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THE MECHANICAL PROPERTY DATA BASE FROM AN AIR FORCE/INDUSTRY COOPERATIVE TEST PROGRAM ON ADVANCED ALUMINUM ALLOYS (7064 AND CW67)

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13. ABSTRACT *(Maximum 200 words)*

A mechanical property data base on Kaiser produced second generation P/M alloys 7064 forging and extrusion and Alcoa produced P/M alloys CW67 sheet, plate, forging and extrusion was generated. Mechanical property data consisted of tension, compression, shear, bearing and fracture toughness values. Fatigue, fatigue crack growth and spectrum fatigue crack growth data were generated.

14. SUBJECT TERMS

CW67	tension	bearing	spectrum
7064	compression	fatigue	R-curve
P/M	shear	fracture toughness	

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PREFACE

This report was prepared by the Materials Engineering Branch (WL/MLSE), Systems Support Division, Materials Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 2418, "Metallic Structural Materials," Task 241807, "Systems Support," Work Unit 24180703, "Engineering and Design Data."

The authors would like to thank the participants Lockheed GA, LTV TX, Martin Marietta LA, McDonnell Aircraft Company MO and the Air Force.

SECTION 1

INTRODUCTION

High performance aerospace systems are dependent on materials that are lighter, have improved mechanical properties, and/or offer a cost savings. Aluminum alloys that met these criteria were the newly developed aluminum-lithium alloys and the second generation powder metallurgy alloys.

In 1985, the Air Force along with the aerospace community found it important to investigate the potential of these promising aluminum alloys. A cooperative program was formed by the Wright Laboratory Materials Directorate, Systems Support Division, and a number of aerospace industries. The Air Force would obtain the test material from the producers, compile the test data, and submit reports to the participants. The participants agreed to support the program by performing mechanical property tests which includes tension, compression, bearing, shear, fracture toughness, and fatigue related properties (S/N, da/dn). The Air Force elected to perform spectrum fatigue crack growth testing on most alloys. A list of participants is shown in the following table.

This interim report contains the powder metallurgy (P/M) aluminum alloys: 7064-T74511 extrusion , and 7064-T74 forging produced by Kaiser and CW67 sheet, plate, extrusion , and forging produced by Alcoa. Comparisons to other materials and ranking of materials are generally avoided since each potential application may be based on different evaluation criteria.

TABLE

PARTICIPANTS AND ADVANCED ALUMINUM ALLOYS IN THE COOPERATIVE TEST PROGRAM

	ALUMINUM LITHIUM ALLOYS														P/M ALUMINUM ALLOYS				
	PECHINEY				ALCAN		IncoMAP		ALCOA				REYNOLDS		KAISER	ALCOA			
PARTICIPANTS	2091 – T3 Sheet (0.063")	2091 – T351 Plate (0.420")	2091 – T6 Forging	8090 – T651 T Extrusion	8090 – T651 Extrusion	8090 – T8771 Plate (1.75")	PM IN905XL Forging	PM AL905XL Forging	2091 – T3 Sheet (0.063")	2091 – T3 Sheet (0.144")	2091 – T8 Plate (0.50")	8090 Extrusion	Weldalite 049 RX815 Plate (0.5")	7064 – T74511 Extrusion	7064 – T74 Forging	CW67 Sheet (0.063")	CW67 Plate (0.40")	CW67 Extrusion	CW67 Forging
Air Force WPAFB, OH		x			x	x	x	x	x	x	x	x	x	x	x			x	x
Army, MA												x	x						
AVCO, TN									x										
Boeing, WA	x	x	x	x															
Douglas Aircraft, CA								x	x	x	x	x	x						
General Dynamics, CA	x	x							x	x	x		x						
General Dynamics, TX	x	x	x	x			x		x	x	x	x							
Grumman Aerospace, NY	x	x			x		x							x	x			x	x
Jet Propulsion, CA								x					x						
Lockheed, CA	x			x				x	x		x								
Lockheed, GA			x		x				x	x					x				x
LTV, TX	x			x			x	x	x			x		x	x			x	
Martin Marietta, LA	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x
McDonnell Douglas Astro, CA										x			x						
McDonnell Douglas Helicopter, AR								x											
McDonnell Douglas Missile Sys, MO													x						
McDonnell Aircraft, MO	x						x	x	x						x	x			x
NASA, VA					x		x	x					x						
Naval Air Development Center		x		x				x			x								x
Northrop, CA	x	x	x		x	x	x	x	x	x	x	x	x						
Sikorsky, CT							x		x						x		x		x
Sundstrand, IL													x						
Wyman–Gordon								x											

SECTION 2

MATERIALS AND TESTS

The Kaiser P/M aluminum alloys 7064-T74511 1 inch x 4 inch x 48 inch extrusion and 7064-T74 1.6 inch x 4 inch x 18 inch forging were received in December 1986. The Alcoa P/M aluminum alloys were received on various dates: CW67 0.063-inch sheet and 0.4-inch plate April 1989, CW67 1.5 inch x 4.5 inch x 36 inch extrusion August 1987 and CW67 2.5 inch x 6 inch x 18 inch hand forging October 1988.

The 7064 extrusion was tested by LTV, Martin Marietta and the Air Force. Forged 7064 was tested by Lockheed, LTV, Martin Marietta, McDonnell Aircraft Company, and the Air Force. CW67 sheet was tested by Martin Marietta and McDonnell Aircraft Company. Only Martin Marietta tested CW67 plate. LTV, McDonnell Aircraft Company and the Air Force tested the CW67 Extrusion material. CW67 forging was tested by Martin Marietta and the Air Force.

Mechanical properties (tension, compression, shear, bearing and fracture toughness), fatigue, and constant amplitude fatigue crack growth tests were generated according to ASTM standards, unless otherwise specified.

Spectrum fatigue crack growth rate tests were performed by the Air Force using FALSTAFF (a severe fatigue environment) and Mini-TWIST (a moderately intense fatigue environment) spectrums.

SECTION 3

PRESENTATION

Each participant compiled a data package which contained the data they generated. Some of these data packages contain discussions, and in other cases, only the data were provided. The tensile, compression, shear and bearing are in tabular form. Fatigue and toughness values are shown in tabular and graphical form. Fatigue crack growth and spectrum fatigue crack growth are in graphical form.

SECTION 4

RESULTS AND DISCUSSION

The data generated by the participants on the 7064 extrusion, 7064 forging, CW67 sheet, CW67 plate, CW67 extrusion and CW67 forging are in the appendices. The table lists the P/M aluminum alloy, form, and the appendix where the data can be found in the following table.

TABLE
CONTENTS OF APPENDICES

P/M Aluminum Alloy	Form	Appendix
7064-T74511	Extrusion	N
7064-T74	Forging	O
CW67	0.063" Sheet	P
CW67	0.40" Plate	Q
CW67	Extrusion	R
CW67	Forging	S

SECTION 5

CONCLUSIONS

Five aerospace laboratories participated in generating data on the 7064 and CW67 P/M aluminum alloys for the cooperative test program. These data combined with previous interim reports on the Air Force/Industry Cooperative Test Program on Advance Aluminum Alloys provide an extensive data base on advanced aluminum alloys.

APPENDIX N

7064-T74511 EXTRUSION
1"X4"X48"

TABLE N1

TENSILE RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	MODULUS (MSI)
LTV	RT	LONG	85.8	79.4	12.2	21.6	10.0
			87.5	81.7	12.3	19.3	9.7
			87.7	82.2	14.3	22.3	10.3
AIR FORCE	RT	LONG	82.2	75.8	10.5	18.0	
			80.7	73.9	11.3	24.3	
			81.2	74.7	12.0	25.6	
MARTIN MARIETTA, LOUISIANA	RT	LONG	91.6	86.5	18.0	27.5	9.8
			90.5	85.3	20.0	30.6	9.4
			90.2	85.0	19.0	31.0	9.7
		AVERAGE	86.4	80.5	14.4	24.5	9.8
	STANDARD DEVIATION		4.2	4.8	3.6	4.6	0.3

TABLE N2

TENSILE RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	MODULUS (MSI)
LTV	RT	L TRANS	83.0	76.6	9.0	11.8	9.2
			85.3	79.6	8.5	19.1	10.4
			85.5	80.2	11.0	22.7	10.4
AIR FORCE	RT	L TRANS	79.2	72.8	10.0	21.6	
			78.3	72.0	10.7	25.6	
			79.1	72.6	11.3	27.8	
MARTIN MARIETTA, LOUISIANA	RT	L TRANS	88.8	82.7	8.0	7.8	10.7
			89.2	83.2	9.0	2.0	10.1
			88.0	82.7	10.0	16.1	9.7
		AVERAGE	84.0	78.0	9.7	17.2	10.1
	STANDARD DEVIATION		4.3	4.6	1.2	8.6	0.5

TABLE N3

COMPRESSION RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
LTV	RT	LONG	97.4	14.8
			79.8	10.3
			83.0	11.8
AIR FORCE	RT	LONG	83.3	
			81.6	
			82.5	
MARTIN MARIETTA, LOUISIANA	RT	LONG	87.1	11.1
			86.0	11.1
			86.9	11.1
		AVERAGE	85.3	11.7
		STANDARD DEVIATION	5.2	1.6

TABLE N4

COMPRESSION RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
LTV	RT	L TRANS	82.7	10.8
			82.9	11.8
			82.8	11.2
AIR FORCE	RT	L TRANS	83.3	
			81.8	
			84.1	
MARTIN MARIETTA, LOUISIANA	RT	L TRANS	87.3	11.4
			86.1	11.3
			86.6	11.9
		AVERAGE	84.2	11.4
		STANDARD DEVIATION	2.0	0.4

TABLE N5

IOSIPESCU SHEAR RESULTS FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
LTV	LONG	49.7
		51.0
		50.9
	AVERAGE	50.5
	STANDARD DEVIATION	0.7

TABLE N6

IOSIPESCU SHEAR RESULTS FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
LTV	L TRANS	50.4
		49.8
		50.2
	AVERAGE	50.1
	STANDARD DEVIATION	0.3

TABLE N7

BEARING RESULTS FOR KAISER

7064-T74511 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	LONG	1.5	124.5	93.9
			134.4	111.9
			129.8	108.2
		AVERAGE	129.6	104.7
		STANDARD DEVIATION	5.0	9.5

TABLE N8

BEARING RESULTS FOR KAISER

7064-T74511 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	LONG	2.0	159.5	122.7
			169.5	122.2
			160.8	117.0
AIR FORCE	LONG	2.0	163.5	139.5
			166.7	125.3
			162.3	120.0
		AVERAGE	163.7	124.5
		STANDARD DEVIATION	3.8	7.9

TABLE N9

BEARING RESULTS FOR KAISER

7064-T74511 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
AIR FORCE	L TRANS	2.0	164.2	123.8
			159.3	114.7
			163.5	115.6
		AVERAGE	162.3	118.0
		STANDARD DEVIATION	2.7	5.0

TABLE N10

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
LTV	L-T		32.6	(1)
			33.5	(1)
			29.6	(1)
AIR FORCE	L-T		29.5	(2)
			27.9	(2)
			28.8	(2)
MARTIN MARIETTA, LOUISIANA	L-T	24.2		VALID
			26.3	(3)
			25.2	(3)
	AVERAGE	24.2	29.2	
	STANDARD DEVIATION		2.8	

(1): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE VIOLATED KIC REQUIREMENTS

(2): INVALID DUE TO SURFACE CRACK LENGTH/AVERAGE CRACK LENGTH > 1.1

(3): INVALID DUE TO CRACK SIZE DID NOT EXCEED PLASTIC ZONE SIZE

TABLE N11

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
LTV	T-L	24.6		VALID
		25.0		VALID
		25.2		VALID
AIR FORCE	T-L	23.5		VALID
		24.1		VALID
		23.8		VALID
MARTIN MARIETTA, LOUISIANA	T-L		10.2	(1)
		17.1		
		17.1		
	AVERAGE	22.6	10.2	
	STANDARD DEVIATION	3.4		

(1): INVALID DUE TO PRECRACKING LOADS WERE TOO HIGH

TABLE N12

FATIGUE RESULTS WITH Kt=1.0 AND R=0.1 FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	LIMIT STRESS (KSI)	CYCLES TO FAILURE
LTV	LONG	65.6	13,900
		65.0	1,800
		56.6	23,400
		47.9	49,900
		47.9	75,700
		47.8	318,100 #
		45.0	6,500
		43.5	2,000,000 *
		39.4	38,500
		39.1	93,100 #
		37.0	193,900
		35.0	113,000
		30.0	800,000 *
		25.2	2,300,000 *

(*): INDICATES A RUN OUT TEST
(#): INDICATES SPECIMEN FAILED IN THE THREADS

TABLE N13

FATIGUE RESULTS WITH Kt=3.0 AND R=0.1 FOR

KAISER 7064-T74511 EXTRUSION

COMPANY	ORIENTATION	LIMIT STRESS (KSI)	CYCLES TO FAILURE
LTV	LONG	43.5	5,100
		34.8	10,800
		32.6	19,700
		31.3	23,500
		30.5	66,200
		28.3	39,300
		26.1	56,700
		26.1	40,400
		24.4	72,000
		23.9	3,000,000 *
		23.5	1,998,100
		21.8	2,000,000 *
		21.7	3,000,000 *
		20.0	2,000,000 *
		17.4	3,000,000 *

(*): INDICATES A RUN-OUT TEST

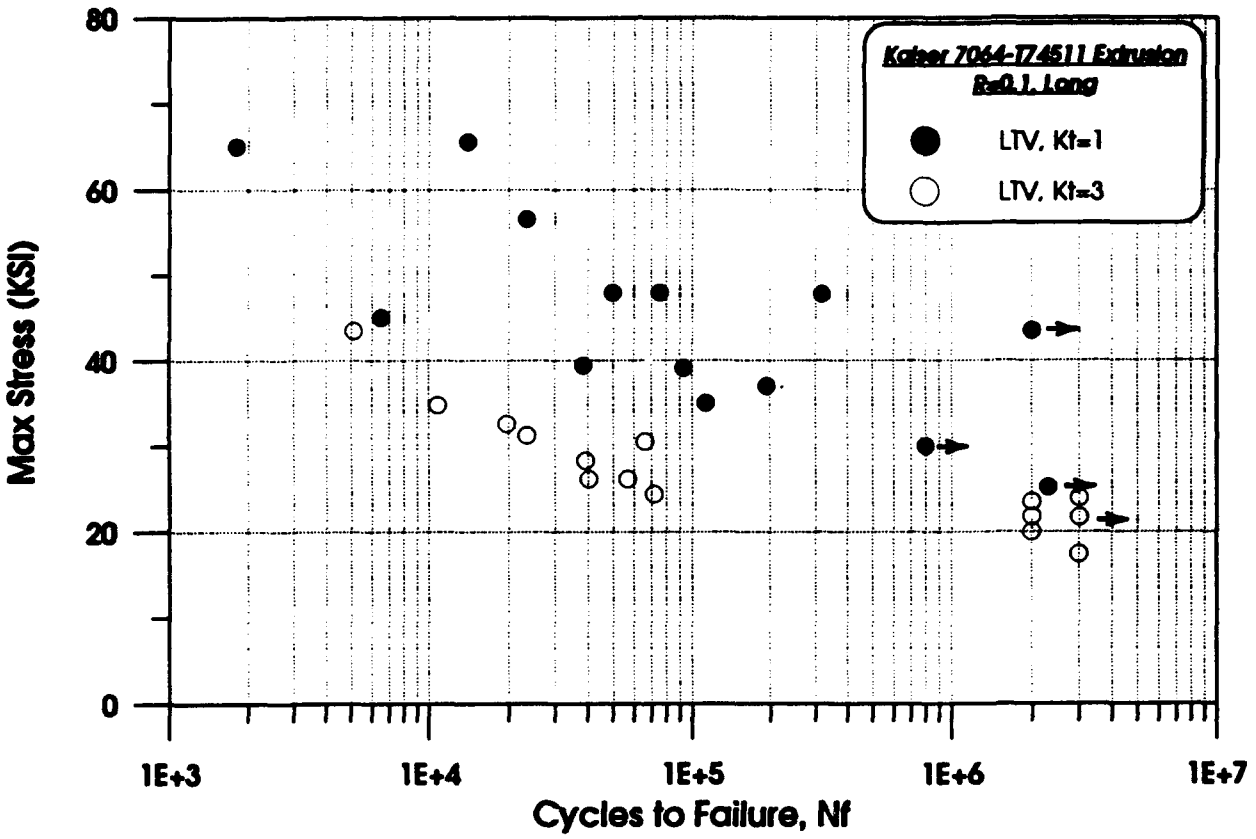


FIGURE N1. FATIGUE RESULTS FOR 7064-T74511 EXTRUSION (LONGITUDINAL ORIENTATION). LTV.

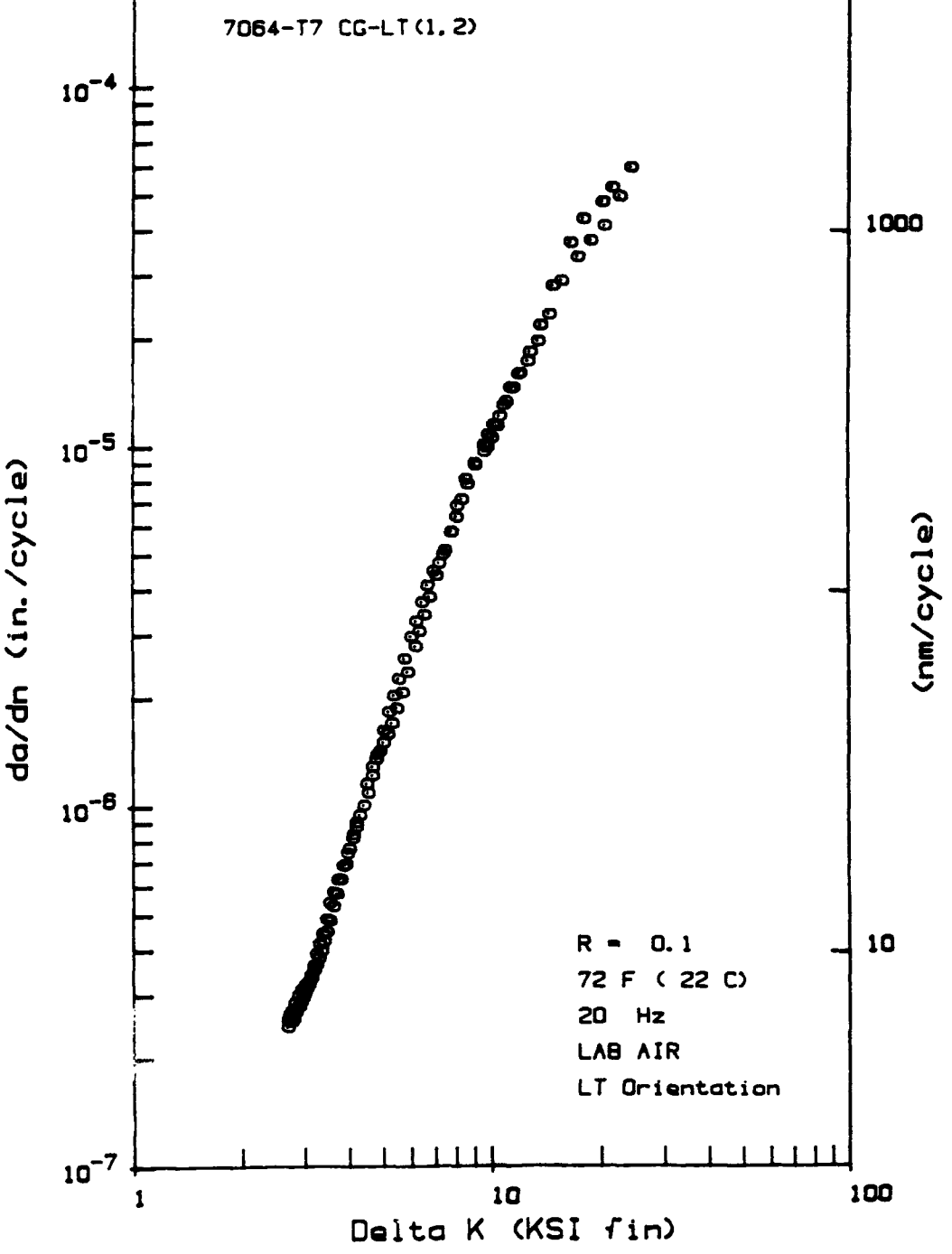


FIGURE N2. FATIGUE CRACK GROWTH RATE DATA for Two 7064-T74511 Extrusion Specimens. (L-T ORIENTATION). AIR FORCE.

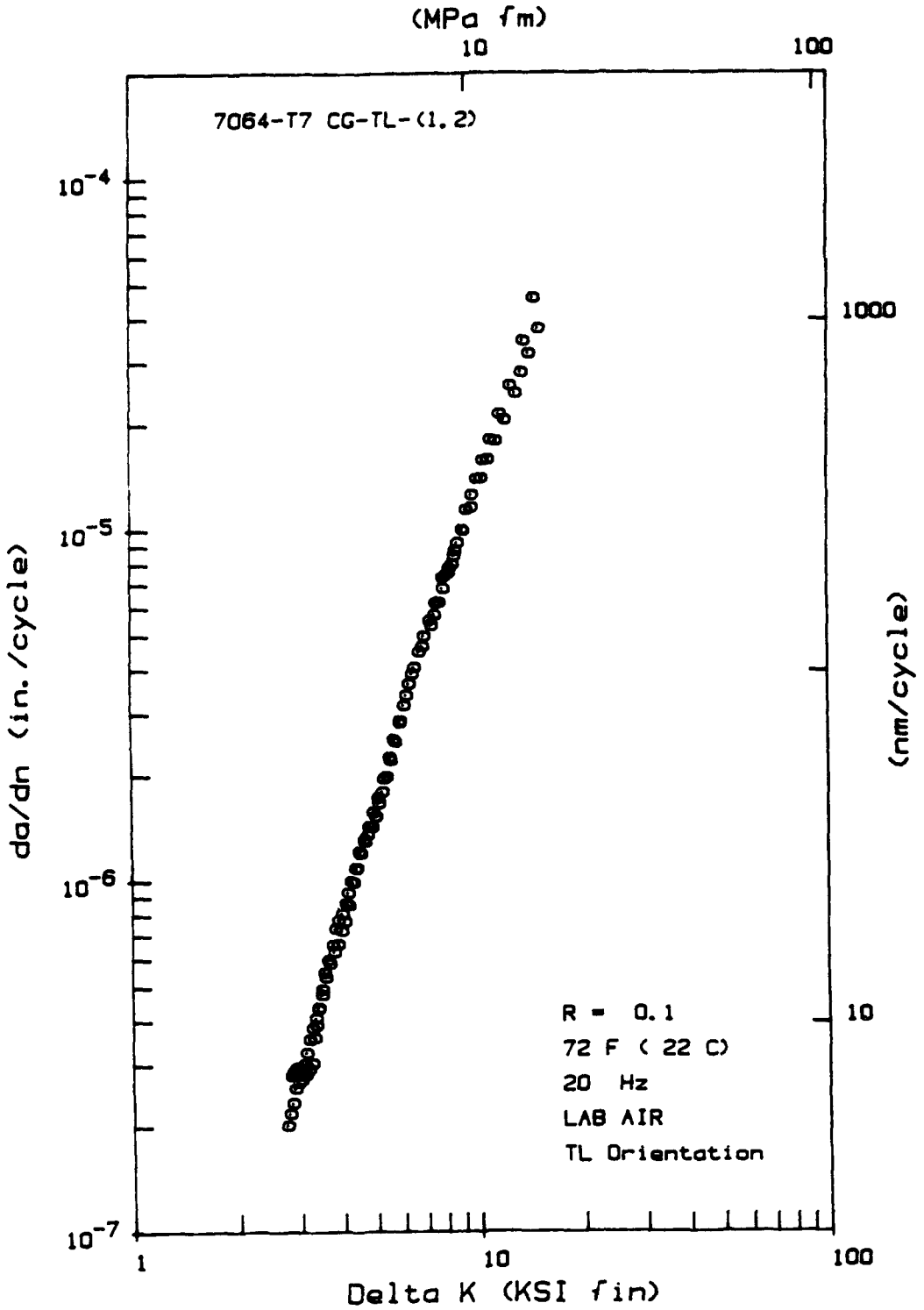


FIGURE N3. FATIGUE CRACK GROWTH RATE DATA for Two 7064-T74511 Extrusion Specimens. (T-L ORIENTATION). AIR FORCE.

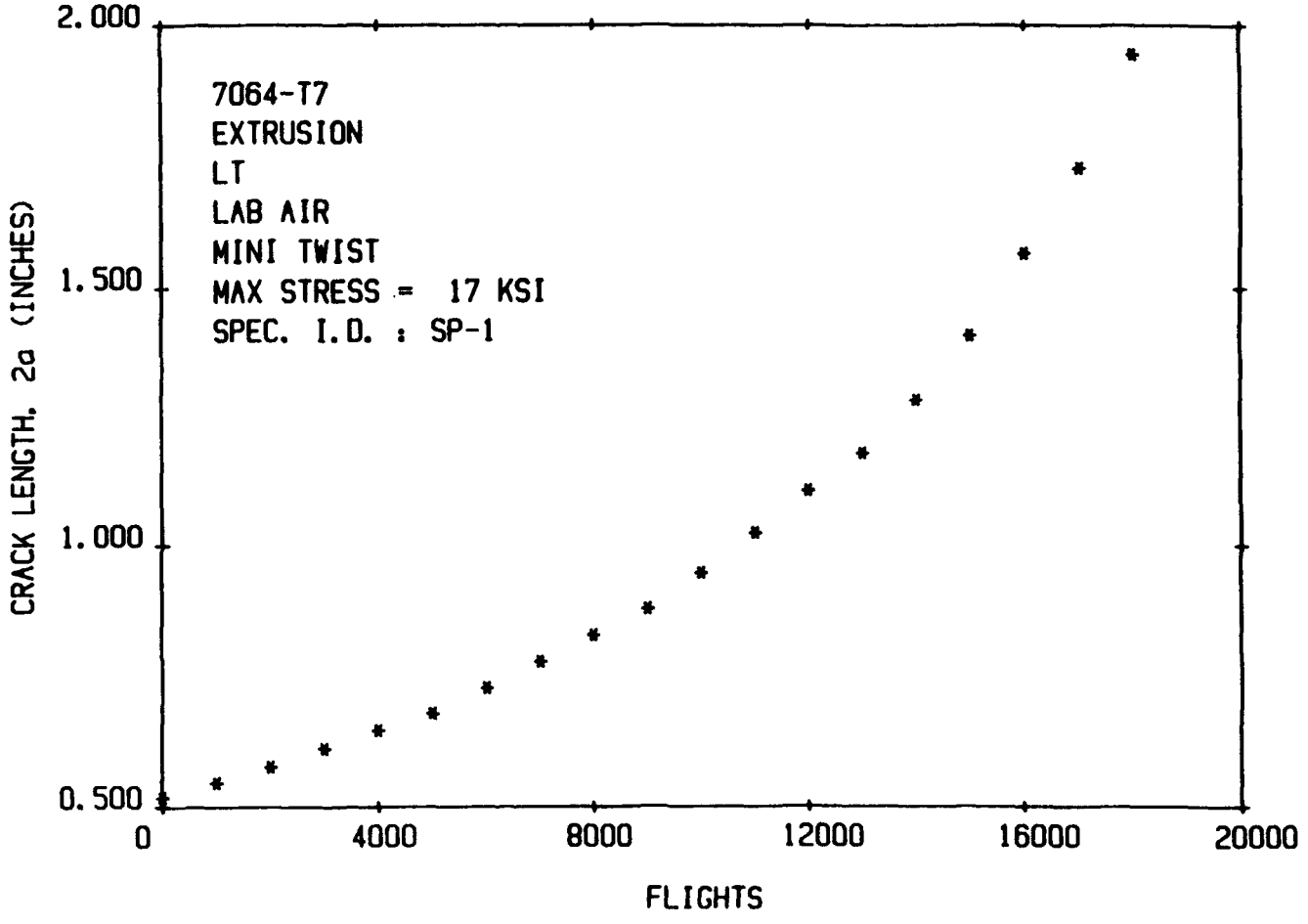


FIGURE N4. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion. Air Force.

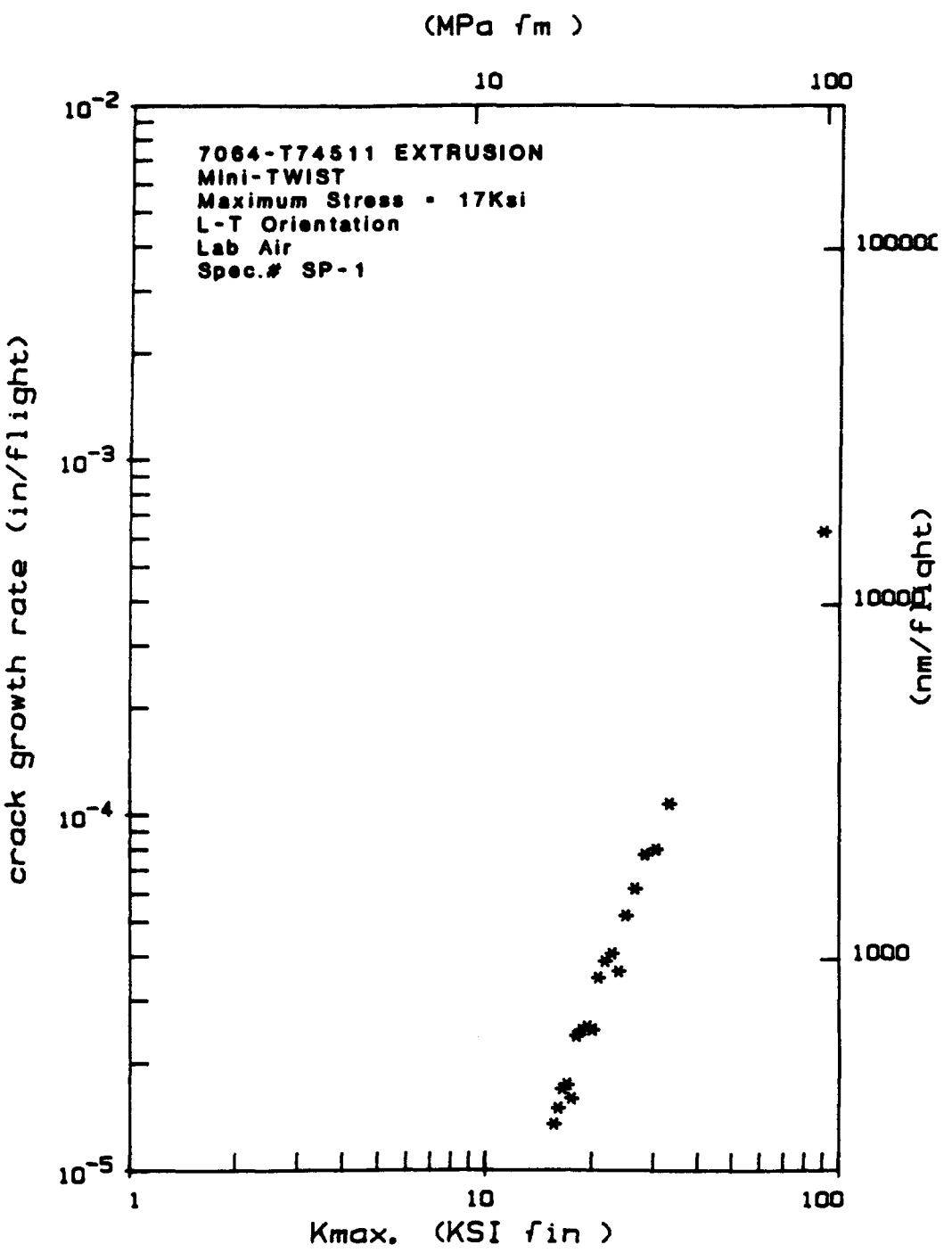


FIGURE N5. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion.
Air Force.

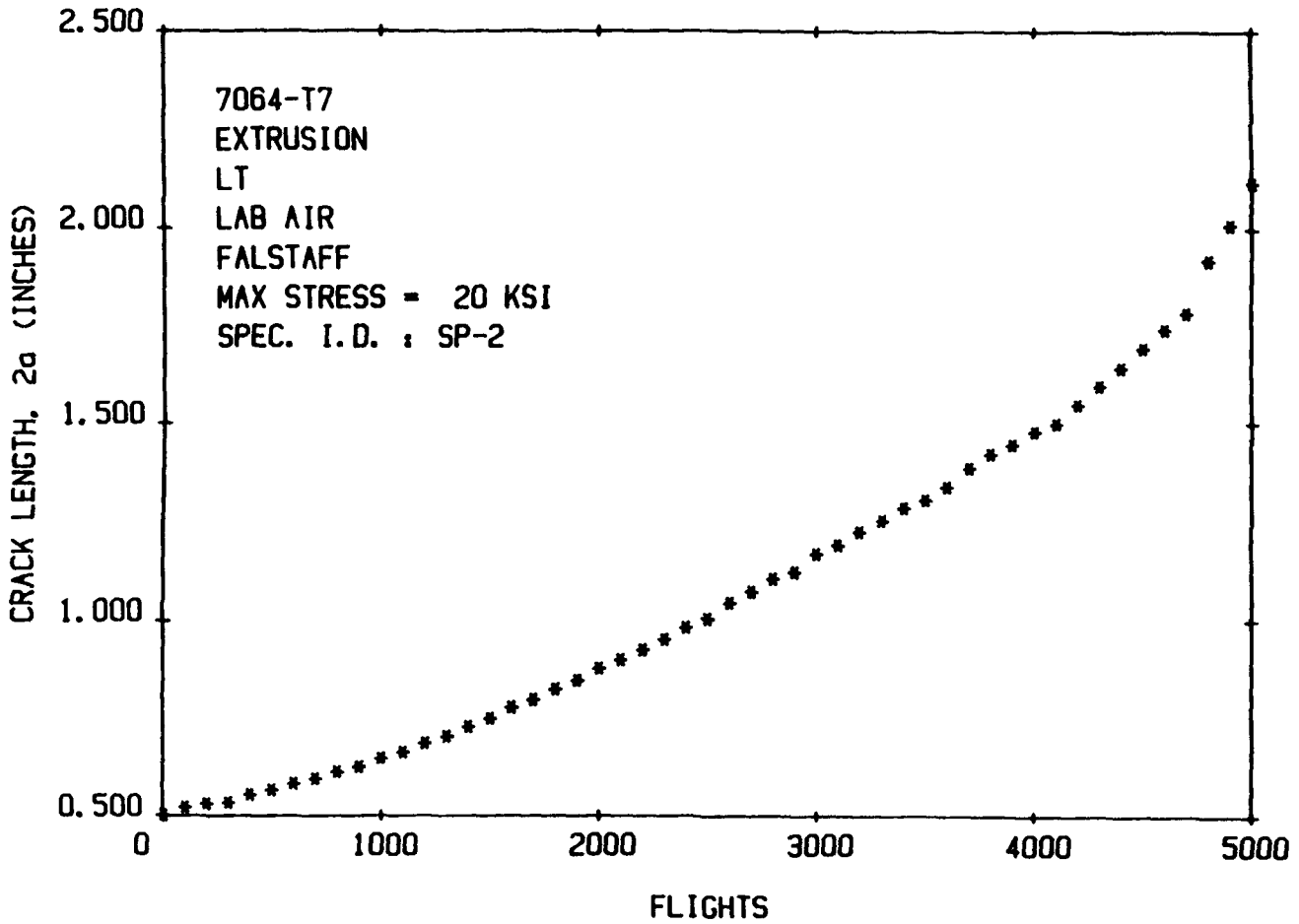


FIGURE N6. FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74511 Extrusion. Air Force.

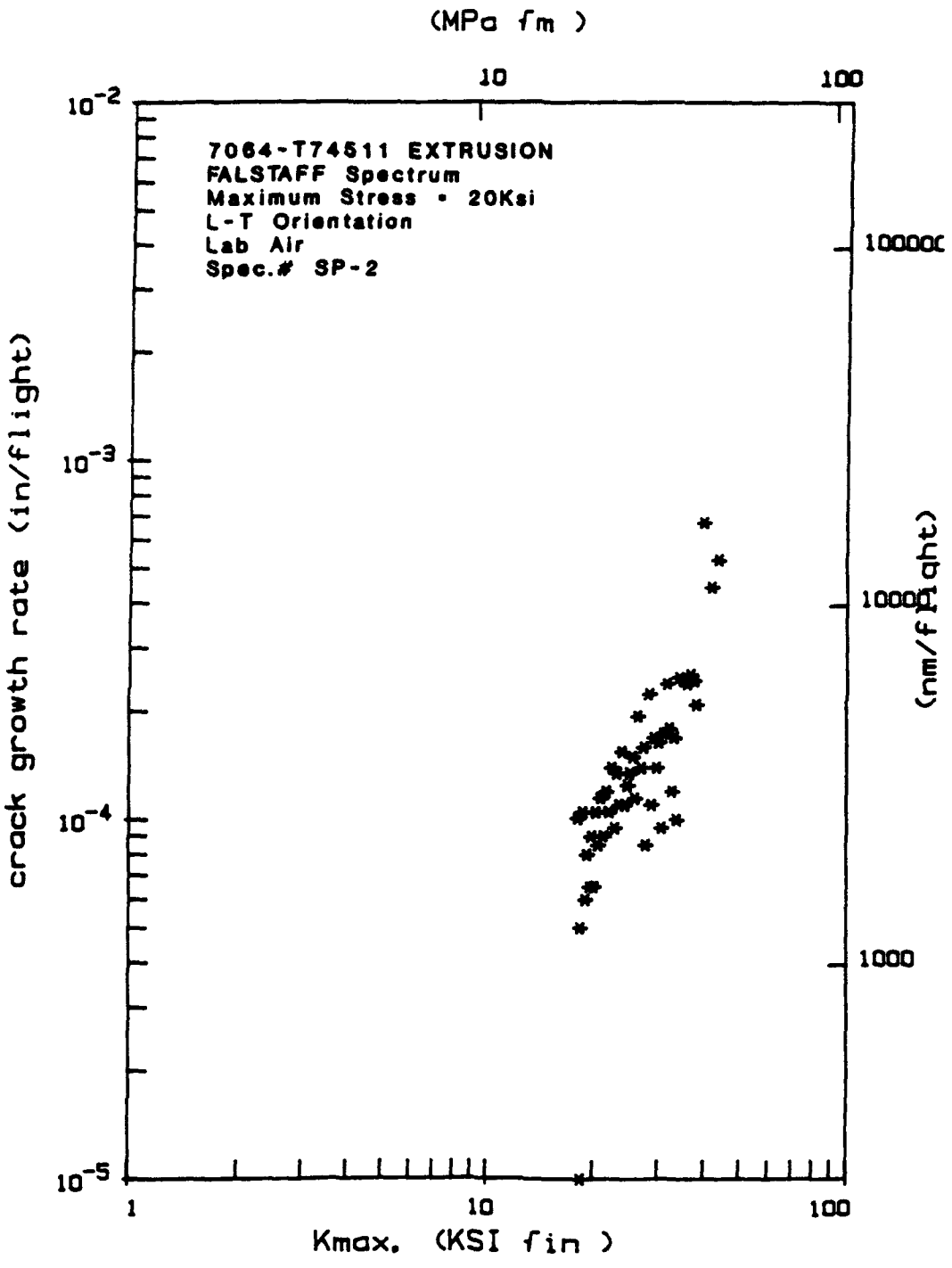


FIGURE N7. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for 7064-T74511 Extrusion.
Air Force.

APPENDIX O

7064-T74 HAND FORGING
1.6"X4"X18"

TABLE 01

TENSILE RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	MODULUS (MSI)
MCAIR, ST. LOUIS	RT	LONG	80.0	74.0	13.0		
			80.0	73.0	14.0		
			81.5	75.0	11.0		
			80.5	74.0	13.0		
LOCKHEED, GEORGIA	RT	LONG	77.2	69.7			9.9
			81.9	75.0			11.2
			81.0	75.2			10.5
			84.9	79.0			10.6
			81.5	74.7			10.2
			81.1	74.1			10.1
			80.0	74.0			10.1
			84.1	78.4			9.9
			80.6	73.6			10.3
			80.5	74.3			10.1
MARTIN MARIETTA, LOUISIANA	RT	LONG	79.5	71.4	5.0	41.6	10.1
			79.4	70.9	12.0	44.0	10.2
			78.6	70.6	14.0	37.9	10.1
LTV	RT	LONG	80.6	74.3	13.3	32.4	9.6
			79.1	72.6	13.7	29.8	9.5
			78.7	71.7	15.4	38.9	9.5
			82.0	75.9	10.6	31.0	9.7
		AVERAGE	80.6	73.9	12.3	36.5	10.1
	STANDARD DEVIATION		1.8	2.3	2.8	5.5	0.4

TABLE 02

TENSILE RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	MODULUS (MSI)
MCAIR, ST. LOUIS	RT	L TRANS	80.0	72.0	8.0		
			80.0	72.5	9.0		
			80.5	73.0	8.0		
			80.0	72.5	8.0		
LOCKHEED, GEORGIA	RT	L TRANS	83.0	77.1			10.8
			80.2	73.3			9.6
			80.5	73.7			9.9
			78.9	72.9			10.0
			79.9	73.0			10.7
			79.9	72.5			9.7
			78.6	71.8			10.6
			79.8	71.3			10.6
			78.0	71.4			10.2
			78.9	70.6			10.4
MARTIN MARIETTA, LOUISIANA	RT	L TRANS	78.5	70.0	6.0	6.1	10.0
			79.2	71.3	8.0	10.2	10.0
			77.5	69.1	13.0	32.7	10.0
LTV	RT	L TRANS	77.8	70.9	8.0	15.3	9.5
			78.1	70.6	10.0	19.3	9.7
			77.8	68.8	8.0	11.7	10.0
			77.2	68.7	7.0	9.7	10.3
		AVERAGE	79.3	71.8	8.5	15.0	10.1
	STANDARD DEVIATION		1.3	1.9	1.8	8.9	0.4

TABLE 03

TENSILE RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	MODULUS (MSI)
MCAIR, ST. LOUIS	RT	S TRANS	82.5	77.0	10.0		
			83.0	76.5	6.0		
			81.5	75.0	6.0		
			82.0	76.0	7.0		
		AVERAGE	82.3	76.1	7.3		
	STANDARD DEVIATION		0.6	0.9	1.9		

TABLE O4

COMPRESSION RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCAIR, ST. LOUIS	RT	LONG	75.5	11.2
			77.5	11.5
			75.0	10.8
LOCKHEED, GEORGIA	RT	LONG	76.6	10.6
			78.0	
			83.4	10.4
			79.9	10.6
			83.5	
			78.5	
			78.1	10.5
MARTIN MARIETTA, LOUISIANA	RT	LONG	76.4	11.0
			77.2	11.0
			75.3	10.9
LTV	RT	LONG	80.4	11.5
			77.7	11.4
			76.4	12.5
			79.6	11.8
		AVERAGE	78.2	11.1
		STANDARD DEVIATION	2.5	0.6

TABLE 05

COMPRESSION RESULTS AT t/2 LOCATION FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCAIR, ST. LOUIS	RT	L TRANS	75.0	11.2
			76.5	11.8
			76.0	11.9
LOCKHEED, GEORGIA	RT	L TRANS	72.9	
			80.5	
			75.3	11.2
			78.3	11.3
			77.7	11.1
			73.8	9.8
			72.0	9.7
MARTIN MARIETTA, LOUISIANA	RT	L TRANS	76.4	11.2
			76.1	11.1
			76.1	11.1
LTV	RT	L TRANS	77.9	11.1
			76.8	12.0
			78.7	11.8
			74.9	11.7
		AVERAGE	76.2	11.2
		STANDARD DEVIATION	2.1	0.7

TABLE O6

SLOTTED SHEAR RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
MCAIR, ST. LOUIS	LONG	53.5
		47.5
		46.5
	AVERAGE	49.2
	STANDARD DEVIATION	3.8

TABLE O7

AMSLER DOUBLE SHEAR RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
LOCKHEED, GEORGIA	L-T	50.0
		51.8
		50.4
	AVERAGE	50.7
	STANDARD DEVIATION	0.9

TABLE 08

IOSIPESCU SHEAR RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
LTV	LONG	50.5
		52.5
		48.0
		48.9
		51.5
		51.3
		51.7
		50.4
	AVERAGE	50.6
	STANDARD DEVIATION	1.5

TABLE 09

IOSIPESCU SHEAR RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	ULTIMATE STRENGTH (KSI)
LTV	L TRANS	50.2
		51.3
		51.2
		52.7
		49.5
		53.7
		51.8
	AVERAGE	51.5
	STANDARD DEVIATION	1.4

TABLE O10

BEARING RESULTS FOR KAISER

7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LOCKHEED, GEORGIA	LONG	1.5	137.0	116.0
			115.0	105.0
			139.0	114.0
LTV	LONG	1.5	132.8	112.4
			132.4	112.1
			137.7	115.9
		AVERAGE	132.3	112.6
		STANDARD DEVIATION	8.9	4.1

TABLE O11

BEARING RESULTS FOR KAISER

7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	L TRANS	1.5	134.3	116.6
			135.2	114.7
			139.1	116.5
			138.5	117.1
		AVERAGE	136.8	116.2
		STANDARD DEVIATION	2.4	1.1

TABLE O12

BEARING RESULTS FOR KAISER

7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCAIR, ST. LOUIS	LONG	2.0	148.0	
			149.0	117.0
			143.0	112.0
LOCKHEED, GEORGIA	LONG	2.0	168.0	135.0
			169.0	123.0
			170.0	126.0
LTV	LONG	2.0	165.1	131.9
			170.6	143.1
			176.1	137.5
		AVERAGE	162.1	128.2
		STANDARD DEVIATION	12.0	10.6

TABLE O13

BEARING RESULTS FOR KAISER

7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCAIR, ST. LOUIS	L TRANS	2.0	149.0	119.0
			149.0	116.0
			151.0	119.0
LTV	L TRANS	2.0	173.0	135.9
			172.1	134.6
			171.8	135.0
			168.1	142.8
		AVERAGE	162.0	128.9
		STANDARD DEVIATION	11.7	10.6

TABLE 014

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
MCAIR,	L-T	24.1		VALID
ST. LOUIS		27.5		VALID
LOCKHEED,	L-T	26.0		VALID
GEORGIA		29.0		VALID
MARTIN	L-T		27.2	(1)
MARIETTA,			23.6	(1)
LOUISIANA				
LTV	L-T		24.1	(2)(3)
			26.4	(2)(3)
			29.4	(2)
	AVERAGE	26.7	26.1	
	STANDARD DEVIATION	2.1	2.4	

(1): INVALID DUE TO a/W=0.552 > 0.55
(2): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE VIOLATED KIC REQUIREMENTS
(3): INVALID DUE TO Kmax PRECRACK > 0.6 Kq

TABLE O15

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
MCAIR,	T-L	17.8		VALID
ST. LOUIS		17.0		VALID
MARTIN MARIETTA, LOUISIANA	T-L		18.7	(1)
LTV	T-L		30.2	(2)
			21.1	(3)
		27.9		VALID
	AVERAGE	20.9	23.3	
	STANDARD DEVIATION	6.1	6.1	

(1): INVALID DUE TO a/W=0.552 > 0.55
(2): INVALID DUE TO TEST SPECIMEN FRACTURE SURFACE VIOLATED KIC REQUIREMENTS
(3): INVALID DUE TO Kmax PRECRACK > 0.6 Kq

TABLE 016

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
MCAIR, ST. LOUIS	S-T	19.9	20.3	(1),(2) VALID
MARTIN MARIETTA, LOUISIANA	S-T		15.8	(1)
			14.3	(1)
	AVERAGE	19.9	16.8	
	STANDARD DEVIATION	0.0	3.1	

(1): INVALID DUE TO SURFACE TRACE/AVERAGE CRACK ERROR VALUE > VALID REQ
(2): AVERAGE CRACK/W VALUE LESS THAN VALID REQUIREMENT

TABLE 017

FRACTURE TOUGHNESS RESULTS FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	KIC (KSI IN^0.5)	Kq (KSI IN^0.5)	COMMENT
MARTIN	S-L		19.3	(1)
MARIETTA,		16.7		
LOUISIANA		15.0		
	AVERAGE	15.9	19.3	
	STANDARD DEVIATION	1.2	0.0	

(1): INVALID DUE TO a/W=0.552 > 0.55

TABLE O18

FATIGUE RESULTS WITH Kt=1.0 AND R=-1.0 FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	LIMIT STRESS (KSI)	CYCLES TO FAILURE
MCAIR, ST. LOUIS	LONG	60.0	2,270
		55.0	5,140
		50.0	10,750
		45.0	18,150
		40.0	86,100
		35.0	206,670
		30.0	2,560,000 *
		25.0	1,000,000 *

(*): INDICATES A RUN OUT TEST

TABLE O19

FATIGUE RESULTS WITH Kt=1.0 AND R=0.1 FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	LIMIT STRESS (KSI)	CYCLES TO FAILURE
LTV	LONG	50.0	11,600
		46.1	15,100
		44.9	17,400
		44.0	12,100
		43.0	28,200
		42.9	18,800
		41.7	28,000
		40.9	28,300
		40.1	10,700
		39.7	7,400
		36.9	24,700
		36.0	285,600
		35.2	18,000
		34.4	318,700
		33.2	3,000,000 *

(*): INDICATES A RUN-OUT TEST

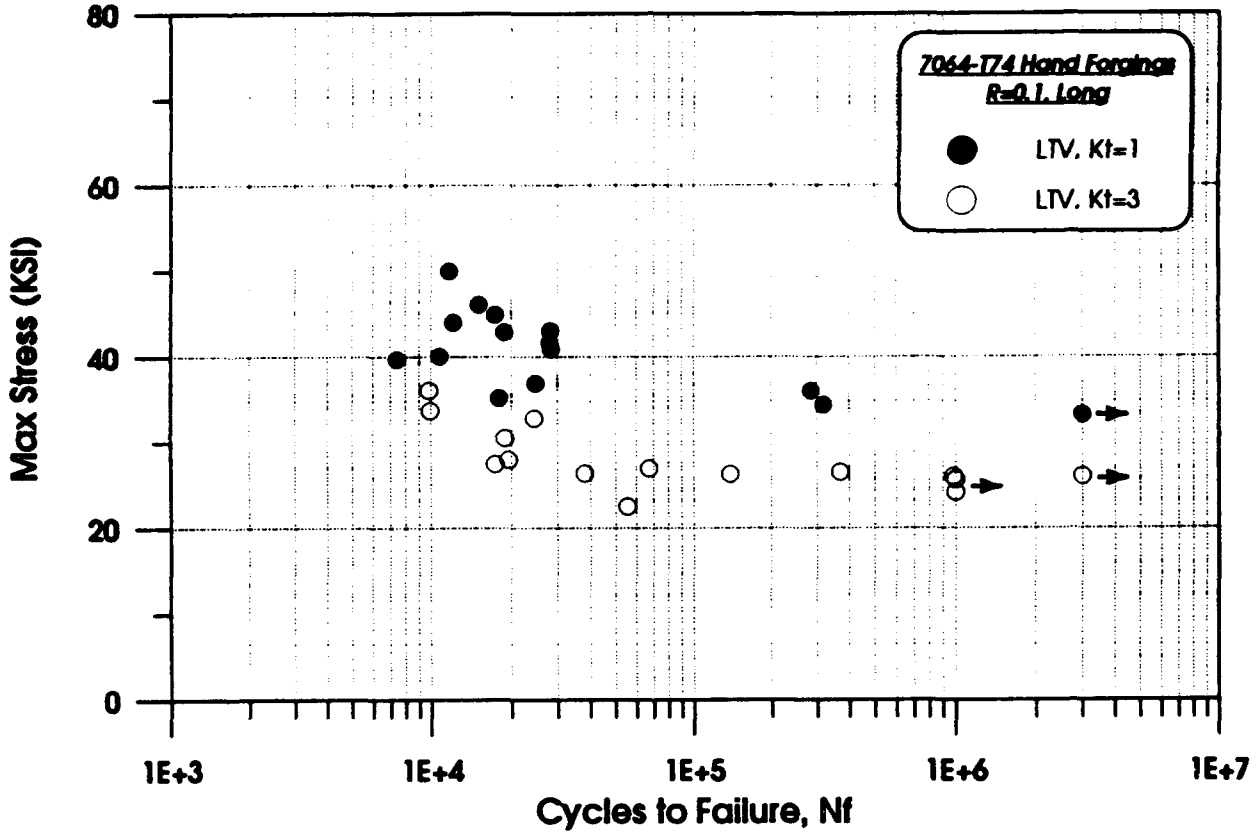


FIGURE O1. FATIGUE DATA for 7064-T74 Hand Forgings (Longitudinal Orientation R=0.1, Kt=1 and Kt=3).
LTV.

TABLE O20

FATIGUE RESULTS WITH Kt=3.0 AND R=0.1 FOR

KAISER 7064-T74 HAND FORGINGS

COMPANY	ORIENTATION	LIMIT STRESS (KSI)	CYCLES TO FAILURE
LTV	LONG	36.1	9,800
		33.7	9,900
		32.8	24,500
		30.5	18,900
		28.0	19,600
		27.5	17,400
		27.0	67,100
		26.5	368,300
		26.4	38,100
		26.3	138,700
		26.0	983,800
		26.0	3,000,000 *
		25.6	1,000,000 *
		24.1	1,000,000 *
		22.5	55,500

(*): INDICATES A RUN-OUT TEST

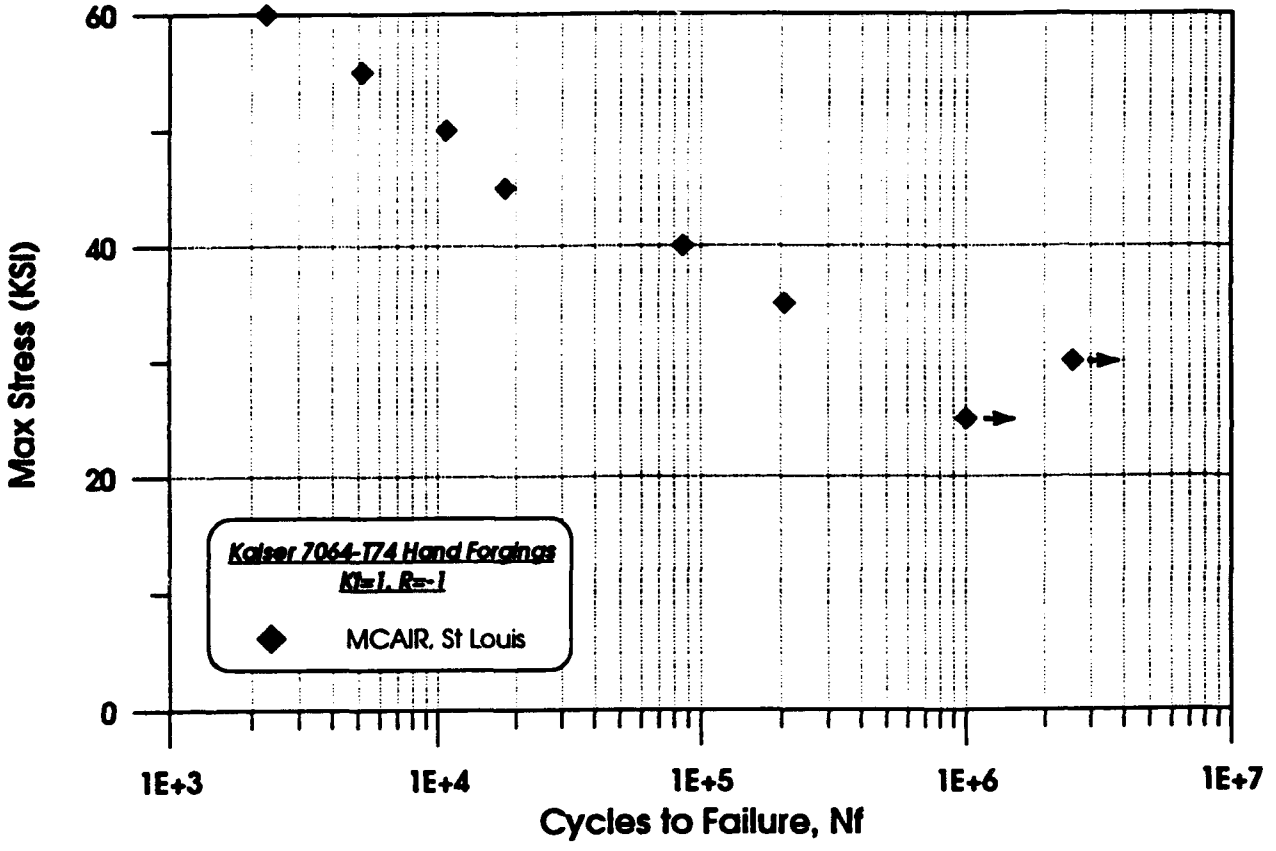
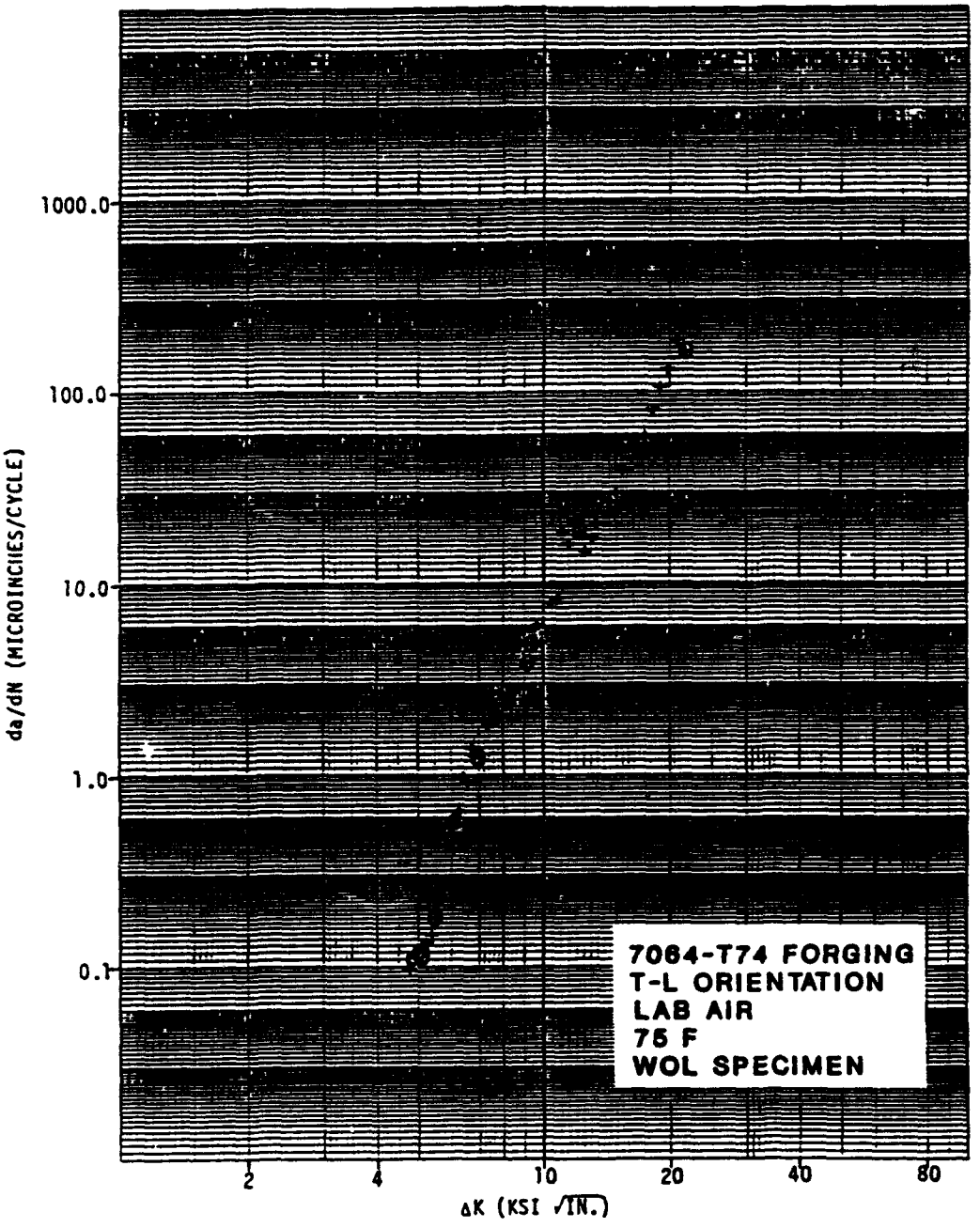


FIGURE O2. FATIGUE DATA FOR 7064-T74 HAND FORGINGS (Longitudinal Orientation, R=-1.0, and Kt=1). McDonnell Aircraft Company.



● DENOTES THAT DATA POINT IS INVALID PER ASTM 647-83, PARAGRAPH 8.6.4.

FIGURE O3. FATIGUE CRACK GROWTH RATE DATA for 7064-T74 Forging (T-L Orientation, WOL Type Specimen). McDonnell Aircraft Company.

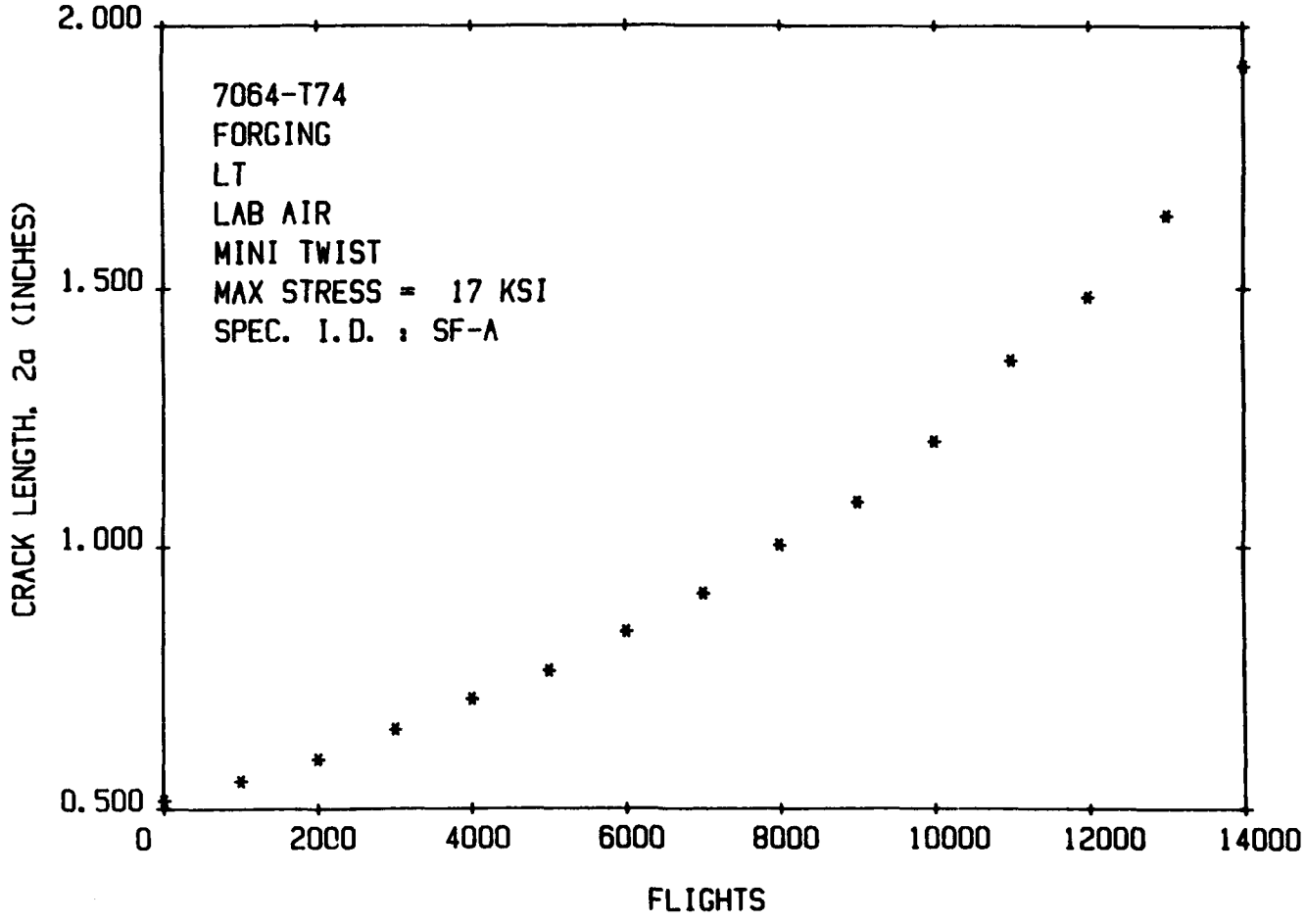


FIGURE O4. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging. Air Force.

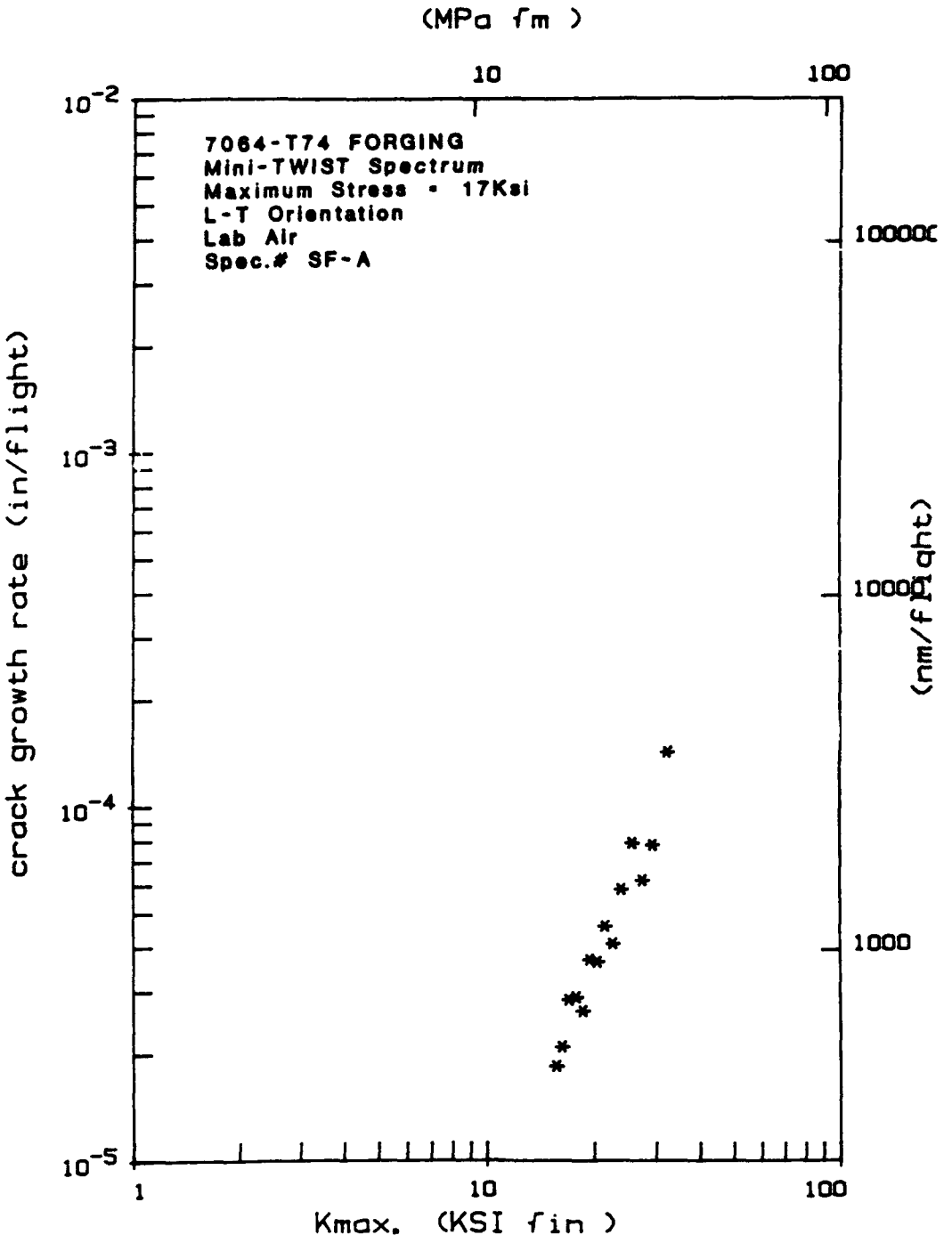


FIGURE O5. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for 7064-T74 Forging.
Air Force.

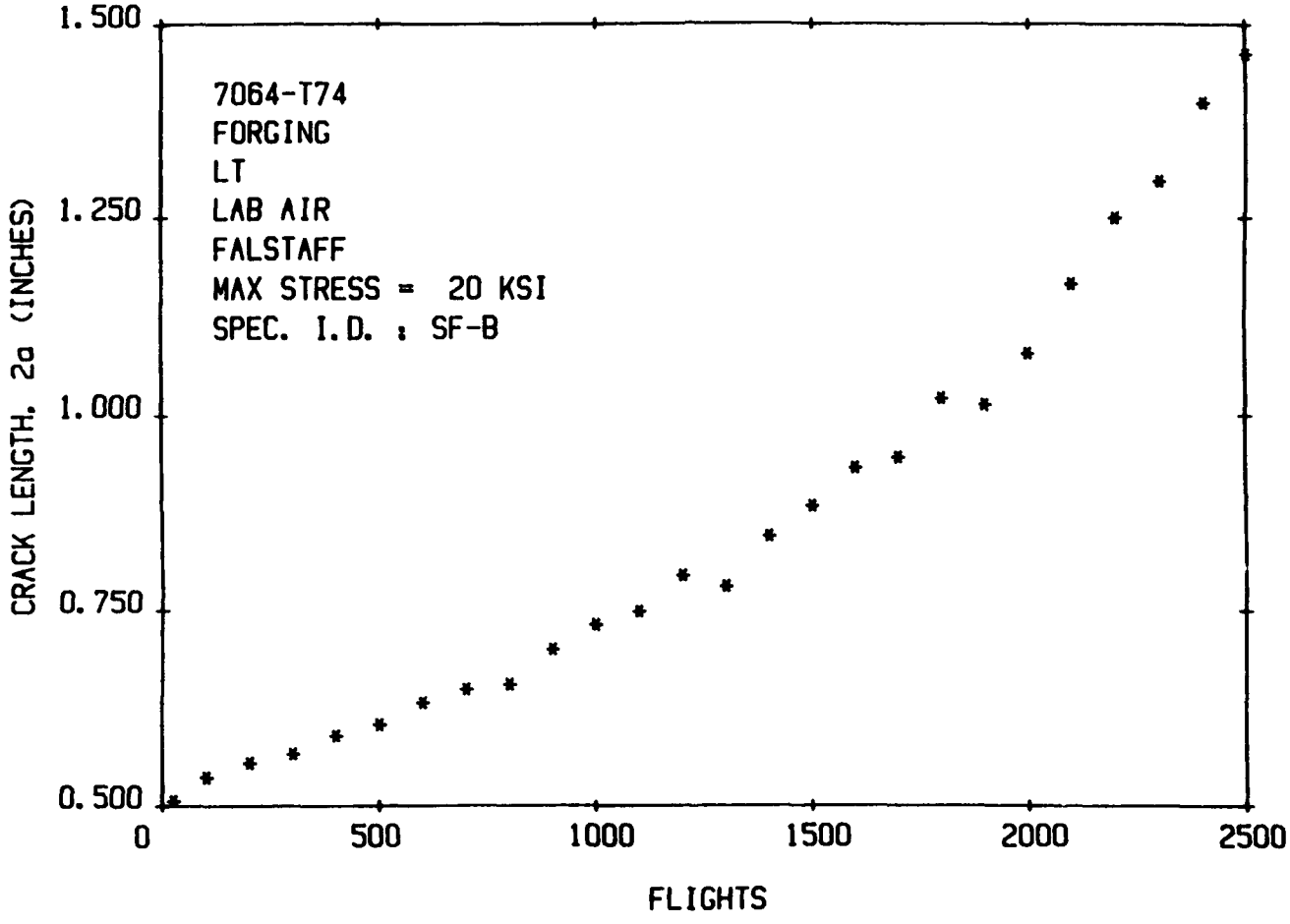


FIGURE O6. FALSTAFF Spectrum Fatigue Crack Length vs Flights Data for 7064-T74 Forging. Air Force.

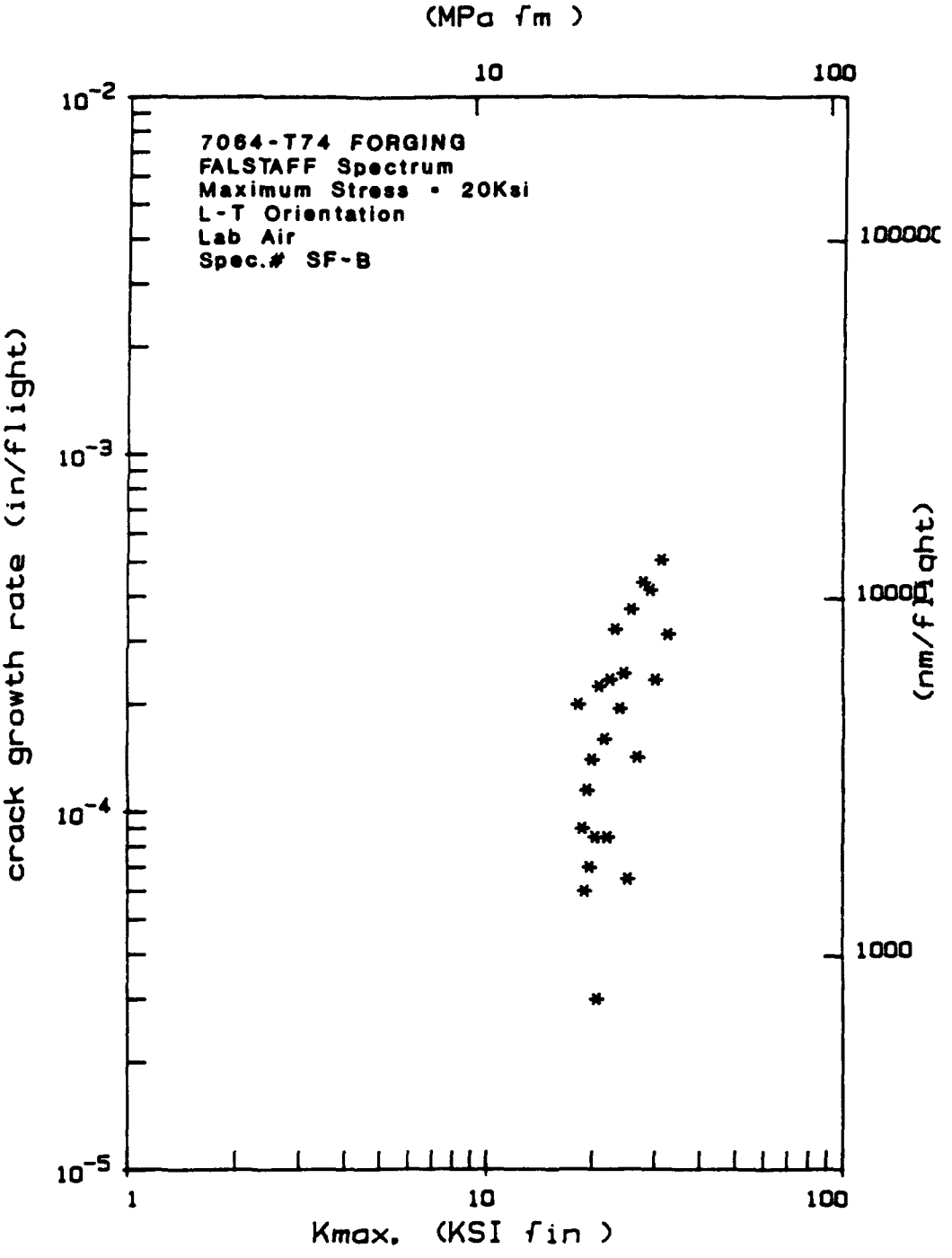


FIGURE 07. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for 7064-T74 Forging.
Air Force.

APPENDIX P

CW67 SHEET
0.063"X16"X48"

TABLE P1

TENSILE RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	LONG	81.5	77.5	8.0	10.0	9.8
MARIETTA,			81.9	78.7	7.0	10.0	9.7
LOUISIANA			82.9	79.5		6.7	9.8
MCDONNELL	RT	LONG	80.0	77.0	6.0		10.0
DOUGLAS			80.0	77.5	8.0		10.4
			81.0	78.5	6.0		10.0
		AVERAGE	81.2	78.1	7.0	8.9	10.0
	STANDARD	DEVIATION	1.1	0.9	1.0	1.9	0.3

TABLE P2

TENSILE RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	L TRANS	83.5	80.8		6.7	9.9
MARIETTA,			83.9	82.0	3.0	3.3	10.0
LOUISIANA			83.7	80.5	2.0	6.7	10.1
MCDONNELL	RT	L TRANS	87.5	83.0	4.0		10.3
DOUGLAS			86.5	82.0	5.0		10.3
			86.5	82.0	5.0		10.4
		AVERAGE	85.3	81.7	3.8	5.6	10.2
	STANDARD	DEVIATION	1.8	0.9	1.3	2.0	0.2

TABLE P3

COMPRESSION RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCDONNELL DOUGLAS	RT	LONG		11.2
				11.5
			72.0	10.3
		AVERAGE	72.0	11.0
		STANDARD DEVIATION	0.0	0.6

TABLE P4

COMPRESSION RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCDONNELL DOUGLAS	RT	L TRANS		10.3
				10.8
				11.2
		AVERAGE		10.8
		STANDARD DEVIATION		0.5

TABLE P5

SLOTTED SHEAR RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
MCDONNELL DOUGLAS	LONG	31.0
		30.0
		29.3
	AVERAGE	30.1
	STANDARD DEVIATION	0.9

TABLE P6

BEARING RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCDONNELL DOUGLAS	LONG	1.5	117.1	101.3
			124.3	107.7
			125.5	111.1
		AVERAGE	122.3	106.7
		STANDARD DEVIATION	4.5	5.0

TABLE P7

BEARING RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCDONNELL DOUGLAS	L TRANS	1.5	127.1	112.0
			126.1	108.9
			126.6	112.9
		AVERAGE	126.6	111.3
		STANDARD DEVIATION	0.5	2.1

TABLE P8

BEARING RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCDONNELL	LONG	2.0	169.4	148.8
DOUGLAS			162.0	116.3
			163.5	139.5
		AVERAGE	165.0	134.9
		STANDARD DEVIATION	3.9	16.7

TABLE P9

BEARING RESULTS FOR ALCOA

CW67 SHEET (0.063" X 16" X 48")

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
MCDONNELL	L TRANS	2.0	166.1	146.4
DOUGLAS			168.5	146.6
			166.2	146.4
		AVERAGE	166.9	146.5
		STANDARD DEVIATION	1.4	0.1

TABLE P10

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 32)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 32
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: L-T
YIELD STRENGTH: 77.7 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 3.999 IN

SPECIMEN IS INVALID PER ASTM E561-86, PARA. 7.5

APPLIED LOAD (lbs)	PHYSICAL CRACK LENGTH (in)	Kr (UNCORRECTED) (psi √in)	EFFECTIVE CRACK LENGTH (in)	Kr (CORRECTED) (psi √in)
1,025	1.519	49,842	1.591	52,248
1,050	1.523	51,181	1.599	53,808
1,250	1.533	61,348	1.649	66,212
1,325	1.592	67,582	1.739	74,594
1,375	1.610	70,986	1.777	79,483
1,400	1.613	72,406	1.788	81,590
1,425	1.638	74,930	1.831	85,575
1,450	1.638	76,245	1.840	87,675
1,475	1.642	77,762	1.856	90,199
1,500	1.660	80,039	1.894	94,283
1,525	1.662	81,493	1.910	96,969
1,550	1.663	82,874	1.924	99,627
1,600	1.667	85,818	1.963	105,834
1,650	1.678	89,128	2.022	114,190
1,700	1.684	92,202	2.092	124,368
1,725	1.706	94,972	***	***
1,750	FAILURE	---	---	---

*** Indicates that the equation for Kr (Corrected) did not converge to a solution.

TABLE P11

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 33)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 33
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: L-T
YIELD STRENGTH: 77.7 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.002 IN

APPLIED LOAD (lbs)	PHYSICAL CRACK LENGTH (in)	Kr (UNCORRECTED) (psi √in)	EFFECTIVE CRACK LENGTH (in)	Kr (CORRECTED) (psi √in)
920	1.509	44,397	1.565	46,045
940	1.533	46,088	1.594	47,956
1,000	1.545	49,395	1.615	51,743
1,020	1.548	50,476	1.622	52,997
1,060	1.565	53,059	1.648	56,048
1,100	1.569	55,188	1.659	58,602
1,140	1.573	57,349	1.672	61,243
1,180	FAILURE	---	---	---

TABLE P12

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 34)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 34
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: T-L
YIELD STRENGTH: 82.3 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.002 IN

APPLIED LOAD (lbs)	PHYSICAL CRACK LENGTH (in)	Kr (UNCORRECTED) (psi √in)	EFFECTIVE CRACK LENGTH (in)	Kr (CORRECTED) (psi √in)
820	1.514	39,692	1.553	40,712
840	1.514	40,660	1.555	41,761
860	1.516	41,677	1.559	42,867
880	1.519	42,754	1.565	44,046
900	1.519	43,726	1.567	45,113
920	1.524	44,843	1.575	46,348
940	1.524	45,818	1.577	47,430
960	1.525	46,811	1.580	48,537
1,000	1.525	48,762	1.585	50,730
1,020	1.526	49,786	1.590	51,892
1,040	1.526	50,762	1.593	53,005
1,060	1.526	51,738	1.595	54,125
1,080	1.529	52,786	1.601	55,336
1,120	1.529	54,741	1.607	57,616
1,140	1.532	55,832	1.613	58,902
1,160	1.534	56,893	1.619	60,164
1,180	1.534	57,874	1.622	61,338
1,180	1.534	57,874	1.622	61,338
1,200	1.534	58,854	1.626	62,520
1,220	1.541	60,117	1.638	64,063
1,260	1.544	62,210	1.648	66,648
1,280	1.546	63,272	1.654	67,979
1,300	1.546	64,260	1.659	69,228
1,320	1.548	65,321	1.665	70,584
1,340	1.562	66,926	1.686	72,682
1,380	1.562	68,923	1.695	75,318
1,400	1.571	70,341	1.711	77,245
1,420	1.575	71,552	1.722	78,913
1,440	1.578	72,679	1.730	80,485
1,460	1.578	73,689	1.735	81,907
1,468	FAILURE	---	---	---

TABLE P13

R-CURVE DATA FOR CW67 0.063 SHEET
(SPECIMEN 35)
McDonnell Aircraft Company

SPECIMEN IDENTIFICATION: 35
MATERIAL DESCRIPTION: CW67 HIGH STRENGTH ALUMINUM SHEET
SPECIMEN TYPE: C(T) (COMPACT SPECIMEN)
SPECIMEN ORIENTATION: T-L
YIELD STRENGTH: 82.3 KSI
SPECIMEN THICKNESS: 0.071 IN
SPECIMEN WIDTH: 4.001 IN

APPLIED LOAD (lbs)	PHYSICAL CRACK LENGTH (in)	Kr (UNCORRECTED) (psi √in)	EFFECTIVE CRACK LENGTH (in)	Kr (CORRECTED) (psi √in)
800	1.501	38,420	1.537	39,340
860	1.505	41,420	1.548	42,585
880	1.505	42,383	1.550	43,636
900	1.505	43,346	1.552	44,692
920	1.505	44,310	1.555	45,753
940	1.507	45,320	1.559	46,871
960	1.507	46,284	1.561	47,943
980	1.507	47,248	1.563	49,021
1,000	1.509	48,260	1.568	50,158
1,020	1.509	49,225	1.570	51,248
1,040	1.514	50,363	1.579	52,544
1,060	1.517	51,449	1.585	53,788
1,080	1.517	52,419	1.588	54,906
1,100	1.521	53,526	1.595	56,191
1,120	1.521	54,499	1.598	57,328
1,140	1.521	55,472	1.602	58,471
1,160	1.521	56,445	1.605	59,623
1,180	1.523	57,482	1.610	60,860
1,200	1.523	58,456	1.613	62,031
1,220	1.523	59,430	1.617	63,210
1,240	1.523	60,405	1.620	64,398
1,260	1.643	66,427	1.765	72,199
1,280	1.643	67,482	1.770	73,588
1,300	1.643	68,536	1.775	74,994
1,320	1.650	69,917	1.789	76,881
1,340	1.665	71,679	1.813	79,365
1,360	1.665	72,749	1.818	80,873
1,380	1.671	74,137	1.832	82,893
1,388	FAILURE	---	---	---

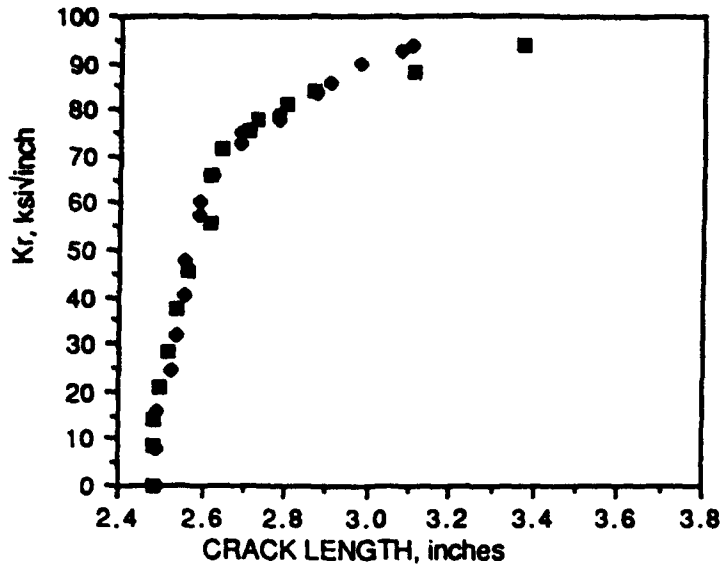


FIGURE P1. R-CURVE DATA for CW67 0.063 Inch Sheet (L-T Orientation).
Martin Marietta.

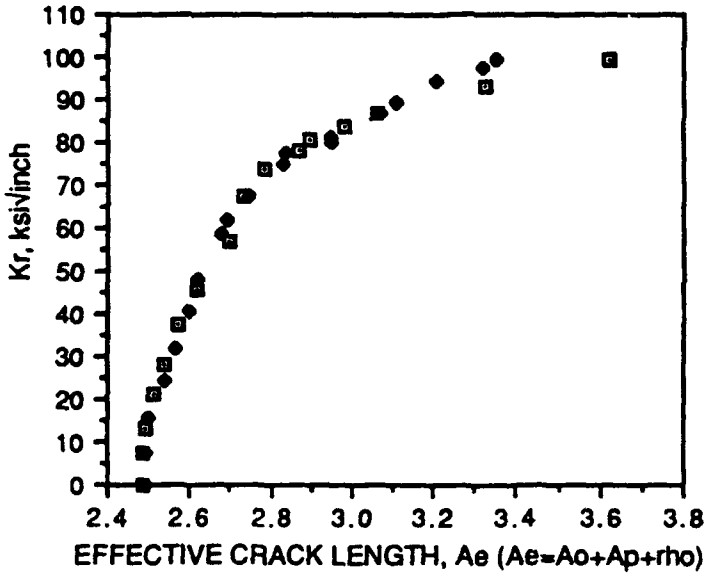


FIGURE P2. R-CURVE EFFECTIVE CRACK LENGTH ADJUSTED for PLASTIC ZONE (L-T Orientation).
Martin Marietta.

TABLE P14

R-CURVE DATA ASSOCIATED WITH FIGURES P1 AND P2
(SPECIMEN 1)

Load, kips	Half Crack Length (a) inch	Half Crack Length, (a + rho) inch	Corresponding Fracture Toughness, ksi √inch	
			Not Adjusted	Adjusted for Plasticity
0	2.485	2.485	0.0	0.0
2.50	2.485	2.487	8.3	7.8
4.25	2.485	2.490	14.1	13.2
6.40	2.500	2.512	21.3	21.4
8.45	2.520	2.541	28.3	28.4
11.10	2.535	2.571	37.3	37.6
13.35	2.565	2.619	45.2	45.8
16.30	2.615	2.698	55.9	56.9
19.25	2.615	2.733	66.1	67.7
20.75	2.645	2.785	71.8	73.8
21.50	2.710	2.866	75.6	77.9
22.15	2.710	2.893	78.1	80.7
22.60	2.800	2.982	81.2	84.0
23.00	2.865	3.060	83.9	87.0
22.85	3.105	3.327	88.3	92.9
22.90	3.365	3.620	94.0	99.5

Thickness = .058 inches
Yield Strength = 78.6 ksi
Specimen Width = 15.50 inches

TABLE P15

R-CURVE DATA ASSOCIATED WITH FIGURES P1 and P2
(SPECIMEN 2)

Load, kips	Half Crack Length (a), inch	Half Crack Length (a + rho), inch	Corresponding Fracture Toughness, ksi √inch	
			Not Adjusted	Adjusted for Plasticity
0	2.490	2.490	0.0	0.0
2.8	2.490	2.492	8.2	7.7
5.4	2.490	2.496	15.8	15.8
8.2	2.525	2.540	24.2	24.3
10.8	2.535	2.562	31.9	32.1
13.5	2.555	2.597	40.1	40.5
16.0	2.555	2.615	47.5	48.1
19.3	2.590	2.680	57.4	58.9
20.2	2.590	2.688	60.5	61.8
21.8	2.625	2.742	65.9	67.5
23.7	2.685	2.829	72.7	74.9
24.4	2.685	2.839	74.9	77.2
24.7	2.780	2.945	77.6	80.1
25.1	2.780	2.951	78.9	81.5
26.1	2.870	3.065	83.8	86.9
26.5	2.905	3.109	85.8	89.1
27.2	2.975	3.205	89.6	94.4
27.4	3.075	3.321	92.4	97.7
27.6	3.100	3.353	93.6	99.1

Thickness = 0.066 inches
Yield Strength = 78.6 ksi
Specimen Width = 15.50 inches

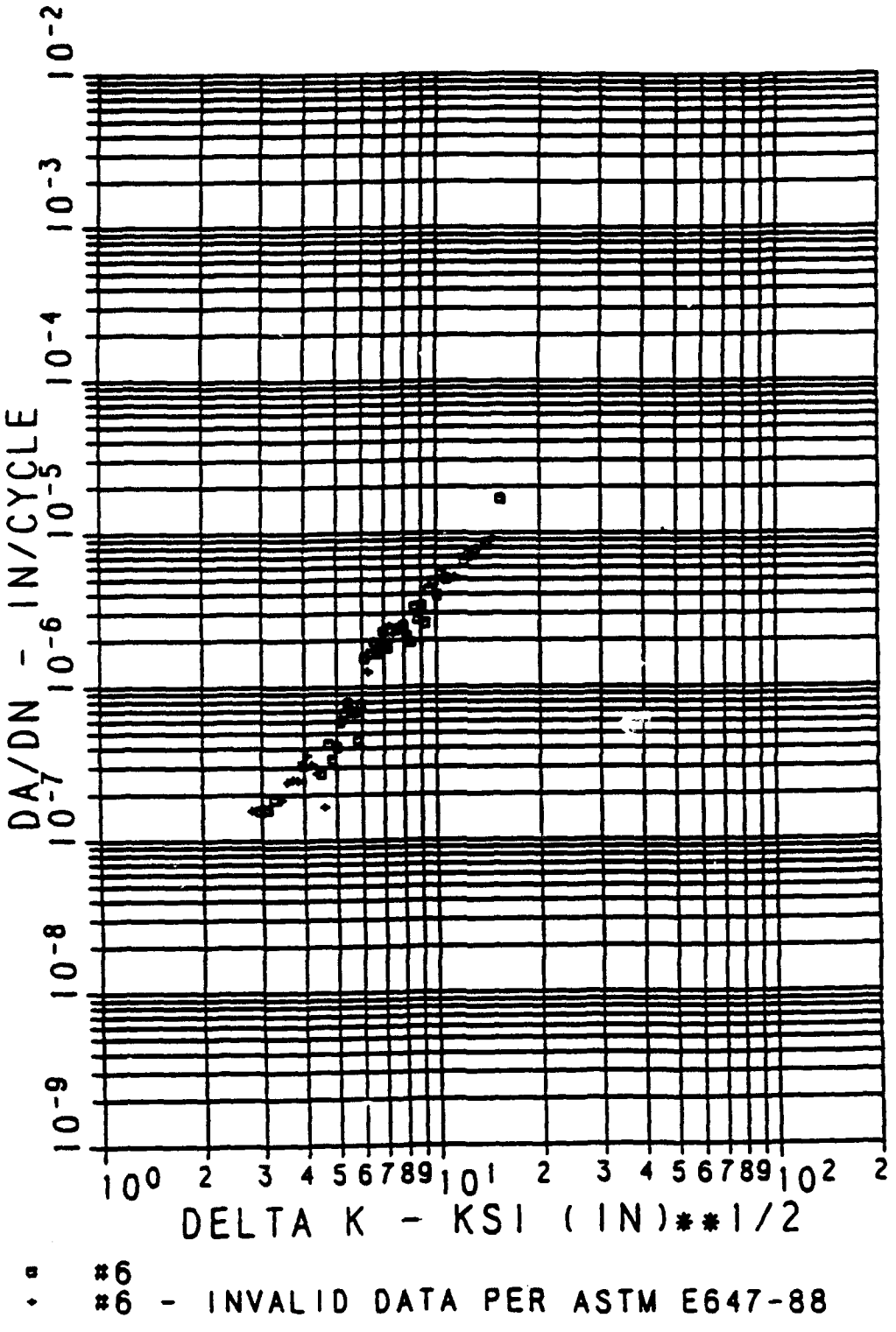


FIGURE P3. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 Sheet (L-T Orientation, R=0.1, Lab Air, Room Temperature and Specimen #6) McDonnell Aircraft Company.

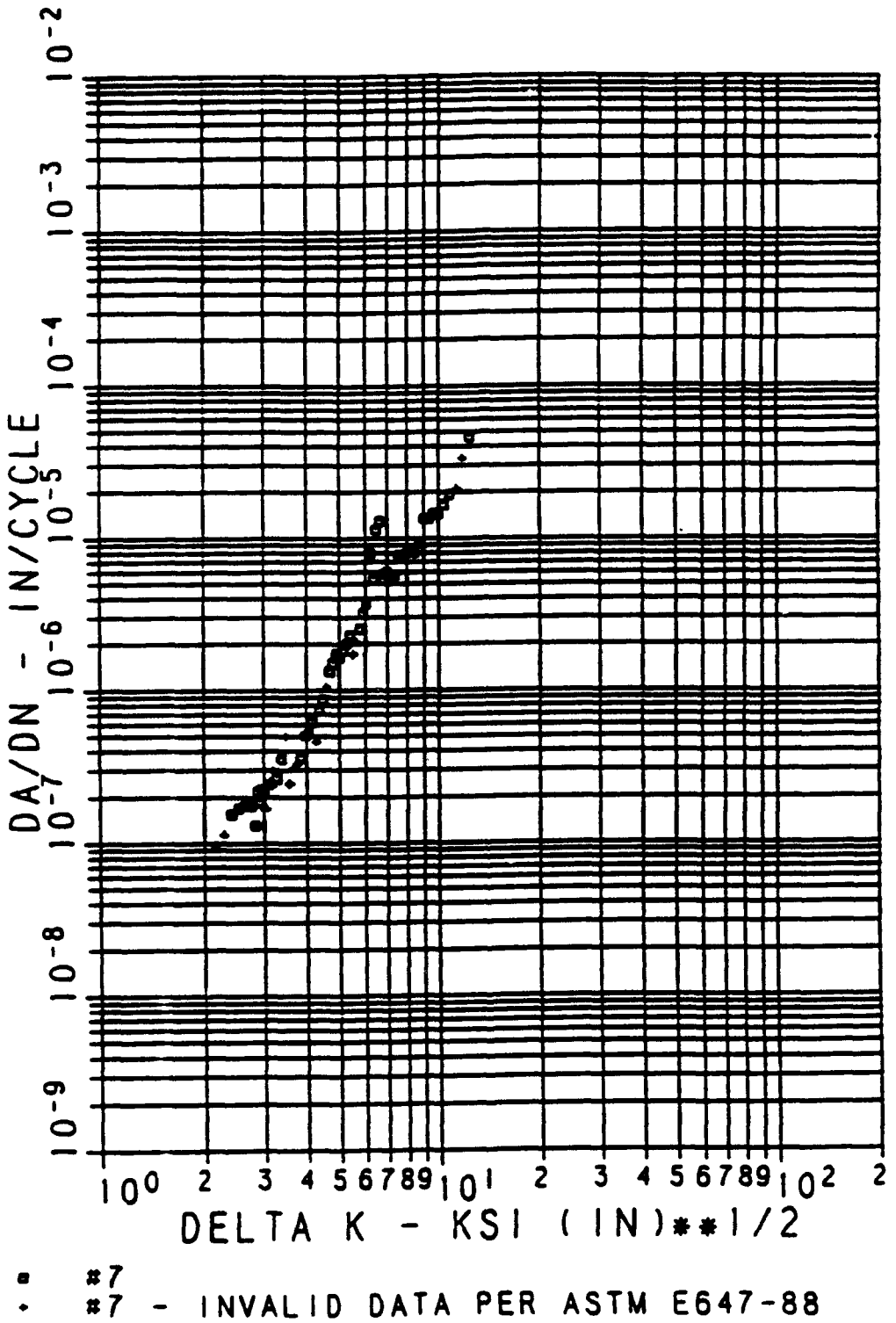


FIGURE P4. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 Sheet (L-T Orientation, R=0.33, Lab Air, Room Temperature and Specimen #7). McDonnell Aircraft Company.

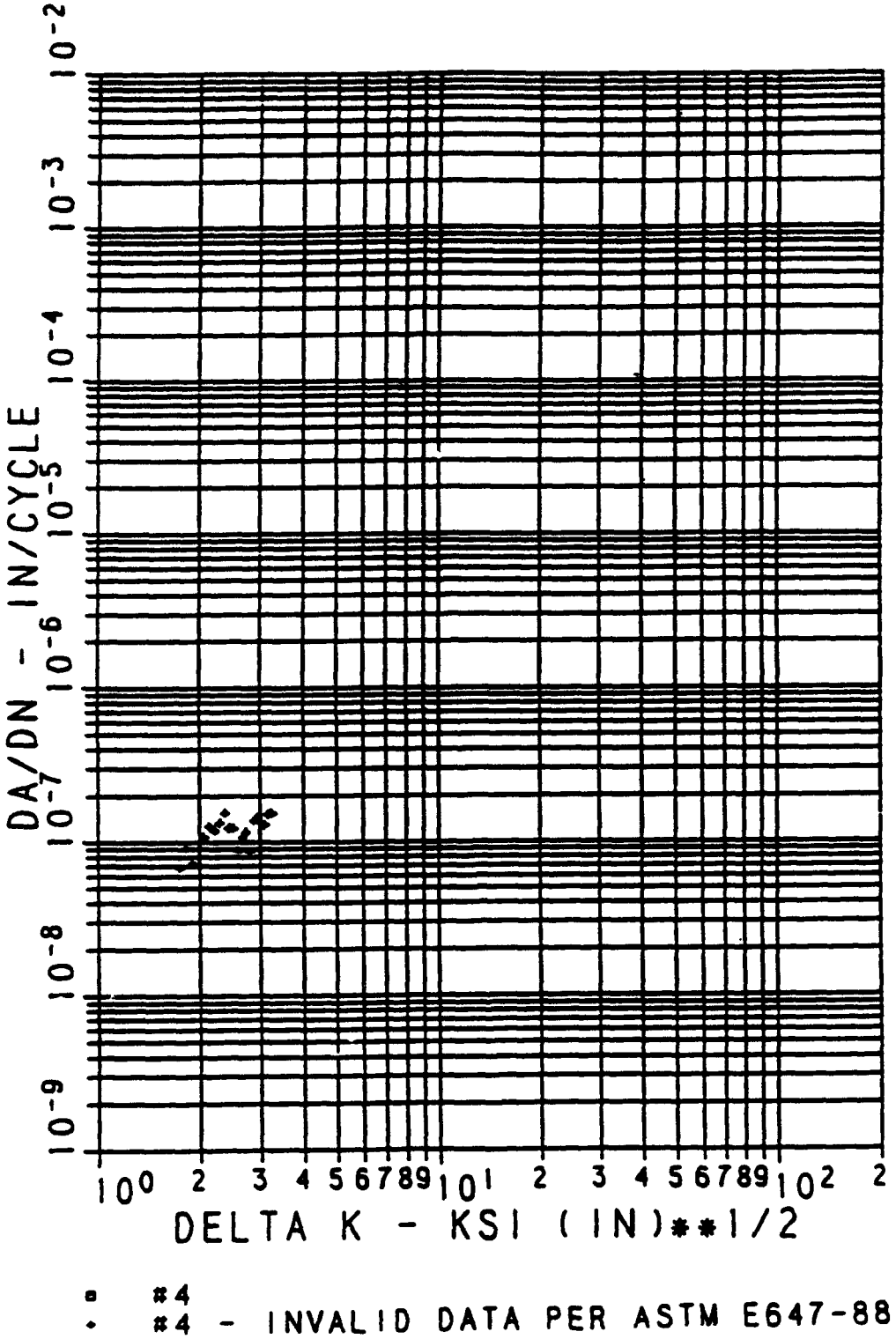


FIGURE P5. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 Sheet (T-L Orientation, R=0.1, Lab Air, Room Temperature and Specimen #4). McDonnell Aircraft Company

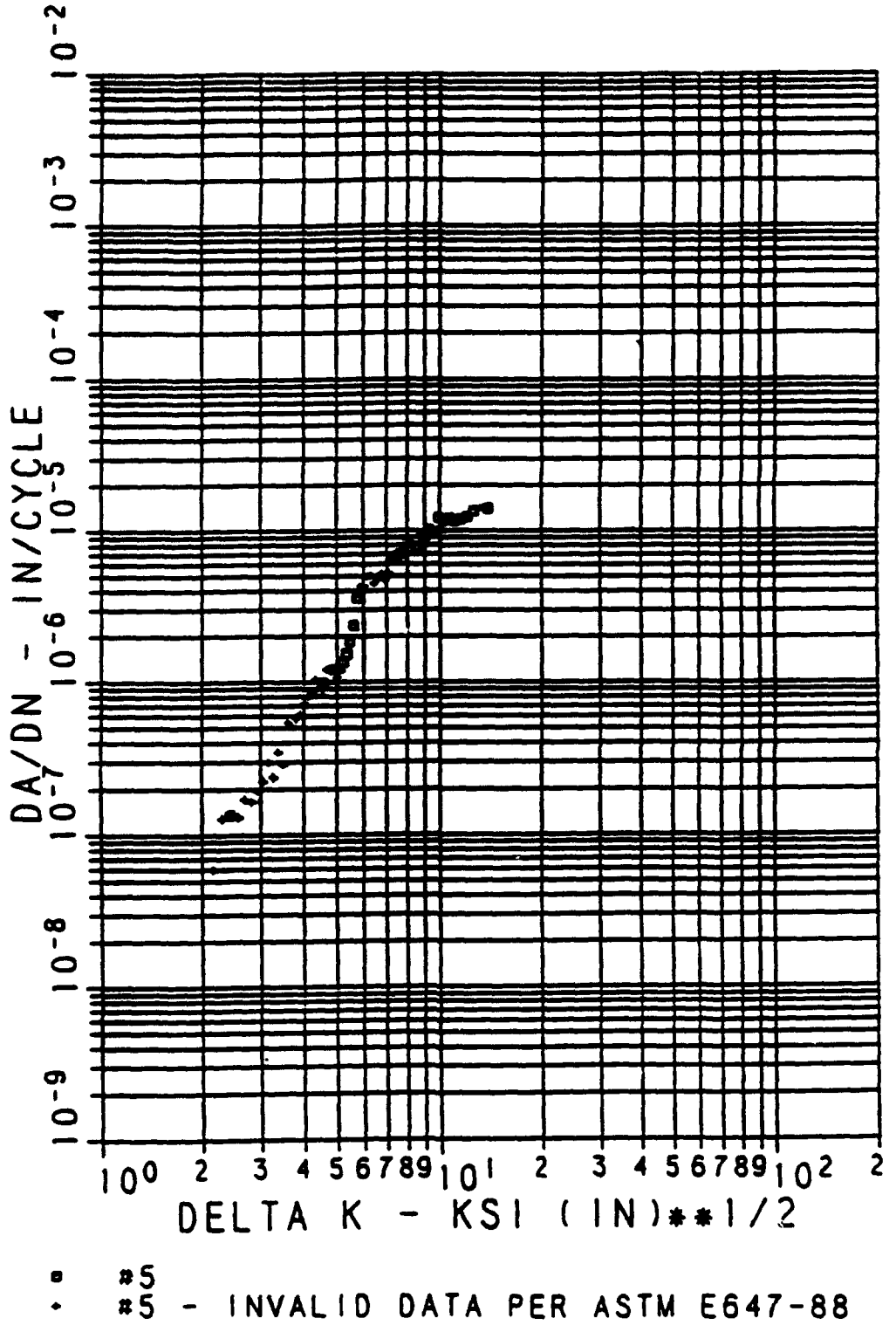


FIGURE P6. FATIGUE CRACK GROWTH RATE DATA for CW67 0.063 " Sheet (T-L Orientation, R=0.33, Lab Air, Room Temperature and Specimen #5). McDonnell Aircraft Company.

APPENDIX Q

CW67 PLATE
0.4"X16"X48"

TABLE Q1

TENSILE RESULTS FOR ALCOA

CW67 PLATE (0.4" X 16" X 48")

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	LONG	81.8	79.1	11.0	18.1	9.8
MARIETTA,			81.1	77.2	13.0	23.1	9.8
LOUISIANA			82.0	78.4	12.5	24.7	9.9
		AVERAGE	81.6	78.2	12.2	22.0	9.8
	STANDARD	DEVIATION	0.5	1.0	1.0	3.4	0.1

TABLE Q2

TENSILE RESULTS FOR ALCOA

CW67 PLATE (0.4" X 16" X 48")

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	L TRANS	88.8	84.6	6.0	5.6	9.9
MARIETTA,			87.8	83.8	6.0	6.1	10.3
LOUISIANA			86.9	83.6	6.5	6.6	10.1
		AVERAGE	87.8	84.0	6.2	6.1	10.1
	STANDARD	DEVIATION	1.0	0.5	0.3	0.5	0.2

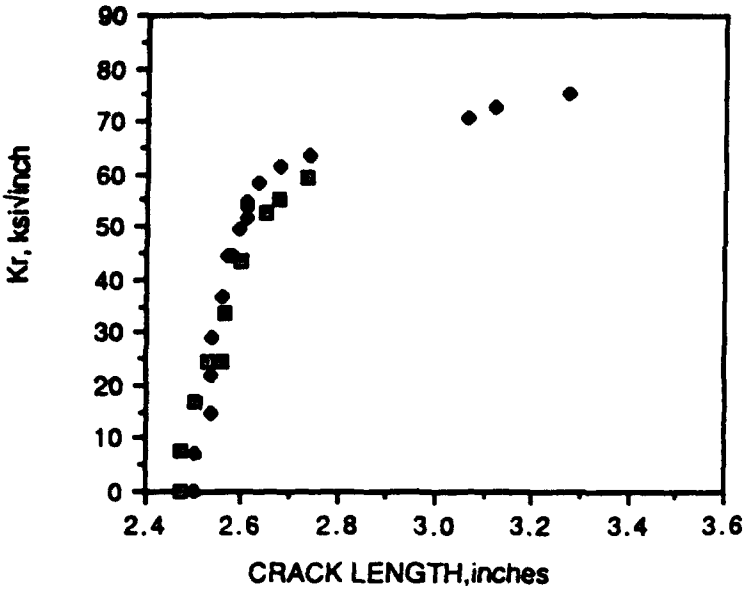


FIGURE Q1. R-CURVE DATA for CW67 0.4 INCH PLATE (L-T ORIENTATION).
Martin Marietta.

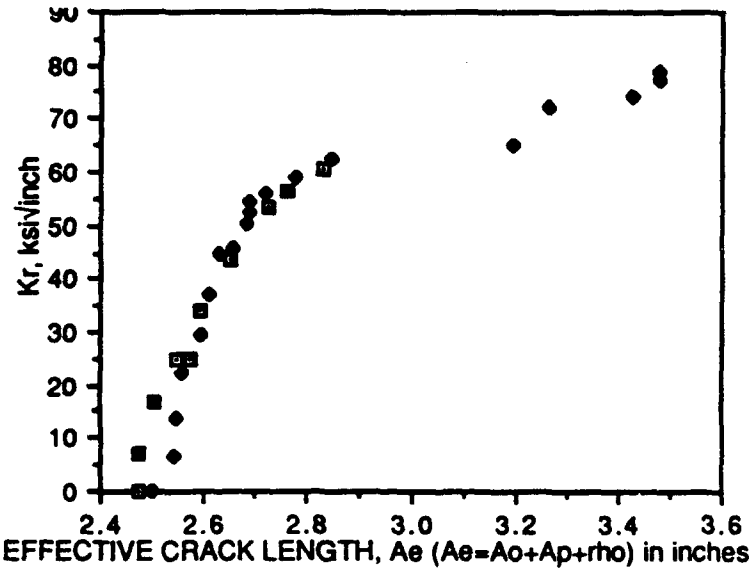


FIGURE Q2. R-CURVE EFFECTIVE CRACK LENGTH ADJUSTED for Plastic Zone Data for CW67 0.4 Inch Plate (L-T Orientation).
Martin Marietta.

TABLE Q3

R-CURVE DATA ASSOCIATED WITH FIGURES Q1 AND Q2
(SPECIMEN 1)

Load, kips	Half Crack Length (a), inch	Half Crack Length (a + rho), inch	Corresponding Fracture Toughness, ksi √inch	
			Not Adjusted	Adjusted for Plasticity
0	2.475	2.475	0.0	0.0
16.1	2.475	2.476	7.8	7.3
34.3	2.500	2.507	16.8	16.8
50.2	2.503	2.546	24.7	24.8
50.2	2.506	2.576	24.7	25.0
68.5	2.507	2.596	34.0	34.3
86.6	2.600	2.650	43.4	43.9
103.4	2.650	2.724	52.5	53.3
108.0	2.680	2.762	55.2	56.2
114.8	2.735	2.831	59.2	60.7

Thickness = 0.396 inches
Yield Strength = 78.2 ksi
Specimen Width = 15.49 inches

TABLE Q4

R-CURVE DATA ASSOCIATED WITH FIGURES Q1 and Q2
(SPECIMEN 2)

Load, kips	Half Crack Length (a), inch	Half Crack Length (a + rno), inch	Corresponding Fracture Toughness, ksi √inch	
			Not Adjusted	Adjusted for Plasticity
0	2.500	2.501	0.0	0.0
15.0	2.500	2.540	7.3	6.8
29.9	2.535	2.548	14.6	13.6
45.5	2.535	2.558	22.2	22.3
60.1	2.535	2.596	29.3	29.5
75.2	2.560	2.609	36.9	37.2
90.3	2.570	2.634	44.4	44.8
91.5	2.580	2.656	44.4	45.7
100.6	2.590	2.682	49.8	50.5
104.3	2.610	2.688	51.8	52.6
108.1	2.610	2.691	53.7	54.6
110.5	2.610	2.721	54.9	55.9
116.3	2.630	2.777	58.1	59.2
121.1	2.675	2.850	61.2	62.4
123.8	2.740	3.196	63.6	65.0
127.1	3.060	3.264	70.5	72.2
129.0	3.120	3.425	72.5	74.4
129.0	3.270	3.481	75.1	77.1
129.8	3.320	3.481	76.5	78.6

Thickness = 0.396 inches
Yield Strength = 78.2 ksi
Specimen Width = 15.50 inches

APPENDIX R

CW67 EXTRUISION
1.5"X4.5"X36"

TABLE R1

TENSILE RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
LTV	RT	LONG	86.4	81.3	10.5		10.2
			85.9	81.3	11.4		10.0
			85.9	81.3	12.3		9.9
			85.5	78.6	12.3		9.4
			86.1	80.4	11.7		9.5
AIR FORCE	RT	LONG	89.1	84.9	10.0	28.0	
			86.2	81.5	9.5	27.0	
			85.5	80.6	15.2	28.7	
MCAIR	RT	LONG	86.0	81.5	10.0	35.0	14.3
			83.0	79.0	14.0	38.0	13.4
			82.5	77.5	12.0	36.0	13.7
		AVERAGE	85.6	80.7	11.7	32.1	11.3
	STANDARD DEVIATION		1.7	1.9	1.7	4.7	2.1

TABLE R2

TENSILE RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
LTV	RT	L TRANS	80.9	75.0	10.0		10.0
			81.0	75.0	12.0		11.1
			81.6	71.0	11.2		12.9
			80.9	72.3	9.1		11.0
			80.9		10.9		12.9
AIR FORCE	RT	L TRANS	82.5	77.4	10.0	26.0	
			83.1	78.2	10.7	35.0	
			82.3	76.7	8.4	20.4	
MCAIR	RT	L TRANS	81.5	76.5	12.0	32.0	14.0
			81.0	72.0	10.0	27.0	14.0
			81.5	76.0	15.0	35.0	13.6
		AVERAGE	81.6	75.0	10.8	29.2	12.4
	STANDARD DEVIATION		0.8	2.5	1.8	5.8	1.5

TABLE R3

COMPRESSION RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCAIR	RT	LONG	78.5	10.8
			80.0	10.9
			79.5	11.0
		AVERAGE	79.3	10.9
		STANDARD DEVIATION	0.8	0.1

TABLE R4

COMPRESSION RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MCAIR	RT	L TRANS	80.0	11.2
			74.0	10.8
			79.0	10.8
		AVERAGE	77.7	10.9
		STANDARD DEVIATION	3.2	0.2

TABLE R5

IOSIPESCU SHEAR RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
LTV	LONG	49.8
		50.0
		49.9
		48.1
		48.7
		50.7
	AVERAGE	49.5
	STANDARD DEVIATION	1.0

TABLE R6

IOSIPESCU SHEAR RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
LTV	L TRANS	51.5
		51.2
		51.5
		48.9
		48.6
		51.0
	AVERAGE	50.5
	STANDARD DEVIATION	1.3

TABLE R7

AMSLER DOUBLE SHEAR RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
MCAIR	L - S	52.1
		48.3
		48.5
	AVERAGE	49.6
	STANDARD DEVIATION	2.1

TABLE R8

BEARING RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	LONG	1.5	124.0	103.0
			123.0	104.0
			126.0	106.0
MCAIR	LONG	1.5	126.9	112.1
			122.9	107.2
		AVERAGE	124.6	106.5
		STANDARD DEVIATION	1.8	3.6

TABLE R9

BEARING RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	L TRANS	1.5	122.0	109.0
			123.0	108.0
			129.0	112.0
MCAIR	L TRANS	1.5	123.7	107.4
			121.7	105.7
		AVERAGE	123.9	108.4
		STANDARD DEVIATION	3.0	2.3

TABLE R10

BEARING RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	LONG	2.0	158.0	118.0
			155.0	126.0
			156.0	121.0
MCAIR	LONG	2.0	174.2	144.4
			171.0	139.0
		AVERAGE	162.8	129.7
		STANDARD DEVIATION	9.0	11.5

TABLE R11

BEARING RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	e/D	BEARING ULT. STR. (KSI)	BEARING YIELD STR. (KSI)
LTV	L TRANS	2.0	153.0	122.0
			162.0	129.0
			156.0	124.0
MCAIR	L TRANS	2.0	170.7	141.3
			171.1	140.5
		AVERAGE	162.6	131.4
		STANDARD DEVIATION	8.3	9.1

TABLE R12

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
LTV	L-T	24.1		VALID
		22.4		VALID
		21.7		VALID
AIR FORCE	L-T	45.3		VALID
		46.9		VALID
		44.1		VALID
MCAIR	L-T	29.4		VALID
		29.0		VALID
	AVERAGE	32.9		
	STANDARD DEVIATION	10.8		

TABLE R13

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
LTV	T-L		38.5	(1)
			36.1	(1)
			42.2	(1)
AIR FORCE	T-L	26.7		VALID
		27.2		VALID
MCAIR	T-L	18.5		VALID
		18.8		VALID
	AVERAGE	22.8	38.9	
	STANDARD DEVIATION	4.8	3.1	

(1): INVALID DUE TO UNSYMMETRIC CRACK FRONT CURVATURE

TABLE R14

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MCAIR	S-T	20.5		VALID
		21.2		VALID
	AVERAGE	20.9		
	STANDARD DEVIATION	0.5		

TABLE R15

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 EXTRUSION

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MCAIR	S-L	33.0		VALID
	AVERAGE	33.0		
	STANDARD DEVIATION	0.0		

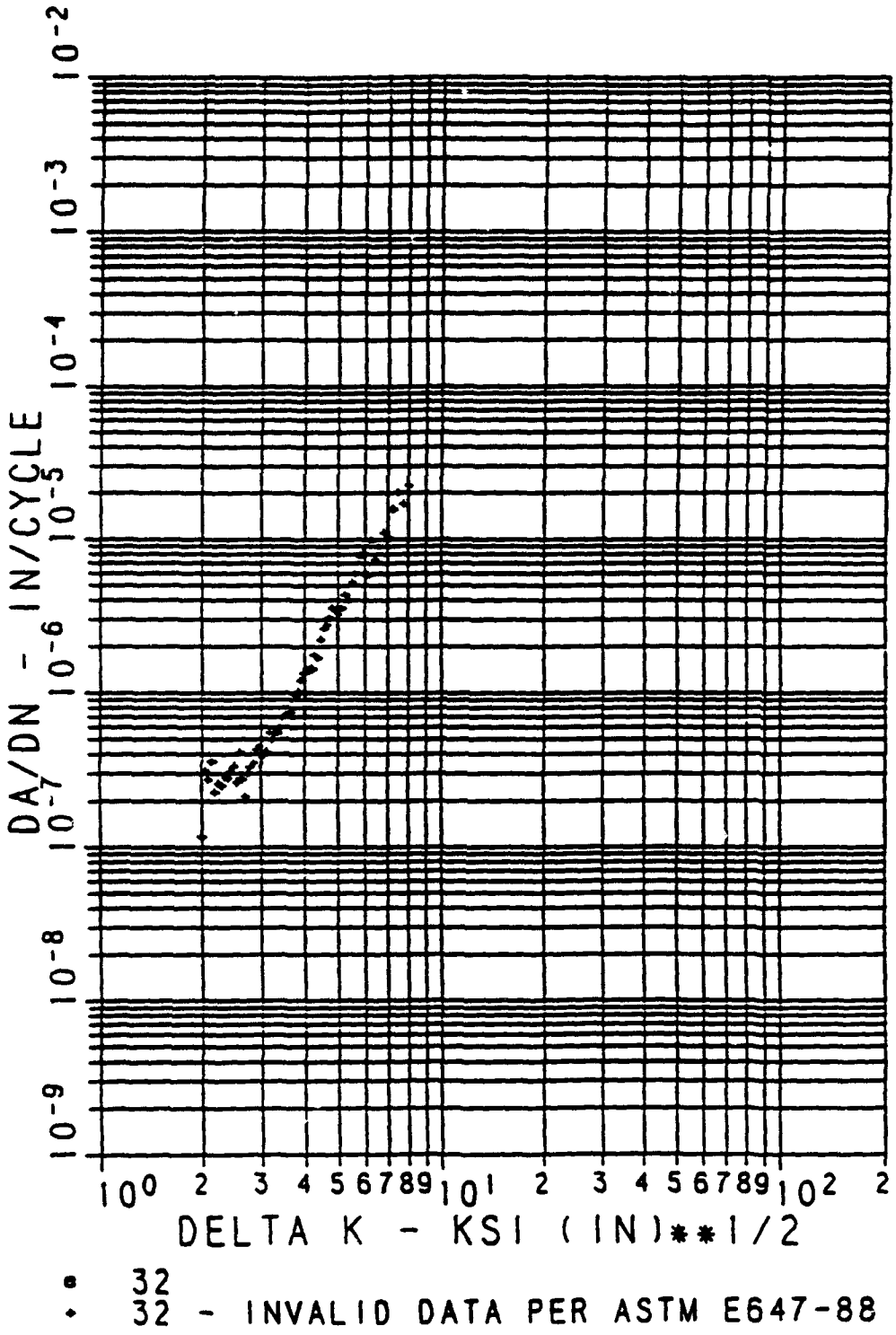


FIGURE R1. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (L-T Orientation, R=0.1, Lab Air and Room Temperature). McDonnell Aircraft Company.

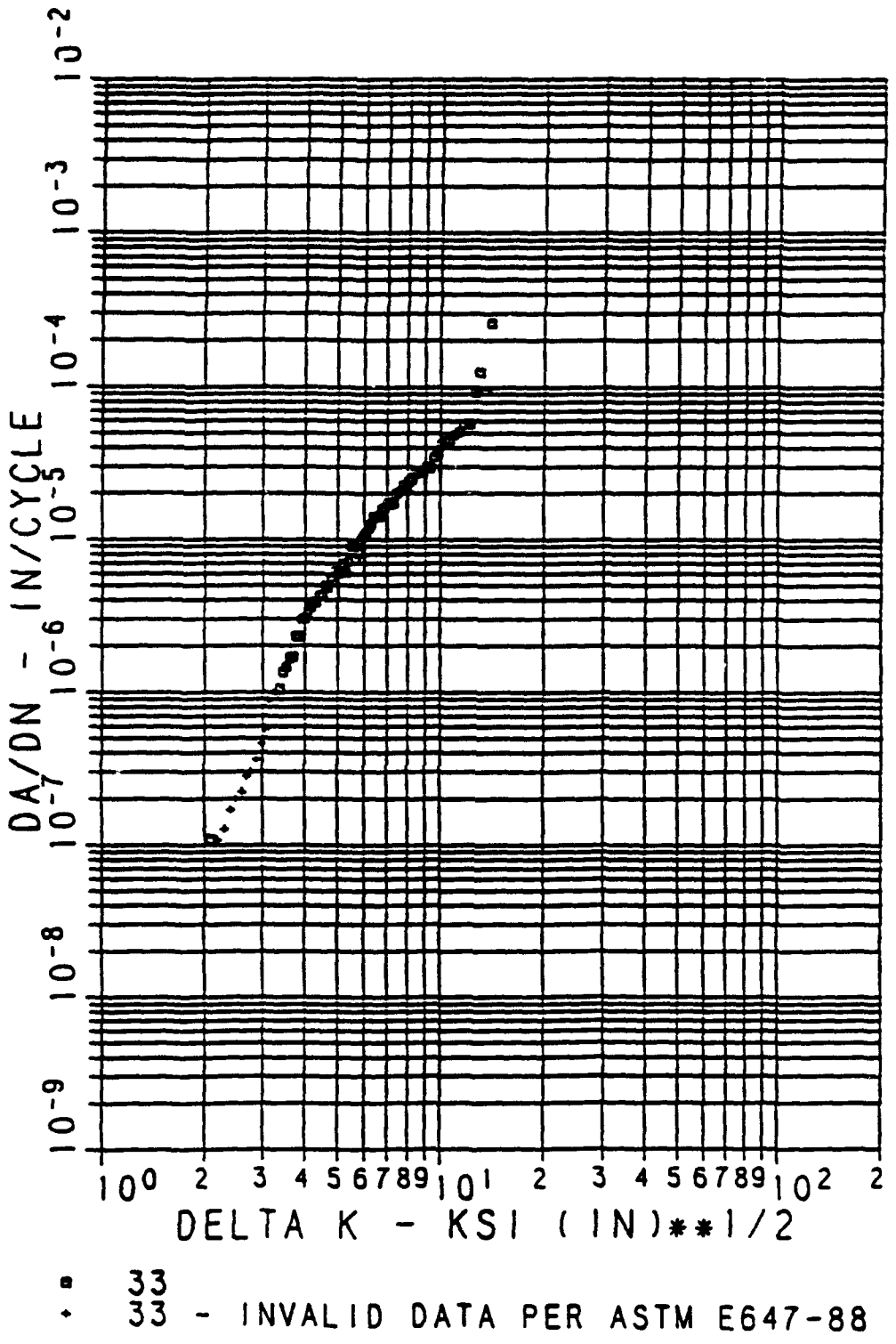


FIGURE R2. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (L-T Orientation, R=0.33, Lab Air and Room Temperature). McDonnell Aircraft Company.

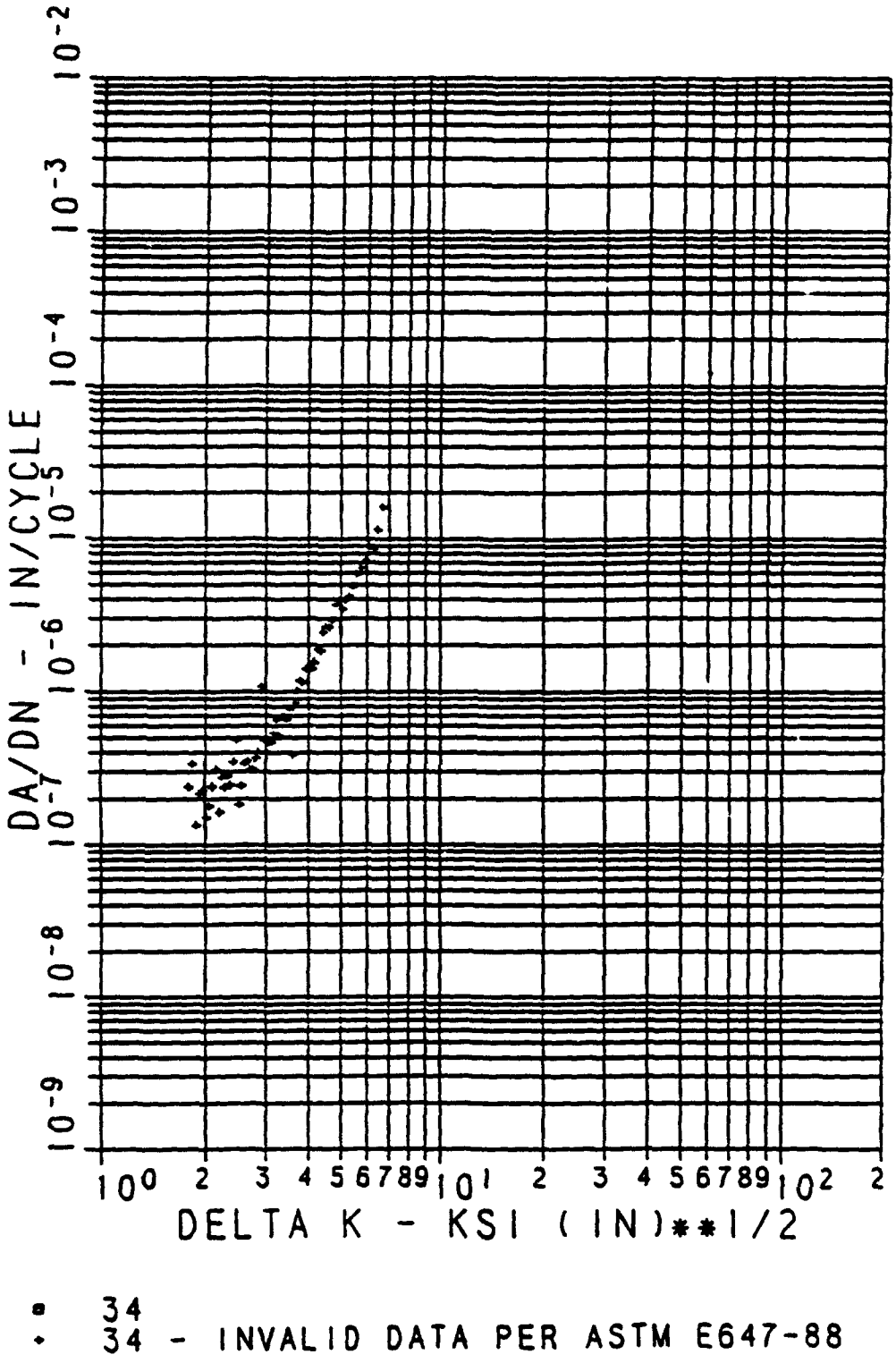


FIGURE R3. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation, R=0.1, Lab Air and Room Temperature). McDonnell Aircraft Company.

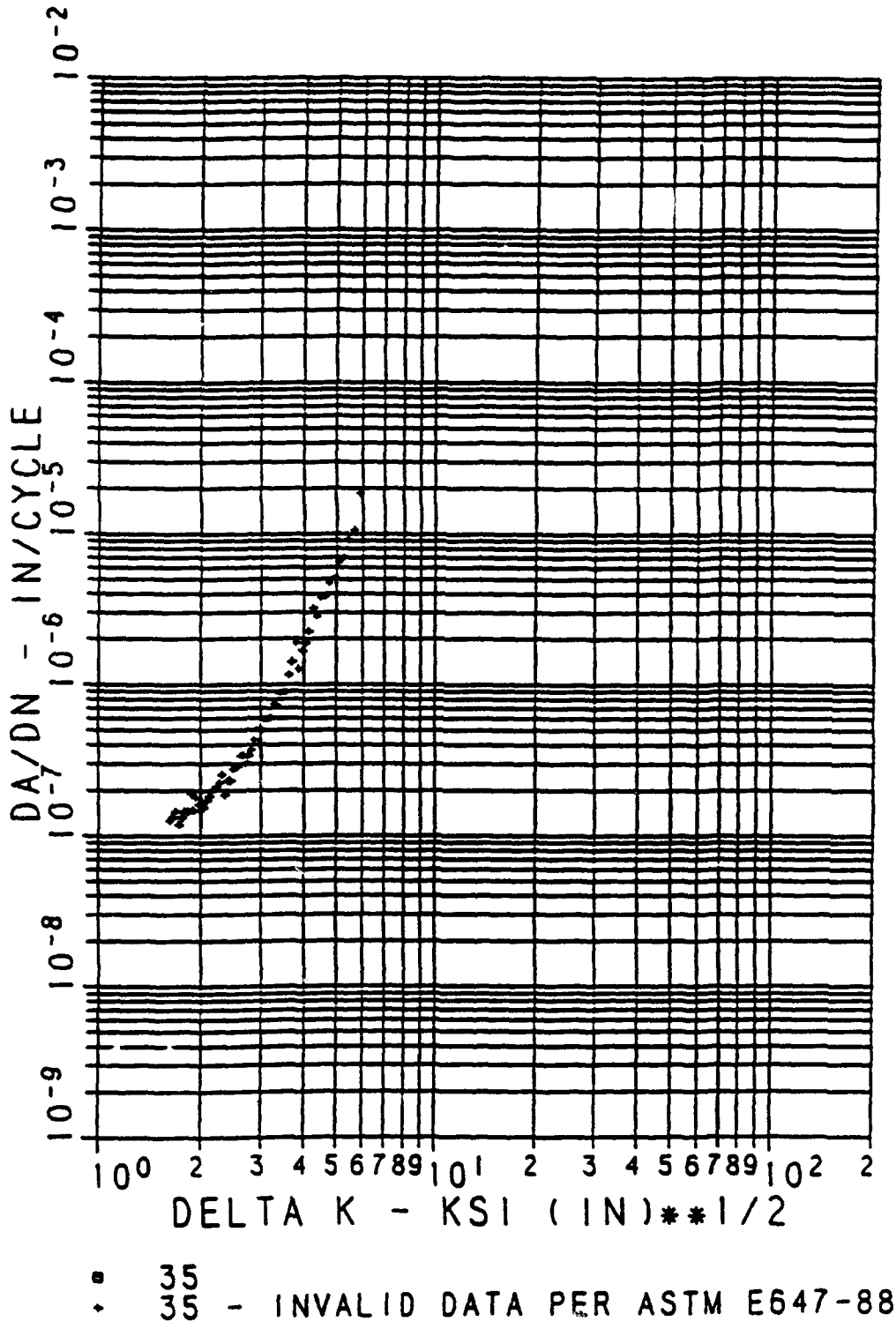


FIGURE R4. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation, R≈0.33, Lab Air and Room Temperature). McDonnell Aircraft Company.

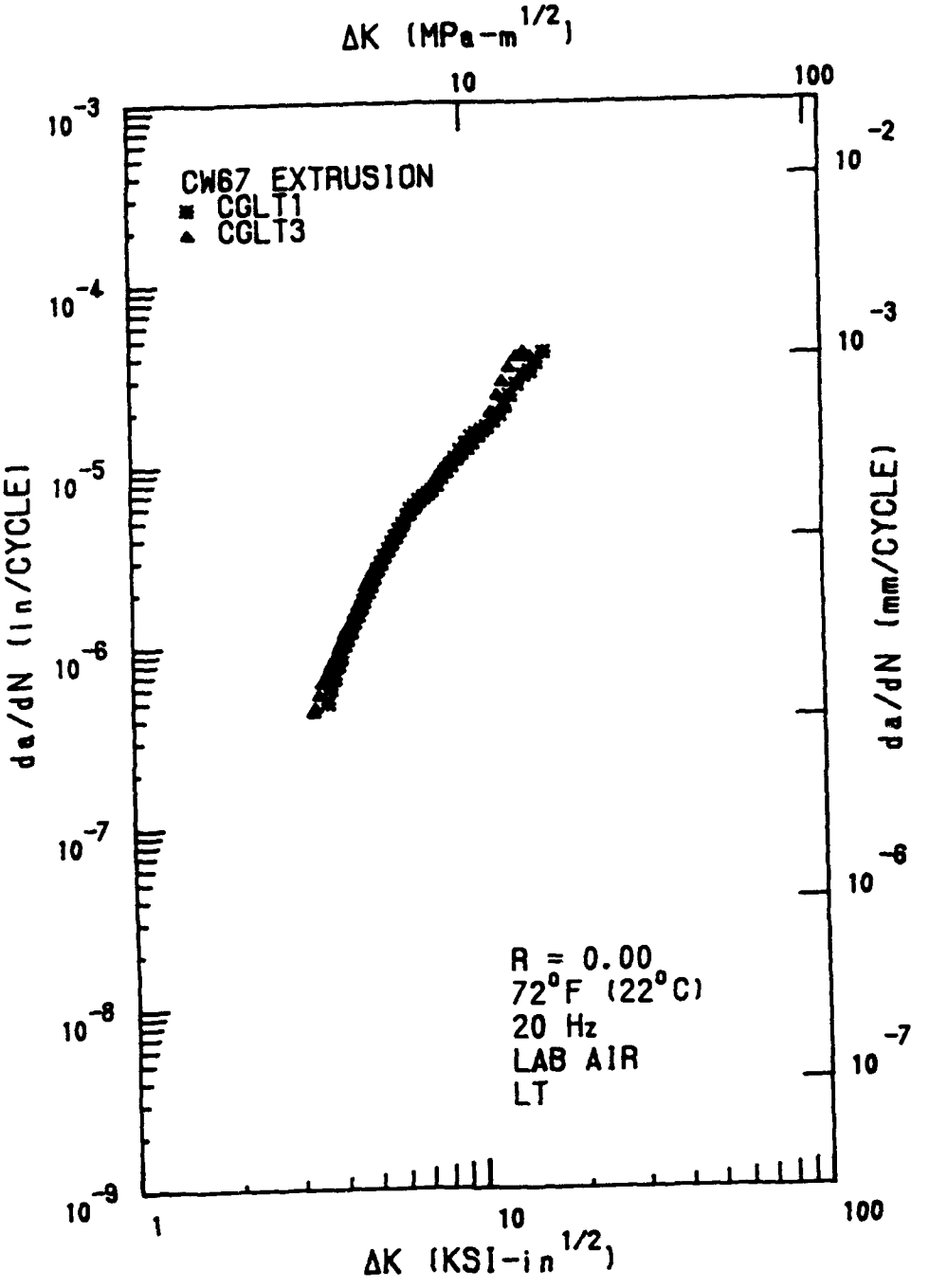


FIGURE R5. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (L-T Orientation).
Air Force.

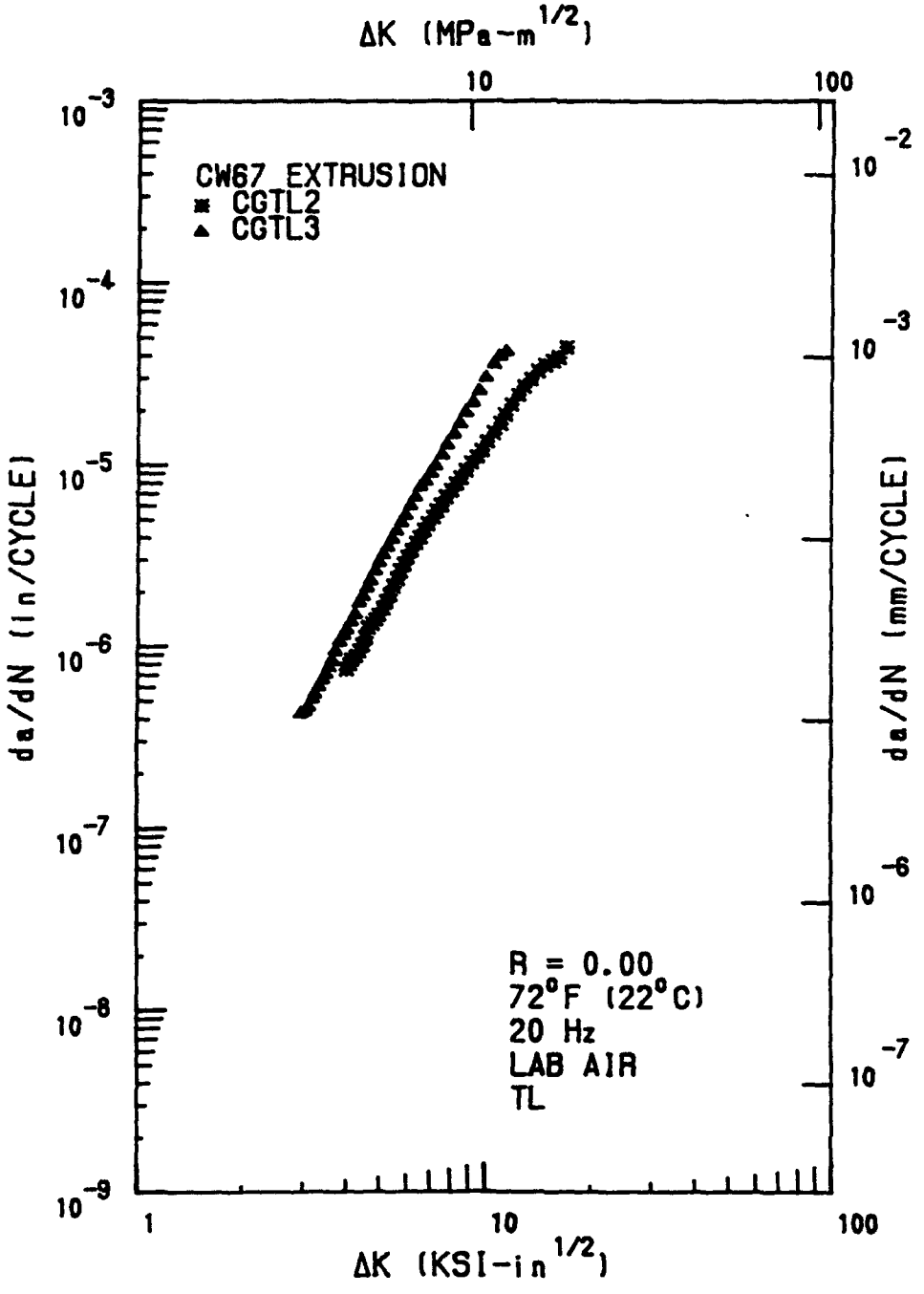


FIGURE R6. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation).
Air Force.

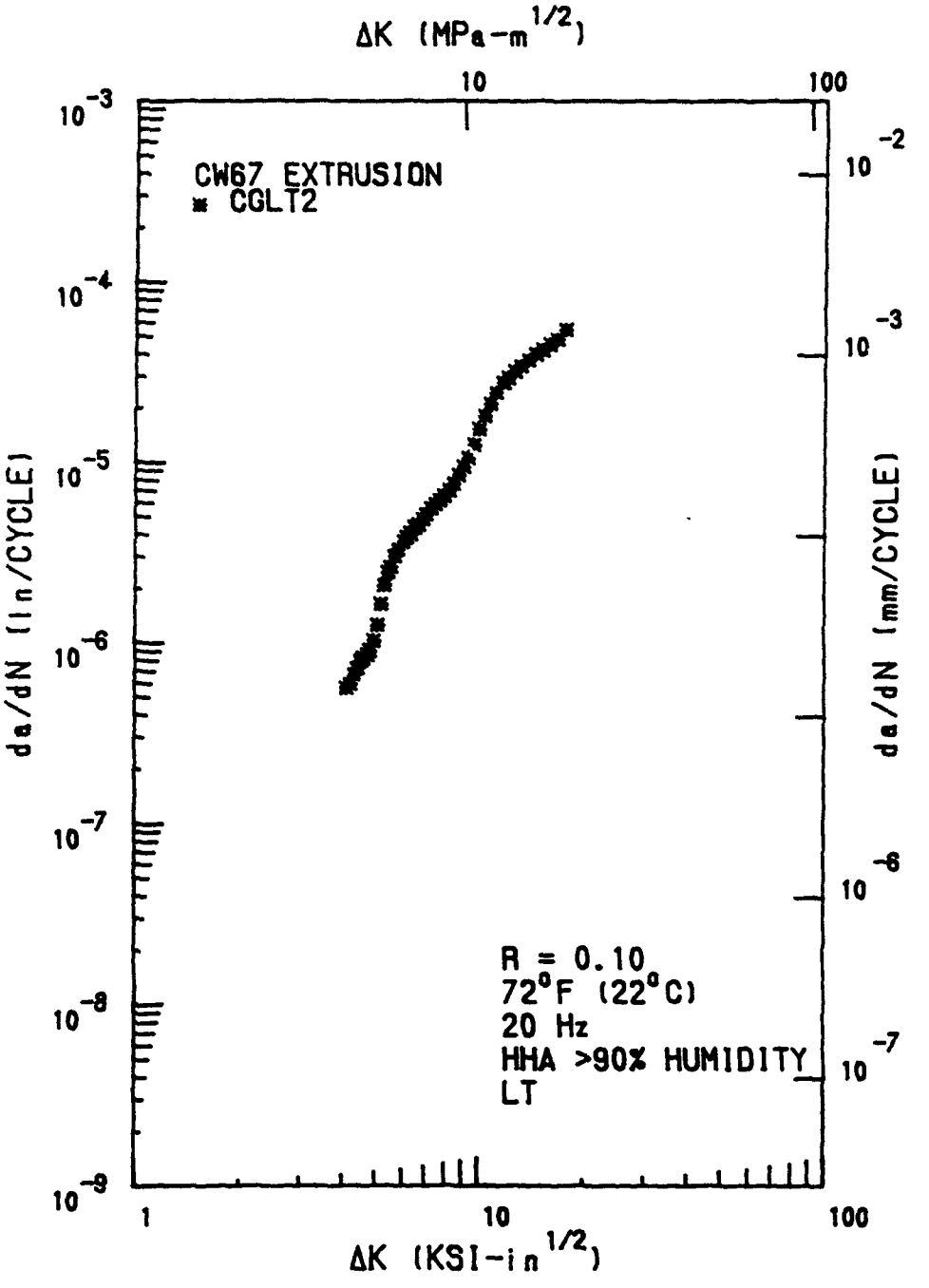


FIGURE R7. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (L-T Orientation and High Humidity). Air Force.

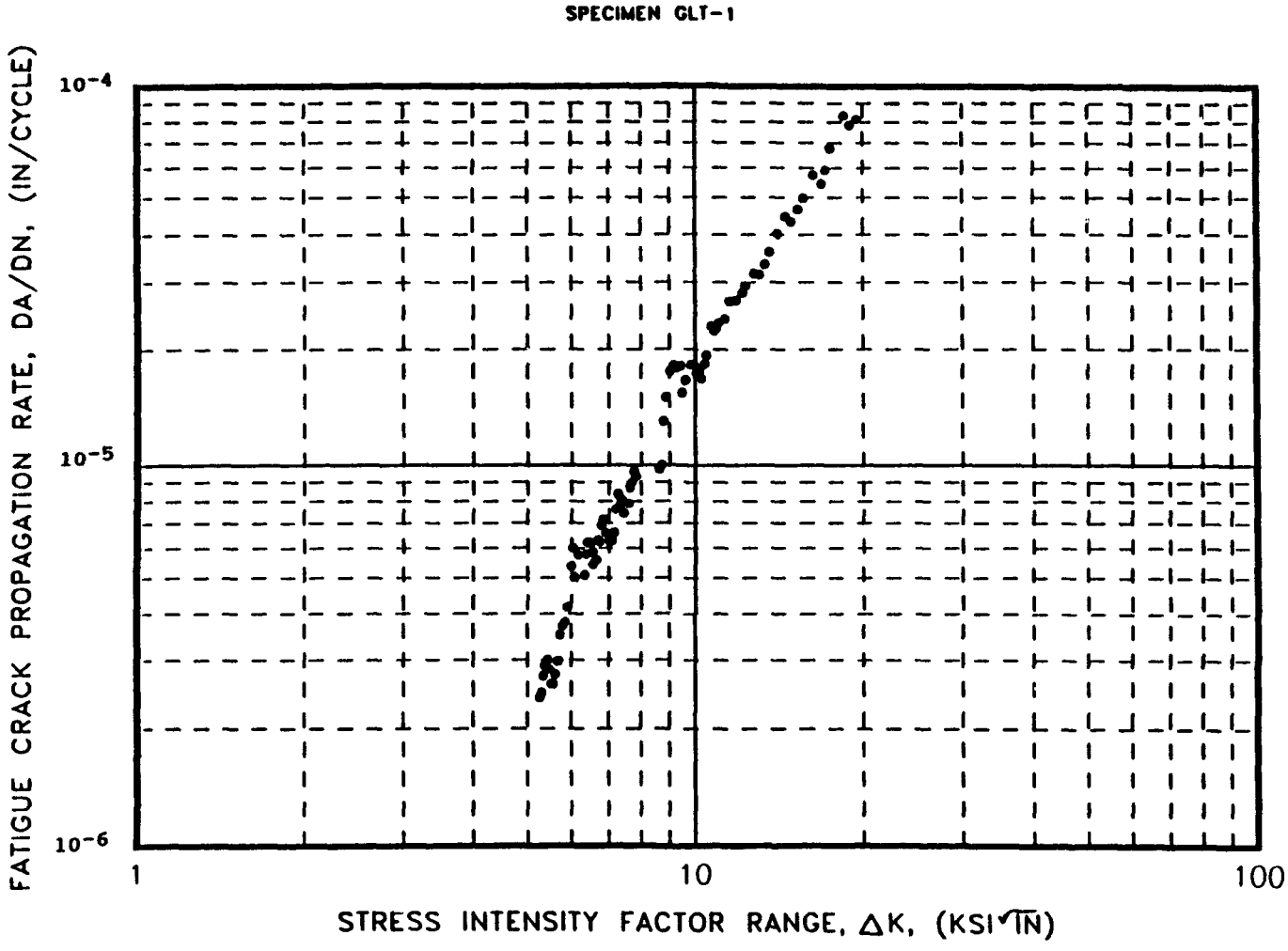


FIGURE R8. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (L-T Orientation, Specimen GLT-1). LTV.

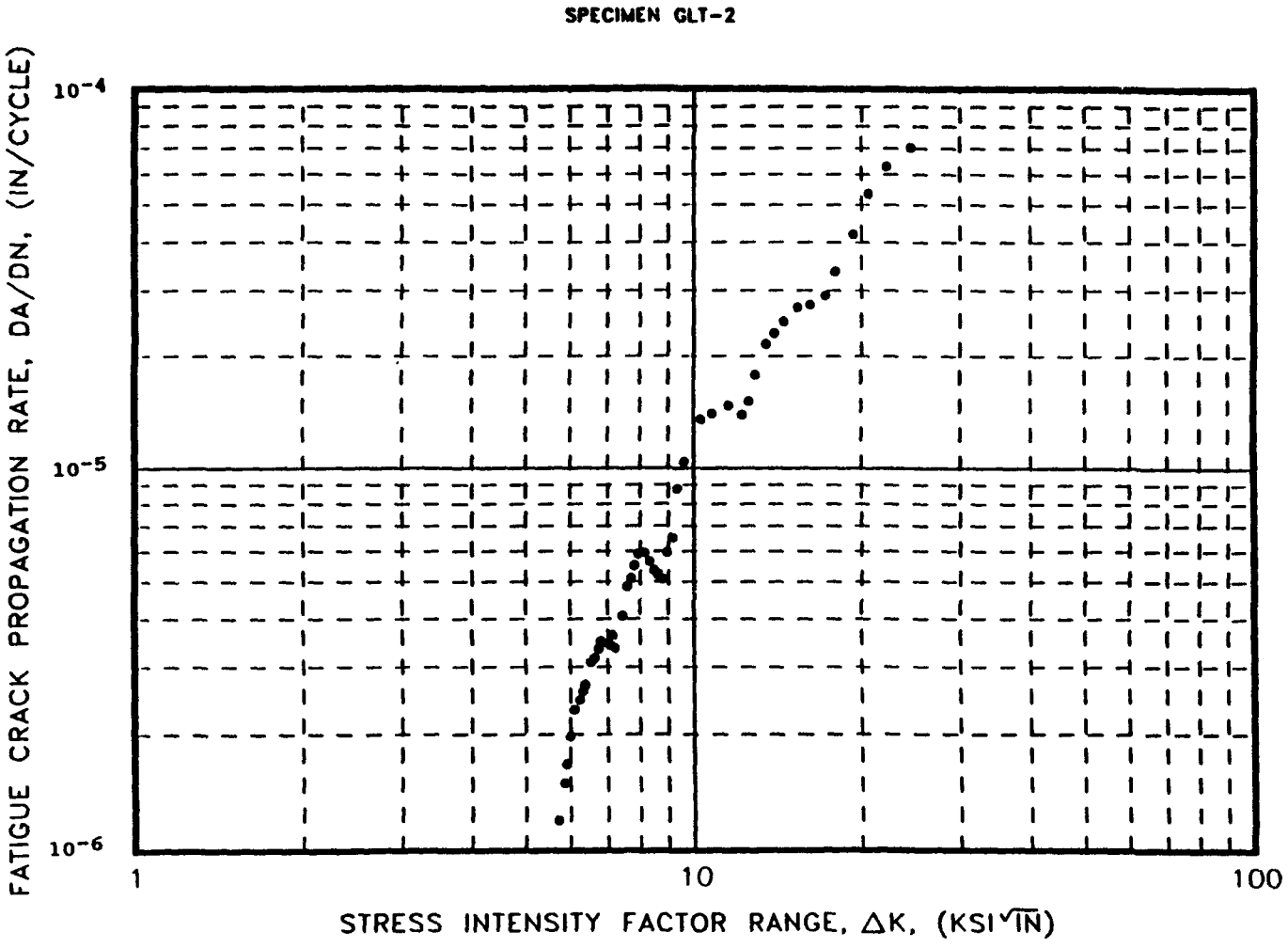


FIGURE R9. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (L-T Orientation, Specimen GLT-2). LTV.

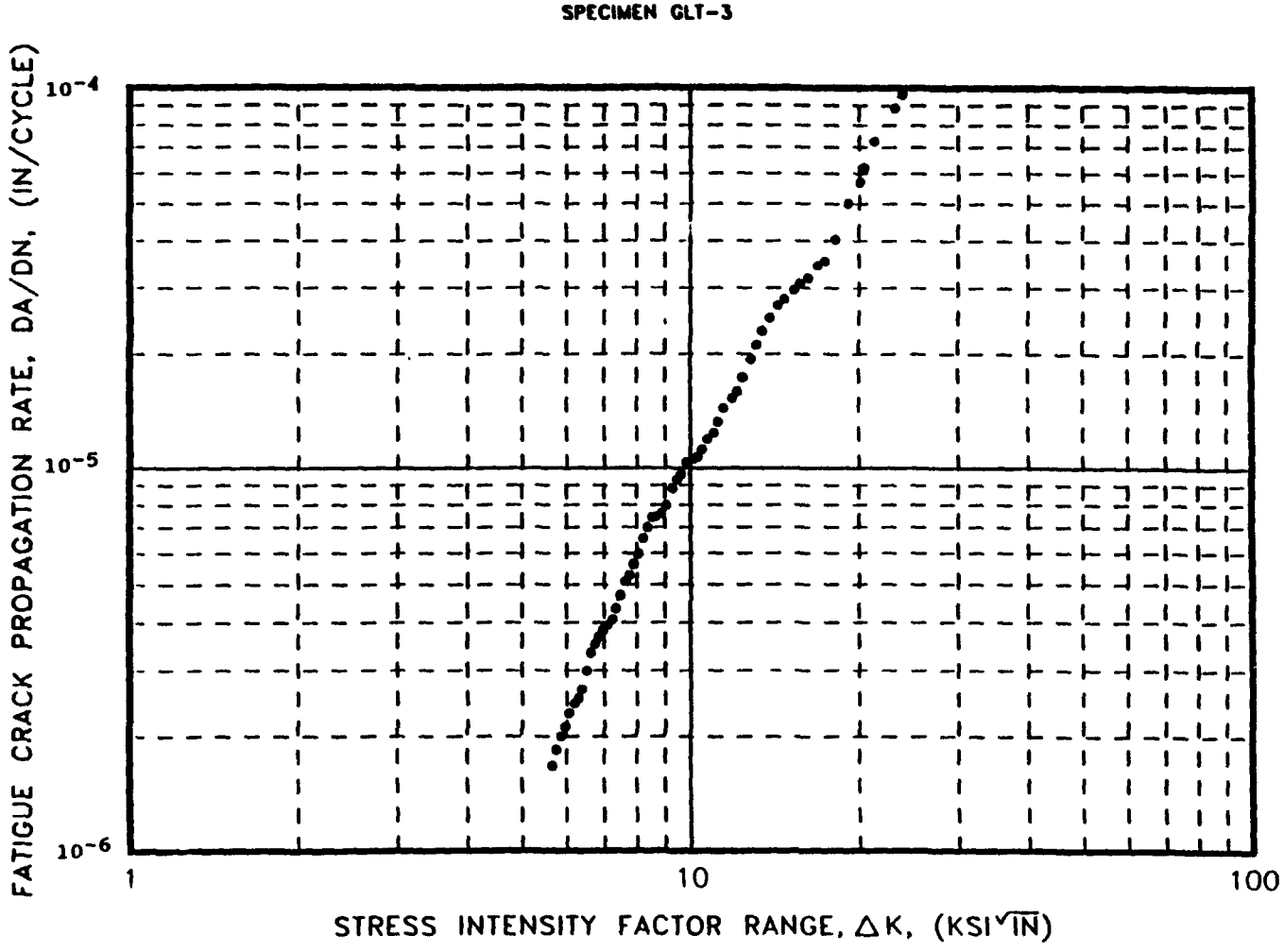


FIGURE R10. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrution. (L-T Orientation, Specimen GLT-3). LTV.

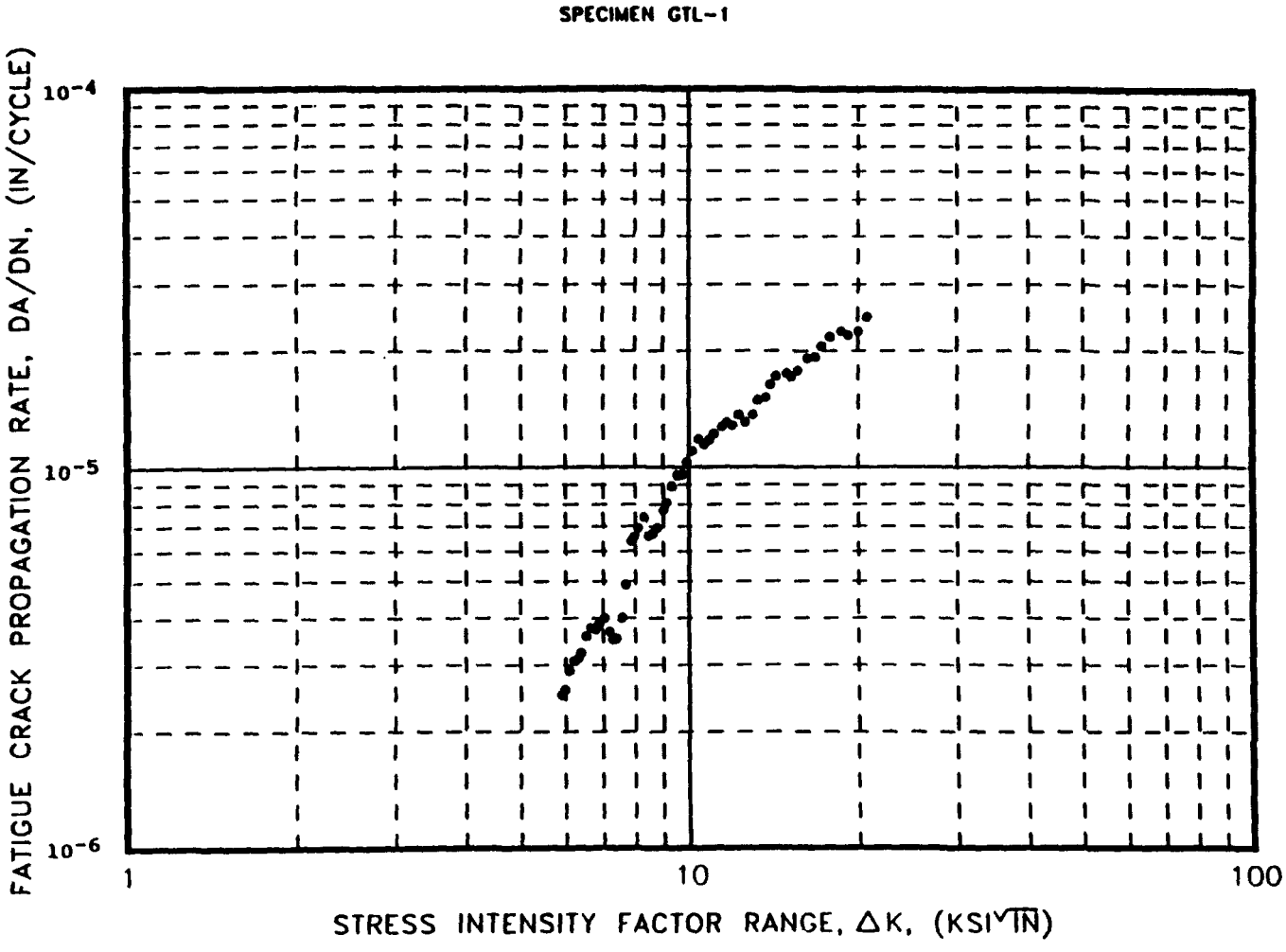


FIGURE R11. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (T-L Orientation, Specimen GLT-1). LTV.

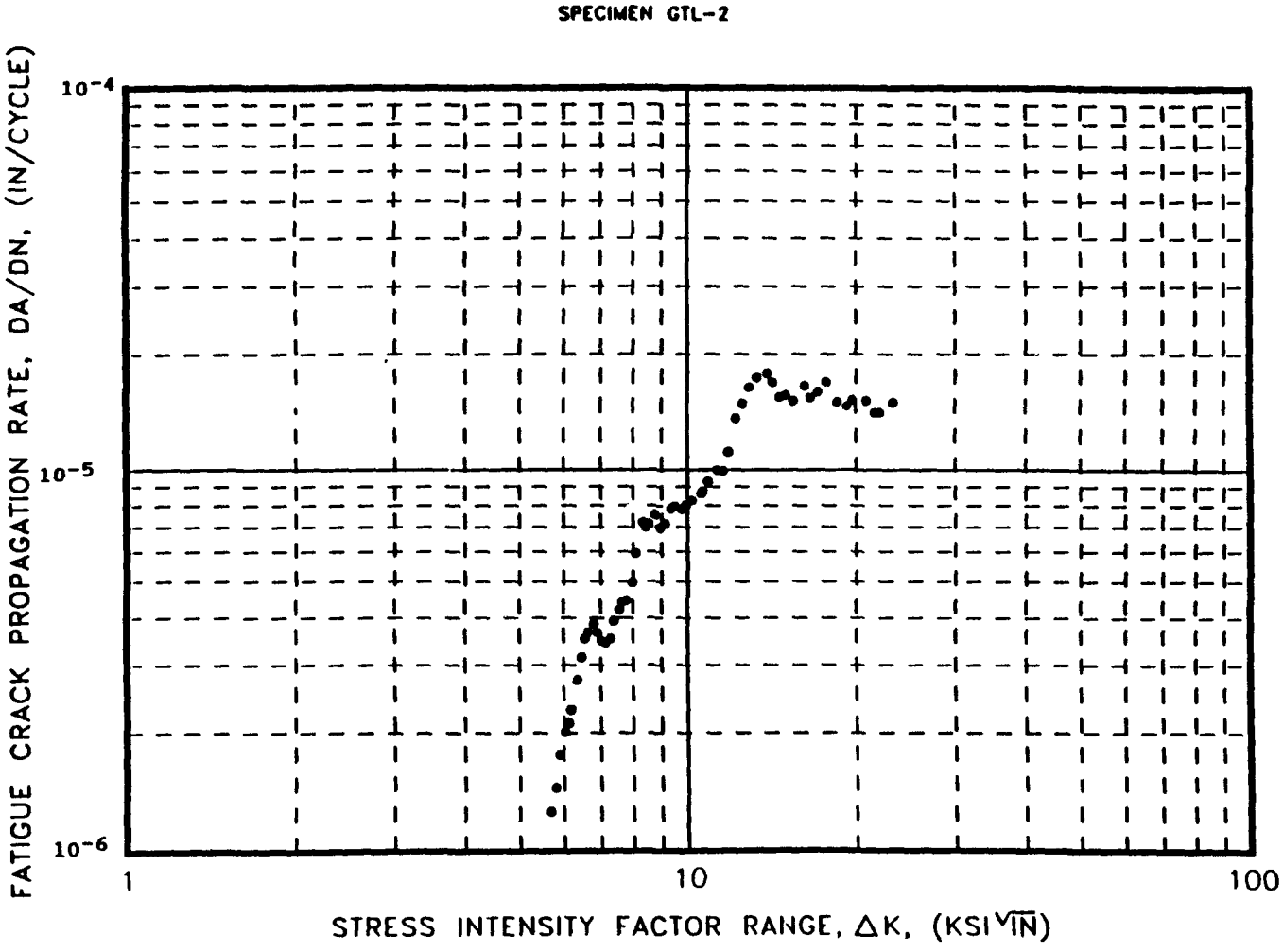


FIGURE R12. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion. (T-L Orientation, Specimen GLT-2). LTV.

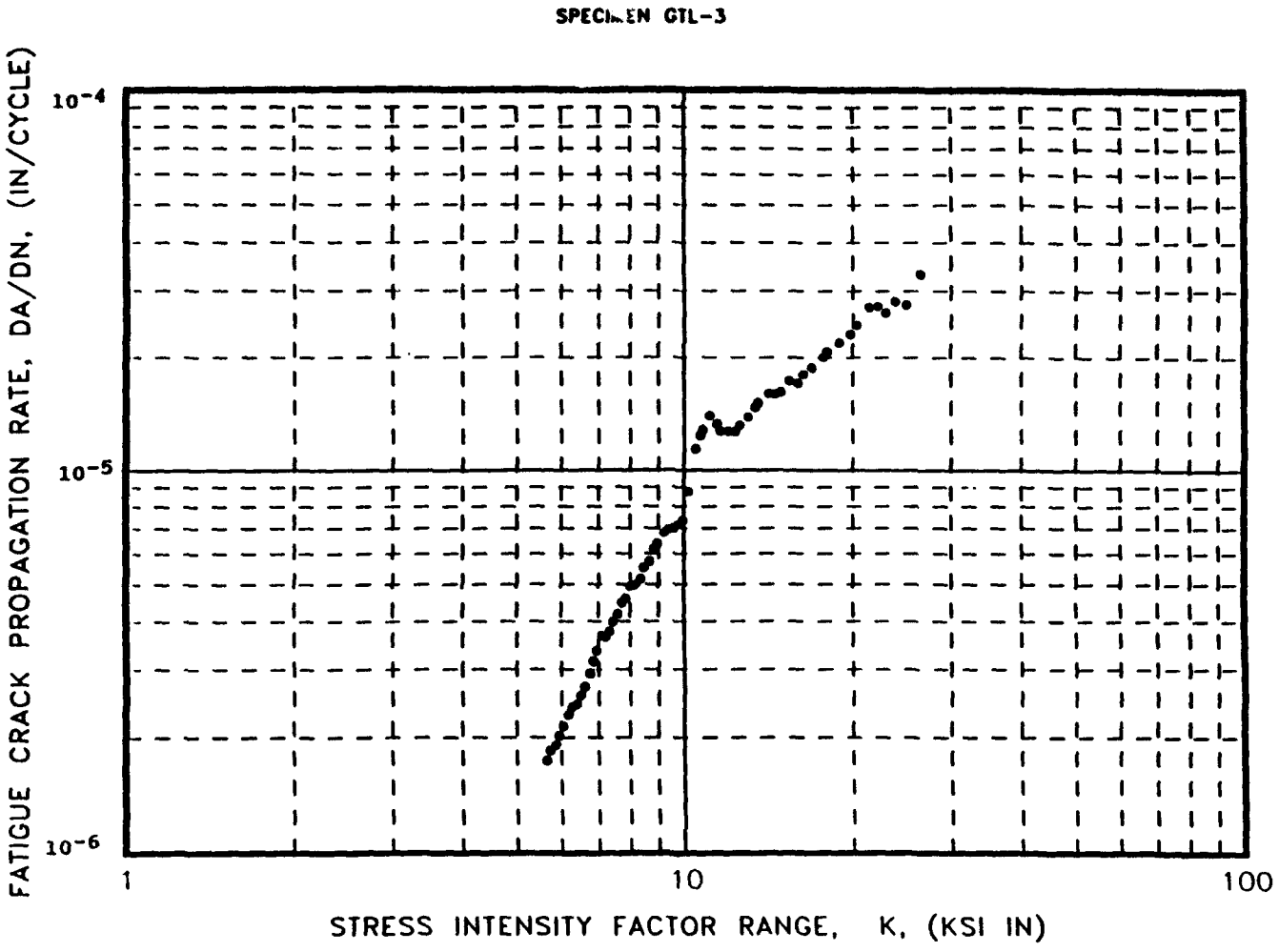


FIGURE R13. FATIGUE CRACK GROWTH RATE DATA for CW67 Extrusion (T-L Orientation, Specimen GLT-3). LTV.

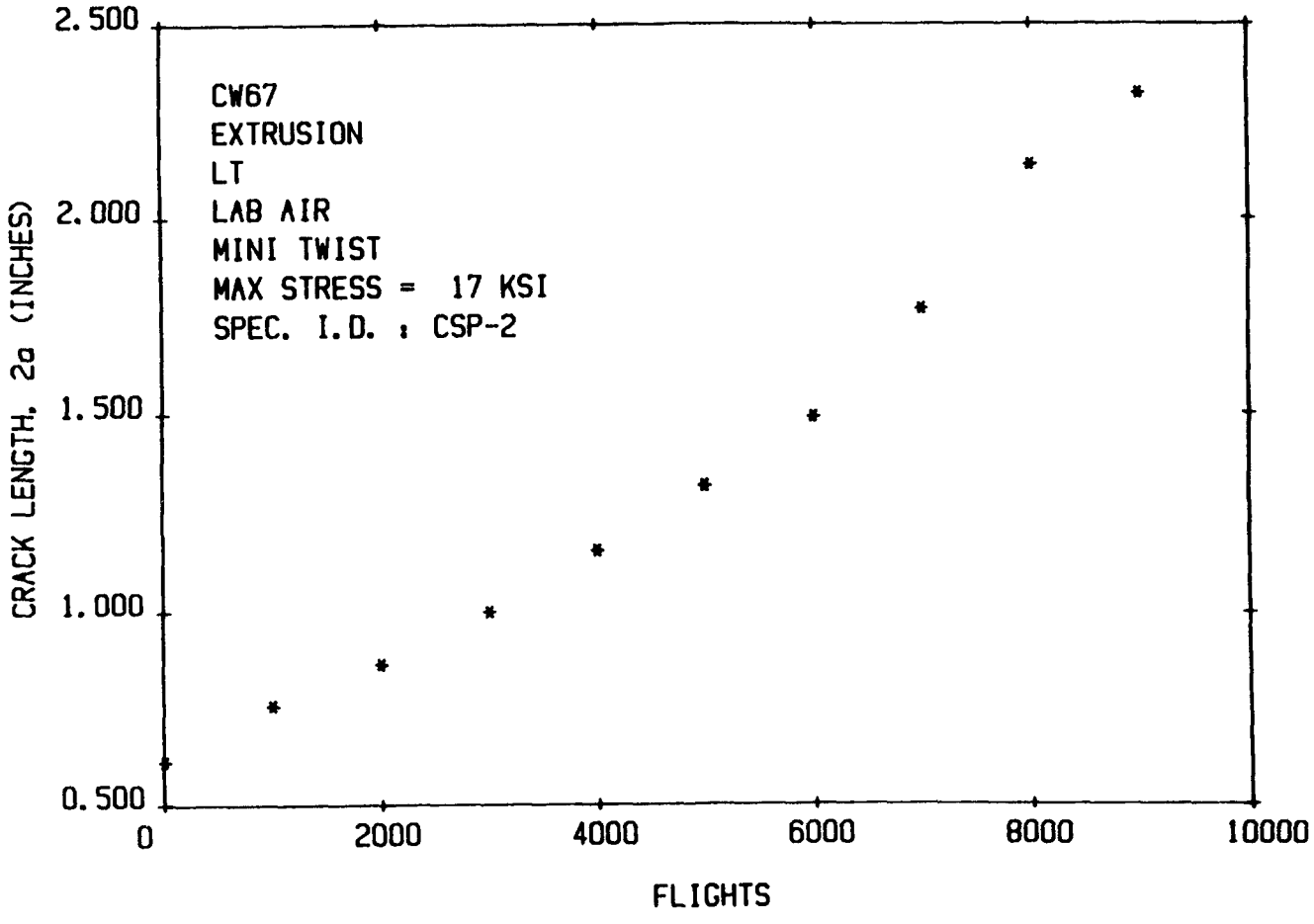


FIGURE R14. Mini-TWIST Spectrum Fatigue Cracklength vs Flights Data for CW67 Extrusion. Air Force.

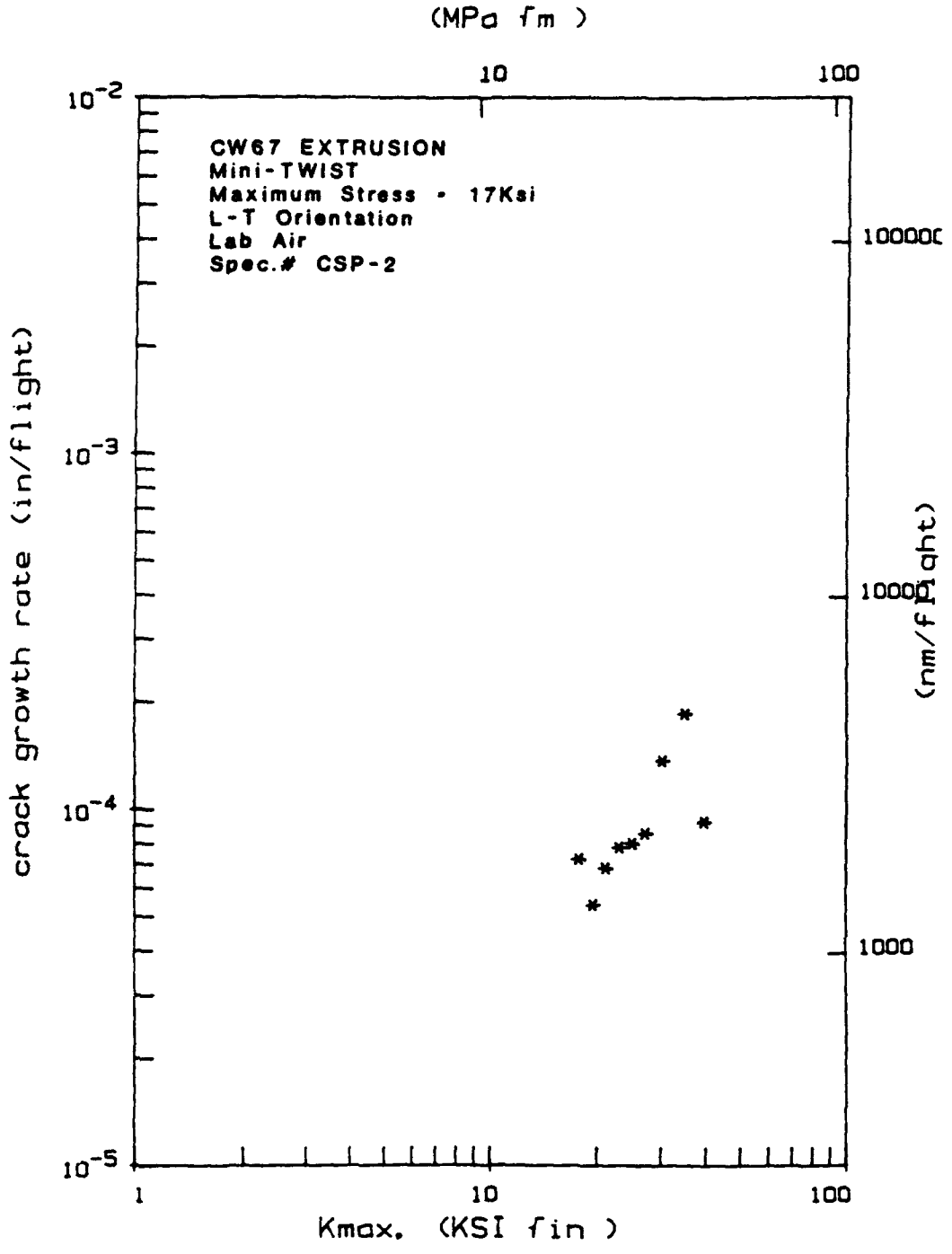


FIGURE R15. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion.
Air Force.

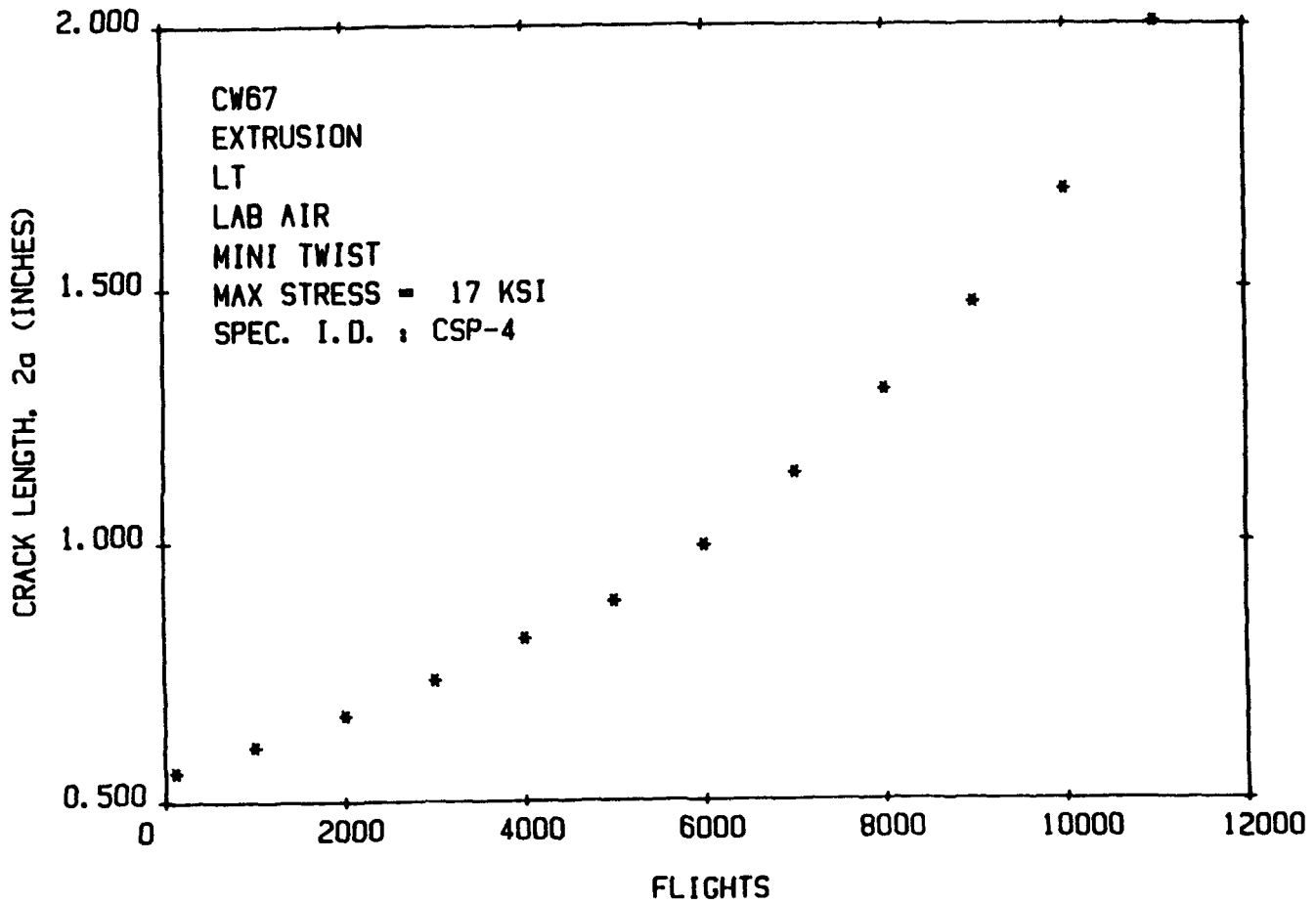


FIGURE R16. Mini-TWIST Spectrum Fatigue Crack Length vs Flights Data for CW67 Extrusion. Air Force.

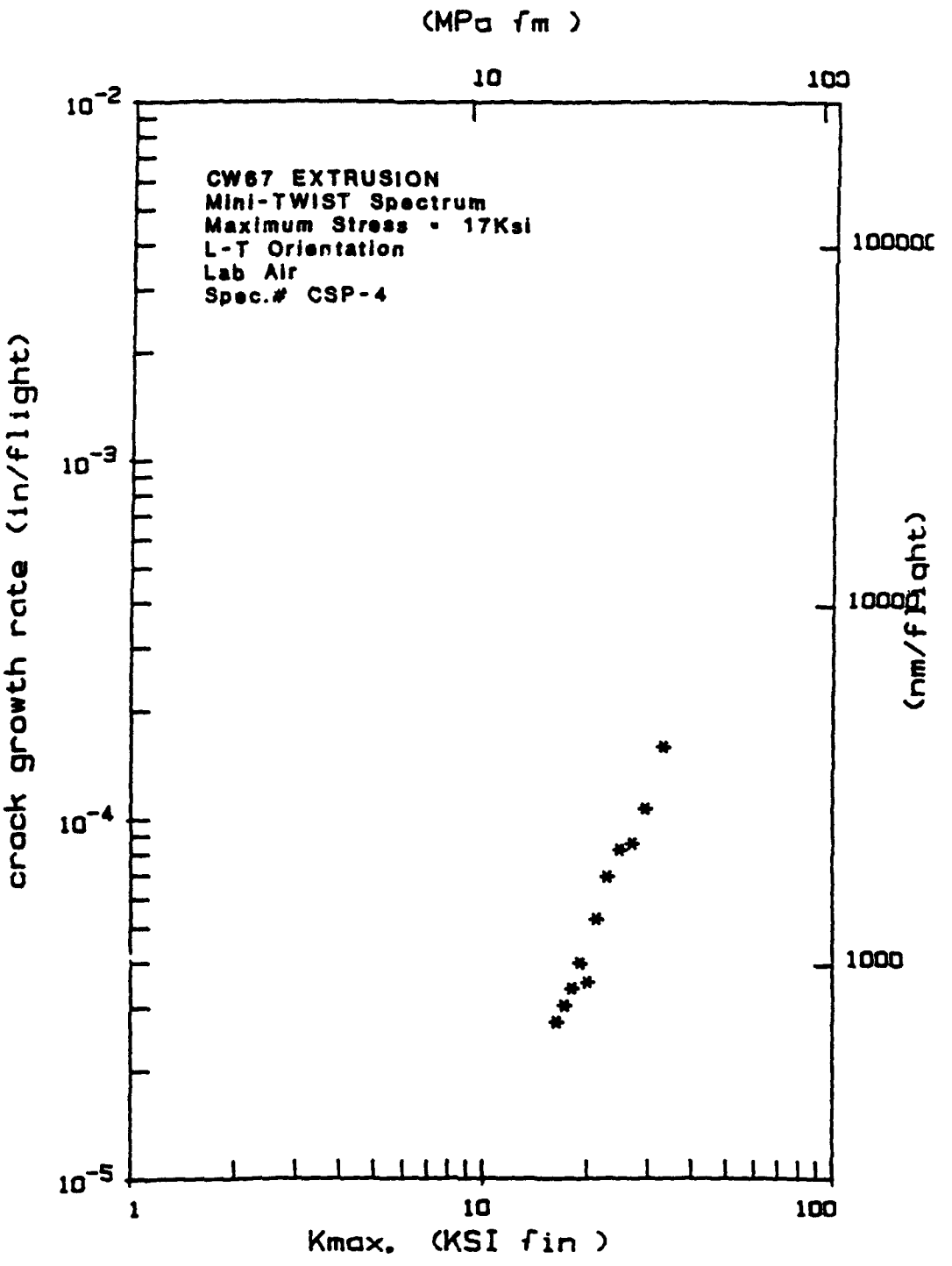


FIGURE R17. Mini-TWIST Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion.
Air Force.

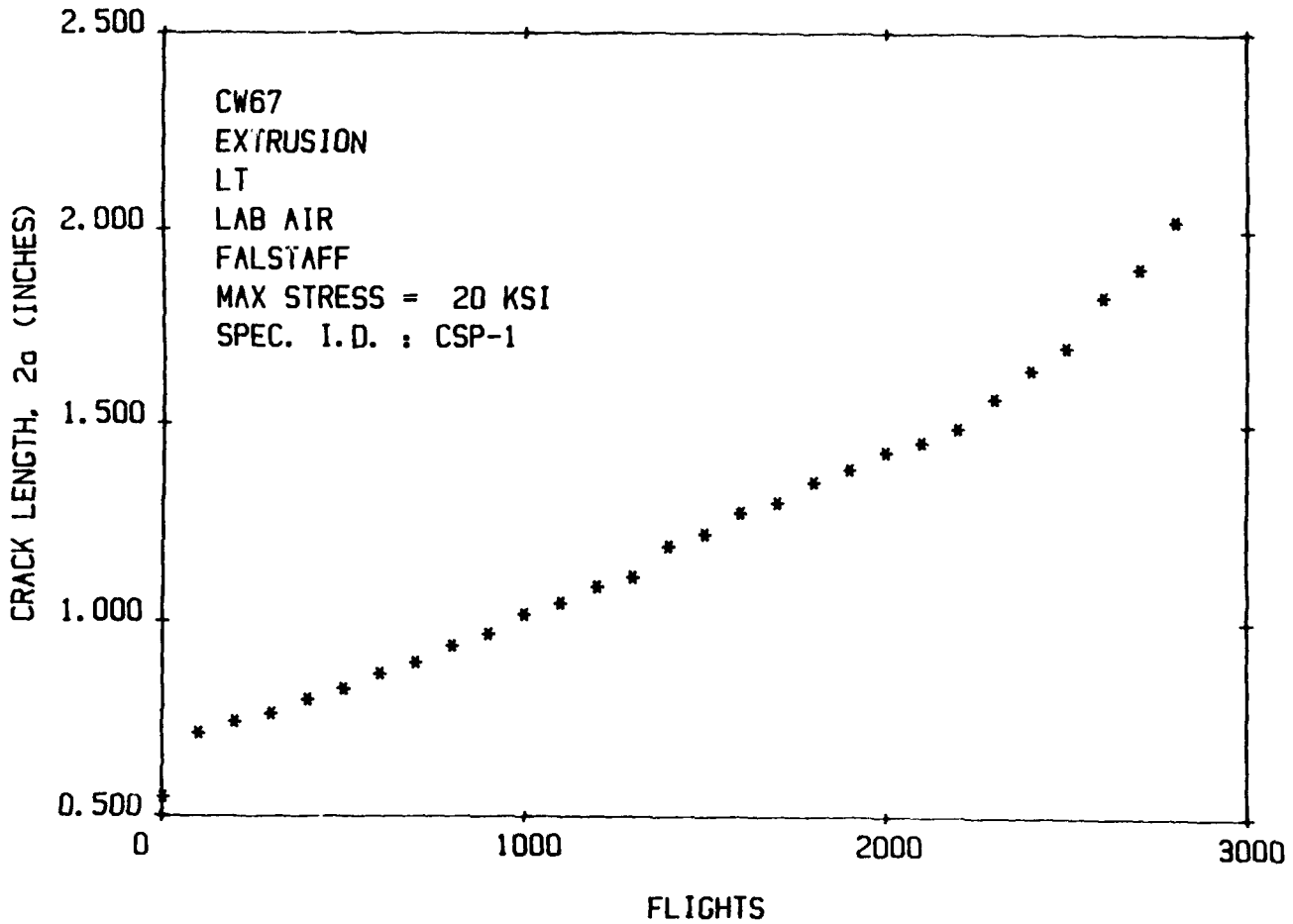


FIGURE R18. FALSTAFF Spectrum Fatigue Crack Length vs Flights. Air Force.

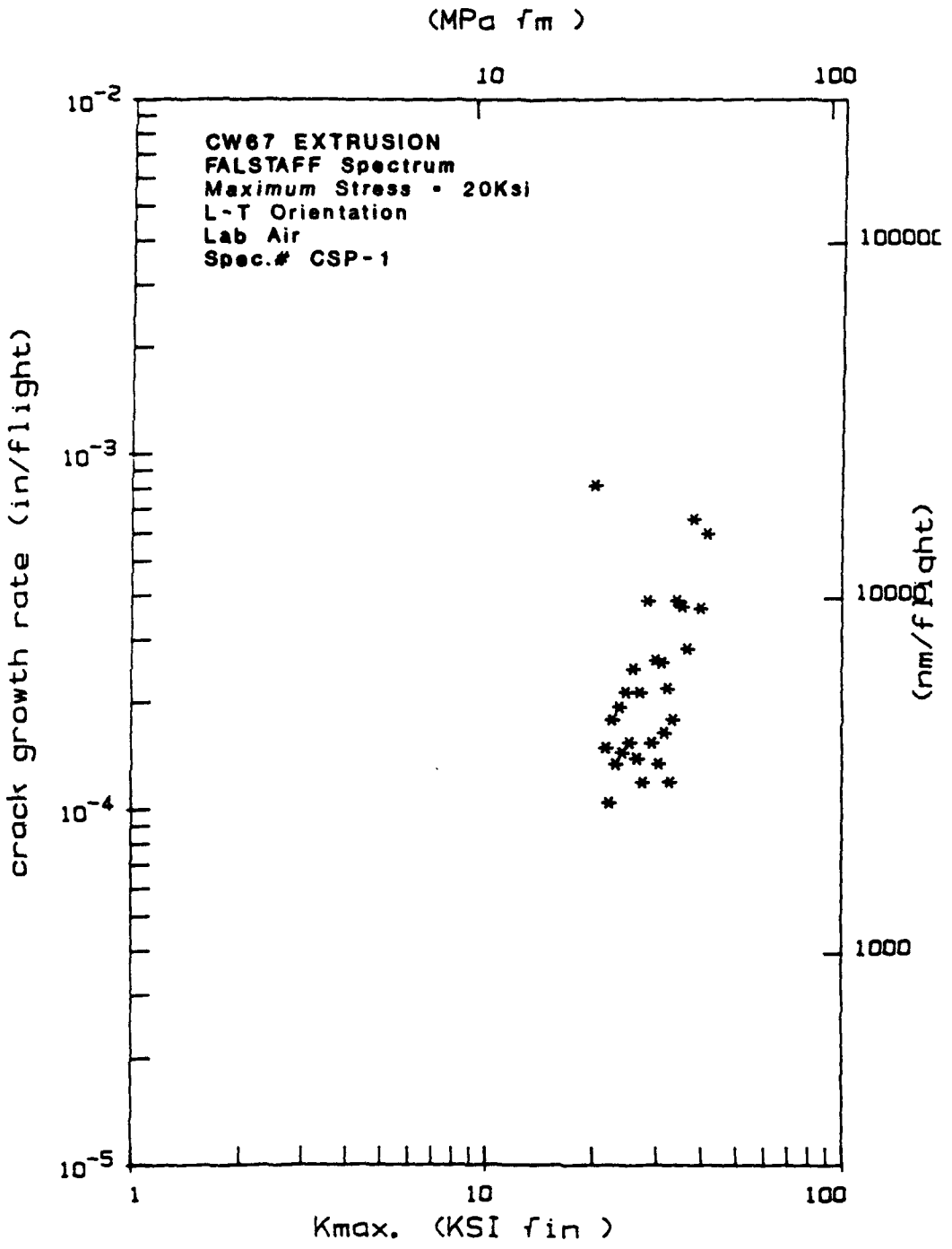


FIGURE R19. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion.
Air Force.

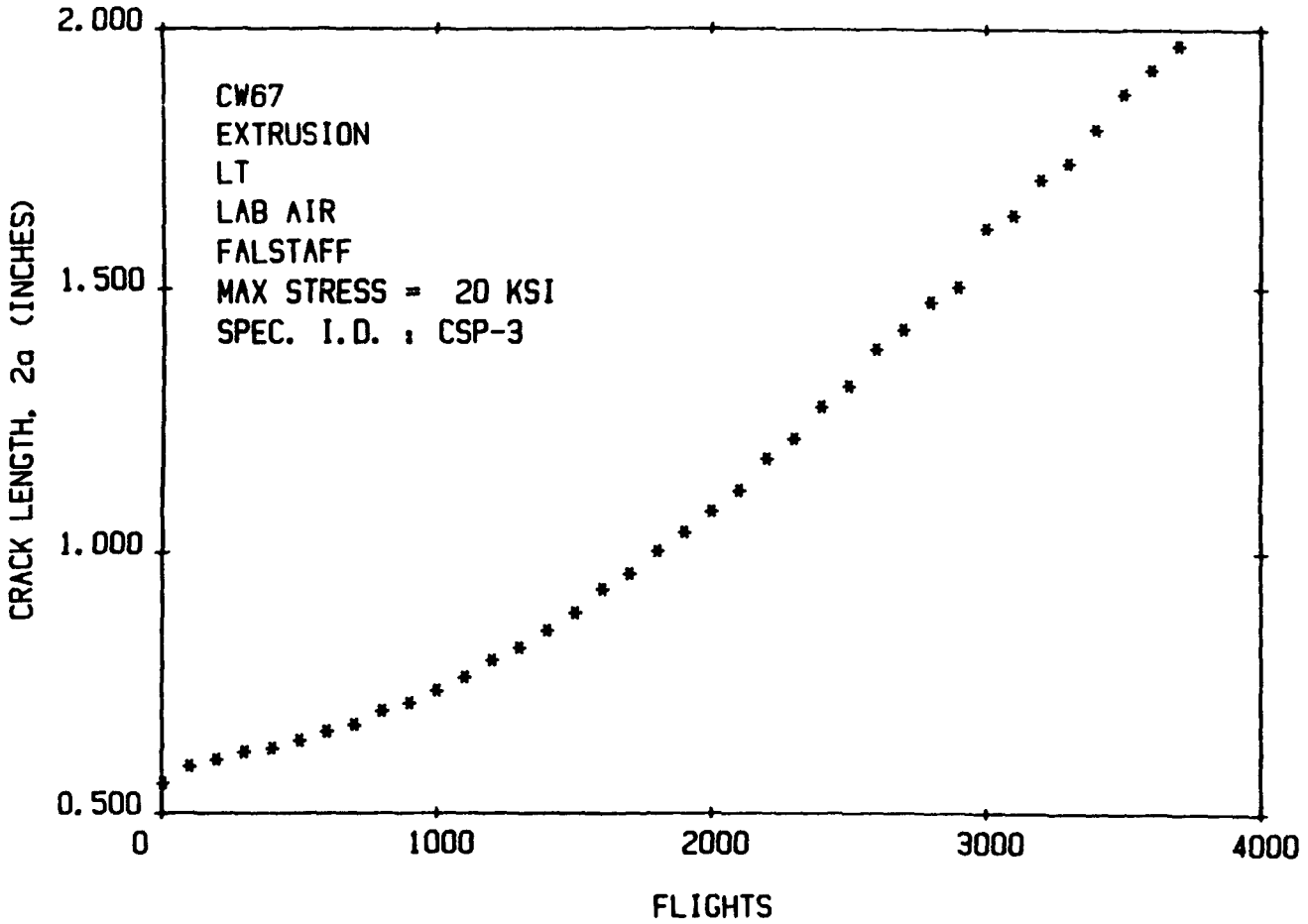


FIGURE R20. FALSTAFF Spectrum Fatigue Crack Length vs Flights. *Air Force.*

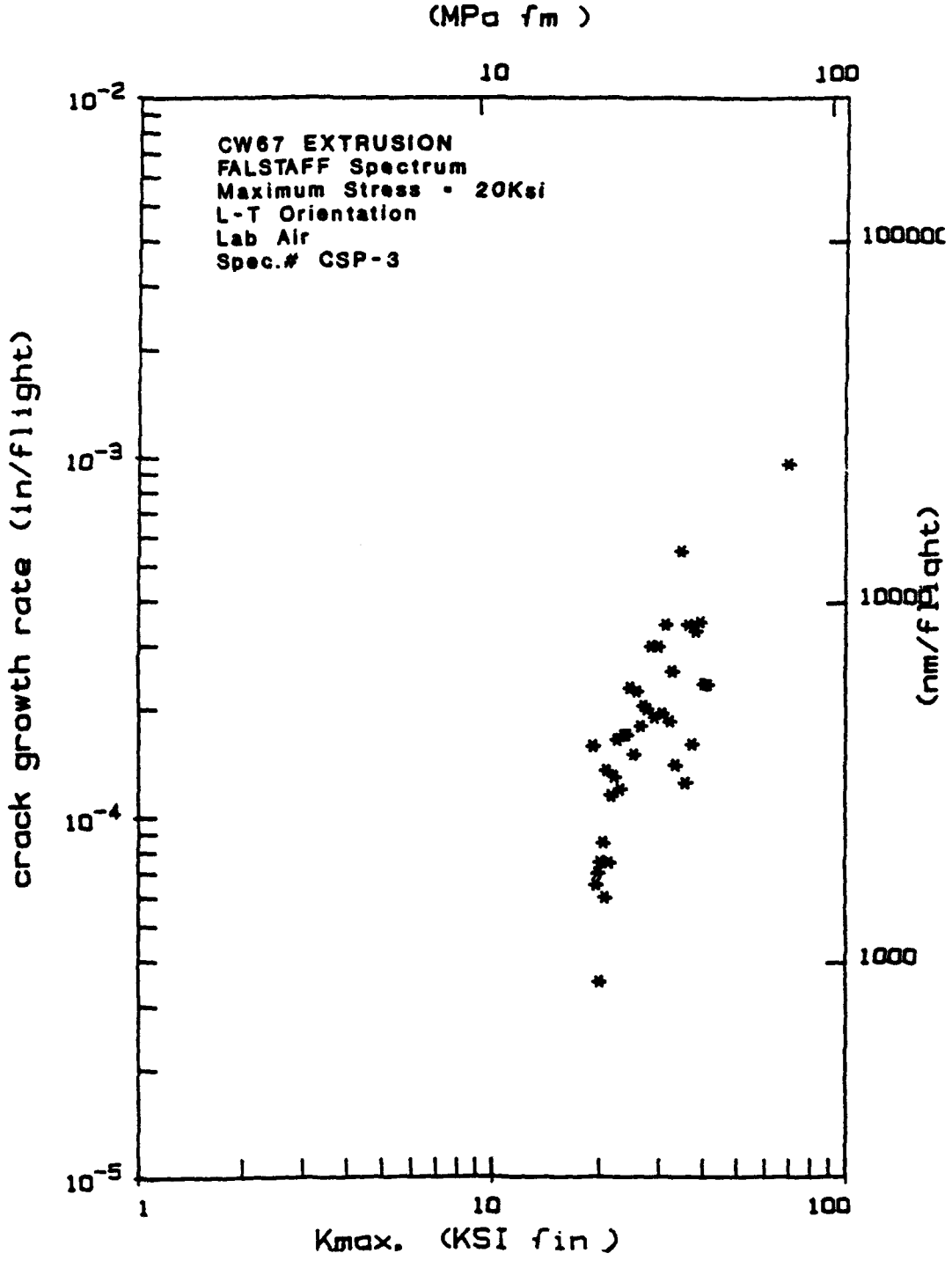


FIGURE R21. FALSTAFF Spectrum Fatigue Crack Growth Rate Data for CW67 Extrusion.
Air Force.

APPENDIX S

CW67 HAND FORGING
2.5"X6"X18"

TABLE S1

TENSILE RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN MARIETTA, LOUISIANA	RT	LONG	87.2	84.0	13.0	29.6	
			83.1	75.9	15.0	39.7	
			85.0	82.5	14.0	27.6	
AIR FORCE	RT	LONG	88.0	83.6	13.0	39.7	
			82.2	78.6	13.8	47.9	
			85.4	80.7	12.7	34.5	
			84.6	80.1	12.1	46.9	
		AVERAGE	85.1	80.8	13.4	38.0	
	STANDARD DEVIATION		2.1	2.9	1.0	7.9	

TABLE S2

TENSILE RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN MARIETTA, LOUISIANA	RT	L TRANS	79.1	73.4	12.0	17.6	
			78.8	73.0	14.0	25.5	
			79.4	74.0	17.0	42.5	
AIR FORCE	RT	L TRANS	82.4	77.2	13.9	40.1	
			83.0	77.0	10.2	25.3	
			83.2	77.2	13.5	38.9	
			82.3	75.4	13.0	32.6	
		AVERAGE	81.2	75.3	13.4	31.8	
	STANDARD DEVIATION		2.0	1.9	2.1	9.3	

TABLE S3

TENSILE RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMP (DEGREES F)	ORIENT-ATION	ULTIMATE STRENGTH (KSI)	YIELD STRENGTH (KSI)	ELONG (%)	RA (%)	E (MSI)
MARTIN	RT	S TRANS	78.7	72.4	12.0	32.7	
MARIETTA,			77.9	71.5	11.0	32.7	
LOUISIANA			77.5	70.8	14.0	36.0	
AIR FORCE	RT	S TRANS	85.7	79.3	6.8	18.1	
			43.8	43.8	9.1	23.1	
		AVERAGE	72.7	67.6	10.6	28.5	
	STANDARD	DEVIATION	16.5	13.7	2.7	7.6	

TABLE S4

COMPRESSION RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MARTIN	RT	LONG	82.9	10.6
MARIETTA,			81.9	10.6
LOUISIANA			81.4	10.6
AIR FORCE	RT	LONG	81.0	
			79.4	
			77.3	
			76.4	
		AVERAGE	80.0	10.6
		STANDARD DEVIATION	2.4	0.0

TABLE S5

COMPRESSION RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MARTIN	RT	L TRANS	78.6	10.8
MARIETTA,			78.8	11.0
LOUISIANA			79.6	11.0
AIR FORCE	RT	L TRANS	81.6	
			82.5	
			81.5	
			80.0	
		AVERAGE	80.4	10.9
		STANDARD DEVIATION	1.5	0.1

TABLE S6

COMPRESSION RESULTS FOR

ALCOA CW67 FORGING

COMPANY	TEST TEMPERATURE (DEGREES F)	ORIENTATION	COMPRESSIVE YIELD STRENGTH (KSI)	COMPRESSIVE MODULUS (MSI)
MARTIN	RT	S TRANS	80.1	10.7
MARIETTA,			82.1	10.8
LOUISIANA			80.2	10.8
		AVERAGE	80.8	10.8
		STANDARD DEVIATION	1.1	0.1

TABLE S7

PIN SHEAR RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
AIR FORCE	LONG	50.0
		50.1
		50.2
		49.8
	AVERAGE	50.0
	STANDARD DEVIATION	0.2

TABLE S8

PIN SHEAR RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	SHEAR STRENGTH (KSI)
AIR FORCE	L TRANS	49.2
		49.8
		49.5
		49.7
	AVERAGE	49.5
	STANDARD DEVIATION	0.3

TABLE S9

BEARING RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	e/D	BEARING ULT. STRENGTH (KSI)	BEARING YIELD STRENGTH (KSI)
AIR FORCE	LONG	1.5	137.9	122.3
			137.3	118.8
			131.2	118.9
		AVERAGE	135.5	120.0
		STANDARD DEVIATION	3.7	2.0
	L TRANS	1.5	136.0	123.0
			137.4	130.5
			132.4	128.2
		AVERAGE	135.2	127.2
		STANDARD DEVIATION	2.6	3.8
	LONG	2.0	165.5	118.0
			164.9	77.8
			162.7	104.1
		AVERAGE	164.3	100.0
		STANDARD DEVIATION	1.5	20.5
	L TRANS	2.0	166.4	103.1
			168.1	117.5
			162.1	99.9
		AVERAGE	165.5	106.8
		STANDARD DEVIATION	3.1	9.4

TABLE S10

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN	L - T	44.8		VALID
MARIETTA,			35.9	INVALID(1)
LOUISIANA				
AIR FORCE	L - T		28.8	INVALID(2)
			34.4	INVALID(2)
	AVERAGE	44.8	33.0	
	STANDARD DEVIATION	0.0	3.8	

(1): a/W > 0.55
(2): EXCESSIVE CRACK FRONT CURVATURE

TABLE S11

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN	L - S		46.7	INVALID(1)
MARIETTA,			52.5	INVALID(1)
LOUISIANA		38.6		VALID
	AVERAGE	38.6	49.6	
	STANDARD DEVIATION	0.0	4.1	

(1): a/W > 0.55

TABLE S12

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA, LOUISIANA	T - L	25.0		VALID
		21.6		VALID
AIR FORCE	T - L		21.0	INVALID(1)
			18.6	INVALID(1)
			22.5	INVALID(1)
	AVERAGE	23.3	20.7	
	STANDARD DEVIATION	2.4	2.0	

(1): EXCESSIVE CRACK FRONT CURVATURE

TABLE S13

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
MARTIN MARIETTA, LOUISIANA	T - S	21.3		VALID
			23.5	INVALID(1)
	AVERAGE	21.3	23.5	
	STANDARD DEVIATION	0.0	0.0	

(1): a/W > 0.55

TABLE S14

FRACTURE TOUGHNESS RESULTS FOR

ALCOA CW67 FORGING

COMPANY	ORIENTATION	KIC (KSI in^0.5)	Kq (KSI in^0.5)	COMMENT
AIR FORCE	S - T		20.9	INVALID(1)
			25.3	INVALID(1)
			23.6	INVALID(1)
	AVERAGE		23.3	
	STANDARD DEVIATION		2.2	

(1): EXCESSIVE CRACK FRONT CURVATURE

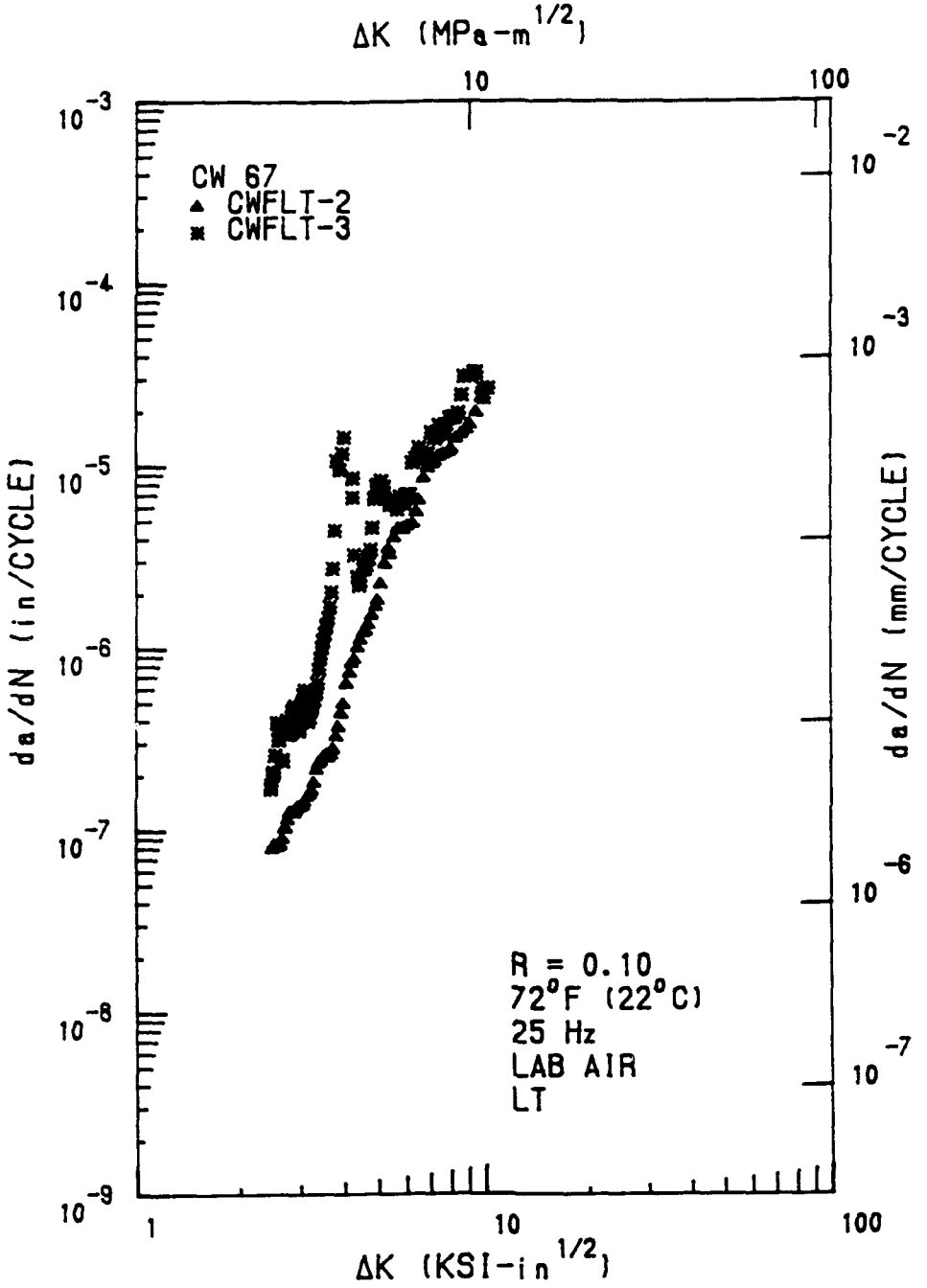


FIGURE S1. Fatigue Crack Growth Rate Data for CW67 Forging (L-T Orientation). Air Force.

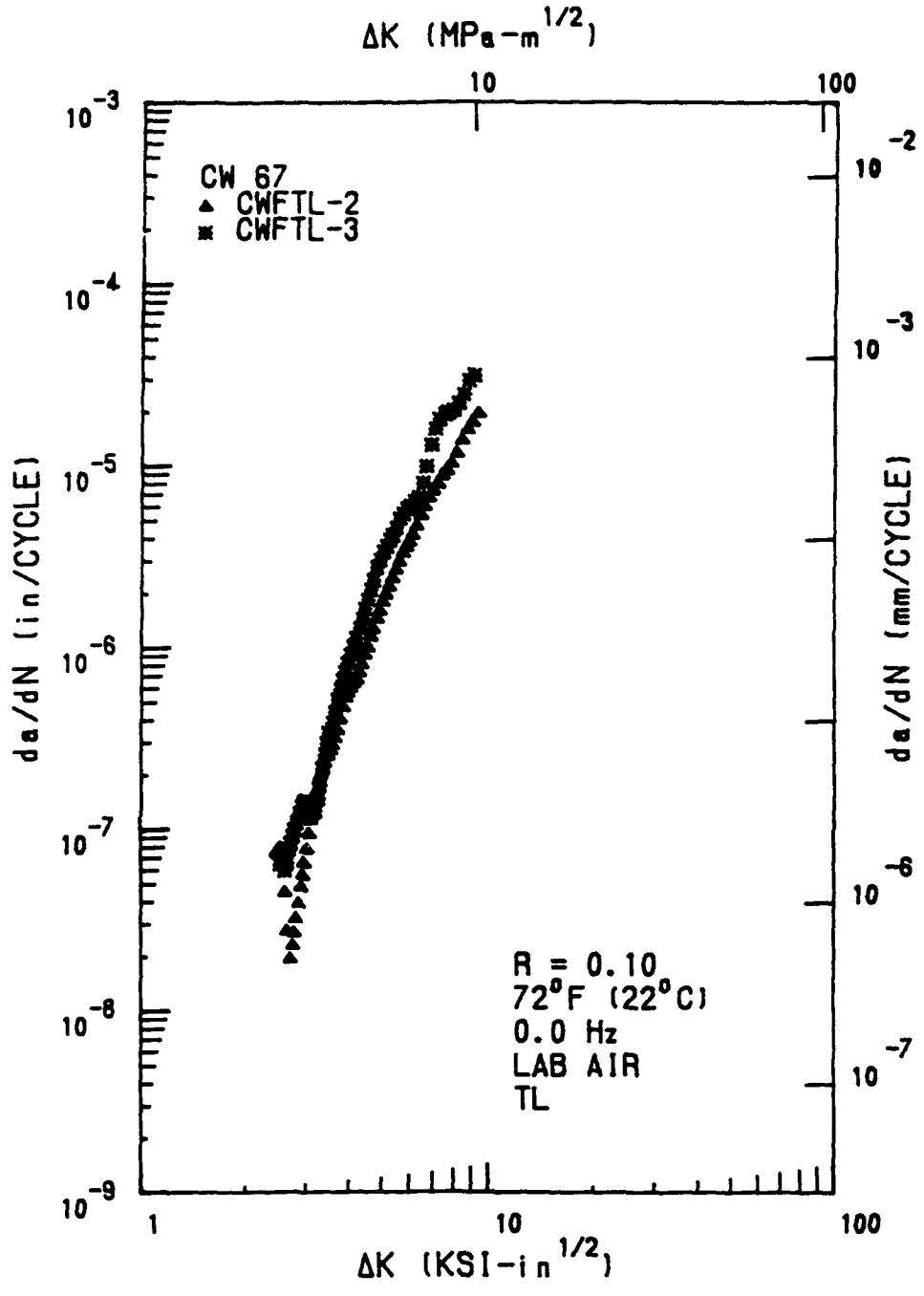


FIGURE S2. Fatigue Crack Growth Rate Data for CW67 Forging (T-L Orientation). Air Force.

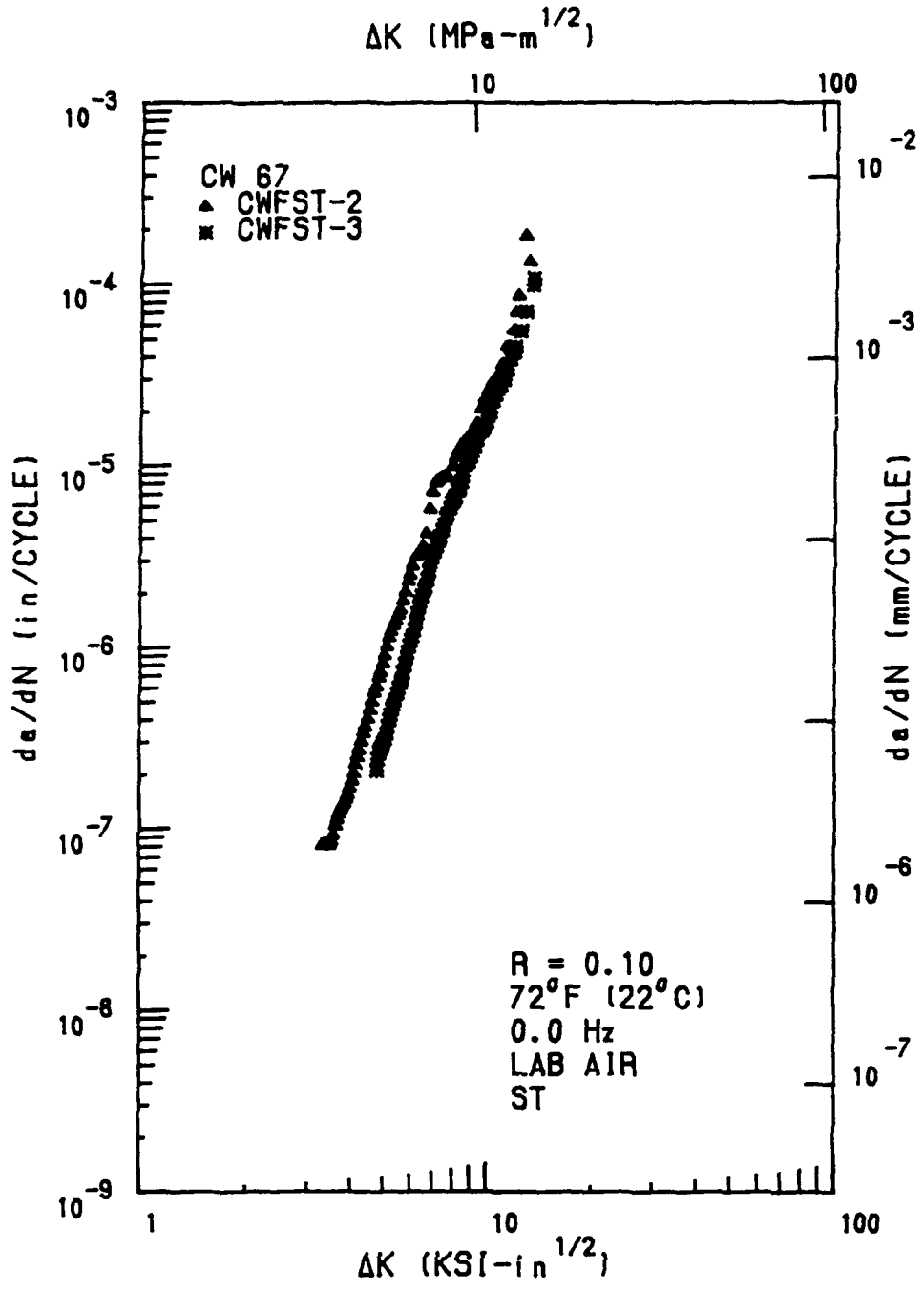


FIGURE S3. Fatigue Crack Growth Rate Data for CW67 Forging (S-T Orientation). Air Force.

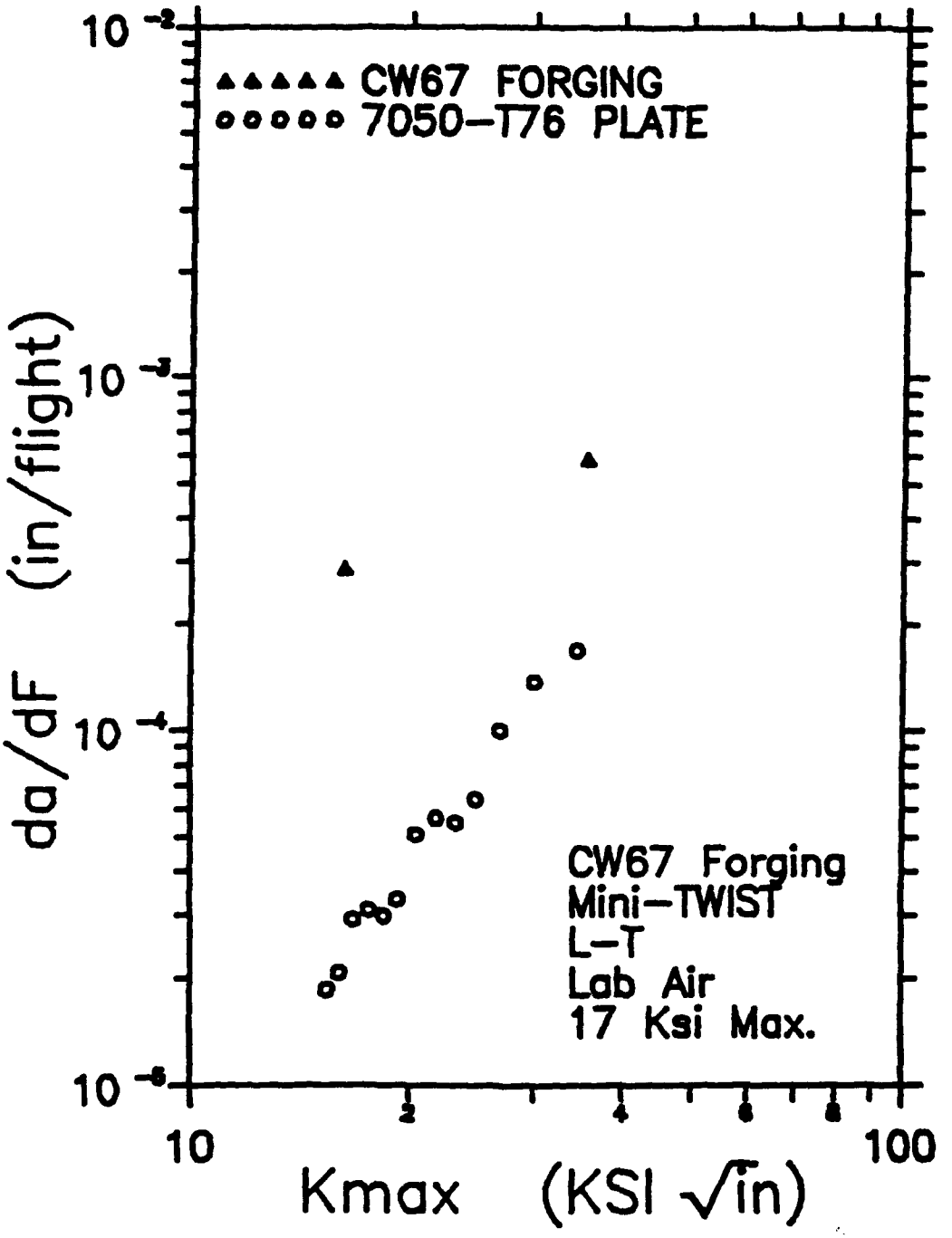


FIGURE S4. Comparison of CW67 Forging and 7050 Plate Mini-TWIST Spectrum Fatigue Crack Growth Rate Data (L-T Orientation). *Air Force.*

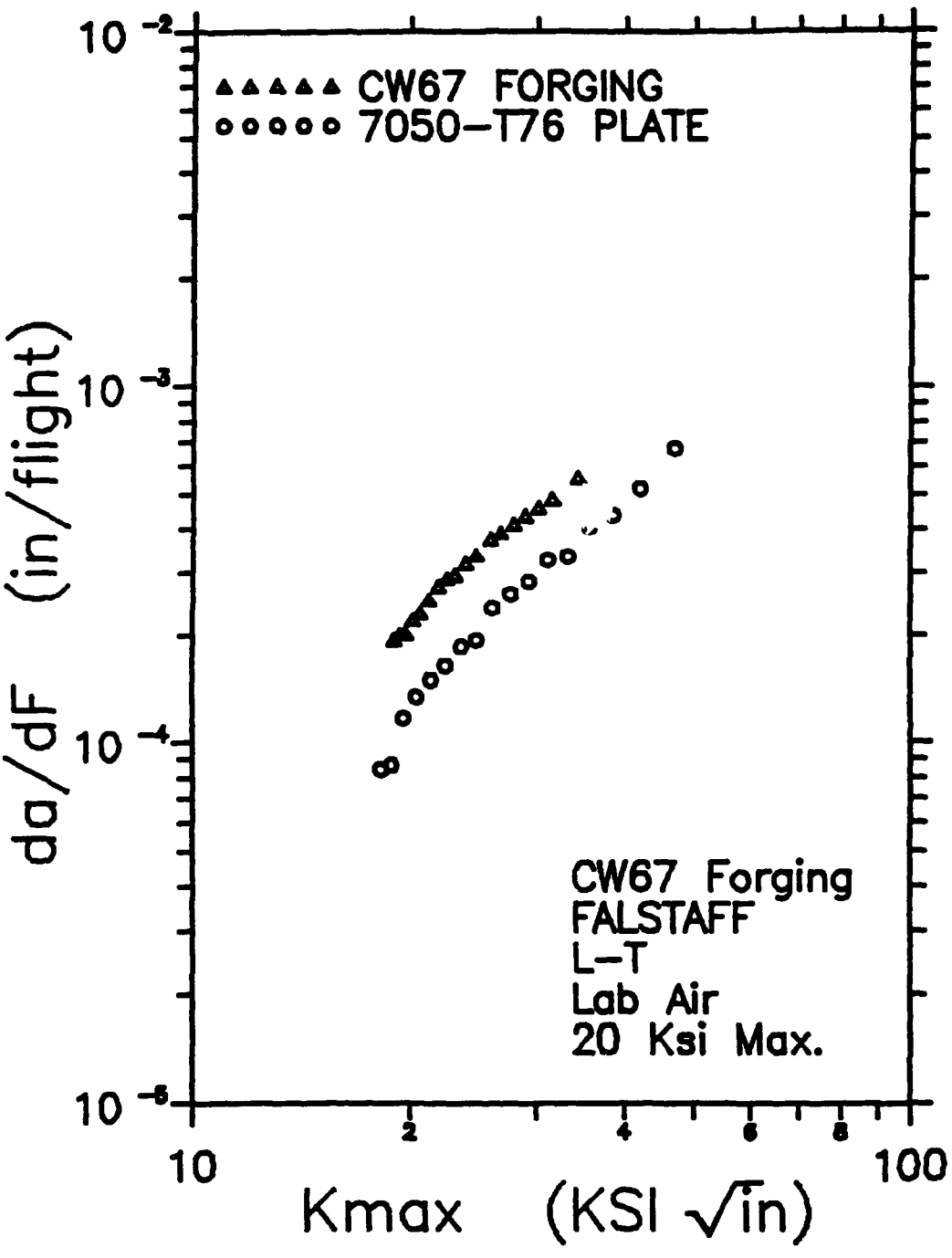


FIGURE S5. Comparison of CW67 Forging and 7050 Plate FALSTAFF Spectrum Fatigue Crack Growth Rate Data (L-T Orientation). Air Force.