LG88ER0016 JANUARY 1988

039268

Piper Aircraft Model PA28-181 and PA32-300 Main Spar Fracture Analysis

Prepared for Piper Aircraft Corp. Vero Beach, FLA



A Division of Lockhead Corporation Marietta, Georgia 30063





•



٦

TITLE PIPER AIRCRAFT MODEL PA 28-181 AND PA 32-300 MAIN SPAR FRACTURE ANALYSIS				
Date	Rev. By	Pages Affected	Remarks	
4-11-88	BKY/RJB	ii, iii, vii,	Incorporate customer comments.	
		4.1, 4.2, 4.3,		
		5.1, 5.5, 5.6,		
		5.7, 6.1		
ļ				
	+			
<u> </u>	+			
	+			
	1			
		<u> </u>		
ļ				





LG88ER0016 January 1988 R-April 1988

FOREWORD

This report presents the results of a fracture analysis of a Piper Aircraft Model PA 28-181 and PA 32-300 main spar fitting. This contract was performed under Purchase Order No. 039268.

Crack growth curves are presented and methodology for deriving initial and recurring inspections is discussed.

Appreciation, for their contributions to this report, is extended to:

D. T. Burns Dr. C. S. Chu B. L. Harrison H. R. Horsburgh M. D. Reid K. A. Thomas

> Use and/or disclosure is governed by the statement on the title page of this document.

Lockheed

• •

LG88ER0016 January 1988 R-April 1988

TABLE OF CONTENTS

Section	Title	Page
	FOREWORD	ii
	TABLE OF CONTENTS	iii
	LIST OF FIGURES	iv
	GLOSSARY	vi
	REFERENCES	vii
1.0	INTRODUCTION	1.1
	1.1 Analysis Approach	1.2
2.0	SPECTRA DEVELOPMENT	2.1
3.0	FINITE ELEMENT MODEL	3.1
4.0	DAMAGE TOLERANCE ASSESSMENT CRITERIA	4.1
	4.1 Critical Crack Size	4.1
	4.2 Initial Inspection	4.2
	4.3 Recurring Inspection Interval	4.2
5.0	CRACK GROWTH ANALYSIS	5.1
6.0	SUMMARY	6.1

Use and/or disclosure is governed by the statement on the title page of this document.



. .

LIST OF FIGURES

Figure	Title	Page
1.1	Plan Views of Main Spar and Attach Structure	1.2
1.2	Isotropic View of Main Spar and Attach Structure	1.3
2.1	Exceedance Data and Stress Definitions as Supplied by Piper Aircraft Company	2.4
2.2	PA 28-181 Manuever/Gust Combined Exceedance Curve	2.5
2.3	PA 32-300 Manuever/Gust Combined Exceedance Curve	2.6
2.4	PA 28-181 Max/Min Stresses Developed from Manuever/Gust Loading	2.7
2.5	PA 32-300 Max/Min Stresses Developed from Manuever/Gust Loading	2.8
2.6	PA 28-181 Exceedance Curve for 5 Min. Taxi Segment	2.9
2.7	PA 32-300 Exceedance Curve for 5 Min. Taxi Segment	2.10
2.8	PA 28-181 Max/Min Stresses Developed from 5 Min. Taxi Segment	2.11
2.9	PA 32-300 Max/Min Stresses Developed from 5 Min. Taxi Segment	2.12
2.10	PA 23-181 Exceedance Curve for Landing Segment	2.13
2.11	PA 32-300 Exceedance Curve for Landing Segment	2.14
2.12	PA 28-181 Max/Min Stresses Developed from Landing Segment	2.15
2.13	PA 32-300 Max/Min Stresses Developed from Landing Segment	2.16
2.14	PA 28-181 Spectra Defining 2 Hour "Pipeline Survey Mission"	2.17
2.15	PA 32-300 Spectra Defining 2 Hour "Pipeline Survey Mission"	2.18
3.1	Finite Element Model of Main Spar and Attach Structure with Critical Hole Detail	3.3
3.2	Main Spar Section	3.4
- · -	Use and/or disclosure is government on the title page of the	verned by the state- his document.

18



LIST OF FIGURES (Cont'd)

Figure	Title	Page		
3.3	Channel Section	3.5		
3.4	Load Distribution Along Critical Fastener Row	3.6		
3.5	Load Transfer Effects	3.7		
3.6	Stress Contour Plat Around Critical Fastener Holes	3.8		
5.1	DADTA da/dn Data 2024-T3 Aluminum Sheet			
5.2	racture Origins and Crack Location	5.4		
5,3	Phased Crack Growth	5.5		
5.4	PA 28-181 Crack Growth Curve	5,6		
5.5	PA 32-300 Crack Growth Curve	5.7		

Use and/or disclosure is governed by the statement on the title page of this document.



aCR



GLOSSARY OF TERMS

- FINITE ELEMENT MODEL Mathematically idealized structure using predefined elastic members to represent actual structure.
- da/dn Crack growth rate given as inches per cycle of growth at a computed ΔK .
- △K Stress intensity factor range which is a function of stress range, crack length, a Beta factors and has the dimensions of KSI-√IN.
- BETA FACTOR Correction factor to account for various geometry or loading conditions.

V_C - Maximum cruise speed.

- Critical value of the crack length.
 At this value, the stress intensity,
 K, reaches the critical value K_C.
- K_C Critical stress intensity. Rapid unstable crack growth will occur when K reaches this value.

 Δq - Incremental acceleration.

Use and/or disclosure is governed by the statement on the title page of this document.

Lockheed

REFERENCES

- RFQ from R. L. Dickey, Piper Aircraft Corporation, to R. L. McDougal, LASC-Ga, dated 20 August 1987.
- Staff, Piper Aircraft Corporation, Vero Beach, Florida transmitted to B. K. Young, LASC-Ga from R. L. Dickey, Piper Aircraft Corporation, 28 September 1987.
- 3. Letter from Alcoa Company of America to Piper Aircraft Corporation, dated 13 July 1987.
- Purchase Order 039268 and attached Statement of Work dated 22 October 1987 from Piper Aircraft Corporation to LASC-Ga.

Use and/or disclosure is governed by the statement on the title page of this document.

'zLockheed

1.0 INTRODUCTION

A Piper PA 28-181 crashed in Texas in March of 1987 following the loss of one wing while performing a pipeline survey mission. Data received from Piper Aircraft indicated that failure of the wing occurred at the wing root and originated approximately 1/16 inch outside of a lower surface main spar attachment bolt hole, initiating by fretting and propagating by fatigue (Ref. 1). The general configuration of the main spar and fuselage attachment structure is illustrated in Figures 1.1 and 1.2. The pipeline survey mission typically is of a two-hour duration and is flown at an altitude of 100 to 200 feet at an airspeed of $.9V_{C}$. The aircraft had accumulated 7488 flight hours, all of which were pipeline survey missions. Piper requested that a fracture mechanics analysis of the wing main spar attach fitting for the PA 28-181 and PA 32-300 series aircraft be conducted to establish an inspection program.

Piper Aircraft supplied all drawings for the wing main spar attach fitting for the PA 28-181 and PA 32-300 aircraft including installation and assembly drawings. Material property tests of the spar were conducted by Alcoa, and a copy of those results were provided. Operational spectra defining the pipeline survey mission, metallurgical results from the in-service failure, stress per g ratios for the wing main spar, and design limit stresses for both models of aircraft were also furnished by Piper.

٠. :





LG88ER0016 April 1988

Analysis Approach 1.1

The fracture mechanics analysis approach starts with the assumption that there exists at time zero on the structure a small flaw which propagates during service to a critical crack size. The time to grow from an initial small size flaw to critical size is analytically derived knowing the structural geometry and loading spectrum. For this analysis the flaw initiation was by fretting and the flaw was not present at time zero but was initiated at some point after time zero. The calculation of time to initiation by fretting is beyond the scope of fracture mechanics type analysis. After initiation, the flaw propagated by fatigue and fracture mechanics can predict the crack growth behavior. The analysis procedure used was to start with a small flaw and calculate the time to critical crack size. The end conditions, measured crack size and time to reach this size, are known quantities and can be used with the calculated crack growth characteristics to define an analytical equivalent initial flaw The EIFS accounts for the initiation by fretting and size (EIFS). propagation by fatigue and correlates the analysis to a measured occurrence. The EIFS can then be used to calculate crack growth times for any other loading spectrum for the same structural geometry. An EIFS was calculated for the PA 28-181 incident and applied to the PA 32-300 aircraft.





	A1-20 BA
	7/2/20
A norm and by	Uate

Use and/or disclosure is governed by the statement on the title page of this dog









VIEW LOOKING FORWARD

Figure 1.1 Plan Views of Main Spar and Attach Structure







Figure 1.2 Isotropic View of Main Spar and Attach Structure



E ZLOCKNOOD

2.0 SPECTRA DEVELOPMENT

Operational spectra defining the pipeline survey mission was provided by Piper Aircraft (Ref. 2) and included stress per g (σ/g) values, design limit stresses, and Δg values with their corresponding number of occurrences, Figure 2.1, for both the PA 28-181 and PA 32-300 aircraft. The exceedance curves which were used to define the spectra were also supplied. A typical pipeline survey mission was assumed to consist of a five minute taxi segment, two hours of combined gust and maneuver, a landing segment followed by a final five minute taxi.

The exceedance data supplied by Piper was converted to a format which would be compatible with LASC-Georgia spectra generation procedures. The Δ g values for the flight and ground conditions were factored by their corresponding σ/g ratios yielding $\Delta \sigma$ while the number of occurrences per hour for maneuver and gust were multiplied by a factor of 2 to convert the data to an equivalent two hour mission. Similarly, the number of taxi occurrences per hour were multiplied by .0833 to convert to number of occurrences per five minute segment. The number of occurrences per hour of landing were assumed to represent number of occurrences per landing. Exceedance curves were then generated for each of the flight and ground conditions. The curves for maneuver and gust were combined into a single exceedance curve for each of the model series aircraft and subsequently layered, Figures 2.2 and 2.3, in accordance with current LASC-Georgia methodology.

Truncation of the spectra is first made at 500 psi. Incremental stresses less than this magnitude are considered insignificant to the crack growth analysis. This truncation is the first slice and is followed by three others at the incremental stress corresponding to 1.5, 0.5, and .001 cumulative occurrences. The .001 occurrence level is the high stress truncation level, meaning that all incremental

Approved

Date



2.0 SPECTRA DEVELOPMENT (Cont'd)

stress magnitudes which statistically occur less than one time every 1000 times the segment is flown are ignored. The portion of the curves between 500 psi and 1.5 occurrences is then sliced four times to create five equal intervals on the variable stress scale. The minimum and maximum stress values for the combined gust/maneuver condition are asymetric in distribution as compared to the taxi and landing segments which are symmetric. This requires slicing the maximum occurrence spectra in a manner as described but with the minimum stress values determined by the occurrences levels defined on the maximum stress distribution.

The nine slices now define eight unique incremental stress intervals. The intervals are sufficiently small such that they may be represented by a single incremental stress value taken as the average of the end point values of the increment.

The incremental stress are combined with the lg stress defined by Piper for the PA 28-181 and PA 32-309 aircraft to form total stress cycles. At this point, the stress cycles for each mission segment are represented by eight distinctly defined values of minimum stress, maximum stress and number of occurrences, Figures 2.4 and 2.5. These sets of values are referred to as spectrum layers. The magnitude of the stress layers within the segment are arranged in the order of low-to-high. This has been shown to be conservative in comparison to random or high-to-low order.

The same spectra slicing procedure was performed on the exceedance curves for the taxi segment, Figures 2.6 and 2.7, and the incremental stresses were combined, Figures 2.8 and 2.9, with the lg ground stress to obtain total stress cycles.

The exceedance curves for landing, Figures 2.10 and 2.11, were truncated on the low $\Delta \sigma$ range at a lg equivalent stress

Approved by



thecked by





2.0 SPECTRA DEVELOPMENT (Cont'd)

instead of 500 psi because of the improbability of a landing occurring at less than lg. The remainder of the exceedance curve to .001 cumulative occurrences was sliced into eight equal layers. The incremental stresses were then combined with the lg ground stress generating the total stress cycles, Figures 2.12 and 2.13.

The spectra for the two hour pipeline mission was completed by assembling the total stress cycles from the five minute taxi, combined two hour gust and maneuver, landing and a final five minute taxi into a single spectra for the PA 28-181, Figure 2.14, and the PA 32-300, Figure 2.15.





Man	Dever		Gust		Та	xi	Landin	8
Number of occ. / hr.		7g ⁺	Number of occ. / hr.	±∆G	Number occ. /	of hr. ±∆G	Number of occ. / fl.	G's
34 30	. 11	. 44	228.60	. 35	320	. 05	1.000	1.00
10 30	.36	.65	137.20	.51	190	.10	. 350	1.25
Q 14	.52	. 85	57.15	.68	80	. 15	. 170	1.42
5 72	.58	1.054	22.90	.84	30	.20	. 026	1.58
2 06	.69	1.26	9.4	1.00	8.5	.25	. 003	1.80
20.00	88	1.46	1.26	1.17	2.1	.30	.0007	2.06
. 00	.97	1.67	. 46	1.33	. 50	. 35	.0002	2.3
126	1.02	1.87	.16	1.49	.10	. 40		
	1.13	2.07	.09	1.65	.018	. 45		
.00	1.24	2.28	. 046	1.82	.010	.465		
006	1.41	2.48	.014	1.99				
.0033	1.55	2.65	.015	2.11				
.0013	1.66	2.86	.007	2.28				
			.0034	2.44				
			.0023	2.60				
Aircrai Model I.D.	[t		Ground Stress (psi)	Stress (psi	; / G /g)	1 G Mean Stress (psi)	Design Stres (psi)	Limit 15
DA - 78 -	181		2409.8	7	816	7689	34,20	34
PA - 32 -	300		2552.0	8	444	10,500	39,20)9

Figure 2.1

Exceedance Data and Stress Definitions as Supplied by Piper Aircraft Company





with the S.

LG88ER0016 January 1988

 \sim



Figure 2.3

LG88ER0016 January 1988

Plockheed

ະ δ

د' 3

Lockheed

LG88ER0016 January 1988

Aircraft Model I.D. : PA - 38 - 181

1 G Stress = 7689 psi

Condition : Manuever and Gust Combined

Max Min Max Min 1 23850 -22500 31539 -14811 .0025 2 21550 -19100 29239 -11411 .0085 3 19250 -16500 26939 -8811 .0260 4 16950 -13600 24639 -5911 .1020 5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	Spectra Laver	*∆ (p	σ si)	**Δσ + 1 (G Stress psi)	Number of Occurences per 2 hr. Flight
1 23850 -22500 31539 -14811 .0025 2 21550 -19100 29239 -11411 .0085 3 19250 -16500 26939 -8811 .0260 4 16950 -13600 24639 -5911 .1020 5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	LLYGE	Max	Min	Max	Min	
2 21550 -19100 29239 -11411 .0085 3 19250 -16500 26939 -8811 .0260 4 16950 -13600 24639 -5911 .1020 5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	1	23850	-22500	31539	-14811	.0025
3 19250 -16500 26939 -8811 .0260 4 16950 -13600 24639 -5911 .1020 5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	2	21550	-19100	29239	-11411	. 0085
4 16950 -13600 24639 -5911 .1020 5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	3	19250	-16500	26939	-8811	. 0260
5 14650 -11700 22339 -4011 .3600 6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50	4	16950	-13600	24639	-5911	. 1020
6 12625 -10350 20314 -2661 1.00 7 8937.5 -5800 16626.5 +1889 93.50 11001 5 -2189 655	5	14650	-11700	22 339	-4011	. 3600
7 8937.5 -5800 16626.5 +1889 93.50 11001.5 #189 655	6	12625	-10350	20314	-2661	1.00
	7	8937.5	-5800	16626.5	+1889	93.50
8 3312.5 -1500 11001.5 0185 000	8	3312.5	-1500	11001.5	~6189	655

* Values found directly from occurence curves ** Values derived by adding 1 G Stress to $\Delta\sigma$

Figure 2.4 PA 28-181 Max/Min Stresses Developed from Manuever/Gust Loading



Lockheed

LG88ER0016 January 1988

Aircraft Model I.D. : PA - 32 - 300

1 G Stress = 10500 psi

Condition : Manuever and Gust Combined

Spectra	* 🋆	J	$**\Delta\sigma + 1$ (ps	G Stress i)	Number of Occurences per 2 hr. Flight
Layer	Max	Min	Max	Min	,
1	25780	-22400	36280	-11900	.0025
2	23340	- 19500	33840	-9000	. 0095
3	20900	-17500	31400	-7000	.025
4	18460	-14900	28960	-4400	. 102
5	16020	-12800	26520	-2300	. 360
0	13850	-11250	24350	-750	1.00
6	6600	-6300	20300	4200	96.5
7	3000	1800	14100	8800	662
8	3600	-1100	14100	~~~~	

* Values found directly from occurence curves

** Values derived by adding 1 G Stress to $\Delta \sigma$

Figure 2.5 PA 32-300 Max/Min Stresses Developed from Manuever/Gust Loading











and the second se





Figure 2.7

PA 32-300 Exceedance Curve for 5 Min Taxi Segment





. .

LG88ER0016 January 1988

- -

. . .

Aircraft Model I.D.: PA - 28 - 181 1 G Stress = 2409.8 psi

Condition : Taxi

Spectra $*\pm \Delta \sigma$		$\overset{\star}{\Delta}\sigma + 1 G$ Stress (psi)		Number of Occurences per 5 min. Taxi
Layer	(psi)	Max	Min	-
1	1063.10	3472.9	1346.7	. 003
2	969.30	3379.1	1440.5	.011
3	875.50	3285.3	1534.3	. 037
4	781.70	3191.5	1628.1	. 118
5	687.90	3097.7	1721.9	. 330
6	593.00	3002.8	1816.8	1.000
7	533.75	2943.55	1876.05	. 250
8	511.25	2921.05	1898.55	. 450

* Values found from occurence curves

** Values derived by adding given 1 G Stress to $\Delta \sigma$

.

Figure 2.8 PA 28-181 Max/Min Stresses Developed from 5 Min. Taxi Segment

Prepared by Difference Date Checked by Date 2.11	7
--	---



Aircraft Model I.D. : PA - 32 - 300

1 G Stress = 2552 psi

Condition : Taxi

Spectra	* $\pm \Delta \sigma$	$\overset{**\Delta\sigma + 1}{(ps}$	G Stress :i)	Number of Occurences per 5 min. Taxi	
Layer	(For)	Max	Min		
1	1120.5	3672.5	1431.5	. 003	
2	1021.5	3573.5	1530.5	.011	
3	922.5	3474.5	1629.5	.037	
4	823.5	3375.5	1728.5	.128	
5	724.5	3276.5	1827.5	. 320	
6	622.5	3174.5	1929.5	1.00	
7	552.5	3104.5	1999.5	. 50	
8	517.5	3069.5	2034.5	.70	

* Values found directly from occurence curves

** Values derived by adding 1 G Stress to $\Delta \sigma$

Figure 2.9 PA 32-300 Max/Min Stresses Developed from 5 Min. Taxi Segment



E / Lockheed



Figure 2.10

PA 28-181 Exceedance Curve for Landing Segment





New Y

Walay Marcalay







Figure 2.11 PA 32-300 Exceedance Curve for Landing Segment





.

Aircraft Model I.D. : PA - 28 -181

.

1 G Stress = 2409.8 psi

Condition : Landing

Spectra	σ	(psi)	Number of Occurences
Layer	Мах	Min	her i randing her tugut
1	4650	2409.8	. 0009
2	4350	2409.8	. 0026
3	4050	2409.8	.0105
4	3750	2409.8	. 0650
5	3450	2409.8	.1400
6	3150	2409.8	.2100
7	2850	2409.8	.2900
8	2550	2409.8	.2800

Figure 2.12

PA 28-181 Max/Min Stresses Developed from Landing Segment







Aircraft Model I.D. : PA - 32 - 300 1 G Stress = 2552 psi

Condition : Landing

Spectra Layer	σ (psi)		Number of Occurences per 1 Landing per Flight	
	Max	Min		
1	4890.6	2552	.001	
2	4571.9	2552	.0028	
3	4253.1	2552	.0142	
4	3934.4	2552	.076	
5	3615.6	2552	. 135	
6	3296.9	2552	.220	
7	2978.1	2552	.270	
8	2659.4	2552	. 380	

Figure 2.13

PA 32-300 Max/Min Stresses Developed from Landing Segment





. .

33



SEGMENT		STRESS	
I.D.	CYCLES	MIN.	MAX.
21	. 4500	1898.55	2921.05
21	.2500	1876.05	2943.55
21	1.0000	1816.80	3002.80
21	. 3300	1721.90	3097.70
21	.1180	1628.10	3191.50
21	.0370	1534.30	3285.30
21	.0110	1440.50	3379.10
21	.0030	1346.70	3472.90
13	655.0000	6189.00	11001.50
13	93.5000	1889.00	18626.50
13	1.0000	-2661,00	20314.00
13	. 3600	-4011.00	22339.00
13	.1020	-5911.00	24639.00
13	. 0260	-8811.00	26939.00
13	.0085	-11411.00	29239.00
13	.0025	-14811.00	31539.00
24	.2800	2409.80	2550.00
24	.2900	2409.80	2850.00
24	.2100	2409.80	3150.00
24	.1400	2409.80	3450.00
24	.0650	2409.80	3750.00
24	.0105	2409.80	4050.00
24	.0026	2409.80	4350.00
24	. 0009	2409.50	4650.00
21	. 4500	1898.5 j	2921.05
21	.2500	1876.05	2943.55
21	1.0000	1816.80	3002.80
21	. 3300	1721.90	© J97 . 70
21	.1180	1628.10	3191.50
21	.0370	1534.30	3285.30
21	.0110	1440.50	3379.10
21	. 0030	1346.70	3472.90

Figure 2.14

PA 28-181 Spectra defining 2 Hour "Pipeline Survey Mission"



Jockheed

LG88ER0016 January 1988

SEGMENT		STRESS	
I.D.	CYCLES	MIN.	MAX.
21	.7000	2034.50	3069.50
21	. 5000	1999.50	3104.50
21	1.0000	1929.5 0	3174.50
21	. 3200	1827.50	3276.50
21	.1280	1728.50	3375.50
21	. 0370	1629. 30	3474.50
21	.0110	1530.50	3573.50
21	.0030	1431.50	3672.50
13	662.0000	8800.00	14100.00
13	96.5000	4200.00	20300.00
13	1.0000	-750.00	24350.00
13	.3600	-2300.00	26520.00
13	.1020	-4400.00	28960.00
13	.0250	-7000.00	31400.00
13	.0095	-9000.00	33840.00
13	.0025	-11900.00	36280.00
24	.3800	2552.00	2659.40
24	.2700	2552.00	2978.10
24	.2200	2552.00	3296.90
24	.1350	2552.00	3615.60
24	.0760	2552.00	3934.40
24	.0142	2552.00	4253.10
24	.0028	2552.00	4571.90
24	.0010	2552.00	4890.60
21	. 7000	2034.50	3069.50
21	.5000	1999.50	3104.50
21	1.0000	1929.50	3174.50
21	.3200	1827.50	3276.50
21	.1280	1728.50	3375 😳0
21	.0370	1629.50	3474.50
21	.0110	1530.50	3573.50
21	.0030	1431.50	3672.50

Figure 2.15

114 88 Checked by

1

PA 32-300 Spectra Defining 2 Hour "Pipeline Survey Mission"

Approved by



Prepared by



3.0 FINITE ELEMENT MODEL

Finite element models were developed of the main spar fitting and spar box assembly attachment to determine both load transfer and stress concentration effects around the critical bolt hole. Fastener spring elements were used to attach the main spar to the channel section of the spar box assembly. An axial load model of the lower portion of the cap-channel connection, in lieu of a bending model of the full connection was developed, Figure 2.1. The axial load model was based on the following assumptions:

(1) A beam with a moment $"M_1"$ applied can be shown with an equivalent force couple Pld, where Pld = Ml



(2) The beam is also assumed to react as three parts. The upper and lower beam caps react the axial force P, while the web between the caps reacts the shear generated by differing moments.



E Lockheed



3.0 FINITE ELEMENT MODEL

The spar cap, Figure 2.2, and channel sections, Figure 2.3, were subjected to a 10 KSI far field stress resulting in a load distribution along the fastener row as illustrated in Figure 2.4. The load distribution was used to calculate the fastener bearing to average stress value, Figure 2.5, as a load transfer effect which is input to the stress intensity solution. The values of σ_1 and σ_2 listed in Figure 2.5 signify local intensification of the stress as the first fastener is approached followed by a drop off in the stress, σ_2 , as the first fastener takes up a portion of the load. A stress contour plot around the critical fastener hole, Figure 2.6, was used to determine stress concentration factors at the crack origin and along the crack front progression.

Chocked by

B Approved by



PIPER SPAR CONNECTION

Figure 3.1 Finite Element Model of Main Spar and Attach Structure with Critical Hole Detail





1

/

Prepared by

~(





28 <u>~</u> ~ ```

Lockheed



Checked by

Date

ELEMENT FORCE

Prepared by

Figure 3.4 Load Distribution Along Critical Fastener Row

Approved by



LALLA .


Prepared by

LG88ER0016 January 1988



Р	σ,	σ _z	t	σ_{BRG}	σ _{BRG} σ _{AVG}	ρ	FSTNR. HOLE DIA.
1,441	10,820	6,963	.275	13,970	1.57	.822	.375



Figure 3.5 Load Transfer Effects





Prepared by

Checked by

Л

Lockheed

LG88ER0016 January 1988 R-April 1988

4.0 DAMAGE TOLERANCE ASSESSMENT CRITERIA

4.1 CRITICAL CRACK SIZE

Critical Crack Size (a_{CR}) is defined as that crack length at which unstable, rapid crack growth occurs when design limit load stress is applied. The crack growth analysis is used to establish the initial and recurring inspection intervals as a means of maintaining safe-use operation of the aircraft.

The Critical Crack Size is defined as the crack length beyond which it is recommended not to operate the aircraft without appropriate inspections, repairs, or modifications.

The inspection times are based on the calculated flight hour interval (for a specific structural component) for an initial crack size (a_i) to grow to an unstable length (a_{CR}) when subjected to the analytical operational loads/environment spectra. This initial flaw shall be assumed to exist in the most unfavorable location and orientation with respect to the applied stresses and material properties.





ŀ

LG88ER0016 January 1988 R-April 1988

 $\sim \backslash$

4.2 INITIAL INSPECTION

The recommended Initial Inspection should occur at one-half the time to grow from an initial crack size to the critical crack size.



4.3 RECURRING INSPECTION INTERVAL

The Recurring Inspection shall occur at one-half the time for a crack to grow from the maximum undetectable flaw size (a_{NDI}) to an unstable length at Design Limit Load (a_{CR}) .





Prepared b

1.



4.3 RECURRING INSPECTION INTERVAL (Cont'd)

It should be noted that Safe-Use intervals of operation, equal to the Recurring Inspection interval, can continue up to, and beyond, the calculated time to critical crack size for a specific structural part provided that no cracking is detected by the specific Non-Destructive Inspection technique at the time of Recurring Inspection.

38 Approved

Date

Lockheed

LG88ER0016 January 1988 R-April 1988

5.0 CRACK GROWTH ANALYSIS

Stress intensity solutions were developed using the finite element model results obtained in Section 3.0 and standard LASC-Georgia geometric stress intensity methodology. Material property tests performed by Alcoa (Ref. 3) on a section of main spar provided by Piper showed the material to be within the required specifications. A compilation of data from in-house tests, industry and government sources was used to generate da/dn data, Figure 5.1. The operational spectra, da/dn data and yield stress were used to compute analytical crack growth.

A double surface flaw was assumed for analysis based on the origin locations shown in Figure 5.2. An initial flaw size and shape of 0.02 inches was used to determine the crack growth characteristics for the defined loading spectrum. Each assumed initial flaw extended .040 inches along the surface with a depth of .020 inches. The first phase of crack growth extended from each initial flaw to a point at which both crack fronts intersected. The second phase of growth assumed a hole with a diameter based on the distance between the surface origins with the crack growth measured from the end of Phase One to a final a_{CR}, Figure 5.3. The analytically determined a CR was found to be shorter than the fatigue damage area observed on the fracture surface. A smaller hole diameter was selected for the second phase of growth rather than the original diameter because the original crack front intersected the edge of the hole rather than along the diameter of the hole.

Crack growth curves were generated for the PA 28-181, Figure 5.4, and the PA 32-300, Figure 5.5, with a time to critical crack size of 7888 hours for the PA 28-181 and 3804 hours for the PA 32-300 based on a double .040 inch surface flaw configuration with a depth for each flaw of .020 inches. An

88 Approved by

Checked by

Prepared by



-LG88ER0016 January 1988

5.0 CRACK GROWTH ANALYSIS (Cont'd)

equivalent initial flaw of .0207 inches (.0414 surface length) was established for the PA 28-181 by determining from the crack growth analysis a flaw size that would be required to generate 7488 hours (total aircraft time to failure) to a_{CR} . The .0207 equivalent initial flaw was applied to the PA 32-300 resulting in a time to a_{CR} of 3658 hours.

A request was made by Piper (Ref. 5) for LASC-Georgia to provide a correlation to service experience on the PA 28-181 accident to determine the reasonability of the crack growth analysis. A series of electron fractographs of the fracture surface were furnished (Ref. 2) which formed the basis for the correlation. An assumption was made that the flight profile was strictly defined as low level, high speed and of a two-hour duration. The fracture surface details were also assumed to represent one flight with distinctive striations representing individual landings at the conclusion of each flight. The fracture features were most pronounced in an area where the crack front broke through the thickness of the spar to where the crack grew to the edge of spar. The spacing between the striations gradually increased rather than having a random spacing. The gradually increasing spacing between the major striations suggests that striations were produced by a regularly applied occurrence such as landing rather than by a random occurrence such as gust. The spacing between the major striations, representing growth per flight, varied from .00591 in/flight to .01181 in/flight while the analytically determined growth per flight for the same crack length increment ranged from .00193 in/flight to .0356 in/flight. The overlap experienced in the growth per flight between the analytic and measured data, for the same crack length interval, indicates that the analytical crack growth provides a reasonable representation of the actual crack growth experience.

Prepared by

Approved b





Prepared by ______ Dete Checked b

Lockheed

LG88ER0016 January 1988 R-April 1988



ASSUMED INITIAL FLAW

		PA 28-181	PA 32-300
PHASE I	.0201065	7,677 Hrs.	3,704 Hrs.
PHASE II	.1065275	211 Hrs.	100 Hrs.
	TOTAL	7,888 Hrs.	3,804 Hrs.

EQUIVALENT INITIAL FLAW

	· .	PA 28-181	PA 32-300
PHASE I	.02071065	7,277 Hrs.	3,558 Hrs.
PHASE II	.1065275	211 Hrs.	100 Hrs.
	TOTAL	7,488 Hrs.	3,658 Hrs.

Figure 5.3 Pha

Phased Crack Growth

4118

Prepared by ______ Beter B Approved b

Prepared b /11/88 Checked by Date Approved b



LG88ER0016 January 1988 R-April 1988

E/Lockheed

5. 6

Prepared by



LG88ER0016 January 1988 R-April 1988

lockheed

4/11/88 Appr

111/88 Checked b

⁷O

E. ? Lockheed

LG88ER0016 January 1988 R-April 1988

il 189

 γ

Approved by

6.0 SUMMARY

A fracture analysis of the wing main spar fitting for Piper Aircraft model PA 28-181 and PA 32-300 was completed. A crack growth analysis was performed to determine the crack growth characteristics of the spar fitting for the defined loading spectrum and a crack growth curve plotted based on an initial flaw. An equivalent initial flaw was defined based on the spar fitting crack growth characteristics and the 7,488 flight hours to failure for the PA 28-181 aircraft. The rationale for initial and recurring inspection times was discussed. The recurring inspection intervals will be dependent on the NDI inspection technique specified by Piper Aircraft.

Heenecked by

Report VB-1337 Page G-1

...

APPENDIX G

PIPER FATIGUE ANALYSIS

٠.

. .

*.e



 \sim

G1 INTRODUCTION

A PA-28-181 lower wing spar cap, at the outboard bolt holes attaching to the wing main spar carry thru, failed due to fatigue initiated by fretting outboard of the bolt hole near Marlin, Texas, March 30, 1987. The aircraft had flown on pipeline patrol during its lifetime. This report contains the fatigue analysis used to establish a relationship of the fatigue lifetime for both a PA-28-181 and PA-32-300 flying pipeline patrol and normal missions.

1. 20

PAC FATIGUE ANALYSIS

TABLE OF CONTENTS

SECTION	DESCRIPTION	PAGE
Gl	Introduction	G1-1
G2	Loads and Stress	G2-1
G3	Stress Concentration	G3-1
G4	Fatigue Spectrum	G4-1
G5	Fatigue Analysis	G5-1
G6	Summary	G6-1
G7	References	G7-1

~

.....

Report VB-1337 Page G2-1

G2 LOADS AND STRESS

The following are the PA-28-181 and PA-32-300 aircraft configurations. The normal flight duration is .65* hours and pipeline is 2.0* hours duration.

. . . .

*Per Ref 1



Report VB-1337 Page G2-2

~ 5-

PA-28-181 3.8 Normal ; 4.4 Utility Normal Typical empty Wt = 1593 lbs 2 Occupants = 340 Baggage = 88 50% Fuel = 150 Flight GW = 2163 lbs. FS95.9 т.о. 55% Fuel, GW = 2178 FS95.9 Ldg 45% Fuel, GW = 2148 FS95.9 Utility (Pipeline) Typical empty Wt = 1593 lbs loccupant 170 2 = 60 Baggage = 210 70% Fuel = 2033 lbs. FS96.7 Flight GW т.о.

85% Fuel, GW = 2078 FS96.7 Ldg 55% Fuel, GW = 1988 FS96.7

. . . .

Report VB-1337 Page G2-3

PA-32-300

3.8 Normal

Normal

Typical empty	Wt	2	1958	lbs	
3 occupants		8	510		
Baggage		=	120		
50% Fuel		=	252		
Flight GW		=	2840	lbs.	FS79.5
т.о.					
55% Fuel, GW		=	2865	FS79.	. 6
Ldg					
45% Fuel, GW		=	2815	FS79.	. 4

Utility (Pipeline)

Typical empty 1 occupant Baggage 70% Fuel Flight GW	Wt	N N N N N	1958 170 60 <u>353</u> 2541	lbs.
T.O. 85% Fuel, GW Ldg 55% Fuel, GW		8 H	2617 2465	FS77.6 FS76.6

.

PAGE	iv D	G2-5
REPT	NO	VB-1337
ADDEL	NO	PA28-15

PIPER AIRCRAFT CORP. VERO BEACH ENGINEERING



DATE 3-SEP-87

** V-N DIAGRAM **

	UTILIT) GROSS WFJ PI PELI		
CONCITION	VELOCITY	MANEUVER LOAD FACTOR	GUST LOAD FACTOR
	(MPH)	(G'S)	(G'S)
STALL	58.5	1.00	
A	122.6	4.40	
С	1 32.3	4.40	3,53
D	206.0	4.40	2.97
Ê	206.0	-1.00	-0,97
F	132.3	-1.76	-1.53
G	92.8	-1.76	
NEG STALL	70.0	-1.00	

FLAPS DOWN ENVELOPE

F-D	STALL	50.2	1.0	
	VE	115.0	2.00	2.10
	VF	115.0	2.00	-0.10

NUTE 1) FAR REFERENCES ON PAGE

- 2) AERODYNAMIC COLFFICIENTS PRESENTED ON PAGE
 - 3) AIRCRAFT GEOMETRY PRESENTED ON PAGE
 - 4) VALUES PRESENTED ARE EITHER FAA MINIMUMS OR
 - PIPER AIRCHAFT POLICY
 - 5) INCLUDES THRU AMENDMENT 6

STRUCI GRP

PIPER AIRCRAFT CORP VERO BEACH ENGINEERING



()

DATE 3-SEP-87

GROSS WEIGHT= 2033. LPS C.G.=0.0400 MAC (INCLUDES THRU AMENDMENT 6) PIPELINE USEASE BALANCE TAIL LOADS FAR 23.421

COND	VEL	CMEN	WIN	IG PROPI	ERTIES	L	DAD FAC	TORS		
		•	CN	CL	CMW	NX	NZ	NZ-W	THR	BTL
	(MPH)	(DLS)	(DLS)	(DLS)	(DLS)	(G'S)	(G'S)	(G'S)	(618)	(LAS)
Δ	123.	0.090	1.456	1.523	-0.065	-1.376	4.400	4.680	-0.230	-570.
Ċ	132.	0.072	1.259	1.296	-0.065	-1.093	4.400	4.712	-0.213	-634.
n n	206.	0.017	0.542	0.542	-0.065	-0.108	4.400	4.919	-0.137	-1055.
Б Е	206.	-0.008	-0.092	-0.091	-0.065	0.027	-1.000	-0.832	-0.137	-341.
E E	132.	-0.026	-0.474	-0.477	-0.065	-0.208	-1.760	~1.775	-0,213	30.
G	93.	-0.066	-0.987	-1.029	-0.065	-0.523	-1.760	-1.818	-0,304	119.
1G-A	123.	0.014	0.360	0.360	-0.065	-0.004	1.000	1.158	-0.230	-320,
1G-C	132.	0.012	0.313	0.312	-0.065	0.009	1.000	1.170	-0,213	-346.
1G=D	206.	0.003	0.143	0.143	-0.065	0.073	1,000	1.297	-0,137	-604.
FO	115.	0.064	0.878	0.881	-0.266	-0.240	2.099	2.482	-0.245	-780,
2/34	123.	0.050	0.990	1.003	-0.065	-0.483	2.933	3.183	-0.230	-508.
2/30	132	0.041	0.856	0.862	-0.065	-0.371	2.933	3.202	-0.213	-547.
2/30	206.	0.014	0.369	0.369	-0.065	-0.019	2.933	3.347	-0.137	-841.

MANEUVER TAIL LOADS FAR 23.423 (A) MAX UP ELEVATOR= -741. LBS MAX DOWN ELEVATOR= 775. LBS

CHECKED MANEUVER TAIL LOADS FAR 23.423 (B) CHKU-WAN 2-LOAD DELTA VELOCITY STL CUNDITION PTH ACC TAIL LOAD FACTOR TAIL LOAD (RPSS) (LBS) (G'S) (LBS) (LBS) (MPH) -831.7 1.000 4.68 -511.3 -320.4 122.6 A-NOSE UP 4.34 ~819.4 1.000 -473.9 -345.5 132.3 UP C-NOSE -908.5 2.79 -304.3 1.000 -604.1 206.0 D-NOSE UP -58.9 4,400 -4.68 -570.2 511.3 122.6 A-NOSE DOWN -160.5 -4.34 4.400 -634.4 473.9 132.3 C-NOSE DOWN -750.6 -2.79 304.3 4,400 -1054.9 206.0 D-NOSE DOWN

GUST. TAIL LOADS

CONDITION	VELOCITY	BALANCE	DELTA TAIL	TOTAL GUST TAIL LOAD
	(MPH)	(LOS)	(LBS)	(LBS)
С	132.3	-345.51	467.1	121.6
	206.0	-679.76	203.0	-476.8
C D C - D A A	,			-917 6
C	132.3	-345.51	40/.1 363.6	-967.7
U FLP-DWN	115.0	-679.76	203.0	-882.8

PIPER AIRCRAFT CORP VERD BEACH ENGINEERING

PAGE H1) 62-7 REPT NO VB-1337 MODEL NO PA**28-19**1

DATE 8-0CT-87

FATIGUE LOADS (PIPELINE USEAGE) - 2033 LBS AT .04MAC

GROSS WEIGHT= 2033.0 LBS V=132.0 MPH NZ= 1.000 NX= 0.009

AIRLOAD LIMIT SHEAR AND MOMENT

STA.	V 2	MXX	VX	MZZ	TOROUE
(INS)	(LAS)	(IN-LE)	(LPS)	(IN-LB)	(IN-L8)
211.57	0.0	0.	0.0	0.	0.
207.90	2.1	4.	0.4	1.	-119.
190.90	33.4	306.	2.1	22.	-563.
174.00	83.4	1293.	3.5	69.	-934
157.00	147.0	3252.	5.0	141.	-1286.
148.60	183.0	4638.	5.7	186.	-1446.
140.09	222.3	6362.	6.5	238.	-1602.
131.60	264.2	8428.	7.3	296.	-1751.
123.15	398.7	10848.	8.3	362.	-1892.
106.19	400.5	16914.	10.3	520.	-2148.
96.00	469.8	21379.	11.6	632.	-2278.
88.75	516.5	24955.	12.6	719.	-2354.
64.59	682.1	39433.	15.8	1063.	-2494.
57.00	736.4	44816.	17.0	1187.	-2513.
49.25	791.8	50738.	18.2	1324.	-2535.
36.22	858.2	61683.	20.7	1577.	-2432.
21.88	1005.7	75262.	23.8	1896.	-1412.
10.00	1107.2	87813.	26.2	2193.	-1425.
0.00	1189.3	99295.	27.9	2464.	-1249.



PIPER AIFCHAFT CORP VERD BEACH ENGINEERING

DATE 8-001-87

PAGE DE G2-8 REPT E VB-1337 AULET E FA**28-18**1

\$

۰ -

FATIGUE LOADS (FEFFIINE USFAGE) - 2033 LHS AT .04MAC

GROSS WEIGHT= 2033.0 LBS V=132.0 MPH NZ= 4.400 NX=-1.043

ALPUCAD EINER SHEAR AND YOMENT

STA,	٧Z	x X v	VX	×ZZ	FORCHE
(INS)	(153)	(IN-18)	(LPS)	(10-18)	(IN-1, F.)
211.57	0.0	O "	0.0	0	()
207.90	12.4	23.	-1.2	-2.	- 4 3
190.90	1 ~ 7 . 1	1719.	-23.8	-257	615
174.00	447.2	7079.	-7×.t	-1164	1475
157.00	755.8	17305.	-141.0	-3030.	3794.
148.60	922.8	24355%	-175.1	-4354	4×58
140.09	1100.4	32484 .	-211.3	- 5002	0(132
131.60	1285.1	43091.	-248.7		7300
123.15	1476.5	54758.	-287.1	-10218.	8662
106.19	1883.2	83249.	-367.1	-15771.	11715
96.00	2138.1	103737.	-417.7	-19773	13644
88.75	2322.0	119905	~ 453.8	-22932	15120
64.59	2954.8	183650.	= 577.3	-35388	20135
57.00	3157.3	206845	-016-0	- 34917	21747
49.25	3361.6	232106.	-n-53_0		23367
36.22	3713.3	278195	+718-2		253870
21.88	4135.8	334477.	-794 7	-53574	27558
10.00	4498.1	385763	-850 H	-74459	37401
0.00	4789.7	432202	-915 1	-83337	-10374

PIPER AIPCRAFT CORP VERC BEACH ENGINEERING

PAGE NO G2-9 REPT NO Report VB-MODEL NO PA28-161

DATE 4-SEP-87

** V-N DIAGRAM **

		NORMA	L CATEGORY	
		GROSS WF	IGHT= 2163. UBS	
		VELOCITY	NANELIVER	CUST
CON	DICION	VELOCITI	LAND FACTOR	LOAD FACTOR
		(MPH)	(G'S)	(G'S)
S	STALL	60.3	1.00	
	А	117.5	3.80	
	с	132.3	3.80	3.41
	D	206.0	3.80	2.88
	ε	206.0	0.00	-0.88
	F	132.3	-1.52	-1.41
	G	89.0	-1.52	
NEG	STALL	72.2	-1.00	

FLAPS DOWN ENVELOPE

F-D STALL	51.8	1.0	
٧F	115.0	2.00	2.05
VF	115.0	2.00	-0.05

NOTE 1) FAR REFERENCES ON PAGE

- 2) AERODYNAMIC COEFFICIENTS PRESENTED ON PAGE
- 3) AIRCRAFT GEOMETRY PRESENTED ON PAGE
- 4) VALUES PRESENTED ARE EITHER FAA MINIMUMS OR PIPER AIRCRAFT POLICY
- 5) INCLUDES THRU AMENDMENT 6

PIPER AIRCRAFT CORP VERO BEACH ENGINEEPING

PAGE NO G2-10 REPT NO VB-1337 MODEL NO PA28-181

DATE 4-SEP-87

GROSS WEIGHT= 2163. LES C.G.=0.1000 MAC (INCLUDES THRU AMENDMENT 6) NORMAL USEAGE BALANCE TAIL LOADS FAR 23.421

COND	VEL	CMEN	wIt	G PROPI	FRTIES	L	DAD FAC'	ICRS		
			CN	CL	CNW	NX	NZ	NZ-W	THR	PTL
	(MPH)	(DLS)	(DLS)	(DLS) (CLS)	(G'S)	(G'S)	(G'S)	(G'S)	(LES)
A	118.	0.089	1.427	1.492	+0.065	-1.176	3.800	3.963	-0.226	- 353.
C	132.	0.061	1.139	1.164	-0.065	-0.802	3.800	4.008	-0,200	-451.
D	206.	0.017	0.490	0.490	-0.065	-0.081	3.800	4.181	-0.129	-P24.
ε	206.	-0.007	-0.082	-0.081	-0.065	0.036	-0.878	-0.698	-0.129	-391.
F	132.	-0.023	-0.424	-0.426	-0.065	-0,162	-1.520	-1.492	-0.200	-61.
G	89.	-0.064	-0.965	-1.003	-0.065	-0.433	-1,520	-1.536	-0,298	34.
IG-A	118.	0.016	0.405	0.405	-0.065	-0.015	1.000	1,125	-0,226	-270.
16-C	132.	0.012	0.325	0.325	-0.065	0.006	1.000	1.142	-9,200	-307.
IG-D	206.	0.003	0.148	0.148	-0.065	0.070	1.000	1.262	-0,129	-567.
FC	115.	0.065	0.891	0.896	-0.266	-0.244	2.049	2.369	-0.231	-694.
2/3A	118.	0.049	0.972	0.984	-0,065	•0.404	2,533	2.698	-0.226	-357.
2/30	132.	0.035	0.775	0.778	-0.065	-0.256	2.533	2.725	-0.200	-415.
2/3D	206.	0.013	0.335	0.335	-0.065	0.007	2,533	2.856	-0.129	-697,

MANEUVER TAIL LOADS FAR 23.423 (A) MAX UP ELEVATOR= -681. LBS MAX DOWN ELEVATOR= 712. LBS

CHECKED MANEUVER TAIL LOADS

			Ľ A I	K 23.423 U	e)		
COND	TION	VELOCITY	BTL	DELTA	Z-LOAD		CHKD-MAN
				TAIL LOAD	FACTOR	PTH ACC	C TAIL LOAD
		(MPH)	(LBS)	(LBS)	(G'S)	(RPSS)	(LAS)
A-NOSE	UP	117.5	-270.2	-384.8	1.000	3.35	~655.0
C-NOSE	UP	132.3	-307.3	-341.9	1.000	2.97	-649.2
D-NOSE	UP	206.0	-566,6	-219.6	1.000	1.91	-786.2
A-NOSE	DOWN	117.5	-353.4	384.8	3.800	-3,35	31.4
C-NOSE	DOWN	132.3	-450.9	341.9	3.800	-2.97	-109.0
D-NOSE	DOWN	206.0	-823.8	219.6	3.800	-1.91	-604.2

	1.1.1		
G	UST TAIL LO	ADS	
	FAR 23.425		
LOCITY	BALANCE	DELTA TAIL	TCTAL GUST
	TAIL LOAD	LOAD	TAIL LCAD

CONDITION	VELOCITY	BALANCE	DELTA TAIL	TCTAL GUST
QD D D D D D D D D D		TAIL LOAD	LOAD	TAIL LCAD
	(MPH)	(LBS)	(LBS)	(LRS)
C	132,3	-307.33	474.4	167.0
D	206.0	-566.63	369.3	-197.3
FLP-DWN	115.0	-641.00	206.2	-434.8
C	132.3	-307.33	474.4	-781.7
D	206.0	-566.63	369.3	-935.9
FLP-DWN	115.0	-641.00	206.2	-847.2



STRUCT GRE

PIPEP AIRCRAFT COPP VERD BEACH ENGINEERING PAGE NO G2-11 REPT NO VB-1337 MODEL NO PA28-181

DATE 8-001-87

FATIGUE LEADS (MORMAL USEAGE) - 2163 LBS AT . TOMAC

GRUSS WEIGHT= 2163.0 LES V=132.0 MPH MZ= 1,000 NX= 0.006

AIRLOAD LIMIT SHEAP AND MOMENT

STA.	٧Z	XXM	V X	►ZZ	TOROUE
(185)	(LBS)	(111-4月)	(LPS)	(1N-LB)	(IN-LP)
211.57	0.0	Ο.	0.0	0.	Ο.
207.90	2.2	4.	0,4	1.	-118.
190.90	\$5.4	324.	2.0	21.	-547.
174.00	88.1	1367.	3.3	66.	-900.
157.00	154.9	3433.	4.6	133.	-1218.
148.60	192.5	4892.	5.2	174.	-1361.
140.09	233.7	6706.	5.9	222.	-149).
131.60	277.4	8875.	6.7	275.	-1624.
123.15	323.8	11415.	7.5	335.	-1750.
106.19	425.5	17770.	9.3	477.	-1911.
96.00	491.3	22441.	10.4	577.	-2053,
88.75	539.7	26176.	11.3	656.	-211×.
64.59	/11.2	41288.	14.2	963.	-2184.
57.00	761.4	46900.	15.1	1074.	-21 Hb.
49.25	024.h	53069.	16.3	1196.	-21-5.
36.22	924.3	64463.	18.6	1423.	-2145 -
21.88	1045.6	78587.	21.4	1710.	-1337.
10.00	1150.3	91630.	23.6	1978.	• ³ · 1 •
0.00	1235.1	103557.	25.2	2222.	<u></u> 7.

PIPER AIRCRAFT CURP VERC BEACH ENGINEERING PAGE NI G2-12 REPT NO VB-1337 MODEL NO P1**28-181**

DATE 8-CCT-87

FATIGUE LEADS (NURMAL USEAGE) - 2163 (HS AT .10MAC

GROSS WEIGHT= 2163.0 LBS V=132.0 MPH NZ= 3.800 NX=+0.802

AIRLOAD LIMIT SHEAR AND MOMENT

STA.	٧Z	MXX	V X	M Z Z	L ROUE
(INS)	(685)	(1N-LB)	(LBS)	(IN-LB)	(f'-LB)
211.57	0.0	0.	0.0	0.	Ο.
207.90	11.1	20.	-0.7	- 1.	-54.
190 90	107.4	1538.	-19.H	-176.	463.
174 00	401.2	6343.	-55,6	-813.	1544.
151 00	679.2	15526.	-100.9	-2143.	:144.
137.00		21864	-125.8	-3095.	• 047.
140.00		29608	-152.4	-4274	5051.
140.09	370.2 1157 D	29700	-180-0	-5690.	h137.
131.60	1137.0	10770	-208.4	-7330	7306.
123.15	1329.9	97427• 74007	-268 3	-11373	9932
106.19	1031-8	62280	-208.5	-14297	11639
96.00	1928.5	93300.	-303.1	-16612	12879
88.75	2095.1	107466.	- 494 4	-75794	17216
64.59	2665.8	165513.	-420.4	-20704.	40646
57.00	2852.4	186466.	-455.8	-24132.	Janio.
49 25	3037.4	209291.	-484.5	-32775.	;0022.
36 22	3357.0	250953	-532.6	-39401.	23014.
30.42	2740 7	301843.	-590.0	-47450.	28045.
21.00	1069 8	348237	-640.1	-54757.	32447.
0.00	4334.7	390260.	-681.7	-61366.	34479.

STRUCI	C GRP	PIPER AIHCRAFT CORP	PAGE	NG 62-13
		VERG BEACH ENGINEERING	REET	NT VB-1337
DATE	5-0CT-87		MOREL	NO PA32-300

** V-N DIAGRAM **

	NORMAL CATEGORY GROSS WEIGHI= 2541. LBS Pipeling Usea44								
C 0 i	IDITIÚN V	FLOCITY GU	MANEUVER PAD FACTOR	GUST Load Factor					
		(MPH)	(6*5)	(6'8)					
5	STALL	65.9	1.00	,					
	Α	128.4	3.80						
	С	151.2	3.80	3,49					
	D	235.0	3.80	2.93					
	E	235.0	0.00	-0.93					
	۴	151.2	-1.52	-1.49					
	G	95.2	-1.52						
NEG	STALL	77.2	-1.00						
		FLAPS DOWN	ENVELOPE						
F-D	STALL	55.4	1.0						
	vF	125.0	2.00	2.03					
	V H	125.0	2.00	-0.0.3					

NOTE 1) FAR REFERENCES ON PAGE

- 2) AERODYNAMIC COEFFICIENTS PRESENTED ON PAGE
- 3) AIRCRAFT GEOMETRY PRESENTED ON PAGE
- 4) VALUES PRESENTED ARE EITHER FAA MINIMUMS CP PIPER AIRCRAFT POLICY
- 5) INCLUDES THRU AMENDMENT 6

PIPER AIRCRAFT CORP VERO BEACH ENGINEERING

PAGE NO 62-14 REPT NO VB-1337 MODEL NO PA32-300

η

DATE 5-0CT-87

GROSS WEIGHT= 2541. LBS C.G.=0.0030 MAC (INCLUDES THRU AMENDMENT 6) **PIPELINE USEAGE** BALANCE TAIL LOADS

EAR 23.421

COND	N 6 1.	CMEN	wIN	G PROPE	ERTIES	L	DAD FACI	TOKS		
LUND	A L		C N	CL	CMW	NX	N.7	ei Z 🗕	. H e	H. I.
	(មកម)	(DLS)	(DLS)	(DLS)	(CLS)	(G*S)	(613)	() () () () () () () () () ()	(c + z)	(UHR)
٨	199	0.038	1.425	1.499	-0.065	-1.255	3.400	4.128	-0.293	-832.
м С	151	0.015	1.043	1.054	-0.065	-0.678	3.000	4 . 18H	-0.249	-986-
	225	-0.006	0.450	0.450	-0.065	-0.121	3.000	4.366	-0.160	-1438.
1/ 1-	235	-0.021	-0.074	-0.074	-0.065	0.081	-0.432	-0.721	-0.160	-535.
с г	151	-0.031	-0.377	-0.379	-0.065	-0.131	-1.520	-1.515	-0.249	-13.
r C	1710	-0 051	-0.994	-1.024	-0.065	-0.381	-1.520	-1.582	-0.395	158.
10-4	128	-0.007	0.405	0.405	-0.065	-0.021	1.000	1.1/4	-0.293	-443.
10-6	151	0.010	0.300	0.300	-0.065	0.007	1.000	1.204	-0.249	-518.
10-0	235.	-0.015	0.140	0.140	-0.065	0.073	1.000	1,358	-0.160	-911.
10- <i>D</i>	125.	0.015	0.893	0.891	-0.266	-0.065	2.028	2.451	-0.301	-1075.
2/28	123.	0.012	0.970	0.981	-0.065	-0.392	2.533	2.809	-0.293	-/01.
2/30	151.	0.002	0.709	0.711	-0.065	-0.229	2.533	2.845	-0.249	-793.
2/30	235.	-0.010	0.310	0.310	-0.065	0.010	2.533	3.007	-0.159	-1204.

MANEUVER TAIL LOADS FAR 23.423 (A) MAX UP ELEVATOR= -653. LES MAX DOWN ELEVATOR= 603. LES

CHECKED MANEUVER TAIL LOADS

			FAE	23.423 (6)			
CUNCITION		VELOCITY	BTL	DELTA	Z-LCAC			<u>CHKD=#4N</u>
		100004.44	TATE LOAD		FACTOR	РТН	ACC	TAIL LOAD
		(MPH)	(LBS)	(LBS)	(6'5)	(RPS	8)	(1985)
1-MILSE	ц₽	128.4	-442.9	-482.4	1.000	3.0	<i>•</i>	-425.4
C=NOSE	UP	151.2	-517.5	-409.8	1.000	1	ί,	
D-NOSE	UP	235.0	-910.6	-263.7	1.000	1.6	n7	-11/4.3
	00.01	1 29 1	-832 4	482.4	3.800	-3.(16	-349.9
A-NUSE		120.4		409 8	3. 600	-2.6	50	-575.8
C-NOSE	00 * N	151.2	-9×3.3	903.0	3 900	- 1 6	.7	-1174.1
D-NOSE	COwN	235.0	+1437.7	203.1	3.000			

GUST TALL LOADS

		FAR 23.425		
OCHEVE THON	VELOCITY	BALANCE	DELTA TALL	TCTAL GUST
COMPTIAN	10001-1	TAIL LOAD	LOAD	TALL LOAD.
	CAPHY	(LBS)	(LBS)	(LBS)
r	151 2	-517.55	396.5	-121.0
	235 0	-910.63	308.2	-602.5
ELP-DWN	125.0	-890.27	163.9	-726.4
C	151.2	-517.55	396.5	-914.1
	235 0	-910.63	308.2	-1218.8
FLP-DWN	125.0	-890.27	163.9	-1054.2

L

PIPEP AIRCHAFT CORP VERG BEACH ENGINEERING

DATE 8-0CT-87

PAGE NI 62-15 PEPT N VB-1337 MODEL NI PA**B2-300**

FATIGUE LOADS (PIPELINE USFAGE) - 2541 LFS AT .003 MC

GROSS WEIGHT= 2541.0 LBS V=151.2 MPH NZ= 1.000 NX= 0.007

AIRLOAD LIMIT SHEAR AND MOMENT

STA.	٧Z	MXX	VX	MZZ	TORGUE
(1NS)	(LBS)	(IN-LA)	(Les)	(IN-L8)	(IN-GR)
194.53	0.0	0.	0.0	0.	0.
181.35	24.9	164.	1.7	11.	-764
172,05	64.8	582.	3.5	35	-1784.
160.0ŭ	127.5	1741.	5.6	89	-3118.
147.70	200.4	3757.	7.7	171.	-4490
137.00	270.1	6274.	9.3	262.	-5691
125.45	350.6	9859.	11.1	380.	-6993.
116.00	420.2	13501.	12.4	491.	-8063.
106.19	495.7	17993,	13.8	620.	-9178.
96.00	577.6	23462.	15.3	768.	-10339.
86.03	660.9	29636.	16.7	928.	-11479.
75.00	756.9	37456.	18.2	1120.	-12745.
69.24	808.6	41964.	19.0	1227.	-13408.
49.25	991.4	59955.	22.0	1636.	-15712.
36.22	1115.1	73679.	24.6	1940.	-17095.
21.88	1261.9	90722.	28.1	2318.	-18298.
0.00	1493.4	120865.	32.7	2983.	-20281.
-3.49	1529.7	126140.	33.2	3098.	-20677.

.



PIPER AIRCRAFT CORP VERD BFACH ENGINEERING PAGE 10 G2-16 REFT 4 VB-1337 MODEL 41 PA 32-300

DATE 8-0CT-87

)

FATIGUE LOADS (PIPELINE USEAGE) - 2541 TES AT .003 U.C.

GROSS WEIGHT= 2541.0 LBS V=151.2 MPH NZ= 3.800 NX=-0. //8

ALRECAD LIMIT SHEAR AND MOMENT

STA.	V Z	MXX	V X	M Z Z	TOPOUE
(INS)	(LHS)	(IN-LE)	(LES)	(1 m - [H)	(1)-15)
194.53	0.0	0.	0.0	Ο.	() .
181.35	103.8	684.	-6.6	-44.	-855.
172.05	267.0	2411.	-19.5	-165.	-2019.
160.00	518.5	7147.	-43.7	-544.	-3572.
147.70	803.1	15275.	-74.6	-1273.	-5191.
137.00	1068.7	25289.	-105.5	-2236.	-6n14.
125.45	1369.4	39369.	-142.0	-3666.	-Ĥ177.
116.00	1624.3	53514.	-173.9	-5158.	-9462.
106.19	1896.4	70783.	-208.6	-7035.	-10805.
96.00	2180.1	91583.	-246.2	-9352.	-12208.
86.03	2476.3	114825.	-284.3	-11996.	-13589.
75.00	2804.5	143949.	-328.3	-15374.	-15125.
69.24	2978.7	160605.	-352.0	-17333.	-15930.
49.25	3586.2	226221.	-431.8	-25167.	-18728.
36.22	3990.7	275584.	-481.1	-31115.	-19885.
21 88	4465.2	336212.	-536.7	-38413.	-14481.
0 00	5205.5	442009.	-627.8	-51151.	-19672.
-3 44	5320.9	460377.	-642.8	-53364.	-20116.

PIPEP AIRCRAFT CORE VERU BEACH ENGINEERING

PAGE NO G2-17 REPT NO VB-1337 MODFI, NO PA32-300

DATE 2-0CT-87

** V-N DIAGRAM **

NORMAL CATEGORY GROSS WEIGHT= 2840. LBS NORMAL USEAGE								
CONCITION	VELOCITY	MANEUVER	GUST					
	(MPH)	LOAD FACTOR (G'S)	LOAD FACTOP (g's)					
STALL	69.7	1.00						
Α	135,8	3.80						
С	151.2	3.80	3.28					
D	235.0	3.80	2.77					
Ε	235.0	0.00	-0.77					
F	151.2	-1.52	-1.28					
G	100.6	-1.52						
NEG STALL	81.6	-1.00						
	STADE C	1054 - EAUETODE						

FLAPS DOWN ENVELOPE

F-D STALL	58.6	1.0	
v ۳	125.0	2.00	1.94
VF	125.0	2.00	0.06

NOTE 1) FAR REFERENCES ON PAGE

- 2) AERODYNAMIC COEFFICIENTS PRESENTED ON PAGE
- 3) AIRCRAFT GEOMETRY PRESENTED ON PAGE
- 4) VALUES PRESENTED ARE EITHER FAA MINIMUMS OR PIPER AIPCRAFT POLICY
- 5) INCLUDES THRU AMENDMENT 6

FIPER AIRCHAFT CORP VERO BEACH ENGINEERING

~

PAGE NO 62-18 REPT NO VB-1337 MODEL NO PA32-300

DATE 2-0CT-87

GROSS WEIGHT= 2840. LBS C.G.=0.0400 MAC (INCLUDES THRU AMENDMENT 6) NOTMAL USERS RALANCE TAIL LOADS FAR 23.421

COND	VEL	CMEN	WIN	G PROPE	ERTLES	L	DAD FAC	rgrs		
			CN	CL	CMW	ΝX	NZ	N Z - W	THP	RTU
	(MPH)	(DLS)	(DLS)	(DLS)) (ELS)	(G'S)	(G'S)	(G'S)	(618)	(LRS)
A	136.	0.038	1.408	1.481	-0.065	-1.254	3,800	4.078	-0.248	-790.
С	151.	0.021	1.147	1.172	-0.065	-0.818	3.800	4.120	-0.223	-910,
Ð	235.	-0.004	().494	0.495	-0.065	-0.161	3.800	4.289	-0.143	-1387.
E	235.	-0.021	-0.065	-0.065	-0.065	0.082	-0,771	-0.568	-0.143	-576.
F	151.	-0.032	-0.420	-0.422	-0.065	-0.149	-1.520	-1.511	-0.223	-27.
G	101.	-0.051	-0.985	-1.014	-0.065	-0.381	-1.520	-1.567	-0,335	134.
1G-A	136.	-0.007	0.400	0.400	-0.065	-0.020	1.000	1.159	-0.248	-453.
16-C	151.	-0,009	0.328	0.328	-0.065	-0.001	1.000	1.178	-0.223	-505.
1G-D	235.	-0.014	0.152	0.152	-0.065	0.065	1.000	1.317	-0.143	-899.
FD	125.	0.017	0.964	0.964	-0.266	-0.102	2.000	2,367	-0.269-	-1042.
2/34	136_	0.011	0.958	0.969	-0.065	-0.385	2.533	2.776	-0,248	-689.
2/30	151.	0.005	0.779	0.783	-0.065	-0.268	2.533	2.799	-0.223	-756.
2/30	235.	-0.009	0.339	0.339	-0.065	-0.011	2.533	2.946	-0.143	-1172.

MANEUVER TAIL LOADS FAR 23,423 (A) MAX UP ELEVATOR= -730. LBS MAX DOWN ELEVATOR= 763. LBS

CHECKED MANEUVER TAIL LOADS

			F A K	23.423 (H J		
CONDI	TTON	VELOCITY	BTL	CELTA	Z-LOAD		CHKC-MAN
COND.			Т	ATL LOAD	FACTOR	PTH P	CC TAIL LUAD
		(MPH)	(LBS)	(LBS)	(G'S)	(RPSS	i) (LRS)
A-NOSE	UP	135.8	-452.7	-510.0	1.000	2.90	-962.7
C-NOSE	UP	151.2	-505.1	-458.0	1.000	2,60	-963.1
D-NOSE	UP	235.0	-898.9	-294.7	1.000	1.67	-1143.6
A⊷NDSF	DOWN	135.8	-789.5	510.0	3.800	-2.90	-279.5
C-NOSE	DOWN	151.2	-909.9	458.0	3,800	-2,60	-451.4
D-NOSE	DUWN	235.0	-1387.4	294.7	3.800	-1.67	-1092.7

GUST TAIL LUADS FAR 23.425

CONDITION	VELOCITY	BALANCE	DELTA TAIL	TCTAL CUST
•		TAIL LOAD	LGAD	TAIL LOAD
	(MPH)	(LPS)	(LAS)	(LHS)
С	151.2	∞505.07	406.2	-98.9
D	235.0	-898.89	315.7	-583.2
FLP-DWN	125.0	-877.99	167.9	-710.1
С	151.2	-505.07	406.2	-911.3
D	235.0	-698,89	315.7	-1214.5
FL,P=DWN	125.0	-877.99	167.9	-1045.9



PIPER AIPCRAFT CORP VERO BEACH ENGINEERING

PAGE NE 62-19 REPT NE VB-1337 MUCEL NU PA 52-300

DATE 8-0CT-87

FATIGUE LOADS (NORMAL USEAGE) - 2840 LHS AT .04MAC

GROSS WEIGHT= 2840.0 LBS V=151.2 MPH NZ= 1.000 NX=-0.001

AIRLOAD LINIT SHEAP AND MONENT

STA.	VZ	мХХ	V X	M Z Z.	TOROUE
(INS)	(L8S)	(IN-1.P)	(LBS)	(IN-LB)	(IN-6B)
194.53	0.0	Ο.	0.0	0.	Ο.
181.35	27.9	184.	1.6	11.	-767.
172.05	72.4	650.	3.3	.33.	-1792.
160.00	142.1	1942.	5.2	85.	-3135.
147.70	223.0	4188.	6.9	159.	-4516.
137.00	300.0	6986.	8.3	241.	-5725.
125.45	388.9	10964.	9.6	344.	-7037.
115.00	465.4	15001.	10.6	440	-8115.
106.19	548.4	19974.	11.6	545.	-9238.
96.00	638.1	26019.	12.6	672.	-10406.
86.03	729.3	32836.	13.6	803.	-11558.
75.00	834.1	41458.	14.6	958.	-12833.
69.24	890.4	46424.	15.1	1043.	-13501.
49.25	1089.2	66211.	17.2	1365.	-15824.
36.22	1223.6	81279.	19.2	1602.	-17198.
21.88	1382.8	99966.	22.0	1898.	-18342.
0.00	1633.5	132963.	25.5	2418.	-20258.
-3.49	1672.8	138733.	25.9	2508.	-20656.



PIPER AIRCRAFT CURP VERO BEACH ENGINEERING FAGE NO 62-20 REPT NO VB-1337 MODED NO PA**32-300**

DATE 8-0CT-87

EALIGUE LOADS (NORMAL USFACE) - 2840 LES AT .04MAC

GROSS WEIGHT= 2840.0 LBS V=151.2 MPH NZ= 3.800 NX=-0.818

AIRLOAD LIMIT SHEAR AND MOMENT

STA.	VZ.	MXX	VX	M Z Z	TOROUF
(INS)	(L8S)	(IN-LF)	(LPS)	(IN-LB)	(IN-1,K)
194.53	0.0	0.	0.0	0.	0.
181.35	115.1	758.	-10.2	-67.	-864.
172.05	296.4	2672.	-29.2	- 251.	-2054.
160.00	573.8	7915.	-63.7	-810.	-3634.
147.70	888.0	16905.	-106.9	-1859.	-5243.
137.00	1180.8	27973.	-149.7	-3232.	~ 6754.
125.45	1512.1	43525.	-199.9	-5251.	-8350.
116.00	1792.5	59139.	-243.5	-7346.	-9666 ·
106.19	2091.8	78192.	-290.6	-9966.	-11042.
46.00	2410.4	101131.	-341.0	-13184.	-124R0.
86.03	2729.4	126753.	-391.3	-16834.	-13895.
75.00	3090.1	158847.	-448.5	-21466.	-15470.
69.24	3281.4	177197.	-478.9	-24137.	-1:2.6.
49.25	3948.6	249461.	-581.3	-30752.	-191mm_
36 22	4392.6	303804.	-646.0	-42730.	-20290.
31 44	4913 0	370524.	-720.2	-52526.	-19652.
0.00	5724.1	486894	-841.6	-64612.	-19582.
-3.49	5850.4	507091.	-861.9	-72584.	-20033.


W.S. 20.301

of 1st Bolt Lwr. Cap) (

1	2	3	4	5	6	7
Elem	b	t	A=b.t	Z	AZ	AZ ²
1 2 3 4 5 6 7 8 9 10 11 12 Upr Aft Bolt Hole Upr Fwd Bolt	1.200 1.200 1.250 1.200 1.485 1.485 1.199 1.485 1.199 2.800 .975	.389 (Avg) .275 .102 .091 .091 .091 .091 .091 .091 .091 .275 .102	.4668 .3300 .1275 .1080 .1351 .1351 .1079 .1351 .1079 .6875 .0995	9.076 9.133 8.645 8.950 8.1385 8.1385 .320 1.1075 1.1075 .320 .138 .488	4.2367 3.0139 1.1022 .9666 1.0998 1.0998 .0345 .1496 .1496 .0345 .0949 .0486	38.452 27.526 9.529 8.651 8.9507 8.9507 .011 .1657 .011 .013 .024
Hole Lwr Aft Bolt Hole	.377	.365	1376	.183	025	005
Lwr Fwd Bolt	.377	.365	1376 2.3003	.183	025 11.9807	005 102.4398

Hole

Z

= 11.9807/2.30035.208 in = IOXX

 $= 102.4398-5,200^{2}(2.3008)$ = 40.041 in⁶ С <u>С</u> І 5.208 in .1301 in² = =



U2 トット

Report VB-133 Page G2-22



Report VB-1337 Page G2-23

$$\mathbf{G} = \frac{Mc}{I}$$
, $M = Net Bending Moment$

Usage	1g o~	₫/g	lg 0 -	07g	
Normal	8320	8469	9253	8819	
Pipeline	7689	7816	9106	8710	



A



Report VB-1337 Page S2+24

Taxi and Landing Impact

(in A

Wing Inertia (lg)

PA-28-181	BM	H	10820
PA-32-300	BM	=	11447

<u>Fuel Inertia (lg)</u>

j	PA-28-	-181	Bending	Moment					
	Norma	11	Pipeline						
T.0	Э.	Ldg	T.O.	Ldg					
110	99	3436	6490	4199					
I	PA-32-	300	Bending	Moment					
	Norma	1	Pipeli	ne					
т.С).	Ldg	т.о.	Ldg					
1006	C 7	5725	22020	10052					



Report VB-1337 Page G2-25

Airload - Bending Moment

	<u>Taxi (30 kts</u>	5)	Landing Impact (2/39)
PA-28-181			
Normal	25,777		54,198
Pipeline	26,265		50,742
PA-32-300			
Normal	24,591		68,435
Pipeline	24,949		60,891
	Main La	nding Gear	Load (lg)
	Taxi T.O.	Ldg	Landing Impact
PA-28-181			
Normal	898	886	358
Pipeline	867	830	331
PA-32-300			
Normal	969	949	469
Pipeline	857	794	411

. . . .

)

Report VB-1337 Page G2-26

Taxi Stresses (PSI)

PA-28-181

PA-32-300

Usage	lg 6 and 6 /g	lg or and σ/g
Normal T.O.	4982	3225
Normal Ldg	5033	3318
Pipeline T.O.	4623	2308
Pipeline Ldg	4774	2574





Landing Impact Stresses (PSI)

PA-28-181

PA-32-300

Usage	1g (0 7g	190	G/g
Normal	6624	2429	7108	1829
Pipeline	5969	2010	5722	1076

G3 STRESS CONCENTRATION



pg. 92 Fig 76 From "Stress Concentration Design Factors" by R.E.

b = .88 + .375 = 1.26a = .375 b/a = $\frac{1.26}{.375}$ = 3.86

 $K_{\rm T}$ = 3.02 AT A

pg 86 Fig 71

 $\begin{array}{rcl} r &=& .375/2 &=& .1875 & e &=& 1.9125 \\ c &=& .40 &+& .375/2 &=& .5875 \\ r/c &=& .1875 &=& .319 & e/c &=& \underline{1.9125} &=& 3.26 \\ \hline & .5875 & & & .5875 \end{array}$

 $K_T = 2.32 \text{ AT } B$



.....

a salating a salating salating

14.11

. (

The actual fatigue crack started outside of the bolt hole due to fretting. The fretting stress concentration is therefore higher than the K_T =3.02 for the bolt hole. Therefore the fatigue analysis will be conducted using a K_T =3 for lower bound and a K_T =4 for the upper bound.

Report VB-1337 Page G4-1

 \sim

G4 FATIGUE SPECTRUM

The taxi and landing impact spectra were obtained from reference 1. The gust and maneuver spectra for normal was also obtained from reference 1. The gust and maneuver spectra for pipeline patrol were obtained using the outer bounding (lightest loads) data prints from figures 6 and 7 of reference 2. The reference 2 data is a draft report containing old and recently reduced NASA VG/VGH data.

The acceleration fraction (An/An_{LLF}) shown on the gust and maneuver exceedance curves is the ratio of incremental load factor at operating weight to the incremental load factor at maximum gross weight.

The ground-air-ground (GAG) cycle is defined as the cycle from the minimum (largest negative or smallest positive) stress to the maximum stress experienced on the average of once per flight. This definition of GAG cycle is from reference 1.

. . . .

Beport VB-1337 ge G4-2

Appendix



~15

Appendix

-28-

Repor

VB-1337 ge G4-3

MANEUVERS



 $\nabla I'$







Appendix

.

-`

-32-



-

` ^



C



G5 FATIGUE ANALYSIS

gage at the

• • • · · ·

The purpose of the fatigue analyses is to provide the safe life relationship of normal environment to pipeline patrol.

Fatigue analyses were conducted for normal, and pipeline patrol environment for stress concentrations of $K_T=3$ and 4. The analyses were performed for the PA-28-181 and PA-32-300 aircraft. The PA-32-300 represent the highest stressed aircraft with the same main spar and spar attachment.

The S-N data used was obtained from constant-life diagrams in Mil Hnd bk 5. The following pages show the constant-life diagrams for 2024-T3 K_T =2 and 4 plus the derived S-N curves for a K_T =3 and 4.



)

-

C13.44

55-



Fig. C13.A3 - Typical Constant-life diagram for notched fatigue behavior of 2024-T3 aluminum alloy.



ND. 340R-LSTO DIETZGEN GRAPH PAPER SEMI-LOGARITHMIC S CYCLES X TO DIVISIONS PER INCH





				<u>~000 / 10 10 4 00 (</u>	5
			4		
		2024			
25	nen en sen e En sen en sen En sen en sen				
20					
╴┑╌╸╏╴┊┍┱╕╄╌┡╻╌╏┱╪┇┽╕ _┍ ┆╺┱╴╴╴╴╴╴ ┟╺╼╴╴╴╴					
15					
					P Re a
					Je C
5					A Ceo Dar 55
				· · · · · · · · · · · · · · · · · · ·	
					3 3 3 3 3 3 3 3 3 3
103		/05		······································	



The maximum taxi load factor once per 10000 landings is $1 \pm .6$ g's. The highest taxi stresses, regardless of aircraft type or environment, are for the PA-28-181 normal environment after landing.

lg $\mathbf{\sigma} = 5033$ psi $\mathbf{\sigma}/g = 5033$ psi The once per 10000 landing stresses are: (1.6g) $\mathbf{\sigma}_{max} = 8053$, (1g) $\mathbf{\sigma}_{m} = 5033$ (.4g) $\mathbf{\sigma}_{min} = 2013$, $\mathbf{\sigma}_{a} = 3020$

Using the S-N curves previously provided the stress levels are below the endurance limit. Therefore neither the PA-28-181 or PA-32-300 accumulate fatigue damage due to taxi.

The PA-28-181 level landing design limit load factors and sink speed are as shown:

 $V_Z = 8.62 \text{ fps} ; N_Z \text{ max} = 3.64 ; N_Z \text{ min} = 1.0$ (Reference VB-703 Pg IX7, VB-396 Pg IX-13)

The design limit sink speed is in excess of the $V_Z=7.0$ fps sink speed representing the once per 10,000 landing for a single engine executive aircraft. Using the highest PA-28-181 landing impact stress configuration lg $\sigma = 6624$ psi and $\sigma/g = 2429$, the following are the maximum, mean, minimum and alternating stress for a design limit condition:

 $\sigma_{max} = 13037$, $\sigma_{M} = 9830$, $\sigma_{min} = 6624$, $\sigma_{a} = 3207$

Using the S-N data, the design limit stress level is below the endurance limit. Therefore the PA-28-181 does not accumulate fatigue damage done to landing impact.

The PA-32-300 level landing design limit load factors and sink speed are as shown:

 $V_Z = 9.22 \text{ fps} ; N_Z mex = 3.22 ; N_Z men = .96$

(Reference VB-33 Pg IX-13)

The design limit sink speed is in excess of the $V_Z = 7.0$ fps sink speed representing the once per 10,000 landings for a single engine executive aircraft. Using the highest PA-32-300 landing impact stress configuration, lg $\sigma = 7108$ psi and $\sigma/g = 1829$ psi, the following are the maximum, mean, minimum and alternating stress for a design limit condition:

 σ_{max} =11168, σ_{m} =9102, σ_{min} =7035, σ_{a} =2067 Using the S-N data, the design limit stress level is below the endurance limit. Therefore the PA-32-300 does not accumulate fatigue damage due to landing impact₂,

The following is the fatigue maneuver and gust damage per hour detail calculations for the PA-28-181 and PA-32-300 at K_T =3.0 and 4.0 and for the pipeline and normal missions. The mean stress used for gust was the 1g flight stress. The mean stress used for maneuver on the normal mission was the 1.2g flight stress and 1.1g for the pipeline mission.

MEDEL 181 PIPELINE MAN. FATIBLE DAMAGE BRDSS WT=2033 VD=127K NOTE 51=7669 +1.1 ANILLE=3.4. -2.76 STRESS/G =7616 KT=3.Q ANJANLLE DERDING FROZING VC+. 9+ F/N DB(-) DS(+) = DS(+,-) = SMSA YI/N 1.0E-01 5.5E-01 -4-08-08 1.3E-01 3. 0E-01 3. 4E+01 1. 1E-01 4. 4E-01 2. BE-01 8. 5E+03 2. 2E+03 1.6E-01 2.5E-01 -1.3E-01 1.9E-01 9. RE-DE 1. RE+RI 3. EE-RI 5. SE-RI 5. RE-RI 8. SE+R3 3. 9E+R3 2.2E-01 1.6E-01 -1.92-01 2.52-01 B. 0E-02 9. 1E+00 5. EE-01 B. 5E-01 6. 9E-01 B. 5E+02 5. 4E+02 2.8E-01 6.0E-02 -E.12-01 E.1E-01 5.00-02 5.70+00 5.80-01 1.10+00 8.00-01 8.50+03 6.40+02 3.4E-01 3.0E-02 -2.5E-01 3.7E-01 1.8E-02 2.1E+00 6.5E-01 1.3E+00 9.7E-01 8.5E+03 7.6E+03 2.5E+06 8.2E-07 4.0E-01 1.2E-02 7.0E-03 8.0E-01 8.8E-01 1.5E+00 1.2E+00 8.5E+03 9.2E+03 4.0E+05 2.0E-06 -3.28-01 4.38-01 4.6E-01 5.0E-03 -3.5E-01 4.3E-01 3.22-03 3.7E-01 9.7C-01 1.7E+00 1.3E+00 B.5E+03 1.0E+04 1.8E+05 2.0E-06 5.2E-01 1.8E-03 1,1E-03 1,3E-01 1,0E+00 1,9E+00 1,4E+00 B.5E+03 1,1E+04 1.2E+05 1.0E-06 -3.76-01 5.56-01 5.8E-01 7.0E-04 -4.12-01 6.12-01 4.5E-04 5.1E-08 1.1E+00 2.1E+00 1.6E+00 B.5E+03 1.3E+04 7.0E+04 7.3E-07 6.40-01 8.50-04 1,5E-04 1.7E-02 1.2E+00 2.3E+00 1.8E+00 B.5E+02 1.4E+04 5.0E+04 3.4E-07 -4.5E-01 5.7E-01 7. RE-R1 1. RE-04 5, 0E-05 5, 7E-03 1, 4E+00 2, 5E+00 1, 9E+00 B, 5E+03 1, 5E+04 3, 7E+04 1, 5E-07 -5.16-01 7.36-01 and the second s 7.5E-01 5.0E-05 2.9E-05 3.3E-03 1.5E+00 2.7E+00 2.1E+00 8.5E+03 1.6E+04 3.0E+03 1.1E-06 -5.6E-01 7.8E-01 8.1E-01 2.1E-05 -E. QE-01 B. 4E-01 1.1E-05 1.3E-03 1.7E+00 2.9E+00 2.3E+00 B.3E+03 1.8E+04 2.4E+04 5.4E-08 8.7E-01 1.0E-05

:

• 1

DAMAGE= 8.3E-06

and a star war war die star war in 1995 war die star war die star war in the star war in the star the star star The start start war in the start start war in the start war in the start start war in the start start start star

an weight i feer in ann

Report VB-133 Page G5-7

PIPELINE GUST FATIGLE DAMAGE GROSS WT. #2033 VC=127K NOTS MODEL 181 147=3.0 ANLLF -- +2.71 STRESS/G=7816 EM=7689 51 n/N 59 DB (+, -) 5M ANVANILLE ANVANILLE DEROVING FROMING VC+. 9+F/N DB(-) DG (+) 1.0E-01 4.0E+00 2.0E+00 2.3E+02 3.5E-01 3.5E-01 3.5E-01 7.7E+03 2.8E+03 R. RE+RR 1.3E-01 1. 6E-01 2. 0E+00 1. 2E+00 1.4E+02 5.1E-01 5.1E-01 5.1E-01 7.7E+03 4.0E+03 0.0E+00 1.9E-01 2.2E-01 8.0E-01 5. 0E-01 5. 7E+01 6. BE-01 6. BE-01 6. BE-01 7. 7E+03 5. 3E+03 9.0E+00 2.5E-01 2.8E-01 3.0E-01 2. 0E-01 2. 3E+01 8. 4E-01 8. 4E-01 8. 4E-01 7. 7E+03 6. 6E+03 2. QE+22 3. 1E-01 B-2E-02 5.4E+00 1.0E+00 1.0E+00 1.0E+00 7.7E+03 7.8E+03 2.5E+06 3.7E-06 1-0E-01 3. 4E-R1 0. 0E+00 3. 7E-01 1.1E-02 1.3E+00 1.2E+00 1.2E+00 1.2E+00 7.7E+03 9.1E+03 4.3E+05 2.9E-06 4. 0E-01 1. BE-02 6. 2E+08 4. 3E-01 4. RE-R3 4. EE-R1 1. 3E+RR 1. 3E+RR 1. 3E+RR 7. 7E+R3 1. RE+R4 2. 3E+R5 2. RE-RE 4.6E-01 7.0E-03 0. 0E+00 4. 9E-01 3. ØE-Ø3 1.4E-03 1.6E-01 1.5E+00 1.5E+00 1.5E+00 7.7E+03 1.2E+04 9.8E+04 1.6E-06 5, 26-01 · · · 0.0E+00 5.5E-01 B. RE-RA 9.1E-RE 1.7E+RR 1.7E+RR 1.7E+RR 7.7E+R3 1.3E+R4 6.6E+R4 1.4E-R6 5, BE-01 1. EETING 0. 0E+00 E. 1E-01 6.4E-01 8.0E-04 " 4. QE-Q4 4. EE-Q2 1. BE+QQ 1. BE+QQ 1. BE+QQ 7. 7E+Q3 1. 4E+Q4 4. BE+Q4 5. SE-Q7 0.0E+00 5.7E-01 7.0E-01 4.0E-04 1.2E-04 1.4E-02 2.0E+00 2.0E+00 2.0E+00 7.7E+03 1.5E+04 3.5E+04 3.5E-07 0.0E+00 7.3E-01 7.5E-01 2.8E-04 1.3E-04 1.5E-02 2.1E+00 2.1E+00 2.1E+00 7.7E+03 1.7E+04 3.0E+04 5.0E-07 0.0E+00 7.8E-01 6. 0E-05 6. 9E-03 2. 3E+00 2. 3E+00 2. 3E+00 7. 7E+03 1. BE+04 2. 4E+04 2. 4E+04 2. 9E-07 8.1E-01 1.5E-04 0. 0E+00 B. 4E-01 3. RE-05 3. 4E-03 2. 4E+08 2. 4E+08 2. 4E+08 7. 7E+03 1. 9E+04 1. 9E+04 1. 9E-07 8.7E-01 9.0E-05 Q. QE+QQ 9. QE-Q1 2. RE-05 2. 3E-03 2. 6E+08 2. 6E+08 2. 6E+08 7. 7E+03 2. RE+04 1. 5E+04 1. 6E-07 9.3E-01 6.0E-05 0.0E+00 9.EE-01 مريحيها والمريحية والمريح والمرجوع ومريح ومريح والمريح والمريح والمريح والمريح والمريح والمريح والمريح والمريح 9.9E-01 4.0E-05 Long to searce TAMAGE -1-4E-05

65-8

μü

~_____

and a set of the second se

.....

.

MODEL	161	NORMAL	MAN. FAT	IGUE DAMA	6E	GROSS WT	=2163	VC=127KN	ots			
		SM=1.2*8	320	STRESS/6	=8464	Kr~3.#	ANLL	F=2.8,-2.5	i			
AN/AML	LF	AN/ANLLF	CFR0./NM	FRGINM	VC#. 9*F/N	DG(-)	DG (+)	DG(+,-)	SM	5A	N	n/N
		1. 0E-01	2.2E-82									
0. 0E+	20	1.3E-01		1.3E-02	1,56+00	r. RE+00	3. EE-01	1,8E-Ø1	1.0E+04	1.5E+03		
		1. EE-01	9. 0E-03							•		
-6. ØE-	Ø.E	1.9E-01		5.5E-03	e. 3e-01	1.5E-01	5.3E-01	3.4E-Ø1	1.0E+04	2.9E+03		
		5° 55-07	3.5E-03					-	:			
-1.2E-	15	e. 5e-01		2.0e-03	2.3E-01	3. Qe-01	7. 0E-01	5. QE-Q1	1.0E+04	4.2E+03		
		2. BE-01	1.5E-03									
-1.7E-	e to	3. 1E-01		B. 5E-04	9,7E-02	4.3E-01	8.7E-01	6. 5e-01	1. QE+Q4	5. 5E+03		
		3. 4E-01	6.5E-03									
-2.2E-	£19	3.7E-01		3.5E-04	4. QE-02	5.5E-01	1.0E+00	B. QE-Q1	1. QE+Q4	e- 7e+03	1.5E+07	2.7E-09
		4. 0E-03	3. ØE-Ø4			•						
-2.6E-	81	4.3E-01		1.EE-04	1.6E-08	e. ee-01	1.2E+00	9. 2e-01	1.0E+04	7.9E+03	1.0E+06	1.8E-08
		4. EE-01	1.4E-04							-		
-3. 1E-	21	4.9E-01		7.0E-05	B. QE-Q3	7.8E-01	1.4E+00	1.1E+00	1. QE+Q4	9.1E+03	4.5E+05	1.8E-08
		5. 2E-01	7.0E-05									
-3. SE-	R 1	5. 5E-01		4.0E-05	4.6E-03	8.8E-01	1.5E+00	1.2E+00	1. @E+04	1. 0E+04	1-5E+05	3.28-08
		5. BE-01	3.0E-05								ورام معرو من	
-3.9E-	15	e. 1e-01		1.58-05	1.7E-03	9. BE-01	1.7E+00	1.3E+00	1.842+614	1,15+64	H. 42+04	5. WE-WB
		6. 4E-01	1.5E-05							4		
-4.3E-	-101	E. 7E-01	•	8. ØE-ØE	9.0E-04	1.1E+00	1.96+00	1.28+444	1.805+904	1.25+04	5.76+04	1.65-08
		7. 9E-01	7.0E-06				a	1 55 .00	1 05 .04	1 15.01	6 05 04	7 15 05
-4.7E-	-@1	7. 3E-01		3. ae-ae	3.0E-04	1.26+08	E. RE+MO	7. EF+8060	1 - Kitz + Ki4	1.46+04	4. <u>1</u> 2+84	1-76-103
		7.5E-01	4. RE-RE	•								

. ...it.

.

. .

٠

· · :

- -

DAMAGE= 1,1E-07

Å,

Report VB-1337 Page G5-9

a second a second s

.. ..

1.

÷

	NORMAL GL	ST FATIS	LE DAMAGE	GROSS WT.	=2163	VC=127K	NOTE			
SINESSIS	*8464	K1=3, K	HNLLF=-	g → <i>E</i> = ≤ /						
AN./ANLLF	CFRG/NM	FR0/NM	VC*, 9*F./N	DG(-)	DG (+)	DG(+,-)	SM	SA	N	n/N
1-8E-61	1.0E+00									
1:3E-01		B. 3E-01	9, 5E+@1	2. 1e-01	3.1E-Ø1	3. 1E-01	8.3E+03	2. EE+03		
1. EE-01	1.7E-@1							•		
1.9601		1.3E-01	1.4E+@1	4.5E-01	4. 5E-01	4. 5E- 01	8. 3E+03	3. BE+03		
2.2E-01	4.5E-02					•				
2.5E-01		3. 5E-02	4. 8E+88	5. 9E-01	5.9E-01	5. 9E-01	8.3E+@3	5. 0E+03		
2. BE-01	1. 8E-82									
3-1E-01		6. 5E-03	7,4E01	7.3E-01	7. 3E-01	7. 3E01	B. 3E+03	6. 2F+03		
3.45-01	3.55-03									
3.75-01		8.45-03	2.7F-01	8. 8E-01	B. BE-01	A. AF-AL	A. 35+03	7 46402	1 05-07	S 75-00
4 0E-01	1 15-02		2372 23					2 2 - C · E C	A # 1055 T 161 J	E./2-00
4 2E-01		6 75-04	7 75-00	1 05+00	1 05+00	1 05-00	B 25107	8 66×07	7 75+35	0 05 00
4.00-01	1 30 AL	54 / E ~ W 7	1772-02	2 2 K.W. 1 K.W.			6. 19 19 19 19 19 19 19 19 19 19 19 19 19	DA DE TRES	1272400	2.36-08
4.65-41	4. SE84	0 A.C. 04	0 75 00	1 05+00	+	1 25.00	6 35407	0 05-07	O FELDE	1 15 27
4.95-01		E. 41-414	E. /E-WE	7. CE - 44	7. 55-44	7. 55+8K	8.36483	2.06+83	5. DE+8D	1. 1E-W/
5.2E-01	1.95-64									
5. 5E-01		1.1E-04	1. 2E-66	7	1. 38+600	1.35+000	8.3E+Ø3	1.16+04	1.46+000	a. 56-08
5.8E-03	8.5E-05									
6- 1E-01		4.5E-05	5,1E-Ø3	1.48+00	1.4E+210	1.4E+00	B. 36+03	1.2E+04	B. ØE+04	6.4E-08
6. 4E-01	4. RE-R 5									
e. 7e-01	20	2.0E-05	2.2E-03	1.65+00	1. EE+00	1.66+00	8.3E+03	1.3E+04	5.7E+04	4. Re-08
7. @E-@1	2.0E-05				•					
7.3E-01	· •	9. ØE- ØE	1.0E-03	1.7E+00	1.75+00	1.7E+00	B. 3E+03	1-5E+04	4.2E+Ø4	2.4E-08
7.5E-01	1.1E-05									
7. BE-01		5. 9E-06	5. 7E-04	1. BE+00	1. BE+00	1.8E+00	8. 3E+Ø3	1.6E+04	3.5E+04	1.98-08
8. 1E-81	5,1E-Ø6									
B- 4E-Q1		2.5E-06	2.9E-04	e. Re+rr	e. Re+rr	1.9E+00	B. 3E+03	1.EE+04	2.8E+Ø4	1.0E-08
8.7E-01	- 2 .6 E- 0 6	Sec. 2	Sector of the	1.1 . 		- - 1				
	$ \begin{array}{c} \text{STRESAGE}_{1} \\ \text{STRESAGE}_{2} \\ \text{ANI/ANLLF}_{1} \\ \text{ANI/ANLF}_{2} \\ \text{ANI/ANLF}_{2}$	NBRMAL GI STRESS/B $=$ 8464 ANI/ANLLF CFRU/NM 1.0E-01 1.0E+00 1.3E-01 1.7E-01 1.9E-01 2.2E-01 2.2E-01 4.5E-02 2.5E-01 3.5E-02 3.1E-01 3.5E-03 3.7E-01 4.3E-04 4.6E-01 3.5E-03 4.6E-01 4.3E-04 5.2E-01 1.9E-04 5.2E-01 1.9E-04 5.2E-01 1.9E-04 5.2E-01 1.9E-04 5.8E-01 8.5E-05 6.1E-01 8.5E-05 7.0E-01 2.0E-05 7.3E-01 1.1E-05 7.3E-01 1.1E-05 7.6E-01 1.1E-05 7.6E-01 1.1E-05 7.6E-01 3.1E-06 8.4E-01 3.1E-06 8.4E-01 3.1E-06	NDRMAL GUST FATIS: STRESS/G = 8464 KT=3, α ANI/ANLLF CFR0/NM FR0/NM 1, α E- α 1 1, α E- α 1 8, 3 E- α 1 1, α E- α 1 1, α E- α 1 8, 3 E- α 1 1, α E- α 1 1, 7 E- α 1 1, 3 E- α 1 1, α E- α 1 1, 7 E- α 1 1, 3 E- α 1 2, 2 E- α 1 4, 5 E- α 2 3, 5 E- α 2 2, 2 E- α 1 4, 5 E- α 2 5, 5 E- α 1 2, 2 E- α 1 4, 5 E- α 2 5, 5 E- α 3 3, 7 E- α 1 6, 5 E- α 3 3, 7 E- α 1 6, 5 E- α 3 4, 4 E- α 1 3, 5 E- α 2 4, 3 E- α 1 5, 5 E- α 3 4, 3 E- α 1 6, 7 E- α 4 4, 6 E- α 1 4, 3 E- α 4 4, 6 E- α 1 5, 5 E- α 5 6, 1 E- α 1 1, 1 E- α 4 5, 5 E- α 1 1, 1 E- α 4 5, 5 E- α 1 1, 1 E- α 5 6, 1 E- α 1 2, α E- α 5 6, 1 E- α 1 5, 5 E- α 6 7, 5 E- α 1 1, 1 E- α 5 <t< td=""><td>NORMAL GUST FATIGUE DAMAGE STRESS/B $= 8464$ $KT=3.0$ ANLLF=- ANLANULF CFR0/NM FR0/NM VC*.9*F/N 1.0E=01 1.0E+00 1.2E=01 8.3E=01 9.5E+01 1.6E=01 1.7E=01 1.3E=01 1.6E+03 1.9E=01 1.3E=01 1.4E+03 2.2E=01 4.5E=02 3.5E=02 4.0E+00 2.2E=01 3.5E=02 4.0E+03 2.7E=01 2.2E=01 3.5E=02 7.4E=01 3.5E=02 3.1E=01 6.5E=03 7.4E=01 3.4E=01 3.4E=01 3.5E=03 2.7E=01 4.0E=03 4.0E=01 1.1E=03 4.7E=04 2.7E=01 4.6E=01 4.3E=04 5.7E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.3E=01 1.1E=05 7.3E=01 2.0E=05 5.1E=02 7.5E=01 1.1E=05 5.9E=06 5.7</td><td>NDRMAL GUST FATIGUE DAMAGE GROSS WT. STRESS/B =8464 KT=3, 0 ANLLF=-, +2, 37 ANLANLLF CFR0/NM FR0/NM VC*, 9*F/N DB(-) 1, 0E=01 1, 0E+00 8, 3E=01 9, 5E+01 2, 1E=01 1, 0E=01 1, 7E=01 1, 3E=01 1, 4E+01 4, 5E=01 1, 6E=01 1, 7E=01 1, 3E=01 1, 4E+03 4, 5E=01 2, 2E=01 4, 5E=02 3, 5E=02 4, 0E+00 5, 9E=01 2, 2E=01 4, 5E=02 3, 5E=02 7, 4E=01 7, 3E=01 2, 2E=01 1, 0E=02 3, 5E=02 7, 4E=01 7, 3E=01 2, 2E=01 1, 0E=02 3, 5E=03 2, 7E=01 8, 8E=01 3, 1E=01 6, 5E=03 7, 4E=01 7, 3E=01 4, 0E=01 1, 1E=03 2, 7E=02 1, 0E+00 4, 6E=01 4, 3E=04 2, 7E=02 1, 2E+00 5, 2E=01 1, 9E=04 1, 1E=04 1, 2E=02 1, 2E+00 5, 8E=01 8, 5E=05 5, 1E=03 1, 4E+00</td><td>NBRMAL GUST FATIGUE DAMAGE GROSS WT.=2163 STRESS/G =8464 KT=3.Q ANLLF=-, +2.37 GN/ANLLF CFR0/NM FR0/NM VC#.9#F/N DB(-) DB(+) 1.0E+01 1.0E+00 0.3E+01 2.1E+01 3.1E+01 1.2E+01 8.3E+01 9.5E+01 3.1E+01 3.1E+01 1.9E+01 1.7E+01 1.3E+01 4.5E+01 4.5E+01 2.2E+01 4.5E+02 3.5E+02 4.0E+04 5.9E+01 5.9E+01 2.2E+01 3.5E+02 4.0E+04 5.9E+01 5.9E+01 5.9E+01 2.2E+01 1.0E+02 3.5E+02 4.0E+04 5.9E+01 5.9E+01 3.5E+02 3.5E+02 7.4E+01 7.3E+01 7.3E+01 3.4E+01 2.5E+03 2.7E+04 7.7E+02 1.0E+00 1.0E+00 4.3E+01 6.7E+03 2.7E+04 1.2E+00 1.2E+00 1.2E+00 5.2E+01 1.9E+04 2.4E+04 2.7E+02 1.2E+00 1.2E+00 5.2E+01 1.9E+05 5.1E+03</td><td>NBRMAL GUET FATIGUE DAMAGE GROSS WT.=2163 VC=127K STRESE/G =8464 KT=2, Q ANLLF=-, +2, 37 GN/ANLLF CFR0/NM FR0/NM VC+.9+F/N DB(-) DB(+) DB(+, -) 1. QE-Q1 1. QE+QQ 1. QE+Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 4. SE-Q1 4. SE-Q1 4. SE-Q1 2. ZE-Q1 4. SE-Q2 3. SE-Q2 4. QE+QQ 5. 9E-Q1 5. 9E-Q1 5. 9E-Q1 2. AE-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 3. 4E-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 4. SE-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 4. SE-Q1 2. 4E-Q3 2. 7E-Q1 8. 8E-Q1 8. 8E-Q1 8. 8E-Q1</td><td>NORMAL GUST FATIGUE DAMAGE GROSS WT.=2163 VC=127KNOTS STRESS/S =8464 KT=2, 0 ANLLF=-, +2, 37 AN/ANLLF CFR0/NM FR0/NM VC*, 9*F/N DB(-) DB(+) DB(+,-) SM 1, 0E-01 1, 0E+00 1, 0E+01 8, 3E-01 9, 5E+01 2, 1E-01 2, 1E-01 3, 1E-01 8, 3E+03 1, 0E-01 1, 7E-01 1, 2E-01 1, 4E+00 5, 5E-01 3, 1E-01 8, 3E+03 2, 2E-01 3, 5E-02 4, 0E+00 5, 9E-01 5, 9E-01 5, 9E-01 8, 3E+03 2, 2E-01 3, 5E-02 7, 4E-01 7, 3E-01 7, 3E-01 8, 3E+03 2, 2E-01 3, 5E-02 7, 4E-01 7, 3E-01 7, 3E-01 8, 3E+03 3, 7E-01 2, 4E-03 2, 7E-01 8, 8E-01 8, 8E-01 8, 8E-01 8, 8E+03 4, 6E-01 3, 3E-04 2, 7E-04 1, 0E+00 1, 0E+00 8, 3E+03 5, 2E-01 1, 1E-04 2, 7E-02 1, 0E+00 1, 0E+00 8, 3E+03 5, 5E-01</td><td>Image: NBRMAL BUST FATIBLE DAMAGE GROSS WT.=2163 UC=127KNOTS STRESK/E RAK6 KT=2.Q ANL[F=-,+2.37 AN/ANLLF CFR0/NM FR0/NM UC*.9*F/N D6(-) D6(+.) D6(+,-) SM SA 1. QE-01 1. QE+01 0. SE+01 2. 1E-01 3. 1E-01 3. 1E-01 B. 3E+02 2. EE+03 1. QE-01 1. 7E-01 1. 2E-01 1. 4E+01 4. 5E-01 4. 5E-01 4. 5E-01 8. 3E+02 3. 4E+03 2. 2E+01 4. SE-02 3. 5E-02 4. 6E+00 5. 9E-01 5. SE-01 8. 3E+02 5. GE+03 3. 1E-01 3. 1E-01 3. 1E-01 8. 3E+02 5. GE+03 7. 4E+03 5. 9E-01 5. SE-01 8. 3E+02 5. GE+03 3. 1E-01 6. 5E-02 7. 4E-01 7. 3E-01 7. 3E-01 8. 3E+02 6. 2E+03 6. 2E+03 3. 4E-01 8. 3E-03 8. 4E-03 8. 6E-01 8. 8E-01 8. 3E+02 9. 6E+03 4. 4E-03 2. 4E-03 2. 7E-04 1. 0E+00 1. 0E+00 1. 0E+00 1. 0E+00 1. 2E+02 3. 2E+03 5. 2E-01 1.</td><td>NORMAL GUST FATIOUE DAMAGE GROSS WT.=2163 VC=127KNOTE STRESS/8 =8464 KT=2, 0 ANULF=., +2, 37 ANULF=., +2, 47 ANULF=., +2, 47 ANU</td></t<>	NORMAL GUST FATIGUE DAMAGE STRESS/B $= 8464$ $KT=3.0$ ANLLF=- ANLANULF CFR0/NM FR0/NM VC*.9*F/N 1.0E=01 1.0E+00 1.2E=01 8.3E=01 9.5E+01 1.6E=01 1.7E=01 1.3E=01 1.6E+03 1.9E=01 1.3E=01 1.4E+03 2.2E=01 4.5E=02 3.5E=02 4.0E+00 2.2E=01 3.5E=02 4.0E+03 2.7E=01 2.2E=01 3.5E=02 7.4E=01 3.5E=02 3.1E=01 6.5E=03 7.4E=01 3.4E=01 3.4E=01 3.5E=03 2.7E=01 4.0E=03 4.0E=01 1.1E=03 4.7E=04 2.7E=01 4.6E=01 4.3E=04 5.7E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.2E=01 1.9E=04 5.2E=02 5.1E=02 5.3E=01 1.1E=05 7.3E=01 2.0E=05 5.1E=02 7.5E=01 1.1E=05 5.9E=06 5.7	NDRMAL GUST FATIGUE DAMAGE GROSS WT. STRESS/B =8464 KT=3, 0 ANLLF=-, +2, 37 ANLANLLF CFR0/NM FR0/NM VC*, 9*F/N DB(-) 1, 0E=01 1, 0E+00 8, 3E=01 9, 5E+01 2, 1E=01 1, 0E=01 1, 7E=01 1, 3E=01 1, 4E+01 4, 5E=01 1, 6E=01 1, 7E=01 1, 3E=01 1, 4E+03 4, 5E=01 2, 2E=01 4, 5E=02 3, 5E=02 4, 0E+00 5, 9E=01 2, 2E=01 4, 5E=02 3, 5E=02 7, 4E=01 7, 3E=01 2, 2E=01 1, 0E=02 3, 5E=02 7, 4E=01 7, 3E=01 2, 2E=01 1, 0E=02 3, 5E=03 2, 7E=01 8, 8E=01 3, 1E=01 6, 5E=03 7, 4E=01 7, 3E=01 4, 0E=01 1, 1E=03 2, 7E=02 1, 0E+00 4, 6E=01 4, 3E=04 2, 7E=02 1, 2E+00 5, 2E=01 1, 9E=04 1, 1E=04 1, 2E=02 1, 2E+00 5, 8E=01 8, 5E=05 5, 1E=03 1, 4E+00	NBRMAL GUST FATIGUE DAMAGE GROSS WT.=2163 STRESS/G =8464 KT=3.Q ANLLF=-, +2.37 GN/ANLLF CFR0/NM FR0/NM VC#.9#F/N DB(-) DB(+) 1.0E+01 1.0E+00 0.3E+01 2.1E+01 3.1E+01 1.2E+01 8.3E+01 9.5E+01 3.1E+01 3.1E+01 1.9E+01 1.7E+01 1.3E+01 4.5E+01 4.5E+01 2.2E+01 4.5E+02 3.5E+02 4.0E+04 5.9E+01 5.9E+01 2.2E+01 3.5E+02 4.0E+04 5.9E+01 5.9E+01 5.9E+01 2.2E+01 1.0E+02 3.5E+02 4.0E+04 5.9E+01 5.9E+01 3.5E+02 3.5E+02 7.4E+01 7.3E+01 7.3E+01 3.4E+01 2.5E+03 2.7E+04 7.7E+02 1.0E+00 1.0E+00 4.3E+01 6.7E+03 2.7E+04 1.2E+00 1.2E+00 1.2E+00 5.2E+01 1.9E+04 2.4E+04 2.7E+02 1.2E+00 1.2E+00 5.2E+01 1.9E+05 5.1E+03	NBRMAL GUET FATIGUE DAMAGE GROSS WT.=2163 VC=127K STRESE/G =8464 KT=2, Q ANLLF=-, +2, 37 GN/ANLLF CFR0/NM FR0/NM VC+.9+F/N DB(-) DB(+) DB(+, -) 1. QE-Q1 1. QE+QQ 1. QE+Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 3. 1E-Q1 3. 1E-Q1 3. 1E-Q1 1. QE-Q1 1. ZE-Q1 1. ZE-Q1 4. SE-Q1 4. SE-Q1 4. SE-Q1 2. ZE-Q1 4. SE-Q2 3. SE-Q2 4. QE+QQ 5. 9E-Q1 5. 9E-Q1 5. 9E-Q1 2. AE-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 3. 4E-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 4. SE-Q1 2. SE-Q2 7. 4E-Q1 7. 3E-Q1 7. 3E-Q1 7. 3E-Q1 4. SE-Q1 2. 4E-Q3 2. 7E-Q1 8. 8E-Q1 8. 8E-Q1 8. 8E-Q1	NORMAL GUST FATIGUE DAMAGE GROSS WT.=2163 VC=127KNOTS STRESS/S =8464 KT=2, 0 ANLLF=-, +2, 37 AN/ANLLF CFR0/NM FR0/NM VC*, 9*F/N DB(-) DB(+) DB(+,-) SM 1, 0E-01 1, 0E+00 1, 0E+01 8, 3E-01 9, 5E+01 2, 1E-01 2, 1E-01 3, 1E-01 8, 3E+03 1, 0E-01 1, 7E-01 1, 2E-01 1, 4E+00 5, 5E-01 3, 1E-01 8, 3E+03 2, 2E-01 3, 5E-02 4, 0E+00 5, 9E-01 5, 9E-01 5, 9E-01 8, 3E+03 2, 2E-01 3, 5E-02 7, 4E-01 7, 3E-01 7, 3E-01 8, 3E+03 2, 2E-01 3, 5E-02 7, 4E-01 7, 3E-01 7, 3E-01 8, 3E+03 3, 7E-01 2, 4E-03 2, 7E-01 8, 8E-01 8, 8E-01 8, 8E-01 8, 8E+03 4, 6E-01 3, 3E-04 2, 7E-04 1, 0E+00 1, 0E+00 8, 3E+03 5, 2E-01 1, 1E-04 2, 7E-02 1, 0E+00 1, 0E+00 8, 3E+03 5, 5E-01	Image: NBRMAL BUST FATIBLE DAMAGE GROSS WT.=2163 UC=127KNOTS STRESK/E RAK6 KT=2.Q ANL[F=-,+2.37 AN/ANLLF CFR0/NM FR0/NM UC*.9*F/N D6(-) D6(+.) D6(+,-) SM SA 1. QE-01 1. QE+01 0. SE+01 2. 1E-01 3. 1E-01 3. 1E-01 B. 3E+02 2. EE+03 1. QE-01 1. 7E-01 1. 2E-01 1. 4E+01 4. 5E-01 4. 5E-01 4. 5E-01 8. 3E+02 3. 4E+03 2. 2E+01 4. SE-02 3. 5E-02 4. 6E+00 5. 9E-01 5. SE-01 8. 3E+02 5. GE+03 3. 1E-01 3. 1E-01 3. 1E-01 8. 3E+02 5. GE+03 7. 4E+03 5. 9E-01 5. SE-01 8. 3E+02 5. GE+03 3. 1E-01 6. 5E-02 7. 4E-01 7. 3E-01 7. 3E-01 8. 3E+02 6. 2E+03 6. 2E+03 3. 4E-01 8. 3E-03 8. 4E-03 8. 6E-01 8. 8E-01 8. 3E+02 9. 6E+03 4. 4E-03 2. 4E-03 2. 7E-04 1. 0E+00 1. 0E+00 1. 0E+00 1. 0E+00 1. 2E+02 3. 2E+03 5. 2E-01 1.	NORMAL GUST FATIOUE DAMAGE GROSS WT.=2163 VC=127KNOTE STRESS/8 =8464 KT=2, 0 ANULF=., +2, 37 ANULF=., +2, 47 ANULF=., +2, 47 ANU

DAMAGE= 4.96-07

, . ; ,

> > Report VB-1337 Page G5-10

NODEL 18	1	PIPELINE	HAN. FAT	IGUE DAMA	ge gross	wt=2033	VC=127K	NOTS			
SN=7689	*1.1	STRESS/G	-7816	KT=4.0		ANLLF-B.	4,-2.76				
	AN/ANLLF	CFRQ/NN	FRQ/NM	VC+.9+F/N	DG <-)	DG <+)	DG(+,-)	sn	SA	N	n / N
	1.0E-01	5.5 E -01									
-4-0E-02	1.35-01		3.0E-01	a.4e +01	1.1E-01	4_4E-01	2.8E-01	#-5E+03	2.22+02		
	1.6E-01	2-5 E -01									
-1.32-01	1.9E -01		9.0E-02	1-0E+01	3.6E-01	6.5E-01	5.0E-01	8.6E+03	3.95+03		
	2.2E-01	1-6 E -01									
-1.9E-01	2.5E-01		8.0E-02	9.12+00	5.2E-01	8.5E-01	6.9E-01	8.52+03	5.4E+03	4-05+06	2-25-06
-	2 .8E -01	8-02-02									
-2.12-01	3.1 E -01		5.0E-02	5.7E+00	5-62-01	1.12+00	8.2E-01	A.52+03	6.42+03	6.02+05	9.55-06
.	3 .4E -01	3-02-03									
-2.5£-01	3.7E-01		1.8E-02	2.1E+00	6.92-01	1_32+00	9.75-01	8.5E+03	7.65+03	1-12+05	1.98-05
	4_0E-01	1,2E-02									
-3.22-01	4.32-01		7 .0e -08	8.0E-01	8-8E-01	1_5E+00	1,22+00	8.5E+03	9.22+03	5.0E+04	1.68-05
	4.6E -01	5.0E-0a									
-3.5E-01	4 .9E -01		3-3E-03	3.7E-01	9.72-01	1.7E+00	1.32+00	8-52+03	1-0E+04	3.3E+04	1.12-05
	5.2E-01	1 -8E-03	· • •								
-3.72-01	5.5E-01		1.1 E -03	1.32-01	1.02+00	1.9E+00	1_4E+00	8-52+03	1_1E+04	2.1E+04	6.0E-06
	5.82-01	2.0E-04									
-4-1E-01	6.12-01		4.5E-04	5-1E-02	1-12400	2.1E+00	1-62+00	8.5E +03	1.3E+04	1.0E+04	5.1E-06
	6.4E-01	2.5E-04									
-4-5e-01	6.7E -01		1.52~04	1.72-02	1-2E+00	2_3E+00	1-8E+00	A-5E+03	1.42+04	7.02+03	2.48-06
	7.0E-01	1-0E04									
-5.1E-01	7.32-01		5-0 e -05	6.7E-03	1.42+00	2.5E+00	1.92+00	8.52+03	1.52+04	6.4£+03	4.9E-07
	7.5e-01	5.0E-05									
-5-62-01	7 _8E -01		2-9E-05	3.35-03	1.52+00	2.72+00	2-15+00	8.5E+03	1.66+04	5.2E+03	6.4E-07
	8.1E-01	2.1E-05									
-6.0E-01	8.4E-01		1-1 E -05	1.25-03	1.72+00	2.92+00	2.32+00	8.5E+03	1.8E+04	4.0E+03	3.1E-07
	8.7E-01	1-0E-05									

DAMAGE= 7.2E-05

..



Š

MODEL 183	P1	IPELINE GU	IST FATIG		GROSS W7.	-2023	VG=127K	Nots			
8X=7689	stri	195/G=7816		ANLLJ'=-	e+2.71	81-9-C	MC 4 4	@¥	A A		
AN/ANLLF	AN/AMLLF	CFRQ/N#	FRQ/NH	VC4 , 94F/N	DG (- 3	ار ۲۰۷ مالاغ	10a (+ y -)	38	23.6	*	n. R
	1.02-01	4-02+00						0 00.00	A 68.44		
0.0E+00	1.3E-01		2.02400	2.2E+02	3.56-01	N-28-01		.	2.02.4UA		
	1.6E-01	2-05+00					C	-	4 45 465		
0_02+00	1,95-01		1.22+00	1.4E+02	5.1E-01	P"1#-01	B-17-01	7 . 7 8. 4 (1 8	4-02404		
	2.25-01	8.0E-01							4 • • • • • •		
0.0 2 +00	2,55-01		5-0 E-0 1	5.7E+01	6.8E-01	6.66-01	6.8E-01	7.75403	8.3£403	2.05406	1-15-08
	2 .8E -01	3-05-01									
0.02+00	3.15-01		2.0E-01	2.3E+01	8.4E-01	8.4E-01	8.4E-01	7.72+03	6.6E+03	4.0E+05	5.7E-05
	3 .4E -01	1.05-01									
0.02+00	3.75-01		8.2E-02	9.42+00	1_02+00	1.0E+00	1_0E+00	7.7E+03	7.8E+03	1.0E+05	9.42-05
	4.0E-01	1.62-02									
0.0E+00	4,2⊑ -01		1.12-02	1.3E+00	1-22+00	1.2E+00	1.22+00	7,75+03	9,1E+03	5.0E+04	2.55-05
	4.6E-01	7_0£-03									
0.02+30.0	4_92-01		4.02-03	4.6E-01	¥-3E+00	1.2E+00	1.3E+00	7.72+03	1.02+04	3.26404	1.48-05
	5 <i>.2</i> 2-01	3~0503									
0.02+00	5.5E-01		1.4E-07	1.6E-01	1.5E+00	1_5E+00	1.5E+00	7.7E+03	1.25404	1.5E+04	1.15-05
	5 .8E -01	1.65-03									
0-02+00	6.1E-01		8-02-04	9.1E-02	1.72+00	1.75+00	1.75+00	7.75+03	1.36+04	1_02+04	9.1E-06
	6.42-01	8-02-04									
0.02+00	6.7E-01		4-02-04	4_6E-02	1-82+00	1,8E+00	1.82+00	7.75+02	1-42+04	6.0E+03	5.76-06
	7.05-01	4.02-34									
0.02+00	7.35-01		1.2E-04	1.4E-02	2_0E+00	2.05+00	2.02+00	7.72+02	1.52+04	6.4E+03	2.12-06
	7.5E-01	2.8E-04									
0.02+00	7.85-01		1.3E-04	1.5E-02	2.12+00	2.1E+00	2.1E+00	7.72+09	1.72+04	' 4.4E +03	3 .4E -06
	A.1E-01	1-52-04									
0.02+00	8.4E-01		6-0E-05	6.9E-03	2.35+00	2.32+00	2.35+00	7.7 E +07	1.82+04	4_02+03	1.72-06
	8.7E-01	9.08-05									•
0.05+00	9.05-01		3.0E-05	3.4E-03	2.45+00	2.42+00	2.4E+00	7.7E+03	1.92+04	3.52+03	9-82-07
	9,35-61	6-08-05									
0.0F+00	9.65-01		2.05-05	2.35-03	2-65+00	2-62+00	2-62+00	7.72+03	2.05+04	3.06+03	7.66-07
	9.95-01	4 05-05									
			•							DANAGE-	2.46-04

..

.

Page 65-12

MODEL	183	NORMAL.	MAN. FAT	IGUE DAMA	ge	GROSS	WT=2163	VC-127KN	ots			
		SH=1.2+4:	320	STRESS/G	-8464	KT=4.0	ANLL	F=2.82.1	5			
AN/AHL	LF	AN/ANLLF	CFRQ/NM	FRQ/NN	VC+.9+F/1	I DGK-:	DG(+)	DG(+,-)	SM	SA	ы	n / N
		1-0E-01	2.28-02					•				*** **
0.0E+	00	1.3E-01		1.3E-02	1.55+00	0.02+0	0 3.62-01	1.8E-01	1.02+04	1.52+03		
		1-6E-01	9.0E-03									
-6.0E-	62	1.92-01		3.5e-03	6.3E-01	1.5E-0	1 5.28-01	3.42-01	1.02+04	2,96+03		
		2-26-01	3.5E-03									
-1.2E-	G1	2-8E-01		2.0E-03	2.3E-01	3.06-0	1 7.05-01	5.0E-01	1.02+04	4.26+03		
		2.65-01	1-5E-03									
-1.72-	01	3.1E-01		8-5E-04	9.7E-02	4.35-0	1 A.7E-01	6.5E-01	1.0E+04	5_5E+03		
		3.4E-01	6.5E-03									
~2.2E-	01	3.75-01		3.5E-04	4.05-02	5.5E-0	1 1.02+00	8.0E-01	1.0E+04	6.72+03	2.02+05	2-0E-07
		4.0E-01	3.0E-04									
-2.6E-	01	4.75-01		1-6E-04	1.42-02	6.6E-0	1.22+00	9.3E-01	1.02+04	7.9E+03	8.5E+04	2-1E-07
		4.65-01	1.4E-04									
-3.12-	01	4_9£~01		7.0E-05	8.05-03	7.8E-0	1 1.4E+00	1.1E+00	1.0E+04	9,12+03	4.25+04	1.9E-07
		5.22-01	7.0E-05									
-3.52-	61	5.6E-01		4-0E-05	4.62-03	8.8E-0	1.52+00	1.2E+00	1.02+04	1.05+04	2.72+04	1.7E-07
		5-82-01	3.0E-05									
-3.92-	01	6.12-01		1-5E-05	1.72-03	9.8E-C	1.72+00	1.32+00	1-02+04	1,12+04	1-92+04	8.9E-08
		6.4E-01	1.5E-05									
-4.25-	01	6.72-01		8.0E-06	9.0E-04	1.12+0	00 1.95+00	1.52+00	1-05+04	1.32+04	1.02+04	9.0E-08
		7.06-01	2-0E-06									
-4.72-	01	7.3E-01		3.0E-06	3.0E-04	1.25+0	0 2.0E+00	1.65+00	1.02+04	1.42+04	7-02+02	4.32-08
		7.5E-01	4.0E-06									

DANAGE- 9.9E-07

- -

Page G5-13

Sar B

.

	N.
	,

NODEL 18:	1	NORMAL G	UST FATIG		GROSS WT.	-2163	VC=127X	nots			
SN-8320	STRESS/G	-8464	xT=4.0	ANLLF	,+2.37						
AN/ANLLF	AN/ANLLF	CFRQ/NN	FRQ/NH	VC+.945/N	DG (-)	DG(+)	DG(+,-)	sk	SA	н	в/ н
	1.0E-01	1_0E+00									
0.02+00	1.3E-01		6.3E-01	9.5 E +01	3.1E-01	3.1E-01	3.1E-01	8.2E +03	2 .6E +03		
	1.6E-01	1.7E-01									
0.02+00	1.9E-01		1.95-01	1.4E+01	4.5E-01	4.6E-01	4_5E-01	8.3E+03	3 . 6E +03		
	2.25-01	4.55-02									
0-02+00	2.6 E -61		3.52-02	4_02+00	5.9E-01	S.9E -01	5.9E-01	8.35+03	5-02+03	1-06+07	4.0E-07
	2.85-01	1.02-02				~				A	0 45 07
0.02+00	3.12-01		6.6E-03	7.4E-01	7.3 E -01	7.25-01	7.3E-01	8-35403	6.26408	#.2£+(ID	A.17-01
	a.4e-01	3.55-03						A	G 48.43	1 55.05	1 45-46
0.0E+00	3.7 E -01		2.4E-03	2.72-01	4.4E -01	a.ae~01	a.se-01	8. 3E403	7.48408	1.000400	1.00
	4 - Oi 01	1.1E-03	1						A 48444	E 05104	1 68-06
0.0E+00	4.32-01		6.7E-04	? .7E-02	1_0E+00	1.06400	1-01400	G. #E+()3	S. DETUS	DAKETUT	
	4.68-01	4 .3E-04						4 98.409	0 05-00	3 05+04	9.15-07
0.02+00	4.92-01		2.42-04	2.7E-02	1.22400	2.26400	\$ - 28.4(R)	6.84TU3	3.02.75A	4.CH+0+	
	5.22-01	1.9E-04					4 98+44	6 25.03	3 15+04	1.95+04	6.38-07
0.0E+0/J	5.5E-01		1,12-04	1.2E-02	1.32400	1.82400		0.0×700	*****		
	5.8E-01	8.5E-05				4 48.00	1 48+00	A 35+03	1.25+04	1.48+04	3.75-07
0.0E400	6.1E-01		4.5E-05	5_1E~03	1.42400	1.05.000	1.45400				
	6.45-01	4.0E-05			1 65.00	1 65+00	1 68+00	A. 38+03	1.26+04	1.02+04	2.38-07
0,05+00	6.7E-01		2-05-05	2.38-03	1.000.4000	A - DALTING					
	7.05-01	2.05-05			1 75+00	1 75+00	1-75+00	A. 3E+03	1.55+04	6.25+03	1.78-07
0.05+00	7.32-01		9.02-06	1.02-08		d . / 2 1					
	7.54-01	1.12-05		C 98-04	1 65400	1 45+00	1.82+00	6. 3E+03	1.62+04	5.02+03	1.35-07
0.06+00	· · · · · · · · · · · · · · · · · · ·		77, 218,CH0		T THE PARTY CITY						
	6,12-01	2,18-06		0 00-04	2 05-00	2.05+00	2.06+00	8.32+03	1.72+04	4.82+03	6.02-08
0.06400	10~142~01 A 717 A				4 4 V E 1 V V						
	8,22401		>								

DAMAGE- 7.1E-06

£

1

NODEL 22 SH-9106	41.1	PIPELINE STRESS/G	MAN. FAT: -6710	IGUE DAHAG KT=3.0	gross	wt=2541 Anllf=2.8	VC-144K	Nots			
	AN/ANLLF	CF9Q/NN	FRG/NH	VCH.9#F/N	DG<-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.02-01	5.52-01									
-4-02-02	1.3E-01		2-0E-01	3.9£+01	1.05-01	2.6E-01	2.35-01	1.0E+04	2.0E+03		
	1.62-01	2.58-01									
-1-36-01	1.9E-01		9.0E-02	1.2E+01	3.35-01	5.3 E -01	4.22-01	1.02+04	3.72+03		
	2.2E-01	1.6E-01									
-1.95-01	2. ee- 01		8.0E-02	1.02+01	4.85-01	7.0E-01	6-9E-01	1.02+04	5.1£+03		
	2.95-01	8.0E-02									
-2.1E-01	3.1E-01		5.05-02	6.52+00	5.3E-01	8.7E-01	7.0E-01	1_05+04	6.1E+03		
	3.4E-01	8-0 <u>5</u> -02									
-2-66-01	3.7E-01		1.02-02	2.3E+00	6.3E-01	1.02+00	A. 3E-01	1.0E+04	7.32+03	2.62+06	9.3E-07
	4.02-01	1.2E-02									
-3.22-01	4.26-01		7.0E-02	9.1E-01	A.1E-01	1_22+00	1-02+00	1.0E+04	8_8E+03	4.02+06	2.3E-06
	4.62 -01	5_0£-03									
-3.56-01	4.9E-01		3_26-03	4_1E-01	A. 82 -01	1_4E+00	1.12+00	1_0E+04	9-82+03	2.22+05	1.92-06
	5.22-01	1.8E-03		_							
-3.72-01	5.5 E -01	•	1_12-03	1.42-01	9.35-01	1_5E+00	1.22+00	1_0E+04	1.1E+04	1.32+05	1.1E-06
	5 .8E -01	7_05-04							4 49.44		
-4-16-01	6.1 E -01		4_52-04	5.8E-02	1.05+00	1.72+00	1.4£+00	1.05404	1.22404	6.8£+04	8.6E-07
	6.4E-01	2.6E-04	_								
- 4 -6e~01	6.7E-01		1.5E-04	1.9E-02	1-15400	1.9£+00	1-66400	1.02404	1.32404	5.0E+04	3.95~07
	7.6 E ~01	1.05-04							4 45.04		~ ~ ~ ~ ~
-6-32-01	7.25-01		6 .0E -05	6.5E-03	1.35400	2-0E+00	1.76400	1.02404	1.442.404	3.28404	2.GE-07
	7.52-01	5-0 5 -05						1 05.04	1 55404	0 68.00	4 45 49
-2 .6 2-01	7.8E -01		2-92-05	3.8E-03	1-46400	2.28400	1-984400		TURACH	2.94.7574	1.48-01
	8.1E-01	2.15-05					4 05.00	4 65 66	1 76.04	0.05.04	
-6.02-01	8.45-01		1.18-05	1.46-03	1.55400	2.42400	1-36400	1.06404	A = 75.404	2.2k+04	8.2E-08
	8.75-01	1_0 E -05									

DAMAGE= 7.9E-06

,

,

.

Report VB-1337 Page G5-15

1

NODEL 22 SN=9106	P. 079	IPELINE G	u <mark>st fati</mark> gi	UE DANAGE	GROSS WT.	-2541	VC=1445	NOTS			
ANIANLLE	AM /ANI 1.5	0580/XX	550/88		, TZ.ZU	DG (A)	004	0 Y	<u>.</u>		
	1.02-01	4.05+00				200 C 4 1	KN⊕(∀ ,−.)	2541	3 A	R	n/N
0.05+00	1.25-01		2-05+00	2.65+02	2-95-01	2,95-01	2 95-01	6 1E+03	4 ER103		
	1.65-01	2-05+00						#.124U#	2 2 DE 108		
0.02+00	1-96-01		1.22+00	1.65+02	4-28-01	4.26-01	4-25-01	9.16+03	3 75+03		
	2.22-01	6.0E-01	,					-122100			
0.02+00	2.55-01		6.0E-01	6-56+01	5.6E-01	5.6E-01	5-68-01	9.15+02	4-95+04		
	2.45-01	2.05-01									
0.02+00	2.1E-01		2.0E-01	2.65+01	6.95-01	6.9E-01	6-9E-01	9.15+03	6.05+02		
	2.4E-01	1.05-01									
0.05+00	8.78-01		6.9E-02	1.18+01	6.28-01	A.3E-01	4.28-61	9.18+08	7.98+09	8.0E+06	9-55-06
	4-02-01	1.8E-02									
0-02+00	4.25-01	4	1.12-02	1-4E+00	9.5E-01	9.5E-01	9.65-01	9.12+03	4.3E+03	6.05+05	2.45-06
	4-65-01	7.05-03									
0-02+00	4.9E-01		4.0E-03	5-2E-01	1-12+00	1.15+00	1.15+00	9.12+03	9.52+03	2.02+05	2.6E-06
	5 <i>.2E</i> -01	3.02-03									
0-02+00	5-52-01		1.45-03	1 .4E -01	1.22+00	1,22400	1.25400	9.1E+02	1-12+04	1.36+05	1.4E-06
	5-8 E -01	1.62-03									
0-0E+00	6.1E-01		4. 0E-04	1.05-01	1.42+00	1.4E+00	1-42+00	9.12+02	1.25+04	6.62+04	1.62-06
	6.4E-01	\$.0E-04									
0.02400	6.7E-01		4.05-04	5.2E-02	1.52+00	1.52+00	1-56+00	9.1£+03	1.3E+04	5.0E+04	1-05-06
	7.0E-01	4.0E-04									
0.06400	7.36-01		1.28-04	1-6E-02	1-6E+00	1.62+00	1.62+00	9_12+02	1.42+04	3.72+04	4.2E-07
0 05+00	7.52-01	2.48-04									_
	7.0xx-01		1.3E~04	1.75-02	1.72400	1.75400	1.76+00	9.1E405	1.56404	3.2E+04	5.35-07
0.05+00		1-25-04	C 07 05	-	4 07.00						
	A.75-01	0 05-05	6.GE-05	7 - MAC(13)	7 - 74F 4 CIO	7.25400	1.96400	9.1E+02	1.72+04	2.36+04	3.4E-07
0.08+00	9 05-01	3.42-48		a aa aa	A 45.44	6 AR. 64					
	9.95-01	6 05-05	a.uz-Uz	3.32.01	ZIGETCRI	2.01400	2-06400	8-16409	1.72404	1.84404	2.28-07
0.05+00	9.65-01	8.01-08	0 05 0E	0 (5 .00	A 48100	0.45.00					
	9.95-01	A 05-05	~ . UR-UD	2 - 945-"STA	~ . 1 E (K)	~~~UU	₩	M°16403	1.8E+04	1.54.+04	1.7E-07
										A	
										JARAGE=	1.46-05

Report VB-133/ e G5-16

1.6

Jej C

•

:

DAMAGE 1. BE-A7

-





MODEL 36		NORMAL 6	UBT FATIGU	E DAMAGE	SROGG WT.	-6.84G	20-1448	010			
SN-9828	STREES/G		XH∎W, ©	ANLLF	· + 0, 101	XX10.0					
AN./GALLE	AN/ANLLF	CFROZNE	FROUND	NU# 8#E.N	C->90	06 (+)	DG(+,-)	Wa	EA EA	z	N/N
	1.05-01	1, 25+30	_								
8. 0E+36	1.3E-Q1		B. 2E-01	1.16+06	3. RE-01	B. RE-RI	3. RE-GI	5. 35+03	2. 6E+03		
	1. EE-01	1, 7E-01						i			
\$7° CVE + 342	1.56-01		1.26-01	1,66+01	4. 3E-01	4. 2E-01	4. 2E-01	9, 3E+00	3. BE+03		
	E. EE-01	4. SE-92									
R. 511+04	E. JE-RI		3, 5E-96	4, SE+00	5. 76-01	5. 7E-01	5. 7E-GJ	9. 3E+03	5. AE+AX		
	E. BE-RI	1, 96-92					I				
R. 66+96	3. 16-01		E. 5E03	B. 4E-01	7. 16-01	7. 16-01	7.15-01	9. 26+03	6. 25+03	A. OF + OA	A ACTOR
	3. 46-01	3. SE-93									
A. AE+ 25	3. 7E-01		8.48-03	3, 16-01	6. 4E-01	B. 4E-C1	B. 4E-01	9. 2E+00	7.46+63	E. 0E+06	1.65-07
	4. RE-01	1.15-03									
A. CE+ BA	4. 3E01		E., 7E-Q4	B. 7E-GE	5. <u>26</u> -01	5. 86-61	9, BE-AJ	9, 36+03	B. 6E+03	5.46+95	1.55-07
	4. EE-01	4. 3E-04						•			
R. CE+96	4, 9E-01		5- 4E-G4	×. 16-02	1.15+40	1-15+00	1.15+90	9. 36+03	90 +96 +00	E. GE+GS	1.65-07
	5. EE-01	1,96-04						1			
8. RE+66	S. 5E-01		1 . 15-64	1.45-00	1-25+90	1. 26+00	1-12-49	9, 2E+03	3-15+04	7.45+34	1. BE-Q7
	S. BE01	8. 5E-65							1		
8- BE+66	E. 1E-61		4, 56-96	E. RE-93	1.46+66	1.45+36	1.45+98	9. 3E+03	1. EE+04	6. 2E+04	9. 7E-08
	6. 4E-01	4. RE-05									
8. AE+00	E. 7E-01		E. NE-OS	2, 66-03	1. SE+00	1. 5E+ GW	1.55+30	9. 26+03	3、反下十分4	4.7E+Q4	5.56-98
	7. 18-191	25-20 °2									
R. RE+CR	7. 3E-01		5. RE-07	1, 25-03	1.7E+00	1.7E+00	1.7E+00	9. ZE+03	1-56+04	3-15+04	3. GE-OB
	7. SE-01	1. JE-05						1 1 1			
8. CE+86	7. BE-01		5.96-06	7.66-04	1.86+00	1 - BE + GR	1. BE+ GR	9. 26+03	1, EE+04	2. 5E+04	3. QE-QB
	B. JERJ	5. JE-46	_								
5. RE+96	E. 4E-61		E. 5E-06	3. EE-94	1.95+34	1,95+66	1.56+60	9. KE+03	1.7E+04	€. 1E+Q4	1. SE-AB
	B. 7E-GU	2. EE-96									

•

DAMAGE & GE-A7

÷A



NODEL 22		PIPELINE	MAN. FAT	IGUE DAMA	ge gross	WT=2541	VC-1448	nots			
SX= 9106	+1.1	STRESS/G	-8710	KT=4.0		ANLLF=2.0	,-2.52				
	AH/AXLLF	CFRQ/NN	Fro/NN	VC# . 9#F/N	DG ()	2)G (+)	DG(+,-)	SM	SA	N	n/N
	1_0E-01	5- <u>G</u> e-01									
-4.02-02	1-35-61		3.0E-01	3.9E+01	1.0E-01	3- 6 -01	2.25-01	1.02+04	2-02+03		
	1-66-01	2-58-01									
~1_3E-01	1 -9E-0 1		9-02-02	1.2E+01	a. 3e-01	6. 3e -01	4.3E-01	1_0E+04	3.76+03		
	2.2E-01	1 -6E -01									
-1.92-01	2.5E-01		4_0E-02	1_0E+01	4.8E-01	7.0E-01	5.9E-01	1_0E+04	5.1E+03	2-5E+06	4.1E-05
	2.8E-01	\$.0E02									
-2.12-01	3.12-01		5.0 E -02	6.52+00	5.3 E -01	8.7E-01	7.0E-01	1.0E+04	6.1 e +03	4-56+05	1-45-05
	3.4E-01	2-0E-02									
-2.5E-01	3.7E-01		1.8E-02	2.32+00	6.32-01	1_02+00	8.3E-01	1_0E+04	7.32+03	1-45+05	1.75-05
	4.02-01	1.2E-02									
-3.2E-01	4.3E-01		7_0E-03	9.1 E- 01	8,15-01	1.22+00	1.02+00	1.0E+04	8-8E+03	5.02+04	1.8E-05
	4.66-01	5.02-02									
	4.98-01		3.2E-03	4.1E-01	8.8E-01	1_4£+00	1.1E+00	1.0E+04	9- 8E +03	3-35+04	1.3E-05
	5.25-01	1.6E-03									
-2.7E-01	5.5E-01		1.1E-03	1 _4E -01	9_3E-01	1.52+00	1.2E+00	1.02+04	1.1E+04	2-36+04	6.2E-06
	5 -85 -01	7.0E-04									
-4.12-01	6.1E-01		4,52-04	5-8E-02	1_0E+00	1.72+00	1_4E+00	1_0E+04	1.22+04	1-2E+04	4.98-06
	6.4E-01	2.56-04	• •								
-4.52-01	6.7E-01		1.5£-04	1.9E-02	1.1E+00	1.92+00	1.5E+00	1.0E+04	1.3E+04	1_0E+04	1.92-06
	7.0E-01	1_0E-04									
-5,12-01	7.3E-01		5_0£-05	6.5E-03	1.3E+00	2.02+00	1_7E+00	1_0£+04	1.42+04	6-8E+03	9.55-07
	7.5E-01	5.0£-05									
-6.62-01	7.8E-01		2.9E-05	3.85-03	1.42+00	2.25+00	8 . 8E+0 0	1_0E+04	1.6E+04	5-62+03	6.7E-07
	8.1E-01	2.18-05									
-6-02-01	8.4E-01		1.1E-05	1.42-03	1.52+00	2.4E+00	1.9E+00	1.0E+04	1.76+04	4.42+03	3.22-07
	8.7E-01	1-02-05									

.

{

(

t

t

l

ļ

Z

DAMAGE- 8.1E-05

ge 65-19

..



.

MODEL 32	P	IPELINE GL	IST FATIS	e damage (ROSS WT.	-2541	VC=144K	NOTS			
Devi	5181	E86/6=671(R	SWNLLF =	+E. 2W	RT=4, Q					
PEP4,734243_1_5	SIN / SINL L.S	CF RO/ NM	FRG./NM	VC#_9#F/N	tag (-)	DG(+)	DG(+,-)	SM	5A	N	n./N
	1.05-31	4. RE+RR									
a. Gerge	1.3E-01		e. ae+aa	e.ee+re	e.9e-01	2.9E-01	2-9 E -01	9.1E+03	2. 5F.+03		
	1.6E-01	e- 96+99									
e. de+da	1.9E-01		1.2E+00	1.6E+@2	4-2E-R1	4.2E-01	4-2E-01	9.1E+03	3.7E+@3		
	2.2E-81	8- 8E-81									
a. Re+rr	2.5E-q1		5. 0E-01	6. 5E+01	5- 6E-01	5. 6E-01	5-6E-01	9.1E+03	4. BE+03	2. 0E+07	3.28-06
	2. BE-91	3. RE-01									. –
a. ae+6a	3. 1e-01		2. QE-01	2. EE+01	E- 9E-01	e. 9e-01	6. 9E-01	9.1E+03	6. 0E+03	1.1E+06	2.48-85
	3. 4E-81	1-8E-01									
R. 66-+68	3.7E-Q1		B. 2E-02	1.1E+@1	8. 2E-01	B. 2E-01	8. 2E-Q1	9. 1E+03	7.2E+03	e. 26+05	4. BE-05
	4. RE-RI	1-8E-98									
el de + ar	4. 3E-Q1		1.1E-08	1.4E+00	5. 5E-01	9, SE-01	9- 5E01	9.1E+03	8.3E+83	7.8E+84	2. RE-R 5
	4- 6E-01	7. RE-83									
1. es+20	4. 9E-Q1		4. RE-03	5.2E-01	1-1E+00	1. 1E+00	1-1E+00	9. 1E+03	9. 5E+Ø3	4. 0E+04	1.3E-05
	5. 2e-q1	3 . R e-R3									
A. RE+RA	5. 5E-01		1.4E-@3	1- BE01	1.2E+00	1. 2E+00	1. 2E+00	9.1E+03	1.1E+84	2. BE+04	E. SE-RE
	5. BE-01	1-6E-83	÷								
a- 8e+86	6. JE-QI		6- RE-04	1. 8E-81	1-4E+00	1. 4E+00	1-4E+00	9.1E+03	1. 2E+04	1.45+04	7.4E-06
	£. 4E-RI	8. RE-84									
R. 8E+68	E. 7E-@1		4. RE-R4	5. 2E-Re	1-56+00	1.5E+00	1.5E+00	9. 1E+03	1.3E+Q4	1.1E+@4	4.7E-06
	7. 8E-81	4. RE-R4									
r. 26+68	7.3E-01		1. EE-04	1. EE-RE	1. EE+00	1. EE + OR	1- 6E+00	9.1£+63	1.4E+&4	B. 4E+83	1.9E-86
	7. 5E-01	e- 86-84			:						
R. 26+00	7. 8E-01		1.2E-04	1.7E-@2	1.7E+00	1.7E+00	1.7E+00	9.1E+Ø3	1.5E+04	e.ee+03	E. EE-DE
	8. 1E-81	1.5E-04									
R. 0E+00	8. 4E@1		E- 8E-85	7.8E-03	1-96+00	1-96+00	1.96+00	9.1E+03	1.7E+@4	5. 0E+03	1. EE-0E
	6. 7E-01	9. NE05									
r. ce+rr	9. @E-@1		3. ae-as	3.9E-03	E. RE+RR	2. RE+00	2- 0E+00	9. 1E+03	1.7E+@4	4.2E+03	9. 3E-07
	9.3E-01	6. RE-05									
R. 0E+00	5. EE-01		2. RE-R5	2. EE-03	2- 1E+00	E. JE-+ MA	2.1E+00	9.1E+Ø3	1. BE+04	3. BE+03	6. BE-07
	9. 9E01	4- 8E-85									

DAMABE = 1.3E-04

J.

MODEL 3	RE NORMAL	MAN. FAT	IGUE DAMA	BE	88055 WT	-2848	VC=144K	10TC			
-	SM=1,2+9	253 STR/	6=4619		kt=4.8	ANULF		80			
AN./GNLLF	F AN/ANLLF	CFR9/NM	FRGINK	VC+-9+F/N	DG (-)	DG(+)	DG(+,-)		60		
	1-8E-81	e. 26- 8 2						(Dar.)	224	N	n./N
R- RE+ RE	1.3E-Q1		1.36-06	1.75+88	R. 25+88	3. EE-81	L AF-AL	1.115-04	1 615.00		
	1.6E-@1	9 . ne -83						** * * 5 * 819	1.515463		
-e. Re-re	1-9E-01		5. 5E-03	7.1E-01	1.56-91	5. 3E-81	3. 4F-01	1.115-04	3 015.00		
	5- 5e-øi	3.5E-03						*****	9. RIE+R3		
-1-25-01	2.5E-01		2. RE-0 3	2. 5E-01	3. 0E-01	7. 8E-81	5. 8E-81	1.115-04	4 405-00	F 45 44	
	2. 8E-81	1.SE-83							7, 4CE 103	E- 81E+81E	4-2E-0E
-1.7E-@1	3. JE-01		B. 5E-04	1.1E-@1	4. 2E-01	8.7E-01	6- 5E-01	1.115-04	5 705-00	1 40.40	• • • • • •
	3. 4E-QI	6. SE-83							0.722-02	4. 56+62	2. BE-07
-2.2E-01	3.7E-01		' É. 5E-04	4. 5E-RE	5. 5E-01	1. 8E+80	8. 0E-01	1.115-84	7 015-02	1 55.65	• • • ••
	4.8E-RI	3. se-84							11015-60	1-28+60	3. BE-07
-2. EE-01	4.3E-01		1.6E-@4	2. IE-02	6. 6E-Q1	1.20+00	9. 3E-Q1	1.115+84	A. 205-02	Erria	
.	4. EE-R1	1.4E-84								3, EE+104	3. BE-87
-3.1E-01	4.9E-01		7 . R e-05	9 . re-r 2	7.8E-81	1-4E+00	1.16+00	1-115-484	9.495402	S 65+64	
	5.2E-01	7.8E-85					-			C. DE-164	5. CE-01
-2- SE-81	5.5E-01		4. RE-05	5. R E- R 3	8. BE-01	1-5E+00	1.25+00	1.11E+64	1-075+04	S 15+04	a is an
	5. BE-01	3 . 9 e- 8 5							a a w.v.t., . Evel	E. 15-464	E. 4E .W./
-3.9E-01	E- 1E-01		1.5E-05	1-96-33	9. BE-R1	1-75+00	1.3E+88	1.115+84	1. 195-404	1 55+04	
	E. 4E-Q1	1.5E-05								1. 202 4 614	1-25-61
-4. 3E-01	6. 7E-61		B. RE-RE	1.15-03	1-1E+00	1- 5E+00	1. 5E+00	1.115+04	1. 315-04	7 65-03	
	7- RE-RI	7. RE -RE							a a 20 a 20 1 20 9	1.56405	7-46-61
-9.7E-01	7.3E-01		3. RE-06	3. BE-04	1.2E+88	2. RE+00	1. EE+00	1.11E+04	1.425+04	7 05-07	E . E . O
	7.5E-01	4. RE-RE							w a merely of Firsh	1. 4. 6. 4. 6. 7.	D. 45-66

15

2(2)

--

DAMAGE -2. RE-RE

Report VB-133/ Page G5-21

. -
MODEL 32		NORMAL G	ust fatig	ue damage (SROSS WT.	-2840	YC=144KNG75				
6M-9253	STRESS/6	-6613	KT=4. Ø	ANLLF	+2.28						
AN/ANLLF	AN/ANLLF	CFRQ./NM	FRGINM	VC+. 9+F/N	DG (-)	DG(+)	DG(+,-)	SM	60	b 1	- 11
	1-RE-01	1. RE+00							201	14	ກ.ເກ
A. RE+RA	1.3E-01		8. 3E-01	1.1E+RE	3. RE-RI	3. RE-01	2. 0E-01	9.28+03	8. EE+07		
	1.6E-R1	1.7E-01									
0. 0E+00	1-9E-&1		1.3E-01	1. EE+01	4.38-61	4. 3E-01	4.2E-01	9.36+03	3. 85+03	0 05.00	0 05.00
	2. 2E-01	4. BE-RE								Read Roll - Malla	Ret Ret + Kake
R. ØE+RR	2. 3e-ri		3.5 E-q e	4. 5E+00	5.7E-01	5.7E-01	5.76-01	9-35+03	5.05+02	1 05-07	4 55 .03
	2. 8 e-01	1. RE-RE								7 2 8 6 T E()	4. 36-47
A. RE+RA	3. 1e-01		E. 5E-03	B. 4E-Q1	7-1E-01	7.12-01	7.1E-Ø1	9, 38+03	F. 25+02	A 05-405	1 15-05
	3 . 4 ER1	3.5E-03								122 C.C. 1.E.C.	7.7E-KE
R. RE+RR	3.7E-ri		2.4E-Q3	3. 1E-01	8-4E-81	B. 4E-01	8-4E-01	9. 36+03	7.45+03	1.55-05	9 15-05
	4. 8E-81	1.15-43									
8. 2E+88	4. 3E-01		6.7E-04	8.7E-02	9. 8E-81	9. BE-01	9. BE-01	9. 3E+03	B. 66+03	5- 2E+04	1.45-05
	4. EE-01	4. 3E-84									2 2 4 K Billi
a. Re+06	4.9E-01		2.4E-04	2. 1 E -Re	1-1E+88	1-15+00	1-15+00	9. 3E+03	9.96+03	3. 5E+64	A. 95-07
	5. 2e-01	1.9E-84									
a. ae+aa	5. 5e-01		1-1E-04	1.4E-82	1-2E+88	1.3E+00	1. 3E+00	9.38+03	1-1E+04	1- BE+04	7.65-07
	5. se -01	8.5E-05									
A. AE+AA	6. JE-01		4.5E~@6	6. RE-R 3	1-4E+00	1. 4E+@@	1.48+88	9. 3E+03	1.2E+04	1-36+04	4.65-07
	6. 4E-01	4. 8E-85									
r. 25+22	6. 7E-01		2.0E- 0 5	2.6E-03	1.5E+00	1- 5E+00	1.5E+00	9. 3E+03	1.3E+04	1- 8E+84	8-65-07
	7. RE-RI	e . n e85									
r. Re+90	7.3E- R 1		9. QE-Q7	1.28-03	1.7E+00	1.78+88	1.7E+00	9, 3E+03	1-5E+04	6. 4E+03	1.95-07
	7.5e-01	1. IE-03									
r. RE+RR	7. BE-@1		5.9E-06	7.6E-04	1. BE+00	1.86+00	1. BE+00	9, 36+03	1.EE+04	5-56+03	1.45-07
	8. IE-RI	5. JE-06.									** 74* (*)
A. 0E+00	8. 4E-RI		2.5E-06	2. EE-04	1.58+66	1,9E+00	1-9E+00	9, 3E+R3	1.75+84	4-65+02	7.05-00
	8. 7E-Q1	2. 6E-06									· · · · · · · · · · · · · · · · · · ·

NORMAL GUST FATIBLE DAMAGE GROSS HT. -2840

MODEL 38

2

DAMAGE-7.7E-06

ge 65-22

The following is the determination of the fatigue damage per hour for the GAG cycle. ere à 1.2

Report VB-1337 Page G5-24

			AIR			
		σ_{max}	Once per	flight		
		PA-28-181		.9 V _C =	127 kts	
	Pipe	line		Norm	<u>al</u>	
Flt Duration	2.0	hrs		.65	hrs	
	Gust	Man		Gust	Man	
+a _{nLLF}	2.71	3.4		2.37	2.8	
a _n /a _{nLLF}	.50	.48		.28	.15	
NZ MAY	2.36	2.63		1.66	1.42	
G max	18319	20429		13910	11877	
		PA-32-300		.9 V _C =1	44kts	
	Pipe	eline	Normal			
Flt Duration	2.0	hrs		.65	hrs	
	Gust	Man		Gust	Man	
+a _{nLLF}	2.20	2.8		2.21	2.8	
a _n /a _{nLLF}	.51	.49		.28	.15	
NZ MAX	2.12	2.37		1.62	1.42	
(T max	18861	21039		14721	12957	

ζ,

. . .

 \land

GROUND

 G_{min} Once per flight Taxi once per flight N_Z=1+.325 N_Z mIN = .675

PA-28-181

	Pipeline		Normal
σ_{min}	3 222		3397
		PA-32-300	
	Pipeline		Normal
σ_{min}	1737		2240

Report VB-1337 Page G5-26

G-A-G

PA-28-181

Mission	σ_{\max}	$\sigma_{\texttt{min}}$	Tm	G a	N	K _T =3.0 Damage/ Hr	N KT=	4.0 Damage/ Hr
Pipeline	20429	3222	11826	8603	4.9x10 ⁶	1.02X10 ⁷	4.2X10 ⁴	1.19x10 ⁵
Normal	13910	3397	8654	5257	ð	0	5.3X10 ⁶	2.44X10 ⁷

PA-32-300

		G min	Tm	Ta	1	K _T =3.0	Kr=	=4.0
Mission	σ_{\max}				N	Damage/ Hr	N -	Damage/ Hr
Pipeline	21039	1737	11388	9651	1.9X10 ⁵	2.63X10 ⁶	2.8X10 ⁴	1.79X10 ⁵
Normal	14721	2240	8481	6241	6 5	0	8.6x10 ⁵	1.79X10 ⁶

. م

Fatigue Damage Summary

PA-28-181

K_T=3.0 Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	1.4X10 ⁻	⁵ 8.3X10 ⁻⁶	0	0	1.02X10 ⁻⁷	44,639
Normal	4.9X10 ⁻	⁷ 1.1X10 ⁻⁷	0	0	0	1,666,667
	No	ormal to P	ipelin	e Life Ratio	= 37.3	

K_T=4.0 Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	2.4X10-	⁴ 7.3x10 ⁻⁵	0	0	1.19X10 ⁻⁵	3,078
Normal	7.1X10 ⁻⁰	⁵ 9.9X10 ⁻⁷	0	0	2.44X10 ⁻⁷	119,990

Normal to Pipeline Life Ratio = 39.0

PA-32-300

K_T=3.0 Damage per Hour Unfactored Maneuver Taxi Ldg Impact G-A-G Life (hrs) Mission Gust Pipeline 1.4X10⁻⁵ 7.9X10⁻⁶ 2.63×10^{-6} 0 0 40,766 8.9×10^{-7} 1.8×10^{-7} 0 Normal 0 0 934,579 Normal to Pipeline Ratio = 22.9 . .

Kr=4.0 Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	1.3X10-4	⁴ 8.1X10 ⁻⁵	0	0	1.79X10 ⁻⁵	4,369
Normal	7.7X10 ⁻⁶	⁵ 2.0X10 ⁻⁶	0	0	1.79X10 ⁻⁶	87,032

Normal to Pipeline Ratio = 19.9



G7 REFERENCES

1 AFS-120-73-2 "Fatigue Evaluation of Wing and Associated Structure" by FAA Airframe Branch of the Engineering and Manufacturing Division.

. . .

2 <u>Draft</u> "Small Airplane Fatigue Loads Program: A standby of the Expanded NASA VGH Data Base and Revision of Fatigue Spectra in FAA Report AFS-120-73-2" dated May 4, 1987.

APPENDIX H

. . . .

A Constant of the second s

PIPER - INITIAL AND REPETITIVE INSPECTION INTERVALS

22

Report VB-1337 Page H1-1

PIPER - INITIAL AND REPETITIVE INSPECTIONS INTERVALS

The initial inspection time for the PA-28-181 on Pipeline Patrol is 3700 hours. The initial inspection time was determined by using one half the time required to achieve a critical crack size, acr. Acr represent design limit load capability. The accident aircraft crack size when compared to the a_{CT} determined for fracture analysis and the fracture analysis crack propagation curve shows negligible difference in time between the two crack lengths. Therefore the accident time 7488 Cas divided by 2 for initial inspections. This is conservative considering a 4100 hour PA-28-161 flying pipeline was found not cracked upon inspection and also the sister ship of the accident aircraft, a PA-28-181, flying the same mission, Pipeline Patrol, was found not cracked upon inspection at 7878 hours.

The PA-32-300 initial inspection time is 1800 hours. This is based upon using the PA-28-181 and PA-32-300 pipeline patrol crack propagation curves. First starting at the a_{CT} on the PA-28-181 curve and backing down the curve 7488 hours, equivalent dual cracks of .0207" in depth, .0414" in length were determined.

Starting at the same crack size on the PA-32-300 curve the equivalent time to $a_{\rm CT}$ was 3658 hours. The 3658 was divided by two for initial inspection.

The initial inspection for the normal usage PA-28-181 is 62,900 hours and for the PA-32-300 it is 30,600 hours. This is the pipeline initial inspection multiplied by 17. The high time normal usage aircraft inspected was a PA-28R-200 and found not to be cracked at 19,147 hours. The fatigue analyses performed on the PA-28-181 and PA-32-300 for K_T =3 and K_T =4 showed the ratio of normal life to pipeline life varied from 19.9 to 39.0. The conservative value of 17 was used.

The repeated inspection interval for the pipeline patrol PA-28-181 is 1600 hours and for the PA-32-300 is 800 hours. The repeated inspection interval was determined by using one half the time from a maximum undetectable crack, a_{NDI} to the critical crack size, a_{CT} . The area to be inspected is approximately 3/8" wide on an arc of 120° of the two outboard main spar bolt holes. Based on this relatively small inspection area a dual a_{NDI} of .05" in depth and .10" in length was selected. Using the PA-28-181 and PA-32-300 crack propagation curves the time from a_{NDI} to a_{CT} were 3169 hours and 1648 hours respectively. These hours were then divided by two for repeated inspection intervals.

The repeated inspection intervals for the normal usage PA-28-181 and PA-32-300 are 6000 hours and 3000 hours respectively. These were determined by using a conservative value of 3.33 multiplied by the respective pipeline repeated inspection intervals.