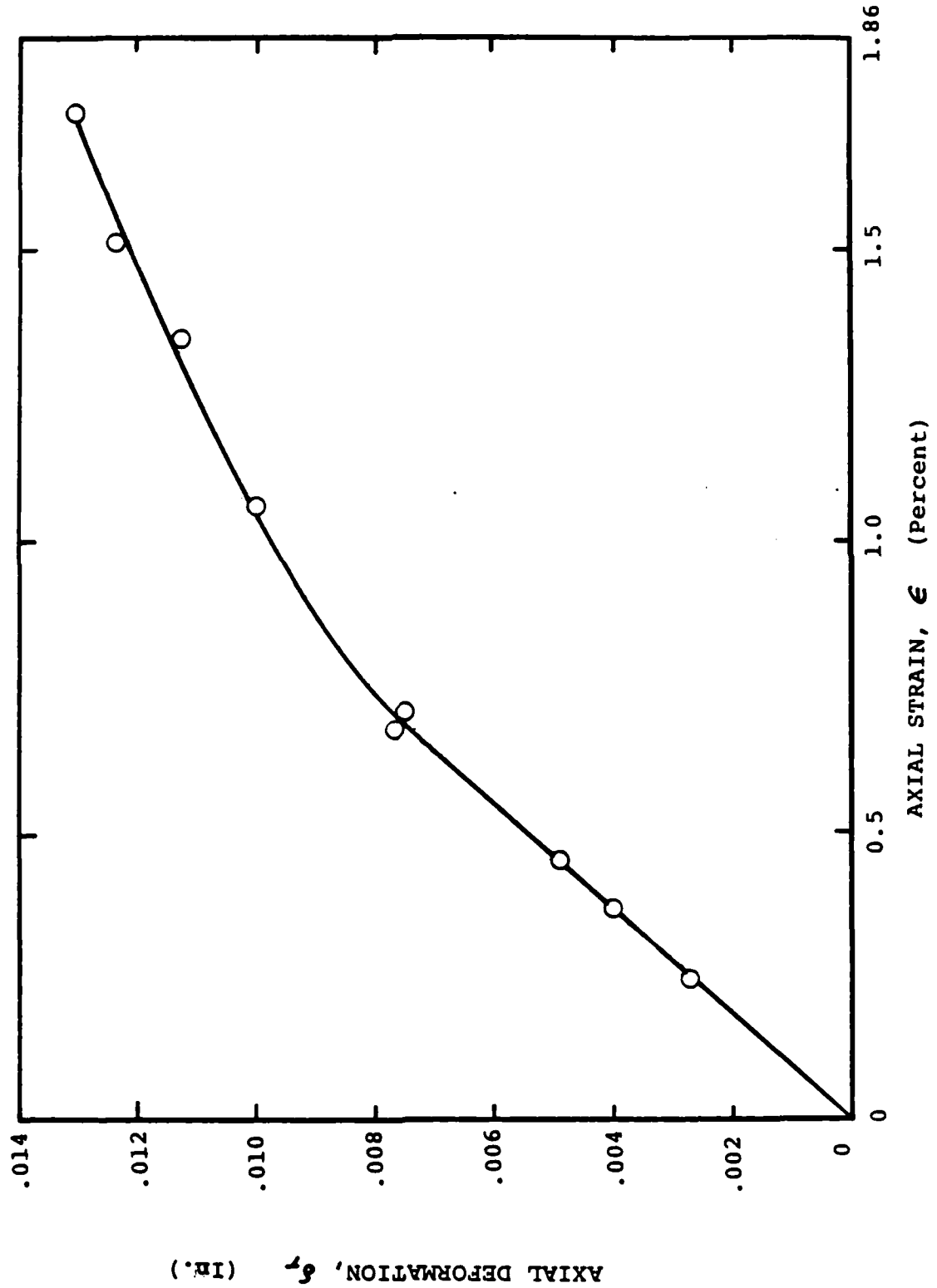


Fig. B2 Axial Deformation Versus Axial Strain for Strain-Controlled Specimen (Beta-Annealed Ti-6Al-4V)

Table B1 Strain-Controlled Test Results for
Beta-Annealed Ti-6Al-4V Alloy in Both
Dry Air and in 3.5% NaCl Solution Environments

Specimen No.	Total Strain Amp. (%)	Freq. (Hz)	2N _i * (Reversals)	Environmental Condition
76CS	.44	5	197,400	Dry Air
77CS	.47	5	>500,000	3.5% NaCl
73CS	.52	2	31,840	3.5% NaCl
78CS	.52	5	>200,000	3.5% NaCl
79CS	.52	5	58,000	Dry Air
66CS	.52	2	32,440	Dry Air
82CS	.62	.5	14,000	Dry Air
85CS	.62	2	16,320	Dry Air
83CS	.62	.5	11,530	3.5% NaCl
84CS	.62	2	13,460	3.5% NaCl
70CS	.71	.5	3,800	Dry Air
68CS	.71	2	5,520	Dry Air
69CS	.71	.5	2,500	3.5% NaCl
67CS	.71	2	4,040	3.5% NaCl
72CS	.87	.5	1,100	Dry Air
71CS	.87	.5	800	3.5% NaCl
62CS	1.06	.5	340	Lab Air
75CS	1.06	.5	460	Dry Air
74CS	1.06	.5	430	3.5% NaCl
63CS	1.36	.1	210	Lab Air
81CS	1.36	.1	210	3.5% NaCl
64CS	1.50	.05	140	Dry Air
80CS	1.50	.05	110	3.5% NaCl
65CS	1.74	.1	96	Dry Air
89CS	.62	.3	13,140	Dry Air
86CS	.62	.5	10,840	Dry Air
87CS	.62	.5	7,800	Dry Air
88CS	.62	2.0	13,000	Dry Air
90CS	.62	5.0	19,480	Dry Air

* For crack depth = 0.010"

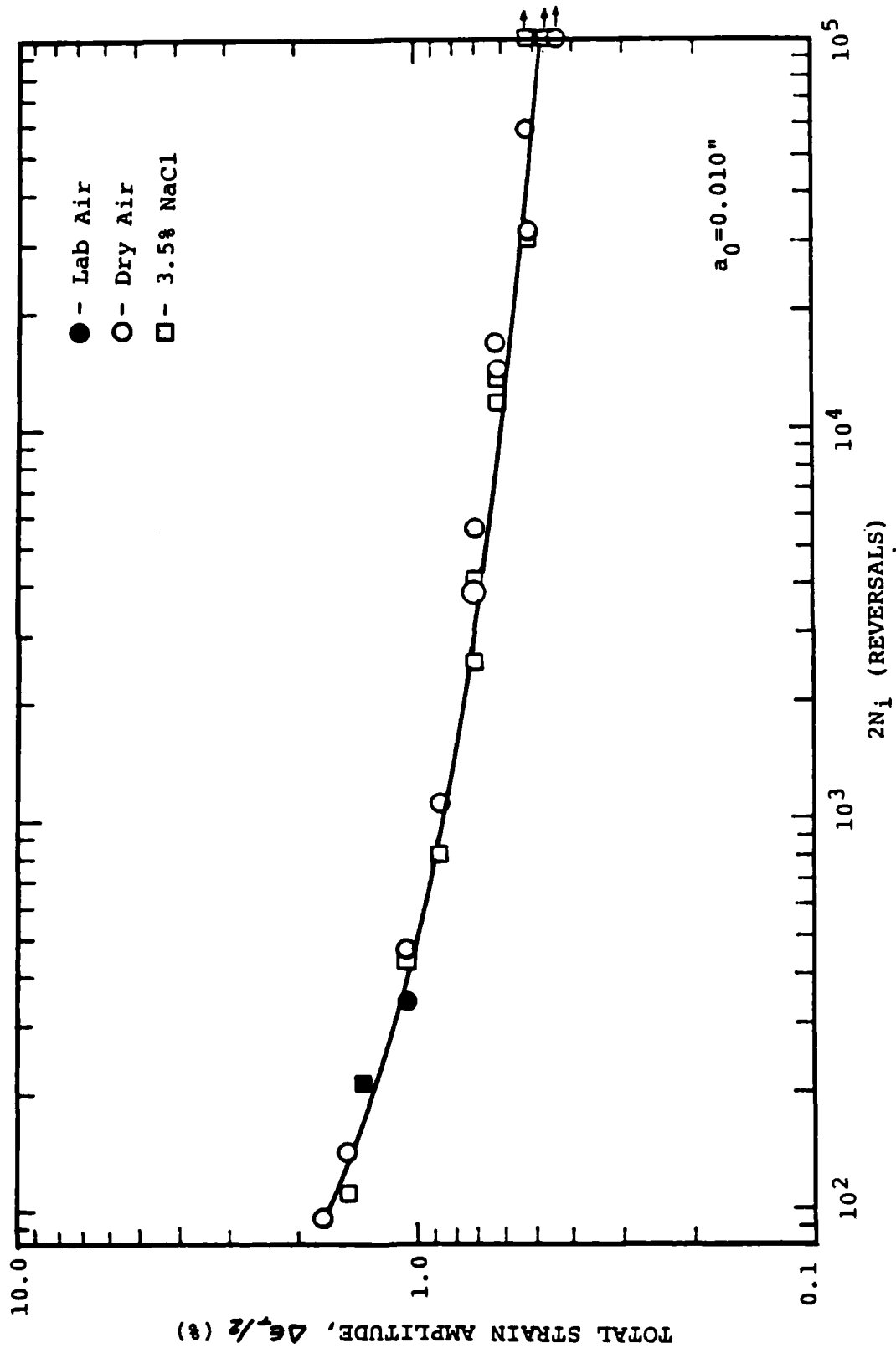


Fig. B3 Total Strain Amplitude Versus $2N_i$ Reversals to Initiation for Beta-Annealed Ti-6Al-4V in Both Dry Air and 3.5% NaCl Environments

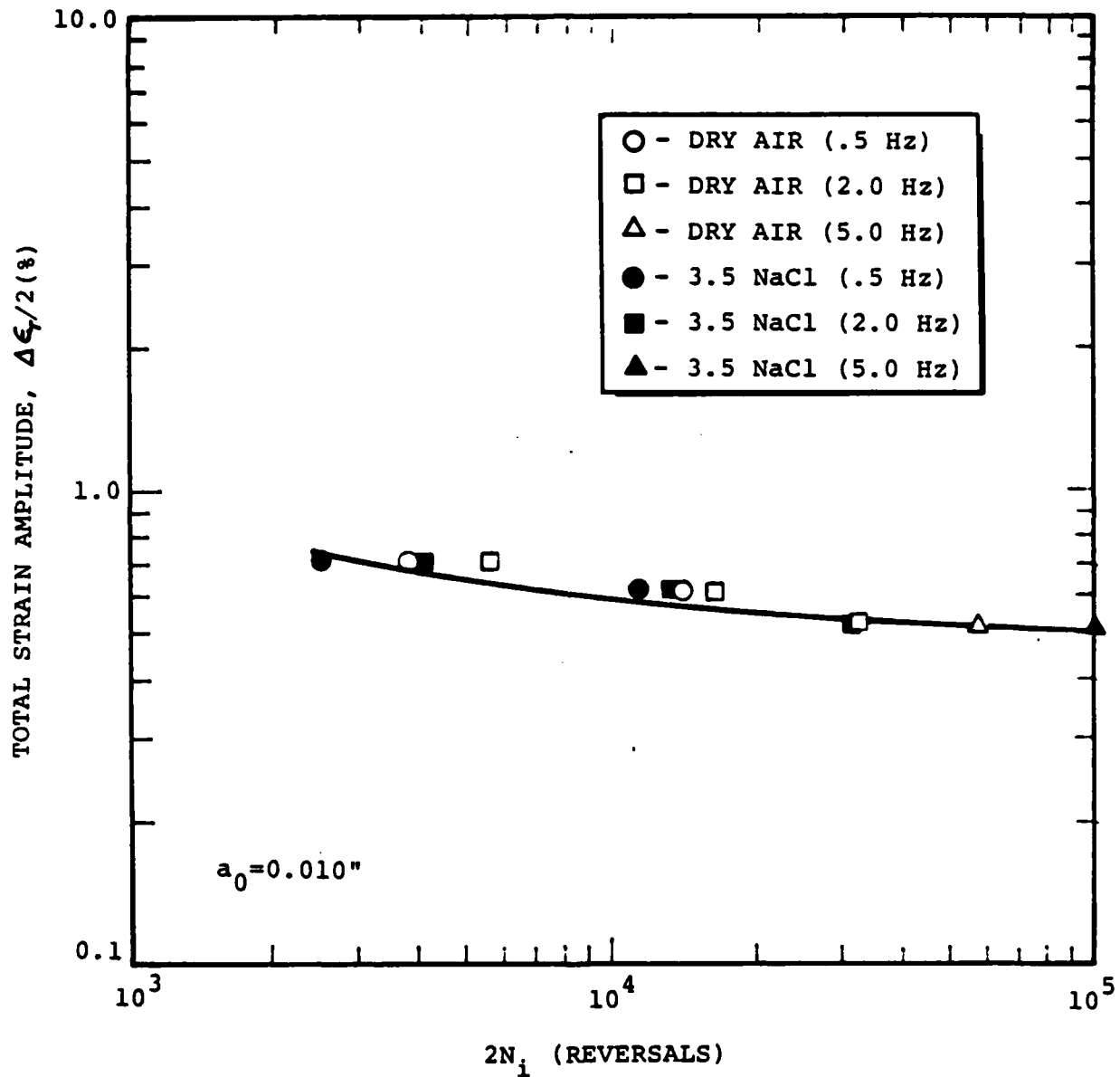


Fig. B4 Total Strain Amplitude Versus $2N_i$ Reversals to Crack Initiation for Different Loading Frequencies for Beta-Annealed Ti-6Al-4V in Both Dry Air and 3.5% NaCl Environments

investigated. Results are plotted in Figs. B5 and B6.

A plot of the plastic work per unit cycle versus $2N_i$ reversals to initiation ($a_0 = 0.010$ inch) for this alloy is shown in Figure B7. The area of the hysteresis stress-strain curve was measured from the loop in which the plastic strain amplitude was maximum.

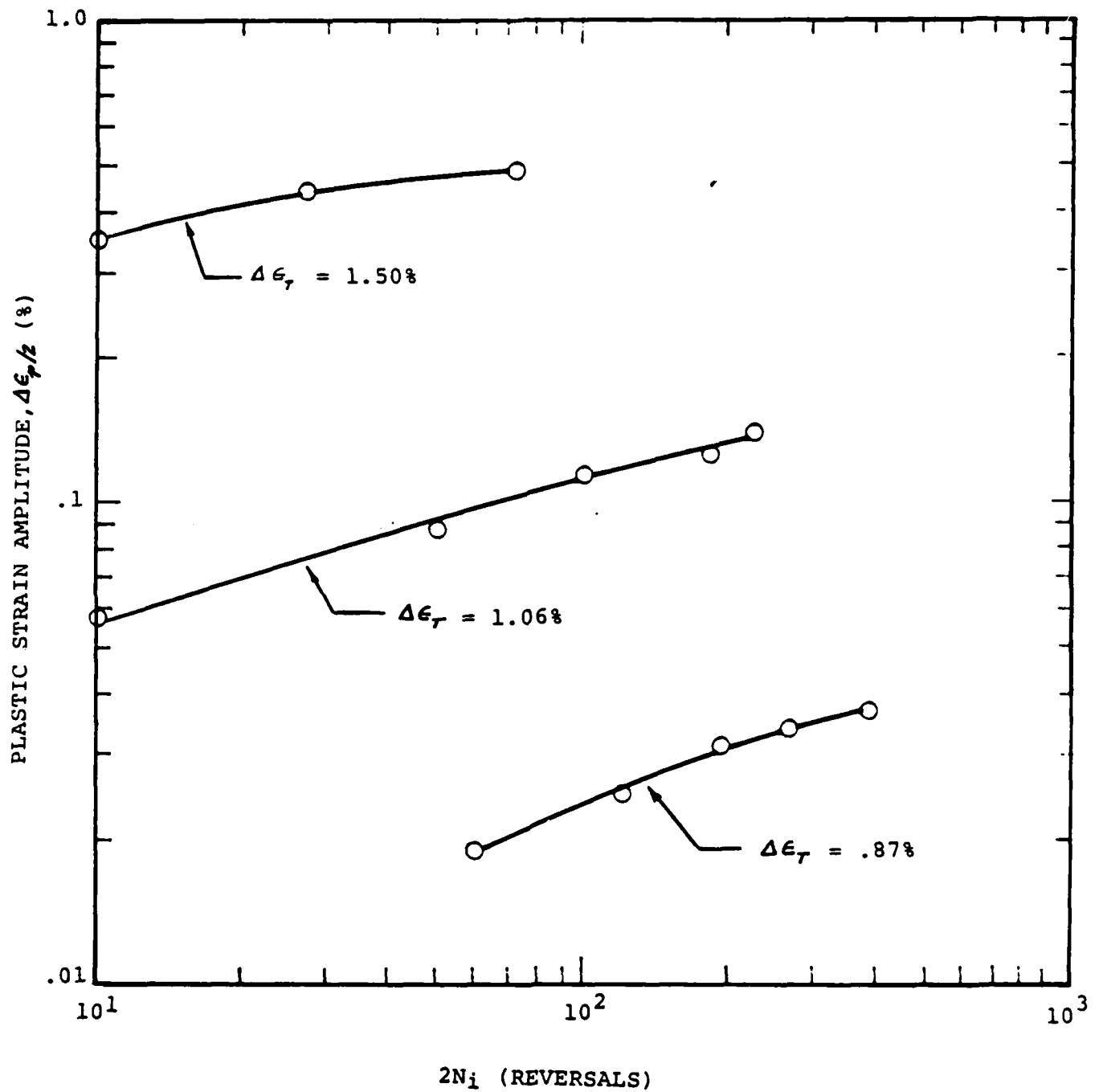


Fig. B5 Change in Plastic Strain Amplitude with Cycling for Beta-Annealed Ti-6Al-4V

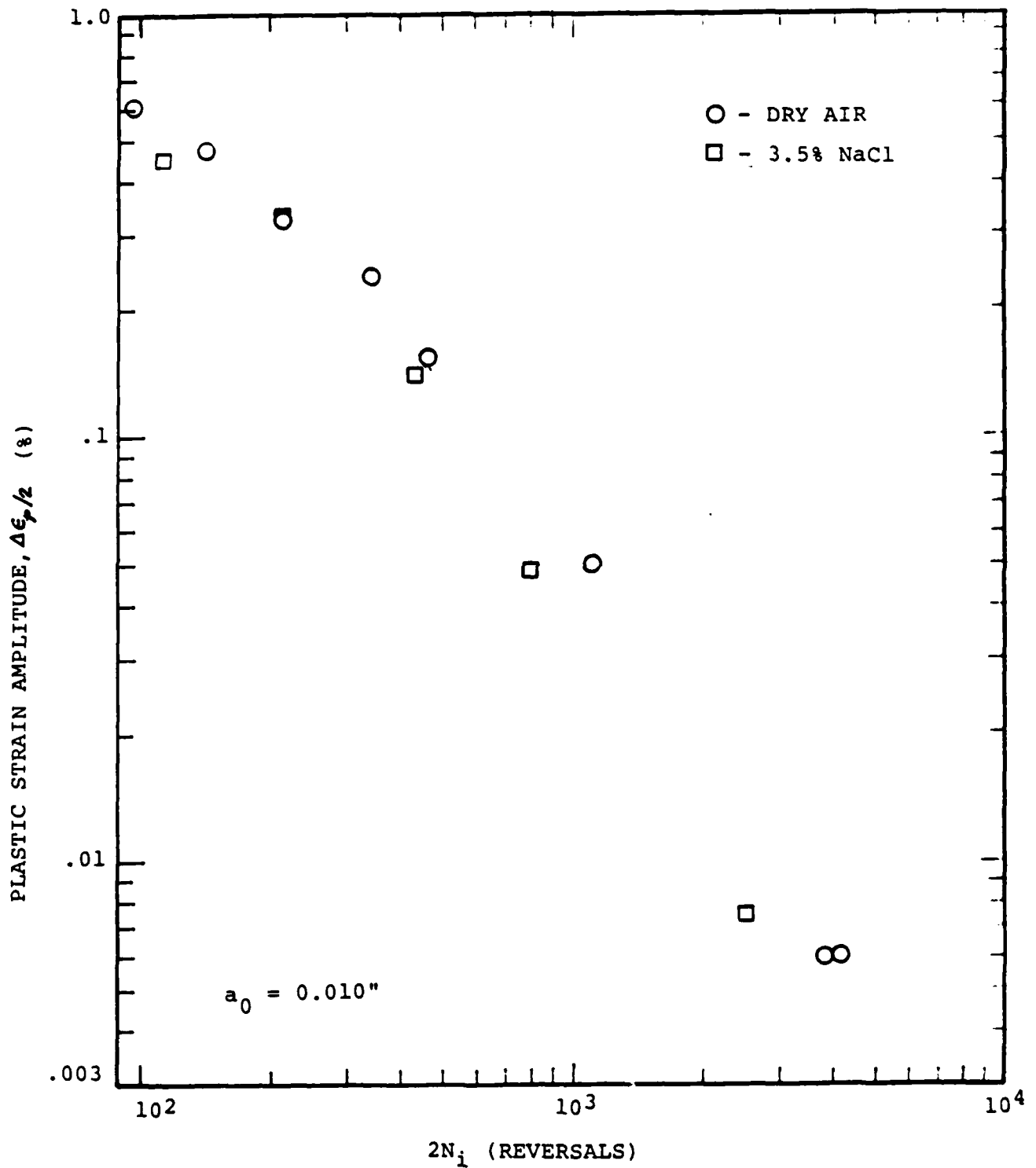


Fig. B6 Plastic Strain Amplitude Versus $2N_i$ Reversals to Crack Initiation for Beta-Annealed Ti-6Al-4V in Both Dry Air and 3.5% NaCl Environment

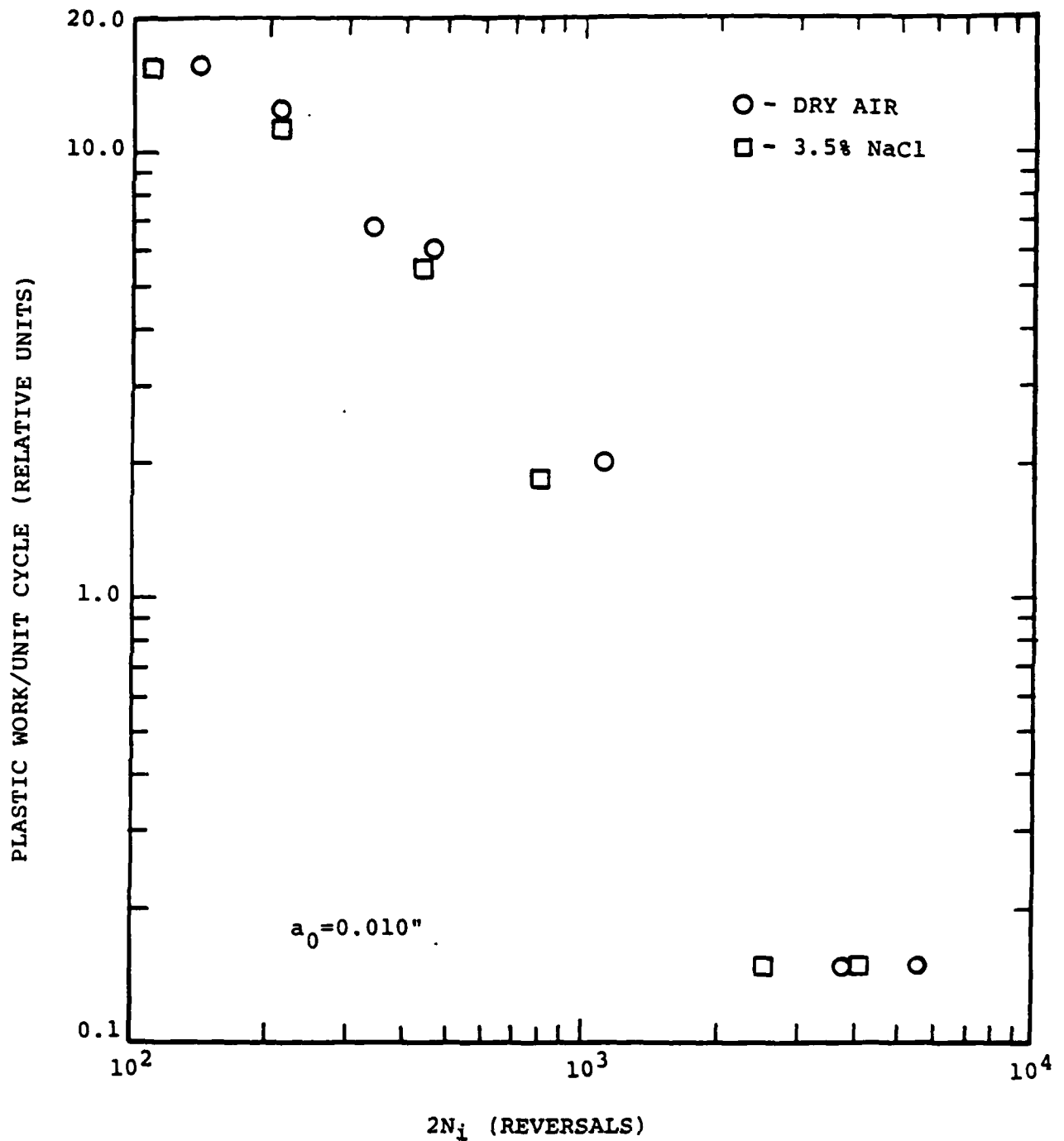


Fig. B7 Plastic Work Per Unit Cycle Versus $2N_i$ Reversals to Crack Initiation for Beta-Annealed Ti-6Al-4V in Both Dry Air and 3.5% NaCl Environments

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APPENDIX C

CONSTANT AMPLITUDE TEST RESULTS FOR DOG-BONE SPECIMENS (7075-T7651 ALUMINUM ALLOY)

C.1 TASK 5 TEST RESULTS

Constant amplitude test results for preconditioned dog-bone specimens (open hole; Fig. 3) are presented in Table C1 for both dry air and 3.5% NaCl environments. These stress-controlled tests were conducted under Task 5 (Ref. Table 6) for selected stress ranges ($\Delta\sigma$). The number of cycles to initiate a crack size of 0.010 inch, N_i , and the number of cycles to failure, N_f , are shown in Table C1.

C.2 TASK 6 TEST RESULTS

Twelve stress - controlled tests were performed under Task 6 (Ref. Table 6) for two different percentages of bolt load transfer (i.e., 20% and 40%). Tests were performed in dry air and in a 3.5% NaCl solution environment. Results are presented in Table C2.

Table. C1 Constant Amplitude Stress-Controlled Test Results
for Preconditioned Dog-Bone Specimens in Both Dry
Air and 3.5% NaCl Environments (7075-T7651 Aluminum;
R=0.05; Freq. - 6HZ; Open Hole)

SPECIMEN NO.	$\Delta\sigma$ (ksi)	N_f (cycles)	N_i (cycles)	ENVIRONMENT
200	16.5	92,827	70,000	Dry Air
204	15.0	85,720	52,000	Dry Air
202	14.0	99,389	70,000	Dry Air
199	14.0	38,202	25,000	3.5% NaCl
203	13.0	44,409	26,000	3.5% NaCl
205	12.0	167,539	95,000	3.5% NaCl
206	12.0	80,887	40,000	3.5% NaCl

Table C2 Constant Amplitude Stress-Controlled Test Results for Dog-Bone Specimens Tested for 20% LT and 40% LT in Both Dry Air and 3.5% NaCl Environments (7075-T7651 Aluminum)

ENVIRONMENT	SPECIMEN NUMBER	DATA SET NO.	$\Delta\sigma$ (KSI)	PERCENT LOAD TRANSFER	NUMBER OF CYCLES TO INITIATION ($a_o = 0.010"$) N_i	NUMBER OF CYCLES TO FAILURE N_f
Dry Air	401	63	23	20	17,000	22,623
	400	64	17	"	49,000	61,958
	402			"	48,000	58,715
	403			"	35,000	40,000
3.5% NaCl	407	66		40	41,000	53,059
	408			"	25,000	32,881
	404	65	17	20	41,000	44,766
	405			"	41,000	44,951
	406			"	20,000	22,000
	410	67		40	12,000	14,515
	412			"	18,000	21,888
	413			"	13,000	15,100

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APPENDIX D

SPECTRUM FATIGUE TEST RESULTS AND FRACTOGRAPHIC DATA
FOR TASK 4 (7075-T7651 ALUMINUM ALLOY)

Spectrum fatigue test results for the dog-bone specimens (Fig. 3) tested under Task 4 are summarized in Table D1. Fractographic data sheets are also presented in this appendix.

The maximum positive load in spectrum "A" (F-16 400 hour block spectrum), 100% load level, was scaled to a test load that would produce the desired gross stress on the specimen cross section. All other loads, positive and negative, were "scaled" to the 100% load level.

Fatigue loading frequencies for spectrum "A" were selected such that the spectrum loads corresponding to 8000 equivalent flight hours could be applied to the respective test specimen in a selected number of days (24 hours a day continuous testing). Three loading frequencies were considered in task 4: (1) F = fast (8000 flight hours/2 days), (2) S = slow (8000 flight hours/16 days) and (3) M = medium (8000 flight hours/8 days).

Table D1 Summary of Dog-Bone Specimen Spectrum
Fatigue Test Results for Task 4 (7075-T7651
Aluminum; P-16 400 Hour Spectrum)

SPECIMEN NO.	TEST I.D. (b)	DATA SET NO.	TEST DATE	SPECIMEN DETAILS				FATIGUE CRACK ORIGIN (f)	TTCI (FLT. HRS.) (g)	TTF (FLT. HRS.) (h)	TTF-TTCI (FLT. HRS.) (i)	TTCI/TTF
				WIDTH (IN.)	THICK (IN.)	HOLE DIA (IN.)	GROSS AREA (IN ²)					
41	A-34/S/W	43	3-3-83	1.9980	.3000	.2502	.5994	B	4657	6640	1983	.70
42	A-34/S/D	41	3-22-83	1.9985	.2990	.4404	.5976		4207	8408	4201	.50
43	A-32/F/W	45	3-24-83	2.00	.3060	.4415	.6120		5147(a)	7606	2459	.68
47	A-30/F/D	47	6-6-83	2.0100	.3010	.4452	.6050		4777	12432	7655	.38
48(a)	A-30/F/D	47	6-10-83	2.0100	.3010	.4422	.6050		(e)	13680	-	-
49	A-32/S/D	44	5-12-83	2.0115	.3010	.4495	.6055		5441	9606	4165	.57
50	A-32/S/D	44	5-16-83	2.0090	.3010	.4426	.6047		2200	9635	7435	.23
51	A-32/S/D	44	5-19-83	2.0100	.3010	.4426	.6050		1000(c)	8835	7835	.11
52(a)	A-30/S/D	48	5-31-83	2.0115	.3020	.4452	.6075		6143	12035	5892	.51
53	A-34/F/W	42	5-6-83	2.0140	.3000	.4450	.6042		433	3235	2802	.13
54	A-30/F/W	49	6-7-83	2.0135	.3015	.4455	.6071		(e)	7606	-	-
55	A-30/F/W	49	6-8-83	2.0145	.3020	.4504	.6084		3067	6678	3611	.46
56	A-30/F/W	49	6-6-83	2.0110	.3005	.4500	.6043	C	(e)	6407	-	-
57	A-34/S/W	43	5-6-83	2.0120	.3000	.4460	.6036		133(d)	2348	2215	.06
58	A-34/S/W	43	5-6-83	2.0115	.3010	.4457	.6055		1200	3206	2006	.37
59	A-32/S/W	46	5-16-83	2.0110	.3010	.4475	.6053		3289	5235	1946	.63
60	A-32/S/W	46	5-11-83	2.0120	.3015	.4465	.6066		4037	6348	2311	.64
61	A-32/M/W	46	5-11-83	2.0120	.3010	.4470	.6056		2451	4835	2384	.51
64	A-30/20/F/W	54	6-21-83	2.0080	.3045	.4392	.6114		(e)	6759	-	-
65	A-30/20/S/W	50	6-29-83	2.0090	.3040	.4408	.6107		(e)	5946	-	-
111(a)	A-28/F/W/B/PC	52	10-14-83	2.002	.301	.4395	.6026	S	(e)	(a)	-	-
121(a)	A-28/F/W/B	51	10-6-83	2.002	.303	.4415	.6066	S	(e)	39120	-	-
129	A-28/S/W/B/PC	53	12-13-83	2.0065	.3025	.4415	.6069	B	6916	11864	4948	.58
143(a)	A-28/F/W/B/PC	52	12-14-83	2.0090	.3030	.4420	.6067	B	6750(d)	11600	4850	.58
144	A-28/S/W/B/PC	53	1-9-84	2.0095	.3030	.4440	.6088	B	10500	16800	6300	.62

Notes for Table D1

- (a) Testing anomaly
- (b) Ref. Table 8 for description code
- (c) Linear extrapolation from two smallest consecutive crack sizes from fractographic data sheet
- (d) Extrapolation based on power law (Eqs. 1 and 3)
- (e) Fractography not read for this specimen for various reasons (e.g., testing anomaly, not 28 ksi baseline stress surface crack away from hole).
- (f) Fatigue crack origins: B = bore of hole, C = corner of hole and S = surface crack away from hole.
- (g) Time to initiate crack depth of 0.010" in fastener hole (determined from fractographic results).
- (h) Time-to-failure
- (i) Time spent in crack growth

FATIGUE TEST DATA

SPECIMEN NUMBER: 41 (Open)
 SPECTRUM: 400hr F16 Fighter (765747 lpts)
 TEST DATE: 3-3-83 //

W1.9980" TH .3000" HOLE DIAM .2502" A .5994 in²

MAX STRESS 34 ksi FREQ. 1 LIFE = 16 days (Slow)

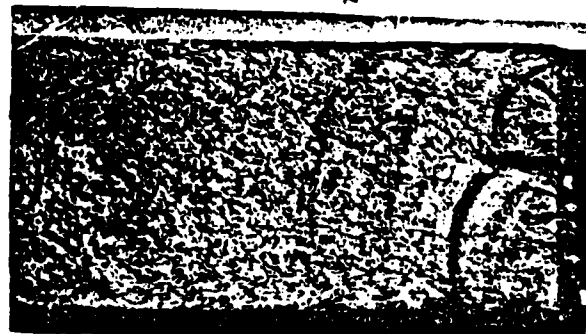
ENVIR. CONDS. 3.5% NaCl PREPS. ---

CYCLES TO FAILURE 639230 lpts % LIFE = 83

TTCI 4657 FLIGHT HOURS Large Flaw = .550"



2X



* Smaller Flaw 5X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	.5245 *
16	6400	.2175
15	6000	.0735
14	5600	.0305
13	5200	.0205
12	4800	.0135
11	4400	.0055
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

* data is for smaller flaw

FATIGUE TEST DATA

SPECIMEN NUMBER: 42 (Open)

SPECTRUM: 400 hr (A)

TEST DATE: 3-22-83 //

W 19985 TH. 2990" HOLE DIAM. .4404" A. .5976 in²
 MAX STRESS 34 ksi FREQ. 1 LIFE = 16 hrs. (Slow)

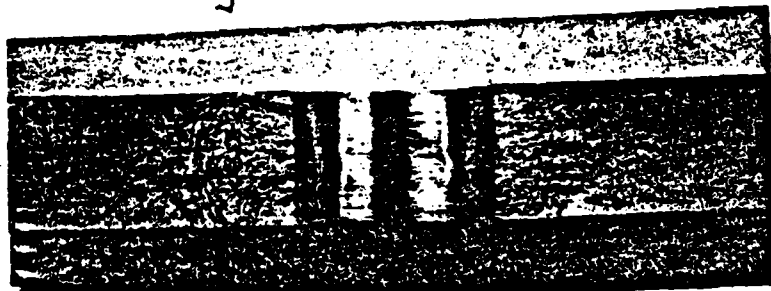
ENVIR. CONDS. Dry Air PREPS. —

CYCLES TO FAILURE 804672 Idpts % LIFE = 105.1

TTCI 4207 FLIGHT HOURS

Smaller Flaw = .180"

Larger Flaw = .268"



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
F 21.02	8408	.268
21	8400	.195
20	8000	.139
19	7600	.102
18	7200	.078
17	6800	.0625
16	6400	.049
15	6000	.039
14	5600	.022
13	5200	.019
12	4800	.016
11	4400	.012
10	4000	.008
9	3600	.0045
8	3200	.0025
7	2800	.0015
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

TTCI

S

2

FATIGUE TEST DATA

SPECIMEN NUMBER: 43 (Open)
 SPECTRUM: 400 hF (A)
 TEST DATE: 3-24-83 //

W 2.00" TH. 3060" HOLE DIAM. 4415" A. .612 in²

MAX STRESS 32 KSI FREQ. 1 LIFE = (Fast) 2 days

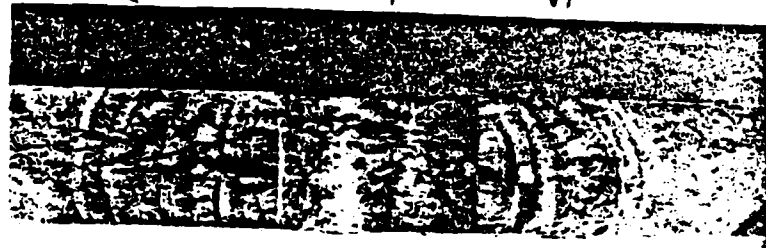
ENVIR. CONDS. 3.5% NaCl PREPS. --- (16 hrs)

CYCLES TO FAILURE 128069 14 pts % LIFE = 95

TTCI 5147 FLIGHT HOURS

Smaller Flow = .380"

Larger Flow = .401"

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
19016	7606.4	.4010
18	7200	.1695
17	6800	.1270
16	6400	.0790
15	6000	.0470
14	5600	.0240
13	5200	.0110
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 47 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 6-06-83 //

W 2.0100 TH .3010 HOLE DIAM .4452" A .6050 ⁱⁿ

MAX STRESS 30 FREQ 1 LIFE = 2 days (Fast)

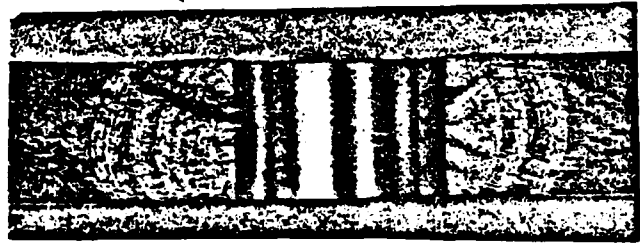
ENVIR. CONDS. Dry PREPS. ---

CYCLES TO FAILURE 1190278 % LIFE = 155

TTCI 4777 FLIGHT HOURS

Smaller Flow = .190"

Larger Flow = .3501"



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
31.08	12422	.3501
31	12400	.3368
30	12000	.2357
29	11600	.1778
28	11200	.1367
27	10800	.1065
26	10400	.0816
25	10000	.0678
24	9600	.0556
23	9200	.0463
22	8800	.0387
21	8400	.0332
20	8000	.0290
19	7600	.0239
18	7200	.0205
17	6800	.0172
16	6400	.0152
15	6000	.0138
14	5600	.0124
13	5200	.0119
12	4800	.0101
11	4400	.0084
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 48 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 6-10-83 // 11
W 2.010" TH .3010" HOLE DIAM .4422" A .6050 IN
 MAX STRESS 30 KSI * FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. none
 CYCLES TO FAILURE 1309458 14 pts % LIFE = 171

TTCI FLIGHT HOURSSmaller Flow =Larger Flow =

* low load for first half life

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	TASK 4
38	15200	
37	14800	NO FRACTOGRAPHIC
36	14400	READINGS
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

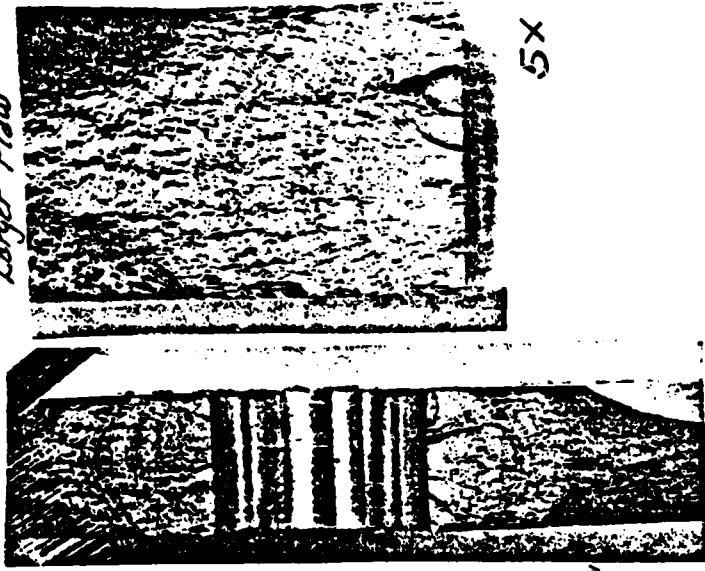
2x

FATIGUE TEST DATA

SPECIMEN NUMBER: 49 (Open Hole)
 SPECTRUM: 400 hr. (A)
 TEST DATE: 5/12/83 11
W 2.0115" TH .3010" HOLE DIAM .4495" A .6055 in²
 MAX STRESS 32 KSC FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. Dry Air PREPS. None
 CYCLES TO FAILURE 919507 14 pts. % LIFE = 120
 TTCT 5441 FLIGHT HOURS

(Larger Flow) FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
F 24.016	9606.4	.3240
24	9600	.2305
23	9200	.1520
22	8800	.1095
21	8400	.0775
20	8000	.0550
19	7600	.0460
18	7200	.0350
17	6800	.0275
16	6400	.0220
15	6000	.0165
14	5600	.0115
13	5200	.0080
12	4800	.0040
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	



Larger Flow

Smaller Flow = .280"
Larger Flow = .324"

FATIGUE TEST DATA

SPECIMEN NUMBER: 50 (Open hole)
 SPECTRUM: 400 br (A)
 TEST DATE: 5-16-83 //

W 2.009" TH .3010" HOLE DIAM .4426" A .6041 in.

MAX STRESS 32 ksi FREQ 1 LIFE = 16 days (Slow)

ENVIR. CONDS. Dry PREPS. None

CYCLES TO FAILURE 9222.57 ld pts % LIFE = 120

TTCI 2200 FLIGHT HOURS

Smaller Flow = .351"

Larger Flow = .348"



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	.348
23	9200	.223
22	8800	.171
21	8400	.137
20	8000	.109
19	7600	.087
18	7200	.073
17	6800	.060
16	6400	.045
15	6000	.037
14	5600	.034
13	5200	.028
12	4800	.025
11	4400	.022
10	4000	.019
9	3600	.018
8	3200	.016
7	2800	.013
6	2400	.011
5	2000	.009
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 51 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 5-19-83 11

W 2.0100" TH .3010" HOLE DIAM .4426" A .6050in"

MAX STRESS 32 KSI FREQ. 1 LIFE = 16 days (Slow)

ENVIR. CONDS. Dry Air PREPS. —

CYCLES TO FAILURE 845690 14 pts% LIFE = 110

TTCI 1000 FLIGHT HOURS

Large Flow: .352"
Smaller Flow: .350" S



L

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
F 22.028	8935.2	.3520
22	8800	.2795
21	8400	.1960
20	8000	.1515
19	7600	.1215
18	7200	.0960
17	6800	.0795
16	6400	.0650
15	6000	.0565
14	5600	.0470
13	5200	.0390
12	4800	.0350
11	4400	.0315
10	4000	.0280
9	3600	.0240
8	3200	.0220
7	2800	.0185
6	2400	.0170
5	2000	.0150
4	1600	—
3	1200	—
2	800	—
1	400	—

714

FATIGUE TEST DATA

SPECIMEN NUMBER: 52 (Open Hole)SPECTRUM: 400 hr (A)TEST DATE: 5-31-83 11W2.0115" TH. 3020 HOLE DIAM. 4452" A. 6075 in²
32 ksi for 7652. 1d ptsMAX STRESS 30 ksi for 1144,339 1d pts FREQ. 1 LIFE = 16 days (Slow)ENVIR. CONDS. Dry PREPS. ---CYCLES TO FAILURE 115199 1d pts % LIFE = 150TTCI 6143 FLIGHT HOURSSmaller Flow = .380"
Larger Flow = .4034"

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30.09	12035	.4034
29	11600	.2664
28	11200	.1678
27	10800	.1278
26	10400	.0960
25	10000	.0766
24	9600	.0617
23	9200	.0518
22	8800	.0348
21	8400	.0320
20	8000	.0265
19	7600	.0207
18	7200	.0173
17	6800	.0140
16	6400	.0115
15	6000	.0092
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 53 (Open Hole)
 SPECTRUM: 400 hr (A)
 TEST DATE: 5-6-83 //

W 2.0140" TH. 3000" HOLE DIAM. .4450" A. .6042 in²

MAX STRESS 34 Ksi FREQ. 1 LIFE = 2 days (Fast)

ENVIR. CONDS. 3.5% NaCl PREPS. ---

CYCLES TO FAILURE 309658 14 pts % LIFE = 40.4

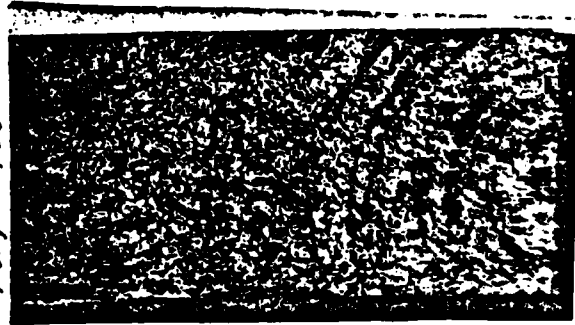
TTCI 433 FLIGHT HOURS

Smaller Flow = .320"

Larger Flow = .492"



Larger Flow



5X

170

2.5X

FRACTOGRAPHIC DATA

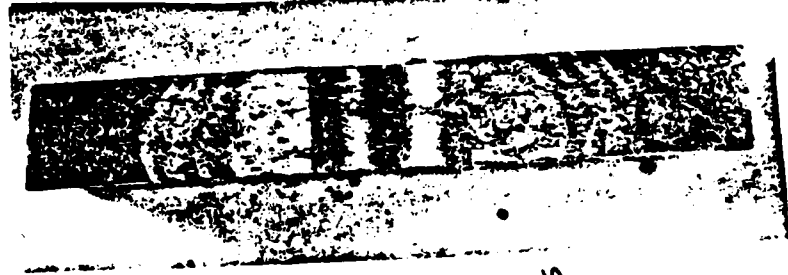
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
8	3235.2	.492
7	2800	.388
6	2400	.284
5	2000	.211
4	1600	.125
3	1200	.079
2	800	.034
1	400	.021
		.009

FATIGUE TEST DATA

SPECIMEN NUMBER: 54 (Open Hole)
 SPECTRUM: 400 hr (A)
 TEST DATE: 6-7-83 //
W 2.0135" TH, 3.015" HOLE DIAM .4455" A .6071 in²
 MAX STRESS 30 KSI FREQ 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. 3.5% NaCl PREPS. none
 CYCLES TO FAILURE 728068 1d pts % LIFE = 95

TTCI FLIGHT HOURS

Smaller Flow =
Larger Flow =



2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.	TASK
40	16000		4
39	15600		
38	15200		
37	14800		
36	14400		
35	14000		
34	13600		
33	13200		
32	12800		
31	12400		
30	12000		
29	11600		
28	11200		
27	10800		
26	10400		
25	10000		
24	9600		
23	9200		
22	8800		
21	8400		
20	8000		
19	7600		
18	7200		
17	6800		
16	6400		
15	6000		
14	5600		
13	5200		
12	4800		
11	4400		
10	4000		
9	3600		
8	3200		
7	2800		
6	2400		
5	2000		
4	1600		
3	1200		
2	800		
1	400		

FATIGUE TEST DATA

SPECIMEN NUMBER: 55 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 6-8-83 //
W 2.0145" TH. 3020" HOLE DIAM. 4504" A. 608412
 MAX STRESS 30 FREQ 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 639243 14 pts % LIFE = 83

TTCI 3067 FLIGHT HOURS

Smaller Flaw = .325"

Larger Flaw = .4352"



L

S

TTCI →

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
16.70	6678	F .4352
16	6400	.3332
15	6000	.1872
14	5600	.1162
13	5200	.0616
12	4800	.0410
11	4400	.0232
10	4000	.0144
9	3600	.0135
8	3200	.0108
7	2800	.0084
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 56 (Open Hole)
 SPECTRUM: 400 hr (A)
 TEST DATE: 6-6-83 //

W 2.0110" TH. 3005" HOLE DIAM. 4500" A. 6043 in²

MAX STRESS 30 KSI FREQ 1 LIFE = 2 days (Fast)

ENVIR. CONDS. 3.5% NaCl PREPS. None

CYCLES TO FAILURE 613235 k pts % LIFE = 80

TTCI FLIGHT HOURS

Smaller Flow =

Larger Flow =



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.	TASK 4
40	16000		
39	15600		
38	15200		
37	14800		
36	14400		
35	14000		
34	13600		
33	13200		
32	12800		
31	12400		
30	12000		
29	11600		
28	11200		
27	10800		
26	10400		
25	10000		
24	9600		
23	9200		
22	8800		
21	8400		
20	8000		
19	7600		
18	7200		
17	6800		
16	6400		
15	6000		
14	5600		
13	5200		
12	4800		
11	4400		
10	4000		
9	3600		
8	3200		
7	2800		
6	2400		
5	2000		
4	1600		
3	1200		
2	800		
1	400		

FATIGUE TEST DATA

SPECIMEN NUMBER: 57 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 5-6-83 //

W 2.0120 TH .3000 HOLE DIAM .4460 A .6036

MAX STRESS 34 KSI FREQ. 1 LIFE = 16 days (Slow)

ENVIR. CONDS. 3.5% NaCl PREPS. ---

CYCLES TO FAILURE 224834 kpts. % LIFE = 29.4

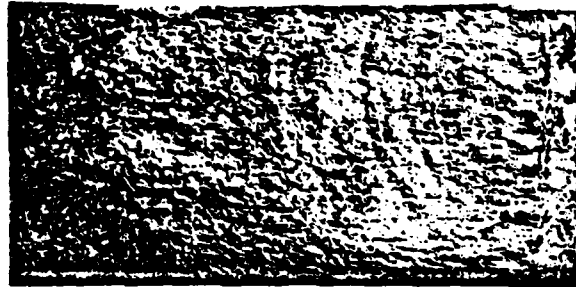
TTCI 133 FLIGHT HOURS

Smaller Flow = .334

Larger Flow = .446



2.8x



5x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
F 5.07	2342	.3345
5	2000	.1970
4	1600	.1300
3	1200	.0680
2	800	.0370
1	400	.0265

FATIGUE TEST DATA

SPECIMEN NUMBER: 58 (Open Hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 5-6-83 //
 W 2.0115" TH .3010" HOLE DIAM .4457" A 605512°
 MAX STRESS 34 Ksi FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 306908 14 pts % LIFE = 40.1

TTCI 1200 FLIGHT HOURS

Smaller Flaw = .300"
Larger Flaw = .515"



Larger Flaw



2.66x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
8016	3206.4	.515
8	3200	.395
7	2800	.182
6	2400	.067
5	2000	.043
4	1600	.024
3	1200	.010
2	800	
1	400	

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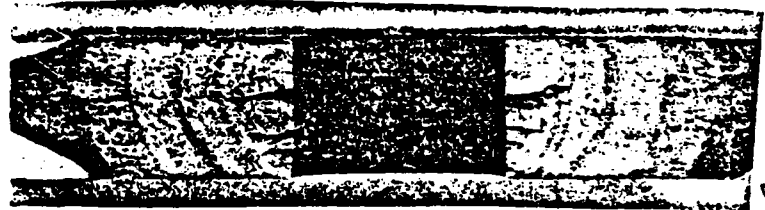
TTCI →

FATIGUE TEST DATASPECIMEN NUMBER: 59 (Open Hole)SPECTRUM: 400hr (A)TEST DATE: 5/16/83 //W 2.0110" TH. .3010" HOLE DIAM. .4475" A. 6053 10²MAX STRESS 32 KSI FREQ. 1 LIFE = 16 days (Slow)ENVIR. CONDS. 3.5% NaCl PREPS. —CYCLES TO FAILURE 501100 1d pts. % LIFE = 65TTCI 3289 FLIGHT HOURSSmaller Flow = .432"Larger Flow = .455"FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

F

Fci →

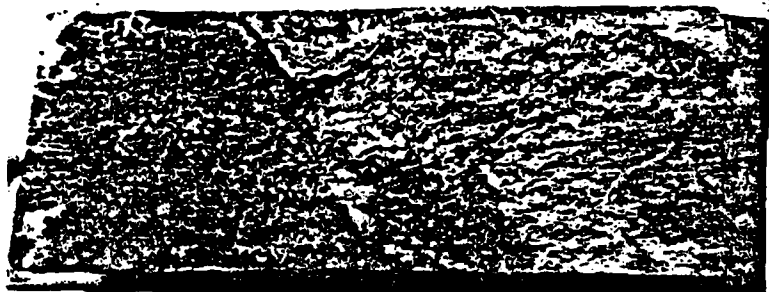


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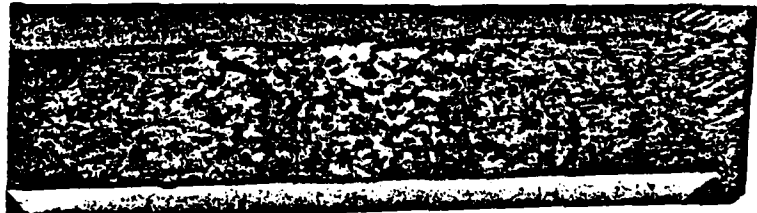
2.66X

FATIGUE TEST DATA

SPECIMEN NUMBER: 60 (Open)SPECTRUM: 400hr (A)TEST DATE: 5-11-83 //W 2.0120 TH. 3015 HOLE DIAM. .4465" A. 6066.12"MAX STRESS 32 KSI FREQ. 1 LIFE = 16 days (Slow)ENVIR. CONDS. 3.5% NaCl PREPS. —CYCLES TO FAILURE 607715 Hrs. % LIFE = 79.4TTCT 4037 FLIGHT HOURSSmaller Flow = 428"Larger Flow = .531"

Smaller Flow

5X



257K

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
F 1587	6348	.531
15	6000	.201
14	5600	.084
13	5200	.052
12	4800	.0315
11	4400	.020
10	4000	.009
9	3600	.0035
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 61 (Open)
 SPECTRUM: 400 hr. (A)
 TEST DATE: 5-11-83 //

W 2.0120" TH .3010" HOLE DIAM .4470" A .6056102

MAX STRESS 32 ksi FREQ. 1 LIFE = 8 days

ENVIR. CONDS. 3.5% NaCl PREPS. —

CYCLES TO FAILURE 462,824 Wpts % LIFE = 60.4

TTCI 2451 FLIGHT HOURS

Smaller Flow = 320"

Larger Flow = 527"

Larger Flow



5X

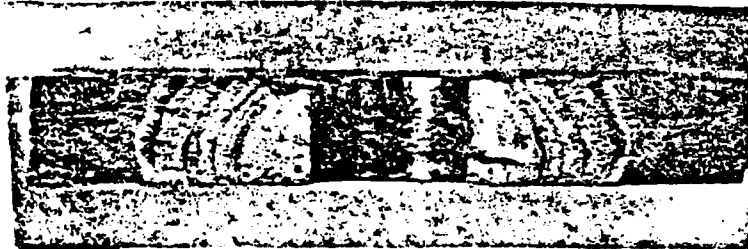
2.66X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15000	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

F

FLU

FATIGUE TEST DATASPECIMEN NUMBER: 64 (Load Transfer)SPECTRUM: 400 hr (A)TEST DATE: 6-21-83 //W 2.0080 TH .3045 HOLE DIAM .4392 A. 6114.02MAX STRESS 30 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. NoneCYCLES TO FAILURE 646914 Id pts % LIFE = 84TTCI FLIGHT HOURSSmaller Flow =Larger Flow =FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.	TASK	4
40	16000			
39	15600			
38	15200			
37	14800	NO FRACTOGRAPHIC		
36	14400	READINGS		
35	14000			
34	13600			
33	13200			
32	12800			
31	12400			
30	12000			
29	11600			
28	11200			
27	10800			
26	10400			
25	10000			
24	9600			
23	9200			
22	8800			
21	8400			
20	8000			
19	7600			
18	7200			
17	6759			
16	6400			
15	6000			
14	5600			
13	5200			
12	4800			
11	4400			
10	4000			
9	3600			
8	3200			
7	2800			
6	2400			
5	2000			
4	1600			
3	1200			
2	800			
1	400			

2X

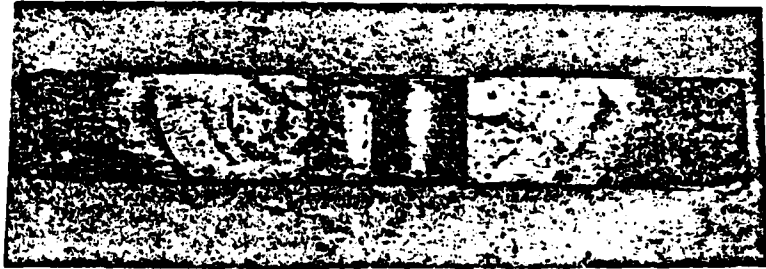
FATIGUE TEST DATA

SPECIMEN NUMBER: 65 (20% LOAD TRANSFER)
 SPECTRUM: ACCF(A)
 TEST DATE: 6-29-83 // 11
W 2.0090" TH .3090" HOLE DIAM. 4408' A .6107m²
 MAX STRESS 30 KSI FREQ 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. none
 CYCLES TO FAILURE 56916 14 pts % LIFE = 74

TTCI FLIGHT HOURS

Smaller Flow =

Larger Flow =



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.	TASK	4	FRACTOGRAPHY NOT	READ
40	16000					
39	15600					
38	15200					
37	14800					
36	14400					
35	14000					
34	13600					
33	13200					
32	12800					
31	12400					
30	12000					
29	11600					
28	11200					
27	10800					
26	10400					
25	10000					
24	9600					
23	9200					
22	8800					
21	8400					
20	8000					
19	7600					
18	7200					
17	6800					
16	6400					
15	5946					
14	5600					
13	5200					
12	4800					
11	4400					
10	4000					
9	3600					
8	3200					
7	2800					
6	2400					
5	2000					
4	1600					
3	1200					
2	800					
1	400					

FATIGUE TEST DATASPECIMEN NUMBER: 111 (Bolt-In)SPECTRUM: F16-400hr(A)TEST DATE: 10-14-83 //W 2.002" TH .301" HOLE DIAM .4395" A .6026 in²MAX STRESS 28 ksi FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. pre-cond.CYCLES TO FAILURE 6891723 1d pts % LIFE*

TTCI

FLIGHT HOURS

2x

* Static Failure after 9 lives ($P_{max} = 30,600$ lbs)
Tight fitting bolt.

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	TASK 4
38	15200	
37	14800	
36	14400	
35	14000	NO FRACTOGRAPHIC
34	13600	READINGS
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 121 (Bolt-In) *

SPECTRUM: F16-400hr

TEST DATE: 10-06-83 //

W 2.002" TH .303" HOLE DIAM. .4415" A .6066in²

MAX STRESS 28 ksi FREQ 1 LIFE = 2 days (Fast)

ENVIR. CONDS. 3.5% NaCl PREPS. NO

CYCLES TO FAILURE 3140699 kpts % LIFE = 489

TTCI FLIGHT HOURS

Smaller Flaw = .434"
Larger Flaw = .648"



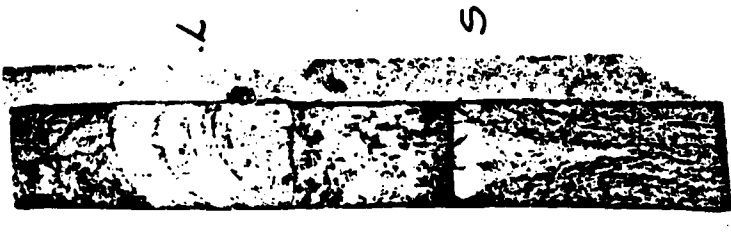
* Surface Flaw

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.	NO FRACTOGRAPHIC READINGS
40	16000		
39	15600		
38	15200		
37	14800		
36	14400		
35	14000		
34	13600		
33	13200		
32	12800		
31	12400		
30	12000		
29	11600		
28	11200		
27	10800		
26	10400		
25	10000		
24	9600		
23	9200		
22	8800		
21	8400		
20	8000		
19	7600		
18	7200		
17	6800		
16	6400		
15	6000		
14	5600		
13	5200		
12	4800		
11	4400		
10	4000		
9	3600		
8	3200		
7	2800		
6	2400		
5	2000		
4	1600		
3	1200		
2	800		
1	400		

FATIGUE TEST DATA

SPECIMEN NUMBER: 129 Bolt
 SPECTRUM: 400hr F-16
 TEST DATE: 12-13-83 //
W 2.0065" TH 3025' HOLE DIAM 4415" A 6069 IN²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl/PREPS. PC F₂₈ = 40
 CYCLES TO FAILURE 1135746 Idpts % LIFE = 1483
 TTCI 69/6 FLIGHT HOURS



Larger Flow = .519" (B)
 Smaller Flow = .086" (B)

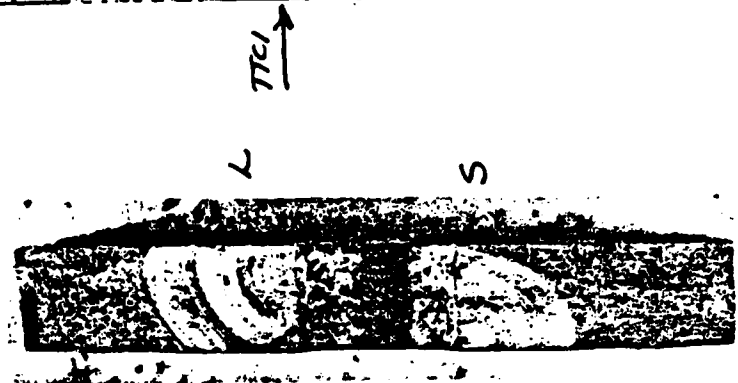
77C1 →

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
29	11600	.519
28	11200	.379
27	10800	.295
26	10400	.213
25	10000	.156
24	9600	.124
23	9200	.091
22	8800	.079
21	8400	.062
20	8000	.051
19	7600	.034
18	7200	.0185
17	6800	.0140
16	6400	.0080
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 143 (Bolt-In)SPECTRUM: Flg-400 hr (A)*TEST DATE: 12-14-83 //W 2.009" TH. 3.030" HOLE DIAM. .4420" A. .6067 in²MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days / Fast Fr-250ENVIR. CONDS. 3.5% NaCl PREPS. P.C.CYCLES TO FAILURE 110948 id pts % LIFE = 145TTCI 6750 FLIGHT HOURS

FRACTOGRAPHIC DATA		
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	<u>.4240</u>
28	11200	<u>—</u>
27	10800	<u>.2245</u>
26	10400	<u>.1645</u>
25	10000	<u>.1380</u>
24	9600	<u>.1065</u>
23	9200	<u>.0765</u>
22	8800	<u>.0640</u>
21	8400	<u>.0520</u>
20	8000	<u>.0420</u>
19	7600	<u>.0340</u>
18	7200	<u>.0210</u>
17	6800	<u>.0105</u>
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

Larger Flow = .424"Smaller Flow = .325"

* unexpected 82% load seen at 596193 id pts. 2x

FATIGUE TEST DATA

SPECIMEN NUMBER: 144 (Belt-In)

SPECTRUM: F16-400hr(A)

TEST DATE: 1-09-84 //

W 2.0095" TH .3030" HOLE DIAM .4440" A. 6088 in²

MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow) FA=40

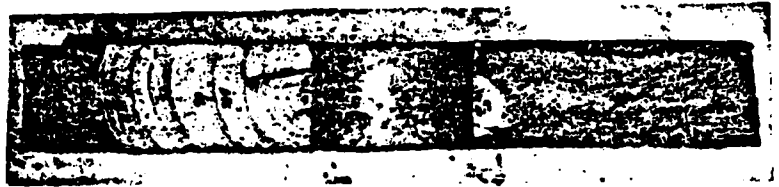
ENVIR. CONDS. 3.5% NaCl PREPS. P.C.

CYCLES TO FAILURE 1608695 lpts % LIFE = 2.10 TTCI

TTCI 10,500 FLIGHT HOURS

Larger Flow = .583 (B)

Smaller Flow = .075 (B)



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.301
39	15600	.205
38	15200	.138
37	14800	.093
36	14400	.066
35	14000	.053
34	13600	.042
33	13200	.036
32	12800	.029
31	12400	.025
30	12000	.021
29	11600	.018
28	11200	.015
27	10800	.013
26	10400	.009
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
F 42	16800	.583
41	16400	.435

APPENDIX E

SPECTRUM FATIGUE TEST RESULTS AND FRACTOGRAPHIC DATA FOR TASK 5 (7075-T7651 ALUMINUM ALLOY)

Spectrum fatigue test results for the dog-bone specimens (Fig. 3) tested under Task 5 are summarized in Table E1. Fractographic data sheets are also presented in this appendix.

The maximum positive load in each load spectra, including overloads, was considered to be the 100% load level. The maximum positive test load for each spectra was selected to produce the desired gross stress on the specimen cross section. All other loads positive and negative in each respective test spectra were "scaled" to the 100% load level. As a result, "overloads" in the F-18 300 hour spectrum were treated as 100% load levels rather than a percentage greater than the 100% load level.

Fatigue loading frequencies for all spectrum tests, including the F-18 300 hour spectrum, were based on the test rates set for the F-16 400 hour spectrum tests. Loading rates were selected to complete 8000 equivalent flight hours of the F-16 400 hour spectrum in a selected number of days (24 hours a day continuous testing). Three basic loading frequencies were considered: (1) F = fast (8000 flight hours/2 days), (2) S = slow (8000 flight hours/16 days) and (3) Δ = extra slow (8000 flight hours/90 days). Accordingly, test machine frequency multipliers (FM) were set for the three basic frequencies: Fast (FM = 250), slow (FM = 40) and extra slow (FM = 1). The frequency multipliers can only be translated into actual frequency measurements for constant amplitude loading.

Table E1 Summary of Dog-Bone Specimen Spectrum Fatigue Test Results
for Task 5 (7075-T7651 Aluminum)

SPECIMEN NO.	TEST I.D. (a)	DATA SET NO.	TEST DATE	SPECIMEN DETAILS				FATIGUE CRACK ORIGIN (b)	TTCI (FLT. HRS.) (c)	TTP (FLT. HRS.) (d)	TTP-TTCI (FLT. HRS.) (e)	TTCI/TTP
				WIDTH (IN.)	THICK (IN.)	HOLE DIA (IN.)	GROSS AREA (IN ²)					
45	A-28/F/D	1	5-31-83	2.0170	.3010	.4412	.6071	B	14000	22000	8000	.64
46	A-28/F/D	1	6-5-83	2.0100	.3005	.4434	.6040	B	6600	16035	9435	.41
62	A-28/F/W	3	6-22-83	2.0110	.3025	.4380	.6083	B	5872	12035	6163	.49
67	A-28/S/W	4	7-1-83	2.012	.3050	.4427	.6137	C	7531(f)	14835	7304	.51
71	A-28/S/W	4	7-13-83	2.005	.3040	.4455	.6095	C	1600	7606	6006	.21
72	A-28/S/D	2	7-21-83	1.9980	.2915	.4440	.5824	B	8471	16435	7964	.52
76	A-28/F/W	3	7-5-83	1.9990	.3045	.4395	.6087	B	8000	13999	5999	.57
77	A-28/F/W	3	8-1-83	2.0105	.3030	.4395	.6092	B	16400	21949	5549	.75
79	A-28/F/D	1	8-11-83	2.0065	.3045	.4435	.6110	B	10600	17558	6958	.60
81	A-28/S/W	4	8-17-83	2.0095	.3025	.4395	.6079	B	3434	6749	3315	.51
82	A-28/F/W	3	8-18-83	2.0120	.3020	.4395	.6076	C	6700	12035	5335	.56
83	A-28/S/D	2	8-22-83	2.0030	.3030	.4395	.6069	B	25200	33677	8477	.75
84	A-28/F/W	5	9-12-83	2.002	.3020	.4440	.6046	B	8063(f)	10228	2165	.79
85	A-28/F/W	5	9-20-83	2.0025	.2880	.4430	.5767	B	8160(f)	10430	2270	.78
86	A-28/F/W	5	9-20-83	2.0085	.3010	.4443	.6045	B	8178(f)	12406	4228	.66
87	A-28/S/D	2	10-6-83	2.0005	.3025	.4410	.6052	B	16800	24835	8035	.68
88	A-28/S/W	4	11-8-83	2.000	.3010	.440	.6020	B	12554(f)	15074	2520	.83
89	A-28/F/D	1	11-3-83	2.006	.3045	---	.6108	B	21600	32806	11206	.66
90	A-28/S/W	4	11-3-83	2.013	.3040	---	.6119	C	15226(f)	21635	6409	.70
91	A-28/S/W	4	11-3-83	2.006	.303	---	.6078	B	9400	18276	8876	.51
92	A-28/S/D	2	12-5-83	2.009	.301	.4435	.6047	B	13249(f)	24279	11030	.54
101	A-28/20/F/W/PC	37	8-23-83	2.0065	.2990	.4380	.5999	B	3775	6007	2232	.63
102	A-28/F/W/PC	8	8-16-83	2.0065	.3010	.4370	.6039	C	1622	4835	3213	.34
103	A-28/F/D/PC	6	8-17-83	2.0090	.3025	.4395	.6077	C	10800	27235	16435	.40
104(h)	A-28/20/F/W/PC	37	8-24-83	2.0045	.2990	.4380	.5993	B	2812	5550	2738	.51
105	A-28/F/D/PC	6	8-24-83	2.0125	.3040	.4395	.6118	B	6651	20007	13356	.33
106	A-28/F/D/PC	6	8-24-83	2.0025	.3030	.4395	.6067	B	2800	10806	8006	.26
107	A-28/F/W/PC	8	8-25-83	2.0045	.3035	.4395	.6083	B	1600	6806	5206	.24
108	A-28/F/W/PC	8	8-26-83	2.0045	.3030	.4395	.6074	B	1097	4192	3095	.26

Table E1 Summary of Dog-Bone Specimen Spectrum Fatigue Test Results
for Task 5 (7075-T7651 Aluminum) (Continued)

SPECIMEN NO.	TEST I.D. (a)	DATA SET NO.	TEST DATE	SPECIMEN DETAILS				FATIGUE CRACK ORIGIN (b)	TTCI (FLT. HRS.) (c)	TTF (FLT. HRS.) (d)	TTF-TTCI (FLT. HRS.) (e)	TTCI/TTF
				WIDTH (IN.)	THICK (IN.)	HOLE DIA (IN.)	GROSS AREA (IN ²)					
109	A-28/S/D/PC	7	8-26-83	2.0055	.3030	.4395	.6076	C	28000	43596	15596	.64
110	A-28/S/D/PC	7	8-30-83	2.012	.3045	.4395	.6126	B	18400	31325	12925	.59
112	A-28/F/W/B/PC	14	10-28-83	2.003	.303	.4415	.6069	B	3120	9635	6515	.32
113	A-28/S/M/PC	9	9-2-83	2.002	.3045	.4400	.6096	B	875	2806	1931	.31
114	A-28/F/W/B/PC	14	10-31-83	2.004	.3015	.4390	.6042	B	2323(f)	10000	7677	.23
115	A-28/S/M/PC	9	9-12-83	2.0110	.3035	.4395	.6103	B	4440	7245	2805	.61
116	A-28/S/M/PC	9	10-31-83	2.0095	.3015	.4395	.6059	C	4549	10835	6286	.42
117	A-28/S/D/PC	7	12-9-83	2.0090	.3010	----	.6047	B	23600	32000	8400	.74
122	A-28/F/W/B	11	10-18-83	1.9983	.304	.4415	.6075	B	3200	16006	12806	.20
123	A-28/F/W/B	11	10-21-83	2.0090	.3040	.4410	.6107	B	13868	18902	5034	.73
124	A-28/F/W/B	11	10-25-83	2.0080	.3015	.4435	.6054	B	11600	16806	5206	.69
125	A-28/F/W/B	11	10-28-83	2.0030	.303	.4405	.6069	C	5777	10358	4581	.56
126	A-28/F/D/B	10	11-28-83	2.009	.304	.4435	.6099	B	23600	36035	12435	.65
127	A-28/F/D/B	10	11-18-83	2.00	.3005	.4415	.6010	B	14800	24748	9948	.60
128	A-28/F/D/B	10	11-29-83	2.0030	.3045	.4430	.6099	B	35600	42835	7235	.83
131	A-28/S/M/B	12	12-14-83	2.0035	.3045	.4420	.6100	C	8359(f)	14007	5648	.59
132	A-28/S/M/B	12	12-16-83	2.003	.3035	.4485	.6079	C	9300(g)	20435	11135	.46
140	A-28/F/D/B/PC	13	12-1-83	2.002	.3035	----	.6076	B	3857(g)	17440	13583	.22
141	A-28/F/D/B/PC	13	12-5-83	2.0115	.3010	.4415	.6055	B	9200	22000	12800	.42
142	A-28/F/D/B/PC	13	12-7-83	2.0035	.3010	.4415	.6031	B	12400	24400	12000	.51
300	B-28/F/W	23	2-1-84	2.0240	.3030	.4460	.6133	B	13002(f)	16646	3644	.78
301	B-28/F/W	23	2-1-84	2.0030	.3038	.4470	.6085	B	9077	12152	3075	.75
302	B-28/F/W	23	2-2-84	2.001	.3030	.4450	.6063	B	8267	11737	3470	.70
303	B-28/F/W	23	2-2-84	2.003	.302	.4415	.6049	B	17323(f)	21452	4129	.81
304	B-28/F/W/PC	27	2-1-84	2.0	.3025	.4400	.6050	B	7310(f)	10716	3406	.68
305	B-28/F/W/PC	27	2-1-84	2.0045	.3010	.4405	.6034	B	5548(f)	8163	2615	.68
306	B-28/F/W/PC	27	2-2-84	2.003	.3045	.4410	.6099	B	3141(f)	5916	2775	.53
307	B-28/F/W/PC	27	2-2-84	2.002	.302	.4415	.6046	B	6161(f)	9558	3197	.64
312	B-28/F/D/PC	25	2-2-84	2.0040	.2900	.4415	.5841	B	9650	15893	6043	.61
313	B-28/F/D/PC	25	2-3-84	2.0030	.3070	.4455	.6149	B	7176(f)	14916	7740	.48
314	B-28/F/D/PC	25	2-3-84	2.0065	.3030	.4435	.6079	B	4733	11493	6760	.41
315	B-28/F/D	21	2-6-84	2.0015	.2960	.4435	.5924	B	15752(f)	20853	5101	.76
316	B-28/F/D	21	2-6-84	2.0035	.3010	.4405	.6031	B	22608(f)	26595	3987	.85
317	B-28/F/D	21	2-6-84	2.0015	.2990	.4435	.5985	B	10824(f)	25053	14229	.43
318	B-28/S/W	24	2-6-84	2.0010	.3020	.4415	.6043	B	12038	14676	2638	.82
319	B-28/S/W	24	2-7-84	2.0010	.3050	.4435	.6103	B	6517	10707	4190	.61
320	B-28/S/W	24	2-7-84	1.9985	.3020	.4425	.6035	B	8447	11916	3469	.71
321	B-28/S/W	24	2-7-84	1.9995	.2980	.4435	.5959	B	7140	9975	2835	.72
322	B-28/S/W/PC	28	2-3-84	2.0045	.3030	.4405	.6074	B	6076	8358	2282	.73
323B	B-28/S/W/PC	28	2-24-84	2.0000	.3020	.4415	.6040	B	6097(f)	9453	3356	.64
324	B-28/S/W/PC	28	2-20-84	2.0000	.3035	.4425	.6070	B	21772	24969	3197	.87

Table E1 Summary of Dog-Bone Specimen Spectrum Fatigue Test Results
for Task 5 (7075-T7651 Aluminum) (Continued)

SPECIMEN NO.	TEST I.D. (a)	DATA SET NO.	TEST DATE	SPECIMEN DETAILS				FATIGUE CRACK ORIGIN (b)	TTCI (FLT. HRS.) (c)	TTF (FLT. HRS.) (d)	TTF-TTCI (FLT. HRS.) (e)	TTCI/TTF
				WIDTH (IN.)	THICK (IN.)	HOLE DIA (IN.)	GROSS AREA (IN ²)					
325	B-28/S/W/PC	28	2-14-84	2.0010	.3015	.4425	.6033	B	5368(f)	7863	2495	.68
326	B-28/S/D	22	2-13-84	2.0010	.3010	.4425	.6023	B	20143	22716	2573	.89
327	B-28/S/D	22	2-13-84	2.0015	.3010	.4415	.6025	B	21824	24516	2692	.89
328	B-28/S/D	22	2-13-84	2.0000	.3025	.4415	.6050	B	19800	22446	2646	.88
329	B-28/S/D/PC	26	2-21-84	2.0005	.3015	.4465	.6032	B	12797(f)	16116	3319	.79
330	B-28/S/D/PC	26	2-17-84	1.9990	.2950	.4470	.5897	B	15650	18753	3103	.83
331	B-28/S/D/PC	26	2-14-84	1.9990	.2990	.4430	.5977	B	12175(f)	15693	3518	.78
336	A-28/S/W/PC	9	3-1-84	2.0040	.3010	.4415	.6032	B	851	3200	2349	.27
337	A-28/S/W/PC	9	3-9-84	2.001	.3005	.4415	.6013	B	4456	5792	1336	.77
338	A-28/20/S/W/PC	38	3-15-84	1.9990	.2950	.4425	.5897	B	2000	3959	1959	.51
515	C-28/F/D	33	5-10-84	1.9955	.3050	.5030	.6086	B	27709	50100	22391	.55
516	C-28/F/D	33	5-16-84	2.0050	.2955	.5065	.5924	B	10789	31596	20807	.34
517	C-28/F/D	33	5-16-84	1.9935	.2970	.5050	.5920	B	40500(g)	64916	24416	.62
518	C-28/F/W	34	5-17-84	1.9955	.2960	.5030	.5906	C	15300	20400	5100	.75
519	C-28/F/W	34	5-18-84	2.0020	.2945	.5030	.5895	C	4500	19500	15000	.23
520	C-28/F/W	34	5-18-84	2.0045	.3010	.5050	.6033	B	11100	19200	8100	.58

Notes: (a) Ref. Table 8 for description code.

(b) Fatigue crack origins: B = bore of hole, C = corner of hole and S = surface crack away from hole.

(c) Time to initiate crack depth of 0.010" in fastener hole (determined from fractographic results).

(d) Time-to-Failure (TTF)

(e) Time spent in crack growth.

(f) Extrapolation based on power law (Eqs. 1 & 3)

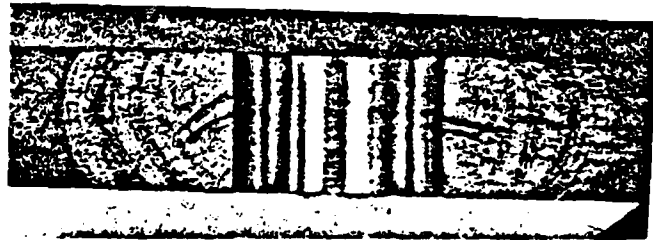
(g) Linear extrapolation.

(h) Testing anomaly

(i) Diameter measurement not recorded.

FATIGUE TEST DATA

SPECIMEN NUMBER: 45 (Open)
 SPECTRUM: 400 Hz (A)
 TEST DATE: 5-31-83 //
W 2.0170" TH .3010" HOLE DIAM .4412" A .607 (in²)
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. —
 CYCLES TO FAILURE 2106423 dpts % LIFE = 275
 TTCT 14000 FLIGHT HOURS

Larger Flaw = .351" BSmaller Flaw = .349" B

2.5x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
20	32000	
19	31600	
18	31200	
17	30800	
16	30400	
15	30000	
14	29600	
13	29200	
12	28800	
11	28400	
10	28000	
09	27600	
08	27200	
07	26800	
06	26400	
05	26000	
04	25600	
03	25200	
02	24800	
01	24400	
00	24000	
59	23600	
58	23200	
57	22800	
56	22400	
55+	22006	.3510
54	21600	.1970
53	21200	.1505
52	20800	.1245
51	20400	.0990
50	20000	.0815
49	19600	.0635
48	19200	.0530
47	18800	.0445
46	18400	.0410
45	18000	.0355
44	17600	.0305
43	17200	.0265
42	16800	.0235
41	16400	.0205

FATIGUE TEST DATASPECIMEN NUMBER: 45 (Open hole)SPECTRUM: 400hr (A)TEST DATE: 5-31-83 //W 2.0170" TH .3010" HOLE DIAM. .4412" A .6071in² netMAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. Dry PREPS. noneCYCLES TO FAILURE 2106423 1d pts % LIFE = 275TTCI 14,000 FLIGHT HOURSFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0185
39	15600	.0160
38	15200	.0145
37	14800	.0125
36	14400	.0110
35	14000	.0100
34	13600	.0090
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 46 (open hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 6-5-83 //
 W 2.0100" TH. 3.005" HOLE DIAM. .4434" A. .6040 in.²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. none
 CYCLES TO FAILURE 1534866 kpts % LIFE = 2.00
 TTCI 6600 FLIGHT HOURS

Larger Flow - .427" Ø
 Smaller Flow - .180" Ø



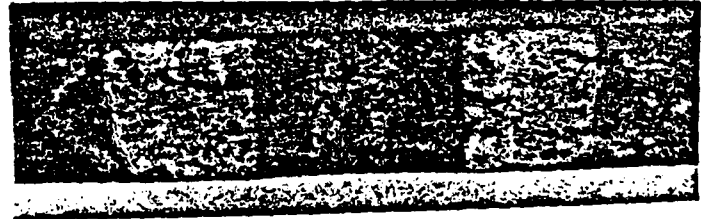
2.5x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16035	.4270
39	15600	.3045
38	15200	.2450
37	14800	.2125
36	14400	.1790
35	14000	.1465
34	13600	.1170
33	13200	.0985
32	12800	.0825
31	12400	.0690
30	12000	.0580
29	11600	.0510
28	11200	.0455
27	10800	.0405
26	10400	.0360
25	10000	.0325
24	9600	.0285
23	9200	.0250
22	8800	.0225
21	8400	.0195
20	8000	.0180
19	7600	.0155
18	7200	.0130
17	6800	.0110
16	6400	.0090
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 62 (open hole)SPECTRUM: 400 hr (A)TEST DATE: 6-22-83 //W 2.0110" TH. 3025 HOLE DIAM. .4380" A. 6083 in²MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDE. 35% NaCl PREPS. noneCYCLES TO FAILURE 1151992 4 pts % LIFE = 150TTCI 5872 FLIGHT HOURSFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	.3515
29	11600	.2150
28	11200	.1470
27	10800	.1130
26	10400	.0890
25	10000	.0805
24	9600	.0730
23	9200	.0640
22	8800	.0565
21	8400	.0515
20	8000	.0410
19	7600	.0310
18	7200	.0250
17	6800	.0205
16	6400	.0145
15	6000	.0110
14	5600	.0080
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

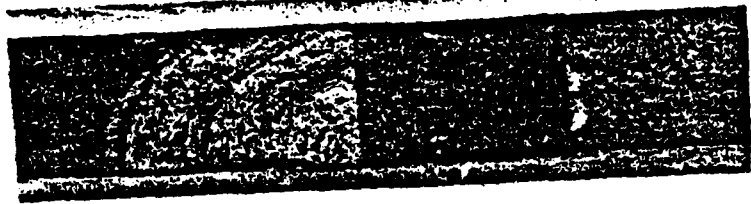


Larger Flaw = .3515"

Smaller Flaw = .282" L

S

2.48X

FATIGUE TEST DATASPECIMEN NUMBER: 67 (open hole)SPECTRUM: 400 hr (A)TEST DATE: 7-1-83 //W 2.0120 TH .5050 HOLE DIAM .4427 A .6137 in^2 MAX STRESS 28 KSI FREQ 1 LIFE = 16 days (Slow)
FM:40ENVIR. CONDS. 3.5% NaCl PREPS. noneCYCLES TO FAILURE 1419995 14 pts. % LIFE = 185TTCI 7531 FLIGHT HOURSLarger Flaw = .5320" CSmaller Flaw = .04" B

2.54X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	.5320
36	14400	.3560
35	14000	.2495
34	13600	.1930
33	13200	.1540
32	12800	.1190
31	12400	.0920
30	12000	.0700
29	11600	.0540
28	11200	.0460
27	10800	.0375
26	10400	.0310
25	10000	.0250
24	9600	.0200
23	9200	.0175
22	8800	.0160
21	8400	.0135*
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

* last readable block marker before flow
if unintentional Original flow at .0115

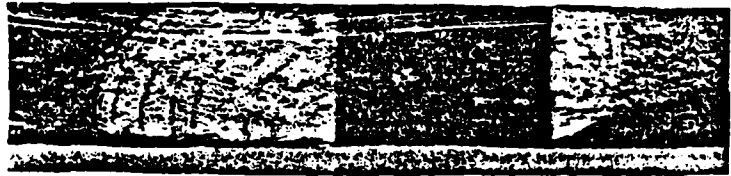
FATIGUE TEST DATA

SPECIMEN NUMBER: 71 (open hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 7-13-83 //
W 2.005" TH. 3040" HOLE DIAM .4455 A .6095 in²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. none
 CYCLES TO FAILURE 728068 14 pts. % LIFE = 95

TTCI 1600 FLIGHT HOURS

Smaller Flow = .158" 0

Larger Flow = .4915" 0



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	.4915
18	7200	.3300
17	6800	.2025
16	6400	.1350
15	6000	.0990
14	5600	.0775
13	5200	.0590
12	4800	.0485
11	4400	.0425
10	4000	.0345
9	3600	.0290
8	3200	.0250
7	2800	.0215
6	2400	.0170
5	2000	.0130
4	1600	.010
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 72 (OPED)SPECTRUM: 400 hr (A)TEST DATE: 7-21-83 //W 1.9980" TH. .2915" HOLE DIAM. .4440" A. 5824₁₀¹²MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (slow)ENVIR. CONDS. Dry PREPS. —CYCLES TO FAILURE 1573153 h.pts % LIFE = 205TTCI 8471 FLIGHT HOURSFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.3670
39	15600	.3200
38	15200	.2660
37	14800	.2175
36	14400	.1605
35	14000	.1265
34	13600	.0985
33	13200	.0810
32	12800	.0620
31	12400	.0510
30	12000	.0435
29	11600	.0375
28	11200	.0330
27	10800	.0270
26	10400	.0230
25	10000	.0200
24	9600	.0170
23	9200	.0140
22	8800	.0120
21	8400	.0095
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
F	41.08 16,400	.4520

Larger Flow = .4520"Smaller Flow = .150"

2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 76 (open hole)
 SPECTRUM: 400hr (A)
 TEST DATE: 7-5-83 //
 W 1.9990" TH .3045 HOLE DIAM .4395" A .6087 in²
 MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. 3.5% NaCl PREPS. None
 CYCLES TO FAILURE 1340057 d pts % LIFE = 175
 TTCI 8000 FLIGHT HOURS

Larger Flaw = .5825" B
Smaller Flaw = .075" C, B



2.53X

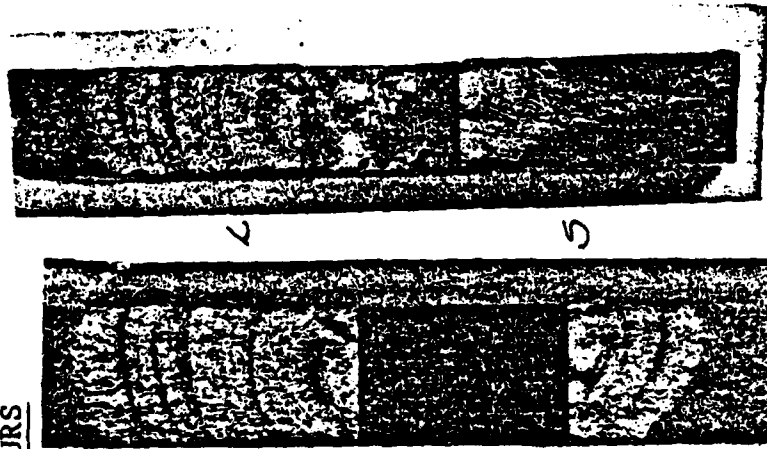
FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
F35	14000	.5825
34	13600	.4320
33	13200	.3065
32	12800	.2130
31	12400	.1535
30	12000	.0970
29	11600	.0620
28	11200	.0445
27	10800	.0325
26	10400	.0275
25	10000	.0225
24	9600	.0185
23	9200	.0150
22	8800	.0135
21	8400	.0115
20	8000	.0100
19	7600	.0085
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 77 (OPED)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-1-83 //
W 2.0105' TH .3030" HOLE DIAM .4395" A .6092 in²
 MAX STRESS 28 KSL FREQ: 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 2100916 d pts % LIFE = 274
 TTCL 16,400 FLIGHT HOURS

Larger Flaw = .6030" B
Smaller Flaw = .300" B



2.7X

2X

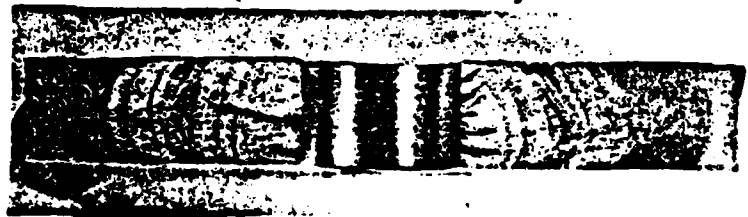
FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
—	—	—
54.87	21948	.6030
53	21200	.2880
52	20800	.1465
51	20400	.0910
50	20000	.0665
49	19600	.0595
48	19200	.0360
47	18800	.0300
46	18400	.0245
45	18000	.0205
44	17600	.0180
43	17200	.0145
42	16800	.0120
41	16400	.0100

FATIGUE TEST DATASPECIMEN NUMBER: 79 (Open)SPECTRUM: 400hr (A)TEST DATE: 8-11-83 //W 2.0065" TH .3045" HOLE DIAM. .4435" A .6110 IN²MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. Dry PREPS. CYCLES TO FAILURE 1680664 k pts % LIFE = 219TTCI 10,600 FLIGHT HOURS

Larger Flow - .5410" B

Smaller Flow - .450" B

FRACTOGRAPHIC DATA

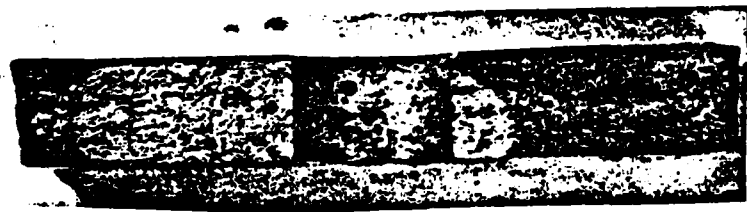
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.1470
39	15600	.1200
38	15200	.0925
37	14800	.0795
36	14400	.0640
35	14000	.0500
34	13600	.0375
33	13200	.0310
32	12800	.0265
31	12400	.0225
30	12000	.0195
29	11600	.0165
28	11200	.0130
27	10800	.0110
26	10400	.0090
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
43.9	17,560	.5410
43	17200	.3575
42	16800	.2420
41	16400	.1890

2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 81 (Open)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-17-83 //
W 2.0095" TH 3.025" HOLE DIAM .4395" A .6079 ID
 MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 646077 Id pts % LIFE = 84
 TTCI 3434 FLIGHT HOURS

Larger Flaw = .6145" B
Smaller Flaw = .175" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
16, 8, 14	6750	.6145
16	6400	.2785
15	6000	.1445
14	5600	.0820
13	5200	.0500
12	4800	.0330
11	4400	.0230
10	4000	.0165
9	3600	.0120
8	3200	.0070
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 82 (Open)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-18-83 //

W 2.01201 TH .30201 HOLE DIAM .4395" A .6076102

MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)

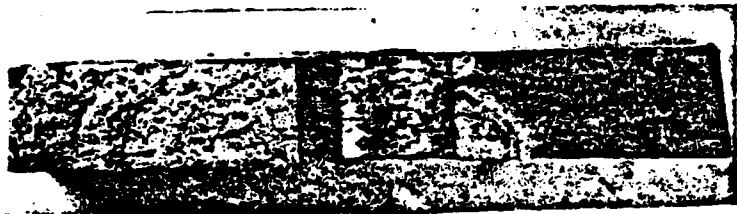
ENVIR. CONDS. 3.5% NaCl PREPS. ---

CYCLES TO FAILURE 1151991 14pts % LIFE = 150

TTCI 6700 FLIGHT HOURS

Larger Flaw = .6245" C

Smaller Flaw = .210" C



S

2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	.6245
29	11600	.3230
28	11200	.2405
27	10800	.1705
26	10400	.1170
25	10000	.0870
24	9600	.0640
23	9200	.0480
22	8800	.0365
21	8400	.0285
20	8000	.0220
19	7600	.0160
18	7200	.0125
17	6800	.0105
16	6400	.0085
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 83 (Open Hole)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-22-83 11
W 2.0030" TH .3030" HOLE DIAM .4395" A .6069" IN
 MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days = Slow
 ENVIR. CONDS. Dry PREPS. none
 CYCLES TO FAILURE 3223534 1d pts % LIFE = 421
 TTCI 25,200 FLIGHT HOURS



Larger Flaw = .4030" B

Smaller Flaw = .350" B L

S

2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	.115
79	31600	.0945
78	31200	.0645
77	30800	.0490
76	30400	.0440
75	30000	.0350
74	29600	.0290
73	29200	.0250
72	28800	.0220
71	28400	.0200
70	28000	.0185
69	27600	.0170
68	27200	.0150
67	26800	.0135
66	26400	.0125
65	26000	.0115
64	25600	.0110
63	25200	.0100
62	24800	
61	24400	
60	24000	
59	23600	
58	23200	
57	22800	
56	22400	
55	22000	
54	21600	
53	21200	
52	20800	
51	20400	
50	20000	
49	19600	
48	19200	
47	18800	
46	18400	
84.194	33,677.6	.4030
83	33,200	.2295
82	32,800	.1830
81	32,400	.1440

F

FATIGUE TEST DATA

SPECIMEN NUMBER: 84 (open hole)
 SPECTRUM: F16-400hr (A)
 TEST DATE: 9-12-83 //
W 2.002" TH .3020" HOLE DIAM .4440" A .6046 in²
 MAX STRESS 28 KSI FREQ 1 LIFE = 3 months
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 979042 Idpts % LIFE = 128

TTCI 8063 FLIGHT HOURS

Larger Flaw = .5490" B
Smaller Flaw = .225" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
25.57	10240	.5490
25	10000	—
24	9600	.1305
23	9200	T.0720
22	8800	T.0410
21	8400	T.0180
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 8.5 (open hole)
 SPECTRUM: F16-400hr (A)
 TEST DATE: 9-20-83 //

W 2.0025" TH. 2880" HOLE DIAM. .4430" A .5767 in²

MAX STRESS 28 ksi FREQ. 1 LIFE = 3 months

ENVIR. CONDS. 3.5% NaCl PREPS. —

CYCLES TO FAILURE 998361 14 pts % LIFE = 130

TTCI 8160 FLIGHT HOURS

Larger Flow - .4335" B

Smaller Flow - .325" B



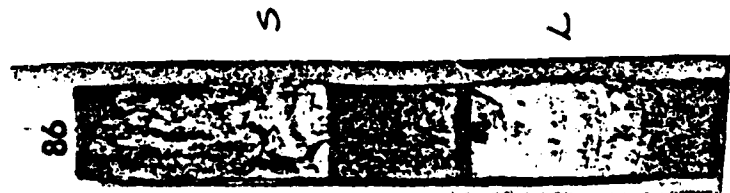
2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	.4335
25	10000	.2045
24	9600	.1125
23	9200	T .0615
22	8800	T .0315
21	8400	T .0155
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: B6 (open hole)SPECTRUM: Fl6-400hr(A)TEST DATE: 9-20-83 //W 2.0085" TH .3010" HOLE DIAM. .4443" A. .6045in²MAX STRESS 28 KSI FREQ 1 LIFE = 3 months FENVIR. CONDS. 3.5% NaCl PREPS. —CYCLES TO FAILURE 1187528 lpts % LIFE = 155TTCI 8178 FLIGHT HOURSSmaller Flaw = .175" BLarger Flaw = .5535" BFRAC TOGRAPHIC DATA

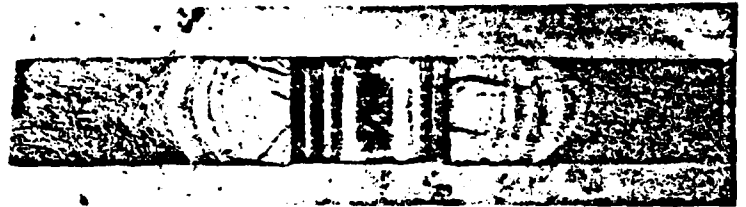
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	.5535
30	12000	.3645
29	11600	.2700
28	11200	.1890
27	10800	.1320
26	10400	T .0930
25	10000	—
24	9600	.0520
23	9200	.0280
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	



FATIGUE TEST DATA

SPECIMEN NUMBER: 87 (open hole)
 SPECTRUM: FL6-400Hz (A)
 TEST DATE: 10-06-83 //
W 2.0005 TH .3025 HOLE DIAM .4410" A .6052 in²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days slow
 (FH:40) PREPS. —
 ENVIR. CONDS. Dry
 CYCLES TO FAILURE 2377183 Hrs. % LIFE = 310
 TTCL 16,800 FLIGHT HOURS

Large Flaw = .3915" B
Smaller Flaw = .375" B



2x

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78	31200	
77	30800	
76	30400	
75	30000	
74	29600	
73	29200	
72	28800	
71	28400	
70	28000	
69	27600	
68	27200	
67	26800	
66	26400	
65	26000	
64	25600	
63	25200	
62	24800	.3915
61	24400	.2910
60	24000	.2265
59	23600	.1880
58	23200	.1530
57	22800	.1295
56	22400	.1090
55	22000	.0910
54	21600	.0780
53	21200	.0665
52	20800	.0580
51	20400	.0505
50	20000	.0445
49	19600	.0420
48	19200	.0380
47	18800	.0330
46	18400	.0290
45	18000	.0250
44	17600	.0185
43	17200	.0135
42	16800	.0100
41	16400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 88 (open hole)
 SPECTRUM: F16-400hr(A)
 TEST DATE: 11-08-83 // F
W 2.00' TH .3010" HOLE DIAM .440" A .6020 ID²
 MAX STRESS 28 ksi FREQ 1 LIFE = 16 days, Slow
 (FM=40)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 1442846 pts % LIFE = 188
 TTCI 12554 FLIGHT HOURS

Larger Flaw = .605"

Smaller Flaw = .375"



S

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	15040	.605
36	14400	.180
35	14000	.099
34	13600	T .052
33	13200	T .033
32	12800	T .014
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

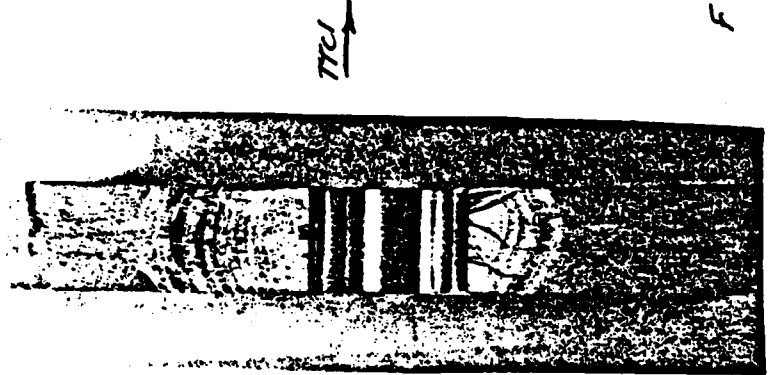
FATIGUE TEST DATA

SPECIMEN NUMBER: 89 (open hole)
 SPECTRUM: F16-400 hr(A)
 TEST DATE: 11-03-83 //
 W 2.006" TH 3045" HOLE DIAM — A 6108 in.
 MAX STRESS 28 KSI FREQ: 1 LIFE = 2 days fast
 ENVIR. CONDS. Dry Air PREPS. — (FM=250)
 CYCLES TO FAILURE 3140181 14 pts % LIFE = 410

TTCI 21,600 FLIGHT HOURS

Larger Flaw = .4705" B

Smaller Flaw = .250" B



2X

FRACTOGRAPHIC DATA

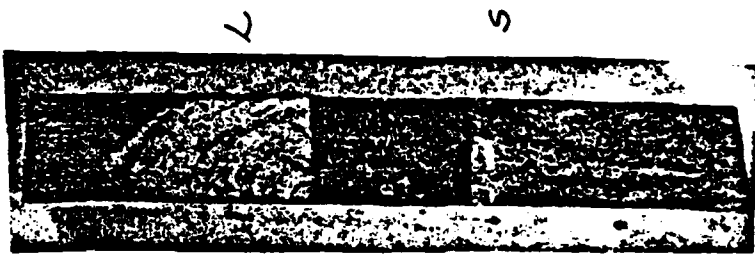
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	.3105
79	31600	.2595
78	31200	.2250
77	30800	.1975
76	30400	.1770
75	30000	.1495
74	29600	.1230
73	29200	.1025
72	28800	.0930
71	28400	.0765
70	28000	.0610
69	27600	.0510
68	27200	.0440
67	26800	.0400
66	26400	.0350
65	26000	.0315
64	25600	.0285
63	25200	.0250
62	24800	.0230
61	24400	.0205
60	24000	.0185
59	23600	.0165
58	23200	.0150
57	22800	.0135
56	22400	.0125
55	22000	.0110
54	21600	.0100
53	21200	
52	20800	
51	20400	
50	20000	
49	19600	
48	19200	
47	18800	
46	18400	
45	18000	
44	17600	
—	—	—
82	32,800	.4705
81	32,400	.3780

FATIGUE TEST DATA

SPECIMEN NUMBER: 90 (open hole)
 SPECTRUM: E16-400 hr(A)
 TEST DATE: 11-03-83 //
W 2.013" TH .3040" HOLE DIAM — A.6119 in²
 MAX STRESS 28 ksi FREQ 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. FM-60
 CYCLES TO FAILURE 2070877 h d p t s % LIFE = 270

TTCI 15226 FLIGHT HOURS

Larger Flaw = .548" c
Smaller Flaw = .075" b, c



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	22000	
79	31600	
78	31200	
77	30800	
76	30400	
75	30000	
74	29600	
73	29200	
72	28800	
71	28400	
70	28000	
69	27600	
68	27200	
67	26800	
66	26400	
65	26000	
64	25600	
63	25200	
62	24800	
61	24400	
60	24000	
59	23600	
58	23200	
57	22800	
56	22400	
55	22000	
54	21600	.548
53	21200	.540
52	20800	.168
51	20400	.0970
50	20000	.0685
49	19600	.0510
48	19200	.0365
47	18800	.0305
46	18400	.0280
45	18000	.0250
44	17600	.0220
43	17200	.0195
42	16800	
41	16400	

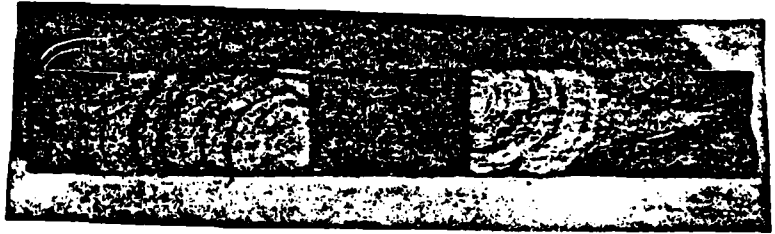
FATIGUE TEST DATA

SPECIMEN NUMBER: 91
 SPECTRUM: F16-400hr(A)
 TEST DATE: 11-03-83 11
W 2.006" TH .303" HOLE DIAM — A.6078
 MAX STRESS 28 KSI FREQ 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 1749361 dpts % LIFE = 228

TTCI 9400 FLIGHT HOURS

Smaller Flow = .375" B

Larger Flow = .619" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0870
39	15600	.0680
38	15200	.0560
37	14800	.0490
36	14400	.0415
35	14000	.0360
34	13600	.0330
33	13200	.0270
32	12800	.0240
31	12400	.0220
30	12000	.0205
29	11600	.0190
28	11200	.0170
27	10800	.0150
26	10400	.0130
25	10000	.0110
24	9600	.0105
23	9200	.0095
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	.6190
3	1200	.2915
2	800	.2230
1	400	.1610
		.1135

FATIGUE TEST DATASPECIMEN NUMBER: 92 (open hole)SPECTRUM: F16-400hrTEST DATE: 12-05-83 11W 2.009" TH .301" HOLE DIAM. .4135" A. .6047 in²MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow)
FM-40ENVIR. CONDS. Dry Air PREPS. ---CYCLES TO FAILURE 2324003 % LIFE = 303TTCI 13249 FLIGHT HOURSLarger Flow = .5235" BSmaller Flow = .350" C

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	10,000	---
39	15,600	---
38	15,200	T .0180
37	14,800	T .0150
75	30,000	---
74	29,600	---
73	29,200	---
72	28,800	---
71	28,400	---
70	28,000	---
69	27,600	---
68	27,200	---
67	26,800	---
66	26,400	---
65	26,000	---
64	25,600	---
63	25,200	---
62	24,800	---
61	24,400	---
60.6	24,240	.5235
59	23,600	.3440
58	23,200	.2840
57	22,800	.2465
56	22,400	.2110
55	22,000	.1765
54	21,600	.1505
53	21,200	.1300
52	20,800	.1070
51	20,400	.0900
50	20,000	.0750
49	19,600	.0630
48	19,200	.0530
47	18,800	.0460
46	18,400	.0400
45	18,000	.0350
44	17,600	.0305
43	17,200	.0280
42	16,800	---
41	16,400	---

FATIGUE TEST DATA

SPECIMEN NUMBER: 101 (20% LI)

SPECTRUM: 400 hr (AL)

TEST DATE: 8-23-83 //

W 2.0065" TH, 2990' HOLE DIAM .4380" A. 5999¹⁰²

MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)

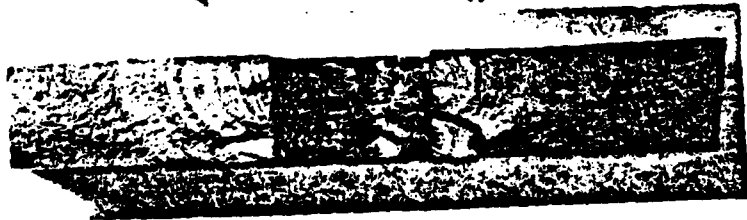
ENVIR. CONDS. 3.5% NaCl PREPS. PC

CYCLES TO FAILURE 574937 14 pts % LIFE = 75

TTCI 3775 FLIGHT HOURS

Smaller Flow = .300" B

Larger Flow = .428" B



L

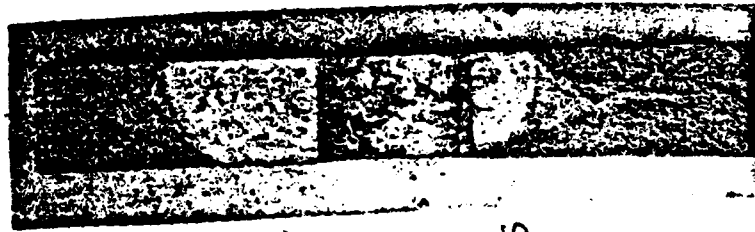
F

S me

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	.4280
14	5600	.1685
13	5200	.0995
12	4800	.0580
11	4400	.0345
10	4000	.0160
9	3600	.0060
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 102 (Open)SPECTRUM: 400br (A)TEST DATE: 8-16-83 //W 2.0065" TH. 3.010" HOLE DIAM. .4370" A. .6039 in.MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. PCCYCLES TO FAILURE 462815 kpts % LIFE = 60TTCI 1622 FLIGHT HOURSSmaller Flow = .175" BLarger Flow = .4515" B

2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	.4515
11	4400	.2120
10	4000	.1400
9	3600	.0810
8	3200	.0500
7	2800	.0370
6	2400	.0240
5	2000	.0175
4	1600	.0095
3	1200	
2	800	
1	400	

F

m4

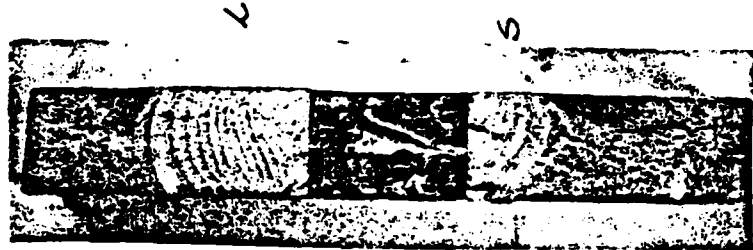
FATIGUE TEST DATA

SPECIMEN NUMBER: 103 (Open)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-17-83 //
W 2.0090' TH .3025" HOLE DIAM .4395" A .6077 in
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. PC
 CYCLES TO FAILURE 2606899 1 dpts % LIFE = 340

TTCI 10,800 FLIGHT HOURS

Smaller Flow = .225" B

Larger Flow = .4385" C.B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	100	
29	600	
28	27200	.4385
27	26800	.3520
26	26400	.3045
25	26000	.2780
24	25600	.2555
23	25200	.2285
22	24800	.2125
21	24400	.1970
20	24000	.1685
19	23600	.1500
18	23200	.1340
17	22800	.1185
16	22400	.1070
15	22000	.0965
14	21600	.0870
13	21200	.0780
12	20800	.0710
11	20400	.0660
10	20000	.0595
9	19600	.0540
8	19200	.0505
7	18800	.0465
6	18400	.0422
5	18000	.0382
4	17600	.0352
3	17200	.0325
2	16800	.0300
1	16400	.0273

FATIGUE TEST DATA

SPECIMEN NUMBER: 103 (continued.)

SPECTRUM: _____

TEST DATE: / /

W TH HOLE DIAM A

MAX STRESS FREQ. 1 LIFE =

ENVIR. CONDS. PREPS.

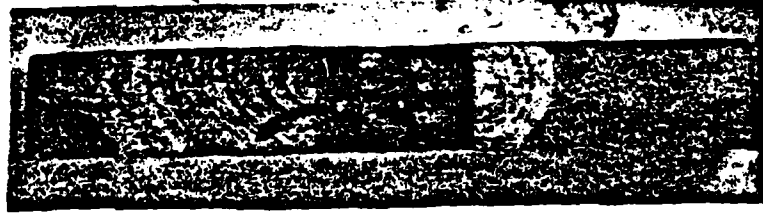
CYCLES TO FAILURE % LIFE = 77%

TTCI FLIGHT HOURS



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0253
39	15600	.0230
38	15200	.0210
37	14800	.0196
36	14400	.0181
35	14000	.0168
34	13600	.0154
33	13200	.0144
32	12800	.0134
31	12400	.0125
30	12000	.0118
29	11600	.0114
28	11200	.0107
27	10800	.0100
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 104 (20% LT)SPECTRUM: 400hr (A)TEST DATE: 8-24-83 //W 2.0045" TH, 2990" HOLE DIAM .4380" A .5993 in²MAX STRESS 28 ksi FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl* PREPS. PCCYCLES TO FAILURE 531209 1dpts % LIFE = 69TTCI 2812 FLIGHT HOURSSmaller Flow = .213" BLarger Flow = .5625" BFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
F 13.87	5550	.5625
13	5200	.4435
12	4800	.2965
11	4400	.1480
10	4000	.0860
9	3600	.0400
8	3200	.0260
7	2800	.0095
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

* may have had combination: salt- water/desiccant

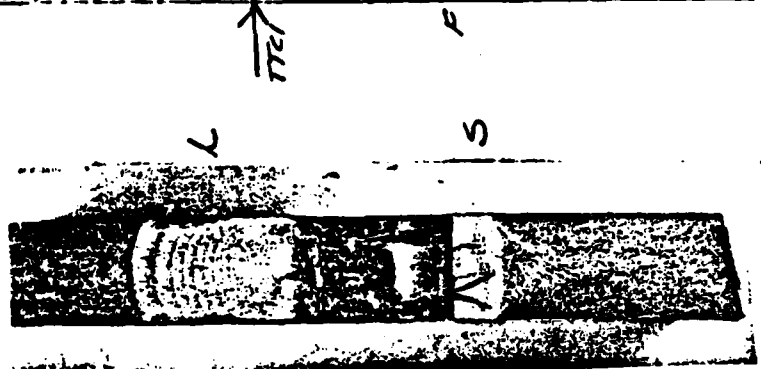
FATIGUE TEST DATA

SPECIMEN NUMBER: 105
 SPECTRUM: 400br (A)
 TEST DATE: 8-24-83 //
W 2.0125" TH .3040" HOLE DIAM .4395" A .6118 in.
 MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. PC
 CYCLES TO FAILURE 1914997 kpts % LIFE = 250

TTCI 6651 FLIGHT HOURS

Smaller Flow = .130" B

Larger Flow = .4695" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.1465
39	15600	.1340
38	15200	.1230
37	14800	.1120
36	14400	.1030
35	14000	.0885
34	13600	.0765
33	13200	.0660
32	12800	.0555
31	12400	.0470
30	12000	.0415
29	11600	.0375
28	11200	.0325
27	10800	.0290
26	10400	.0255
25	10000	.0230
24	9600	.0200
23	9200	.0185
22	8800	.0160
21	8400	.0150
20	8000	.0135
19	7600	.0125
18	7200	.0115
17	6800	.0105
16	6400	.0080
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
50.016	20000	.4695
49	19600	.4010
48	19200	.3490
47	18800	.3105
46	18400	.2490
45	18000	.2460
44	17600	.2190
43	17200	.2230
42	16800	.1765
41	16400	.1600

FATIGUE TEST DATA

SPECIMEN NUMBER: 106 (Open)
 SPECTRUM: 400hr (A)
 TEST DATE: 8-24-83 //
W 2.0025" TH 3030' HOLE DIAM 4395' A 6067 lb²
 MAX STRESS 28 ksi FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. — PC
 CYCLES TO FAILURE 1034374 k pts % LIFE = 135%

TTCI 2800 FLIGHT HOURS

Smaller Flow = .050" e, 8

Larger Flow = .5120" B



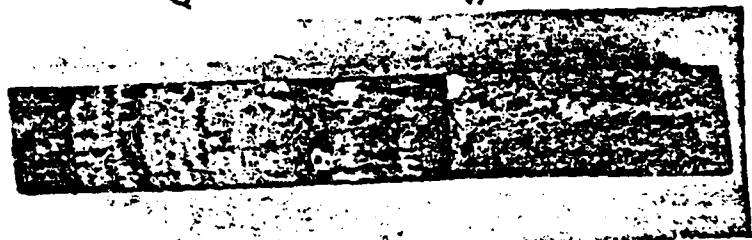
2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	.5120
26	10400	.3780
25	10000	.3330
24	9600	.2920
23	9200	.2625
22	8800	.2265
21	8400	.1925
20	8000	.1625
19	7600	.1310
18	7200	.1035
17	6800	.0760
16	6400	.0620
15	6000	.0495
14	5600	.0415
13	5200	.0350
12	4800	.0280
11	4400	.0225
10	4000	.0185
9	3600	.0155
8	3200	.0135
7	2800	.0100
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 107 (Open)SPECTRUM: 400hr (A)TEST DATE: 8-25-83 //W 2.0045" TH .3035" HOLE DIAM .4395" A .6083"MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. PCCYCLES TO FAILURE 651498 14 pts % LIFE = 85TTCI 1600 FLIGHT HOURSSmaller Flow = .075" BLarger Flow = .567" BFRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
F		
17-016	6806	.5670
16	6400	.2990
15	6000	.2020
14	5600	.1320
13	5200	.0835
12	4800	.0535
11	4400	.0405
10	4000	.0320
9	3600	.0260
8	3200	.0210
7	2800	.0180
6	2400	.0150
5	2000	.0120
4	1600	.0100
TTCI		
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 108 (Open)SPECTRUM: 400hr (A)TEST DATE: 8-26-83 //W 2.0045 TH .3030" HOLE DIAM, 4395" A .6074 IN²MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. PCCYCLES TO FAILURE 401239 1d pts % LIFE = 52TTCI 1097 FLIGHT HOURSSmaller Flow = .050" cLarger Flow = .660" BFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10AE	4192	.6600
9	3600	.2720
8	3200	.1130
7	2800	.0540
6	2400	.0325
5	2000	.0225
4	1600	.0165
3	1200	.0110
2	800	.0075
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 109 (Open Hole)

SPECTRUM: 400hrs(A)

TEST DATE: 8-26-83 //

W 2.0055" TH. 3030' HOLE DIAM. 4.395" A, 6076in-

MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slow)

ENVIR. CONDS. Dry PREPS. P.C.

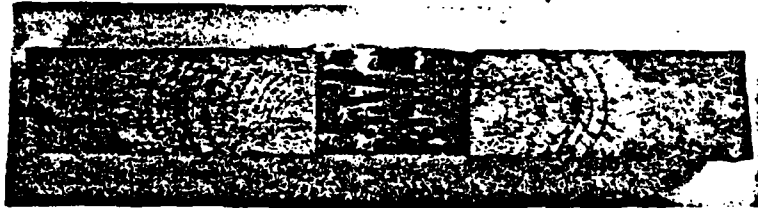
CYCLES TO FAILURE 4172937 dpts % LIFE = 545

TTCI 28000 FLIGHT HOURSSmaller Flow = .500" cLarger Flow = .443" c

2X

ICTOGRAPHIC DATA

BLK #		CRACK LENGTH IN.
108.99	43.596	.443
108	43.200	.369
107	42.800	.310
106	42.400	.265
105	42.000	.2305
104	41.600	.2055
103	41.200	.181
102	40.800	.163
101	40.400	.149
100	40.000	.136
99	39.600	.125
98	39.200	.114
97	38.800	.106
96	38.400	.095
95	38.000	.0885
94	37.600	.082
93	37.200	.075
92	36.800	.0695
91	36.400	.067
90	36.000	.063
89	35.600	.059
88	35.200	.056
87	34.800	.051
86	34.400	.0465
85	34.000	.045
84	33.600	.0415
83	33.200	.038
82	32.800	.036
81	32.400	.034
80	32.000	.033
79	31.600	.031
78	31.200	.030
—	—	—
—	—	—
—	—	—
—	—	—
73	292.00	.023
—	—	—
—	—	—
63	280.00	.010

FATIGUE TEST DATASPECIMEN NUMBER: 110 (Open Hole)SPECTRUM: 400 hr (A)TEST DATE: 8-30-83 //W 2.0120 TH .3045 HOLE DIAM .4395 A-6126 in²MAX STRESS 28 KSI FREQ 1 LIFE = 16 days (Slow)ENVIR. CONDS. Dry PREPS. pre-cond.CYCLES TO FAILURE 29897711 d. pts. % LIFE = 390TTCI 18,400 FLIGHT HOURSSmaller Flaw = .475" BLarger Flaw = .570" C

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78.08	31235	
77	30800	.570
76	30400	.3030
75	30000	.257
74	29600	.219
73	29200	.190
72	28800	.168
71	28400	.147
70	28000	.129
69	27600	.113
68	27200	.099
67	26800	.086
66	26400	.075
65	26000	.066
64	25600	.057
63	25200	.051
62	24800	.0445
61	24400	.040
60	24000	.037
59	23600	.033
58	23200	.031
57	22800	.027
56	22400	.0255
55	22000	.0240
54	21600	.0215
53	21200	.020
52	20800	.0175
51	20400	.0165
50	20000	.0150
49	19600	.0140
48	19200	.0130
47	18800	.0120
46	18400	.0110
45	18000	.0100
44	17600	
43	17200	
42	16800	
41	16400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 112 (Bolt-In)
 SPECTRUM: El6-400hr(A)
 TEST DATE: 10-28-83 //

W 2.003" TH .303" HOLE DIAM .4415" A .6069in²

MAX STRESS 28 ksi FREQ 1 LIFE = 2 days (Fast)

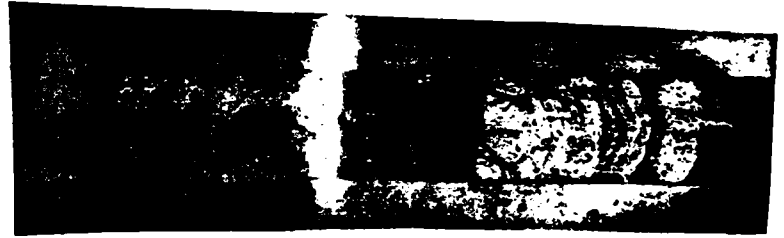
ENVIR. CONDS. 3.5% NaCl PREPS. P.C.

CYCLES TO FAILURE 922257 % LIFE = 120

TTCI 3120 FLIGHT HOURS

Smaller Flaw = .575" B

Larger Flaw = .6030" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9635	.16030
23	9200	.3970
22	8800	.2780
21	8400	.2240
20	8000	.1435
19	7600	.1030
18	7200	.0810
17	6800	.0600
16	6400	.0465
15	6000	.0350
14	5600	.0290
13	5200	.0250
12	4800	.0215
11	4400	.0180
10	4000	.0155
9	3600	.0130
8	3200	.0105
7	2800	.0080
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

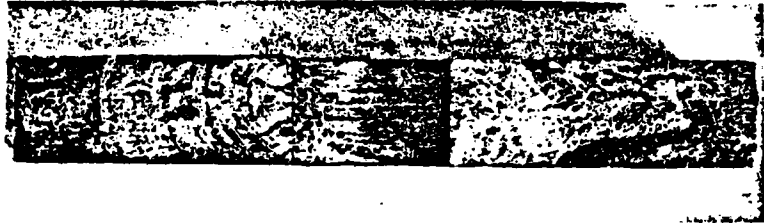
FATIGUE TEST DATASPECIMEN NUMBER: 113 (Open Hole)SPECTRUM: 400hr(A)TEST DATE: 9-2-83 11W 2.0020" TH. .3045" HOLE DIAM. .4400" A. .6096 IN²MAX STRESS 28 KSI FREQ. 1 LIFE = 2 weeks (Slow)
FM: 40ENVIR. CONDS. 3.5% NaCl PREPS. PCCYCLES TO FAILURE 268626 14 pts % LIFE = 35TTCI 875 FLIGHT HOURSSmaller Flow = .300" BLarger Flow = .6145" BFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7016	2806	.6145
6	2400	.1640
5	2000	.0695
4	1600	.0260
3	1200	.0165
2	800	.0085
1	400	

S F

1721

2X

FATIGUE TEST DATASPECIMEN NUMBER: 114 (Bolt-In)SPECTRUM: Fl6-400hr (A)TEST DATE: 10-31-83 //W 2.004" TH .3015" HOLE DIAM .4390" A .6042" IDMAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5% NaCl PREPS. P.C.CYCLES TO FAILURE 957186 Id pts % LIFE = 125TTCI 2323 ✓ FLIGHT HOURSSmaller Flow = .500" BLarger Flow = .5180" BFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	.5180
24	9600	.3530
23	9200	.2360
22	8800	.1640
21	8400	.1185
20	8000	.0850
19	7600	.0685
18	7200	.0550
17	6800	.0445
16	6400	.0410
15	6000	.0365
14	5600	.0315
13	5200	.0280
12	4800	.0245
11	4400	.0230
10	4000	.0190
9	3600	T .0170
8	3200	T .0150
7	2800	T .0125
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 115 (Open Hole)
 SPECTRUM: 400 hr (A)
 TEST DATE: 9-12-83 // 11
W 2.0110" TH .3035" HOLE DIAM .4395" A .6103 in
 MAX STRESS 28 FREQ 1 LIFE = 2 weeks (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. PC
 CYCLES TO FAILURE 693464 4 pts % LIFE = 91

TTCI 4440 FLIGHT HOURS

Smaller Flow = .324'B

Larger Flow = .3955'B



L

S

2.31x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18.112	7245	.3955
17	6800	.1325
16	6400	.0795
15	6000	.0510
14	5600	.0350
13	5200	.0210
12	4800	.0145
11	4400	.0095
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

F

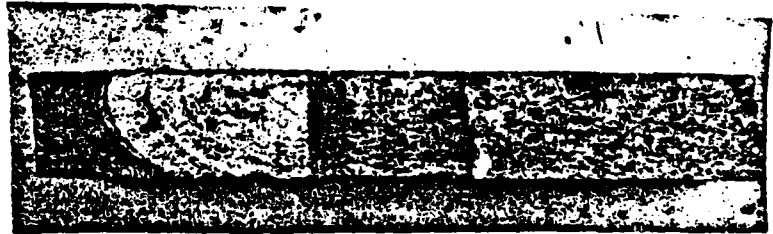
7725

FATIGUE TEST DATA

SPECIMEN NUMBER: 116 (Bolt-In)
 SPECTRUM: F16-400hr(A)
 TEST DATE: 10-31-83 //
W 2.0095" TH .3015" HOLE DIAM .4395" A .6059 in
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. 3.5% NaCl PREPS. pc
 CYCLES TO FAILURE 103712314 pts % LIFE = 135%

TTCI 4549 FLIGHT HOURSSmaller Flow = .050" BLarger Flow = .5660" CFRACTOGRAPHIC DATA

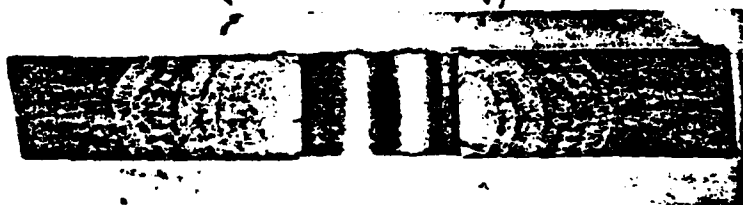
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10835	.5660
26	10400	
25	10000	.3625
24	9600	.2520
23	9200	.2155
22	8800	.1600
21	8400	.1110
20	8000	.0760
19	7600	.0485
18	7200	.0400
17	6800	.0310
16	6400	.0245
15	6000	.0210
14	5600	.0180
13	5200	.0145
12	4800	.0120
11	4400	.0085
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	



2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 117
 SPECTRUM: F16-400hr(A)
 TEST DATE: 12-9-83 //
 W 2.009" TH .3010" HOLE DIAM. A .6047 in²
 MAX STRESS 28 KSI FREQ 1 LIFE = 16 days - Slow FM=40
 ENVIR. CONDS. Dry Air PREPS. PC
 CYCLES TO FAILURE 3062988 % LIFE = 400

TTCI 23,600 FLIGHT HOURSLarger Flaw = .526" BSmaller Flaw = .423" B

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78	31200	.435
77	30800	.288
76	30400	.230
75	30000	.195
74	29600	.164
73	29200	.135
72	28800	.120
71	28400	.107
70	28000	.098
69	27600	.088
68	27200	.078
67	26800	.070
66	26400	.060
65	26000	.047
64	25600	.040
63	25200	.034
62	24800	.027
61	24400	.022
60	24000	.0185
59	23600	.0135
58	23200	.010
57	22800	
56	22400	
55	22000	
54	21600	
53	21200	
52	20800	
51	20400	
50	20000	
49	19600	
48	19200	
47	18800	
46	18400	
45	18000	
44	17600	
43	17200	
42	16800	
41	16400	

FATIGUE TEST DATA

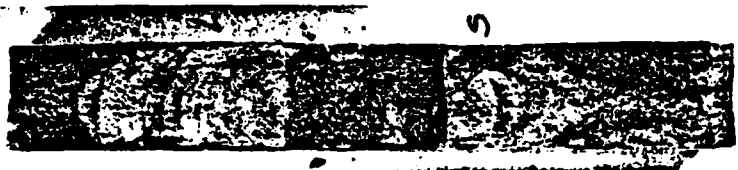
SPECIMEN NUMBER: 122 (Bolt-In)
 SPECTRUM: 400hr(A)
 TEST DATE: 10-18-83 //
 W 1.9983 TH .304 HOLE DIAM .4415 A .6075 IN.
 MAX STRESS 28 KSI FREQ 1 LIFE = 2 days - Fast (FM-250)
 ENVIR. CONDS. 3.5% NaCl PREPS. None
 CYCLES TO FAILURE 153216 14 pts % LIFE = 200

TTCI 3200 FLIGHT HOURSLarger Flow = .549" BSmaller Flow = .213" B

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.5490
39	15600	.A065
38	15200	.3100
37	14800	.2355
36	14400	.1850
35	14000	.1515
34	13600	.1250
33	13200	.1020
32	12800	.0830
31	12400	.0695
30	12000	.0590
29	11600	.0535
28	11200	.0480
27	10800	.0430
26	10400	.0380
25	10000	.0340
24	9600	—
23	9200	—
22	8800	—
21	8400	—
20	8000	.022
19	7600	.020
18	7200	—
17	6800	—
16	6400	—
15	6000	—
14	5600	.0155
13	5200	—
12	4800	—
11	4400	—
10	4000	—
9	3600	—
8	3200	.0100
7	2800	—
6	2400	—
5	2000	—
4	1600	—
3	1200	—
2	800	—
1	400	—

FATIGUE TEST DATASPECIMEN NUMBER: 123 (Bolt-In)SPECTRUM: 400bf (A)TEST DATE: 10-21-83 //W 2.0090" TH .3040" HOLE DIAM .4410" A .6107 in²MAX STRESS 28 ksi FREQ 1 LIFE = 2 days (Fast)
 $f_H = 250$ ENVIR. CONDS. 3.5% NaCl PREPS. NoneCYCLES TO FAILURE 1809316 1dpts % LIFE = 236TTCI 13,868 FLIGHT HOURSLarger Flaw = .5745 BSmaller Flaw = .250" B

2X

FRACTOGRAPHIC DATA

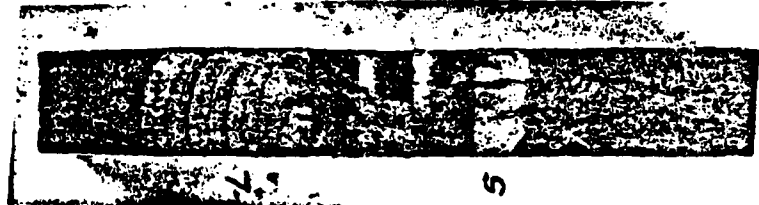
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0220
39	15600	.0195
38	15200	.0160
37	14800	.0140
36	14400	.0120
35	14000	.0105
34	13600	.0090
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
F		
47.25	18900	.5745
47	18800	.3925
46	18400	.2475
45	18000	.1540
44	17600	.0915
43	17200	.0660
42	16800	.0460
41	16400	.0335

FATIGUE TEST DATA

SPECIMEN NUMBER: 124 (Bolt-Id)
 SPECTRUM: Flk-400hr(A)
 TEST DATE: 10-25-83 //
W 2.008" TH .3015" HOLE DIAM .4435" A .6054 ID
 MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast Frac)
 ENVIR. CONDS. 3.5% NaCl PREPS. NO 174
 CYCLES TO FAILURE 1608687 14pts % LIFE = 210
 TTCT 11600 FLIGHT HOURS

Larger Flow = .4760 B

Smaller Flow = .150" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.2510
39	15600	.1640
38	15200	.0905
37	14800	.0550
36	14400	.0400
35	14000	.0315
34	13600	.0250
33	13200	.0210
32	12800	.0175
31	12400	.0145
30	12000	.0120
29	11600	.0100
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	
42	16806	.4760
1	16400	

F
2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 125 (Bolt-In)

SPECTRUM: Flg-400hr(A)

TEST DATE: 10-28-83 //

W 2.003" TH. 303" HOLE DIAM. .4405" A. 6069IN²

MAX STRESS 28 KSI FREQ. 1 LIFE = Z days (Fast)

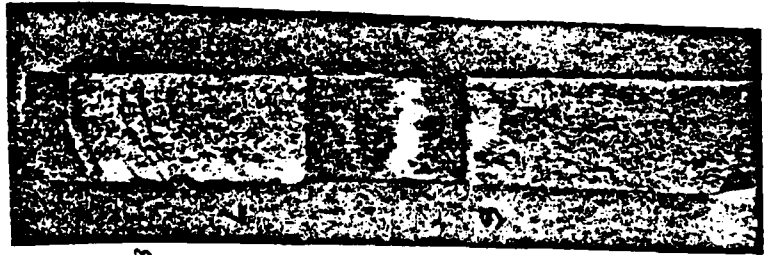
ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 991497 kpts. % LIFE = 129

TTCI 5777 FLIGHT HOURS

Larger Flaw = .65458

Smaller Flaw = .1003



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25.89	10356	.6545
24	9600	.3355
23	9200	.2275
22	8800	.1535
21	8400	.0930
20	8000	.0510
19	7600	.0405
18	7200	.0345
17	6800	.0245
16	6400	.0180
15	6000	.0130
14	5600	.0075
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 126 (Bolt-ID)SPECTRUM: F16-400bf(A)TEST DATE: 11-28-83 //W 2.009" TH .304" HOLE DIAM .4435" A .6099 IDMAX STRESS 28 ksi FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. Dry Air PREPS. NoCYCLES TO FAILURE 3449232 dpts% LIFE = 450TTCI 23,600 FLIGHT HOURSLarger Flaw = .379" BSmaller Flaw = .250" B

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	.062
79	31600	.0545
78	31200	.049
77	30800	.046
76	30400	.041
75	30000	.0375
74	29600	.034
73	29200	.031
72	28800	.029
71	28400	—
70	28000	—
69	27600	—
68	27200	—
67	26800	—
66	26400	—
65	26000	.015
64	25600	—
63	25200	—
62	24800	—
61	24400	—
60	24000	.0105
59	23600	.0100
58	23200	—
57	22800	—
56	22400	—
55	22000	—
54	21600	—
53	21200	—
52	20800	—
90	36,035	.379
89	35,600	.303
88	35,200	.237
87	34,800	.196
86	34,400	.171
85	34,000	.1335
84	33,600	.111
83	33,200	.094
82	32,800	.081
81	32,400	.069

FATIGUE TEST DATA

SPECIMEN NUMBER: 127 (Bolt-In)
 SPECTRUM: Flb-400bf(A)
 TEST DATE: 11-18-83 //
W 2.00" TH .3005" HOLE DIAM .4415" A .6010 IN²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast) ^{FN-250}
 ENVIR. CONDS. Dry Air PREPS. None
 CYCLES TO FAILURE 236,886.5 KPS % LIFE = 309
 TTCT 14,800 FLIGHT HOURS

Larger Flaw = .497" B
Smaller Flaw = .490" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78	31200	
77	30800	
76	30400	
75	30000	
74	29600	
73	29200	
72	28800	
71	28400	
70	28000	
69	27600	
68	27200	
67	26800	
66	26400	
65	26000	
64	25600	
63	25200	
62	24800	
61.8	24748	.497
60	24000	.231
59	23600	.183
58	23200	.153
57	22800	.1245
56	22400	.097
55	22000	.082
54	21600	.070
53	21200	.0605
52	20800	.054
51	20400	.049
50	20000	.0445
49	19600	.041
48	19200	.0365
47	18800	.033
46	18400	.029
45	18000	.027
44	17600	—
43	17200	—
42	16800	—
41	16400	—

FATIGUE TEST DATASPECIMEN NUMBER: 12.7 (cont.)

SPECTRUM: _____

TEST DATE: _____

W _____ TH _____ HOLE DIAM _____ A _____

MAX STRESS _____ FREQ _____ 1 LIFE = _____

ENVIR. CONDS. _____ PREPS. _____

CYCLES TO FAILURE _____ % LIFE ± _____

TTCI _____ FLIGHT HOURS _____

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0145
39	15600	—
38	15200	—
37	14800	.0100
36	14400	—
35	14000	.0065
34	13600	—
33	13200	—
32	12800	—
31	12400	—
30	12000	—
29	11600	—
28	11200	—
27	10800	—
26	10400	—
25	10000	—
24	9600	—
23	9200	—
22	8800	—
21	8400	—
20	8000	—
19	7600	—
18	7200	—
17	6800	—
16	6400	—
15	6000	—
14	5600	—
13	5200	—
12	4800	—
11	4400	—
10	4000	—
9	3600	—
8	3200	—
7	2800	—
6	2400	—
5	2000	—
4	1600	—
3	1200	—
2	800	—
1	400	—

DEVELOPMENT OF FATIGUE AND CRACK PROPAGATION DESIGN &
ANALYSIS METHODOLOG. (U) GENERAL DYNAMICS FORT WORTH TX
FORT WORTH DIV D E GORDON ET AL. AUG 84

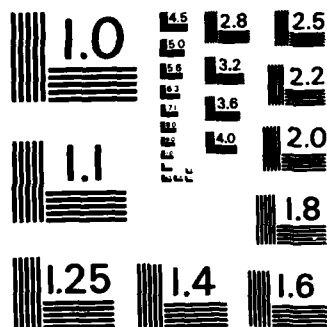
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FATIGUE TEST DATA

SPECIMEN NUMBER: 128 (Bolt-In)
 SPECTRUM: F16-400hr(A)
 TEST DATE: 11-29-83 11
W20030 TH. 3045 HOLE DIAM 4430 A. 6099 IN.
 MAX STRESS 28ksi FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Day PREPS. None
 CYCLES TO FAILURE 410011 1dpts 7 LIFE = 535
 TTCT 35,600 FLIGHT HOURS

LARGER FLAW = .448' (B)

SMALLER FLAW = .411' (B)



FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
107	42,835	.448
106	42,400	.315
105	42,000	.243
104	41,600	.179
103	41,200	.148
102	40,800	.124
101	40,400	.109
100	40,000	.085
99	39,600	.079
98	39,200	.066
97	38,800	.053
96	38,400	.042
95	38,000	.032
94	37,600	.027
93	37,200	.023
92	36,800	.020
91	36,400	.016
90	36,000	.0135
89	35,600	.010
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 131 (Belt-In)

SPECTRUM: F16-400hr (A)

TEST DATE: 12-14-83 //

W 2.0035 TH. 3045 HOLE DIAM. 4420 A. 6100 IN²

MAX STRESS 28 KSI FREQ 1 LIFE = 16 days (Skw)
M=40

ENVIR. CONDS. 3.5% NaCl PREPS. Nc

CYCLES TO FAILURE 1340691 dpts % LIFE = 175

TTCI 8359 FLIGHT HOURS

Larger Flaw = .448"

Smaller Flaw = .400"



2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14007	.4480
34	13600	.3095
33	13200	.2115
32	12800	.1490
31	12400	.1065
30	12000	.0800
29	11600	.0720
28	11200	.0565
27	10800	.0480
26	10400	.0400
25	10000	.0320
24	9600	.0240
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 132 (Belt-In)SPECTRUM: F16-400 BT (A)TEST DATE: 12-16-83 //W 2.003" TH .3035" HOLE DIAM .4485" A .6079 IDMAX STRESS 28 KSI FREQ 1 LIFE = 16 days (512w)
PH140ENVIR. CONDS. 3.5% NaCl PREPS. NoCYCLES TO FAILURE 1956024 14 pts% LIFE = 2.55TTCI 9300 FLIGHT HOURSLarger Flaw = .512" CSmaller Flaw = .0375" CFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78	31200	
77	30800	
76	30400	
75	30000	
74	29600	
73	29200	
72	28800	
71	28400	
70	28000	
69	27600	
68	27200	
67	26800	
66	26400	
65	26000	
64	25600	
63	25200	
62	24800	
61	24400	
60	24000	
59	23600	
58	23200	
57	22800	
56	22400	
55	22000	
54	21600	
53	21200	
52	20800	
51	20435	.512
50	20000	.373
49	19600	.276
48	19200	.189
47	18800	.153
46	18400	.121
45	18000	.098
44	17600	.086
43	17200	.073
42	16800	.062
41	16400	.054

FATIGUE TEST DATASPECIMEN NUMBER: 132 (Cont)

SPECTRUM: _____

TEST DATE: _____

W _____ TH _____ HOLE DIAM _____ A _____

MAX STRESS _____ FREQ _____ 1 LIFE = _____

ENVIR. CONDS. _____ PREPS. _____

CYCLES TO FAILURE _____ % LIFE = _____

TTCI 9300 FLIGHT HOURS _____FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	—
39	15600	—
38	15200	—
37	14800	—
36	14400	—
35	14000	—
34	13600	—
33	13200	T.026
32	12800	—
31	12400	—
30	12000	.019
29	11600	—
28	11200	—
27	10800	Y.015
26	10400	—
25	10000	—
24	9600	—
23	9200	—
22	8800	—
21	8400	—
20	8000	—
19	7600	—
18	7200	—
17	6800	—
16	6400	—
15	6000	—
14	5600	—
13	5200	—
12	4800	—
11	4400	—
10	4000	—
9	3600	—
8	3200	—
7	2800	—
6	2400	—
5	2000	—
4	1600	—
3	1200	—
2	800	—
1	400	—

FATIGUE TEST DATASPECIMEN NUMBER: 140 (Bolt-In)SPECTRUM: Fl6-400hr(A)TEST DATE: 12-1-83 //W 2.002" TH. 3.035" HOLE DIAM. - A.6076 in²MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. Dry Air PREPS. P.C.CYCLES TO FAILURE 1672744 kpts % LIFE = 218TTCI 3857 FLIGHT HOURSLarger Flaw = .5850"Smaller Flaw = .300"

2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.3020
39	15600	.2735
38	15200	.2410
37	14800	.2195
36	14400	.1980
35	14000	.1800
34	13600	.1600
33	13200	.1445
32	12800	.1295
31	12400	.1135
30	12000	.1015
29	11600	.088
28	11200	.0760
27	10800	.0650
26	10400	.0550
25	10000	.0485
24	9600	—
23	9200	—
22	8800	—
21	8400	—
20	8000	.0290
19	7600	—
18	7200	—
17	6800	—
16	6400	—
15	6000	.0175
14	5600	—
13	5200	—
12	4800	—
11	4400	—
10	4000	.0105
9	3600	—
8	3200	—
7	2800	—
6	2400	—
5	2000	—
4	1600	—
43.6	17410	.5850
42	16800	.3805
41	16400	.3370

TTCI

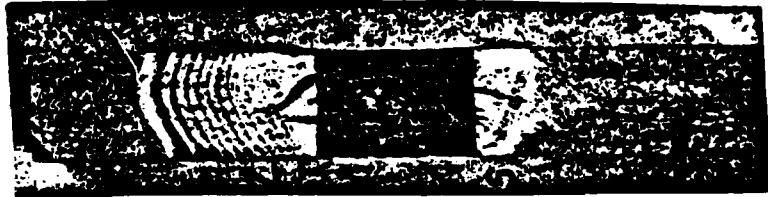
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FATIGUE TEST DATA

SPECIMEN NUMBER: 141 (Bait-Id)
 SPECTRUM: Flk-400b5(A)
 TEST DATE: 12-05-83 //
W 2.0115" TH .3010" HOLE DIAM .4415" A .6055 IN²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast) _{FM-250}
 ENVIR. CONDS. Dry Air PREPS. PC
 CYCLES TO FAILURE 2106431 dpts % LIFE = 275
 TTCT 9200 ✓ FLIGHT HOURS

Larger Flaw = .488"

Smaller Flaw = .175"



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
55	22000	.488
54	21600	.444
53	21200	.392
52	20800	.356
51	20400	.324
50	20000	.296
49	19600	.267
48	19200	.239
47	18800	.214
46	18400	.191
45	18000	.173
40	16000	.093
35	14000	.060
34	6	.052
33	2	.045
32	8	.037
31	4	.033
30	0	.025
29	6	.022
28	2	.019
23	9200	.010
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 142 (Bolt-In)
 SPECTRUM: F16-400bf(A)
 TEST DATE: 12-07-83 //
W 2.0035" TH .3010" HOLE DIAM, 4415" A .6031 IN.
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (F₁₆)
 ENVIR. CONDS. Dry Air PREPS. PC
 CYCLES TO FAILURE 2336.149 14pts 2 LIFE = 30.5
 TTCTI 12,400 FLIGHT HOURS

Larger Flaw = .4715" B
 Smaller Flaw = .250" B



2x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
80	32000	
79	31600	
78	31200	
77	30800	
76	30400	
75	30000	
74	29600	
73	29200	
72	28800	
71	28400	
70	28000	
69	27600	
68	27200	
67	26800	
66	26400	
65	26000	
64	25600	
63	25200	
62	24800	
61	24400	.4715
60	24000	—
59	23600	.3460
58	23200	.3095
57	22800	.2765
56	22400	.2465
55	22000	.2260
54	21600	.2065
53	21200	.1755
52	20800	.1545
51	20400	.1350
50	20000	.1170
49	19600	.1025
48	19200	.0890
47	18800	.0765
46	18400	—
45	18000	—
44	17600	—
43	17200	—
42	16800	.0365
41	16400	.0300

FATIGUE TEST DATA

SPECIMEN NUMBER: 142 (cont.)

SPECTRUM: _____

TEST DATE: _____

W _____ TH _____ HOLE DIAM _____ A _____

MAX STRESS _____ FREQ. 1 LIFE = _____

ENVIR. CONDS. _____ PREPS. 771

CYCLES TO FAILURE _____ % LIFE = _____

TTCI _____ FLIGHT HOURS _____

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	1600	.0240
39	1560	—
38	1520	—
37	1480	—
36	1440	.0175
35	1400	—
34	1360	—
33	1320	—
32	1280	—
31	1240	.0100
30	1200	—
29	1160	—
28	1120	—
27	1080	—
26	1040	—
25	1000	—
24	960	—
23	920	—
22	880	—
21	840	—
20	800	—
19	760	—
18	720	—
17	680	—
16	640	—
15	600	—
14	560	—
13	520	—
12	480	—
11	440	—
10	400	—
9	360	—
8	320	—
7	280	—
6	240	—
5	200	—
4	160	—
3	120	—
2	80	—
1	40	—

FATIGUE TEST DATA

SPECIMEN NUMBER: 300 Open Hole

SPECTRUM: F-18 300 hr

TEST DATE: 2-1-84 11

W 2.0240" TH. 3.030" HOLE DIAM .4460" A. 6.133 IN.

MAX STRESS 28 KSI FREQ Fast (FM=250)

ENVIR. CONDS. 3.5% NaCl PREPS. —

CYCLES TO FAILURE 174062 4 pts % LIFE —

TTCI 13002 FLIGHT HOURS

LARGER FLAW = .544" B

SMALLER FLAW = .305" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
5349	16646	.544
53	16500	.382
54	16200	.2875
32	15900	.184
32	15600	.160
31	15300	.121
50	15000	.089
49	14700	.072
48	14400	.061
47	14100	.046
46	13800	.0345
45	13500	.023
44	13200	.0135
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 301 Open Hole
 SPECTRUM: F-18 300hr
 TEST DATE: 2-1-84 //
W 2.0030" TH 3038" HOLE DIAM 4470" A 6085 in²
 MAX STRESS 28 KSI FREQ. Fast (FM=250) ms
 ENVIR. CONDS. 3.5% NaCl PREPS. ---
 CYCLES TO FAILURE 127070 10 pts % LIFE ---

TTCI 9077 FLIGHT HOURS

LARGER FLAW = .438" B

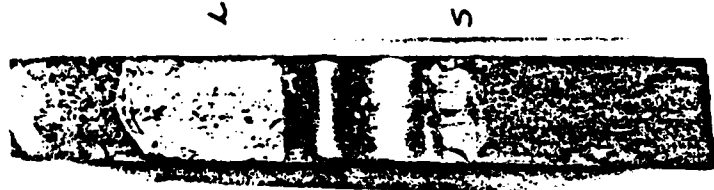
SMALLER FLAW = .301" B



2x

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	12000	.372"
39	11700	.261
38	11400	.1890
37	11100	.1355
36	10800	.0914
35	10500	.064
34	10200	.0475
33	9900	.0355
32	9600	.025
31	9300	.015
30	9000	.0085
29		
28		
27		
26		
25		
24		
23		
22		
21		
20		
19		
18		
17		
16		
15		
14		
13		
12		
11		
10		
9	12152.1	.438
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATASPECIMEN NUMBER: 302 Open HoleSPECTRUM: F18-300hr (B)TEST DATE: 2-2-84 11W 2.001" TH .3030" HOLE DIAM .4450" A .6063 IN²MAX STRESS 28 KSI FREQ Fest (FM = 250)ENVIR. CONDS. 3.5% NaCl PREPS. NoneCYCLES TO FAILURE 122725 / dptsTTCI 8267 FLIGHT HOURSLARGER FLAW = .4690" (B)SMALLER FLAW = .1175" (B)FRACTOGRAPHIC DATA

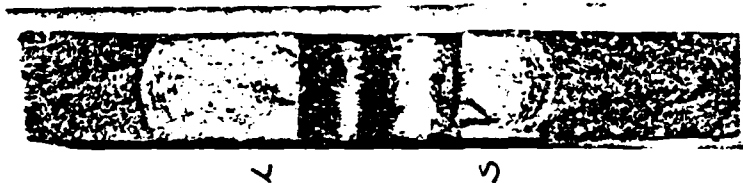
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
3912	11737	.4690
38	11400	.3750
37	11100	.270
36	10800	.2010
35	10500	.170
34	10200	.1225
33	9900	.0865
32	9600	.066
31	9300	.0495
30	9000	.040
29	8700	.024
28	8400	.014
27	8100	.005
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 303 Open hole
 SPECTRUM: F18 300br
 TEST DATE: 2-2-84 11
W 2.003" TH .302" HOLE DIAM. 4415" A. 6049 ID²
 MAX STRESS 28 KSI FREQ: FAST (FM=250) F
 ENVIR. CONDS. 3.5% NaCl PREPS. —
 CYCLES TO FAILURE 22,437 kpts % LIFE —
 TTCT 17,323 FLIGHT HOURS

LARGER FLAW = .437" B

SMALLER FLAW = .256" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
71.51	21452	.437
71	21300	.360
70	21000	.278
69	20700	.204
68	20400	.156
67	20100	.130
66	19800	.112
65	19500	.095
64	19200	.080
63	18900	.065
62	18600	.048
61	18300	.040
60	18000	.028
59	17700	.017
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 304 Open hole

SPECTRUM: F18 300hr

TEST DATE: 2-1-84 11

W 2.0" TH. 302.5' HOLE DIAM. .4400" A. .6050 in²

MAX STRESS 28 KSI FREQ. Fast (FM = 250)

ENVIR. CONDS. 3.5% NaCl PREPS. pc

CYCLES TO FAILURE 112055 kpts % LIFE —

TTCI 7310 FLIGHT HOURS

L LARGER FLAW = .4195" B

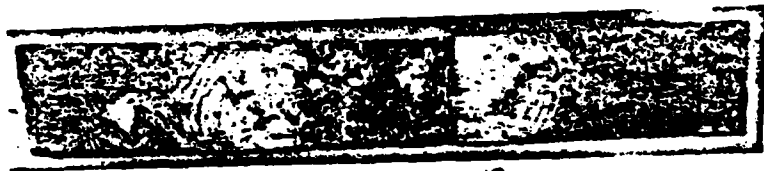
S SMALLER FLAW = .2522" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
35.72	10716.2	.4195
33	10500	.2925
34	10200	.2275
33	9900	.1805
32	9600	.1370
31	9300	.1025
30	9000	.0855
29	8700	.0530
28	8400	.0430
27	8100	.0310
26	7800	.0220
25	7500	.0130
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATASPECIMEN NUMBER: 305 ORINOLSPECTRUM: F18 300hr (B)TEST DATE: 2-1-84 //W 2.0045" TH. 3010" HOLE DIAM. .4405" A. .6033A IN.MAX STRESS 28 KSI FREQ. Fast (FM=250)ENVIR. CONDS. 3.5% NaCl PREPS. PCCYCLES TO FAILURE 85356 % LIFE —TTCI 5548 FLIGHT HOURSLARGER FLAW = .358" BSMALLER FLAW = .353" B

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
27	8163	.358
27	8168	.303
26	7800	.184
25	7500	.117
24	7200	.093
23	6900	.072
22	6600	.049
21	6300	.035
20	6000	.022
19	5700	.013
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
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1		
0		
9		
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2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 306 Open hole
 SPECTRUM: F18 300hr
 TEST DATE: 2-2-84 11
W 2.003" TH. 3045' HOLE DIAM. 4410' A. 6099 m.
 MAX STRESS 28 KSI FREQ. Fast
 ENVIR. CONDS. 3.5% NaCl PREPS. pc
 CYCLES TO FAILURE 61862 14 pts % LIFE —

TTCI 3/41 FLIGHT HOURS

LARGER FLAW = .4010" B

SMALLER FLAW = .2510" B



2x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
1972	5916	.4010
19	3700	.3060
18	3400	.2385
17	5100	.1870
16	4800	.1400
15	4500	.0950
14	4200	.0735
13	3900	T.055
12	3600	T.0355
11	3300	T.0140
0		
9		
8		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 307 Open Hole

SPECTRUM: F18 300hr(B)

TEST DATE: 2-2-64 11

W2.002 TH .302" HOLE DIAM .4435" A .6046 in²

MAX STRESS 28 KSI FREQ. F

ENVIR. CONDS. 3.5% NaCl PREPS. PC (FM-250)

CYCLES TO FAILURE 99943 kpts % LIFE —

TTCI 6/61 FLIGHT HOURS

LARGER FLAW = .433" B

SMALLER FLAW = .274" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
31	9557.8	.433
30	9300	.310
29	9000	.239
28	8700	.1965
27	8400	.148
26	8100	.1085
25	7800	.0655
24	7500	.0475
23	7200	.0340
22	6900	.0230T
21	6600	.0180T
20	6300	.0115T
19		
18		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 312 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-2-84 11

W 2.0040 TH. 2900 HOLE DIAM. .4415 A. .584 IN²

MAX STRESS 20 KSI FREQ. Fast (FM=250)

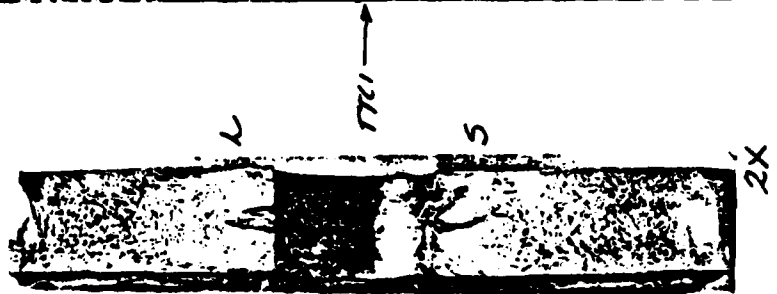
ENVIR. CONDS. Dry PREPS. PC

CYCLES TO FAILURE 164102 14 pts % LIFE ---

TTCI 9650 FLIGHT HOURS

LARGER FLAW = .378" (B)

SMALLER FLAW = .299" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
31	15693	.378
32	15600	.335
31	15300	.267
30	15000	.213
29	14700	.191
28	14400	.175
27	14100	.155
26	13800	.133
25	13500	.119
24	13200	.106
23	12900	.096
22	12600	.085
21	12300	.077
20	12000	.064
19	11700	.051
18	11400	.044
17	11100	.034
16	10800	.028
15	10500	.024
14	10200	.020
13	9900	.015
12	9600	.009
1		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 313 Open Hole
 SPECTROM: F18-300hr
 TEST DATE: 2-3-84 11
W 2.0030" TH .3070" HOLE DIAM .4455" A.6149.102
 MAX STRESS 28ksi FREQ: Fast (FN=250)
 ENVIR. CONDS. Day PREPS. PC
 CYCLES TO FAILURE 155972 14pts % LIFE * ---
 TTCI 7176 FLIGHT HOURS

LARGER FLAW = .416" (8)

SMALLER FLAW = .292" (8)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
47	14916	.416
48	14700	.340
47	14400	.280
46	14100	.235
45	13800	.204
44	13500	.178
43	13200	.150
42	12900	.137
41	12600	.122
40	12300	.108
39	12000	.097
38	11700	.090
37	11400	.079
36	11100	.073
35	10800	.060
34	10500	.052
33	10200	.044
32	9900	.039
31	9600	.033
30	9300	.030
29		
28		
27		
26		
25		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 314 Open Hole F
 SPECTROM: F18-300hr
 TEST DATE: 2-3-84 11
W 2.0065" TH .3030" HOLE DIAM. 44.35" A .6079 IN²
 MAX STRESS 28 KSI FREQ. (Fast FM=250)
 ENVIR. CONDS. Day PREPS. PC
 CYCLES TO FAILURE 120172 ldpts % LIFE —
 TTCI 4733 FLIGHT HOURS

LARGER FLAW = .420" (B)

SMALLER FLAW = .240" (B)



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
3831	11493	.420
38	11400	.325
37	11100	.311
36	10800	.268
35	10500	.237
34	10200	.212
33	9900	.198
32	9600	.188
31	9300	.162
30	9000	.150
29	8700	.136
28	8400	.125
27	8100	.114
26	7800	.095
25	7500	.083
24	7200	.070
23	6900	.058
22	6600	.047
21	6300	.040
20	6000	.033
19	5700	.024
18	5400	.020
17	5100	.016
16	4800	.011
15	4500	.0065
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FATIGUE TEST DATA

SPECIMEN NUMBER: 315 Open Hole F
 SPECTRUM: F18-300hr
 TEST DATE: 2-6-84 11
W 2.0015" TH .2960" HOLE DIAM. .4435" A .592A102
 MAX STRESS 28ksi FREQ. Fast (FM=250)
 ENVIR. CONDS. Dry PREPS. No
 CYCLES TO FAILURE 218044 Hrs % LIFE —

TTCI 15752 FLIGHT HOURSLARGER FLAW = .410" (B)SMALLER FLAW = .232" (B)

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
67.51	20853	.410
69	20700	.354
68	20400	.299
67	20100	.265
66	19800	.235
65	19500	.202
64	19200	.181
63	18900	.157
62	18600	.139
61	18300	.122
60	18000	.105
59	17700	.088
58	17400	.073
57	17100	.060
56	16800	.045
55	16500	.032
54	16200	.021
53	15900	.0125
52		
51		
50		
49		
48		
47		
46		
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FATIGUE TEST DATASPECIMEN NUMBER: 316 Open HoleSPECTRUM: F18-300HRTEST DATE: 2-6-84 11W 2.0035" TH .3010" HOLE DIAM .4405" A. 6031102MAX STRESS 28KSI FREQ. Fast (FM=250)ENVIR. CONDS. Day PREPS. NoCYCLES TO FAILURE 278098 14pts % LIFE —TTCI 22608 FLIGHT HOURSL LARGER FLAW = .472" (B)S SMALLER FLAW = .370" (B)

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
88.65	26.575	.472
88	26.400	.340
87	26.100	.267
86	25.900	.216
85	25.500	.173
84	25.200	.145
83	24.900	.120
82	24.600	.097
81	24.300	.068
80	24.000	.049
79	23.700	.035
78		
77		
76		
75		
74		
73		
72		
71		
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65		
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45		
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42		
41		

FATIGUE TEST DATA

SPECIMEN NUMBER: 317 Open hole

SPECTRUM: F18 300hr

TEST DATE: 2-6-84 11

W 2.0015" TH 2990" HOLE DIAM 4435" A 5985 MPa

MAX STRESS 28 KSI FREQ. Fast
FM = 250

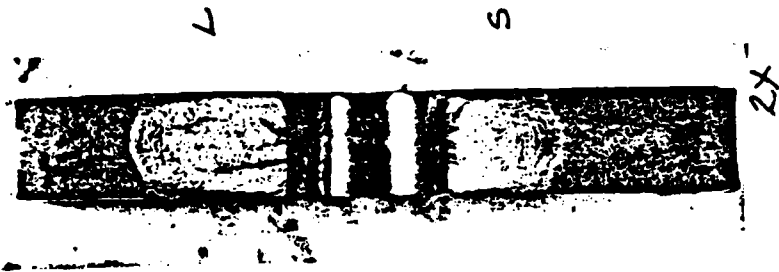
ENVIR. CONDS. Dry PREPS. ---

CYCLES TO FAILURE 261961 Hrs % LIFE ---

TTCI 10324 FLIGHT HOURS

LARGER FLAW = .430" B

SMALLER FLAW = .324" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
83.51	250.53	.430
82	249.00	.359
82	246.00	.295
81	243.00	.265
80	240.00	.242
79	237.00	.221
78	234.00	.207
77	231.00	.192
76	228.00	.187
75	225.00	.167
74	222.00	.152
73	219.00	.134
72	216.00	.119
71	213.00	.109
70	210.00	.097
69	207.00	.081
68	204.00	.073
67	201.00	.065
66	198.00	.059
65	195.00	.053
64	192.00	.046
63	189.00	.046
62	186.00	.044
61	183.00	.042
60	180.00	.040
59	177.00	.038
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49	147.00	.023
6		
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3		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 318 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-6-84 11

W 2.0010" TH .3020" HOLE DIAM .4415" A .6043 122

MAX STRESS 28 KSI FREQ. Slow (Freq. Multiplier = 40)

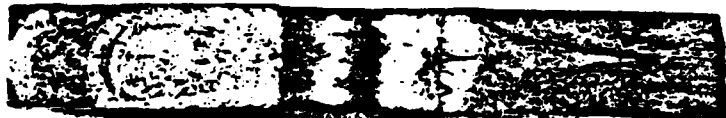
ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 153460 14745 % LIFE —

TTCI 12038 FLIGHT HOURS

LARGER FLAW = .554" (B)

SMALLER FLAW = .121" (B)



2X

FRAC TOG R A P H I C D A T A

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
48	14176	.554
47	14440	.413
46	14100	.315
45	13800	.239
44	13500	.154
43	13200	.109
42	12900	.080
41	12600	.036
40	12300	.017
	12000	.009
8		
7		
6		
5		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 319 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-7-84 11

W 2.0010" TH .3050" HOLE DIAM 4445" A. 6103 102

MAX STRESS 28 KSI FREQ. Slow (FM=40)

ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 111973 14 pts % LIFE —

TTCI 6517 FLIGHT HOURS

LARGER FLAW = .4830" (B)

SMALLER FLAW = .2875" (B)



2X

FRACTOGRAPHIC DATA		
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
35.65	10,707	.4830
35	10,500	.3465
34	10,200	.2955
33	9,900	.1855
32	9,600	.1620
31	9,300	.1395
30	9,000	.1105
29	8,700	.0885
28	8,400	.0720
27	8,100	.0595
26	7,800	.0455
25	7,500	.0365
24	7,200	.0285
23	6,900	
22	6,600	.0125
21	6,300	.0045
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

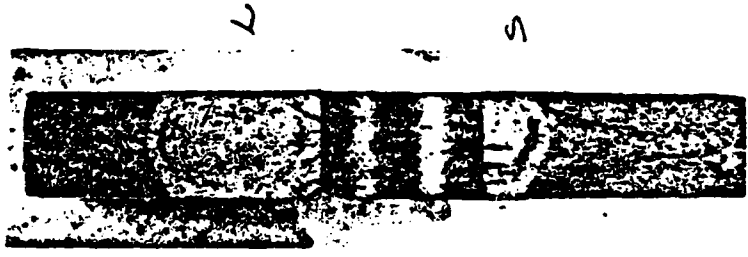
FATIGUE TEST DATA

SPECIMEN NUMBER: 320 Open Hole
 SPECTRUM: F18-300hr
 TEST DATE: 2-7-84 11
W1.9985" TH. 3020' HOLE DIAM. .4425" A. 6035 in²
 MAX STRESS 28ksi FREQ. Slew (FM=40)
 ENVIR. CONDS. 3.5% NaCl PREPS. No
 CYCLES TO FAILURE 124602 14pts % LIFE 74

TTCI 0447 FLIGHT HOURS

LARGER FLAW = (.487") (B)

SMALLER FLAW = .183" (B)



2x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
39.72	11916	.487"
39	11700	.362
38	11400	.277
37	11100	.205
36	10800	.158
35	10500	.126
34	10200	.086
33	9900	.072
32	9600	.055
31	9300	.044
30	9000	.028
29	8700	.018
28	8400	.0085
7		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 321 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-7-84 11

W 1.9995" TH 2980 HOLE DIAM .4435" A 5959122-F

MAX STRESS 28ksi FREQ Slow (FM=40)

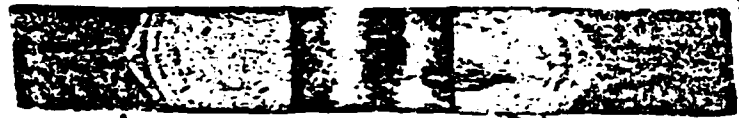
ENVIR COND 3.5% NaCl PREPS. No

CYCLE TO FAILURE 104322 Idpts % LIFE —

TIME TO FAILURE 104322 Idpts % LIFE —

CARTRIDGE FLAW 4555" B

SMALLER FLAW 3935" B



L

S

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
1		
2		
3		
4		
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7		
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99		
100		

FATIGUE TEST DATA

SPECIMEN NUMBER: 322 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-3-84 11

W 2.0045" TH .3030" HOLE DIAM .4405" A .6074" L

MAX STRESS 28 KSI FREQ. Slow (FM=40)

ENVIR. CONDS. 3.5% NaCl PREPS. PC

CYCLES TO FAILURE 82395 ldpts % LIFE —

TTCI 6076 FLIGHT HOURS

LARGER FLAW = .358" Ø

SMALLER FLAW = .3495" Ø



FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
2786	8358	.358
27	8100	.219
26	7800	.153
25	7500	.122
24	7200	.084
23	6900	.063
22	6600	.024
21	6300	.0135
20	6000	.007
19		
18		
17		
16		
15		
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0		
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2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 323(b) Open Hole

SPECTROM: F18-300hr

TEST DATE: 2-24-84 11

W2.000" TH .3020" HOLE DIAM. .4415" A. .6040 in

MAX STRESS 28 KSI FREQ. Slow (FM = 40)

ENVIR. CONDS. 3.5% NaCl PREPS. PC

CYCLES TO FAILURE 98837 1d pts.

TTCI 6097 FLIGHT HOURS

LARGER FLAW = .4725" (C)

SMALLER FLAW = .2835" (B)

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
31	9453	.4725
30	9300	.3715
29	9000	.2860
28	8700	.2915
27	8400	.1965
26	8100	.1635
25	7800	.1005
24	7500	.080
23	7200	.061
22	6900	.040
21	6600	.0235
0		
9		
8		
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0		
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2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 324 Open Hole

SPECTRUM: F18-300hr (B)

TEST DATE: 2-20-84 11

W 2.0000" TH .3035' HOLE DIAM .4425" A .6070 in F

MAX STRESS 28 KSI FREQ Slow (FM=40)

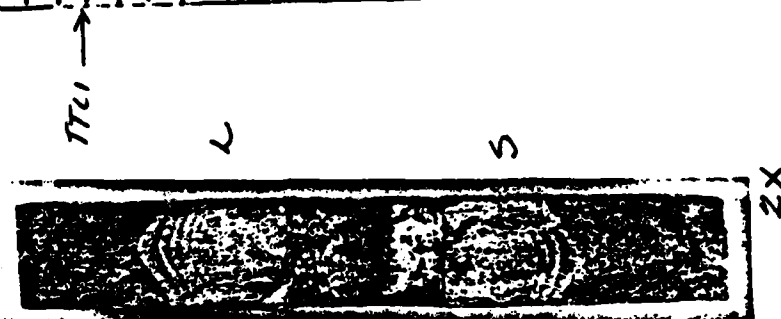
ENVIR. CONDS. 3.5% NaCl PREPS. pc

CYCLES TO FAILURE 261100 1dpts

TTCI 21772 FLIGHT HOURS

LARGER FLAW = .4255" (B)

SMALLER FLAW = .3770" (B)



FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
83.23	24969	.4255
83	24900	.395
82	24600	.2095
81	24300	.1490
80	24000	.1120
79	23700	.0855
78	23400	.0590
77	23100	.0510
76	22800	.0390
75	22500	.0310
74	22200	.023
73	21900	.013
72	21600	.0065
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FATIGUE TEST DATA

SPECIMEN NUMBER: 325 Open Hole
 SPECTRUM: F18-300hr
 TEST DATE: 2-14-84 11
 W 2.0010 TH .3015 HOLE DIAM .4425 A .6033 IN.
 MAX STRESS 28 KSI FREQ Slow (FM = 40)
 ENVIR. CONDS. 2.5% NaCl PREPS. pc
 CYCLES TO FAILURE 82219 1d pts

TTCI 5368 FLIGHT HOURS

LARGER FLAW = .4335 (B)

SMALLER FLAW = .289 (B)



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
1		
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99		
100		

FATIGUE TEST DATA

SPECIMEN NUMBER: 326 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-13-84 11

W 2.0010" TH. 3010' HOLE DIAM 4425" A. 6023"

MAX STRESS 28 KSI FREQ Slow (FM = 40)

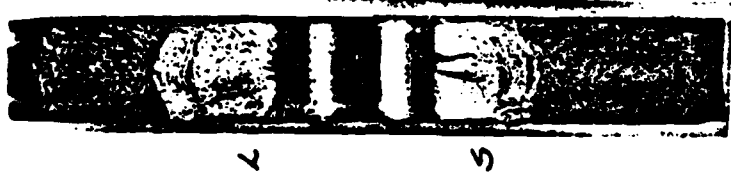
ENVIR. CONDS. Day PREPS. Ne

CYCLES TO FAILURE 237534 14 pts TR

TICI 20143 FLIGHT HOURS

LARGER FLAW = .349" B

SMALLER FLAW = .294" B



FRAC TOGRAPHIC DATA

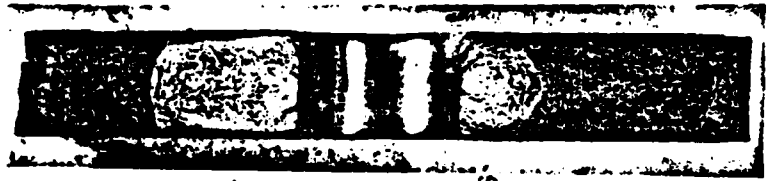
BLK #	FLIGHT HRS	CRACK LENGTH IN.
0		
9		
8		
7	22716	.349
6	22500	.271
5	22200	.189
4	21900	.152
3	21600	.103
2	21300	.077
1	21000	.052
0	20700	.029
9	20400	.016
8	20100	.009
7		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 327
 SPECTRUM: F18-300hr
 TEST DATE: 2-13-84 11
N 2.0015" TH, 3010" HOLE DIAM, 4415" A .6025"
 MAX STRESS 28 KSI FREQ Slow (FM=40)
 ENVIR. CONDS. Dry PREPS. No
 CYCLES TO FAILURE 256356 1dpts
 TTCT 21824 FLIGHT HOURS

LARGER FLAW = .406" B

SMALLER FLAW = .234" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 328 Open Hole

SPECTRUM: F18-300hr

TEST DATE: 2-13-84 11

W 2.000" TH .3025" HOLE DIAM .4415" A .6050"

MAX STRESS 28 KSI FREQ Slow (FM=40)

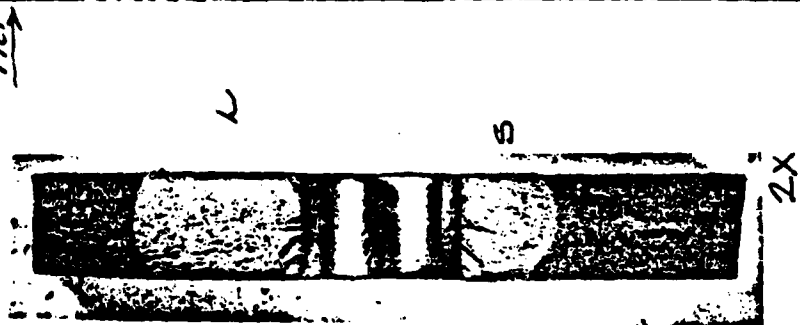
ENVIR. CONDS. Dry PREPS. No

CYCLES TO FAILURE 234721 ld. pbs.

TTCI 19800 FLIGHT HOURS

LARGER FLAW = .463" B

SMALLER FLAW = .265" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
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8		

FATIGUE TEST DATA

SPECIMEN NUMBER: 329 Open Hole

SPECTRUM: F18-300hr(8)

TEST DATE: 2-21-84 11

N 2.0005" TH .3015" HOLE DIAM .4965" A .6032 IN² F

MAX STRESS 28 KSI FREQ. Slow (FM = 40)

ENVIR. CONDS. Dry PREPS. PC

CYCLES TO FAILURE 168520 1dpts

TCI 12,797 FLIGHT HOURS

LARGER FLAW = .4125" (8)

SMALLER FLAW = .3545" (8)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
5372	16116	.4125
53	15900	.2915
32	15600	.231
31	15300	.199
30	15000	.169
49	14700	.142
48	14400	.114
47	14100	.076
45	13800	.0545
43	13500	.0340
44	13200	.020
43	12900	.0120
42	12600	
1		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 330
 SPECTRUM: F18-300bf(B)
 TEST DATE: 2-17-84 11

W 1.9990" TH .2950" HOLE DIAM .4470" A .5897

MAX STRESS 28 KSI FREQ Slow (FM=40)

ENVIR. CONDS. Dry PREPS. pc

CYCLES TO FAILURE 196089 1d pfs

TTCT 15650 FLIGHT HOURS

LARGER FLAW = .3715" (B)

SMALLER FLAW = .355" (B)



L S

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
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100		

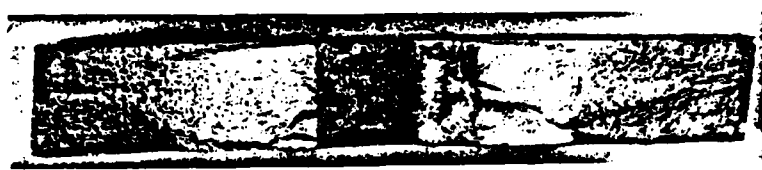
F 62.51 18753 .3715
 62 18600 .320
 61 18300 .264
 60 18000 .223
 59 17700 .169
 58 17400 .127
 57 17100 .074
 56 16800 .055
 55 16500 .035
 54 16200 .024
 53 15900 .015
 52 15600 .009
 50 15000
 49 14700
 48 14400
 47 14100
 46 13800
 45 13500
 44 13200
 43 12900
 42 12600
 41 12300
 40 12000
 39 11700
 38 11400
 37 11100
 36 10800
 35 10500
 34 10200
 33 9900
 32 9600
 31 9300
 30 9000
 29 8700
 28 8400
 27 8100
 26 7800
 25 7500
 24 7200
 23 6900
 22 6600
 21 6300
 20 6000
 19 5700
 18 5400
 17 5100
 16 4800
 15 4500
 14 4200
 13 3900
 12 3600
 11 3300
 10 3000
 9 2700
 8 2400
 7 2100
 6 1800
 5 1500
 4 1200
 3 900
 2 600
 1 300

FATIGUE TEST DATA

SPECIMEN NUMBER: 331
 SPECTRUM: F18-300hr(8)
 TEST DATE: 2-14-84 11
W1.9990" TH .2990" HOLE DIAM .4430" A .5977"
 MAX STRESS 28 KSI FREQ Slew (FM = 40)
 ENVIR. CONDS. Dry PREPS. PC
 CYCLES TO FAILURE 164101 14 pts
 TTCT 12175 FLIGHT HOURS

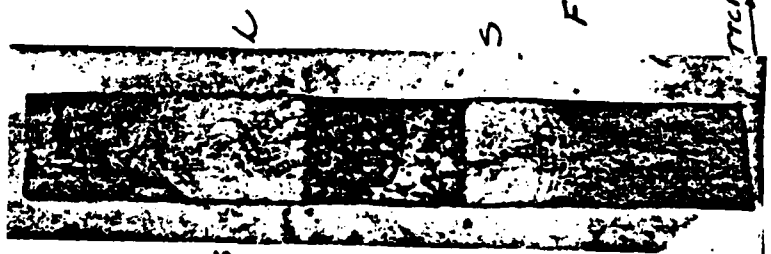
LARGER FLAW = .4325" (B)

SMALLER FLAW = .3050" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
331	15693	.4325
52	15600	.3850
51	15300	.3170
50	15000	.250
49	14700	.8095
48	14400	.1625
47	14100	.1325
46	13800	.0825
45	13500	.0665
44	13200	.0440
43	12900	.0280
42	12600	.0180
41	12300	.0120
9		
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FATIGUE TEST DATASPECIMEN NUMBER: 336 Open HakSPECTRUM: Fl6-400hr(A)TEST DATE: 3-1-84 11W 2.0040" TH .3010" HOLE DIAM. 4415" A. 6032"MAX STRESS 28 KSI FREQ. 1 LIFE = 16 days (Slew = 40)ENVIR. CONDS. 3.5% NaCl PREPS. pcCYCLES TO FAILURE 306 908 14 pts % LIFE = 40TTCI 851 FLIGHT HOURSLarge Flow = .440" BSmall Flow = .288" BFRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	.440
7	2800	.154
6	2400	.099
5	2000	.056
4	1600	.034
3	1200	.018
2	800	.009
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 337 Open Hole
 SPECTRUM: F16-400hr (A)
 TEST DATE: 3-9-84 11

W 2.0010" TH .3025" HOLE DIAM. .4415" A. .6013"

MAX STRESS 20ksi FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 3.5% NaCl PREPS. PC FH=10

CYCLES TO FAILURE 551385 14 pts % LIFE = 72

TTCI 4456 FLIGHT HOURS



Larger Flow = .5625" (B)

Smaller Flow = .086" (B)

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
19	7600	
18	7200	
17	6800	
16	6400	
14.47	5792	.5625
14	5600	.3480
13	5200	.1380
12	4800	.13
11	4400	.0770
10	4000	.0455
9	3600	.0335
8	3200	.0245
7	2800	.0195
6	2400	.0150
5	2000	.009
4	1600	
3	1200	
2	800	
1	400	

774

2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 338 20% LT
 SPECTRUM: F16-400hr(A)
 TEST DATE: 3-15-84 11

W 1.9970" TH. 2850" HOLE DIAM .4425" A. .5897"

MAX STRESS 28KSI FREQ. 1 LIFE = 16 days (Slow)
FM=40

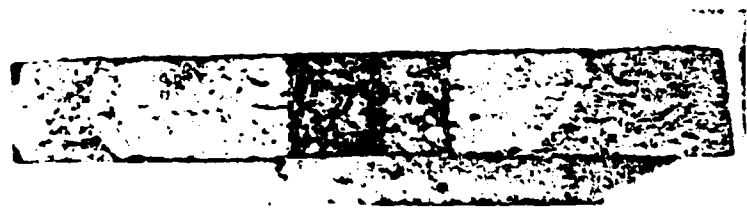
ENVIR. CONDS. 3.5% NaCl PREPS. PC

CYCLES TO FAILURE 378903 1 dpts % LIFE = 49

TTCI 2000 FLIGHT HOURS

Larger Flaw - .544" B

Smaller Flaw - .377" C



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FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
F 9.8	3927	.544
9	3600	.192
8	3200	.082
7	2800	.041
6	2400	.022
5	2000	.010
4	1600	.006
3	1200	
2	800	
1	400	

TTCI

FATIGUE TEST DATASPECIMEN NUMBER: 515 Open HoleSPECTRUM: F18 BLOCKEST DATE: 5-10-84 11W 1.9955" TH .3050" HOLE DIAM .5030" A .6086"MAX STRESS 28 KSI FREQ Fast (FM = 2.50)ENVIR. CONDS. Dry PREPS. NoCYCLES TO FAILURE 523879 14 pts.TTCI 27709 FLIGHT HOURSLARGER FLAW = .388" (B)SMALLER FLAW = .242" (B)FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
167	50100	.388
166	48800	.346
165	48500	.298
164	48200	.277
163	47900	.252
162	47600	.339
161	47300	.223
160	47000	.208
150	45000	.108
140	42000	.066
130	39000	.045
120	36000	.030
110	33000	.019
100	30000	.0135
90	27000	.0080
80		
70		
60		
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40		
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6		
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4		
3		
2		
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FATIGUE TEST DATASPECIMEN NUMBER: 516 Open HoleSPECTRUM: F18 BLACKTEST DATE: 5-16-84 11N 2.0050" TH. 2965" HOLE DIAM. .5065" A. .5924"M₁ STRESS 28 KSI FREQ. Fast (FM = 250)ENVIR. CONDS. Dry PREPS. NoCYCLES TO FAILURE 330,397 14 ptsTTCT 10,789 FLIGHT HOURSLARGER FLAW = .408" (B)SMALLER FLAW = .278" (B)FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
103.32	31,596	.408"
102	31,200	.308
103	30,900	.270
102	30,600	.245
101	30,300	.224
100	30,000	.210
99	29,700	.192
98	29,400	.179
97	29,100	.165
96	28,800	.152
95	28,500	.140
94	28,200	.128
93	27,900	.116
92	27,600	.104
91	27,300	.092
90	27,000	.080
89	26,700	.068
88	26,400	.056
87	26,100	.044
86	25,800	.032
85	25,500	.020
84	25,200	.017
83	24,900	.014
82	24,600	.011
81	24,300	.008
80	24,000	.005
79	23,700	.002
78	23,400	.001
77	23,100	.000
76	22,800	.000
75	22,500	.000
74	22,200	.000
73	21,900	.000
72	21,600	.000
71	21,300	.000
70	21,000	.000
69	20,700	.000
68	20,400	.000
67	20,100	.000
66	19,800	.000
65	19,500	.000
64	19,200	.000
63	18,900	.000
62	18,600	.000
61	18,300	.000
60	18,000	.000
59	17,700	.000
58	17,400	.000
57	17,100	.000
56	16,800	.000
55	16,500	.000
54	16,200	.000
53	15,900	.000
52	15,600	.000
51	15,300	.000
50	15,000	.000
49	14,700	.000
48	14,400	.000
47	14,100	.000
46	13,800	.000
45	13,500	.000
44	13,200	.000
43	12,900	.000
42	12,600	.000
41	12,300	.000
40	12,000	.000
39	11,700	.000
38	11,400	.000
37	11,100	.000
36	10,800	.000
35	10,500	.000
34	10,200	.000
33	9,900	.000
32	9,600	.000
31	9,300	.000
30	9,000	.000
29	8,700	.000
28	8,400	.000
27	8,100	.000
26	7,800	.000
25	7,500	.000
24	7,200	.000
23	6,900	.000
22	6,600	.000
21	6,300	.000
20	6,000	.000
19	5,700	.000
18	5,400	.000
17	5,100	.000
16	4,800	.000
15	4,500	.000
14	4,200	.000
13	3,900	.000
12	3,600	.000
11	3,300	.000
10	3,000	.000
9	2,700	.000
8	2,400	.000
7	2,100	.000
6	1,800	.000
5	1,500	.000
4	1,200	.000
3	900	.000
2	600	.000
1	300	.000



2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 517 Open HoleSPECTRUM: F18 BLOCKTEST DATE: 5-16-84 11* 1.9935" TH. 2970" HOLE DIAM. 5050" A. 5920"MAX STRESS 28 KSI FREQ. Fast (FM = 250)ENVIR. CONDS. Dry PREPS. NoCYCLES TO FAILURE 678804 ld ptsTTCT 40500 FLIGHT HOURSLARGER FLAW = .648" (B)SMALLER FLAW = .344" (B)

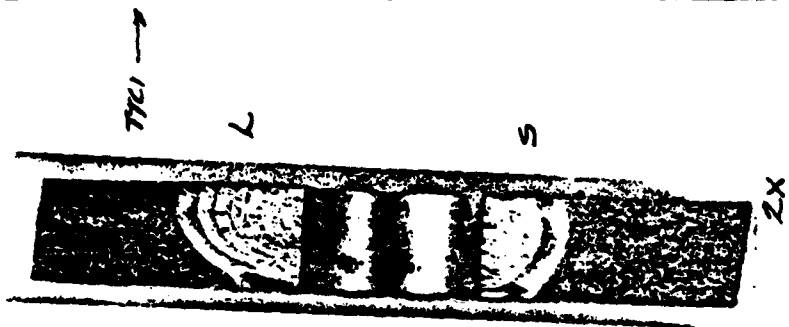
FRACTOGRAPHIC DATA		
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
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15		
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97		
98		
99		
100		

FATIGUE TEST DATA

SPECIMEN NUMBER: 518 Open Hole
 SPECTRUM: F18 BLOCK
 TEST DATE: 5-17-84 11
N 1.9955" TH .2960" HOLE DIAM .5030" A .5906"
 MAX STRESS 28 KSI FREQ. Fast (FM = 250)
 ENVIR. CONDS. 3.5% NaCl PREPS. No
 CYCLES TO FAILURE 213317 14 pts.
 TTCT 15,200 FLIGHT HOURS

LARGER FLAW = .355" (B)

SMALLER FLAW = .240" (B)

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
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91		
92		
93		
94		
95		
96		
97		
98		
99		
100		

FATIGUE TEST DATA

SPECIMEN NUMBER: 519 Open Hole

SPECTRUM: F18 BLOCK

TEST DATE: 5-18-84 11

W 2.0020" TH .2945" HOLE DIAM .5030" A .5895" F

MAX STRESS 28 KSI FREQ Fast (FM = 2.50)

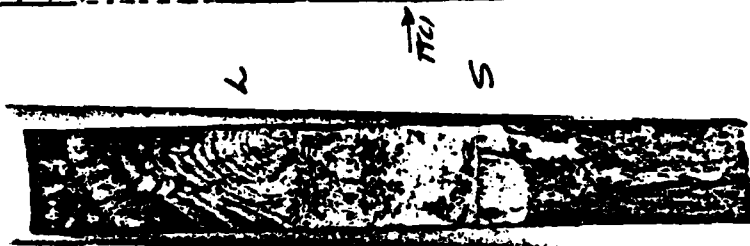
ENVIR. CONDS. 3.5% NaCl PREPS. N6

CYCLES TO FAILURE 203905 14 pfs.

TTCT 4500 FLIGHT HOURS

LARGER FLAW = .627" (C)

SMALLER FLAW = .134" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5	19500	.627
4	19200	.541
3	18900	.432
2	18600	.405
1	18300	.368
0	18000	.332
9	17700	.294
8	17400	.259
7	17100	.229
6	16800	.199
5	16500	.175
4	16200	.151
3	15900	.134
2	15600	.118
1	15300	.106
0	15000	.095
9	14700	.087
8		
7	13000	.035
6		
5	9000	.013
4		
3	4500	.010
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 520 Open Hole

SPECTRUM: F18 BLOCK

TEST DATE: 5-18-84 11

W 2.0045" TH .3010" HOLE DIAM .5050" A .6033" F

MAX STRESS 28 KSI FREQ. F2st (FM=250)

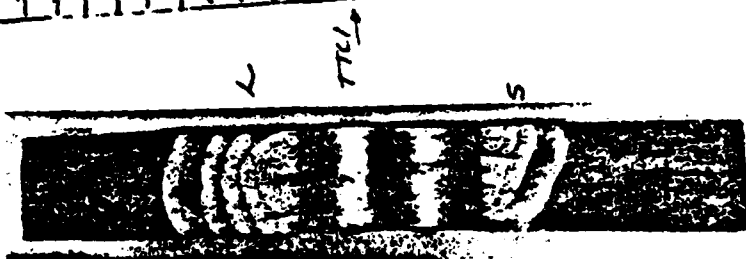
ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 200768 ld pfs

TTCI 11,100 FLIGHT HOURS

LARGER FLAW = .380" (B)

SMALLER FLAW = .241" (B)



FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
64	19200	.380
63	18900	.341
62	18600	.237
61	18300	.178
60	18000	.121
59	17700	.097
58	17400	.080
57	17100	.067
56	16800	.058
55	16500	.051
54	16200	.046
53	15900	.042
52	15600	.039
51	15300	.036
50	15000	.033
49	14700	.021
48	14400	.014
47	14100	.010
46	13800	
45	13500	
44	13200	
43	12900	
42	12600	
41	12300	
40	12000	
39	11700	
38	11400	
37	11100	
36	10800	
35	10500	
34	10200	
33	9900	
32	9600	
31	9300	
30	9000	
29	8700	
28	8400	
27	8100	
26	7800	
25	7500	
24	7200	
23	6900	
22	6600	
21	6300	
20	6000	
19	5700	
18	5400	
17	5100	
16	4800	
15	4500	
14	4200	
13	3900	
12	3600	
11	3300	
10	3000	
9	2700	
8	2400	
7	2100	
6	1800	
5	1500	
4	1200	
3	900	
2	600	
1	300	

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APPENDIX F

SPECTRUM FATIGUE TEST RESULTS AND FRACTOGRAPHIC DATA FOR TASK 6 (7075-T7651 ALUMINUM ALLOY)

Spectrum fatigue test results for the dog-bone specimens (Fig. 3) tested under Task 6 are summarized in Table F1. Fractographic data sheets are also presented in this appendix.

The maximum positive load in each load spectra, including overloads, was considered to be the 100% load level. The maximum positive test load for each spectra was selected to produce the desired gross stress on the specimen cross section. All other loads positive and negative in each respective test spectra were "scaled" to the 100% load level. As a result, "overloads" in the F-18 300 hour spectrum were treated as 100% load levels rather than a percentage greater than the 100% load level.

Fatigue loading frequencies for all spectrum tests, including the F-18 300 hour spectrum, were based on the test rates set for the F-16 400 hour spectrum tests. Loading rates were selected to complete 8000 equivalent flight hours of the F-16 400 hour spectrum in a selected number of days (24 hours a day continuous testing). Three basic loading frequencies were considered: (1) F = fast (8000 flight hours/2 days), (2) S = slow (8000 flight hours/16 days) and (3) A = extra slow (8000 flight hours/90 days). Accordingly, test machine frequency multipliers (FM) were set for the three basic frequencies: Fast (FM = 250), slow (FM = 40) and extra slow (FM = 1). The frequency multipliers can only be translated into actual frequency measurements for constant amplitude loading.

Table F1 Summary of Dog-Bone Specimen Fatigue Test
Results for Task 6 (7075-T7651 Aluminum)

SPECIMEN NO.	TEST I.D. (a)	DATA SET NO.	TEST DATE	SPECIMEN DETAILS				FATIGUE CRACK ORIGIN (b)	TTCI (FLT. HRS.) (c)	TTF (FLT. HRS.) (d)	TTF-TTCI (FLT. HRS.) (e)	TTCI/TTF
				WIDTH (IN)	THICK (IN)	HOLE DIA (IN.)	GROSS AREA (IN ²)					
66	A-28/20/F/W	16	6-20-83	2.0	.2975	.4444	.5950	B	3400	8904	5504	.38
68	A-28/20/F/W	16	7-6-83	2.0139	.3079	(h) -	.6201	B	4508	7600	3092	.59
69	A-28/20/S/W	18	7-11-83	2.0800	.3040	.4450	.6323	B	1662	5607	3945	.29
70	A-28/20/S/W	18	7-11-83	2.0065	.3040	.447	.6099	B	3665	7068	3403	.52
73	A-28/20/S/D	17	7-20-83	2.0450	.3040	.4455	.6217	B	14100	24800	10700	.57
74	A-28/20/F/D	15	7-21-83	2.0350	.3030	.446	.6166	B	8800	18000	9200	.49
75	A-28/20/F/D	15	8-1-83	2.010	.3025	.4405	.6080	B	10203	20000	9797	.51
80	A-28/20/F/D	15	8-9-83	1.9995	.3035	.4410	.6068	B	16800	28000	11200	.600
308	B-28/20/F/D	30	2-6-84	2.0010	.3030	.4405	.6063	B	7228	11163	3935	.65
309	B-28/20/F/D	30	2-7-84	2.0035	.3010	.4415	.6031	B	8100	12037	3917	.67
310	B-28/20/F/D	30	2-8-84	1.9990	.3020	.4435	.6037	B	17115	21037	3922	.81
311	B-28/20/F/D	30	2-9-84	1.9995	.3020	.4435	.6039	B	8764	11916	3152	.74
332	B-28/20/F/W	29	2-17-84	2.0000	.3010	.4465	.6020	B	6343	11358	5015	.56
333	B-28/20/F/W	29	2-20-84	2.0005	.3030	.4415	.6062	B	11311(f)	14253	2942	.79
334	B-28/20/F/W	29	2-21-84	2.0000	.3020	.4430	.6040	B	6712	9258	2546	.72
335	B-28/20/F/W	29	2-23-84	2.0020	.3015	.4435	.6036	B	7799(f)	9858	2059	.79
500	B-28/40/F/D	31	5-2-84	2.0025	.3065	.4455	.6138	B	16800	19653	2853	.85
501	B-28/40/F/D	31	5-3-84	1.9995	.3020	.4460	.6039	B	21522	25236	3714	.85
502	B-28/40/F/D	31	5-3-84	2.0000	.3035	.4445	.6070	B	16064	19716	3652	.81
503	B-28/40/F/W	32	5-7-84	2.0010	.3020	.4435	.6043	B	6633	8916	2283	.74
504	B-28/40/F/W	32	5-7-84	2.0010	.3030	.4440	.6063	B	8218	11446	3228	.72
505	B-28/40/F/W	32	5-9-84	2.0000	.3030	.4435	.6060	B	5127	7836	2709	.65
506	A-28/40/F/D	19	4-16-84	2.0025	.3020	.4450	.6048	B	11736	24835	13099	.47
507	A-28/40/F/D	19	4-17-84	2.0030	.3020	.4450	.6049	B	16000	30006	14006	.53
508	A-28/40/F/D	19	4-23-84	2.0015	.3030	.4440	.6065	B	22218	36006	13788	.62
509	A-28/40/F/W	20	4-23-84	2.0010	.3015	.4450	.6033	B	6048	11206	5158	.54
510	A-28/40/F/W	20	4-25-84	2.0030	.3030	.4455	.6069	B	5149	8400	3251	.61
511	A-28/40/F/W	20	4-27-84	2.0015	.3000	.4455	.6005	B	6821	9635	2814	.71
521	C-28/40/F/D	35	5-10-84	2.0030	.3015	.4455	.6039	B	9591(f)	30600	21009	.31
522	C-28/40/F/D	35	5-10-84	2.0010	.3015	.4470	.6033	B	16200	33300	17100	.49
523	C-28/40/F/D	35	5-14-84	2.0020	.3020	.4465	.6046	B	21278	40200	18922	.53
524	C-28/F/W	36	5-14-84	2.0000	.2995	.5030	.5990	B	6900	13500	6600	.51
525	C-28/F/W	36	5-16-84	1.9965	.3005	.5030	.5999	B	6600	13800	7200	.48
526	C-28/F/W	36	5-17-84	2.0025	.3005	.5045	.6017	B	955(g)	9900	8945	.09

Notes For Table F1

- (a) Ref. Table 8 for description code
- (b) Fatigue Crack Origins: B = bore of hole, C = Corner of hole and S = surface crack away from hole
- (c) Time to initiate crack depth of 0.010" in fastener hole (determined from fractographic results)
- (d) Time-to-failure
- (e) Time spent in crack growth
- (f) Extrapolation based on power law (Eqs. 1 and 3)
- (g) Linear extrapolation from two smallest consecutive crack sizes from fractographic data sheet
- (h) Diameter measurement not recorded

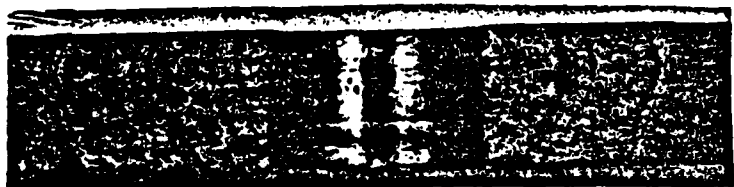
FATIGUE TEST DATASPECIMEN NUMBER: 66 ^{20%} (Lead Trans.)SPECTRUM: 400hr(A)TEST DATE: 6-30-83 //W 2.0" TH. 2975" HOLE DIAM. .4444" A. .5950 in²MAX STRESS 28 ksi FREQ. 1 LIFE = 2 days (Fast)
F_A = 250ENVIR. CONDS. 3.5% NaCl PREPS. noneCYCLES TO FAILURE 852414 14 pts % LIFE = 111.32TTCI 3400 FLIGHT HOURSSmaller Flow = .249" BLarger Flow = .5470" B

(F) 22.264

7211 →

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	8904	.5470
22	8800	
21	8400	.3790
20	8000	.2720
19	7600	.1870
18	7200	.1275
17	6800	.0820
16	6400	.0625
15	6000	.0480
14	5600	.0320
13	5200	.0250
12	4800	.0220
11	4400	.0190
10	4000	.0145
9	3600	.0115
8	3200	.0085
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 68 (2070 LT)SPECTRUM: 400hr (A)TEST DATE: 7-6-83 11W 2.0139" TH .3079" HOLE DIAM A .6201 in²MAX STRESS 28 KSI FREQ 1 LIFE = 2 days (Fast)ENVIR. CONDS. 3.5 % NaCl PREPS. noneCYCLES TO FAILURE 727457 ld pts. % LIFE = 95.0TTCT 4508 FLIGHT HOURS*Smallest Flaw = .4038" B**Larger Flaw = .4510" B*

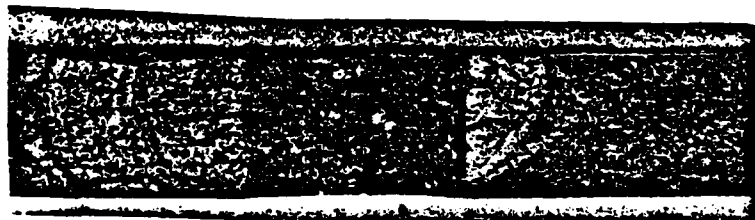
(F)

TTC

2.6X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	.4510
18	7200	.2365
17	6800	.1180
16	6400	.0630
15	6000	.0360
14	5600	.0240
13	5200	.0115
12	4800	.0135
11	4400	.0085
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATASPECIMEN NUMBER: 69 (20% LT)SPECTRUM: 400 hr (A)TEST DATE: 7-11-83 //W 2.0800" TH 3040" HOLE DIAM .445" A .6323 in²MAX STRESS 20 Ksi FREQ 1 LIFE = 16 days (Slow) ^{FM-40}ENVIR. CONDS. 3.5% NaCl PREPS. noneCYCLES TO FAILURE 536655 14 pts. % LIFE = 70.08TTCI 1662 FLIGHT HOURSSmaller Flaw = .152" BLarger Flaw = .4155" B

(F) 14.016

S

TTCI →

2.63X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
14.02	5608	.4155
14	5600	
13	5200	.2230
12	4800	.1545
11	4400	.1265
10	4000	.1025
9	3600	.0840
8	3200	.0635
7	2800	.0490
6	2400	.0275
5	2000	.0165
4	1600	.0090
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 70 (20% LT)
 SPECTRUM: 400 hr. (A)
 TEST DATE: 7-11-83 //
W 2.0065" TH. 3040 HOLE DIAM .447" A. 6099 in²
 MAX STRESS 20 KSI FREQ. 1 LIFE = 16 days (Slow)
 ENVIR. CONDS. 35% NaCl PREPS. none
 CYCLES TO FAILURE 677380 id pts % LIFE = 88.46

TTCI 3665 FLIGHT HOURS

Smaller Flaw = .380" B

Larger Flaw = .6415" B



2.63X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
	7268	.6415
17	6800	.3985
16	6400	.2160
15	6000	.1155
14	5600	.0640
13	5200	.0410
12	4800	.0280
11	4400	.0230
10	4000	.0130
9	3600	.0095
8	3200	
7	2800	
6	2400	
5	2000	
4	1600	
3	1200	
2	800	
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: T3 (20%LT)

SPECTRUM: 400 hr (A)

TEST DATE: 7-20-83 11 AM

W 2.0450" TH .3040" HOLE DIAM .4455" A .6217 in

MAX STRESS 28 FREQ 1 LIFE = 16 days (Slow)
PM-40

ENVIR. CONDS. Dry PREPS. ---

CYCLES TO FAILURE 2374269 kpts % LIFE = 310

TTCI 14100 FLIGHT HOURS

Smaller Flow = .300" B

Larger Flow = .4850" B



L

S

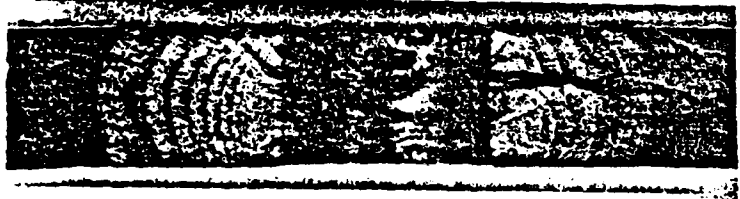
2X

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0175
39	15600	.0175
38	15200	.0150
37	14800	.0135
36	14400	.0115
35	14000	.0095
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	
29	11600	
28	11200	
27	10800	
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	.4850
21	8400	.3895
20	8000	.3085
19	7600	.2605
18	7200	.2135
17	6800	.1780
16	6400	.1530
15	6000	.1300
14	5600	.1095
13	5200	.0900
12	4800	.0790
11	4400	.0690
10	4000	.0600
9	3600	.0525
8	3200	.0455
7	2800	.0405
6	2400	.0360
5	2000	.0325
4	1600	.0300
3	1200	.0260
2	800	.0240
1	400	.0220

FATIGUE TEST DATA

SPECIMEN NUMBER: 74 (20% LT)
 SPECTRUM: 400hr (A)
 TEST DATE: 7-21-83 //
W 2.0350" TH 3030" HOLE DIAM 446" A 6166 in²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. None
 CYCLES TO FAILURE 1723550 4 pts % LIFE = 22.5
 TTCT 2800 FLIGHT HOURS
Smaller Flaw = .362" B
Larger Flaw = .3055" B



L

S

2.48x

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.1405
39	15600	.1150
38	15200	.0950
37	14800	.0765
36	14400	.0630
35	14000	.0560
34	13600	.0495
33	13200	.0445
32	12800	.0395
31	12400	.0355
30	12000	.0320
29	11600	.0295
28	11200	.0255
27	10800	.0225
26	10400	.0190
25	10000	.0170
24	9600	.0150
23	9200	.0120
22	8800	.0100
21	8400	.0080
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	
9	3600	
8	3200	
7	2800	
6	2400	
5	16000	.3855
44	17600	.3320
43	17200	.2470
42	16800	.2025
41	16400	.1690

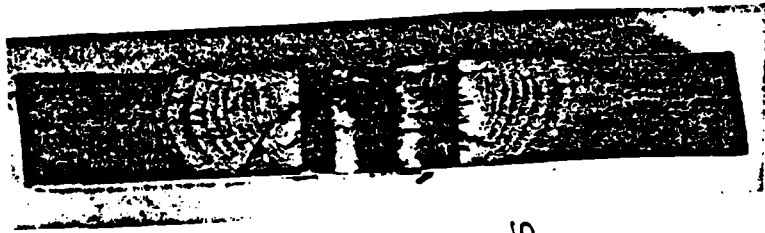
FATIGUE TEST DATA

SPECIMEN NUMBER: 75 (207LT)
 SPECTRUM: 400bf(A)
 TEST DATE: 8-1-83 //
W 2.010" TH .3025" HOLE DIAM .4405" A .6080 in²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 7 days (Fast)
 ENVIR. CONDS. Dry PREPS. FM²⁵⁰
 CYCLES TO FAILURE 1917739 1d pts % LIFE = 250

TTCI 10,203 FLIGHT HOURS

Smaller Flaw = .330" B

Larger Flaw = .390" B



L

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2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0840
39	15600	.0740
38	15200	.0650
37	14800	.0590
36	14400	.0530
35	14000	.0460
34	13600	.0400
33	13200	.0350
32	12800	.0315
31	12400	.0260
30	12000	.0225
29	11600	.0200
28	11200	.0160
27	10800	.0130
26	10400	
25	10000	
24	9600	
23	9200	
22	8800	
21	8400	
20	8000	
19	7600	
18	7200	
17	6800	
16	6400	
15	6000	
14	5600	
13	5200	
12	4800	
11	4400	
10	4000	.3900
9	3600	.3320
8	3200	.2770
7	2800	.2370
6	2400	.2040
5	2000	.1750
4	1600	.1520
3	1200	.1265
2	800	.1100
1	400	.0955

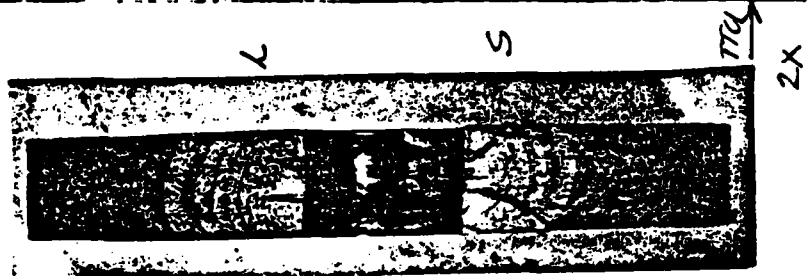
FATIGUE TEST DATA

SPECIMEN NUMBER: 80 (20% LT)
 SPECTRUM: 400 hr (A)
 TEST DATE: 8-9-83 //
W 1.9995" TH .3035" HOLE DIAM .4410" A .6068 in²
 MAX STRESS 28 KSI FREQ. 1 LIFE = 2 days (Fast)
 ENVIR. CONDS. Dry PREPS. FM-250
 CYCLES TO FAILURE 2680756 1d pks % LIFE = 350

TTCI 16,800 FLIGHT HOURS

Smaller Flow = .510" B

Larger Flow = .388" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	
39	15600	
38	15200	
37	14800	
36	14400	
35	14000	
34	13600	
33	13200	
32	12800	
31	12400	
30	12000	.3880
29	11600	.2670
28	11200	.2260
27	10800	.1855
26	10400	.1580
25	10000	.1300
24	9600	.1120
23	9200	.0990
22	8800	.0810
21	8400	.0685
20	8000	.0605
19	7600	.0545
18	7200	.0485
17	6800	.0450
16	6400	.0405
15	6000	.0365
14	5600	.0340
13	5200	.0310
12	4800	.0285
11	4400	.0260
10	4000	.0230
9	3600	.0210
8	3200	.0190
7	2800	.0170
6	2400	.0150
5	2000	.0135
4	1600	.0125
3	1200	.0115
2	800	.0100
1	400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 308 Load Trans (20%)
 SPECTRUM: F18 300hr(B)
 TEST DATE: 2-6-84 //
W 2.0010" TH .3030" HOLE DIAM. 4405" A. 6063 in²
 MAX STRESS 28 KSI FREQ. Fast
 ENVIR. CONDS. DAY PREPS. (FM-250)
 CYCLES TO FAILURE 116727 1 dpts % LIFE —
 TTCT 7228 FLIGHT HOURS

LARGER FLAW = .483" B

SMALLER FLAW = .225" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
3721	11162.9	.483
37	11100	.441
36	10800	.338
35	10500	.280
34	10200	.234
33	9900	.193
32	9600	.153
31	9300	.120
30	9000	.096
29	8700	.078
28	8400	.064
27	8100	.047
26	7800	.020
25	7500	.016
24		
23		
22		
21		
20		
19		
18		
17		
16		
15		
14		
13		
12		
11		
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 309 20% Load Trans.

SPECTRUM: F18-300hr (B)

TEST DATE: 2-7-84 11

W 2.0035" TH. .3010" HOLE DIAM. .4415" A. .6031in F

MAX STRESS 28 KSI FREQ. Fast (FM=250)

ENVIR. CONDS. DRY PREPS. ---

CYCLES TO FAILURE 125862 14 pts % LIFE = ---

TTCI 8100 FLIGHT HOURS blocks = 40.12

LARGER FLAW = .4075" (B)

SMALLER FLAW = .2945" (B)



FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
40.12	12037	.4075
40	12000	.390
39	11700	.291
38	11400	.210
37	11100	.1495
36	10800	.094
35	10500	.068
34	10200	.052
33	9900	.0405
32	9600	.0325
31	9300	.027
30	9000	.0225
29	8700	.018
28	8400	.014
27	8100	.010
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8		
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5		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 310 20%LT

SPECTRUM: F18-3000r (B)

TEST DATE: 2-8-84 11

W1.9990 TH. 3020" HOLE DIAM. 4435" A. 6037 IN.

MAX STRESS 28 KI FREQ. Fast (FM=250)

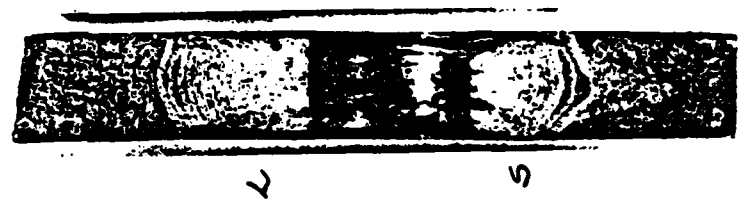
ENVIR. CONDS. dry PREPS. No

CYCLES TO FAILURE 219972 14 pts % LIFE = 771

TTCI 17115 FLIGHT HOURS

LARGER FLAW = .4195" (B)

SMALLER FLAW = .380" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
70	21000	.4045
69	20700	.2870
68	20400	.224
67	20100	.1855
66	19800	.1490
65	19500	.1195
64	19200	.1025
63	18900	.082
62	18600	.0675
61	18300	.0535
60	18000	.042
59	17700	.038
58	17400	.0195
57	17100	.0095
56		
55		
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14		
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9		
8		
7		
6		
5		
4		
3		
2		
1		
7112	21336	.4195

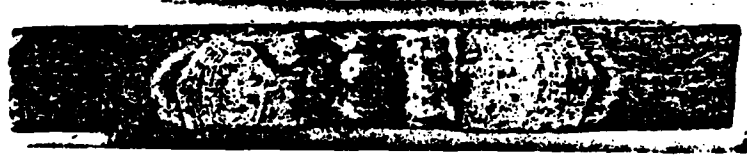
2X F

FATIGUE TEST DATA

SPECIMEN NUMBER: 311 20% LT
 SPECTRUM: F18-300 hr (B)
 TEST DATE: 2-9-84 11
W 1.9995" TH .3020" HOLE DIAM. 44.35" A. 60.39 IN.
 MAX STRESS 20 KSI FREQ. Fast (FM=250)
 ENVIR. CONDS. DRY PREPS. No PREP
 CYCLES TO FAILURE 124602 4pts % LIFE —
 TTCT 8764 FLIGHT HOURS

LARGER FLAW = .448" (B)

SMALLER FLAW = .4215" (B)



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
39.12	11.916	.448
39	11.900	.344
38	11.400	.231
37	11.100	.165
36	10.800	.1025
35	10.500	.078
34	10.200	.057
33	9.900	.039
32	9.600	.029
31	9.300	.0215
30	9.000	.0155
29	8.700	.0085
28		
27		
26		
25		
24		
23		
22		
21		
20		
19		
18		
17		
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4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 332 20% LT

SPECTRUM: F18-300hr (a)

TEST DATE: 2-17-84 11

W 2.0000" TH .3010" HOLE DIAM .4465" A .6020"

MAX STRESS 28 KSI FREQ. Fast (FM=250)

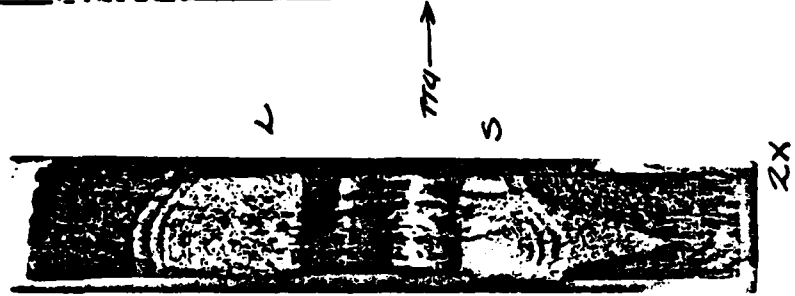
ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 118764 14 pts.

TTCI 6343 FLIGHT HOURS

LARGER FLAW = .4630" (B)

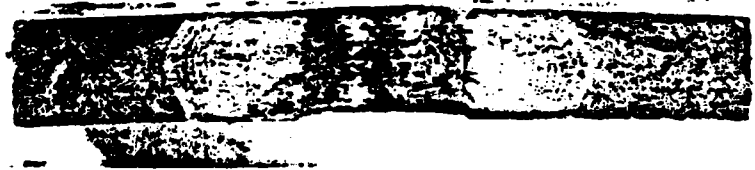
SMALLER FLAW = .3025" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
3786	11358	.4630
37	11100	.332
36	10800	.2505
35	10500	.1815
34	10200	.166
33	9900	.1455
32	9600	.1290
31	9300	.1175
30	9000	.1030
29	8700	.089
28	8400	.0805
27	8100	.068
26	7800	.054
25	7500	.043
24	7200	.030
23	6900	.023
22	6600	.016
21	6300	.009
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 333 20% LTSPECTRUM: F18-3000hr (B)TEST DATE: 2-20-84 11W 2.0005" TH. 3030" HOLE DIAM. .4415" A. .6062"MAX STRESS 28 KSI FREQ. Fast (FM = 250)ENVIR. CONDS. 3.5% NaCl PREPS. NoCYCLES TO FAILURE 149030 14 pts.TTCI 11311 FLIGHT HOURSLARGER FLAW = .387" BSMALLER FLAW = .355" B

2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
1	14253	.387
2	14100	.268
3	13800	.184
4	13500	.134
5	13200	.094
6	12900	.074
7	12600	.065
8	12300	.046
9	12000	T .026
10	11700	T .019
11	11400	T .011
12		
13		
14		
15		
16		
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47		
48		
49		
50		

FATIGUE TEST DATA

SPECIMEN NUMBER: 334
 SPECTRUM: E18-300hr (B)
 TEST DATE: 2-21-84 11
W 2.000" TH .3020" HOLE DIAM .4430" A .6040"
 MAX STRESS 28 KSI FREQ Fast (FM = 250)
 ENVIR. CONDS. 3.5% Nacl PREPS. No
 CYCLES TO FAILURE 96805 14 pts
 TTCI 6712 FLIGHT HOURS

LARGER FLAW = .4375" (B)

SMALLER FLAW = .2225" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
2		
30.86	9258	.4735
30	9000	.3280
29	8700	.2500
28	8400	.1910
27	8100	.1385
26	7800	.1050
25	7500	.051
24	7200	.0335
23	6900	.0150
22	6600	.0070
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 335 2070 LT

SPECTRUM: F18-300hr (B)

TEST DATE: 2-23-84 11

W 2.0020" TH .3015" HOLE DIAM 4435" A. 6036"

MAX STRESS 28 KSI FREQ: Fast (FM = 2.50)

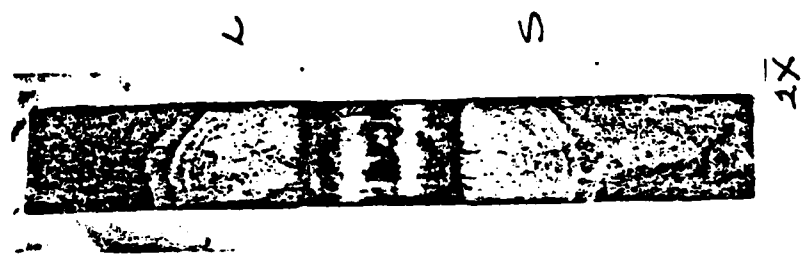
ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 103079 1d pbs.

TTCI 7799 FLIGHT HOURS

LARGER FLAW = .429" B

SMALLER FLAW = .411" B



FRACTOGRAPHIC DATA

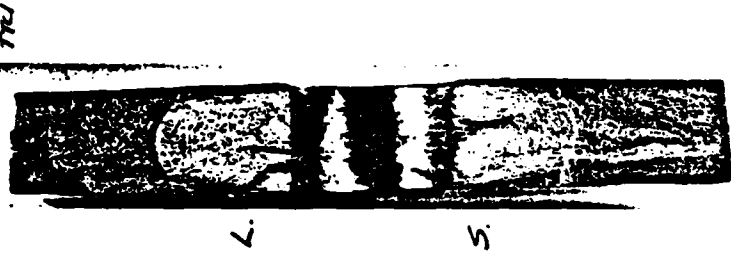
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
3		
32	9858	.429
31	9600	.267
30	9300	.216
29	9000	.153
28	8700	.098
27	8400	.067
26	8100	.028
25	7800	.011
24		
23		
22		
21		
20		
19		
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17		
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14		
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12		
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2		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 500 40% LT
 SPECTROM: F18-300hr (B)
 TEST DATE: 5-2-84 11
W2.0025" TH .3065" HOLE DIAM .4455" A .6138"
 MAX STRESS 28 KSI FREQ Fast (FM = 250)
 ENVIR. CONDS. Dry PREPS. No
 CYCLES TO FAILURE 205496 14 pts
 TTCT 16,800 FLIGHT HOURS

LARGER FLAW = .373" B

SMALLER FLAW = .347" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
9		
8		
7		
65.51	19653	.373
65	19500	.312
64	19200	.244
63	18900	.1855
62	18600	.145
61	18300	.1185
60	18000	.0905
59	17700	.0655
58	17400	.0395
57	17100	.020
55	16800	.010
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2		
1		
0		
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0		
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2		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 501 A020 LTSPECTRUM: F18-3000hr(B)TEST DATE: 5-3-84 11W 1.9995" TH .3020" HOLE DIAM .4460" A .6039"MAX STRESS 28 KSI FREQ Fast (FM = 250)ENVIR. CONDS. Dry PREPS. NoCYCLES TO FAILURE 263889 ld.pts.TTCT 21522 FLIGHT HOURSLARGER FLAW = .4425" BSMALLER FLAW = .4065" B

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
1		
2		
3		
4		
5		
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97		
98		
99		
100		



2X

FATIGUE TEST DATA

SPECIMEN NUMBER: 502 40% LT

SPECTRUM: F18-300hr(B)

TEST DATE: 5-3-84 11

W 2.0000" TH .3035" HOLE DIAM .4445" A .6070 in²

MAX STRESS 28 KSI FREQ: Fast (FM = 250)

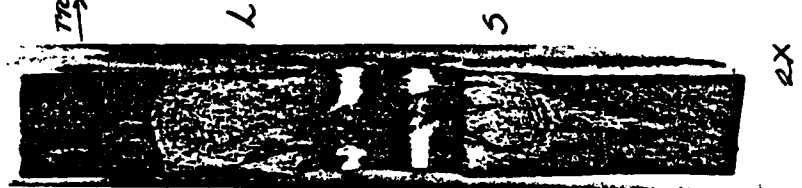
ENVIR. CONDS. Dry PREPS. None

CYCLES TO FAILURE 206165 1dpts

TTCI 16,064 FLIGHT HOURS

LARGER FLAW = .420" B

SMALLER FLAW = .253" B



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
65.72	19716	.420
65	19500	.324
64	19200	.282
63	18900	.233
62	18600	.198
61	18300	.123
60	18000	.088
59	17700	.0685
58	17400	.050
57	17100	.033
56	16800	.028
55	16500	.0225
54	16200	.014
53	15900	.005
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 503 40% LT

SPECTRUM: F18-300hr(B)

TEST DATE: 5-7-84 11

W 2.0010" TH .3020" HOLE DIAM .4435" A .6043 in²

MAX STRESS 28 KSI FREQ Fast (FM = 250)

ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 93232 14 pts

TTCI 6633 FLIGHT HOURS

LARGER FLAW = .4395" B

SMALLER FLAW = .2565" B



2X

FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
2972	8916	.4395
29	8700	.3675
28	8400	.2815
27	8100	.2247
26	7800	.140
25	7500	.0955
24	7200	.0455
23	6900	.0195
22	6600	.009
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		
9		
8		
7		
6		
5		
4		
3		
2		
1		

FATIGUE TEST DATA

SPECIMEN NUMBER: 504 40% LT

SPECTRUM: F18-300hr (B)

TEST DATE: 5-7-84 11

W 2.0010" TH .3030" HOLE DIAM .4440" A .6063"

MAX STRESS 28 KSI FREQ. Fast (FM=250)

ENVIR. CONDS. 3.5% NaCl PREPS. No

CYCLES TO FAILURE 119683 1d pts

TTCI 8218 FLIGHT HOURS

LAGER FLAW = .503" B

SMALLER FLAW = .349" B



2X

FRACTOGRAPHIC DATA

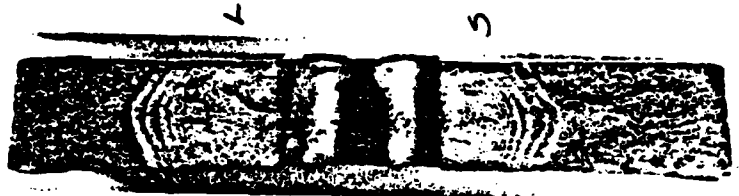
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
38.15	11446	.503
38	11400	.416
37	11100	.296
36	10800	.233
35	10500	.203
34	10200	.1415
33	9900	.103
32	9600	.080
31	9300	.058
30	9000	.044
29	8700	.021
28	8400	.014
27	8100	.0075
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FATIGUE TEST DATA

SPECIMEN NUMBER: 505 A074LT
 SPECTRUM: F18-300hrF(8)
 TEST DATE: 5-9-84 11
W 2.000" TH .3030" HOLE DIAM .4435" A 606012
 MAX STRESS 28 KSI FREQ Fast (FM=250)
 ENVIR. CONDS. 3.5% NaCl PREPS. No
 CYCLES TO FAILURE 81944 14 pfs 776
 TTCT 5127 FLIGHT HOURS

LARGER FLAW = .414" Ø

SMALLER FLAW = .331" Ø



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
26/27	7836	.414
26	7800	.376
25	7500	.239
24	7200	.178
23	6900	.137
22	6600	.0983
21	6300	.075
20	6000	.055
9	5700	.035
8	5400	.020
7	5100	.0095
6	4800	.005
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FATIGUE TEST DATA

SPECIMEN NUMBER: 506 40% LT 7761
 SPECTRUM: F16 (400hr)(A)
 TEST DATE: 4-16-84 11
W 2.0025" TH .3020" HOLE DIAM .4450" A .609859"
 MAX STRESS 28ksi FREQ. 1 LIFE = 2 days Fast En = F
 ENVIR. CONDS. Dry PREPS. None
 CYCLES TO FAILURE 2377184 ldpts % LIFE = 310
 TTCT 11,733 FLIGHT HOURS

LARGER FLAW = .3741(B)

SMALLER FLAW = .325"(B)



FRACTOGRAPHIC DATA

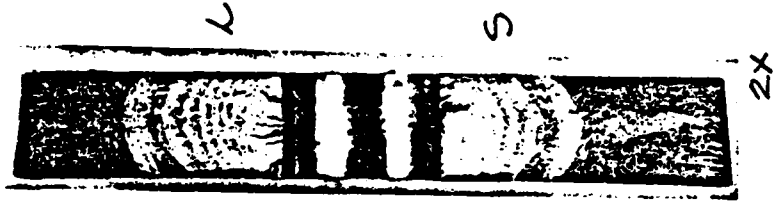
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
30	12000	.0110
29	11600	.0095
28	11200	
27	10800	
26	10400	
62	24800	.3741
61	24400	.3084
60	24000	.2624
59	23600	.2257
58	23200	.1952
57	22800	.1634
56	22400	.1385
55	22000	.1190
54	21600	.1030
53	21200	.0886
52	20800	.0778
51	20400	.0701
50	20000	.0631
49	19600	.0575
48	19200	.0522
47	18800	.0480
46	18400	.0444
45	18000	.0412
44	17600	.0383
43	17200	.0359
42	16800	.0335
41	16400	.0312
40	16000	.0290
39	15600	.0271
38	15200	.0252
37	14800	.0232
36	14400	.0215
35	14000	.0194
34	13600	.0176
33	13200	.0158
32	12800	.0142
31	12400	.0126

FATIGUE TEST DATA

SPECIMEN NUMBER: 507 40% LT in
 SPECTRUM: F16 (400 hr) (A)
 TEST DATE: 4-17-84 11
W 2.0030" TH .3020" HOLE DIAM. 4450" A. 60495" F
 MAX STRESS 28 KSI FREQ 1 LIFE 2 days, Fast, FY-28
 ENVIR. CONDS. Dry PREPS. None
 CYCLES TO FAILURE 2872169 4pk% LIFE 375
 TTIC 16,000 FLIGHT HOURS

LARGER FLAW = .446 (B)

SMALLER FLAW = .375" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
40	16000	.0100
39	15600	.0090
38	15200	
37	14800	
75	30000	.446
74	29600	.387
73	29200	.277
72	28800	.2338
71	28400	.1974
70	28000	.1671
69	27600	.1413
68	27200	.1205
67	26800	.1032
66	26400	.0910
65	26000	.0807
64	25600	.0722
63	25200	.0648
62	24800	.0595
61	24400	.0545
60	24000	.0511
59	23600	.0461
58	23200	.0436
57	22800	.0404
56	22400	.0380
55	22000	.0355
54	21600	.0321
53	21200	.0303
52	20800	.0281
51	20400	.0266
50	20000	.0244
49	19600	.0229
48	19200	.0206
47	18800	.0189
46	18400	.0171
45	18000	.0158
44	17600	.0146
43	17200	.0134
42	16800	.0120
41	16400	.0110

FATIGUE TEST DATA

SPECIMEN NUMBER: 508 40% LT
 SPECTROM: F16-100hr(A)
 TEST DATE: 1-23-84 11
W 2.0015" TH .3030" HOLE DIAM .4440" A.60655"
 MAX STRESS 28ksi FREQ. 1 LIFE = 2 days Fst FM-20
 ENVIR. CONDS. Dry PREPS. None
 CYCLES TO FAILURE 3446482 100% LIFE = 450
 TTCI 22,218 FLIGHT HOURS

LARGER FLAW = .440" (B)

SMALLER FLAW = .360" (B)



FRACTOGRAPHIC DATA		
BLK #	FLIGHT HRS.	CRACK LENGTH IN.
70	36,000	.240
69	35,600	.3189
68	35,200	.2635
67	34,800	.2249
66	34,400	.1931
65	34,000	.1700
64	33,600	.1447
63	33,200	.1282
62	32,800	.1127
61	32,400	.1022
60	32,000	.0930
59	31,600	.0845
58	31,200	.0770
57	30,800	.0698
56	30,400	.0647
55	30,000	.0584
54	29,600	.0537
53	29,200	.0495
52	28,800	.0456
51	28,400	.0411
50	28,000	.0370
49	27,600	.0337
48	27,200	.0310
47	26,800	.0282
46	26,400	.0265
45	26,000	.0250
44	25,600	.0234
43	25,200	.0217
42	24,800	.0203
41	24,400	.0180
40	24,000	.0167
39	23,600	.0150
38	23,200	.0132
37	22,800	.0116
36	22,400	.0105
35	22,000	.0094
34	21,600	
33	21,200	
32	20,800	
31	20,400	

FATIGUE TEST DATA

SPECIMEN NUMBER: 510 40% LT

SPECTRUM: F16-400hr (A)

TEST DATE: 4-25-84 11

W 2.0030' TH .3030' HOLE DIAM .4455" A.60698"

MAX STRESS 28 KSI FREQ 1 LIFE 2 days Fast FH=250

ENVIR. CONDS. 3.5% NaCl PREPS. None

CYCLES TO FAILURE 807656 14pts % LIFE 105

TTCT 5143 FLIGHT HOURS

LARGER FLAW = .480" (c)

SMALLER FLAW = .250" (B)



FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
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FATIGUE TEST DATA

SPECIMEN NUMBER: 511 402 LT
 SPECTRUM: F16-400hr (A)
 TEST DATE: 4-27-84 11

W 2.0015" TH .3000" HOLE DIAM. 4455" A .6005" R
MAX STRESS 28KSI FREQ. 1 LIFE = 2 days F356, FH=250
ENVIR. CONDS. 3.5% NaCl PREPS. None
CYCLES TO FAILURE 922257 Hrs % LIFE = 120%

TTCI 6821 FLIGHT HOURS

LARGER FLAW = .450" (B)

SMALLER FLAW = .125" (B)

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
24	9600	.450
23	9200	.2789
22	8800	.1587
21	8400	.0790
20	8000	.0317
19	7600	.0214
18	7200	.0136
17	6800	.0098
6		
5		
4		
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FATIGUE TEST DATA

SPECIMEN NUMBER: 521 4070 LT
 SPECTRUM: F18-BLOCK
 TEST DATE: 5-10-84 11
W 2.0030" TH .3015' HOLE DIAM .4455" A .6039"
 MAX STRESS 28 KSI FREQ First (FM = 250) F
 ENVIR. CONDS. Dry PREPS. No
 Cycles to FAILURE 319975 1d pts
 TTCL 8481 FLIGHT HOURS

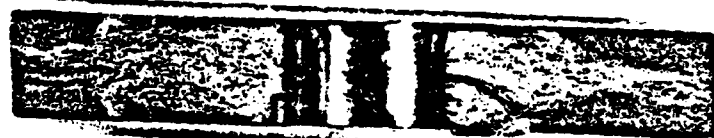
LARGER FLAW = . 377" (I)

SMALLER FLAW = .367" (B)

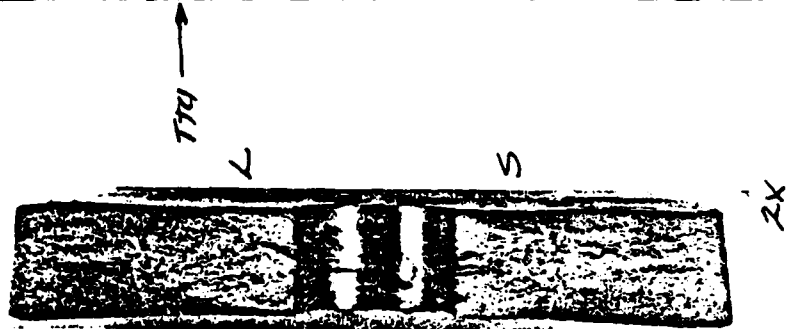


FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
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5		
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3		
102	30600	.377
101	30300	.340
100	30000	.298
99	29700	.270
98	29400	.259
97	29100	.237
96	28800	.217
95	28500	.203
—	—	—
85	25500	.108
—	—	—
75	22500	.064
—	—	—
65	19500	.040
—	—	—
55	16500	.035
—	—	—
45	13500	.019
—	—	—
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FATIGUE TEST DATASPECIMEN NUMBER: 522 10% LTSPECTRUM: F18-BLOCKTEST DATE: 5-10-84 11W 2.0010" TH .3015" HOLE DIAM .4470" A .6033"MAX STRESS 28 KSI FREQ. Fast (FM=250)ENVIR. CONDS. Dry PREPS. NoCYCLES TO FAILURE 348207 ld ptsTTCI 16,200 FLIGHT HOURSLARGER FLAW = .525" (B)SMALLER FLAW = .361" (B)FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
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FATIGUE TEST DATASPECIMEN NUMBER: 523 40% LTSPECTRUM: F18 BLOCKTEST DATE: 5-14-84 11W 2.0020 TH. 3020 HOLE DIAM. .4465 A. .6046 FMAX STRESS 28 KSI FREQ. Fast (FM=250)ENVIR. CONDS. Dry PREPS. N6CICLES TO FAILURE 420359 1d ptsTTCI 2/278 FLIGHT HOURSLARGER FLAW = .439" (B)SMALLER FLAW = .333" (B)FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
134	40200	.439
133	39900	.401
132	39600	.371
131	39300	.338
130	39000	.306
129	36000	.171
128	33000	.096
127	30000	.059
126	27000	.038
125	24000	.021
124	21025	.009
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120		
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100		

FATIGUE TEST DATASPECIMEN NUMBER: 524 (OPEN HOLE)SPECTRUM: F18 BLOCKTEST DATE: 5-14-84 11W 2.000" TH 2995' HOLE DIAM .5030' A .5990 FMAX STRESS 28 KSI FREQ Fast (FM=250)ENVIR. CONDS. 3.5% NaCl PREPS. NoCYCLES TO FAILURE 141165 1d pts.TTCI 6900 FLIGHT HOURSLARGER FLAW = .425" (B)SMALLER FLAW = .293" (B)

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FRACTOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
45	13500	.425
44	13200	.36
43	12900	.274
42	12600	.215
41	12300	.185
40	12000	.154
39	11700	.139
38	11400	.115
37	11100	.096
36	10800	.081
35	10500	.071
34	10200	.055
33	9900	.048
32	9600	.043
31	9300	.039
30	9000	.032
29	8700	.027
28	8400	.023
27	8100	.020
26	7800	.018
25	7500	.015
24	7200	.013
23	6900	.010
2		
1		
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FATIGUE TEST DATASPECIMEN NUMBER: 526 (OPEN HOLE)SPECTRUM: F18 BLOCK (B')TEST DATE: 5-17-84 11W 2.0025" TH .3005" HOLE DIAM. .5045" A. .6017" FMAX STRESS 28 KSI FREQ. Fast (FM = 250)ENVIR. CONDS. 3.5 % NaCl PREPS. NoCYCLES TO FAILURE 103521 18 pts.TTCI 955 FLIGHT HOURSLARGER FLAW = .575" (c)SMALLER FLAW = .432" (B)

2x

FRAC TOGRAPHIC DATA

BLK #	FLIGHT HRS.	CRACK LENGTH IN.
0		
9		
8		
7		
6		
5		
4		
33	9900	.575
32	9600	.405
31	9300	.326
30	9000	.278
29	8700	.249
28	8400	.228
27	8100	.205
26	7800	.192
25	7500	.181
24	7200	.157
23	6900	.150
22	6600	.142
21	6300	.138
20	6000	.133
15	4500	.098
10	3000	.040
5	1500	.018
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