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

Prepared for
Piper Aircraft Corp.
Vero Beach, FLA

Lockheed-Georgia Company
A Division of Lockheed Corporation
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TITLE

PIPER AIRCRAFT MODEL PA 28-181 AND PA 32-300
MAIN SPAR FRACTURE ANALYSIS

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		5.7, 6.1	

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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
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H. R. Horsburgh
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K. A. Thomas

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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.

ΔK - Stress intensity factor range which is a function of stress range, crack length, a Beta factors and has the dimensions of $KSI\text{-}\sqrt{IN}$.

BETA FACTOR - Correction factor to account for various geometry or loading conditions.

V_C - Maximum cruise speed.

a_{CR} - 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.

Δg - Incremental acceleration.

REFERENCES

1. RFQ from R. L. Dickey, Piper Aircraft Corporation, to R. L. McDougal, LASC-Ga, dated 20 August 1987.

2. 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.

4. Purchase Order 039268 and attached Statement of Work dated 22 October 1987 from Piper Aircraft Corporation to LASC-Ga.

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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.

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1.1 Analysis Approach

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 size (EIFS). The EIFS accounts for the initiation by fretting and 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.

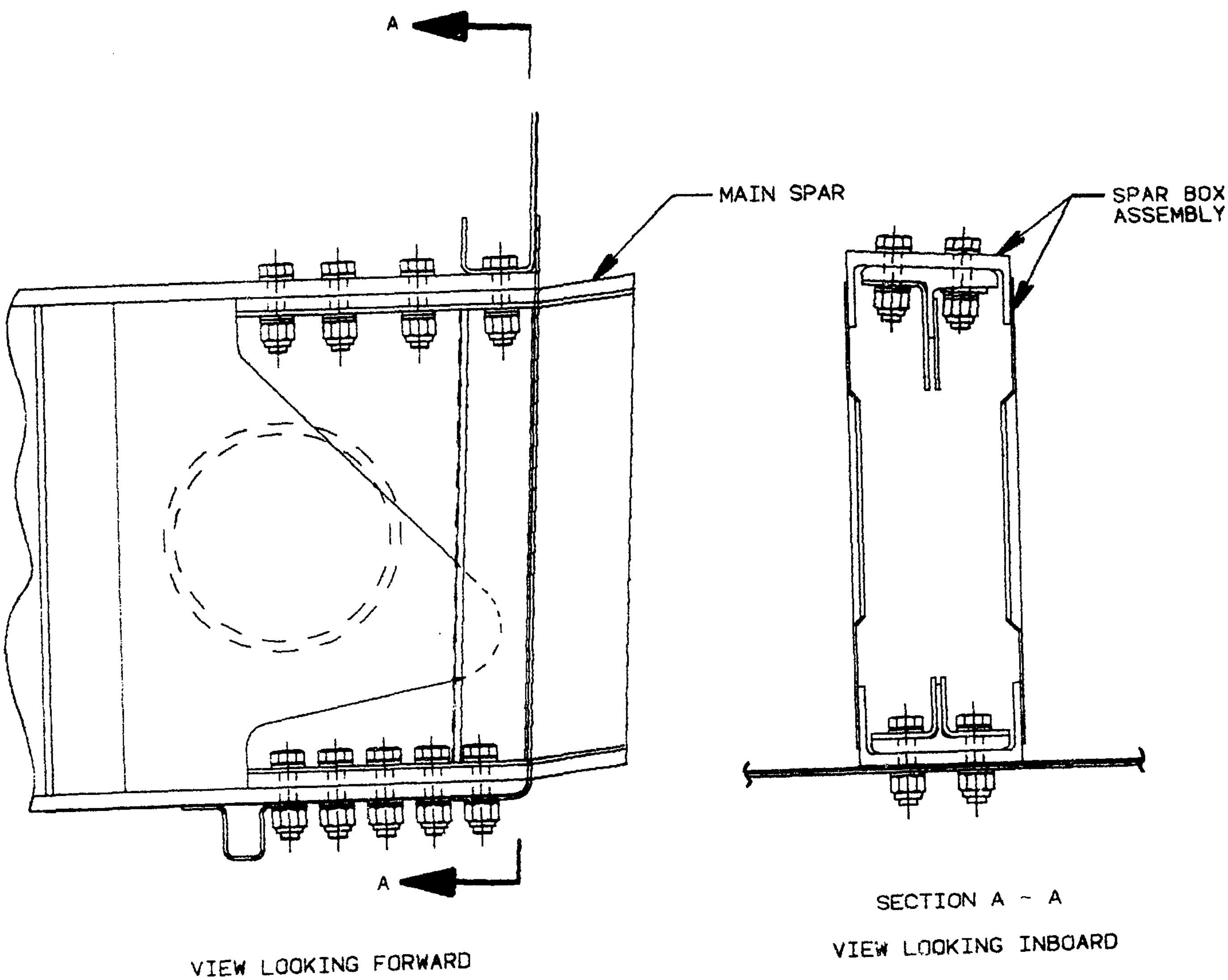

Figure 1.1 Plan Views of Main Spar and Attach Structure

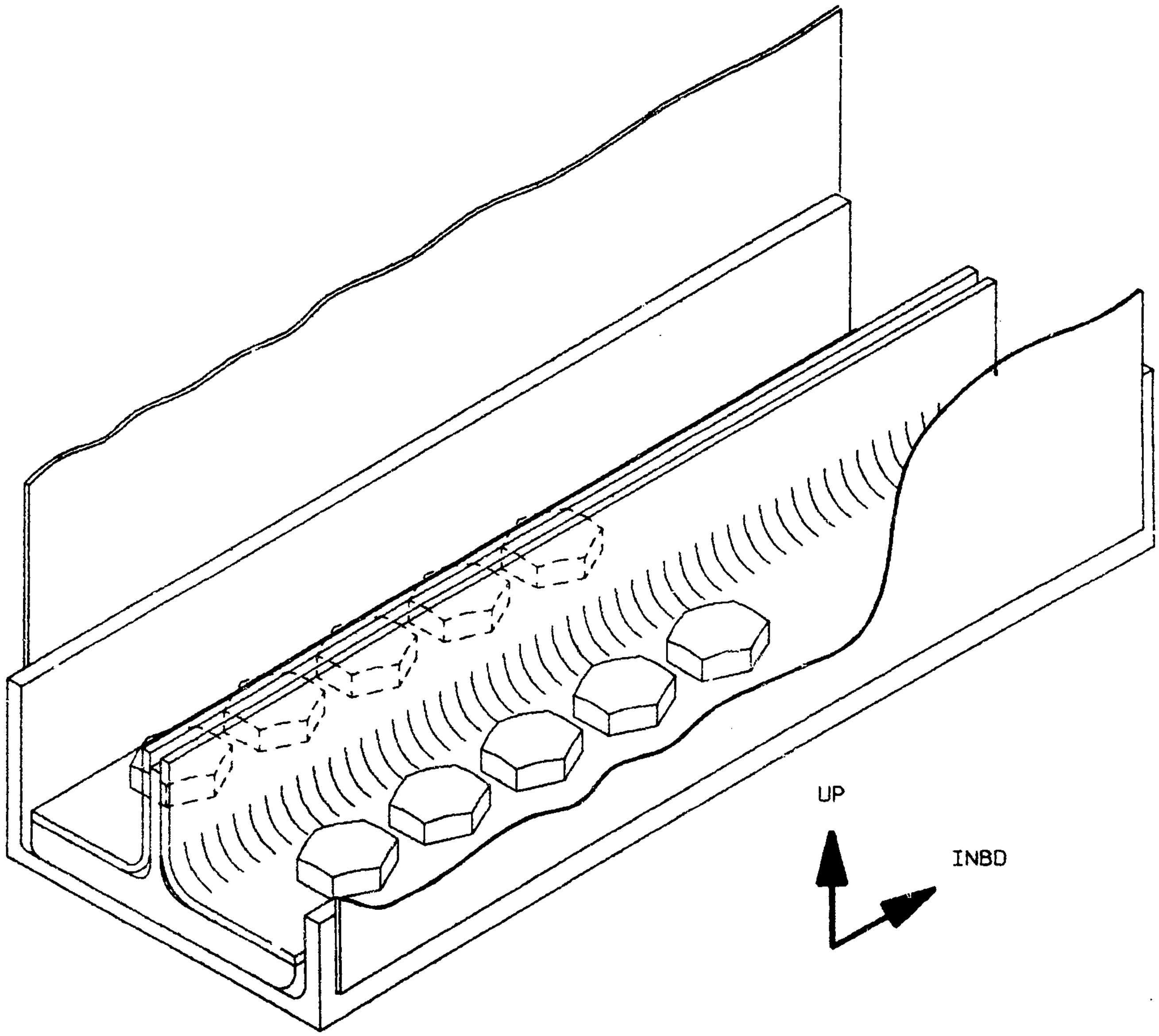

Figure 1.2 Isotropic View of Main Spar and Attach Structure

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 Δg 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

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 1g stress defined by Piper for the PA 28-181 and PA 32-300 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 1g 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 1g equivalent stress

2.0 SPECTRA DEVELOPMENT (Cont'd)

instead of 500 psi because of the improbability of a landing occurring at less than 1g. The remainder of the exceedance curve to .001 cumulative occurrences was sliced into eight equal layers. The incremental stresses were then combined with the 1g 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.

Manuever

Number of occ. / hr.	ΔG -	ΔG +
34.30	.11	.44
10.30	.36	.65
9.14	.52	.85
5.72	.58	1.054
2.06	.69	1.26
.80	.88	1.46
.37	.97	1.67
.126	1.02	1.87
.05	1.13	2.07
.017	1.24	2.28
.006	1.41	2.48
.0033	1.55	2.65
.0013	1.66	2.86

Gust

Number of occ. / hr.	±ΔG
228.60	.35
137.20	.51
57.15	.68
22.90	.84
9.4	1.00
1.26	1.17
.46	1.33
.16	1.49
.09	1.65
.046	1.82
.014	1.99
.015	2.11
.007	2.28
.0034	2.44
.0023	2.60

Taxi

Number of occ. / hr.	±ΔG
320	.05
190	.10
80	.15
30	.20
8.5	.25
2.1	.30
.50	.35
.10	.40
.018	.45
.010	.465

Landing

Number of occ. / fl.	G's
1.000	1.00
.350	1.25
.170	1.42
.026	1.58
.003	1.80
.0007	2.06
.0002	2.3

Aircraft Model I.D.	Ground Stress (psi)	Stress / G (psi/g)	1 G Mean Stress (psi)	Design Limit Stress (psi)
PA - 28 - 181	2409.8	7816	7689	34,264
PA - 32 - 300	2552.0	8444	10,500	39,209

Figure 2.1 Exceedance Data and Stress Definitions as Supplied by Piper Aircraft Company

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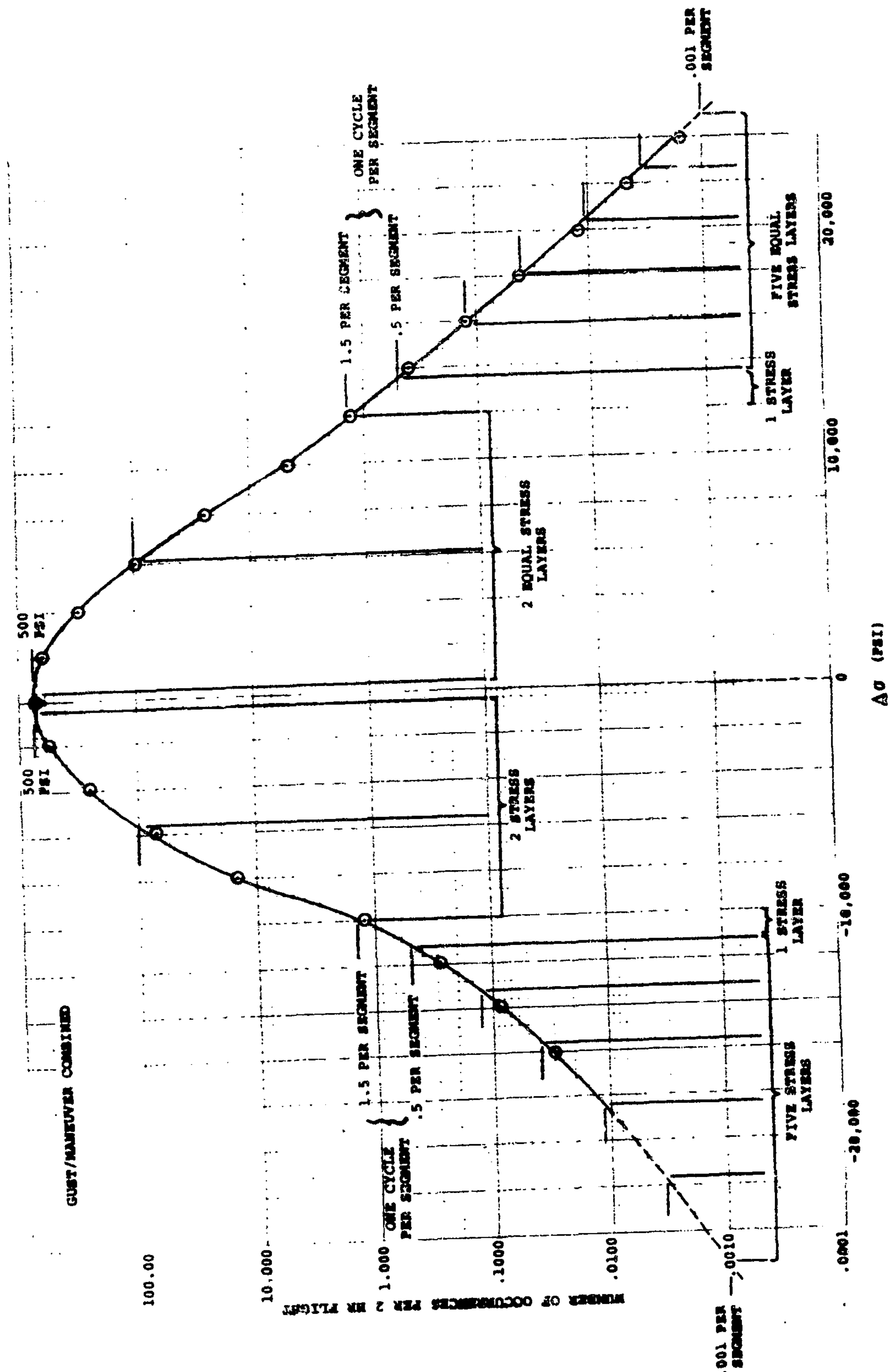

Figure 2.2 PA 28-181 Manuever/Gust Combined Exceedance Curve

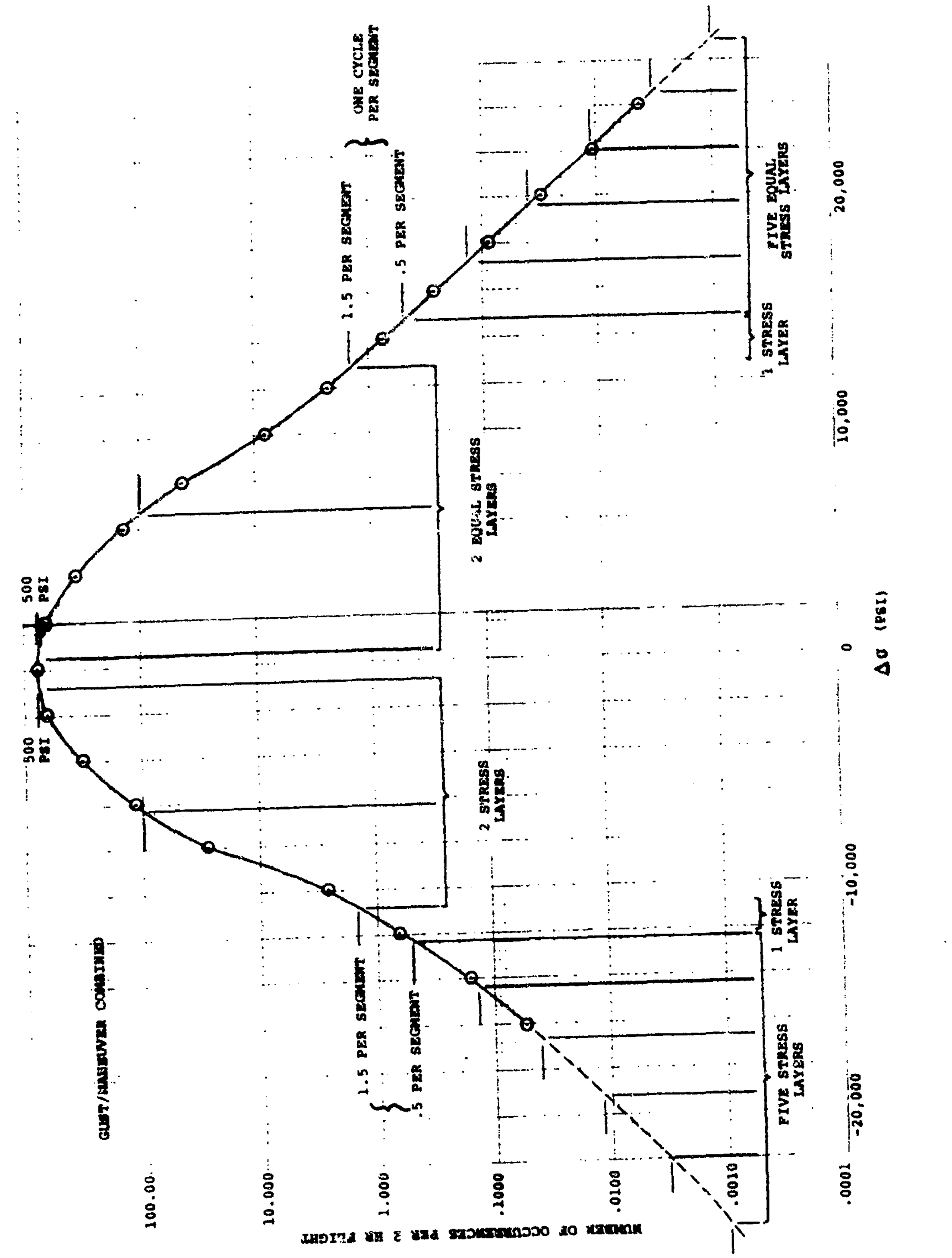

Figure 2.3 PA 32-300 Manuever/Gust Combined Exceedance Curve

Aircraft Model I.D. : PA - 28 - 181 **1 G Stress = 7689 psi**

Condition : Manuever and Gust Combined

Spectra Layer	*Δ σ (psi) Max	Min	**Δσ + 1 G Stress (psi) Max	Min	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
8	3312.5	-1500	11001.5	+6189	655

* Values found directly from occurence curves

** Values derived by adding 1 G Stress to Δσ

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

Prepared by [redacted] 1/14/88 Date Checked by [redacted] /88 Approved by [redacted] 88 Date

Aircraft Model I.D. : PA - 32 - 300 1 G Stress = 10500 psi

Condition : Manuever and Gust Combined

Spectra Layer	* $\Delta\sigma$ (psi) Max	Min	** $\Delta\sigma$ + 1 G Stress (psi) Max	Min	Number of Occurences per 2 hr. Flight
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
6	13850	-11250	24350	-750	1.00
7	9800	-6300	20300	4200	96.5
8	3600	-1700	14100	8800	662

* 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

Prepared [redacted] Date Checked by [redacted] Date Approved by [redacted]

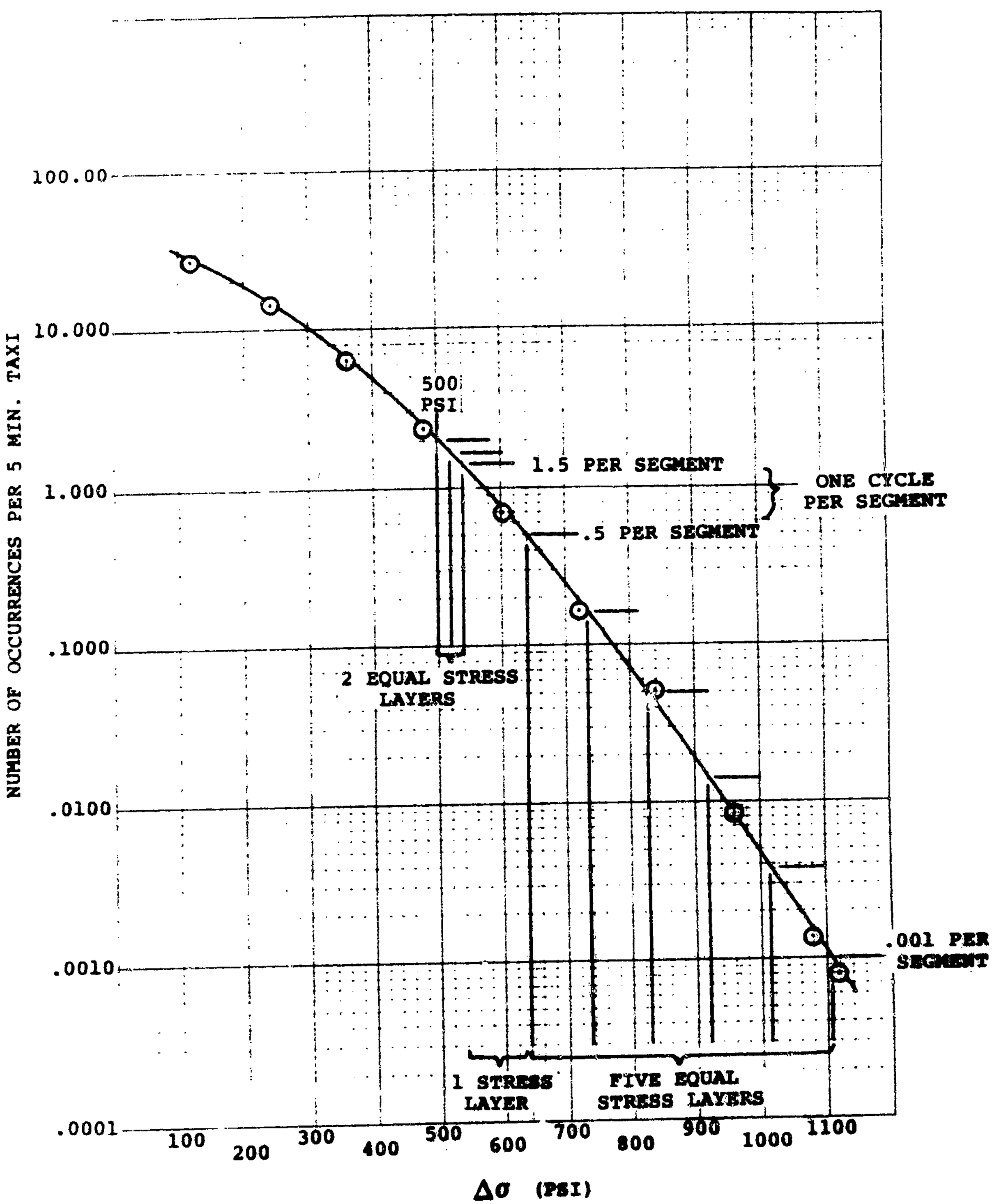

Figure 2.6 PA 28-181 Exceedance Curve for 5 Min. Taxi Segment

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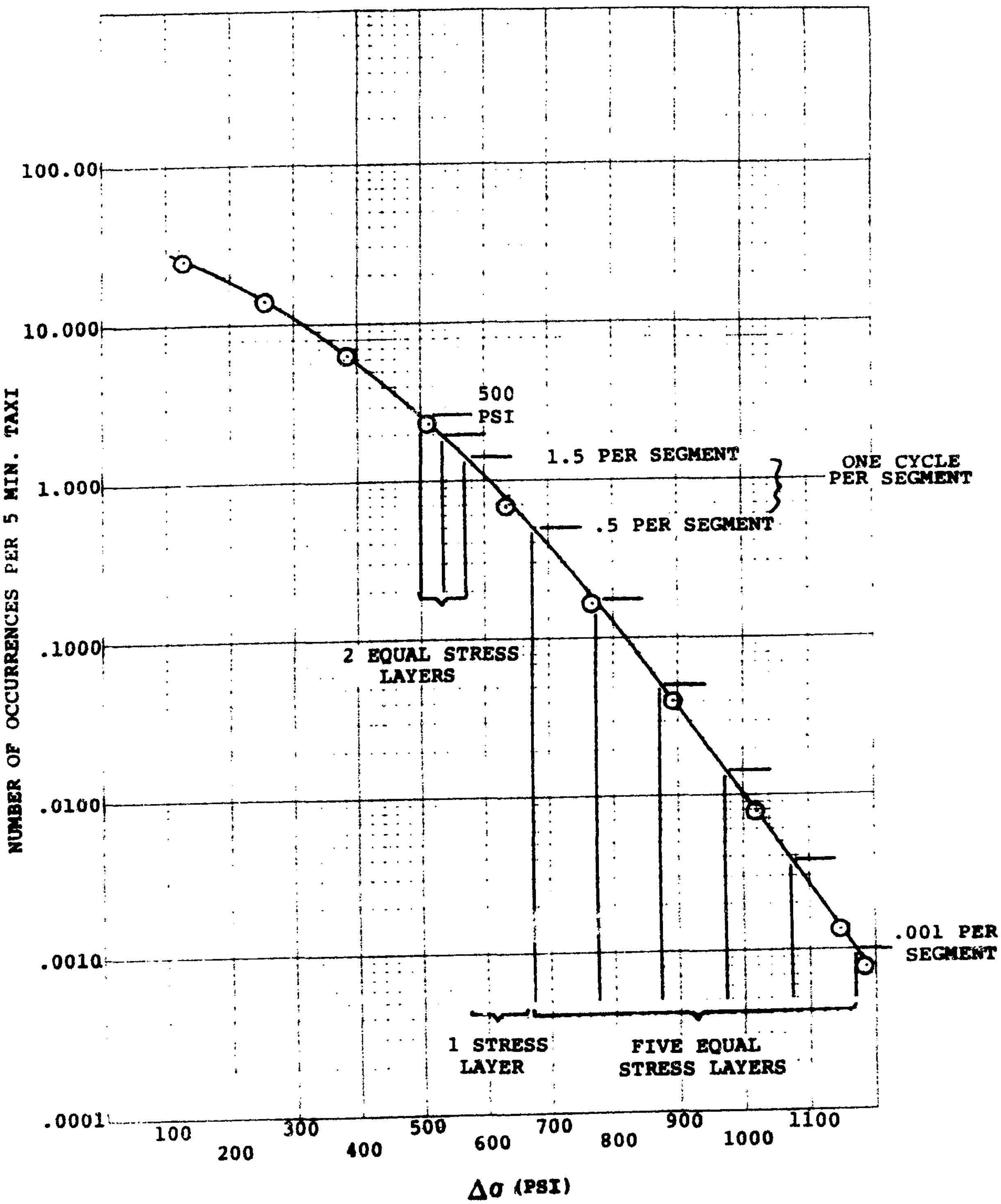

Figure 2.7 PA 32-300 Exceedance Curve for 5 Min Taxi Segment

Prepared by [redacted] Checked by [redacted] ved by [redacted] Date

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

Condition : Taxi

Spectra Layer	*$\pm\Delta\sigma$ (psi)	**$\Delta\sigma$ + 1 G Stress (psi) Max	Min	Number of Occurences per 5 min. Taxi
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 ____ Date Checked by [redacted] Date Approved by [redacted] Date

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

Condition : Taxi

Spectra Layer	*± $\Delta\sigma$ (psi)	**$\Delta\sigma$ + 1 G Stress (psi) Max	Min	Number of Occurences per 5 min. Taxi
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

Prepared by [redacted] 1/14/88 Date Checked by [redacted] 1/14/88 Date Approved by [redacted] '88 Date

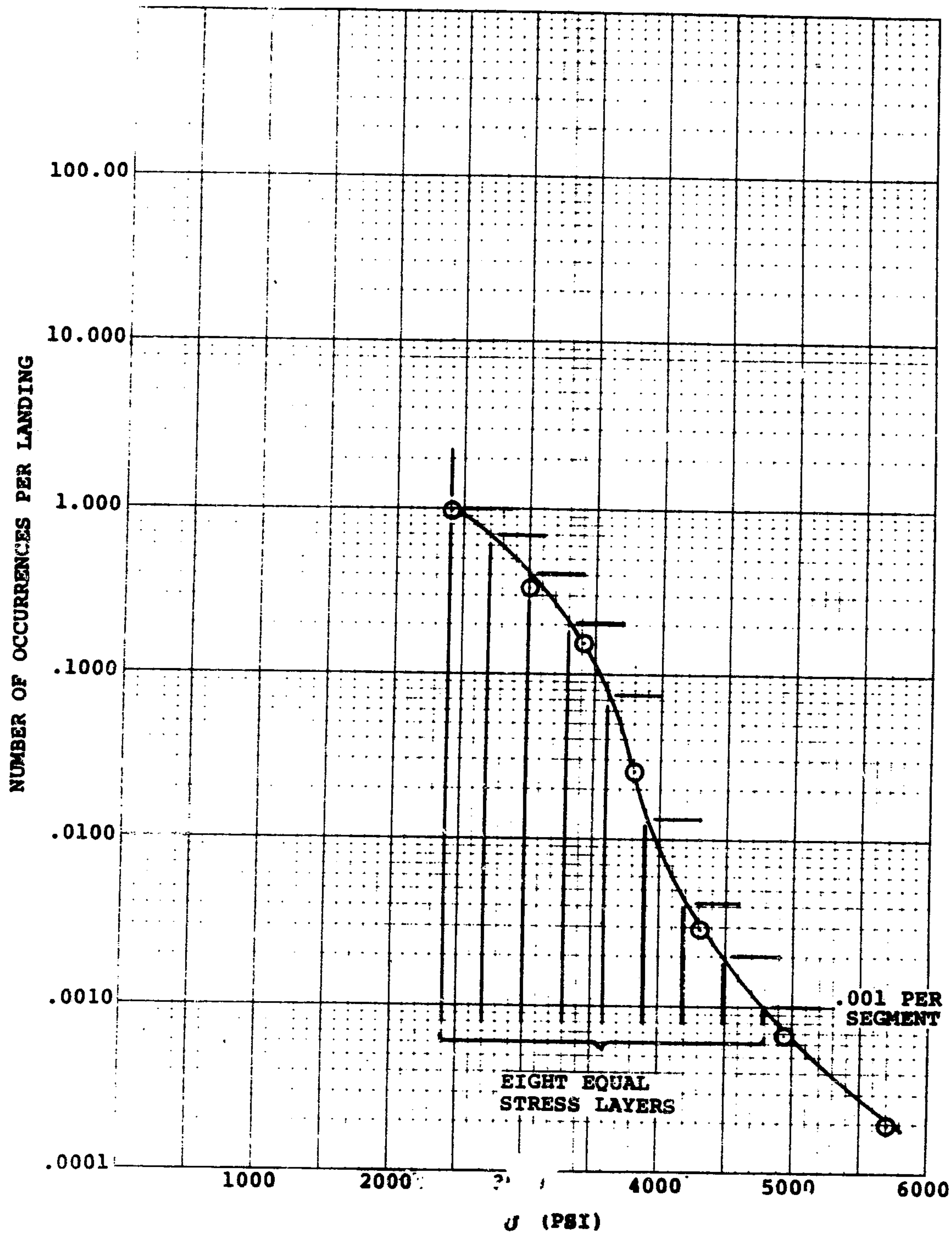

Figure 2.10 PA 28-181 Exceedance Curve for Landing Segment

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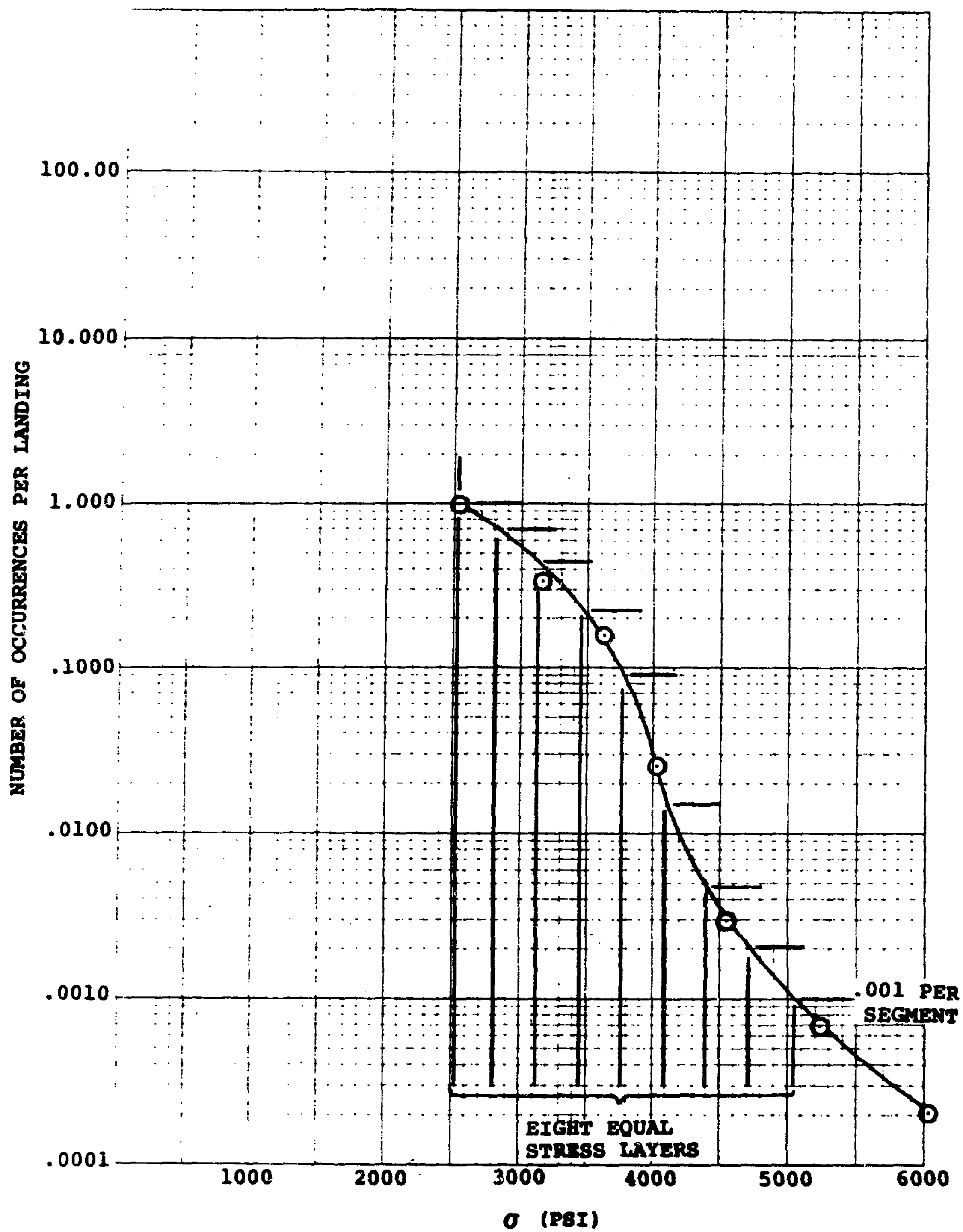

Figure 2.11 PA 32-300 Exceedance Curve for Landing Segment

Prepared by [redacted] 1/14/88 Date Checked by [redacted] 1/14/88 Date Approved by [redacted] Date

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

Condition : Landing

Spectra Layer	σ (psi) Max	Min	Number of Occurences per 1 Landing per Flight
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

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

Condition : Landing

Spectra Layer	σ (psi) Max	Min	Number of Occurences per 1 Landing per Flight
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

Prepared by [redacted] 1/14/88 Date Checked by [redacted] Approved by [redacted] Date

SEGMENT I.D.	CYCLES	STRESS MIN.	STRESS 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	16626.50
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	2409.80	4650.00
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

Figure 2.14 PA 28-181 Spectra defining 2 Hour "Pipeline Survey Mission"

Prepared by [redacted] 14/88 Date Checked by [redacted] /88 Approved by [redacted] /88 Date

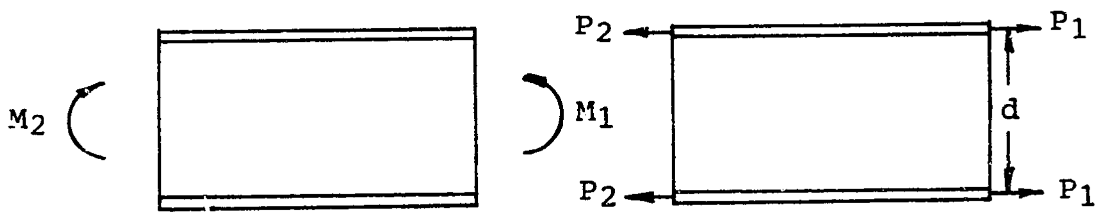
SEGMENT I.D.	CYCLES	STRESS MIN.	STRESS MAX.
21	.7000	2034.50	3069.50
21	.5000	1999.50	3104.50
21	1.0000	1929.50	3174.50
21	.3200	1827.50	3276.50
21	.1280	1728.50	3375.50
21	.0370	1629.50	3474.50
21	.0110	1530.50	3573.50
21	.0030	1431.50	3672.50
13	662.0000	8800.00	14100.00
13	96.5000	4200.00	20300.00
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	3375.50
21	.0370	1629.50	3474.50
21	.0110	1530.50	3573.50
21	.0030	1431.50	3672.50

Figure 2.15 PA 32-300 Spectra Defining 2 Hour "Pipeline Survey Mission"

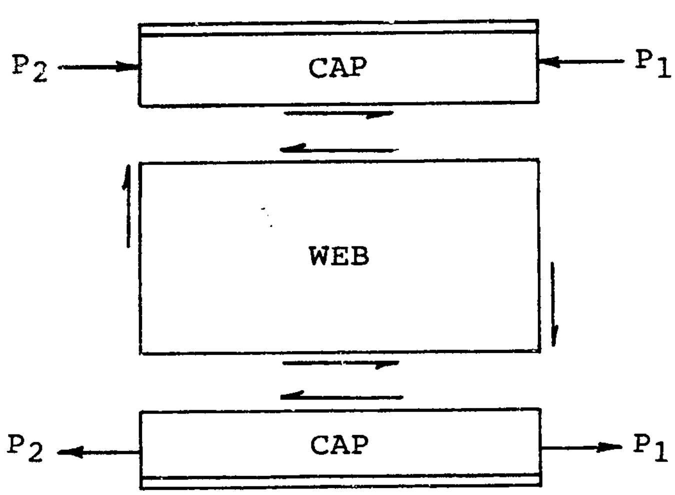
3.0 FINITE ELEMENT MODEL

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 P_1d, where $P_1d = M_1$

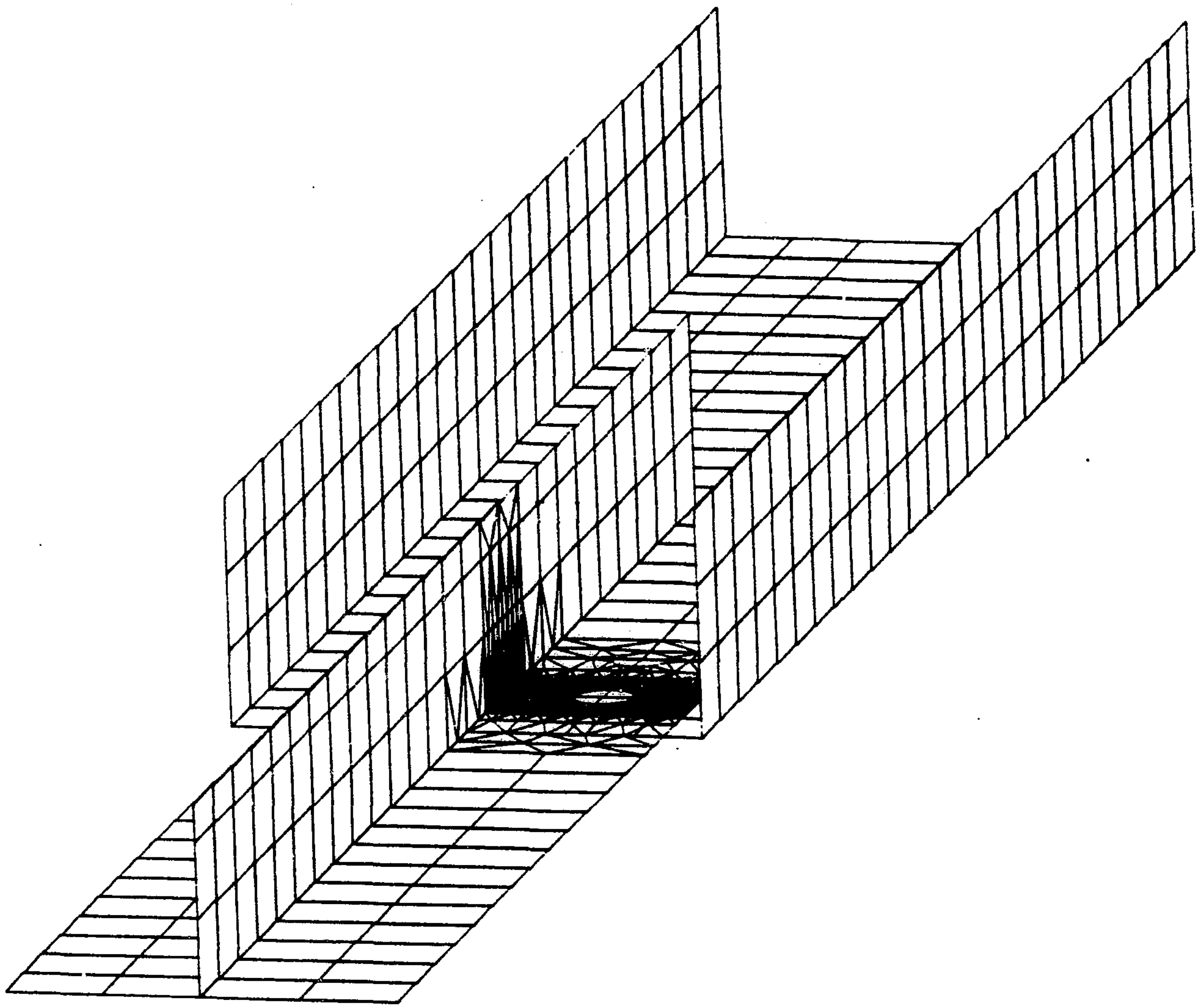


(2) The beam is also assumed to react as three parts. The upper and lower beam caps react the axial force P, while the web between the caps reacts the shear generated by differing moments.



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.



PIPER SPAR CONNECTION

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

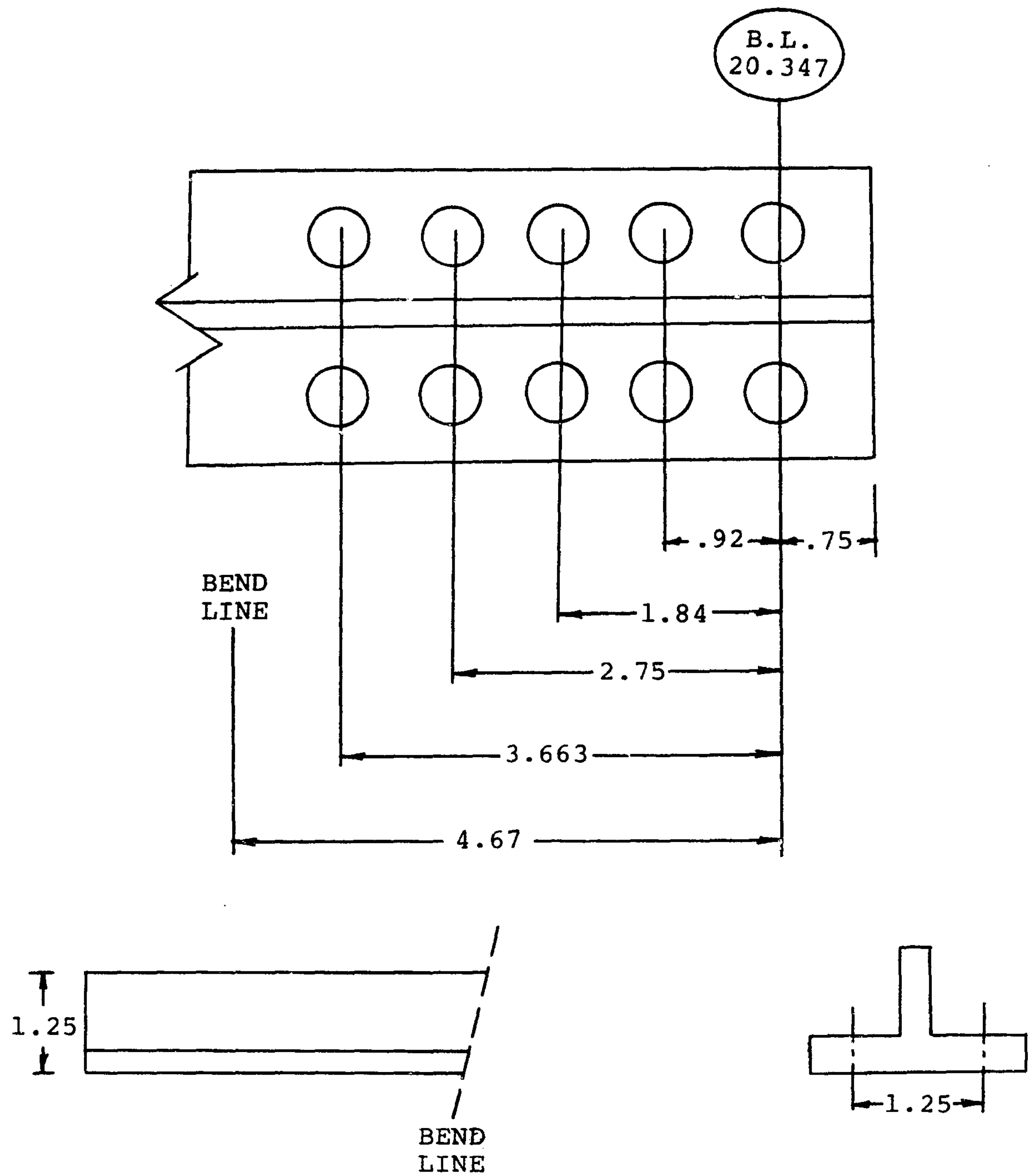


Figure 3.2 Main Spar Section

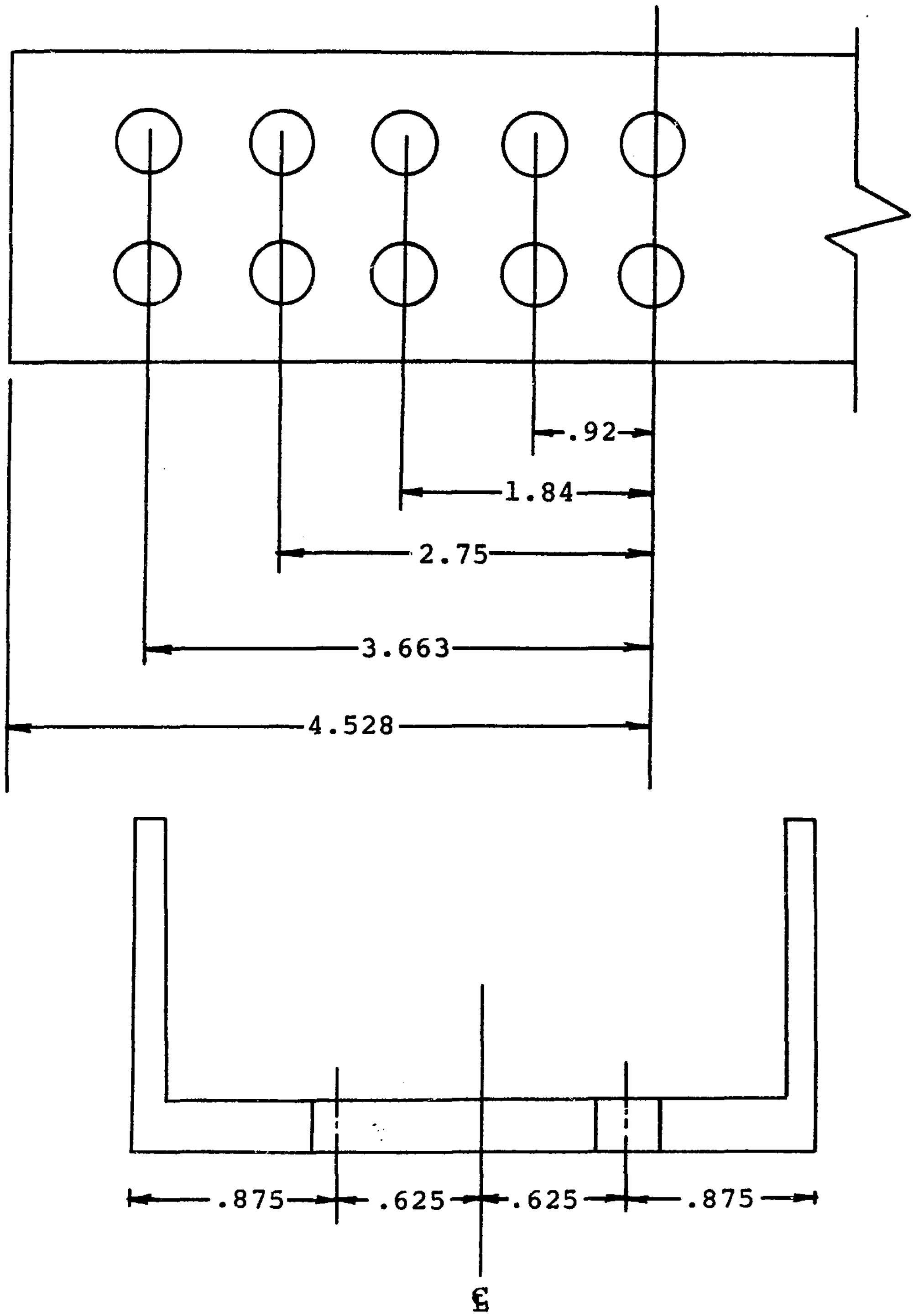


Figure 3.3 Channel Section

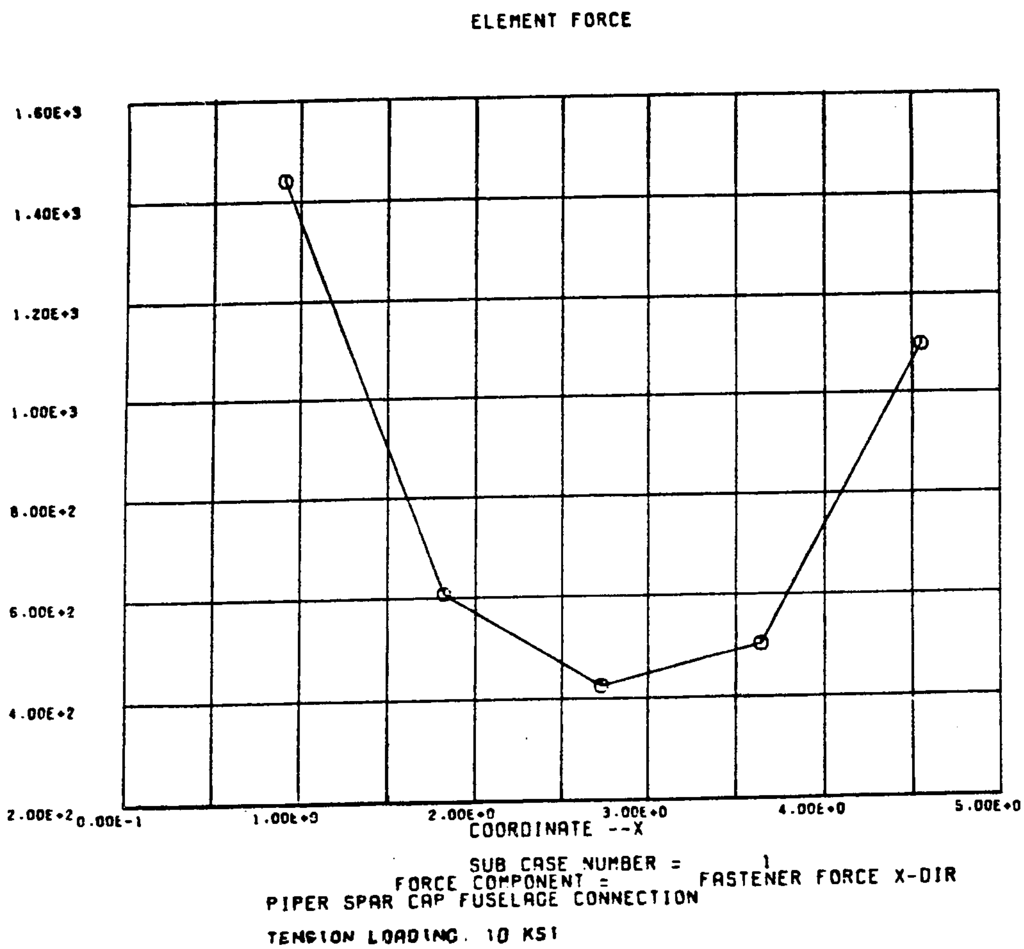
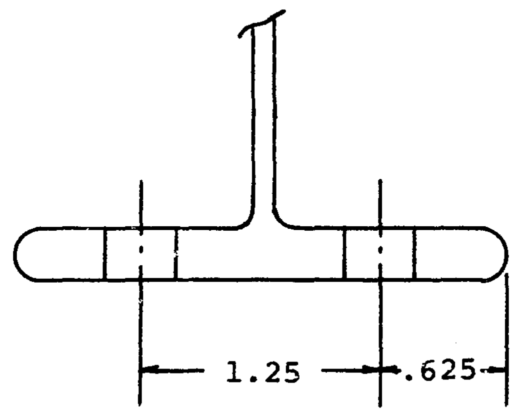


Figure 3.4 Load Distribution Along Critical Fastener Row



P	σ_1	σ_2	t	σ_{BRG}	$\sigma_{BRG}/\sigma_{AVG}$	ρ	FSTNR. HOLE DIA.
1,441	10,820	6,963	.275	13,970	1.57	.822	.375

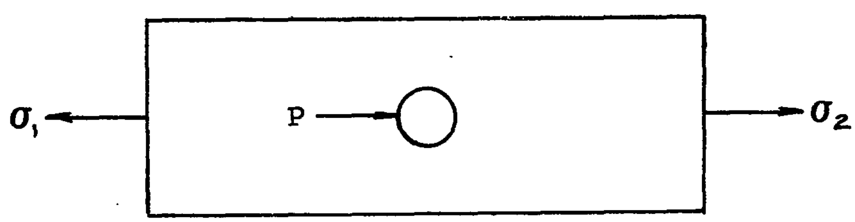


Figure 3.5 Load Transfer Effects

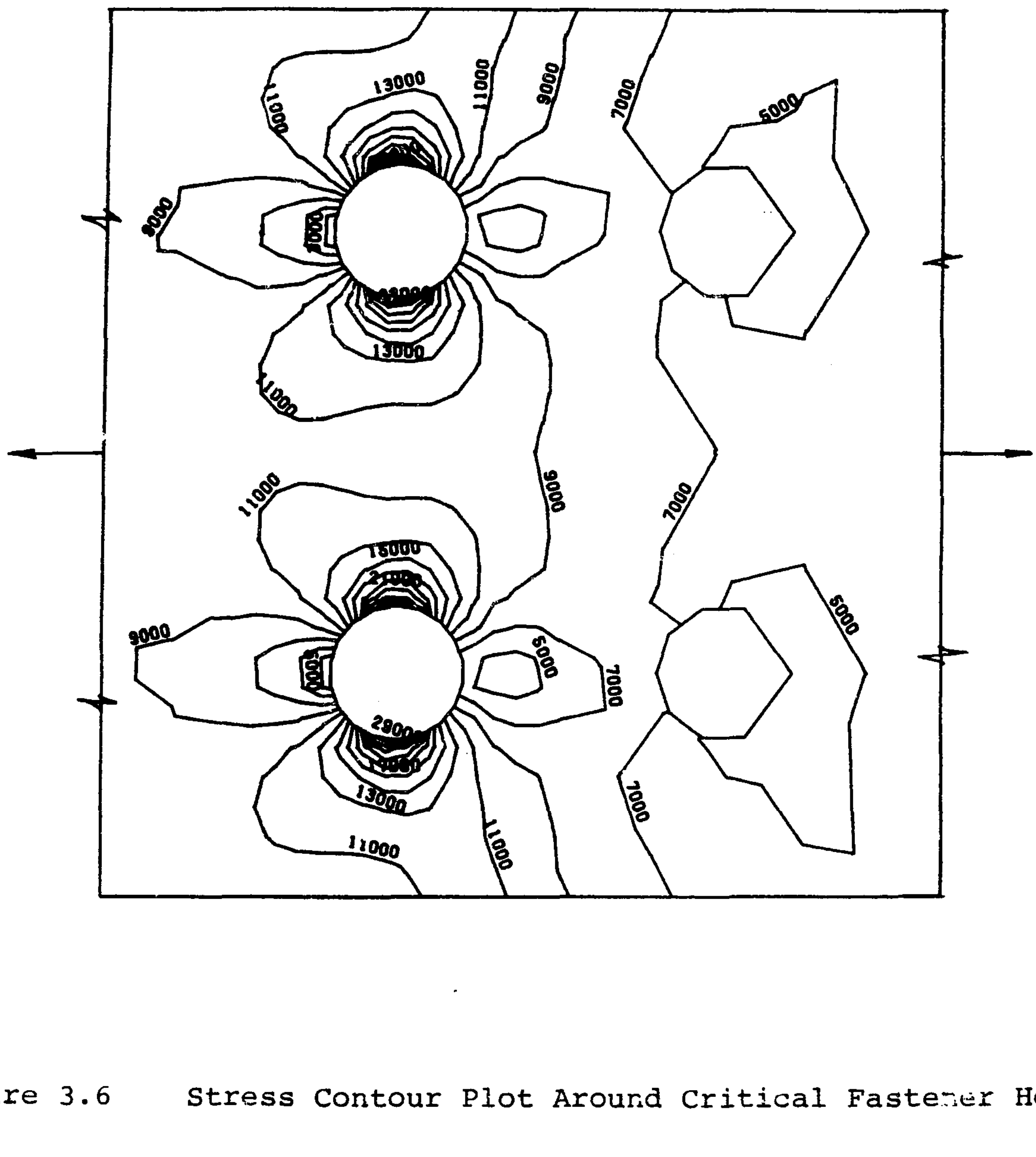


Figure 3.6 Stress Contour Plot Around Critical Fastener Holes

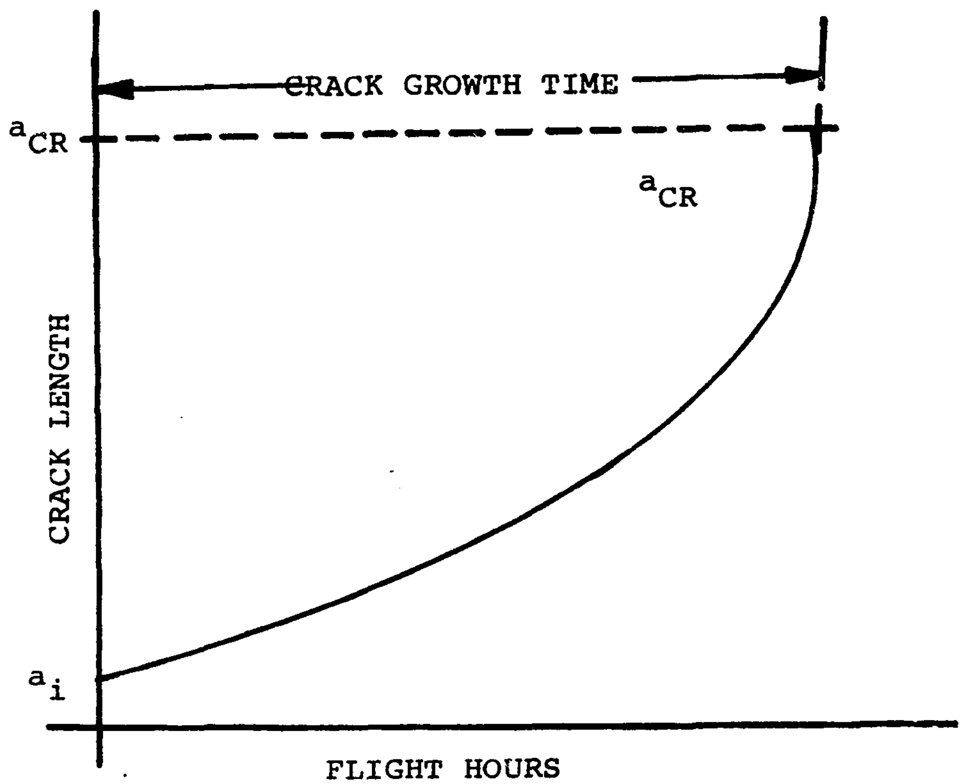
4.0 DAMAGE TOLERANCE ASSESSMENT CRITERIA

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.

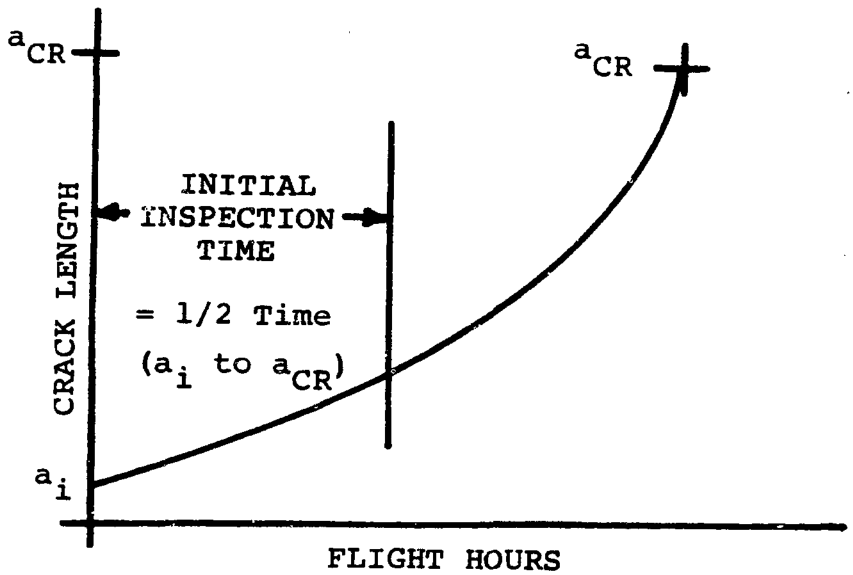
The Critical Crack Size is defined as the crack length beyond which it is recommended not to operate the aircraft without appropriate inspections, repairs, or modifications.

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.



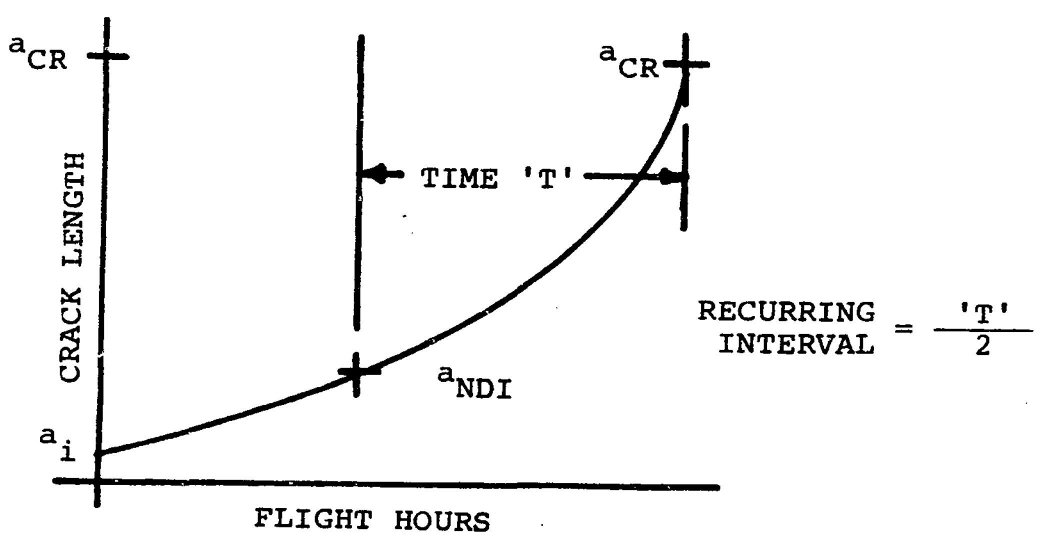
4.2 INITIAL INSPECTION

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}).



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.

Prepared b[redacted] Date Checked by [redacted] Date Approved [redacted]

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

Prepared by [redacted] /88 Checked by [redacted] 4/11/88 Date Approved by [redacted] 4/11/88 Date

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 [redacted] Checked by [redacted] 1/5/88 Date Approved by [redacted] Date

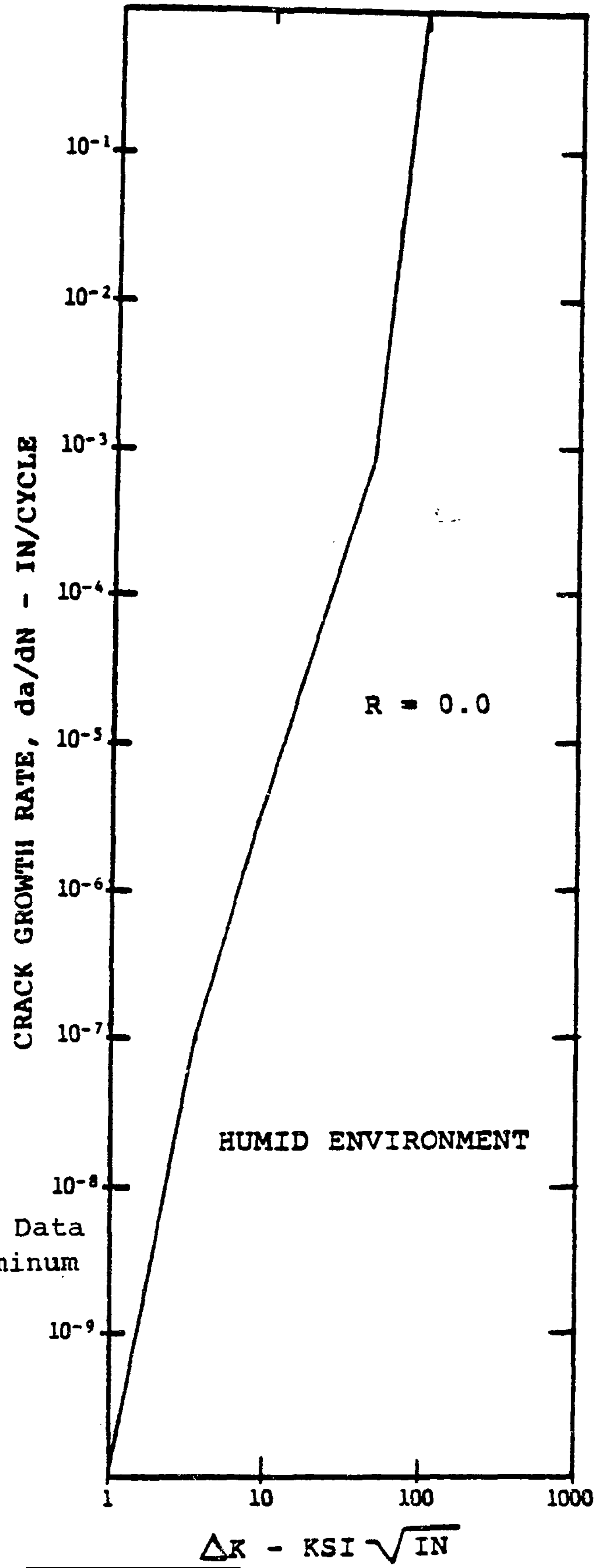


Figure 5.1 DADTA da/dn Data 2024-T3 Aluminum Sheet

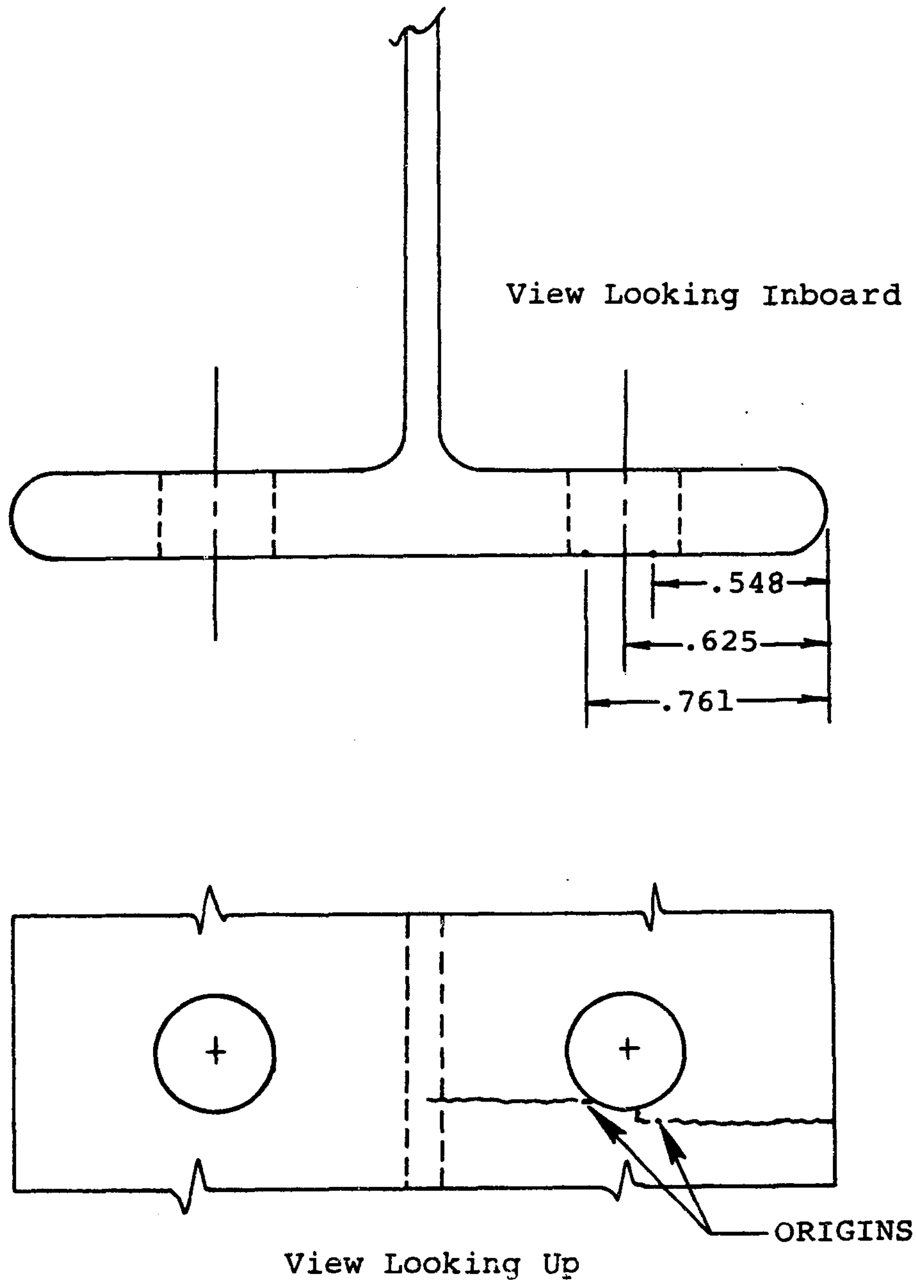
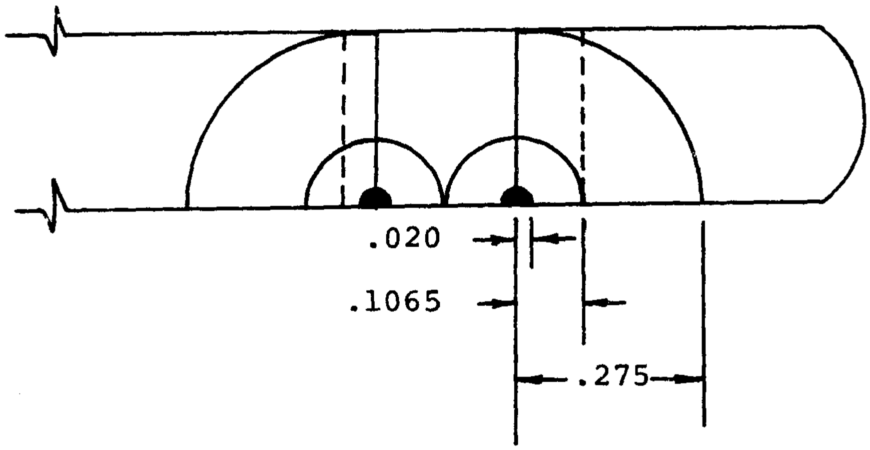


Figure 5.2 Fracture Origins and Crack Location



ASSUMED INITIAL FLAW

		PA 28-181	PA 32-300
PHASE I	.020 - .1065	7,677 Hrs.	3,704 Hrs.
PHASE II	.1065 - .275	211 Hrs.	100 Hrs.
	TOTAL	7,888 Hrs.	3,804 Hrs.

EQUIVALENT INITIAL FLAW

		PA 28-181	PA 32-300
PHASE I	.0207 - .1065	7,277 Hrs.	3,558 Hrs.
PHASE II	.1065 - .275	211 Hrs.	100 Hrs.
	TOTAL	7,488 Hrs.	3,658 Hrs.

Figure 5.3 Phased Crack Growth

Prepared by [redacted] Date Checked by [redacted] Date Approved by [redacted] 4/11/88 Date

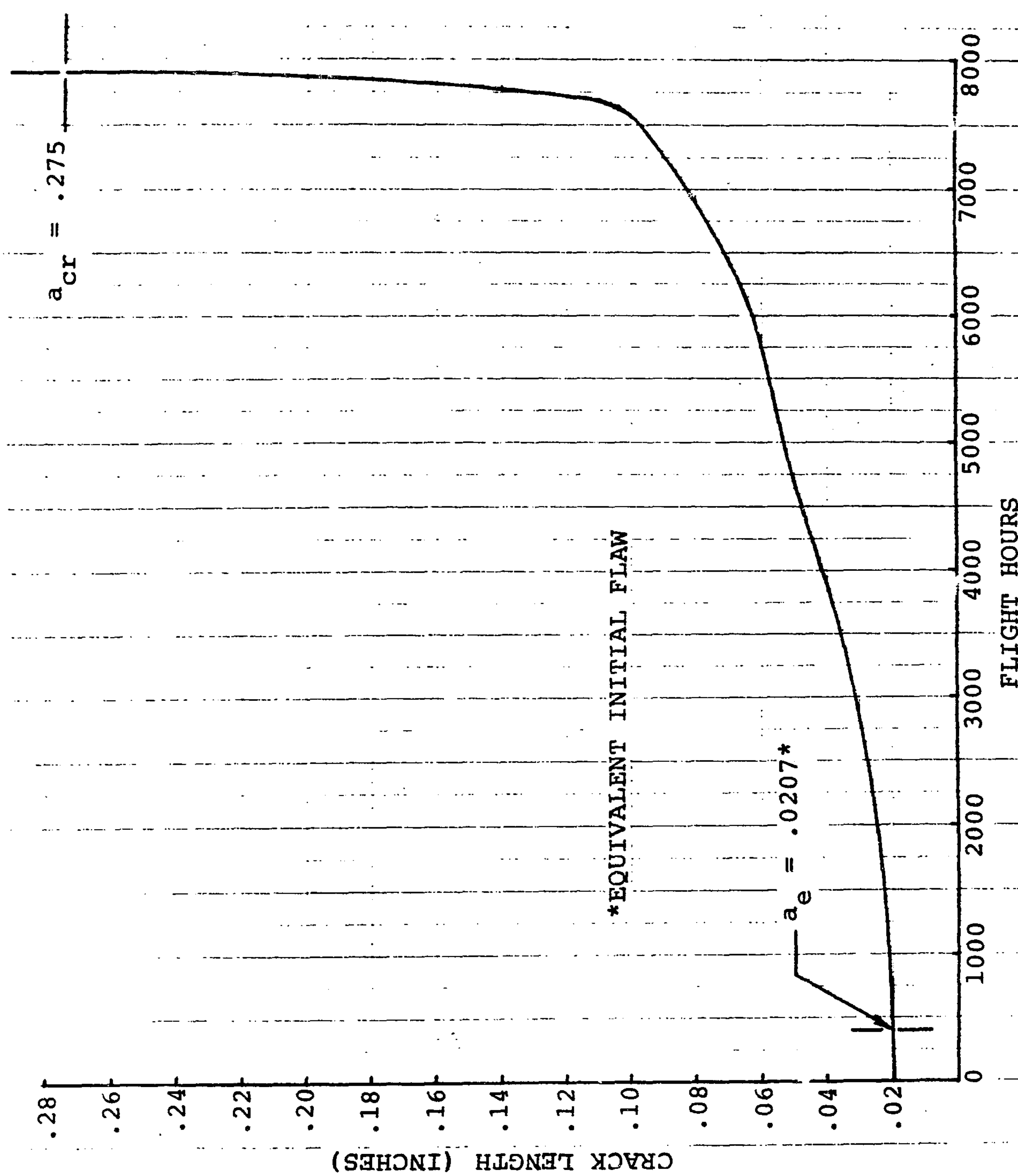


Figure 5.4 PA 28-181 Crack Growth Curve

Prepared by [redacted] /11/88 Checked by [redacted] 88 Date Approved by [redacted] 4/11/88 Date

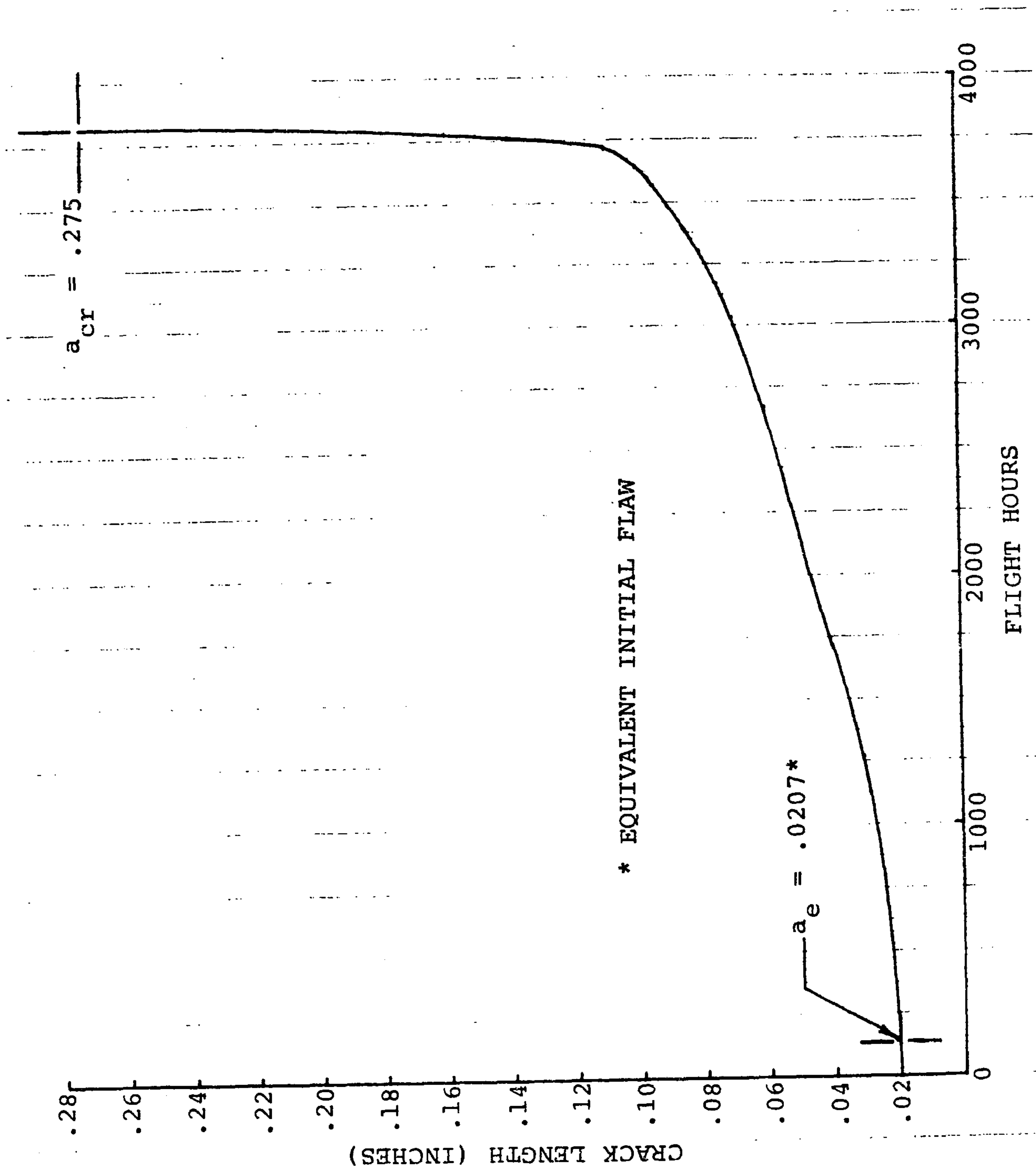


Figure 5.5 PA 32-300 Crack Growth Curve

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.

APPENDIX G

PIPER FATIGUE ANALYSIS

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.

PAC FATIGUE ANALYSIS

TABLE OF CONTENTS

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

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

T.O.		
55% Fuel, GW	=	2178 FS95.9
Ldg		
45% Fuel, GW	=	2148 FS95.9

Utility (Pipeline)

Typical empty Wt	=	1593 lbs
1 occupant	=	170
Baggage	=	60
70% Fuel	=	210
Flight GW	=	2033 lbs. FS96.7

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

PA-32-300

3.8 Normal

Normal

Typical empty Wt	=	1958 lbs
3 occupants	=	510
Baggage	=	120
50% Fuel	=	252
Flight GW	=	2840 lbs. FS79.5

T.O.
55% Fuel, GW = 2865 FS79.6
Ldg
45% Fuel, GW = 2815 FS79.4

Utility (Pipeline)

Typical empty Wt	=	1958 lbs
1 occupant	=	170
Baggage	=	60
70% Fuel	=	353
Flight GW	=	2541 lbs.

T.O.
85% Fuel, GW = 2617 FS77.6
Ldg
55% Fuel, GW = 2465 FS76.6

** V-N DIAGRAM **

UTILITY CATEGORY
GROSS WEIGHT= 2033. LBS
PIPELINE USEAGE

CONDITION	VELOCITY (MPH)	MANEUVER LOAD FACTOR (G'S)	GUST LOAD FACTOR (G'S)
STALL	58.5	1.00	
A	122.6	4.40	
C	132.3	4.40	3.53
D	206.0	4.40	2.97
E	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

CONDITION	VELOCITY (MPH)	MANEUVER LOAD FACTOR (G'S)	GUST LOAD FACTOR (G'S)
F-D STALL	50.2	1.0	
VF	115.0	2.00	2.10
VF	115.0	2.00	-0.10

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

GROSS WEIGHT= 2033. LBS C.G.=0.0400 MAC
(INCLUDES THRU AMENDMENT 6)
PIPELINE USEAGE

BALANCE TAIL LOADS
FAR 23.421

COND	VEL	CMFN	WING PROPERTIES CN	CL	CMW	LOAD FACTORS NX	NZ	NZ-W	THR	BTL
	(MPH)	(DLS)	(DLS)	(DLS)	(DLS)	(G'S)	(G'S)	(G'S)	(G'S)	(LBS)
A	123.	0.090	1.456	1.523	-0.065	-1.376	4.400	4.680	-0.230	-570.
C	132.	0.072	1.259	1.296	-0.065	-1.093	4.400	4.712	-0.213	-634.
D	206.	0.017	0.542	0.542	-0.065	-0.108	4.400	4.919	-0.137	-1055.
E	206.	-0.008	-0.092	-0.091	-0.065	0.027	-1.000	-0.832	-0.137	-341.
F	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.
FD	115.	0.064	0.878	0.881	-0.266	-0.240	2.099	2.482	-0.245	-780.
2/3A	123.	0.050	0.990	1.003	-0.065	-0.483	2.933	3.183	-0.230	-508.
2/3C	132.	0.041	0.856	0.862	-0.065	-0.371	2.933	3.202	-0.213	-547.
2/3D	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)

CONDITION	VELOCITY	BTL	DELTA TAIL LOAD	Z-LOAD FACTOR	PTH ACC	CHKD-MAN TAIL LOAD
	(MPH)	(LBS)	(LBS)	(G'S)	(RPSS)	(LBS)
A-NOSE UP	122.6	-320.4	-511.3	1.000	4.68	-831.7
C-NOSE UP	132.3	-345.5	-473.9	1.000	4.34	-819.4
D-NOSE UP	206.0	-604.1	-304.3	1.000	2.79	-908.5
A-NOSE DOWN	122.6	-570.2	511.3	4.400	-4.68	-58.9
C-NOSE DOWN	132.3	-634.4	473.9	4.400	-4.34	-160.5
D-NOSE DOWN	206.0	-1054.9	304.3	4.400	-2.79	-750.6

GUST TAIL LOADS
FAR 23.425

CONDITION	VELOCITY	BALANCE TAIL LOAD	DELTA TAIL LOAD	TOTAL GUST TAIL LOAD
	(MPH)	(LBS)	(LBS)	(LBS)
C	132.3	-345.51	467.1	121.6
D	206.0	-604.12	363.6	-240.5
FLP-DWN	115.0	-679.76	203.0	-476.8
C	132.3	-345.51	467.1	-812.6
D	206.0	-604.12	363.6	-967.7
FLP-DWN	115.0	-679.76	203.0	-882.8

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. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
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.	-939.
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	308.7	10848.	8.3	362.	-1892.
106.19	406.5	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	888.2	61683.	20.7	1577.	-2432.
21.88	1005.7	75262.	23.8	1896.	-1912.
10.00	1107.2	87813.	26.2	2193.	-1425.
0.00	1189.3	99295.	27.9	2464.	-1249.

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

GROSS WEIGHT= 2033.0 LBS V=132.0 MPH NZ= 4.400 NX=-1.093

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
211.57	0.0	0.	0.0	0.	0.
207.90	12.4	23.	-1.2	-2.	-43.
190.90	187.1	1719.	-28.8	-257.	618.
174.00	447.2	7079.	-78.6	-1164.	1975.
157.00	755.8	17305.	-141.0	-3030.	3799.
148.60	922.8	24355.	-179.1	-4358.	4858.
140.09	1100.4	32964.	-211.3	-6002.	6032.
131.60	1285.1	43091.	-248.7	-7955.	7300.
123.15	1476.5	54758.	-287.1	-10218.	8662.
106.19	1883.2	83249.	-367.7	-15771.	11715.
96.00	2138.1	103737.	-417.7	-19773.	13694.
88.75	2322.0	119905.	-453.8	-22932.	15130.
64.59	2954.8	183650.	-577.3	-35388.	20135.
57.00	3157.3	206845.	-616.0	-39917.	21747.
49.25	3361.6	232106.	-654.0	-44838.	23367.
36.22	3713.3	278195.	-718.2	-53777.	26792.
21.88	4135.8	334477.	-794.7	-64624.	32558.
10.00	4498.1	385763.	-869.8	-74458.	37491.
0.00	4789.7	432202.	-915.1	-83337.	40378.

** V-N DIAGRAM **

NORMAL CATEGORY
GROSS WEIGHT= 2163. LBS
NORMAL USAGE

CONDITION	VELOCITY (MPH)	MANEUVER LOAD FACTOR (G'S)	GUST LOAD FACTOR (G'S)
STALL	60.3	1.00	
A	117.5	3.80	
C	132.3	3.80	3.41
D	206.0	3.80	2.88
E	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	
VF	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

GROSS WEIGHT= 2163. LBS C.G.=0.1000 MAC
(INCLUDES THRU AMENDMENT 6)
NORMAL USEAGE

BALANCE TAIL LOADS
FAR 23.421

COND	VEL	CMFN	WING PROPERTIES CN	CL	CMW	LOAD FACTORS NX	NZ	NZ-W	THR	BTL
	(MPH)	(DLS)	(DLS)	(DLS)	(DLS)	(G'S)	(G'S)	(G'S)	(G'S)	(LBS)
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	-824.
E	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.
1G-A	118.	0.016	0.405	0.405	-0.065	-0.015	1.000	1.125	-0.226	-270.
1G-C	132.	0.012	0.325	0.325	-0.065	0.006	1.000	1.142	-0.200	-307.
1G-D	206.	0.003	0.148	0.148	-0.065	0.070	1.000	1.262	-0.129	-567.
FD	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.
2/3C	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
FAR 23.423 (B)

CONDITION	VELOCITY	BTL	DELTA TAIL LOAD	Z-LOAD FACTOR	PTH ACC	CHKD-MAN TAIL LOAD
	(MPH)	(LBS)	(LBS)	(G'S)	(RPSS)	(LBS)
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

GUST TAIL LOADS
FAR 23.425

CONDITION	VELOCITY	BALANCE TAIL LOAD	DELTA TAIL LOAD	TOTAL GUST TAIL LOAD
	(MPH)	(LBS)	(LBS)	(LBS)
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 GRP

PIPER AIRCRAFT CORP
VERO BEACH ENGINEERING

PAGE NO G2-11
REPT NO VB-1337
MODEL NO PA28-181

DATE 8-OCT-87

FATIGUE LOADS (NORMAL USEAGE) - 2163 LBS AT .10MAC

GROSS WEIGHT= 2163.0 LBS V=132.0 MPH NZ= 1.000 NX= 0.006

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
211.57	0.0	0.	0.0	0.	0.
207.90	2.2	4.	0.4	1.	-118.
190.90	35.4	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.	-1493.
131.60	277.4	8875.	6.7	275.	-1629.
123.15	323.8	11415.	7.5	335.	-1750.
106.19	425.5	17770.	9.3	477.	-1931.
96.00	491.3	22441.	10.4	577.	-2053.
88.75	539.7	26178.	11.3	656.	-2118.
64.59	711.2	41288.	14.2	963.	-2189.
57.00	767.4	46900.	15.1	1074.	-2186.
49.25	824.6	53069.	16.3	1196.	-2185.
36.22	924.3	64463.	18.6	1423.	-2[illegible].
21.88	1045.6	78587.	21.4	1710.	-13[illegible].
10.00	1150.3	91630.	23.6	1978.	-[illegible].
0.00	1235.1	103557.	25.2	2222.	-[illegible]7.

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STRUCT GRP	PIPER AIRCRAFT CORP VERO BEACH ENGINEERING	PAGE NO G2-12 REPT NO VB-1337 MODEL NO PA28-181
DATE 8-OCT-87		

FATIGUE LOADS (NORMAL USEAGE) - 2163 LBS AT .10MAC

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

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
211.57	0.0	0.	0.0	0.	0.
207.90	11.1	20.	-0.7	-1.	-54.
190.90	167.4	1538.	-19.8	-176.	463.
174.00	401.2	6343.	-55.6	-813.	1598.
157.00	679.2	15526.	-100.9	-2143.	3144.
148.60	829.8	21864.	-125.8	-3095.	4047.
140.09	990.2	29608.	-152.4	-4279.	5051.
131.60	1157.0	38722.	-180.0	-5690.	6137.
123.15	1329.9	49229.	-208.4	-7330.	7306.
106.19	1697.8	74904.	-268.3	-11373.	9932.
96.00	1928.5	93380.	-305.7	-14297.	11639.
88.75	2095.1	107966.	-332.8	-16612.	12879.
64.59	2668.8	165513.	-426.4	-25784.	17216.
57.00	2852.4	186466.	-455.8	-29132.	18616.
49.25	3037.8	209291.	-484.5	-32775.	20022.
36.22	3357.0	250953.	-532.6	-39401.	23014.
21.88	3740.7	301843.	-590.0	-47450.	28095.
10.00	4069.8	348237.	-640.1	-54757.	32447.
0.00	4334.7	390260.	-681.7	-61366.	34979.

** V-N DIAGRAM **

NORMAL CATEGORY
GROSS WEIGHT= 2541. LBS
PIPELING USEAGE

CONDITION	VELOCITY (MPH)	MANEUVER LOAD FACTOR (G'S)	GUST LOAD FACTOR (G'S)
STALL	65.9	1.00	
A	128.4	3.80	
C	151.2	3.80	3.49
D	235.0	3.80	2.93
E	235.0	0.00	-0.93
F	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
VF	125.0	2.00	-0.03

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

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

BALANCE TAIL LOADS
FAR 23.421

CCND	VEL (MPH)	CMFN (DLS)	WING PROPERTIES CN (DLS)	CL (DLS)	CMW (DLS)	NX (G'S)	LOAD FACTORS NZ (G'S)	NZ- [illegible]	[illegible]	[illegible]
A	128.	0.038	1.425	1.499	-0.065	-1.255	3.800	4.128	-0.293	-832.
C	151.	0.015	1.043	1.059	-0.065	-0.678	3.800	4.188	-0.249	-986.
D	235.	-0.006	0.450	0.450	-0.065	-0.121	3.800	4.366	-0.160	-1438.
E	235.	-0.021	-0.074	-0.074	-0.065	0.081	-0.932	-0.721	-0.160	-535.
F	151.	-0.031	-0.377	-0.379	-0.065	-0.131	-1.520	-1.515	-0.249	-13.
G	95.	-0.051	-0.994	-1.024	-0.065	-0.381	-1.520	-1.582	-0.395	158.
1G-A	128.	-0.007	0.405	0.405	-0.065	-0.021	1.000	1.174	-0.293	-443.
1G-C	151.	-0.010	0.300	0.300	-0.065	0.007	1.000	1.204	-0.249	-518.
1G-D	235.	-0.015	0.140	0.140	-0.065	0.073	1.000	1.358	-0.160	-911.
FD	125.	0.015	0.893	0.891	-0.266	-0.065	2.028	2.451	-0.301	-1075.
2/3A	128.	0.012	0.970	0.981	-0.065	-0.392	2.533	2.809	-0.293	-701.
2/3C	151.	0.002	0.709	0.711	-0.065	-0.229	2.533	2.845	-0.249	-793.
2/3D	235.	-0.010	0.310	0.310	-0.065	0.010	2.533	3.007	-0.160	-1204.

MANEUVER TAIL LOADS
FAR 23.423 (A)
MAX UP ELEVATOR= -653. LBS
MAX DOWN ELEVATOR= 683. LBS

CHECKED MANEUVER TAIL LOADS
FAR 23.423 (B)

CONDITION	VELOCITY (MPH)	BTL (LBS)	DELTA TAIL LOAD (LBS)	Z-LOAD FACTOR (G'S)	PTH ACC (RPSS)	CHKD-MAN TAIL LOAD (LBS)
A-NOSE UP	128.4	-442.9	-482.4	1.000	3.06	-925.4
C-NOSE UP	151.2	-517.5	-409.8	1.000	[illegible]	[illegible]
D-NOSE UP	235.0	-910.6	-263.7	1.000	1.67	-1174.3
A-NOSE DOWN	128.4	-832.4	482.4	3.800	-3.06	-349.9
C-NOSE DOWN	151.2	-985.5	409.8	3.800	-2.60	-575.8
D-NOSE DOWN	235.0	-1437.7	263.7	3.800	-1.67	-1174.1

GUST TAIL LOADS
FAR 23.425

CONDITION	VELOCITY (MPH)	BALANCE TAIL LOAD (LBS)	DELTA TAIL LOAD (LBS)	TOTAL GUST TAIL LOAD (LBS)
C	151.2	-517.55	396.5	-121.0
D	235.0	-910.63	308.2	-602.5
FLP-DWN	125.0	-890.27	163.9	-726.4
C	151.2	-517.55	396.5	-914.1
D	235.0	-910.63	308.2	-1218.8
FLP-DWN	125.0	-890.27	163.9	-1054.2

FATIGUE LOADS (PIPELINE USEAGE) - 2541 LBS AT .003 IAC

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

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
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.
160.00	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.

STRUCT GRP

DATE 8-OCT-87

PIPER AIRCRAFT CORP
VERO BEACH ENGINEERING

PAGE NO G2-16
REPT NO VB-1337
MODEL NO PA 32-300

FATIGUE LOADS (PIPELINE USEAGE) - 2541 LBS AT .003 UC

GROSS WEIGHT= 2541.0 LBS V=151.2 MPH NZ= 3.800 NX=-0.078

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
194.53	0.0	0.	0.0	0.	0.
181.35	103.8	684.	-6.6	-44.	-855.
172.05	267.6	2411.	-19.5	-165.	-2019.
160.00	518.5	7147.	-43.7	-546.	-3572.
147.70	803.1	15275.	-74.6	-1273.	-5191.
137.00	1068.7	25289.	-105.5	-2236.	-6619.
125.45	1369.4	39369.	-142.0	-3666.	-8177.
116.00	1624.3	53514.	-173.9	-5158.	-9462.
106.19	1896.4	70783.	-208.6	-7035.	-10805.
96.00	2186.1	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.	-19481.
0.00	5205.5	442009.	-627.8	-51151.	-19672.
-3.49	5320.9	460377.	-642.8	-53369.	-20116.

** V-N DIAGRAM **

NORMAL CATEGORY
GROSS WEIGHT= 2840. LBS
NORMAL USEAGE

CONDITION	VELOCITY (MPH)	MANEUVER LOAD FACTOR (G'S)	GUST LOAD FACTOR (G'S)
STALL	69.7	1.00	
A	135.8	3.80	
C	151.2	3.80	3.28
D	235.0	3.80	2.77
E	235.0	0.00	-0.77
F	151.2	-1.52	-1.28
G	100.6	-1.52	
NEG STALL	81.6	-1.00	

FLAPS DOWN ENVELOPE

F-D STALL	58.6	1.0	
VF	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 AIRCRAFT POLICY
5) INCLUDES THRU AMENDMENT 6

GROSS WEIGHT= 2840. LBS   C.G.=0.0400 MAC

(INCLUDES THRU AMENDMENT 6)

NORMAL USAGE

BALANCE TAIL LOADS

FAR 23.421

COND	VEL	CMFN	WING PROPERTIES CN	CL	CMW	LOAD FACTORS NX	NZ	NZ-W	THR	BTL
	(MPH)	(DLS)	(DLS)	(DLS)	(DLS)	(G'S)	(G'S)	(G'S)	(G'S)	(LBS)
A	136.	0.038	1.408	1.481	-0.065	-1.254	3.800	4.078	-0.248	-790.
C	151.	0.021	1.147	1.172	-0.065	-0.818	3.800	4.120	-0.223	-910.
D	235.	-0.004	0.494	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.
1G-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.
2/3A	136.	0.011	0.958	0.969	-0.065	-0.385	2.533	2.776	-0.248	-689.
2/3C	151.	0.005	0.779	0.783	-0.065	-0.268	2.533	2.799	-0.223	-756.
2/3D	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

FAR 23.423 (B)

CONDITION	VELOCITY	BTL	DELTA TAIL LOAD	Z-LOAD FACTOR	PTH ACC	CHKD-MAN TAIL LOAD
	(MPH)	(LBS)	(LBS)	(G'S)	(RPSS)	(LBS)
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	-1193.6
A-NOSE 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	-451.9
D-NOSE DOWN	235.0	-1387.4	294.7	3.800	-1.67	-1092.7

GUST TAIL LOADS

FAR 23.425

CONDITION	VELOCITY	BALANCE TAIL LOAD	DELTA TAIL LOAD	TOTAL GUST TAIL LOAD
	(MPH)	(LBS)	(LBS)	(LBS)
C	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
C	151.2	-505.07	406.2	-911.3
D	235.0	-698.89	315.7	-1214.5
FLP-DWN	125.0	-877.99	167.9	-1045.9

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

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

AIRLOAD LIMIT SHEAR AND MOMENT

STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
194.53	0.0	0.	0.0	0.	0.
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.
116.00	465.4	15001.	10.6	440.	-8115.
106.19	548.4	19974.	11.6	549.	-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.

STRUCT GRP

DATE 8-OCT-87

PIPER AIRCRAFT CORP
VERO BEACH ENGINEERING

PAGE NO G2-20
REPT NO VB-1337
MODEL NO PA32-300

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

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

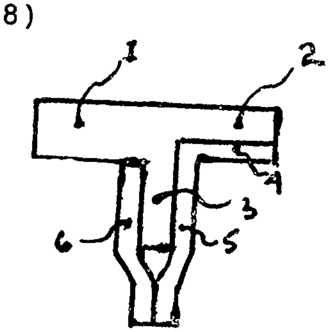
AIRLOAD LIMIT SHEAR AND MOMENT

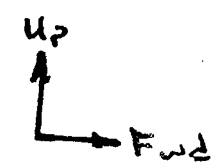
STA. (INS)	VZ (LBS)	MXX (IN-LB)	VX (LBS)	MZZ (IN-LB)	TORQUE (IN-LB)
194.53	0.0	0.	0.0	0.	0.
181.35	115.1	758.	-10.2	-67.	-869.
172.05	296.4	2672.	-29.2	-251.	-2054.
160.00	573.8	7915.	-63.7	-810.	-3639.
147.70	888.0	16905.	-106.9	-1859.	-5293.
137.00	1180.8	27973.	-149.7	-3232.	-6754.
125.45	1512.1	43525.	-199.9	-5251.	-8350.
116.00	1792.5	59139.	-243.5	-7346.	-9666.
106.19	2091.8	78192.	-290.6	-9966.	-11042.
96.00	2410.4	101131.	-341.0	-13184.	-12480.
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[illegible]2[illegible]6.
49.25	3948.6	249461.	-581.3	-3[illegible]7[illegible]4.	-19166.
36.22	4392.6	303804.	-646.0	-42730.	-20290.
21.88	4913.0	370524.	-720.2	-52526.	-19652.
0.00	5724.1	486894.	-841.6	-69612.	-19582.
-3.49	5850.4	507091.	-861.9	-72584.	-20033.

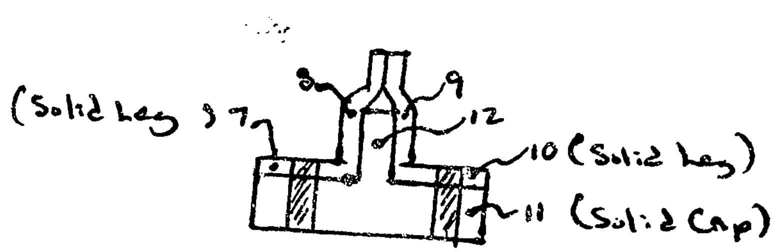
W.S. 20.301 (of 1st Bolt Lwr. Cap)

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

$Z = 11.9807/2.3003$
$= 5.208$ in
$IO_{XX} = 102.4398 - 5.200^2(2.3008)$
$= 40.041$ in^6
$C = 5.208$ in
$\frac{C}{I} = .1301$ in^2







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

Flight Stresses (PSI)

	PA-28-181		PA-32-300	
Usage	1g σ	σ/g	1g σ	σ/g
Normal	8320	8469	9253	8819
Pipeline	7689	7816	9106	8710

Taxi and Landing Impact

Wing Inertia (1g)

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

Fuel Inertia (1g)

PA-28-181 Bending Moment

Normal		Pipeline	
T.O.	Ldg	T.O.	Ldg
4199	3436	6490	4199

PA-32-300 Bending Moment

Normal		Pipeline	
T.O.	Ldg	T.O.	Ldg
18062	16736	22038	18062

Airload - Bending Moment

	Taxi (30 kts)	Landing Impact (2/3g)
PA-28-181		
Normal	25,777	54,198
Pipeline	26,266	50,742
PA-32-300		
Normal	24,591	68,435
Pipeline	24,949	60,891

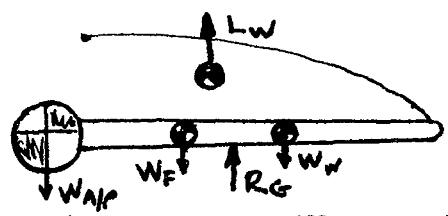
Main Landing Gear Load (1g)

	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

Taxi Stresses (PSI)

Usage	PA-28-181 1g σ and σ/g	PA-32-300 1g σ and σ/g
Normal T.O.	4982	3225
Normal Ldg	5033	3318
Pipeline T.O.	4623	2308
Pipeline Ldg	4774	2574

Landing Impact



L_W = airload (2/3g)
W_W = Wing Wt
W_F = Wing Fuel

is gear reaction $R_G = (W_{A/P} - 2 L_W)/2$

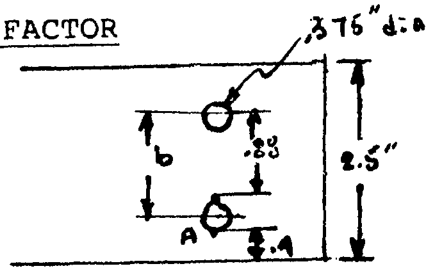
$$BM_{XX} = L_W \Delta Y_A - W_W \Delta Y_W - W_F \Delta Y\ W_W + R_G \Delta Y_G$$

Landing Impact Stresses (PSI)

	PA-28-181		PA-32-300	
Usage	1g σ	σ/g	1g σ	σ/g
Normal	6624	2429	7108	1829
Pipeline	5969	2010	5722	1076

G3 STRESS CONCENTRATION

K_T FACTOR



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

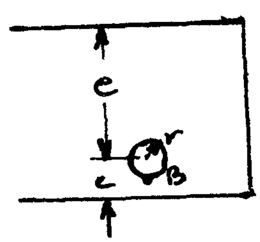
$b = .88 + .375 = 1.26$
$a = .375$
$b/a = \frac{1.26}{.375} = 3.86$

$K_T = 3.02$ AT A

pg 86 Fig 71

$r = .375/2 = .1875$ $e = 1.9125$
$c = .40 + .375/2 = .5875$
$r/c = \frac{.1875}{.5875} = .319$ $e/c = \frac{1.9125}{.5875} = 3.26$

$K_T = 2.32$ AT B



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.

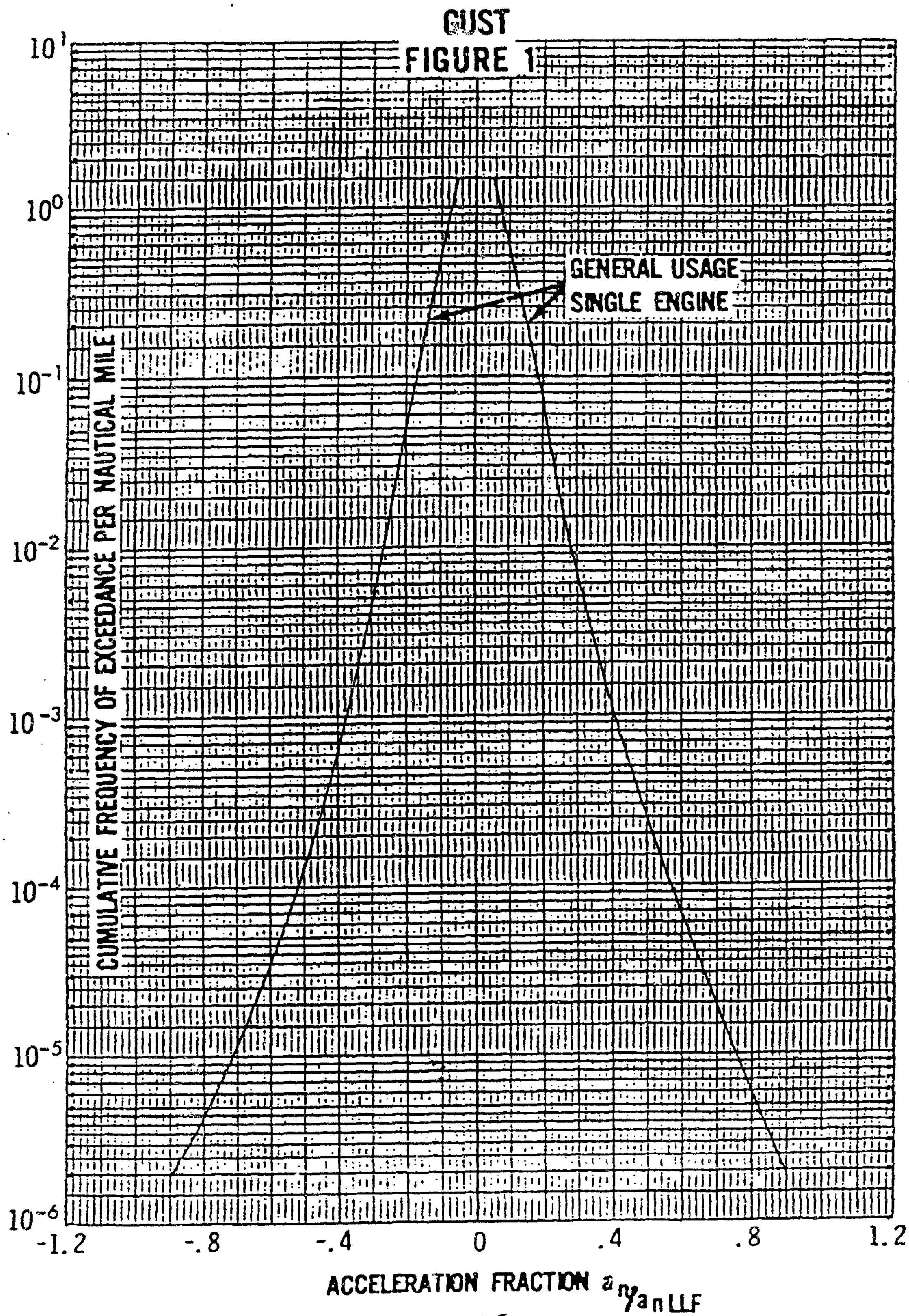
G4 FATIGUE SPECTRUM

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.

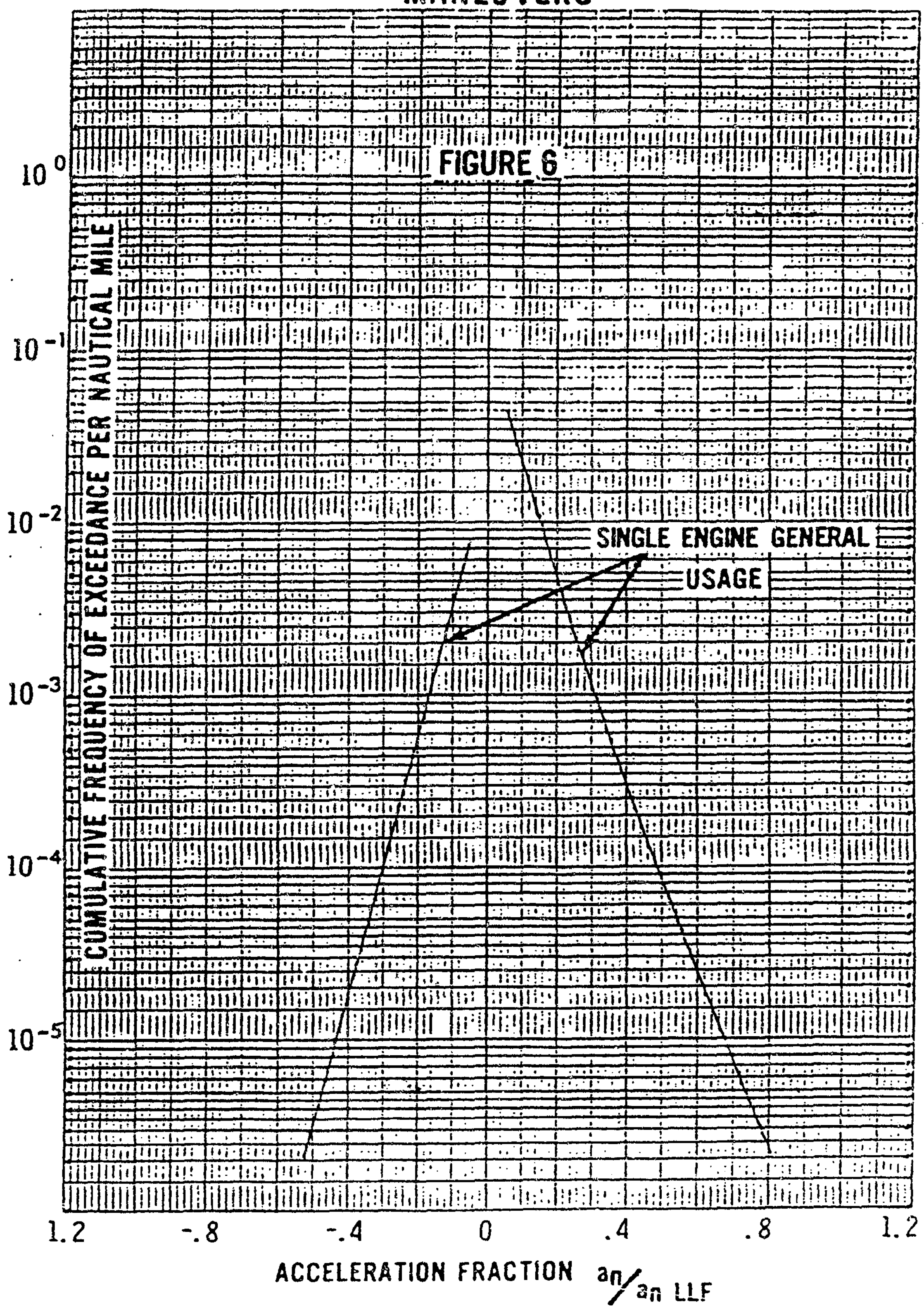
The ground-air-ground (GAG) cycle is defined as the cycle from the minimum (largest negative or smallest positive) stress to the maximum stress experienced on the average of once per flight. This definition of GAG cycle is from reference 1.

Appendix

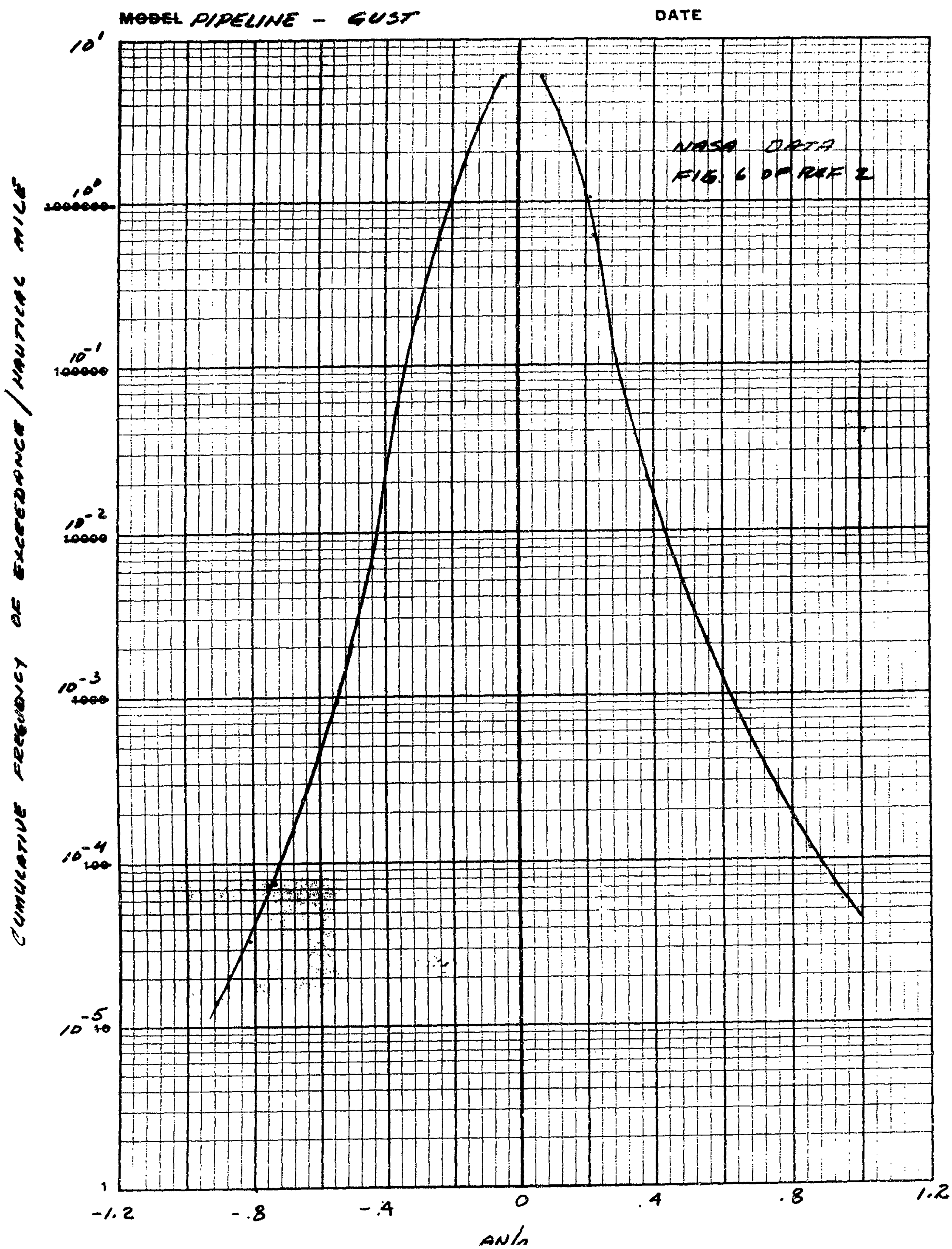

GUST
FIGURE 1
GENERAL USAGE
SINGLE ENGINE
CUMULATIVE FREQUENCY OF EXCEEDANCE PER NAUTICAL MILE
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
-1.2
-.8
-.4
0
.4
.8
1.2
ACCELERATION FRACTION

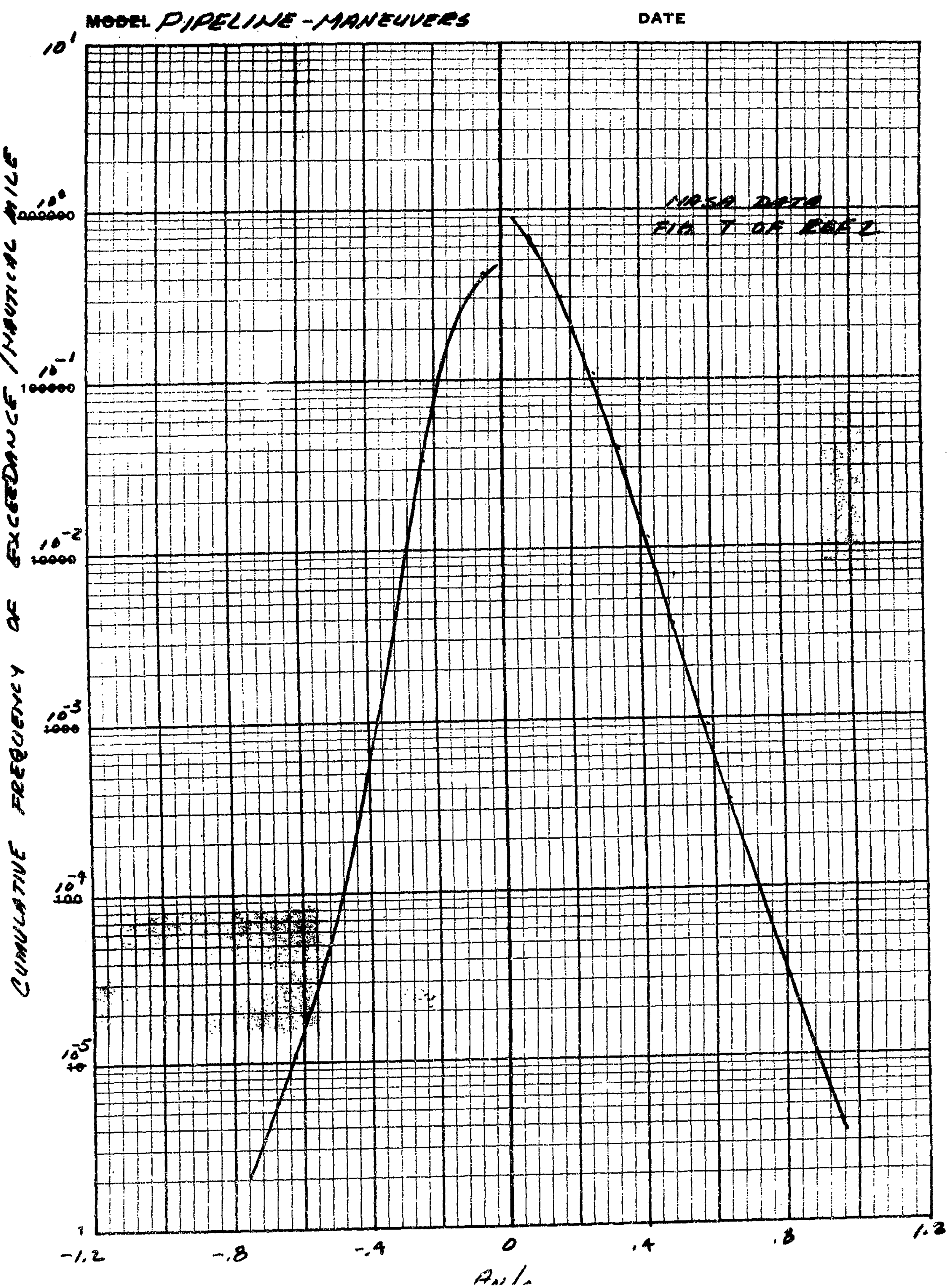
Appendix

MANEUVERS



7114


MODEL PIPELINE - GUST
DATE
NASA DATA
FIG. 6 OF REF 2
CUMULATIVE FREQUENCY OF EXCEEDANCE / NAUTICAL MILE
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
-1.2
-.8
-.4
0
.4
.8
1.2
AN/n
SEMI-LOGARITHMIC 46 6463
7 CYCLES X 60 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


MODEL PIPELINE-MANEUVERS
DATE
NASA DATA
FIG. 7 OF REF 2
CUMULATIVE FREQUENCY OF EXCEEDANCE / NAUTICAL MILE
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
-1.2
-.8
-.4
0
.4
.8
1.2

Appendix

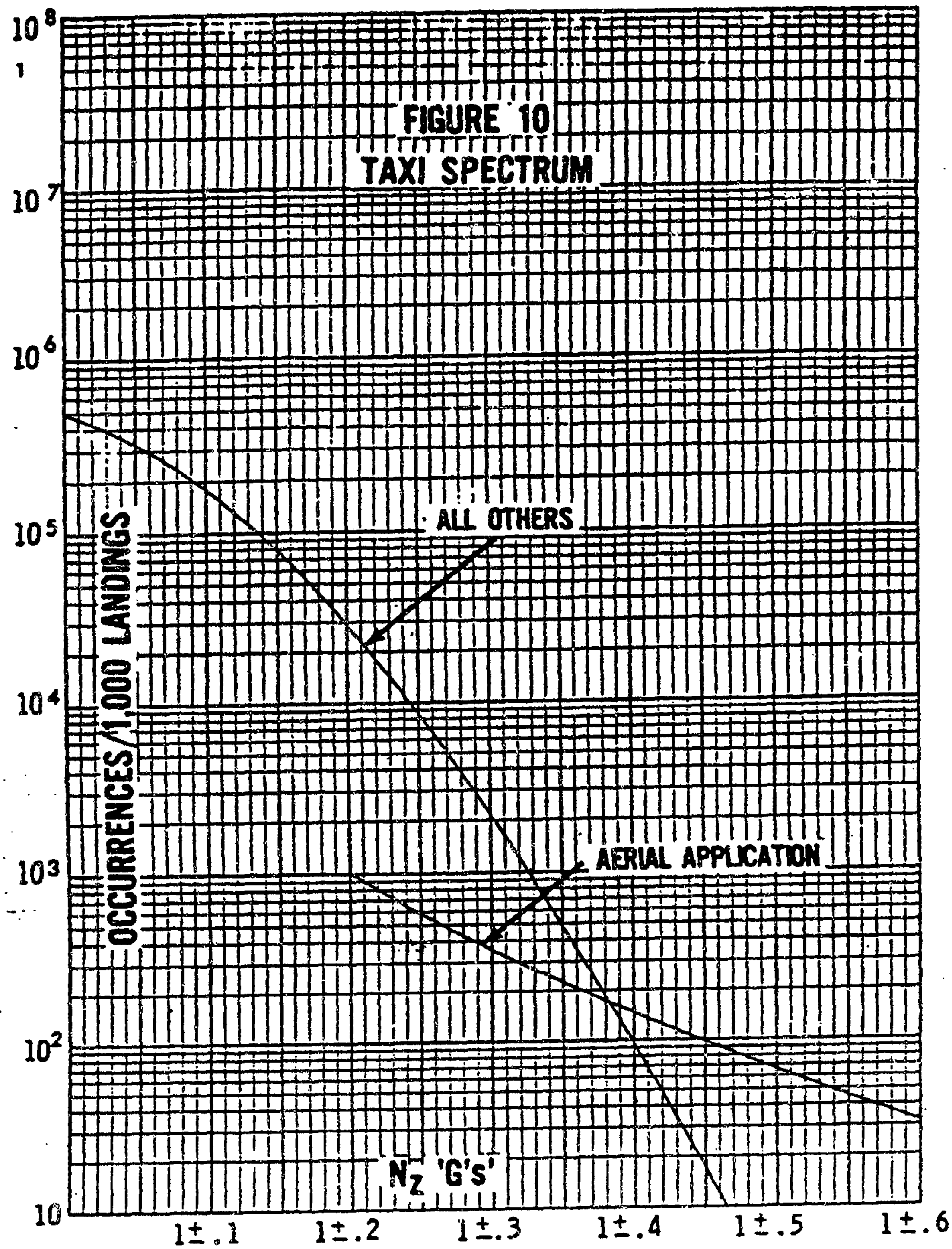


FIGURE 10
TAXI SPECTRUM
ALL OTHERS
AERIAL APPLICATION
OCCURRENCES/1,000 LANDINGS
N_Z 'G's'
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
10
1±.1
1±.2
1±.3
1±.4
1±.5
1±.6

Appendix

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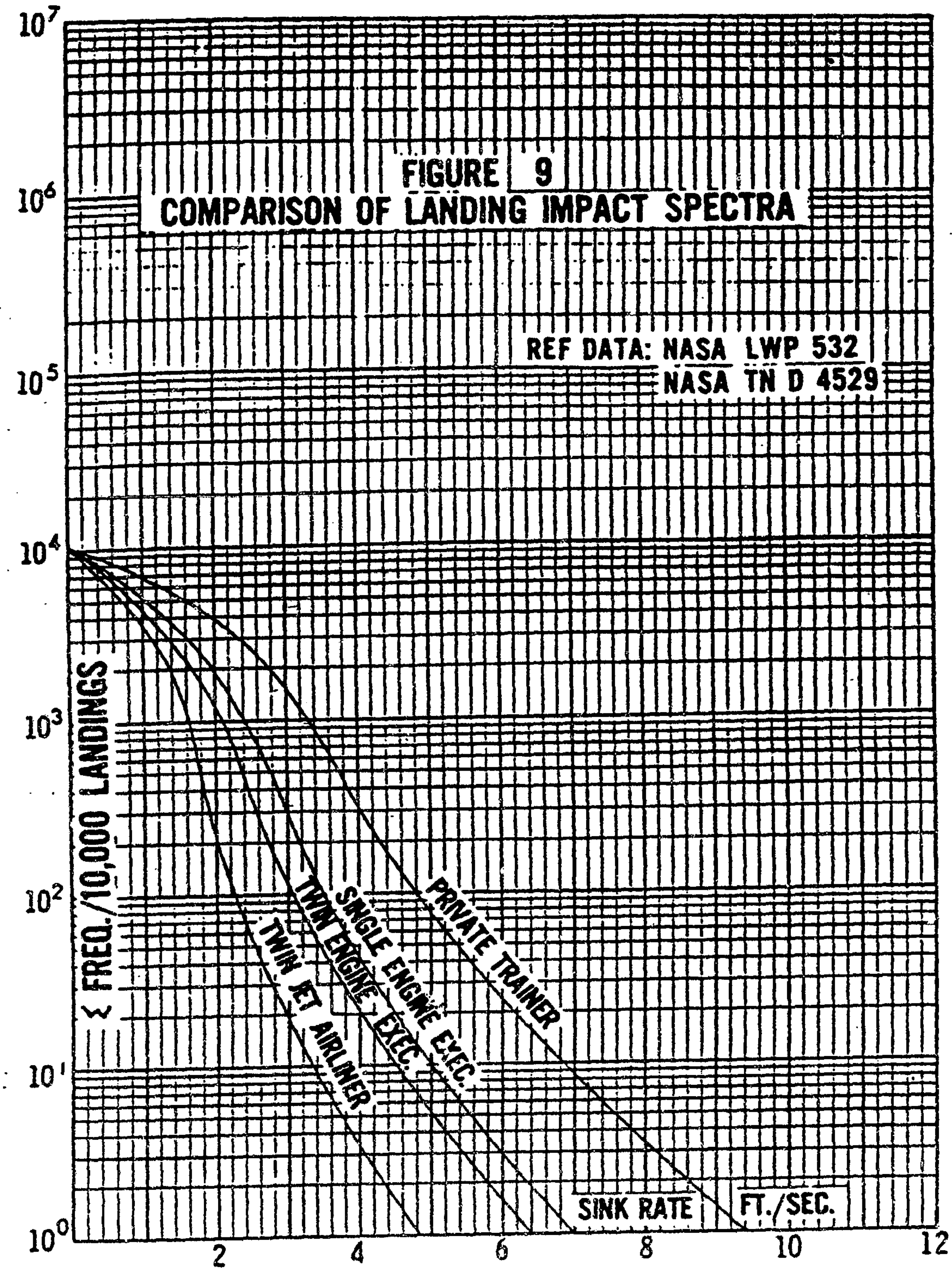


FIGURE 9
COMPARISON OF LANDING IMPACT SPECTRA
REF DATA: NASA LWP 532
NASA TN D 4529
Σ FREQ./10,000 LANDINGS
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
PRIVATE TRAINER
SINGLE ENGINE EXEC.
TWIN ENGINE EXEC.
TWIN JET AIRLINER
SINK RATE FT./SEC.
2
4
6
8
10
12

G5 FATIGUE ANALYSIS

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.

Fig. C13.A1 - Typical Constant-life diagram for unnotched fatigue behavior of 2024-T3 aluminum alloy.

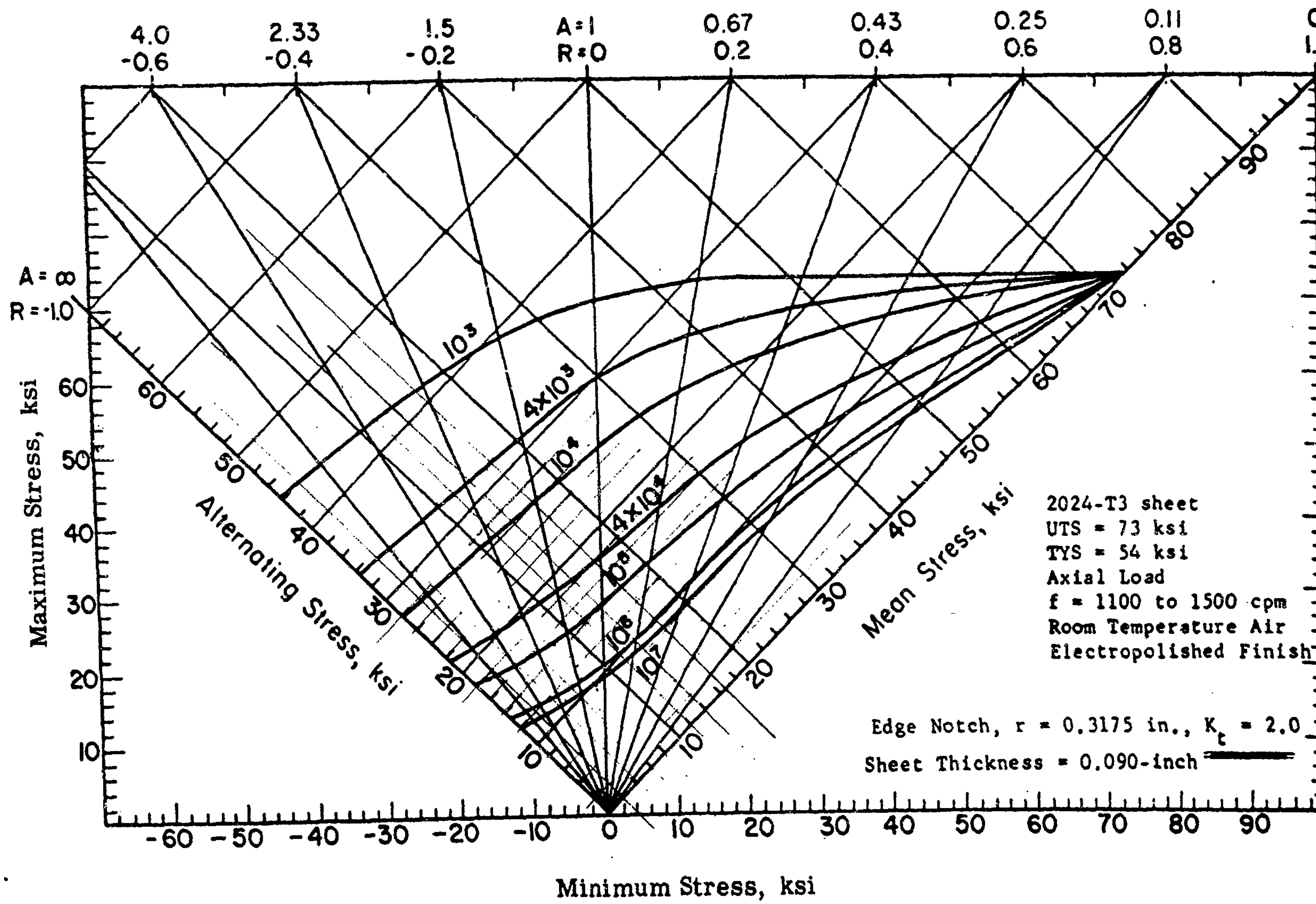


Fig. C13.A2 - Typical Constant-life diagram for notched fatigue behavior of 2024-T3 aluminum alloy.

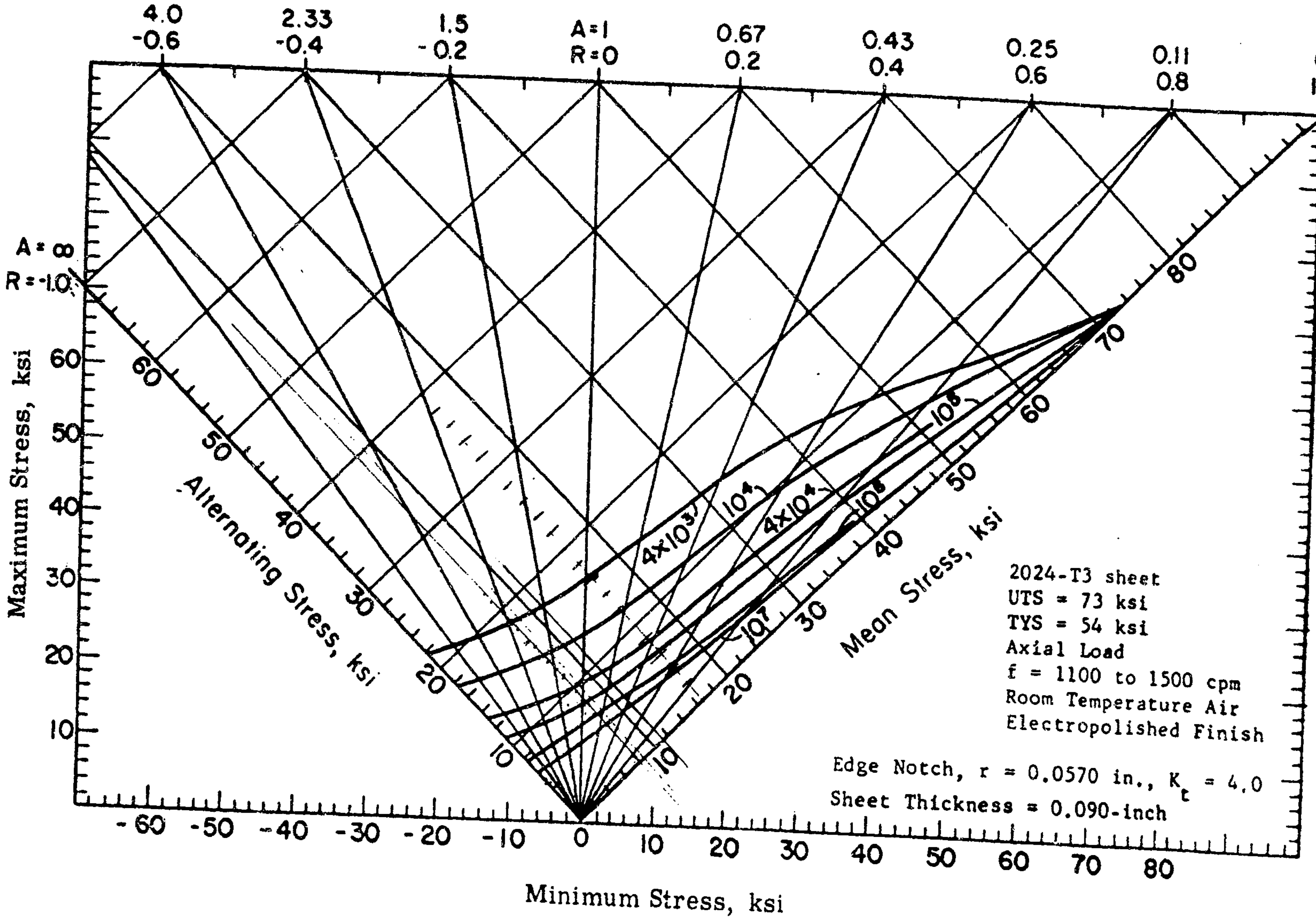
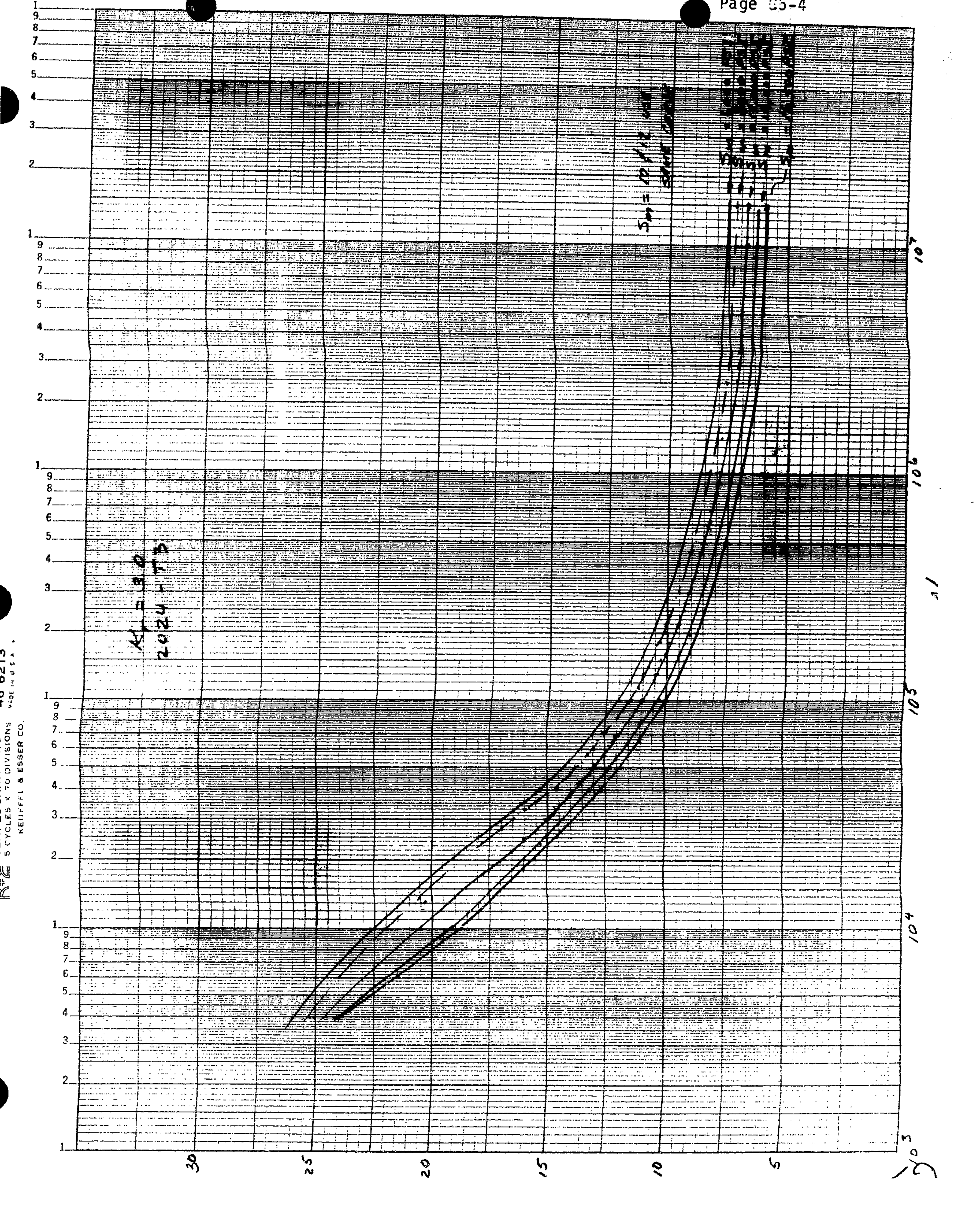
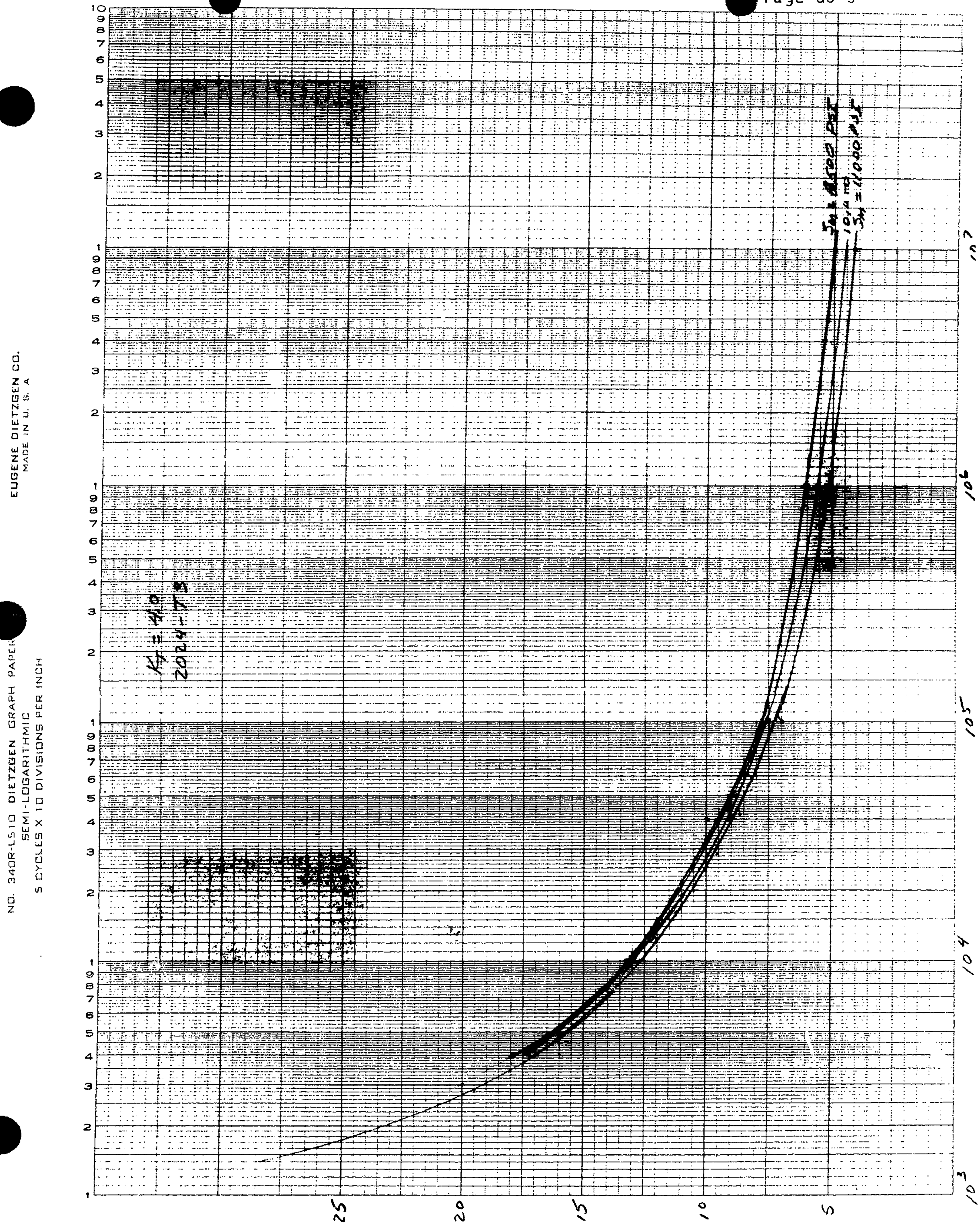


Fig. C13.A3 - Typical Constant-life diagram for notched fatigue behavior of 2024-T3 aluminum alloy.

351


2024-T3
30
25
20
15
10
5
KEUFFEL & ESSER CO.


EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
$K_t = 4.0$
2024-T3
10,000 PSI
10^3
10^4
10^5
10^6
10^7
25
20
15
10
5

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

1g σ = 5033 psi σ/g = 5033 psi
The once per 10000 landing stresses are:
(1.6g) σ_{max} = 8053, (1g) σ_m = 5033
(.4g) σ_{min} = 2013, σ_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 fps ; $N_{Z\,max}$ = 3.64 ; $N_{Z\,min}$ = 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 1g σ = 6624 psi and σ/g = 2429, the following are the maximum, mean, minimum and alternating stress for a design limit condition:

σ_{max} = 13037, σ_M = 9830, σ_{min} = 6624, σ_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 fps ; $N_{Z\,max}$ = 3.22 ; $N_{Z\,min}$ = .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, 1g σ = 7108 psi and σ/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 impact.

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.

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MODEL 181 PIPELINE MAN. FATIGUE DAMAGE GROSS WT=2033 VC=127K NOTS
S'=7689 *1.1 STRESS/G =7616 KT=3.0 ANLLF=3.4,-2.76

	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	5.5E-01									
-4.0E-02	1.3E-01		3.0E-01	3.4E+01	1.1E-01	4.4E-01	2.8E-01	8.5E+03	2.2E+03		
	1.6E-01	2.5E-01									
-1.3E-01	1.9E-01		9.0E-02	1.0E+01	3.6E-01	6.5E-01	5.0E-01	8.5E+03	3.9E+03		
	2.2E-01	1.6E-01									
-1.9E-01	2.5E-01		8.0E-02	9.1E+00	5.2E-01	8.5E-01	6.9E-01	8.5E+03	5.4E+03		
	2.8E-01	8.0E-02									
-2.1E-01	3.1E-01		5.0E-02	5.7E+00	5.8E-01	1.1E+00	8.2E-01	8.5E+03	6.4E+03		
	3.4E-01	3.0E-02									
-2.5E-01	3.7E-01		1.8E-02	2.1E+00	6.9E-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									
-3.2E-01	4.3E-01		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
	4.6E-01	5.0E-03									
-3.5E-01	4.9E-01		3.2E-03	3.7E-01	9.7E-01	1.7E+00	1.3E+00	8.5E+03	1.0E+04	1.8E+05	2.0E-06
	5.2E-01	1.8E-03									
-3.7E-01	5.5E-01		1.1E-03	1.3E-01	1.0E+00	1.9E+00	1.4E+00	8.5E+03	1.1E+04	1.2E+05	1.0E-06
	5.8E-01	7.0E-04									
-4.1E-01	6.1E-01		4.5E-04	5.1E-02	1.1E+00	2.1E+00	1.6E+00	8.5E+03	1.3E+04	7.0E+04	7.3E-07
	6.4E-01	2.5E-04									
-4.5E-01	6.7E-01		1.5E-04	1.7E-02	1.2E+00	2.3E+00	1.8E+00	8.5E+03	1.4E+04	5.0E+04	3.4E-07
	7.0E-01	1.0E-04									
-5.1E-01	7.3E-01		5.0E-05	5.7E-03	1.4E+00	2.5E+00	1.9E+00	8.5E+03	1.5E+04	3.7E+04	1.5E-07
	7.5E-01	5.0E-05									
-5.6E-01	7.8E-01		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
	8.1E-01	2.1E-05									
-6.0E-01	8.4E-01		1.1E-05	1.3E-03	1.7E+00	2.9E+00	2.3E+00	8.5E+03	1.8E+04	2.4E+04	5.4E-08
	8.7E-01	1.0E-05									

DAMAGE= 8.3E-06

MODEL 181 PIPELINE GUST FATIGUE DAMAGE GROSS WT.=2033 VC=127KNOTS
EN=7689 STRESS/G=7816 ANLLF=-,+2.71 K_T=3.0

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	4.0E+00									
0.0E+00	1.3E-01		2.0E+00	2.3E+02	3.5E-01	3.5E-01	3.5E-01	7.7E+03	2.8E+03		
	1.6E-01	2.0E+00									
0.0E+00	1.9E-01		1.2E+00	1.4E+02	5.1E-01	5.1E-01	5.1E-01	7.7E+03	4.0E+03		
	2.2E-01	8.0E-01									
0.0E+00	2.5E-01		5.0E-01	5.7E+01	6.8E-01	6.8E-01	6.8E-01	7.7E+03	5.3E+03		
	2.8E-01	3.0E-01									
0.0E+00	3.1E-01		2.0E-01	2.3E+01	8.4E-01	8.4E-01	8.4E-01	7.7E+03	6.6E+03		
	3.4E-01	1.0E-01									
0.0E+00	3.7E-01		8.2E-02	9.4E+00	1.0E+00	1.0E+00	1.0E+00	7.7E+03	7.8E+03	2.5E+06	3.7E-06
	4.0E-01	1.8E-02									
0.0E+00	4.3E-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
	4.6E-01	7.0E-03									
0.0E+00	4.9E-01		4.0E-03	4.6E-01	1.3E+00	1.3E+00	1.3E+00	7.7E+03	1.0E+04	2.3E+05	2.0E-06
	5.2E-01	3.0E-03									
0.0E+00	5.5E-01		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
	5.8E-01	1.6E-03									
0.0E+00	6.1E-01		8.0E-04	9.1E-02	1.7E+00	1.7E+00	1.7E+00	7.7E+03	1.3E+04	6.6E+04	1.4E-06
	6.4E-01	8.0E-04									
0.0E+00	6.7E-01		4.0E-04	4.6E-02	1.8E+00	1.8E+00	1.8E+00	7.7E+03	1.4E+04	4.8E+04	9.5E-07
	7.0E-01	4.0E-04									
0.0E+00	7.3E-01		1.2E-04	1.4E-02	2.0E+00	2.0E+00	2.0E+00	7.7E+03	1.5E+04	3.9E+04	3.5E-07
	7.5E-01	2.8E-04									
0.0E+00	7.8E-01		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
	8.1E-01	1.5E-04									
0.0E+00	8.4E-01		6.0E-05	6.9E-03	2.2E+00	2.3E+00	2.3E+00	7.7E+03	1.8E+04	2.4E+04	2.9E-07
	8.7E-01	9.0E-05									
0.0E+00	9.0E-01		3.0E-05	3.4E-03	2.4E+00	2.4E+00	2.4E+00	7.7E+03	1.9E+04	1.9E+04	1.9E-07
	9.3E-01	6.0E-05									
0.0E+00	9.6E-01		2.0E-05	2.3E-03	2.6E+00	2.6E+00	2.6E+00	7.7E+03	2.0E+04	1.5E+04	1.6E-07
	9.9E-01	4.0E-05								DAMAGE=	1.4E-05

MODEL 181 NORMAL MAN. FATIGUE DAMAGE GROSS WT=2163 VC=127KN OTS

SM=1.2*B320 STRESS/G =8464 K_T=3.0 ANLLF=2.8,-2.5

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	2.2E-02									
0.0E+00	1.3E-01		1.3E-02	1.5E+00	0.0E+00	3.6E-01	1.8E-01	1.0E+04	1.5E+03		
	1.6E-01	9.0E-03									
-6.0E-02	1.9E-01		5.5E-03	6.3E-01	1.5E-01	5.3E-01	3.4E-01	1.0E+04	2.9E+03		
	2.2E-01	3.5E-03									
-1.2E-01	2.5E-01		2.0E-03	2.3E-01	3.0E-01	7.0E-01	5.0E-01	1.0E+04	4.2E+03		
	2.8E-01	1.5E-03									
-1.7E-01	3.1E-01		8.5E-04	9.7E-02	4.3E-01	8.7E-01	6.5E-01	1.0E+04	5.5E+03		
	3.4E-01	6.5E-03									
-2.2E-01	3.7E-01		3.5E-04	4.0E-02	5.5E-01	1.0E+00	8.0E-01	1.0E+04	6.7E+03	1.5E+07	2.7E-09
	4.0E-01	3.0E-04									
-2.6E-01	4.3E-01		1.6E-04	1.8E-02	6.6E-01	1.2E+00	9.3E-01	1.0E+04	7.9E+03	1.0E+06	1.8E-08
	4.6E-01	1.4E-04									
-3.1E-01	4.9E-01		7.0E-05	8.0E-03	7.8E-01	1.4E+00	1.1E+00	1.0E+04	9.1E+03	4.5E+05	1.8E-08
	5.2E-01	7.0E-05									
-3.5E-01	5.5E-01		4.0E-05	4.6E-03	8.8E-01	1.5E+00	1.2E+00	1.0E+04	1.0E+04	1.5E+05	3.2E-08
	5.8E-01	3.0E-05									
-3.9E-01	6.1E-01		1.5E-05	1.7E-03	9.8E-01	1.7E+00	1.3E+00	1.0E+04	1.1E+04	8.4E+04	2.0E-08
	6.4E-01	1.5E-05									
-4.3E-01	6.7E-01		8.0E-06	9.0E-04	1.1E+00	1.9E+00	1.5E+00	1.0E+04	1.3E+04	5.7E+04	1.6E-08
	7.0E-01	7.0E-06									
-4.7E-01	7.3E-01		3.0E-06	3.0E-04	1.2E+00	2.0E+00	1.6E+00	1.0E+04	1.4E+04	4.2E+04	7.1E-09
	7.5E-01	4.0E-06									

DAMAGE= 1.1E-07

MODEL 181 NORMAL GUST FATIGUE DAMAGE GROSS WT.=2163 VC=127KNOTS
SM=8320 STRESS/G =8464 KT=3.0 ANLLF=-,+2.37

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DB(-)	DB(+)	DB(+,-)	SM	SA	N	n/N
	1.0E-01	1.0E+00									
0.0E+00	1.3E-01		8.3E-01	9.5E+01	3.1E-01	3.1E-01	3.1E-01	8.3E+03	2.6E+03		
	1.6E-01	1.7E-01									
0.0E+00	1.9E-01		1.3E-01	1.4E+01	4.5E-01	4.5E-01	4.5E-01	8.3E+03	3.8E+03		
	2.2E-01	4.5E-02									
0.0E+00	2.5E-01		3.5E-02	4.0E+00	5.9E-01	5.9E-01	5.9E-01	8.3E+03	5.0E+03		
	2.8E-01	1.0E-02									
0.0E+00	3.1E-01		6.5E-03	7.4E-01	7.3E-01	7.3E-01	7.3E-01	8.3E+03	6.2E+03		
	3.4E-01	3.5E-03									
0.0E+00	3.7E-01		2.4E-03	2.7E-01	8.8E-01	8.8E-01	8.8E-01	8.3E+03	7.4E+03	1.0E+07	2.7E-08
	4.0E-01	1.1E-03									
0.0E+00	4.3E-01		6.7E-04	7.7E-02	1.0E+00	1.0E+00	1.0E+00	8.3E+03	8.6E+03	7.7E+05	9.9E-08
	4.6E-01	4.3E-04									
0.0E+00	4.9E-01		2.4E-04	2.7E-02	1.2E+00	1.2E+00	1.2E+00	8.3E+03	9.8E+03	2.5E+05	1.1E-07
	5.2E-01	1.9E-04									
0.0E+00	5.5E-01		1.1E-04	1.2E-02	1.3E+00	1.3E+00	1.3E+00	8.3E+03	1.1E+04	1.3E+05	9.2E-08
	5.8E-01	8.5E-05									
0.0E+00	6.1E-01		4.5E-05	5.1E-03	1.4E+00	1.4E+00	1.4E+00	8.3E+03	1.2E+04	8.0E+04	6.4E-08
	6.4E-01	4.0E-05									
0.0E+00	6.7E-01		2.0E-05	2.3E-03	1.6E+00	1.6E+00	1.6E+00	8.3E+03	1.3E+04	5.7E+04	4.0E-08
	7.0E-01	2.0E-05									
0.0E+00	7.3E-01		9.0E-06	1.0E-03	1.7E+00	1.7E+00	1.7E+00	8.3E+03	1.5E+04	4.2E+04	2.4E-08
	7.5E-01	1.1E-05									
0.0E+00	7.8E-01		5.9E-06	6.7E-04	1.8E+00	1.8E+00	1.8E+00	8.3E+03	1.6E+04	3.5E+04	1.9E-08
	8.1E-01	5.1E-06									
0.0E+00	8.4E-01		2.5E-06	2.9E-04	2.0E+00	2.0E+00	1.9E+00	8.3E+03	1.6E+04	2.8E+04	1.0E-08
	8.7E-01	2.6E-06									

DAMAGE= 4.9E-07

MODEL 181 PIPELINE MAN. FATIGUE DAMAGE GROSS WT=2033 VC=127K NOTS
SM=7689 *1.1 STRESS/G =7816 KT=4.0 ANLLF=3.4,-2.76

	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	5.5E-01									
-4.0E-02	1.3E-01		3.0E-01	3.4E+01	1.1E-01	4.4E-01	2.8E-01	8.5E+03	2.2E+03		
	1.6E-01	2.5E-01									
-1.3E-01	1.9E-01		9.0E-02	1.0E+01	3.6E-01	6.5E-01	5.0E-01	8.5E+03	3.9E+03		
	2.2E-01	1.6E-01									
-1.9E-01	2.5E-01		8.0E-02	9.1E+00	5.2E-01	8.5E-01	6.9E-01	8.5E+03	5.4E+03	4.0E+06	2.2E-06
	2.8E-01	8.0E-02									
-2.1E-01	3.1E-01		5.0E-02	5.7E+00	5.8E-01	1.1E+00	8.2E-01	8.5E+03	6.4E+03	6.0E+05	9.5E-06
	3.4E-01	3.0E-02									
-2.5E-01	3.7E-01		1.8E-02	2.1E+00	6.9E-01	1.3E+00	9.7E-01	8.5E+03	7.6E+03	1.1E+05	1.9E-05
	4.0E-01	1.2E-02									
-3.2E-01	4.3E-01		7.0E-03	8.0E-01	8.8E-01	1.5E+00	1.2E+00	8.5E+03	9.2E+03	5.0E+04	1.6E-05
	4.6E-01	5.0E-03									
-3.5E-01	4.9E-01		3.2E-03	3.7E-01	9.7E-01	1.7E+00	1.3E+00	8.5E+03	1.0E+04	3.3E+04	1.1E-05
	5.2E-01	1.8E-03									
-3.7E-01	5.5E-01		1.1E-03	1.3E-01	1.0E+00	1.9E+00	1.4E+00	8.5E+03	1.1E+04	2.1E+04	6.0E-06
	5.8E-01	7.0E-04									
-4.1E-01	6.1E-01		4.5E-04	5.1E-02	1.1E+00	2.1E+00	1.6E+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		1.5E-04	1.7E-02	1.2E+00	2.3E+00	1.8E+00	8.5E+03	1.4E+04	7.0E+03	2.4E-06
	7.0E-01	1.0E-04									
-5.1E-01	7.3E-01		5.0E-05	5.7E-03	1.4E+00	2.5E+00	1.9E+00	8.5E+03	1.5E+04	6.4E+03	8.9E-07
	7.5E-01	5.0E-05									
-5.6E-01	7.8E-01		2.9E-05	3.3E-03	1.5E+00	2.7E+00	2.1E+00	8.5E+03	1.6E+04	5.2E+03	6.4E-07
	8.1E-01	2.1E-05									
-6.0E-01	8.4E-01		1.1E-05	1.3E-03	1.7E+00	2.9E+00	2.3E+00	8.5E+03	1.8E+04	4.0E+03	3.1E-07
	8.7E-01	1.0E-05									

DAMAGE= 7.3E-05

MODEL 181 PIPELINE GUST FATIGUE DAMAGE GROSS WT.=2023 VC=127K NOTS
SM=7689 STRESS/G=7816 ANLLF=-,+2.71 KT=4.0

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	4.0E+00									
0.0E+00	1.3E-01		2.0E+00	2.2E+02	3.5E-01	3.5E-01	3.5E-01	7.7E+03	2.6E+03		
	1.6E-01	2.0E+00									
0.0E+00	1.9E-01		1.2E+00	1.4E+02	5.1E-01	5.1E-01	5.1E-01	7.7E+03	4.0E+03		
	2.2E-01	8.0E-01									
0.0E+00	2.5E-01		5.0E-01	5.7E+01	6.8E-01	6.8E-01	6.8E-01	7.7E+03	5.3E+03	5.0E+06	1.1E-05
	2.8E-01	3.0E-01									
0.0E+00	3.1E-01		2.0E-01	2.3E+01	8.4E-01	8.4E-01	8.4E-01	7.7E+03	6.6E+03	4.0E+05	5.7E-05
	3.4E-01	1.0E-01									
0.0E+00	3.7E-01		8.2E-02	9.4E+00	1.0E+00	1.0E+00	1.0E+00	7.7E+03	7.8E+03	1.0E+05	9.4E-05
	4.0E-01	1.8E-02									
0.0E+00	4.3E-01		1.1E-02	1.3E+00	1.2E+00	1.2E+00	1.2E+00	7.7E+03	9.1E+03	5.0E+04	2.5E-05
	4.6E-01	7.0E-03									
0.0E+00	4.9E-01		4.0E-03	4.6E-01	1.3E+00	1.3E+00	1.3E+00	7.7E+03	1.0E+04	3.2E+04	1.4E-05
	5.2E-01	3.0E-03									
0.0E+00	5.5E-01		1.4E-03	1.6E-01	1.5E+00	1.5E+00	1.5E+00	7.7E+03	1.2E+04	1.5E+04	1.1E-05
	5.8E-01	1.6E-03									
0.0E+00	6.1E-01		8.0E-04	9.1E-02	1.7E+00	1.7E+00	1.7E+00	7.7E+03	1.3E+04	1.0E+04	9.1E-06
	6.4E-01	8.0E-04									
0.0E+00	6.7E-01		4.0E-04	4.6E-02	1.8E+00	1.8E+00	1.8E+00	7.7E+03	1.4E+04	8.0E+03	5.7E-06
	7.0E-01	4.0E-04									
0.0E+00	7.3E-01		1.2E-04	1.4E-02	2.0E+00	2.0E+00	2.0E+00	7.7E+03	1.5E+04	6.4E+03	2.1E-06
	7.5E-01	2.8E-04									
0.0E+00	7.8E-01		1.3E-04	1.5E-02	2.1E+00	2.1E+00	2.1E+00	7.7E+03	1.7E+04	4.4E+03	3.4E-06
	8.1E-01	1.5E-04									
0.0E+00	8.4E-01		6.0E-05	6.9E-03	2.3E+00	2.3E+00	2.3E+00	7.7E+03	1.8E+04	4.0E+03	1.7E-06
	8.7E-01	9.0E-05									
0.0E+00	9.0E-01		3.0E-05	3.4E-03	2.4E+00	2.4E+00	2.4E+00	7.7E+03	1.9E+04	3.5E+03	9.8E-07
	9.3E-01	6.0E-05									
0.0E+00	9.6E-01		2.0E-05	2.3E-03	2.6E+00	2.6E+00	2.6E+00	7.7E+03	2.0E+04	3.0E+03	7.6E-07
	9.9E-01	4.0E-05									
										DAMAGE=	2.4E-04

MODEL 181 NORMAL MAN. FATIGUE DAMAGE GROSS WT=2163 VC=127KN OTS
SM=1.2*8320 STRESS/G =8464 KT=4.0 ANLLF=2.8,-2.5

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	2.2E-02									
0.0E+00	1.3E-01		1.3E-02	1.5E+00	0.0E+00	3.6E-01	1.8E-01	1.0E+04	1.5E+03		
	1.6E-01	9.0E-03									
-6.0E-02	1.9E-01		3.5E-03	6.3E-01	1.5E-01	5.3E-01	3.4E-01	1.0E+04	2.9E+03		
	2.2E-01	3.5E-03									
-1.2E-01	2.5E-01		2.0E-03	2.3E-01	3.0E-01	7.0E-01	5.0E-01	1.0E+04	4.2E+03		
	2.8E-01	1.5E-03									
-1.7E-01	3.1E-01		8.5E-04	9.7E-02	4.3E-01	8.7E-01	6.5E-01	1.0E+04	5.5E+03		
	3.4E-01	6.5E-02									
-2.2E-01	3.7E-01		3.5E-04	4.0E-02	5.5E-01	1.0E+00	8.0E-01	1.0E+04	6.7E+03	2.0E+05	2.0E-07
	4.0E-01	3.0E-04									
-2.6E-01	4.3E-01		1.6E-04	1.8E-02	6.6E-01	1.2E+00	9.3E-01	1.0E+04	7.9E+03	8.5E+04	2.1E-07
	4.6E-01	1.4E-04									
-3.1E-01	4.9E-01		7.0E-05	8.0E-03	7.8E-01	1.4E+00	1.1E+00	1.0E+04	9.1E+03	4.2E+04	1.9E-07
	5.2E-01	7.0E-05									
-3.5E-01	5.5E-01		4.0E-05	4.6E-03	8.8E-01	1.5E+00	1.2E+00	1.0E+04	1.0E+04	2.7E+04	1.7E-07
	5.8E-01	3.0E-05									
-3.9E-01	6.1E-01		1.5E-05	1.7E-03	9.8E-01	1.7E+00	1.3E+00	1.0E+04	1.1E+04	1.9E+04	8.9E-08
	6.4E-01	1.5E-05									
-4.3E-01	6.7E-01		8.0E-06	9.0E-04	1.1E+00	1.9E+00	1.5E+00	1.0E+04	1.3E+04	1.0E+04	9.0E-08
	7.0E-01	7.0E-06									
-4.7E-01	7.3E-01		3.0E-06	3.0E-04	1.2E+00	2.0E+00	1.6E+00	1.0E+04	1.4E+04	7.0E+03	4.3E-08
	7.5E-01	4.0E-06									

DAMAGE= 9.9E-07

MODEL 181 NORMAL GUST FATIGUE DAMAGE GROSS WT.=2163 VC=127KNOTS

SM=8320 STRESS/G =8464 KT=4.0 ANLLF=-,+2.37

AN/ANLLF	AN/ANLLF	CFRQ/NN	FRQ/NN	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	1.0E+00									
0.0E+00	1.3E-01		6.3E-01	9.5E+01	3.1E-01	3.1E-01	3.1E-01	8.3E+03	2.6E+03		
	1.6E-01	1.7E-01									
0.0E+00	1.9E-01		1.3E-01	1.4E+01	4.5E-01	4.5E-01	4.5E-01	8.3E+03	3.8E+03		
	2.2E-01	4.5E-02									
0.0E+00	2.5E-01		3.5E-02	4.0E+00	5.9E-01	5.9E-01	5.9E-01	8.3E+03	5.0E+03	1.0E+07	4.0E-07
	2.8E-01	1.0E-02									
0.0E+00	3.1E-01		6.5E-03	7.4E-01	7.3E-01	7.3E-01	7.3E-01	8.3E+03	6.2E+03	8.2E+05	9.1E-07
	3.4E-01	3.5E-03									
0.0E+00	3.7E-01		2.4E-03	2.7E-01	8.8E-01	8.8E-01	8.8E-01	8.3E+03	7.4E+03	1.5E+05	1.8E-06
	4.0E-01	1.1E-03									
0.0E+00	4.3E-01		6.7E-04	7.7E-02	1.0E+00	1.0E+00	1.0E+00	8.3E+03	8.6E+03	5.2E+04	1.5E-06
	4.6E-01	4.3E-04									
0.0E+00	4.9E-01		2.4E-04	2.7E-02	1.2E+00	1.2E+00	1.2E+00	8.3E+03	9.8E+03	3.0E+04	9.1E-07
	5.2E-01	1.9E-04									
0.0E+00	5.5E-01		1.1E-04	1.2E-02	1.3E+00	1.3E+00	1.3E+00	8.3E+03	1.1E+04	1.9E+04	6.3E-07
	5.8E-01	8.5E-05									
0.0E+00	6.1E-01		4.5E-05	5.1E-03	1.4E+00	1.4E+00	1.4E+00	8.3E+03	1.2E+04	1.4E+04	3.7E-07
	6.4E-01	4.0E-05									
0.0E+00	6.7E-01		2.0E-05	2.3E-03	1.6E+00	1.6E+00	1.6E+00	8.3E+03	1.3E+04	1.0E+04	2.3E-07
	7.0E-01	2.0E-05									
0.0E+00	7.3E-01		9.0E-06	1.0E-03	1.7E+00	1.7E+00	1.7E+00	8.3E+03	1.5E+04	6.2E+03	1.7E-07
	7.5E-01	1.1E-05									
0.0E+00	7.8E-01		5.9E-06	6.7E-04	1.8E+00	1.8E+00	1.8E+00	8.3E+03	1.6E+04	5.0E+03	1.3E-07
	8.1E-01	5.1E-06									
0.0E+00	8.4E-01		2.5E-06	2.9E-04	2.0E+00	2.0E+00	2.0E+00	8.3E+03	1.7E+04	4.8E+03	6.0E-08
	8.7E-01	2.6E-06									

DAMAGE= 7.1E-06

MODEL 22 PIPELINE MAN. FATIGUE DAMAGE GROSS WT=2541 VC=144KNOTS
SM=9106 *1.1 STRESS/G =8710 KT=3.0 ANLLF=2.8,-2.52

	AN/ANLLF	CFRQ/NN	FRQ/NN	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	5.5E-01									
-4.0E-02	1.3E-01		3.0E-01	3.9E+01	1.0E-01	3.6E-01	2.3E-01	1.0E+04	2.0E+03		
	1.6E-01	2.5E-01									
-1.3E-01	1.9E-01		9.0E-02	1.2E+01	3.3E-01	5.3E-01	4.3E-01	1.0E+04	3.7E+03		
	2.2E-01	1.6E-01									
-1.9E-01	2.5E-01		8.0E-02	1.0E+01	4.8E-01	7.0E-01	5.9E-01	1.0E+04	5.1E+03		
	2.8E-01	8.0E-02									
-2.1E-01	3.1E-01		5.0E-02	6.5E+00	5.3E-01	8.7E-01	7.0E-01	1.0E+04	6.1E+03		
	3.4E-01	3.0E-02									
-2.5E-01	3.7E-01		1.8E-02	2.3E+00	6.3E-01	1.0E+00	8.3E-01	1.0E+04	7.3E+03	2.5E+06	9.3E-07
	4.0E-01	1.2E-02									
-3.2E-01	4.3E-01		7.0E-03	9.1E-01	8.1E-01	1.2E+00	1.0E+00	1.0E+04	8.8E+03	4.0E+06	2.3E-06
	4.6E-01	5.0E-03									
-3.5E-01	4.9E-01		3.2E-03	4.1E-01	8.8E-01	1.4E+00	1.1E+00	1.0E+04	9.8E+03	2.2E+05	1.9E-06
	5.2E-01	1.8E-03									
-3.7E-01	5.5E-01		1.1E-03	1.4E-01	9.3E-01	1.5E+00	1.2E+00	1.0E+04	1.1E+04	1.3E+05	1.1E-06
	5.8E-01	7.0E-04									
-4.1E-01	6.1E-01		4.5E-04	5.8E-02	1.0E+00	1.7E+00	1.4E+00	1.0E+04	1.2E+04	6.8E+04	8.6E-07
	6.4E-01	2.5E-04									
-4.5E-01	6.7E-01		1.5E-04	1.9E-02	1.1E+00	1.9E+00	1.6E+00	1.0E+04	1.3E+04	5.0E+04	3.9E-07
	7.0E-01	1.0E-04									
-5.1E-01	7.3E-01		5.0E-05	6.5E-03	1.3E+00	2.0E+00	1.7E+00	1.0E+04	1.4E+04	3.2E+04	2.0E-07
	7.5E-01	5.0E-05									
-5.6E-01	7.8E-01		2.9E-05	3.8E-03	1.4E+00	2.2E+00	1.8E+00	1.0E+04	1.5E+04	2.6E+04	1.4E-07
	8.1E-01	2.1E-05									
-6.0E-01	8.4E-01		1.1E-05	1.4E-03	1.5E+00	2.4E+00	1.9E+00	1.0E+04	1.7E+04	2.2E+04	3.2E-08
	8.7E-01	1.0E-05									

DAMAGE= 7.9E-06

MODEL 33 PIPELINE GUST FATIGUE DAMAGE GROSS WT. =2541 VC=144KNOTS

SN=9106 STRESS/G=8710 ANLLF=-,+2.20 KT=3.0

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	4.0E+00									
0.0E+00	1.3E-01		2.0E+00	2.6E+02	2.9E-01	2.9E-01	2.9E-01	9.1E+03	2.5E+03		
	1.6E-01	2.0E+00									
0.0E+00	1.9E-01		1.2E+00	1.6E+02	4.2E-01	4.2E-01	4.2E-01	9.1E+03	3.7E+03		
	2.2E-01	8.0E-01									
0.0E+00	2.5E-01		5.0E-01	6.5E+01	5.6E-01	5.6E-01	5.6E-01	9.1E+03	4.9E+04		
	2.8E-01	3.0E-01									
0.0E+00	3.1E-01		2.0E-01	2.6E+01	6.9E-01	6.9E-01	6.9E-01	9.1E+03	6.0E+03		
	3.4E-01	1.0E-01									
0.0E+00	3.7E-01		8.3E-02	1.1E+01	8.2E-01	8.2E-01	8.2E-01	9.1E+03	7.2E+03	3.6E+06	3.5E-06
	4.0E-01	1.8E-02									
0.0E+00	4.3E-01		1.1E-02	1.4E+00	9.5E-01	9.5E-01	9.6E-01	9.1E+03	8.3E+03	6.0E+05	2.4E-06
	4.6E-01	7.0E-03									
0.0E+00	4.9E-01		4.0E-03	5.2E-01	1.1E+00	1.1E+00	1.1E+00	9.1E+03	9.5E+03	2.0E+05	2.6E-06
	5.2E-01	3.0E-03									
0.0E+00	5.5E-01		1.4E-03	1.8E-01	1.2E+00	1.2E+00	1.2E+00	9.1E+03	1.1E+04	1.3E+05	1.4E-06
	5.8E-01	1.6E-03									
0.0E+00	6.1E-01		8.0E-04	1.0E-01	1.4E+00	1.4E+00	1.4E+00	9.1E+03	1.2E+04	6.6E+04	1.6E-06
	6.4E-01	8.0E-04									
0.0E+00	6.7E-01		4.0E-04	5.2E-02	1.5E+00	1.5E+00	1.5E+00	9.1E+03	1.3E+04	5.0E+04	1.0E-06
	7.0E-01	4.0E-04									
0.0E+00	7.3E-01		1.2E-04	1.6E-02	1.6E+00	1.6E+00	1.6E+00	9.1E+03	1.4E+04	3.7E+04	4.2E-07
	7.5E-01	2.8E-04									
0.0E+00	7.8E-01		1.3E-04	1.7E-02	1.7E+00	1.7E+00	1.7E+00	9.1E+03	1.5E+04	3.2E+04	5.3E-07
	8.1E-01	1.5E-04									
0.0E+00	8.4E-01		6.0E-05	7.8E-03	1.9E+00	1.9E+00	1.9E+00	9.1E+03	1.7E+04	2.3E+04	3.4E-07
	8.7E-01	9.0E-05									
0.0E+00	9.0E-01		3.0E-05	3.9E-03	2.0E+00	2.0E+00	2.0E+00	9.1E+03	1.7E+04	1.8E+04	2.2E-07
	9.3E-01	6.0E-05									
0.0E+00	9.6E-01		2.0E-05	2.6E-03	2.1E+00	2.1E+00	2.1E+00	9.1E+03	1.8E+04	1.5E+04	1.7E-07
	9.9E-01	4.0E-05									

DAMAGE= 1.4E-05

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MODEL 32 NORMAL MAN. FATIGUE DAMAGE GROSS WT =2840 VC=144KNOTS
SM=1.2*9253 STR/G=8819 kt=3.0 ANLLF=2.8,-2.52

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.5*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	2.2E-02									
0.0E+00	1.3E-01		1.3E-02	1.7E+00	0.0E+00	3.6E-01	1.8E-01	1.11E+04	1.61E+03		
	1.6E-01	9.0E-03									
-6.0E-02	1.9E-01		5.5E-03	7.1E-01	1.5E-01	5.2E-01	3.4E-01	1.11E+04	3.01E+03		
	2.2E-01	3.5E-03									
-1.2E-01	2.5E-01		2.0E-03	2.5E-01	3.0E-01	7.0E-01	5.6E-01	1.11E+04	4.42E+03		
	2.8E-01	1.5E-03									
-1.7E-01	3.1E-01		8.5E-04	1.1E-01	4.3E-01	8.7E-01	6.5E-01	1.11E+04	5.72E+03	0.0E+00	0.0E+00
	3.4E-01	6.5E-03									
-2.2E-01	3.7E-01		3.5E-04	4.5E-02	5.5E-01	1.0E+00	8.0E-01	1.11E+04	7.01E+03	4.0E+06	1.1E-08
	4.0E-01	3.0E-04									
-2.6E-01	4.3E-01		1.6E-04	2.1E-02	6.6E-01	1.2E+00	9.3E-01	1.11E+04	8.20E+03	7.0E+05	3.0E-08
	4.6E 01	1.4E-04									
-3.1E-01	4.9E-01		7.0E-05	9.0E-03	7.8E-01	1.4E+00	1.1E+00	1.11E+04	9.49E+03	2.0E+05	4.5E-08
	5.2E-01	7.0E-05									
-3.5E-01	5.5E-01		4.0E-05	5.0E-03	8.8E-01	1.5E+00	1.2E+00	1.11E+04	1.07E+04	1.3E+05	3.8E-08
	5.8E-01	3.0E-05									
-3.9E-01	6.1E-01		1.5E-05	1.9E-03	9.8E-01	1.7E+00	1.3E+00	1.11E+04	1.19E+04	7.4E+04	2.6E-08
	6.4E-01	1.5E-05									
-4.3E-01	6.7E-01		8.0E-06	1.1E-03	1.1E+00	1.9E+00	1.5E+00	1.11E+04	1.31E+04	4.6E+04	2.4E-08
	7.0E-01	7.0E-06									
-4.7E-01	7.3E-01		3.0E-06	3.8E-04	1.2E+00	2.0E+00	1.6E+00	1.11E+04	1.42E+04	3.8E+04	1.0E-08
	7.5E-01	4.0E-06									

DAMAGE= 1.8E-07

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MODEL 32 NORMAL GUST FATIGUE DAMAGE GROSS WT.=2840 VC=144KNOTS
SM=9252 STRESS/G =8819 KT=3.0 ANLLF=-,+2.21 KT=3.0

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	1.0E+00									
0.0E+00	1.3E-01		8.3E-01	1.1E+02	3.0E-01	3.0E-01	3.0E-01	9.3E+03	2.6E+03		
	1.6E-01	1.7E-01									
0.0E+00	1.9E-01		1.2E-01	1.6E+01	4.3E-01	4.3E-01	4.3E-01	9.3E+03	3.8E+03		
	2.2E-01	4.5E-02									
0.0E+00	2.3E-01		3.5E-02	4.5E+00	5.7E-01	5.7E-01	5.7E-01	9.3E+03	5.0E+03		
	2.8E-01	1.0E-02									
0.0E+00	3.1E-01		6.5E-03	8.4E-01	7.1E-01	7.1E-01	7.1E-01	9.3E+03	6.2E+03	0.0E+00	0.0E+00
	3.4E-01	3.5E-03									
0.0E+00	3.7E-01		2.4E-03	3.1E-01	8.4E-01	8.4E-01	8.4E-01	9.3E+03	7.4E+03	2.0E+06	1.6E-07
	4.0E-01	1.1E-03									
0.0E+00	4.3E-01		6.7E-04	8.7E-02	9.8E-01	9.8E-01	9.8E-01	9.3E+03	8.6E+03	5.4E+05	1.6E-07
	4.6E-01	4.3E-04									
0.0E+00	4.9E-01		2.4E-04	3.1E-02	1.1E+00	1.1E+00	1.1E+00	9.3E+03	9.9E+03	2.0E+05	1.6E-07
	5.2E-01	1.9E-04									
0.0E+00	5.5E-01		1.1E-04	1.4E-02	1.3E+00	1.3E+00	1.3E+00	9.3E+03	1.1E+04	7.4E+04	1.8E-07
	5.8E-01	8.5E-05									
0.0E+00	6.1E-01		4.5E-06	6.0E-03	1.4E+00	1.4E+00	1.4E+00	9.3E+03	1.2E+04	6.2E+04	9.7E-08
	6.4E-01	4.0E-05									
0.0E+00	6.7E-01		2.0E-05	2.6E-03	1.5E+00	1.5E+00	1.5E+00	9.3E+03	1.3E+04	4.7E+04	5.5E-08
	7.0E-01	2.0E-05									
0.0E+00	7.3E-01		9.0E-07	1.2E-03	1.7E+00	1.7E+00	1.7E+00	9.3E+03	1.5E+04	3.1E+04	3.9E-08
	7.5E-01	1.1E-05									
0.0E+00	7.8E-01		5.9E-06	7.6E-04	1.8E+00	1.8E+00	1.8E+00	9.3E+03	1.6E+04	2.5E+04	3.0E-08
	8.1E-01	5.1E-06									
0.0E+00	8.4E-01		2.5E-06	3.2E-04	1.9E+00	1.9E+00	1.9E+00	9.3E+03	1.7E+04	2.1E+04	1.5E-08
	8.7E-01	2.6E-06									

DAMAGE= 8.9E-07

MODEL 32 PIPELINE MAN. FATIGUE DAMAGE GROSS WT=2541 VC=144KNOTS
SM= 9106 *1.1 STRESS/G =8710 KT=4.0 ANLLF=2.8,-2.52

	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	5.0E-01									
-4.0E-02	1.3E-01		3.0E-01	3.9E+01	1.0E-01	3.6E-01	2.3E-01	1.0E+04	2.0E+03		
	1.6E-01	2.5E-01									
-1.3E-01	1.9E-01		9.0E-02	1.2E+01	3.3E-01	5.3E-01	4.3E-01	1.0E+04	3.7E+03		
	2.2E-01	1.6E-01									
-1.9E-01	2.5E-01		4.0E-02	1.0E+01	4.3E-01	7.0E-01	5.9E-01	1.0E+04	5.1E+03	2.5E+06	4.1E-06
	2.8E-01	8.0E-02									
-2.1E-01	3.1E-01		5.0E-02	6.5E+00	5.3E-01	8.7E-01	7.0E-01	1.0E+04	6.1E+03	4.5E+05	1.4E-05
	3.4E-01	3.0E-02									
-2.5E-01	3.7E-01		1.8E-02	2.3E+00	6.3E-01	1.0E+00	8.3E-01	1.0E+04	7.3E+03	1.4E+05	1.7E-05
	4.0E-01	1.2E-02									
-3.2E-01	4.3E-01		7.0E-03	9.1E-01	8.1E-01	1.2E+00	1.0E+00	1.0E+04	8.8E+03	5.0E+04	1.8E-05
	4.6E-01	5.0E-03									
-3.5E-01	4.9E-01		3.2E-03	4.1E-01	8.8E-01	1.4E+00	1.1E+00	1.0E+04	9.8E+03	3.3E+04	1.3E-05
	5.2E-01	1.8E-03									
-3.7E-01	5.5E-01		1.1E-03	1.4E-01	9.3E-01	1.5E+00	1.2E+00	1.0E+04	1.1E+04	2.3E+04	6.2E-06
	5.8E-01	7.0E-04									
-4.1E-01	6.1E-01		4.5E-04	5.8E-02	1.0E+00	1.7E+00	1.4E+00	1.0E+04	1.2E+04	1.2E+04	4.9E-06
	6.4E-01	2.5E-04									
-4.5E-01	6.7E-01		1.5E-04	1.9E-02	1.1E+00	1.9E+00	1.5E+00	1.0E+04	1.3E+04	1.0E+04	1.9E-06
	7.0E-01	1.0E-04									
-5.1E-01	7.3E-01		5.0E-05	6.5E-03	1.3E+00	2.0E+00	1.7E+00	1.0E+04	1.4E+04	6.8E+03	9.5E-07
	7.5E-01	5.0E-05									
-5.6E-01	7.8E-01		2.9E-05	3.8E-03	1.4E+00	2.2E+00	1.8E+00	1.0E+04	1.6E+04	5.6E+03	6.7E-07
	8.1E-01	2.1E-05									
-6.0E-01	8.4E-01		1.1E-05	1.4E-03	1.5E+00	2.4E+00	1.9E+00	1.0E+04	1.7E+04	4.4E+03	3.2E-07
	8.7E-01	1.0E-05									

DAMAGE= 8.1E-05

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MODEL 32 PIPELINE GUST FATIGUE DAMAGE GROSS WT. =2541 VC=144KNOTS
SM=9106 STRESS/G=8710 ANLLF=-,+2.20 KT=4.0

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	4.0E+00									
0.0E+00	1.3E-01		2.0E+00	2.6E+02	2.9E-01	2.9E-01	2.9E-01	9.1E+03	2.5E+03		
	1.6E-01	2.0E+00									
0.0E+00	1.9E-01		1.2E+00	1.6E+02	4.2E-01	4.2E-01	4.2E-01	9.1E+03	3.7E+03		
	2.2E-01	8.0E-01									
0.0E+00	2.5E-01		5.0E-01	6.5E+01	5.6E-01	5.6E-01	5.6E-01	9.1E+03	4.8E+03	2.0E+07	3.2E-06
	2.8E-01	3.0E-01									
0.0E+00	3.1E-01		2.0E-01	2.6E+01	6.9E-01	6.9E-01	6.9E-01	9.1E+03	6.0E+03	1.1E+06	2.4E-05
	3.4E-01	1.0E-01									
0.0E+00	3.7E-01		8.2E-02	1.1E+01	8.2E-01	8.2E-01	8.2E-01	9.1E+03	7.2E+03	2.2E+05	4.8E-05
	4.0E-01	1.8E-02									
0.0E+00	4.3E-01		1.1E-02	1.4E+00	9.5E-01	9.5E-01	9.5E-01	9.1E+03	8.3E+03	7.0E+04	2.0E-05
	4.6E-01	7.0E-03									
0.0E+00	4.9E-01		4.0E-03	5.2E-01	1.1E+00	1.1E+00	1.1E+00	9.1E+03	9.5E+03	4.0E+04	1.3E-05
	5.2E-01	3.0E-03									
0.0E+00	5.5E-01		1.4E-03	1.8E-01	1.2E+00	1.2E+00	1.2E+00	9.1E+03	1.1E+04	2.8E+04	6.5E-06
	5.8E-01	1.6E-03									
0.0E+00	6.1E-01		8.0E-04	1.0E-01	1.4E+00	1.4E+00	1.4E+00	9.1E+03	1.2E+04	1.4E+04	7.4E-06
	6.4E-01	8.0E-04									
0.0E+00	6.7E-01		4.0E-04	5.2E-02	1.5E+00	1.5E+00	1.5E+00	9.1E+03	1.3E+04	1.1E+04	4.7E-06
	7.0E-01	4.0E-04									
0.0E+00	7.3E-01		1.2E-04	1.6E-02	1.6E+00	1.6E+00	1.6E+00	9.1E+03	1.4E+04	8.4E+03	1.9E-06
	7.5E-01	2.6E-04									
0.0E+00	7.8E-01		1.3E-04	1.7E-02	1.7E+00	1.7E+00	1.7E+00	9.1E+03	1.5E+04	6.6E+03	2.6E-06
	8.1E-01	1.5E-04									
0.0E+00	8.4E-01		6.0E-05	7.8E-03	1.9E+00	1.9E+00	1.9E+00	9.1E+03	1.7E+04	5.0E+03	1.6E-06
	8.7E-01	9.0E-05									
0.0E+00	9.0E-01		3.0E-05	3.9E-03	2.0E+00	2.0E+00	2.0E+00	9.1E+03	1.7E+04	4.2E+03	9.3E-07
	9.3E-01	6.0E-05									
0.0E+00	9.6E-01		2.0E-05	2.6E-03	2.1E+00	2.1E+00	2.1E+00	9.1E+03	1.8E+04	3.8E+03	6.8E-07
	9.9E-01	4.0E-05									

DAMAGE= 1.3E-04

3k

MODEL 32 NORMAL MAN. FATIGUE DAMAGE GROSS WT=2840 VC=144KNOTS
SM=1.2*9253 STR/G=8819 kt=4.0 ANLLF=2.8,-2.52

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	2.2E-02									
0.0E+00	1.3E-01		1.3E-02	1.7E+00	0.0E+00	3.6E-01	1.8E-01	1.11E+04	1.61E+03		
	1.6E-01	9.0E-03									
-6.0E-02	1.9E-01		5.5E-03	7.1E-01	1.5E-01	5.3E-01	3.4E-01	1.11E+04	3.01E+03		
	2.2E-01	3.5E-03									
-1.2E-01	2.5E-01		2.0E-03	2.5E-01	3.0E-01	7.0E-01	5.0E-01	1.11E+04	4.42E+03	6.0E+06	4.2E-08
	2.8E-01	1.5E-03									
-1.7E-01	3.1E-01		8.5E-04	1.1E-01	4.3E-01	8.7E-01	6.5E-01	1.11E+04	5.72E+03	4.0E+05	2.8E-07
	3.4E-01	6.5E-03									
-2.2E-01	3.7E-01		3.5E-04	4.5E-02	5.5E-01	1.0E+00	8.0E-01	1.11E+04	7.01E+03	1.2E+05	3.8E-07
	4.0E-01	3.0E-04									
-2.6E-01	4.3E-01		1.6E-04	2.1E-02	6.6E-01	1.2E+00	9.3E-01	1.11E+04	8.20E+03	5.6E+04	3.8E-07
	4.6E-01	1.4E-04									
-3.1E-01	4.9E-01		7.0E-05	9.0E-03	7.8E-01	1.4E+00	1.1E+00	1.11E+04	9.49E+03	2.8E+04	3.2E-07
	5.2E-01	7.0E-05									
-3.5E-01	5.5E-01		4.0E-05	5.0E-03	8.8E-01	1.5E+00	1.2E+00	1.11E+04	1.07E+04	2.1E+04	2.4E-07
	5.8E-01	3.0E-05									
-3.9E-01	6.1E-01		1.5E-05	1.9E-03	9.8E-01	1.7E+00	1.3E+00	1.11E+04	1.19E+04	1.5E+04	1.3E-07
	6.4E-01	1.5E-05									
-4.3E-01	6.7E-01		8.0E-06	1.1E-03	1.1E+00	1.9E+00	1.5E+00	1.11E+04	1.31E+04	7.6E+03	1.4E-07
	7.0E-01	7.0E-06									
-4.7E-01	7.3E-01		3.0E-06	3.8E-04	1.2E+00	2.0E+00	1.6E+00	1.11E+04	1.42E+04	7.0E+03	5.4E-08
	7.5E-01	4.0E-06									

DAMAGE= 2.0E-06

MODEL 32 NORMAL GUST FATIGUE DAMAGE GROSS WT.=2840 VC=144KNOTS
SM=9253 STRESS/G =8819 KT=4.0 ANLLF=-,+2.20

AN/ANLLF	AN/ANLLF	CFRQ/NM	FRQ/NM	VC*.9*F/N	DG(-)	DG(+)	DG(+,-)	SM	SA	N	n/N
	1.0E-01	1.0E+00									
0.0E+00	1.3E-01		8.3E-01	1.1E+02	3.0E-01	3.0E-01	3.0E-01	9.3E+03	2.6E+03		
	1.6E-01	1.7E-01									
0.0E+00	1.9E-01		1.3E-01	1.6E+01	4.3E-01	4.3E-01	4.3E-01	9.3E+03	3.8E+03	0.0E+00	0.0E+00
	2.2E-01	4.5E-02									
0.0E+00	2.5E-01		3.5E-02	4.5E+00	5.7E-01	5.7E-01	5.7E-01	9.3E+03	5.0E+03	1.0E+07	4.5E-07
	2.8E-01	1.0E-02									
0.0E+00	3.1E-01		6.5E-03	8.4E-01	7.1E-01	7.1E-01	7.1E-01	9.3E+03	6.2E+03	8.0E+05	1.1E-06
	3.4E-01	3.5E-03									
0.0E+00	3.7E-01		2.4E-03	3.1E-01	8.4E-01	8.4E-01	8.4E-01	9.3E+03	7.4E+03	1.5E+05	2.1E-06
	4.0E-01	1.1E-03									
0.0E+00	4.3E-01		6.7E-04	8.7E-02	9.8E-01	9.8E-01	9.8E-01	9.3E+03	8.6E+03	6.2E+04	1.4E-06
	4.6E-01	4.2E-04									
0.0E+00	4.9E-01		2.4E-04	3.1E-02	1.1E+00	1.1E+00	1.1E+00	9.3E+03	9.9E+03	3.5E+04	8.9E-07
	5.2E-01	1.9E-04									
0.0E+00	5.5E-01		1.1E-04	1.4E-02	1.2E+00	1.3E+00	1.3E+00	9.3E+03	1.1E+04	1.8E+04	7.6E-07
	5.8E-01	8.5E-05									
0.0E+00	6.1E-01		4.5E-06	6.0E-03	1.4E+00	1.4E+00	1.4E+00	9.3E+03	1.2E+04	1.3E+04	4.6E-07
	6.4E-01	4.0E-05									
0.0E+00	6.7E-01		2.0E-05	2.6E-03	1.5E+00	1.5E+00	1.5E+00	9.3E+03	1.3E+04	1.0E+04	2.6E-07
	7.0E-01	2.0E-05									
0.0E+00	7.3E-01		9.0E-07	1.2E-03	1.7E+00	1.7E+00	1.7E+00	9.3E+03	1.5E+04	6.4E+03	1.9E-07
	7.5E-01	1.1E-03									
0.0E+00	7.8E-01		5.9E-06	7.6E-04	1.8E+00	1.8E+00	1.8E+00	9.3E+03	1.6E+04	5.5E+03	1.4E-07
	8.1E-01	5.1E-06									
0.0E+00	8.4E-01		2.5E-06	3.2E-04	1.9E+00	1.9E+00	1.9E+00	9.3E+03	1.7E+04	4.6E+03	7.0E-08
	8.7E-01	2.6E-06									

DAMAGE= 7.7E-06

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

AIR

σ_{max} Once per flight

PA-28-181 .9 V_C=127 kts

	Pipeline		Normal	
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
$N_{Z\,max}$	2.36	2.63	1.66	1.42
σ_{max}	18319	20429	13910	11877

PA-32-300 .9 V_C=144kts

	Pipeline		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
$N_{Z\,max}$	2.12	2.37	1.62	1.42
σ_{max}	18861	21039	14721	12957

GROUND

σ_{min} Once per flight

Taxi once per flight $N_Z = 1 \pm .325$

$N_{Z_{MIN}} = .675$

PA-28-181

	Pipeline	Normal
σ_{min}	3222	3397

PA-32-300

	Pipeline	Normal
σ_{min}	1737	2240

G-A-G

PA-28-181

Mission	σ_{max}	σ_{min}	σ_m	σ_a	N (K_T=3.0)	Damage/Hr (K_T=3.0)	N (K_T=4.0)	Damage/Hr (K_T=4.0)
Pipeline	20429	3222	11826	8603	4.9×10^{6}	1.02×10^{-7}	4.2×10^{4}	1.19×10^{-5}
Normal	13910	3397	8654	5257	∞	0	6.3×10^{6}	2.44×10^{-7}

PA-32-300

Mission	σ_{max}	σ_{min}	σ_m	σ_a	N (K_T=3.0)	Damage/Hr (K_T=3.0)	N (K_T=4.0)	Damage/Hr (K_T=4.0)
Pipeline	21039	1737	11388	9651	1.9×10^{5}	2.63×10^{-6}	2.8×10^{4}	1.79×10^{-5}
Normal	14721	2240	8481	6241	∞	0	8.6×10^{5}	1.79×10^{-6}

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	1.4×10^{-5}	8.3×10^{-6}	0	0	1.02×10^{-7}	44,639
Normal	4.9×10^{-7}	1.1×10^{-7}	0	0	0	1,666,667

Normal to Pipeline Life Ratio = 37.3

$K_T=4.0$
Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	2.4×10^{-4}	7.3×10^{-5}	0	0	1.19×10^{-5}	3,078
Normal	7.1×10^{-6}	9.9×10^{-7}	0	0	2.44×10^{-7}	119,990

Normal to Pipeline Life Ratio = 39.0

PA-32-300

$K_T=3.0$
Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	1.4×10^{-5}	7.9×10^{-6}	0	0	2.63×10^{-6}	40,766
Normal	8.9×10^{-7}	1.8×10^{-7}	0	0	0	934,579

Normal to Pipeline Ratio = 22.9

$K_T=4.0$
Damage per Hour

Mission	Gust	Maneuver	Taxi	Ldg Impact	G-A-G	Unfactored Life (hrs)
Pipeline	1.3×10^{-4}	8.1×10^{-5}	0	0	1.79×10^{-5}	4,369
Normal	7.7×10^{-6}	2.0×10^{-6}	0	0	1.79×10^{-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 Draft "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

PIPER - INITIAL AND REPETITIVE INSPECTION INTERVALS

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, a_{cr}. A_{cr} represent design limit load capability. The accident aircraft crack size when compared to the a_{cr} 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 was 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_{cr} 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_{cr} 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_{cr}. The area to be inspected is approximately 3/8" wide on an arc of 120^{o} 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_{cr} 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.

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