AD-A019 519

CATAPULT LAUNCH FATIGUE INVESTIGATION OF THE MODEL E-1B/C-1 AIRPLANE

H. D. Lystad

Naval Air Development Center
Warminster, Pennsylvania

19 November 1975

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

ADA019519

023104

REPORT NO. NADC-75310-30

CATAPULT LAUNCH FATIGUE INVESTIGATION OF THE MODEL E-1B/C-1 AIRPLANE

H. D. Lystad
Air Vehicle Technology Department
NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

19 November 1975

FINAL REPORT
AIRTASK NO. A510-5103/001-4/2510-000002
Work Unit No. KG101

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D. C. 20361

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

DDC
RECEIVED
JAN 22 1976
A

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NADC-75310-30	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Catapult Launch Fatigue Investigation of the Model E-1B/C-1 Airplane	5. TYPE OF REPORT & PERIOD COVERED: Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): H. D. Lystad	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Air Vehicle Technology Department, Naval Air Development Center, Warminster, Pa. 18974	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Airtask No. A510-5103/001-4/2510-000002 Work Unit No. KG101
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Air Systems Command, Department of the Navy, Washington, D. C. 20361	12. REPORT DATE: 19 November 1975
	13. NUMBER OF PAGES: 48
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fatigue (Materials)
Fatigue Tests
Catapult Start of Run
Catapult Release
Service Life

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laboratory fatigue investigation was performed on an E-1B fuselage with a reinforced catapult keel to determine if it could sustain the loads associated with 3,000 catapult launches. The bulkhead at fuselage station 135 failed after 8,420 test cycles of the catapult start of run condition. Using a test scatter factor of 2, this is equivalent to 4,210 service catapult launches. The holdback structure failed after 8,188 test cycles of the catapult release condition. Again, using a test scatter factor of 2, this is equivalent to 4,094 service catapult releases.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

NOTICES

REPORT NUMBERING SYSTEM - The numbering of technical project reports issued by the Naval Air Development Center is arranged for specific identification purposes. Each number consists of the Center acronym, the calendar year in which the number was assigned, the sequence number of the report within the specific calendar year, and the official 2-digit correspondence code of the Command Office or the Functional Department responsible for the report. For example: Report No. NADC-73015-40 indicates the fifteenth Center report for the year 1973, and prepared by the Crew Systems Department. The numerical codes are as follows:

CODE	OFFICE OR DEPARTMENT
00	Commander, Naval Air Development Center
01	Technical Director, Naval Air Development Center
02	Program and Financial Management Department
03	Anti-Submarine Warfare Program Office
04	Remote Sensors Program Office
05	Ship and Air Systems Integration Program Office
06	Tactical Air Warfare Office
10	Naval Air Facility, Warminster
20	Aero Electronic Technology Department
30	Air Vehicle Technology Department
40	Crew Systems Department
50	Systems Analysis and Engineering Department
60	Naval Navigation Laboratory
81	Administrative and Technical Services Department
85	Computer Department

White Section ☑
Buff Section ☐
☐

BY
DISTRIBUTION/AVAILABILITY CODES
AVAIL. and/or SPECIAL
A

APPROVED BY: ______________________ DATE: 19 November 1975

P. D. STOGIS
Commander, USN
Deputy Director, AVTD

S U M M A R Y

A laboratory fatigue investigation was performed on an E-1B fuselage with a reinforced catapult keel to determine if it could sustain the loads associated with 3,000 catapult launches.

The bulkhead at fuselage station 135 failed after 8,420 test cycles of the catapult start of run condition. Using a test scatter factor of 2, this is equivalent to 4,210 service catapult launches. The holdback structure failed after 8,188 test cycles of the catapult release condition. Again, using a test scatter factor of 2, this is equivalent to 4,094 service catapult releases.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The majority of E-1/C-1 airplanes now in service have exceeded or are approaching their authorized limit of 750 catapult launches. Projected operational requirements for these airplanes necessitate their possessing a capability for sustaining 3,000 catapult launches. To obtain this new capability, the catapult structure of these airplanes has been strengthened by installing a keel beam modification. The E-1/C-1 airplanes, with or without reinforced catapult keels, have never been tested to establish their catapult launch fatigue lives.

The fuselage structure of the model E-1 and C-1 airplanes are identical in the region critical for the catapult start of run condition, but are dissimilar in the region critical for the catapult release condition. The gross weight of the E-1 is 25% higher than that of the C-1. Therefore, test results of an E-1 airplane subjected to simulated catapult launches are applicable to the C-1 for the catapult start of run condition only. The fuselage structure of the C-1 airplane is identical to the S-2 airplane in the region critical for the catapult release condition and has been substantiated by a catapult fatigue investigation of the S-2 airplane recently completed by the NAVAIRDEVCEN.

The objective of this program is to ascertain the structural capacity of the E-1/C-1 airplanes with reinforced catapult keels to sustain the cumulative effects of repeated catapult launches and to safely extend the current usage limits of these airplanes to 3,000 catapult launches.

DESCRIPTION OF TEST SPECIMEN

The test specimen was an E-1B airplane, serial number 147236, which was removed from service. The history of the test specimen when it was made available to the NAVAIRDEVCEN is as shown in Table I.

TABLE I

HISTORY OF TEST SPECIMEN

E-1B Airplane - Serial Number 147236

Age	149 months
Total Flight Time	4,776.7 hours
Number of Flights	780
Number of Arrestments	788
Number of Catapults	619*

* The number of catapults (not a log book entry) was determined by using the Naval Weapons - Dahlgren, Va. Naval aircraft usage tape data. Based on this data, it can be determined that the E-1B aircraft experiences 0.786 catapults per arrestment. Therefore, the assumed number of catapults for the test specimen is:

788 arrestments x 0.786 catapults/arrestment = 619 catapults

For the purpose of this test program, and as a prototype for the E-1/C-1 model airplanes, the catapult keel was reinforced by NAVAIREWORKFAC, Quonset Point. This reinforcement is detailed in AFC #92 and in reference (a). A stress analysis and fatigue life analysis of the reinforced catapult keel is given in reference (b).

The wing outer panels, vertical and horizontal stabilizers, main and nose landing gears were removed, as were the engines, engine cowling, radome and fuselage nose structure forward of fuselage station (FS) 46. Figure 1 shows the final test specimen.

For the catapult start of run condition, the loads are introduced into the fuselage through a dummy catapult hook into the center line catapult fitting located at FS 132. The forward loads are carried by a center line keel beam which extends along the bottom of the fuselage. The vertical and side loads are carried primarily by the bulkhead at FS 135.

Holdback loads for the catapult release condition are introduced into the fuselage through a fitting located at FS 479.25. This fitting distributes the axial load through two longitudinal stringers that extend forward to FS 449.51. The vertical and side loads are carried primarily by two vertical channels located at FS 474.

T E S T P R O G R A M

The test program consisted of two parts, a catapult start of run condition and a catapult release (holdback) condition, performed separately and in that order. To demonstrate a service fatigue life of 3,000 catapult launches, 6,000 catapult launch simulations (test cycles) were required for each of the two conditions.

The details of each test condition are as follows:

CATAPULT START OF RUN CONDITION

The catapult start of run condition loads, locations and magnitudes, are shown in Appendix A, Figure A-2, and Table A-I. These loads correspond to GAC (Grumman Aerospace Corporation) condition 7B, catapult start of run for a catapulting gross weight of 26,600 pounds. Loads were applied in accordance with the test spectrum shown below:

1. Apply mean tow axial and vertical loads.
2. While holding the above, apply the side load as follows:
   - Zero side load
   - Mean side load to the left
   - Zero side load
   - Mean side load to the right
   - Zero side load

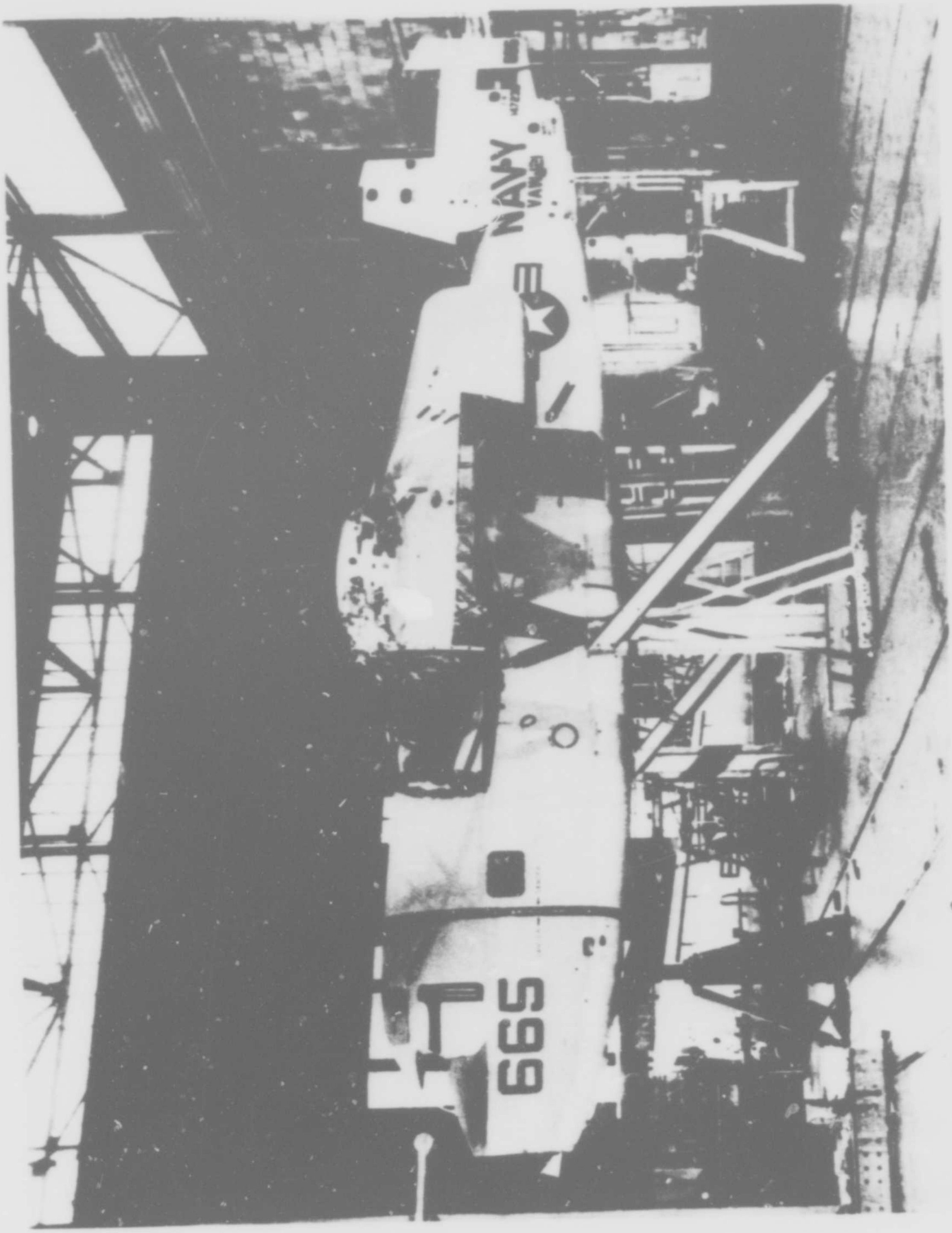
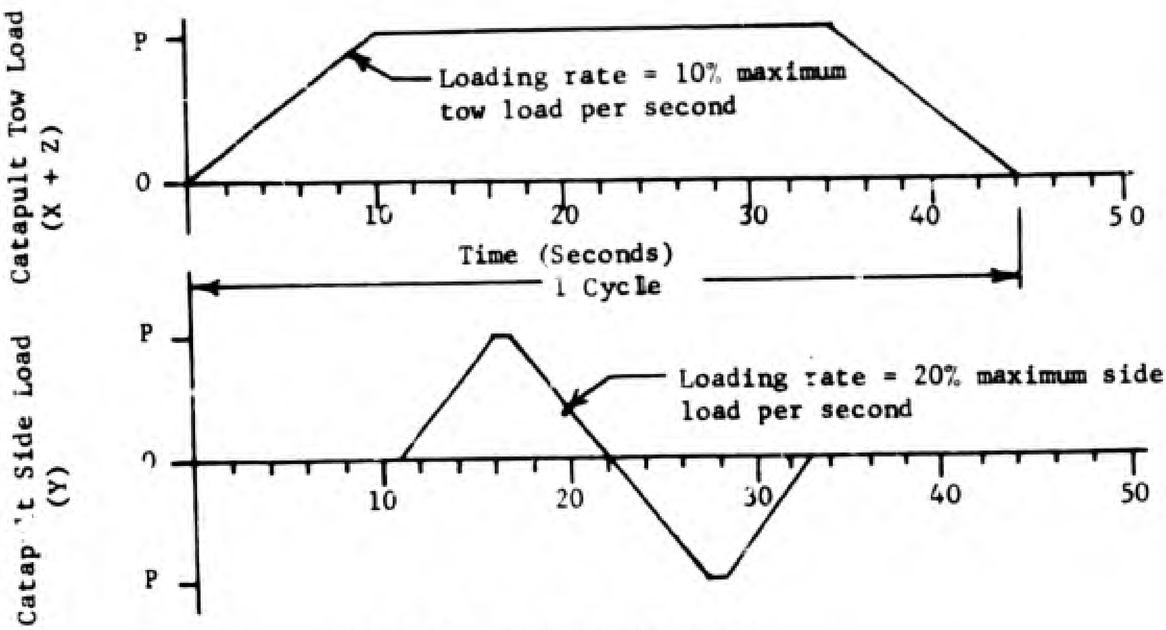


FIGURE 1 - E-1B Test Specimen

3. Reduce the loads of step 1 to zero.
4. Repeat steps 1 - 3 (one application of the catapult start of run condition) nine times.
5. Repeat steps 1 - 3 using maximum loads in lieu of mean load one time.
6. Repeat steps 1 - 5 (ten applications at the catapult start of run condition) 600 times.

A typical catapult start of run load cycle is as shown graphically below:



TYPICAL START OF RUN CYCLE

The above spectrum was modified from MIL-A-8867 (reference(c)) by NAVAIRSYSCOM and is based on aircraft usage information.

CATAPULT RELEASE CONDITION

The catapult release (holdback) condition loads, locations and magnitudes are shown in Appendix A, Figure A-9 and Table A-IV. These loads correspond to the GAC condition 7A, catapult release for a catapulting gross weight of 26,600 pounds.

The test was performed according to MIL-A-8867, paragraph 3.5.3.2, which specifies simulation of dynamic effects caused by holdback link failure. Side loads resulting from catapult spotting misalignments were applied, and these side loads were reversed after every 250 cycles.

A total of 6,000 holdback cycles were required to satisfy this condition.

TEST METHOD

The test specimen was supported with the fuselage reference line parallel to the floor and 120 inches above it. The plane of symmetry of the aircraft was perpendicular to the floor.

To support the aircraft and to react the test loads, the main landing gear was removed and replaced by more rigid dummy gear. The dummy gear was supported on vertical columns. A third support reaction point, designed to react only vertical loads, was provided at the holdback fitting for the catapult start of run condition and at the catapult fitting for the catapult release condition. The tare weight of the test specimen was reacted by the support points.

Loads were applied to the test specimen by hydraulic actuators which are part of an electro-hydraulic, closed-loop, servo-controlled loading system. Each hydraulic actuator had independent control by means of individual servo valves and servo controllers with load cells to generate feedback information. Loads were monitored on a multichannel bar-video display and strip chart recorders, both of which provided overload protection. Two additional and independent overload protection systems were provided by error detectors on each servo controller and stroke limit switches on each actuator. Triggering of any overload system would immediately dump hydraulic pressure at all actuators and at the hydraulic power supply.

Other test method details particular to each test condition are given below.

CATAPULT START OF RUN CONDITION

The catapult hook was removed and replaced by a dummy fitting which incorporated the same self-aligning spherical bearing from the original catapult hook. The arresting hook was removed and replaced by a dummy hook.

The catapult axial (X) and vertical (Z) loads simulating the tow load, were applied as a resultant, using a single hydraulic actuator. Catapult side loads (Y) were applied with a separate hydraulic actuator. Figures 2 and 3 show the catapult start of run condition test set-up. Figure 4 shows the catapult hook loading system.

CATAPULT RELEASE CONDITION

The holdback fitting was removed from the specimen and replaced by a dummy fitting. The X, Y, and Z components of the release loads were applied

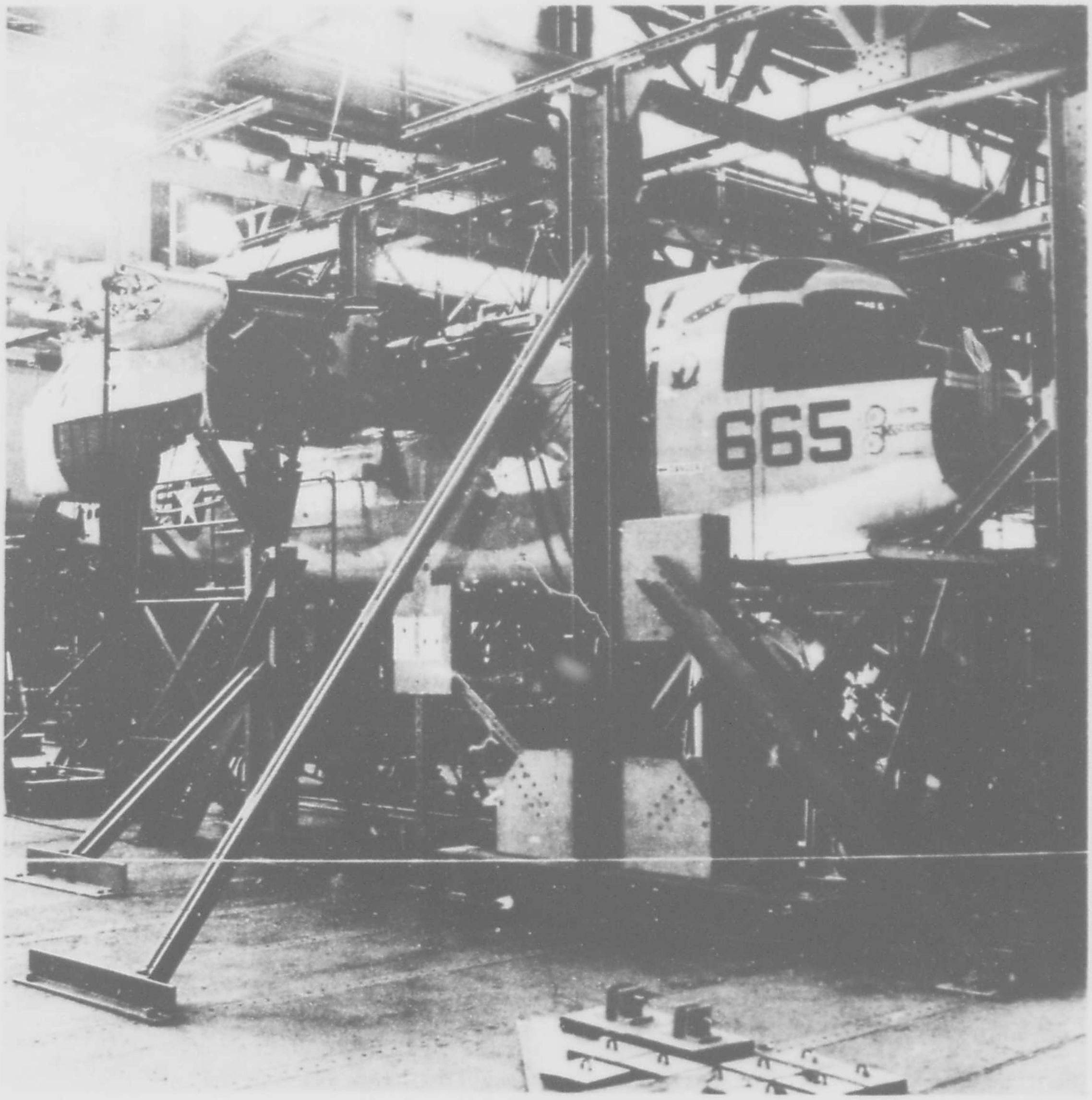


FIGURE 2 - Catapult Start of Run Condition Test Set-Up - View Looking Aft

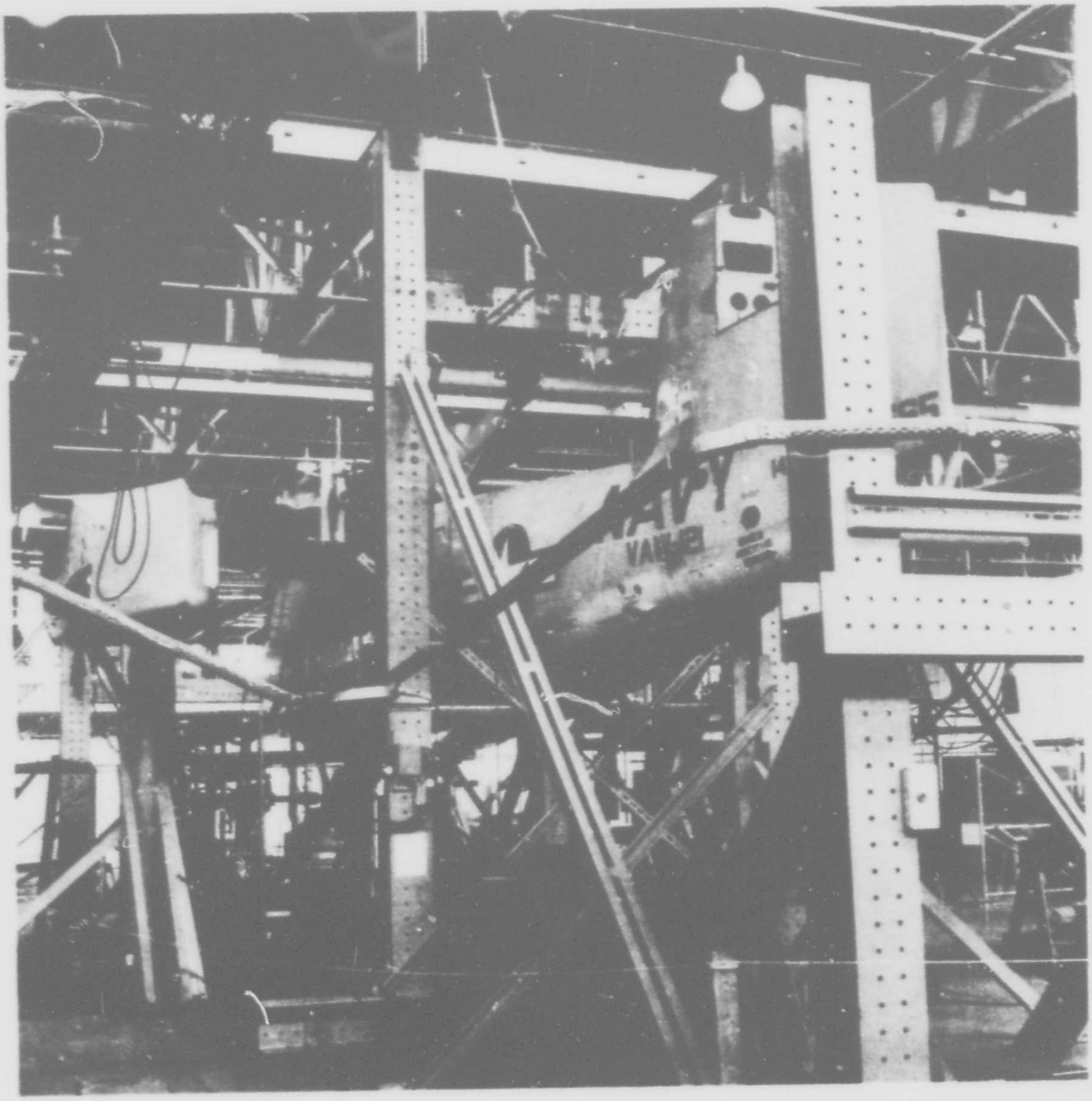


FIGURE 3 - Catapult Start of Run Condition Test Set-Up - View Looking Forward

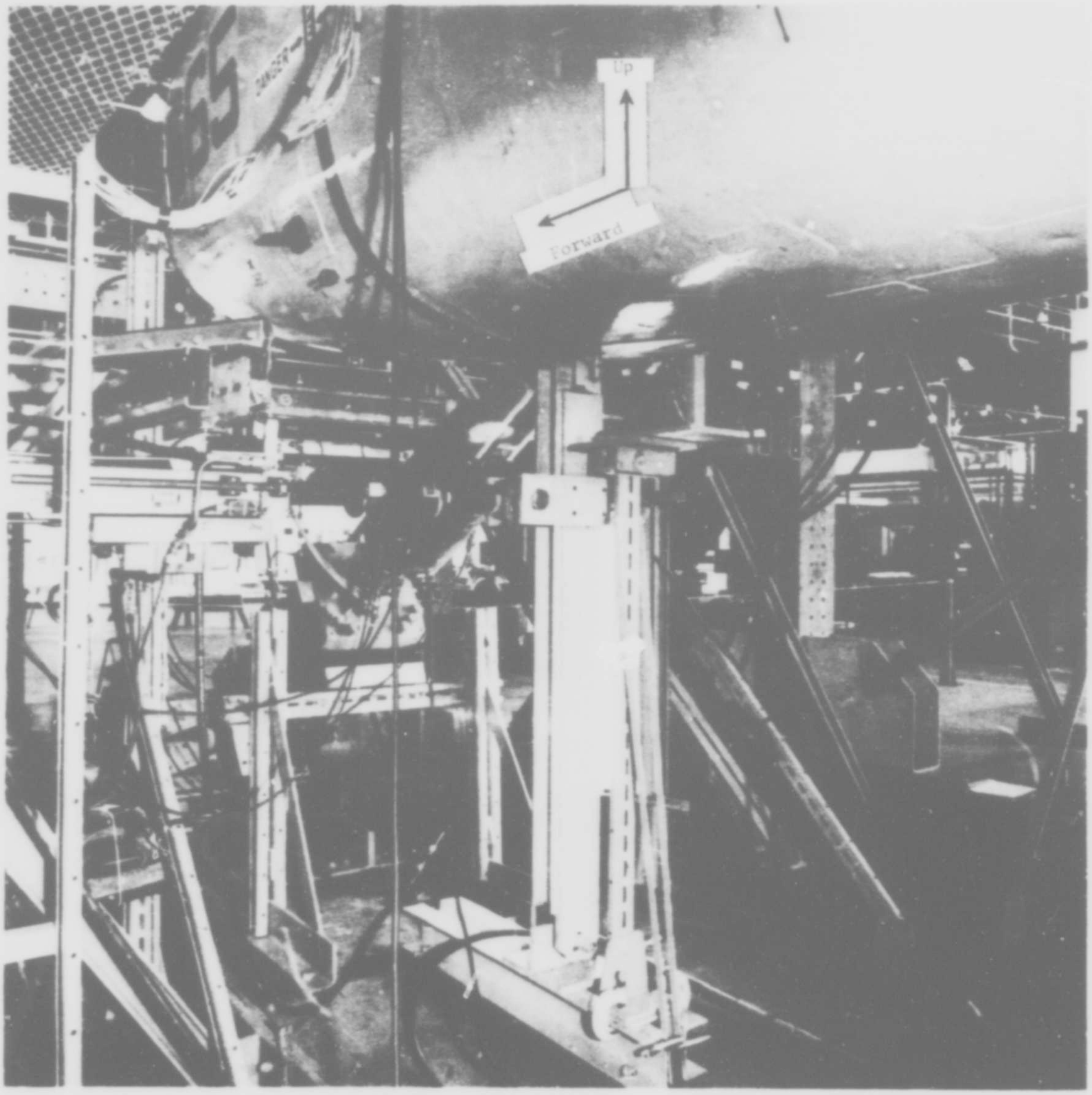


FIGURE 4 - Catapult Hook Loading System

as a resultant using a single hydraulic actuator. The load was released dynamically by using a quick release mechanism to simulate the breaking of a frangible holdback link used in service. Figure 5 shows the catapult release loading system.

TEST RESULTS

CATAPULT START OF RUN CONDITION

During the start of run condition, structural failure occurred in cycle number 8,420 at FS 135 bulkhead. The failed portion of the bulkhead was removed from the test specimen. Visual examination of the failure revealed three distinct cracks, hereby designated point A, point B, and point C. Figure 6 shows the failure.

Metallurgical examination of the fracture surfaces revealed striations emanating from the edge of the drilled rivet holes indicated in Figure 6. These striations indicated a fatigue mode of failure. No evidence of corrosion or material defects were found. The complexity of the failure, due to number of crack initiation sites observed, makes the establishment of the initial crack an uncertainty. However, it is concluded that the failure initiated at point A (Figure 6), in the thin section on the left-hand side of the bulkhead. A redistribution of the stresses of the applied load then initiated the fatigue crack at point B (Figure 6), in the thin section on the right-hand side of the bulkhead. After failure of the thin section of the bulkhead at points A and B, the final fatigue crack initiated at point C (Figure 6) and propagated approximately 50% across the surface. At this point the crack length was critically sized and resulted in catastrophic failure of the bulkhead due to shear overload.

No other significant occurrences were experienced during the start of run condition. Figure 7 and Figure 8 depict fuselage skin deflection for the zero load and maximum load conditions, respectively.

CATAPULT RELEASE CONDITION

During the release condition, structural failure occurred in cycle number 8,188. The left-and right-hand stringers severed completely just forward of the holdback fitting. Figures 9 and 10 show the failure.

Visual inspection of the fracture surfaces revealed dark areas adjacent to rivet holes in both stringers suggesting that this was the point of origin and the mode of failure was fatigue.

Metallurgical examination of the fracture surfaces revealed that failure occurred in essentially the same manner in both stringers. A fatigue crack developed from the edge of the rivet hole and propagated to approximately a quarter of an inch. A much smaller fatigue crack developed on the opposite side of the rivet hole. At this point, these fatigue cracks were critically sized and the remaining section failed due to shear overload.

FIGURE 5 - Catapult Release Loading System

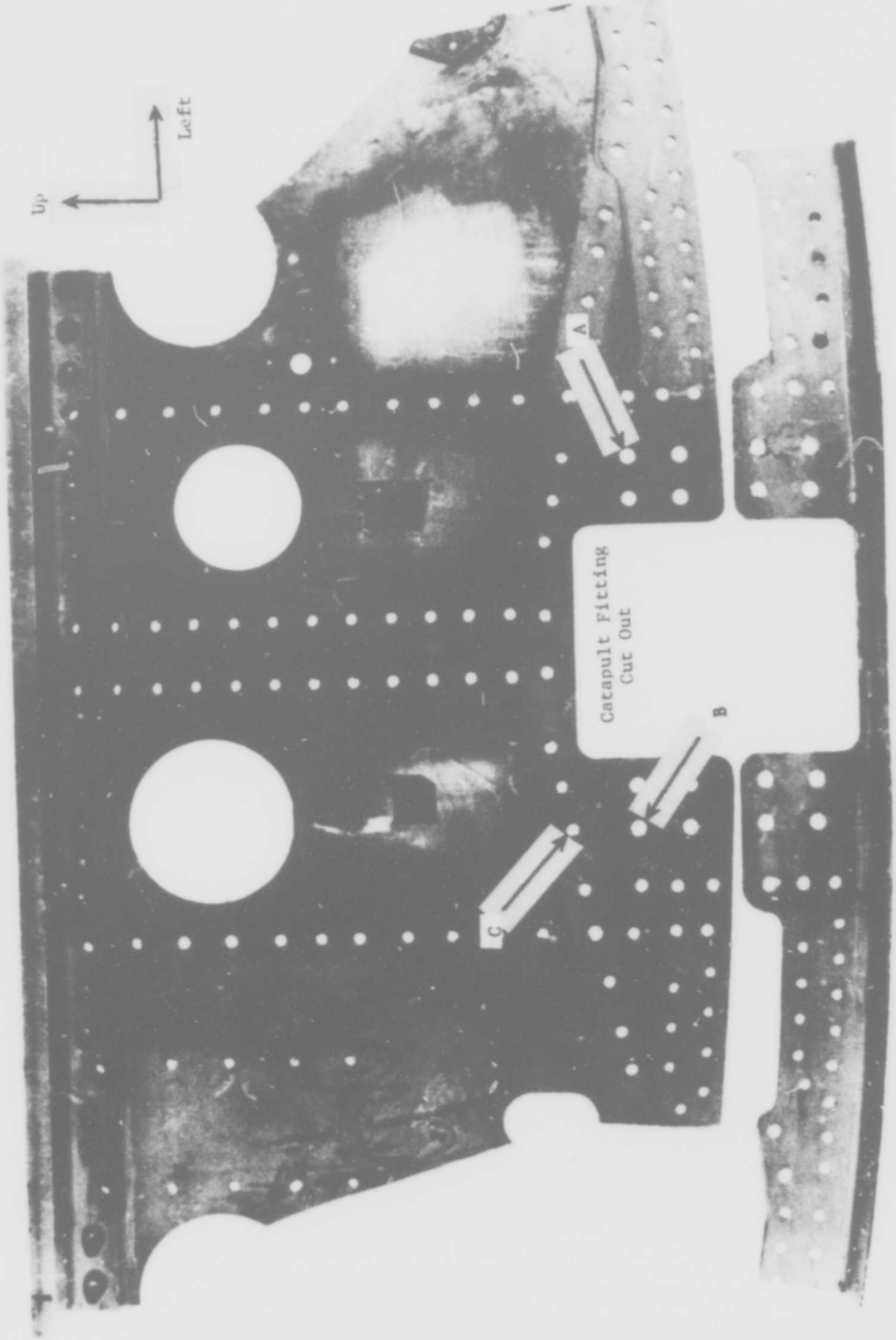


FIGURE 6 - FS 135 Bulkhead Failure, View Looking Aft

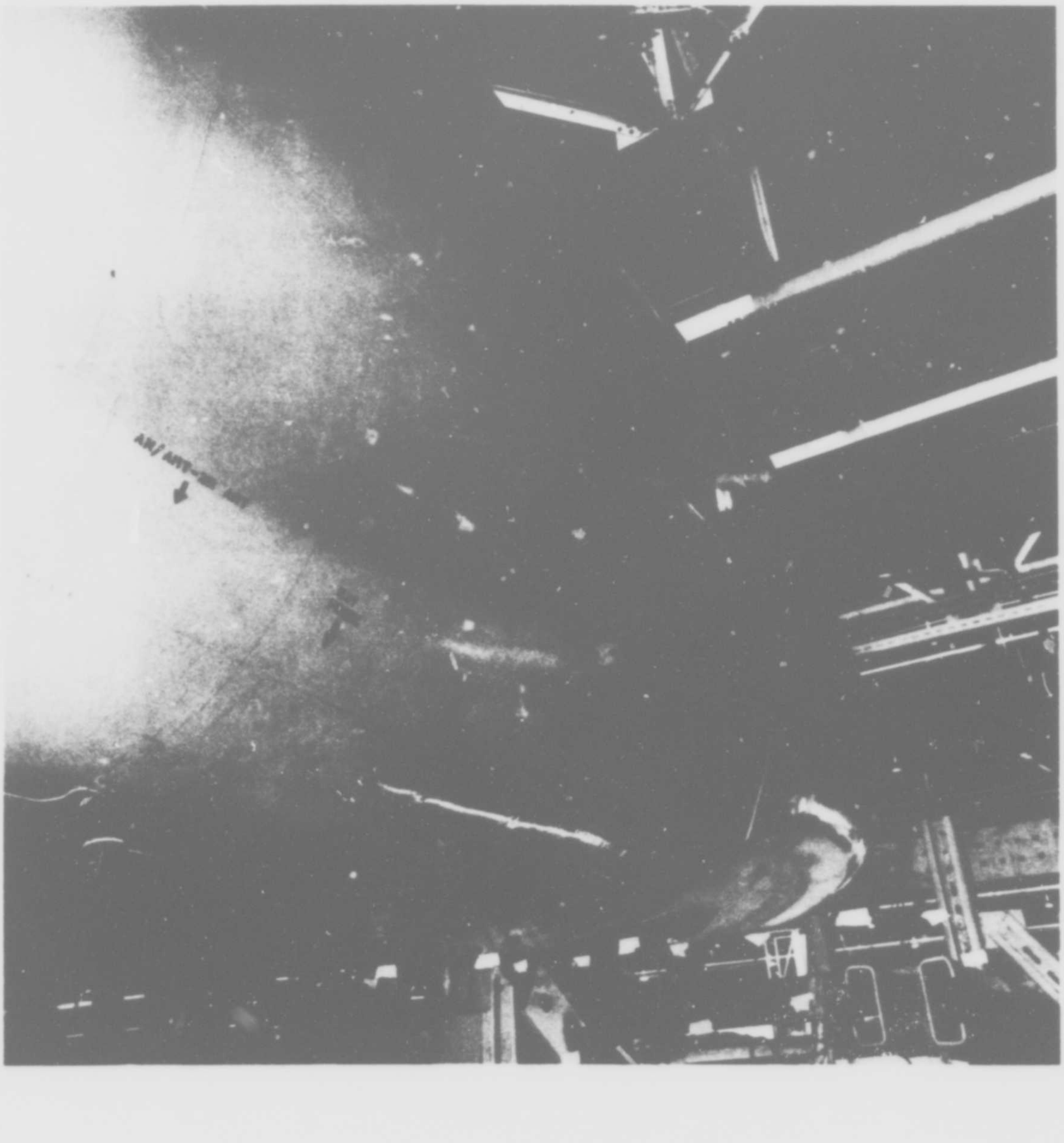


FIGURE 7 - View Looking Forward at Zero Load
Catapult Start of Run Condition

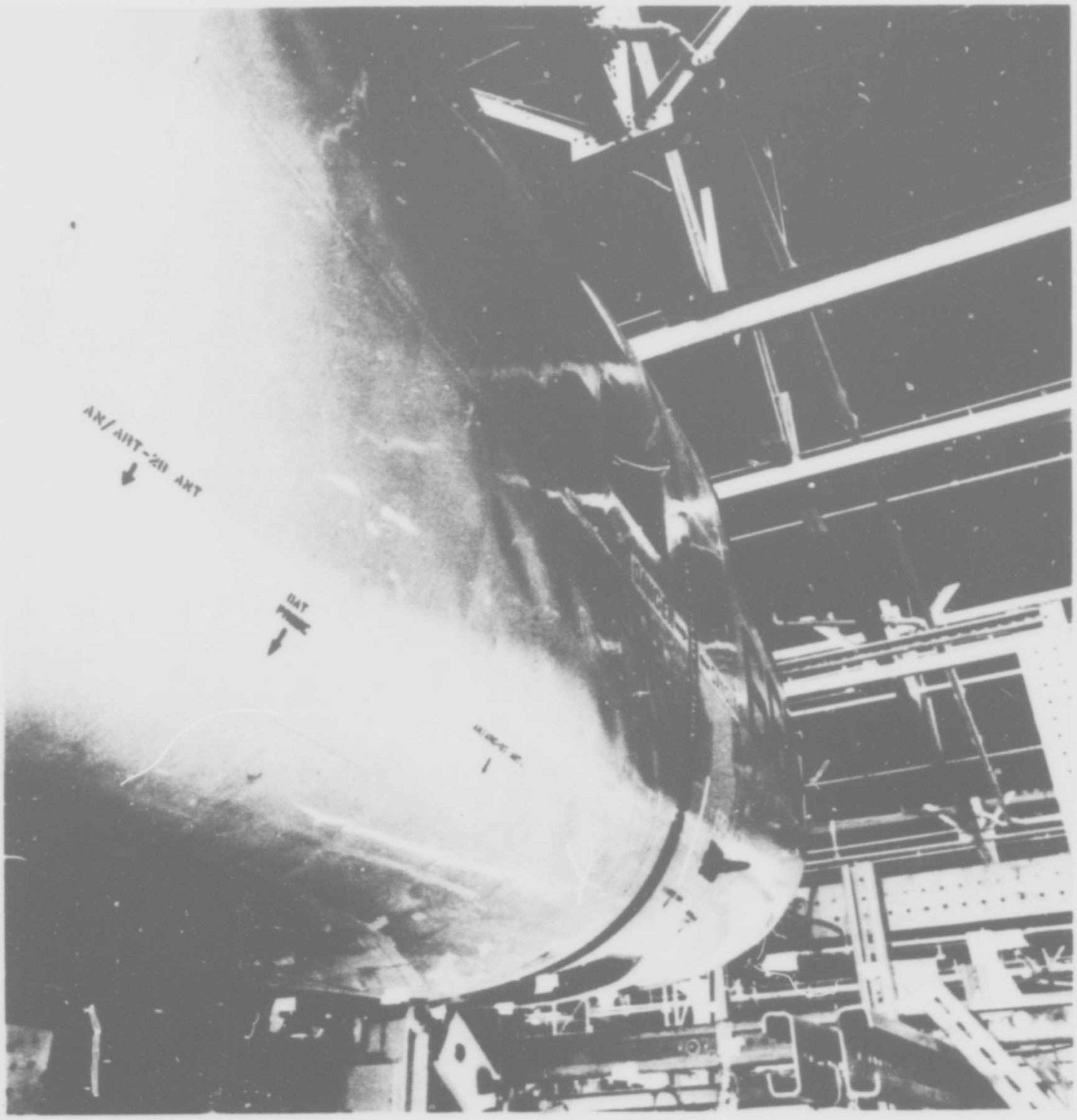


FIGURE 8 - View Looking Forward at Maximum Load
Catapult Start of Run Condition

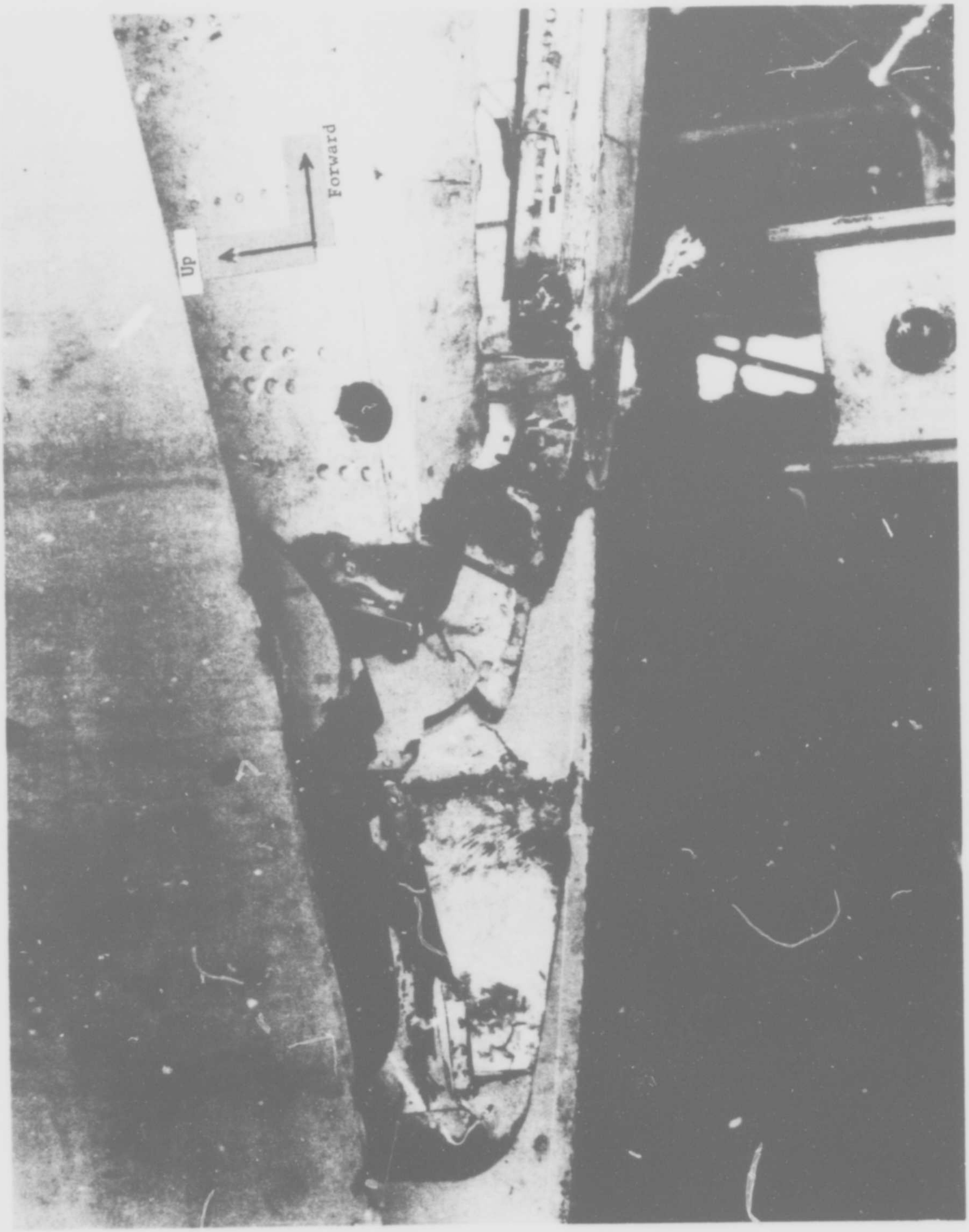


FIGURE 9 - Holdback Failure - View from Starboard Side

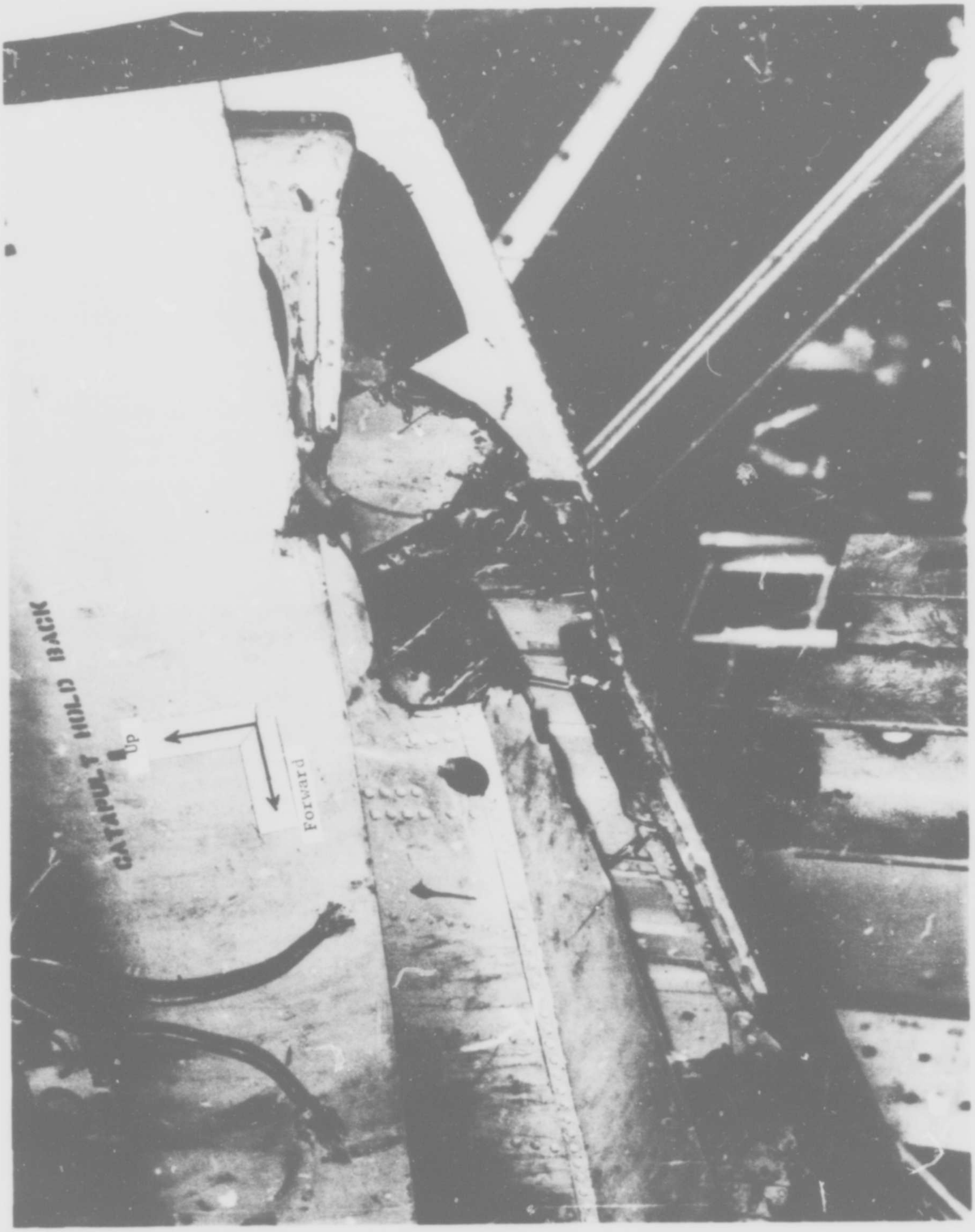


FIGURE 10 - Holdback Failure - View from Port Side

A scanning electron microscope examination of the fracture surfaces revealed fatigue striation spacing of 42,000 striations per inch at the crack origin and 14,000 striations per inch at the outer edge of the fatigue crack prior to structural failures. Based on an average crack growth rate of 28,000 striations (cycles) per inch and a crack length of 0.250 inch, the fatigue crack developed in about 7,000 cycles of load subsequent to initiation.

CONCLUSIONS

Based on the results of this fatigue investigation, the E-1B fuselage is capable of sustaining the effects of 3,000 catapult launches with a reinforced catapult keel.

The program results are also applicable to the C-1 fuselage with the exception of the holdback structure. However, the C-1 holdback structure, which is similar to the S-2 aircraft, has been verified by an S-2 catapult launch fatigue investigation in excess of 10,000 holdback test cycles after the installation of a holdback structure reinforcement. Therefore, the C-1 fuselage is capable of sustaining the effects of 3,000 catapult launches with reinforced catapult keel and holdback structures.

This fatigue life is limited to the catapult launch mode of service and does not imply any other structural limitations on the aircraft.

RECOMMENDATIONS

It is recommended that the catapult keel beam reinforcement installed on the test article be installed on all E-1B and C-1 aircraft and the holdback structure reinforcement, to be installed on the S-2 aircraft be installed on the C-1 aircraft.

It is further recommended that the current authorized catapult launch limit of 750 launches for the E-1B and C-1 aircraft be extended to 4,000 launches after installation of the reinforcements indicated above.

REFERENCES

(a) GAC Drawing No. 117-201B, Catapult Hook Reingorcing Strap for Extended Service Life - Model E-1B, 23 Feb 1972

(b) GAC Report No. [illegible]-72-1, Analytical Evaluation of Service Life for the S-2, E-1B, C-1A Aircraft - Phase V, 31 Mar 1972

(c) MIL-A-8867 (ASG), Military Specification - Airplane Strength and Rigidity Ground Tests, 18 May 1960

A P P E N D I X A

TEST DATA FOR CATAPULT LAUNCH FATIGUE INVESTIGATION OF THE MODEL E-1B AIRPLANE

LIST OF FIGURES

LIST OF TABLES

SYMBOLS

All symbols used in this appendix and in the text of the report are defined below:

FS . . . . fuselage station

FRL . . . . fuselage reference line

LL . . . . limit load = 2/3 design ultimate load

Re . . . . resultant load

MLG . . . . main landing gear

SIGN CONVENTION

The following sign convention is used: Distances and forces are positive when they are up, aft and to the left with respect to the reference axes. (See Figure A-1)

Positive bending moments produce compression in the top surface and left side of the fuselage.

Positive vertical shear results when the positive vertical loads are summed from a station of greater magnitude to one of lesser magnitude. Positive lateral shear results when the positive lateral loads are summed from a station of greater magnitude to one of lesser magnitude.

Positive torsion about the FRL results when a station of higher magnitude rotates clockwise in relation to a station of lower magnitude when viewed from aft.

REFERENCE AXES

X - axis: Lies in the plane of symmetry and is coincident with the FRL.

Y - axis: Perpendicular to the plane of symmetry through the X - axis at FS 0.

Z - axis: Perpendicular to the X-Y plane through the intersection of the X and Y axes.

BASIC DATA

Catapulting design gross weight - 26,600 pounds.

Catapulting test conditions (references (a) and (b)).

1. Catapult start of run - Grumman Aerospace Corporation (GAC) Condition 7B

2. Catapult release - GAC Condition 7A

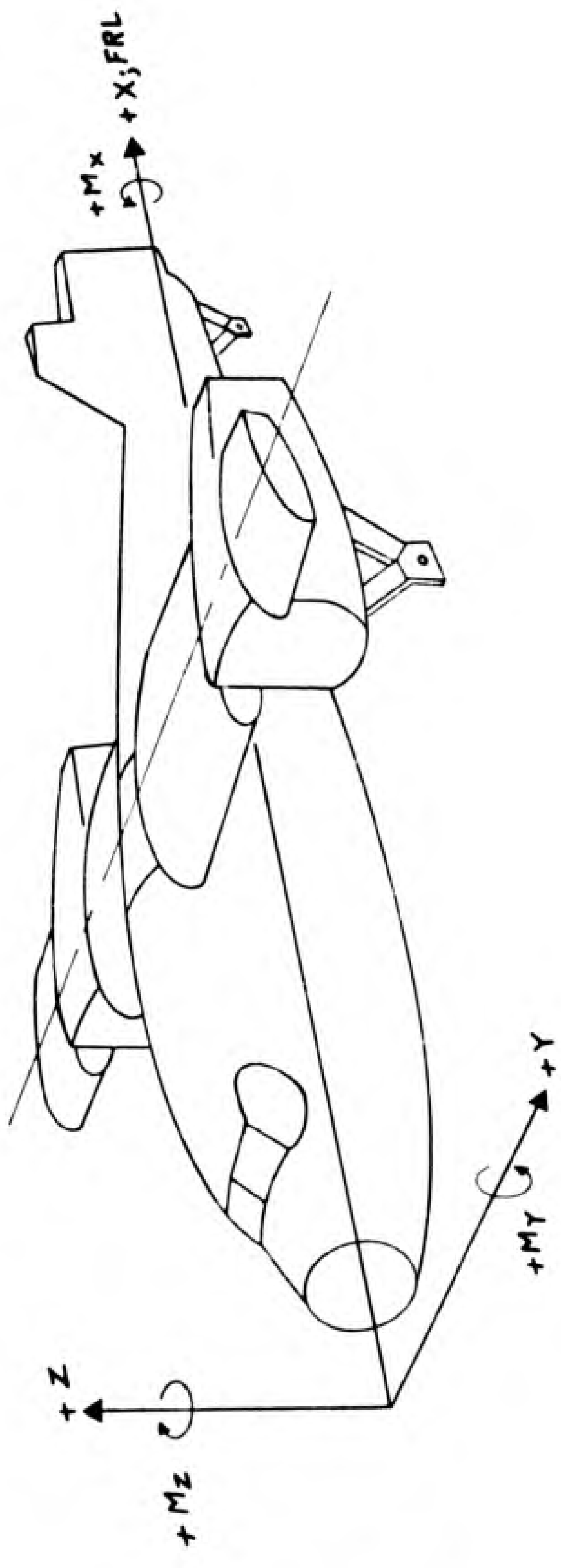


FIGURE A-1. Reference Axes and Sign Convention

TEST LOADS

START OF RUN CONDITION

The E-1 aircraft was designed for use with hydraulic powered shipboard catapults. The corresponding launching conditions design curves are found in reference (a). The hydraulic powered catapults have since been replaced with steam powered catapults which produce a smoother, more uniform catapulting stroke. As a result, the E-1 catapult drag load has been reduced and is determined as follows:

For C11-1 steam catapult; dry conditions; W-O-D (Wind-Over-Deck) = 0 kts.; 100 kts. end speed; and single engine operation.

Design gross weight = 26,600 lbs. (References (a) and (b))

With 90° day and W-O-D = 0 kts; (Reference (c))

Effective gross weight = 27,400 lbs.

Effective W-O-D = -3 kts. (1 $^{kt}/_{10°F}$ above 59°F)

Receiver pressure = 224 psi

Therefore, using reference (d),

Mean tow load parallel to deck = 82,000 lbs. limit

Maximum tow load parallel to deck = 88,000 lbs. limit

(Design tow load parallel to deck = 95,449 lbs. limit; reference (b))

Using the equations of reference (b), the catapult maximum/mean loads are:

Ground Axis	Fuselage Reference Axis
D = -88,000#/-82,000#	X = -82,426#/-76,806#
V = -39,160#/-36,490#	Z = -49,837#/-46,439#
S = 15,592#/ 14,529#	Y = 15,592#/ 14,529#

The above maximum/mean horizontal (D or X) and vertical (V or Z) loads were used as the test loads. The side load (S or Y) was further modified as follows:

GAC Design Side Load = 16,911#

GAC Proposed Side Load = 5,900#

The GAC proposed side load is based on reference (a) and the assumption that the steam powered catapults produce lower side loads. A test side load equal to 11,400# maximum and 10,620# mean was selected, with NAVAIR concurrence, by averaging the GAC design side load and the GAC proposed side load, thus allowing some conservatism for any unusual conditions or major mission changes.

The locations of all applied loads and reactions are shown on Figure A-2. The magnitudes of all test loads are shown in Table A-I. The distribution of loads are shown in Tables A-II and A-III. Comparison of the design and test curves are shown in Figures A-3 through A-8. The differences between the design and test curves are due to the new catapulting loads as derived above.

CATAPULT RELEASE CONDITON

The holdback loads for catapult release, GAC condition 7A, as shown in reference (a) are as follows:

X = 27,542#

Y = ±4,515#

Z = 5,771#

The location of all applied loads and reactions are shown on Figure A-9. The magnitude of all test loads are shown in Table A-IV. The distribution of loads are shown in Tables A-V and A-VI. The test curves are shown in Figures A-10 through A-15.

R E F E R E N C E S

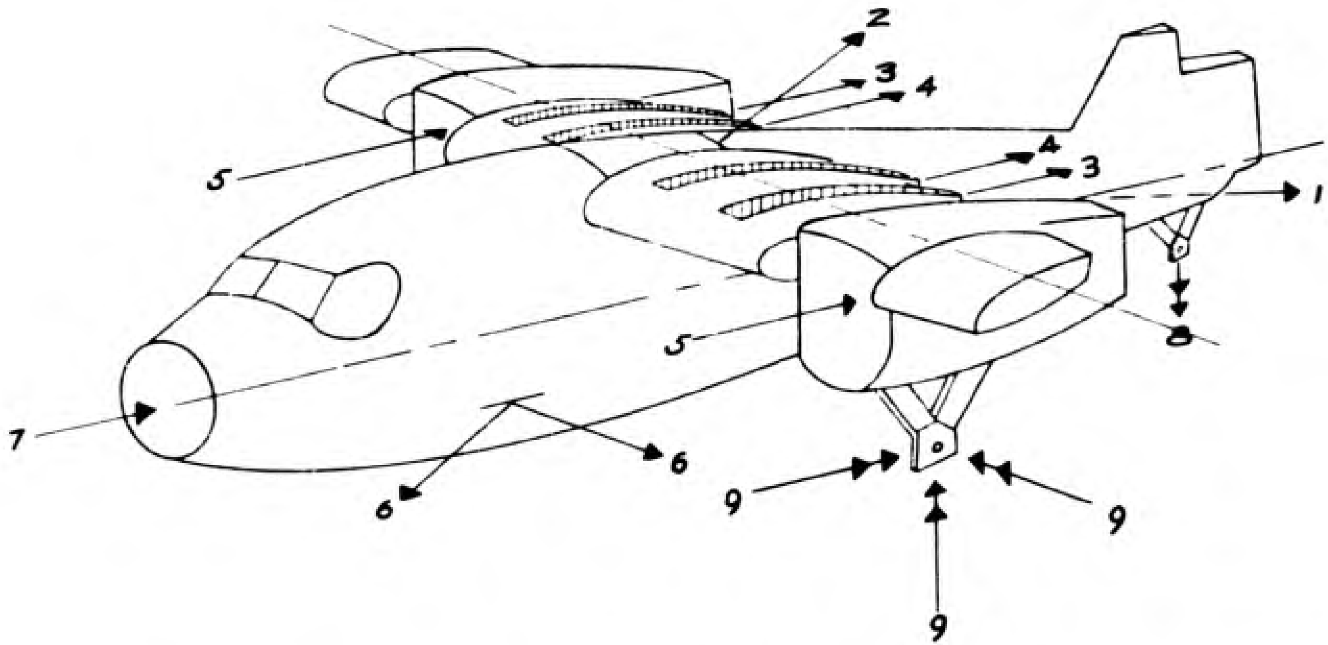
(a) GAC Report No. 3639.01C, Determination of Conditions for Catapulting Static Tests, Model WF-2, 3 Dec 1958

(b) GAC Report No. 3603.3C, Ground Loads, Model WF-2, Rev. 20 Aug 1957

(c) Aircraft Launch Bulletin No. 6-52D

(d) LTV Report 2-53420/6R-2259, Appendix C, Determination of the Characteristic Non-Dimensional Load Stroke Diagram for Ship Based and Shore Based Catapult and Arresting Gear from Analysis of Airplane and Dead Load Test Data

(e) GAC Report 3625.9, Carrier Suitability Trials of XS2F-1



Notes: 1. The numbers correspond to the load point numbers of Table A-1.

2. ⟶ = applied load.

3. ⟶⟶ = reaction load.

FIGURE A-2. Load Points, Catapult Start of Run Condition

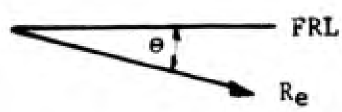
TABLE A-I - TEST LOADS - CATAPULT START OF RUN CONDITION - SIDE LOAD LEFT

Load Point	Applied Loads					
	Location, Inches			Maximum Load, Lbs		
	X	Y	Z	X	Y	Z
1. Arresting Hook	449.513	0	-6.000	13,330	0	-2,270
2. Radome Drag Fitting	266.761	0	49.904	6,670	0	2,530
3. Wing, left	231.816	51.25	38.140	3,330	0	0
right	231.816	-51.25	38.140	3,330	0	0
4. Wing, left	231.816	60.75	38.140	3,330	0	0
right	231.816	-60.75	38.140	3,330	0	0
5. Engine, left	210.000	110.00	23.000	16,000	0	0
right	210.000	-110.00	23.000	16,000	0	0
6. Catapult Hook	132.000	0	-35.250	-82,424	11,400	-49,857
7. Nose Bulkhead	46.000	0	0	6,670	0	0
	Reaction Load					
8. Holdback Fitting	475.25	0	-13.92	0	0	306
9. Main Gear, left	220.563	+102.395	-30.00	277	-5700	24,353
right	220.563	-102.395	-30.00	10,137	-5700	24,938

NOTES:

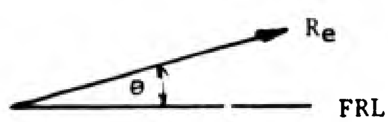
1. The X and Z loads at load points 1, 2 and 6 are applied as the following resultant loads at the following angles:

Load Point 1.



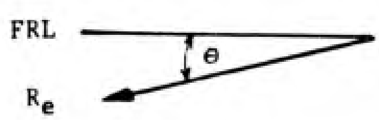
θ = 9° 39.9'
R_e = 13,522#

Load Point 2.



θ = 20° 46.3'
R_e = 7,134

Load Point 6.



θ = 31° 10.1'
R_e = 96,330#

2. For the side load right condition the side loads (Y) at points 6 and 9 reverse direction and the axial loads (X) and vertical loads (Z) at point 9 interchange.

TABLE A-II - FUSELAGE VERTICAL SHEAR, BENDING MOMENT AND AXIAL LOAD - CATAPULT START OF RUN CONDITION - MAXIMUM LOAD

Location	FS In	Δ x In	Vertical Load Lbs	Vertical Shear Lbs	Axial Load Lbs	Δ z In	ΔBM Axial In-Lbs	ΔBM Vert In-Lbs	ΣBM In-Lbs
Holdback Fitting	475.250		306		0	-13.92	0		
		25.737		306				7875	7875
Arresting Hook	449.513		-2270		13,330	6.0	79,980		8⁷,855
		182,752		-1964				-358,925	-271,07:
Radome Fitting	266.761		2530		6,670	49.904	-332,860		-603,930
		34.945		566				19,779	-584,151
Wing	231.816		0		6,670 ①	38.14	-244,394		-838,545
		0		566				0	-838,545
Wing	231.816		0		6,670 ①	38.14	-254,394		-1,092,939
		11.253		566				6,369	-1,086,570
MLG	220.563		49,291 ②		10,414 ③	-30.0	312,420		-774,150
		10.563		49,857				526,639	-247,511
Engine Mount	210.000		0		32,000 ④	23.0	-736,000		-983,511
								3,888,846	2,805,335
		78.000		49,857		-35.25	-2,905,446		111
Catapult Hook	132.000		49,857		-82,424				
		86.000		0				0	111
Nose Bulkhead	ʌ6.000		0		6,670	0	0		111

NOTES:

① Wing drag loads are X=3,335# at y = ±51.25 and y = ±60.75

② For catapult side load left { Left MLG, Z = 24,353# @ y = 102.395; Right MLG, Z = 24,938# @ y = -102.395 }

③ For catapult side load left { Left MLG, X = 277# @ y = 102.395; Right MLG, X = 10,137# @ y = -102.395 }

④ Engine mount loads are X = 16,000# @ y = ±110.000

TABLE A-III- FUSELAGE LATERAL SHEAR, BENDING MOMENT AND TORSION - CATAPULT START OF RUN CONDITION - MAXIMUM LOAD

Location	FS In	Δx In	Lat Load Lbs	Lat Shear Lbs	ΔBM In-Lbs	ΣBM In-Lbs	Δz In	ΔTorsion In-Lbs	ΣTorsion In-Lbs
Holdback Fitting	475.250		0				-13.92	0	0
		25.737		0	0	0 0	-6.0	0	0 0
Arresting Hook	449.513		0						
		182.752		0	0	0 0	+49.904	0	0 0
Radome Fitting	266.761		0						
		34.945		0	0	0 0	+38.14	0	0 0
Wing	231.816		0						
		0		0	0	0 0	+38.14	0	0 0
Wing	231.816		0						
		11.253		0	0	0	-30.00		0
Main Landing Gear	220.563		-11,400 ①		1,009,615 ②	1,009,615		-59,901 ③ -342,000	-401,901
		10.563		-11,400	-120,418	889,197 889,197	+23.00	0	-401,901 -401,901
Engine Mount	210.00		0						
		78.000		-11,400	-889,200	-3 -3	-35.25	401,850	-401,901 -51
Catapult Hook	132.00		11,400						
		86.000		0	0	-3	0		-51 -51
Nose Bulkhead	46.000		0						

NOTES:

① Right MLG = Left MLG, y = -5/00#

② From MLG X loads

③ From MLG Z loads

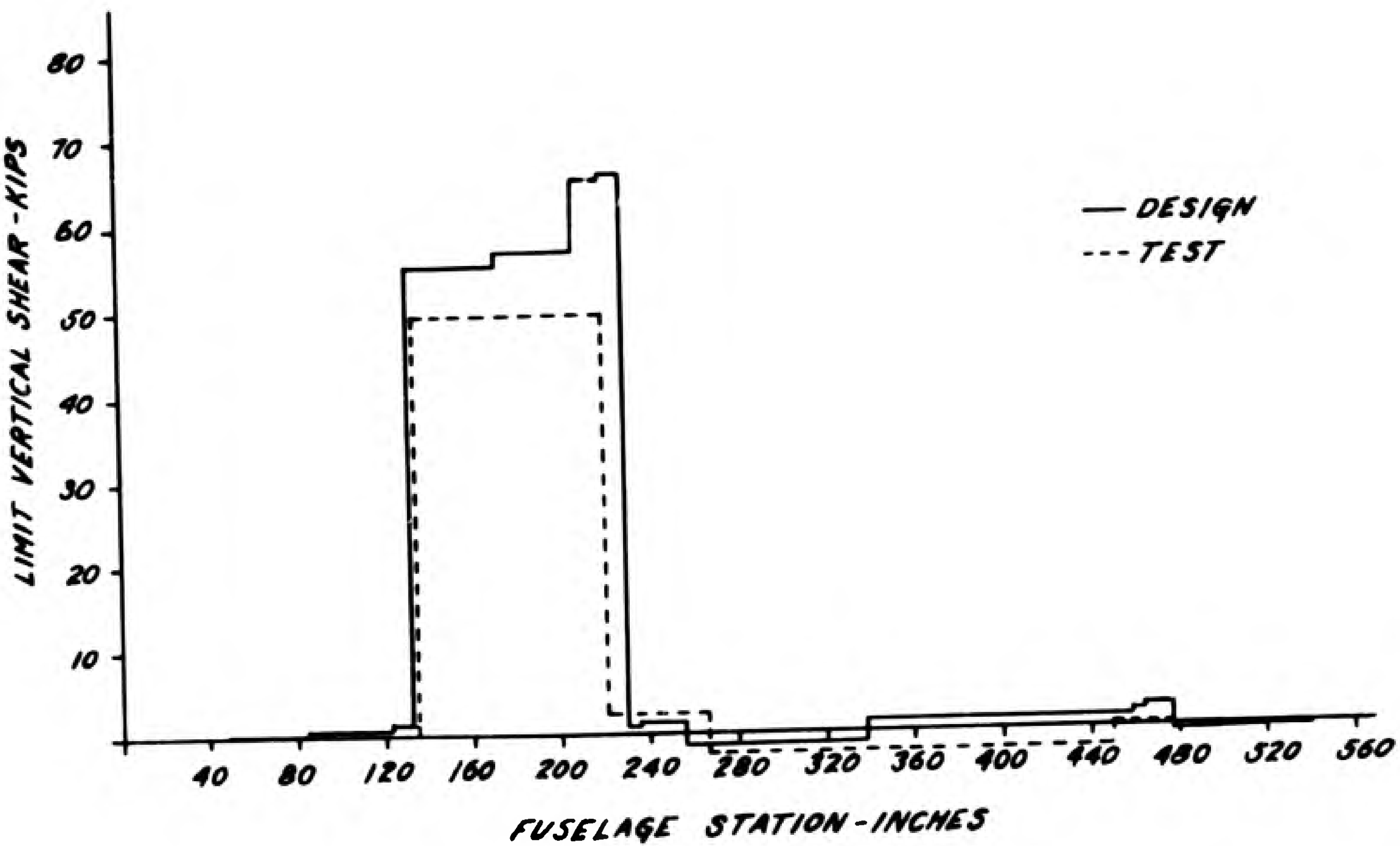


FIGURE A-3. **Fuselage Vertical Shear Distribution - Catapult Start of Run Condition**

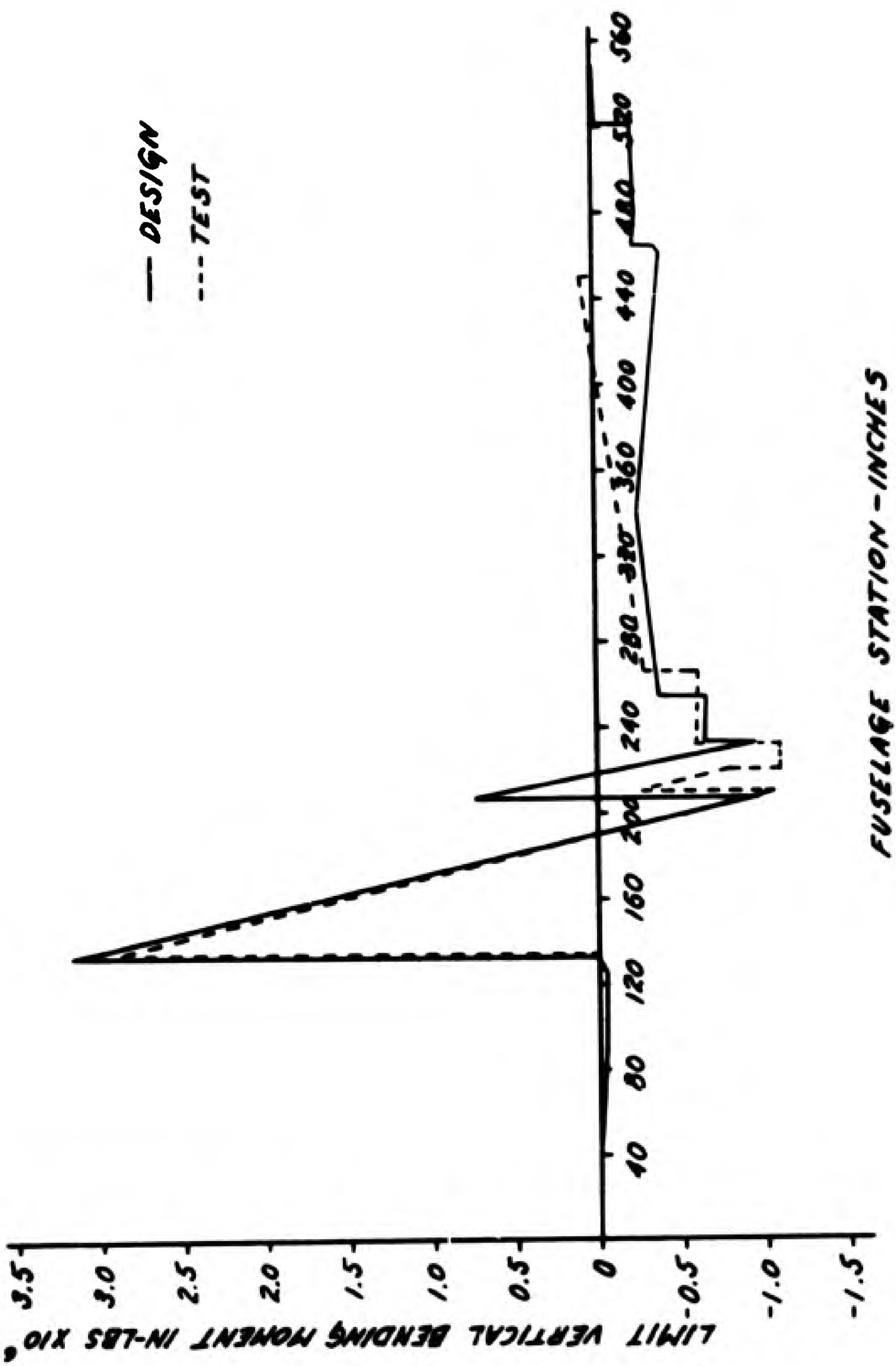


FIGURE A-4. Fuselage Vertical Bending Moment Distribution - Catapult Start of Run Condition

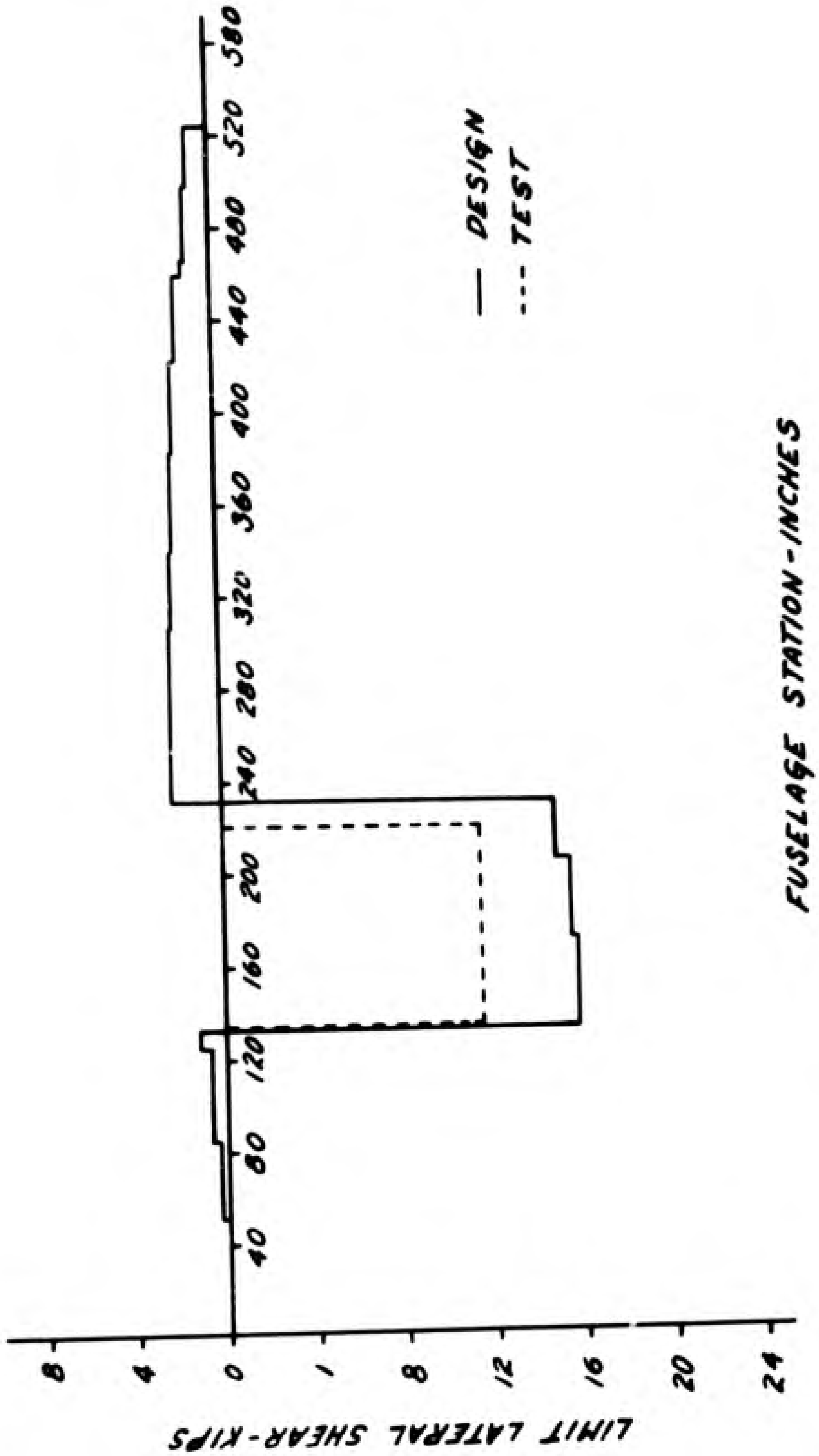


FIGURE A-5. Fuselage Lateral Shear Distribution - Catapult Start of Run Condition

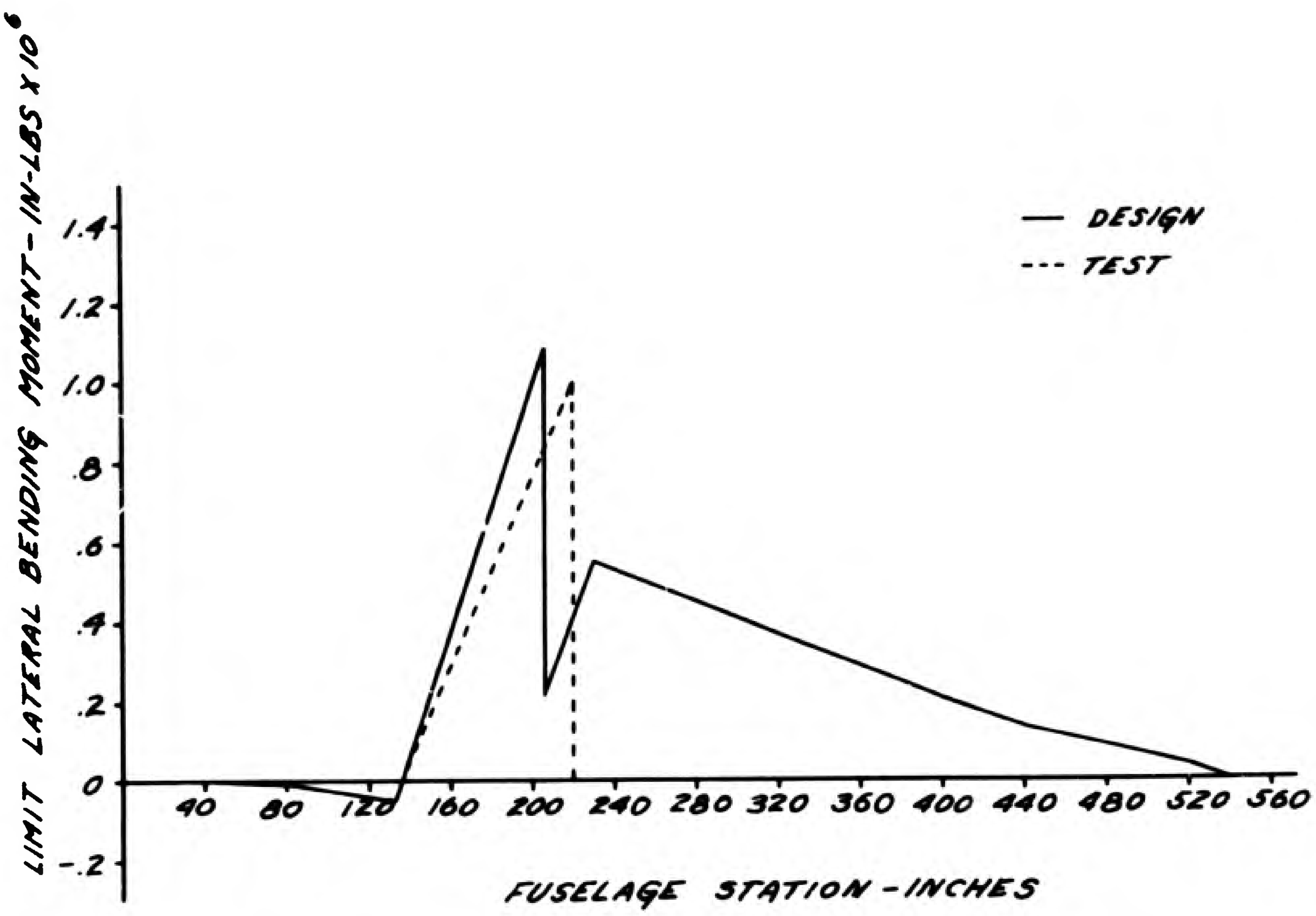


FIGURE A-6. Fuselage Lateral Bending Moment Distribution - Catapult Start of Run Condition

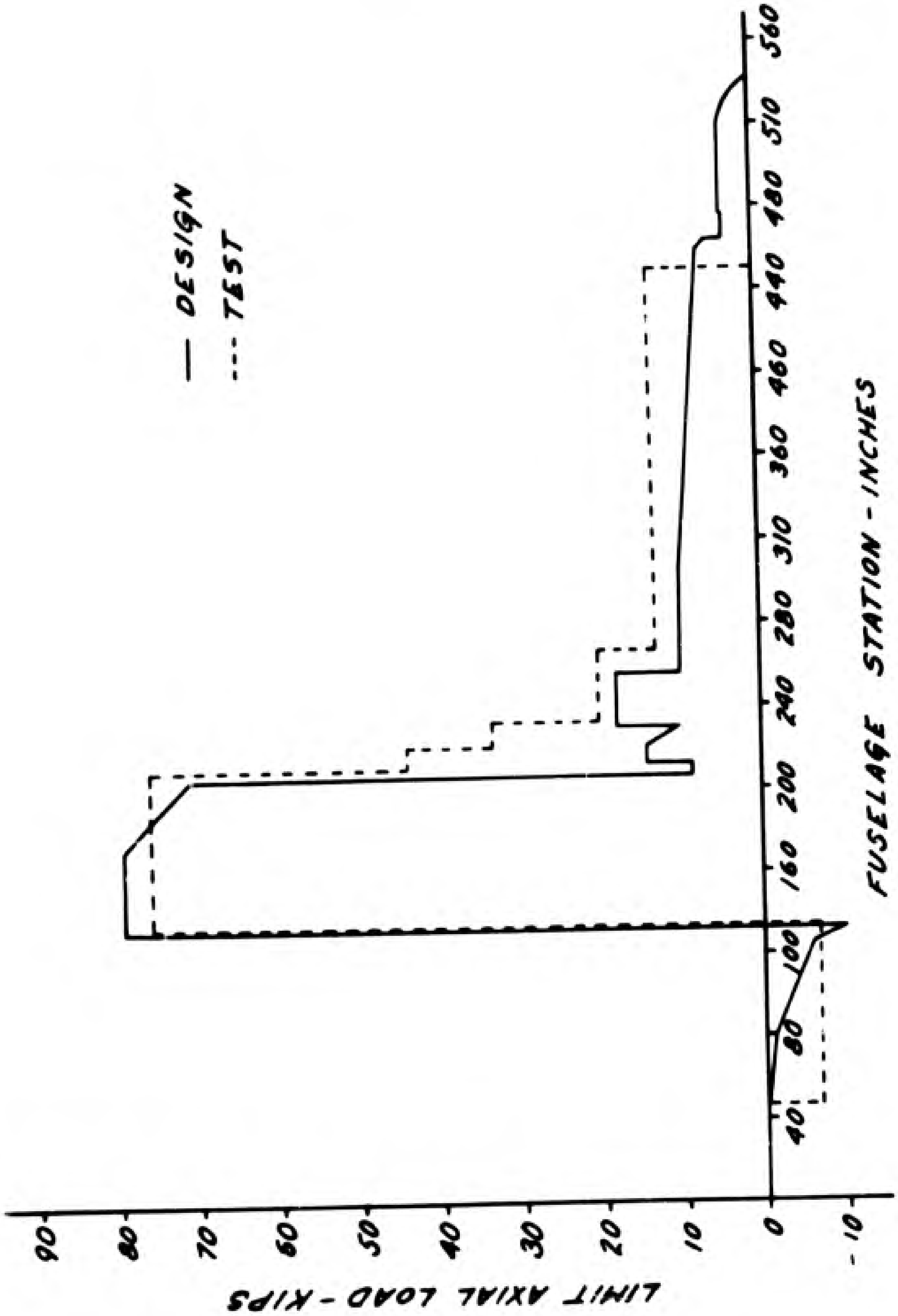


FIGURE A-7. Fuselage Axial Load Distribution - Catapult Start of Run Condition

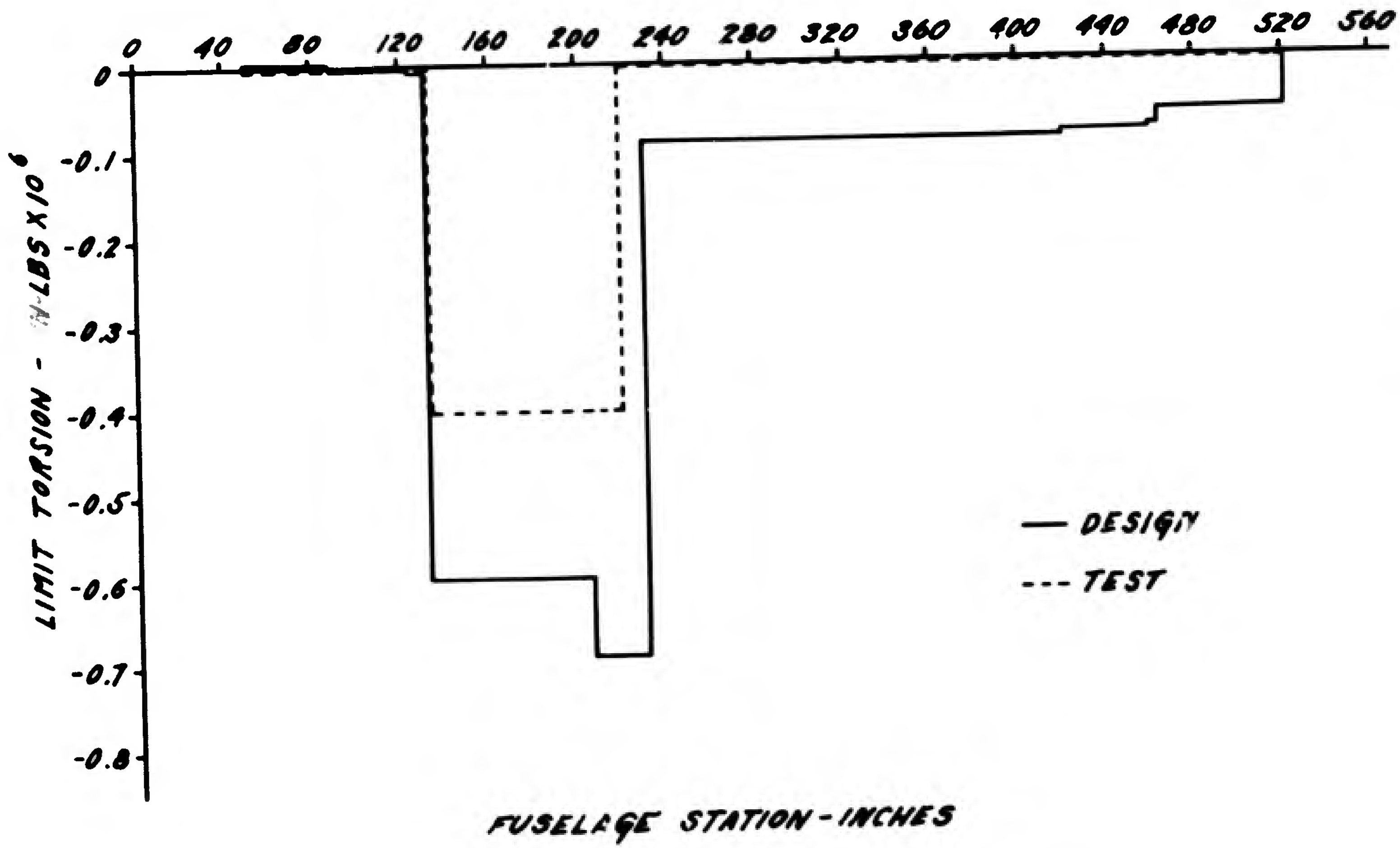
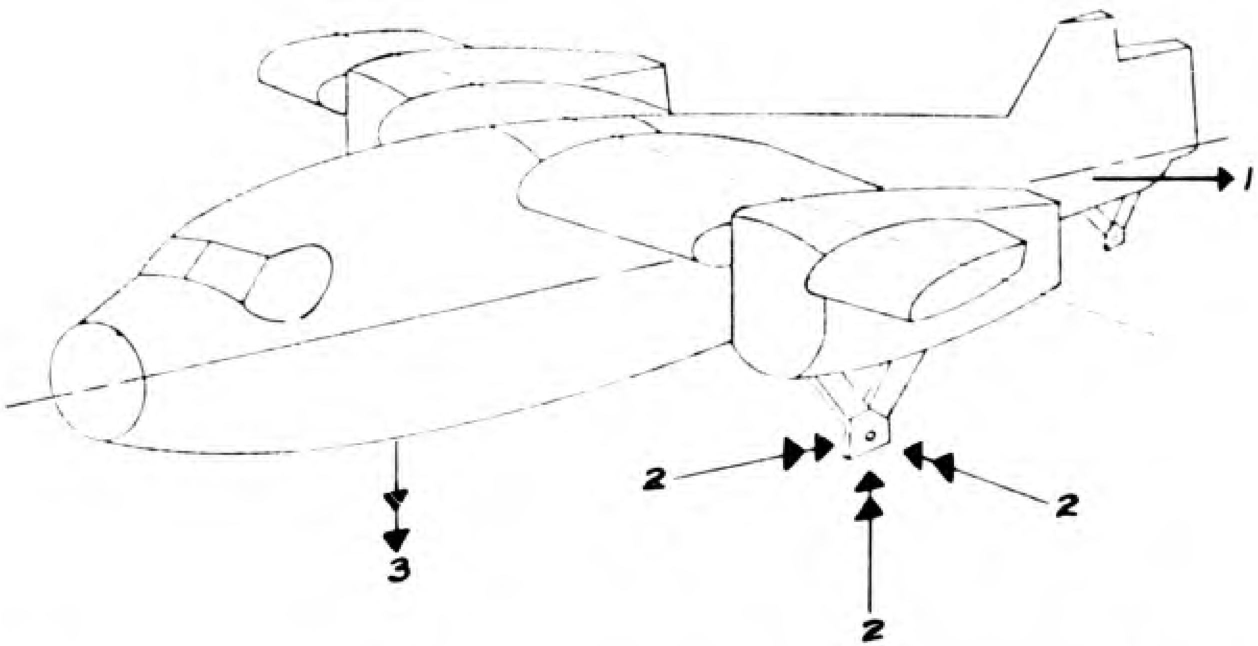


FIGURE A-8. Fuselage Torsional Moment Distribution - Catapult Start of Run Condition



Notes: 1. The numbers correspond to the load point numbers of Table A-4.

2. ———▶ = applied load.

3. ———▶▶ = reaction load.

FIGURE A-9. Load Points, Catapult Release Condition

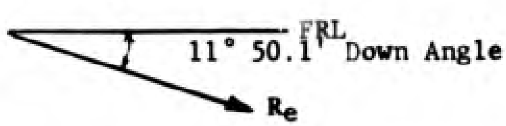
TABLE A-IV - TEST LOADS - CATAPULT RELEASE CONDITION - SIDE LOAD LEFT

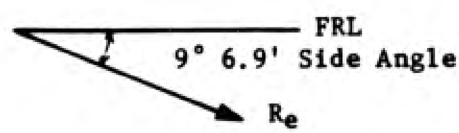
Load Point	Applied Loads					
	Location, Inches			Maximum Load, Lbs		
	X	Y	Z	X	Y	Z
1. Holdback Fitting	475.250	0	-13.92	27,542	4,514	-5,771
	Reaction Loads					
2. Main Gear, left	220.563	102.395	-30.000	-8,157	-2,257	14,038
right	220.563	-102.395	-30.000	-19,385	-2,257	13,330
3. Catapult hook	132.000	0	-35.250	0	0	-21,597

NOTES:

1. Catapult release is holdback link fracture simulated by use of a quick-release mechanism.

2. The loads at point 1 are applied as a resultant load Re = 28,500# at the following angles:





3. For the side load right condition the side loads (Y) at points 1 and 2 reverse direction and the axial loads (X) and vertical loads (Z) at point 2 interchange.

TABLE A-V - FUSELAGE VERTICAL SHEAR, BENDING MOMENT AND AXIAL LOAD - CATAPULT RELEASE CONDITION

Location	FS In	Δ x In	Vertical Load Lbs	Vertical Shear Lbs	Axial Load Lbs	Δ z In	Δ BM Axial In-Lbs	Δ BM Vertical In-Lbs	Σ BM In-Lbs
Holdback Fitting	475.25		-5,771		+27,542	-13.92	+383,385		+383,385
		254.687		-5,771				-1,469,799	-1,086,414
MLG	220.563		+27,368 ①		-27,542 ②	-30.00	-826,260		-1,912,674
		88.563		+21,597				+1.912,695	+21
Catapult Hook	132.00		-21,597		0	-35.25	0		+21
				0					

NOTES:

① For catapult release side load left { Left MLG, Z = 14,038# @ y = 102.395; Right MLG, Z = 13,330# @ y = -102.395 }

② For catapult release side load left { Left MLG, X = -8,157# @ y = 102.395; Right MLG, X = -19, 385# @ y = -102.395 }

TABLE A-VI - FUSELAGE LATERAL SHEAR, BENDING MOMENT AND TORSION - CATAPULT RELEASE CONDITION

Location	FS In	Δ x In	Lateral Load Lbs	Lateral Shear Lbs	Δ BM In-Lbs	Σ BM In-Lbs	Δ z In	Δ Torsion In-Lbs	Σ Torsion In-Lbs
Holdback Fitting	475.250		+4,514			0	-13.92	+62,835	+62,835
		254.687		+4,514	+1,149,657	+1,149,657			+62,835
MLG	22[illegible] 563		-4,514 (1)		-1,149,691 (2)	-33	-30.00	+72,496 (3) -135,420	-89
		88.563		0		-33			-89
Catapult Hook	132.000		0			-33	-35.25		-89
				0		-33			-89

NOTES:

(1) Right MLG = Left MLG, y = 2257

(2) From MLG X loads

(3) From MLG Z loads

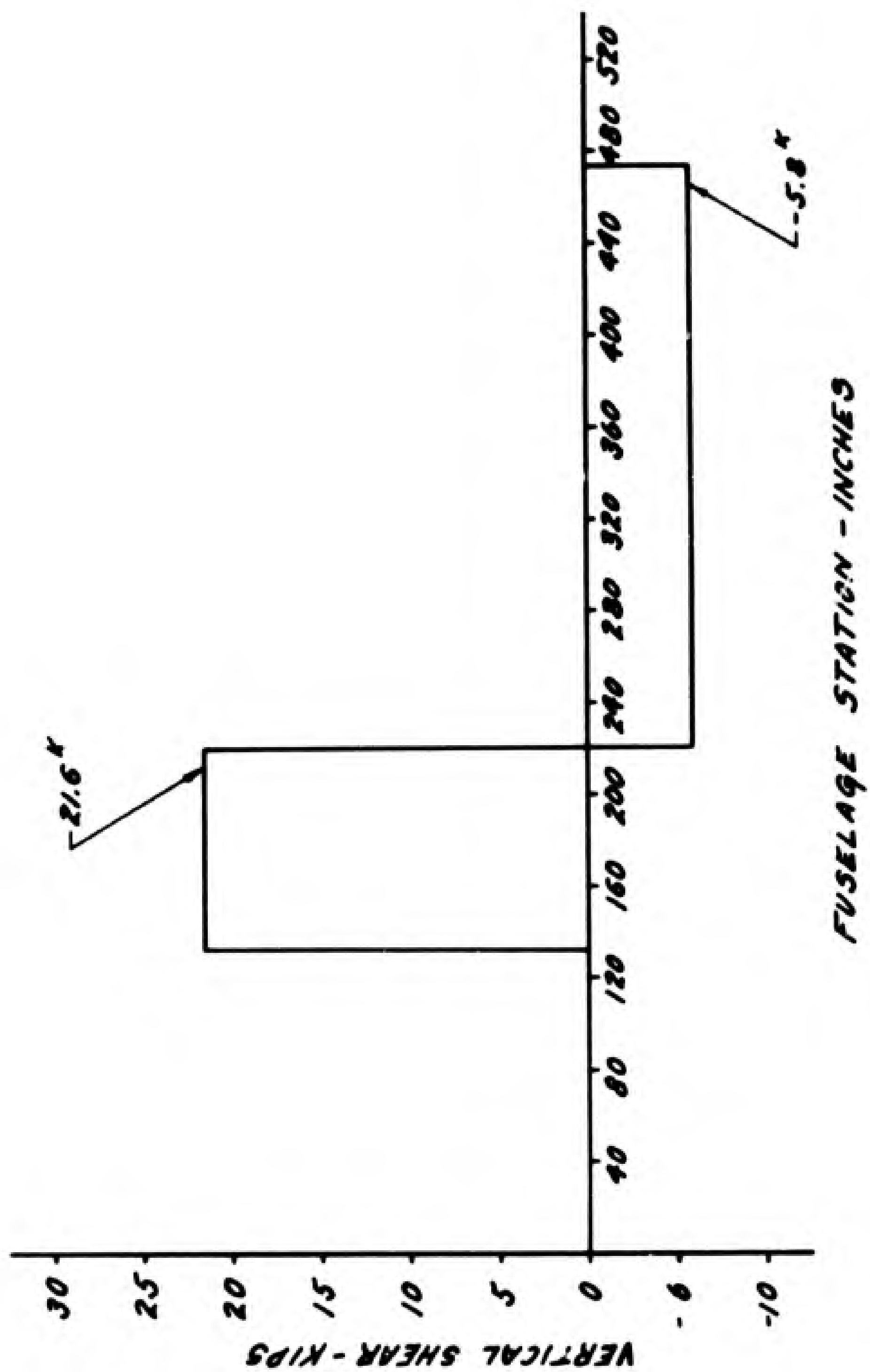


FIGURE A-10. Fuselage Vertical Shear Distribution - Catapult Release Condition

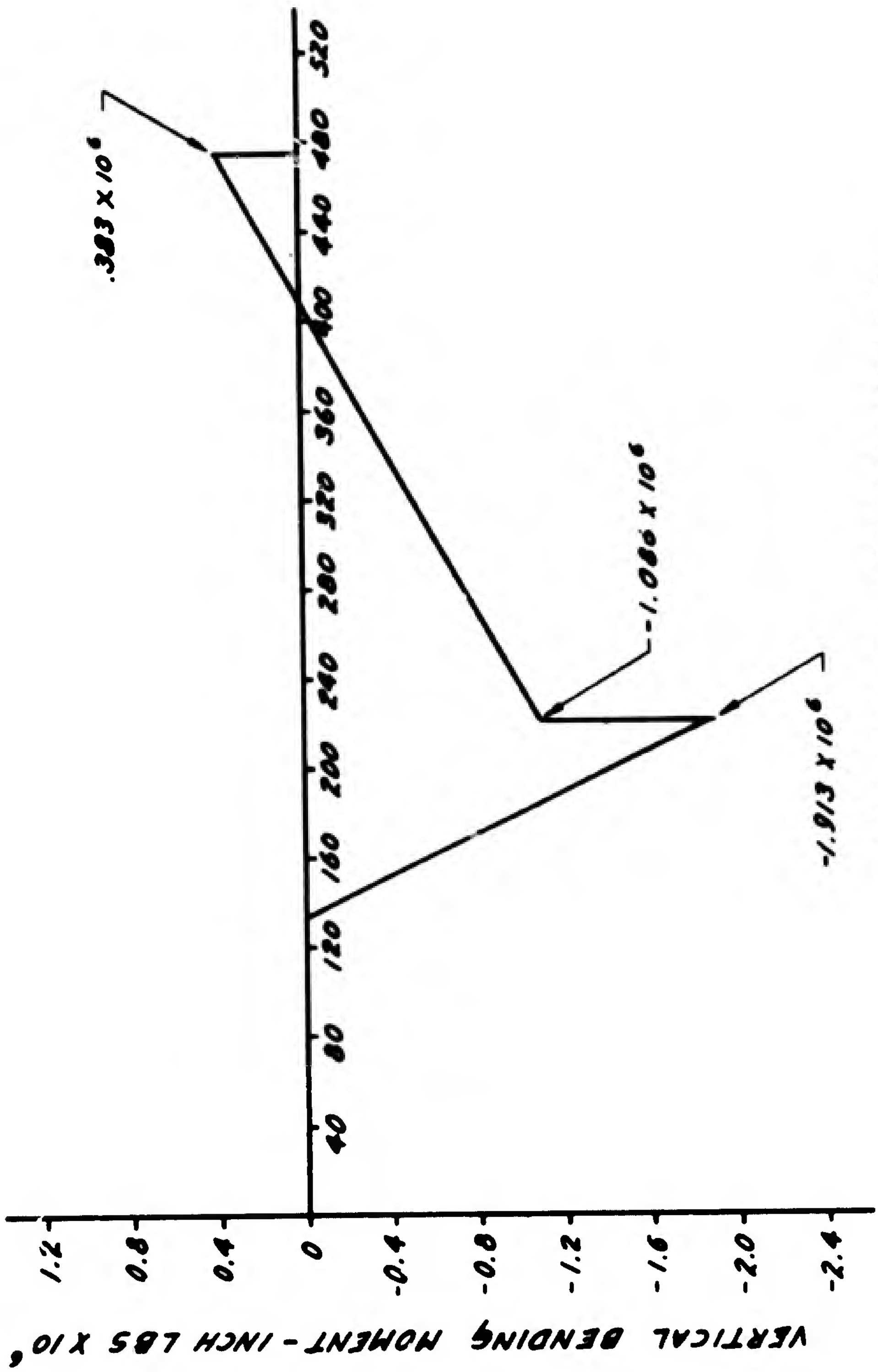


FIGURE A-11. Fuselage Vertical Bending Moment Distribution - Catapult Release Condition

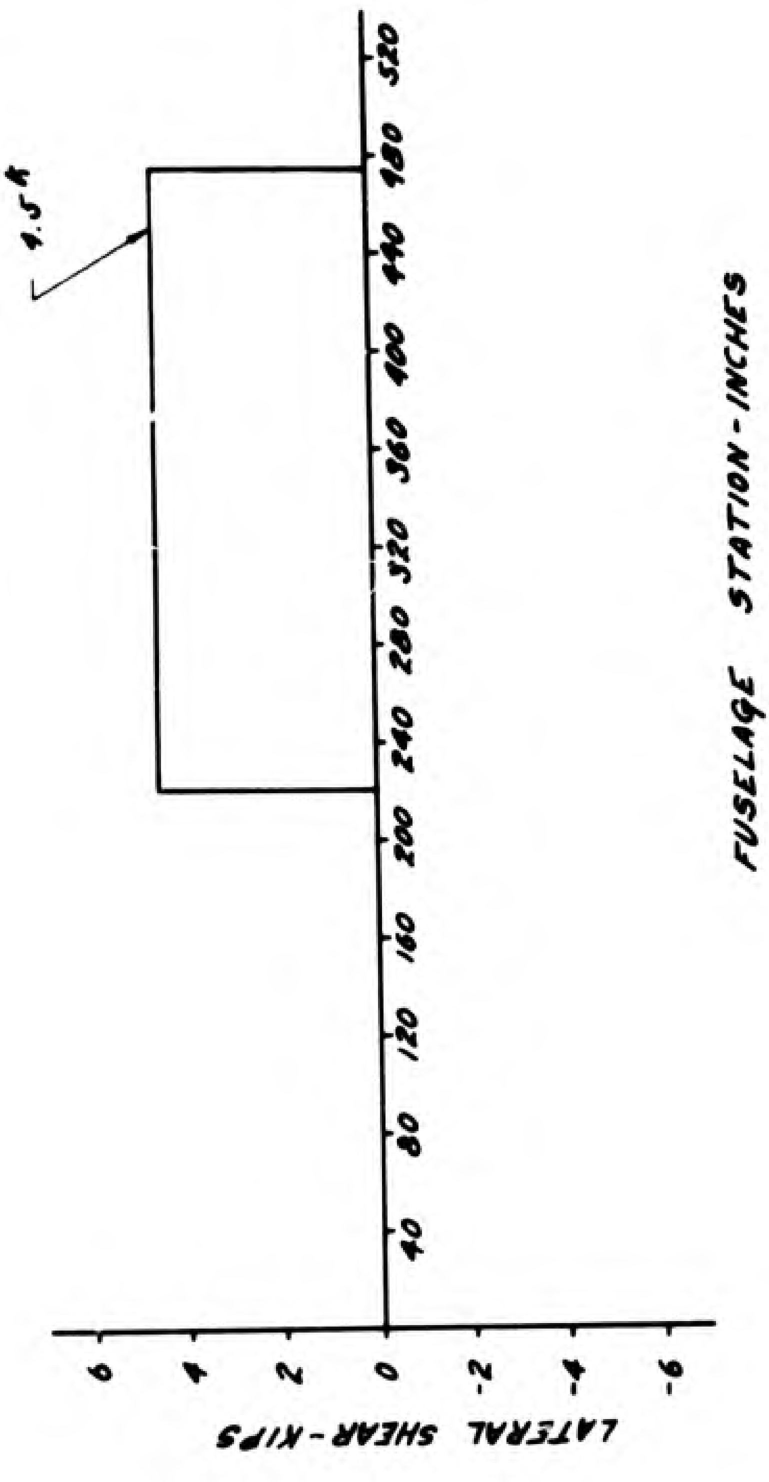


FIGURE A-12. Fuselage Lateral Shear Distribution - Catapult Release Condition

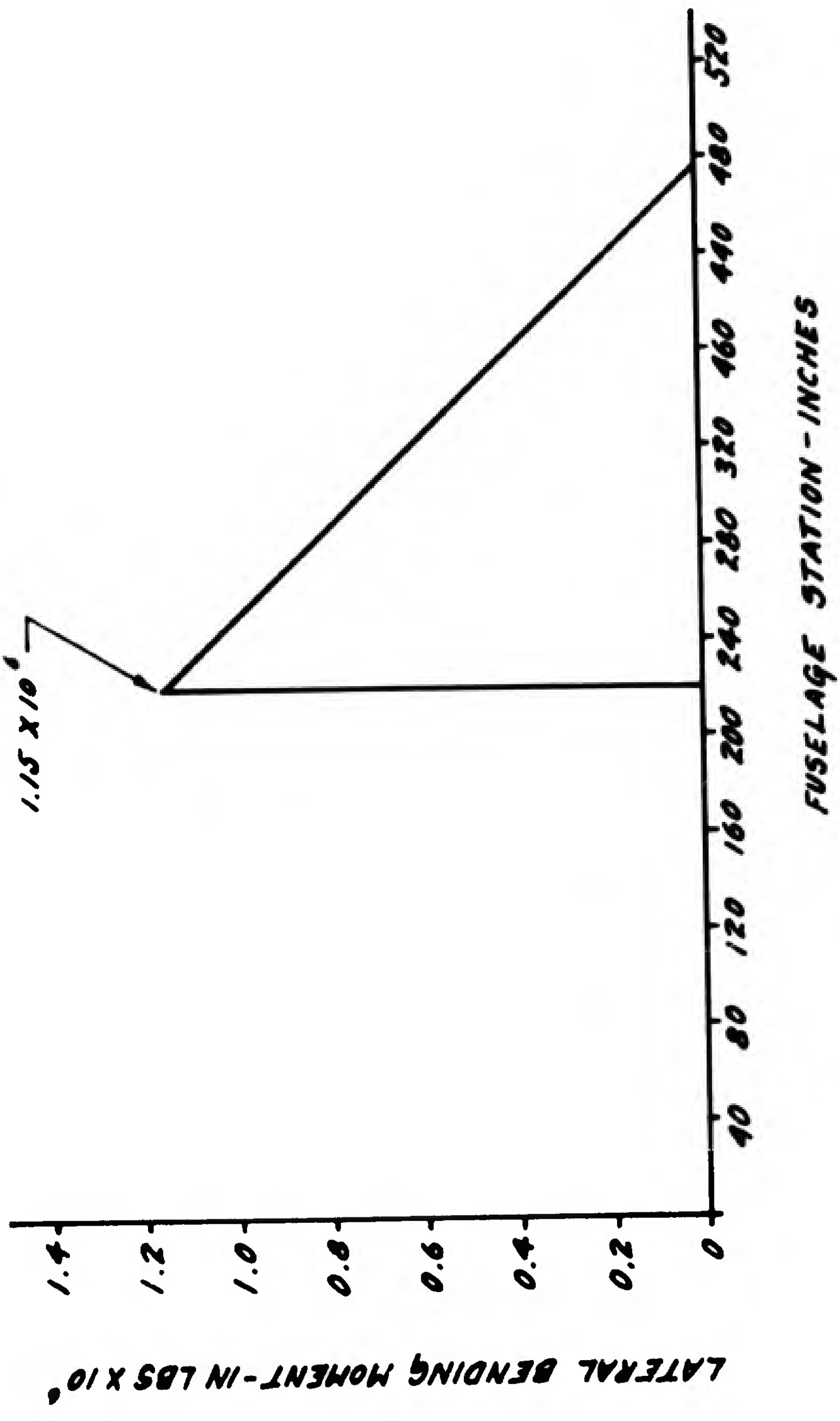


FIGURE A-13. Fuselage Lateral Bending Moment Distribution - Catapult Release Condition

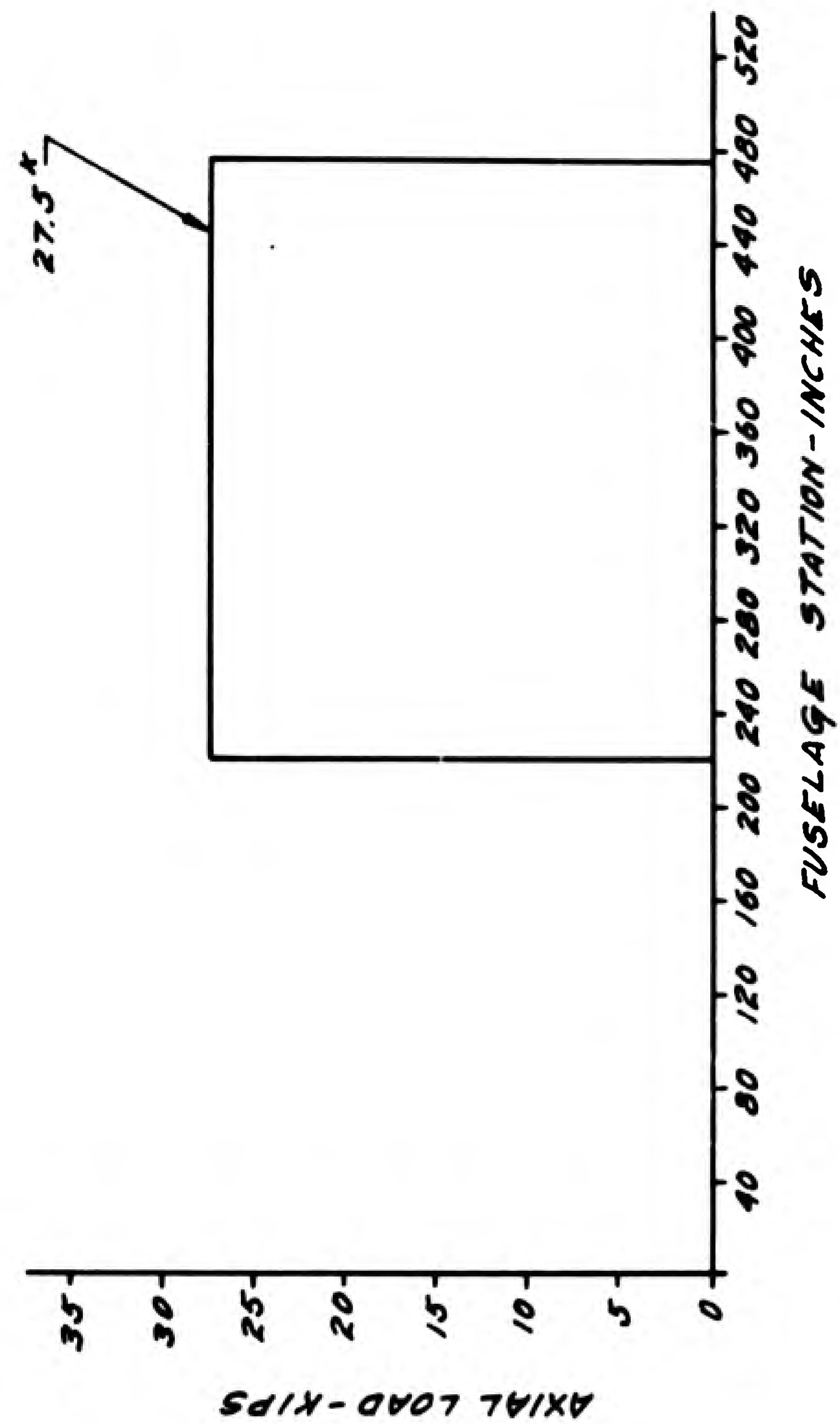


FIGURE A-14. Fuselage Axial Load Distribution

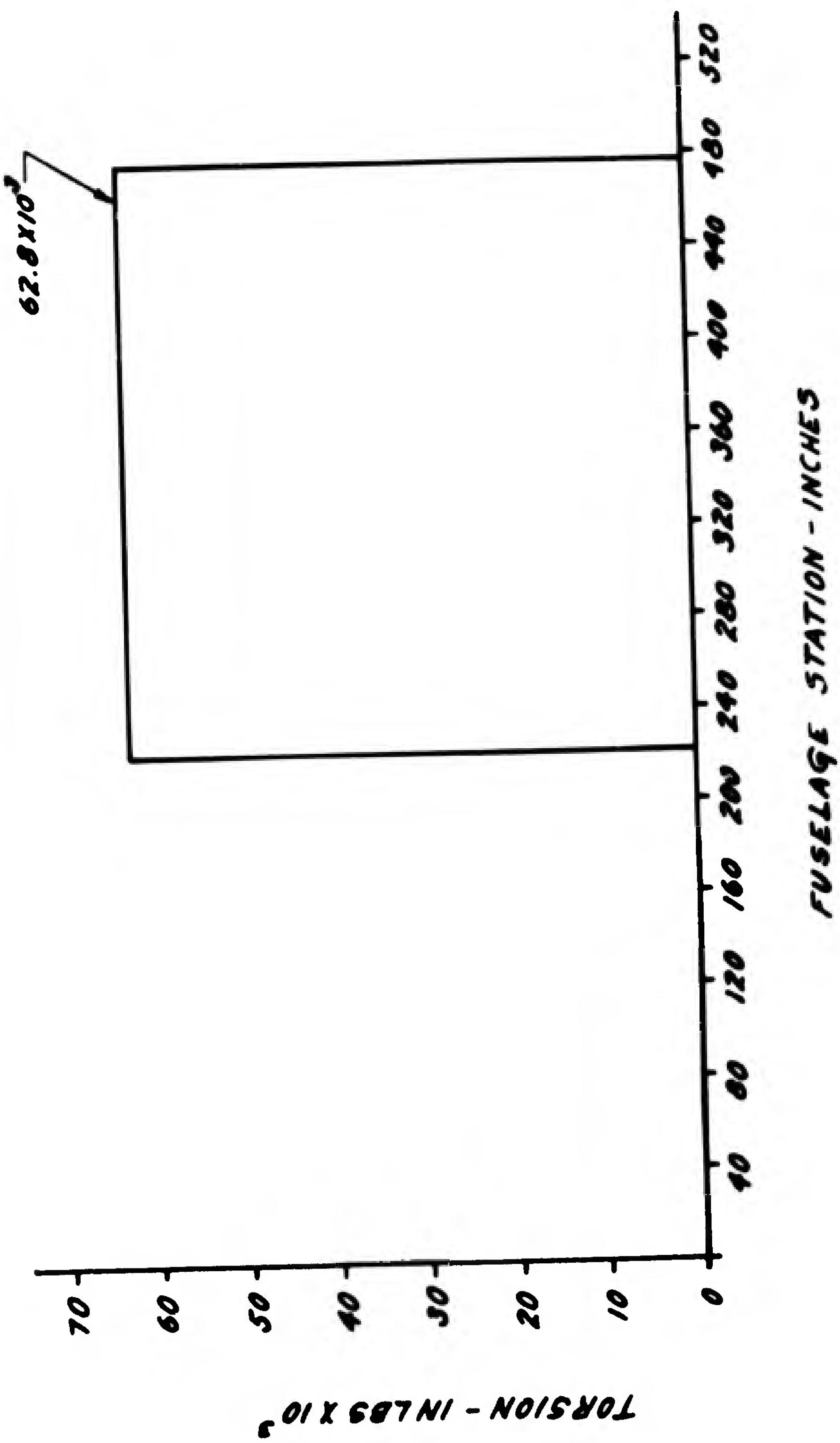


FIGURE A-15. Fuselage Torsional Moment Distribution - Catpult Release Condition