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FATIGUE INVESTIGATION OF THE E-2B/C NOSE LANDING GEAR

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A laboratory fatigue investigation was performed on an E-2B and an E-2C nose landing gear to determine whether the authorized limit of 650 catapult launches could be extended.

The starboard holdback lug of the E-2B nose landing gear, with modified drag brace attachment lugs, failed after the application of 3,336 test cycles. Using a test scatter factor of two, this is equivalent to 1,668 service catapult launches. The outer cylinder of the E-2C shock strut assembly cracked

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20. under the packing nut after completion of 7,430 test cycles. Again, using a test scatter factor of two, this is equivalent to 3,715 service catapult launches.

S U M M A R Y

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The starboard holdback lug of the E-2B nose landing gear, with modified drag brace attachment lugs, failed after the application of 3,336 test cycles. Using a test scatter factor of two, this is equivalent to 1,668 service catapult launches. The outer cylinder of the E-2C shock strut assembly cracked under the packing nut after completion of 7,430 test cycles. Again, using a test scatter factor of two, this is equivalent to 3,715 service catapult launches.

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INTRODUCTION

The E-2 nose landing gear assembly was fatigue tested to the catapult launch condition several years ago by the Grumman Aerospace Corporation (GAC) as reported in reference (a). The nose gear shock strut inner cylinder, having the bottle bore configuration, failed at 1,298 test launches. The nose gear shock strut outer cylinder failed, at 1,904 test launches, through the drag brace attachment lugs. These test results imposed a usable fatigue life of 650 catapult launches for the E-2 nose landing gear which is now insufficient to satisfy the current operational requirements for the E-2 airplane.

The original nose gear test article had manufacturing and minor design anomalies which were subsequently eliminated to improve the nose gear fatigue strengths, but these improved fatigue strengths were never fully evaluated by tests. In view of the long lead time required for procuring nose gear replacement components and the nearly depleted fatigue lives of these components, fatigue investigations of each configuration of E-2 nose landing gear was required to determine the number of catapult launches the E-2 nose gear can now safely endure.

DESCRIPTION OF TEST SPECIMENS

The test specimens were an E-2B and an E-2C nose landing gear (NLG), which were removed from service. A list of the test specimens is given in Table I.

TABLE I

TEST SPECIMENS

Item	Condition	Part No. (P/N)
E-2B Shock Strut Assembly	Used	P/N 173758-29
E-2C Shock Strut Assembly	Used (BIS trials only)	P/N 2578489-1
E-2B Drag Brace #1	Used	P/N 173760-35
E-2B Drag Brace #2	Used	P/N 173760-35
Tow Link #1	New	P/N 123LM10189-1
Tow Link #2	Used	P/N 123LM10180-3
Tow Link #3	New	P/N 123LM10189-1
Tow Link #4	Used	P/N 123LM10180-3
Tow Link Pins	Used	P/N 123LM10094
Holdback Assembly	Used	P/N 123LM10085-11 and P/N 123LM10086-5
Receiver Assembly	Used	P/N 123L10074-1

Each shock strut assembly consists of the axle-caster barrel, outer cylinder and inner cylinder. Since none of the test specimens from Table I is included in a component tracking system, service data, such as total service time, number of landings and number of launches experienced, were not available.

The E-2 is a nose tow type airplane. The nose gear is a retractable, dual wheel assembly equipped with an inverted metered orifice oleo shock strut. The catapult forces on the NLG tow link are transmitted by the shock strut and drag brace to support fittings attached to the fuselage. The shock strut support (trunnion) fittings, located at fuselage station (FS) 64.50, provide vertical and lateral stability and also serve as the pivot for gear retraction and extension. Fore and aft stability is provided by the drag brace support fittings, located at FS126.50. Torsion about the oleo centerline is transmitted through the caster barrel and steering damper into the outer cylinder and finally reacted by the drag brace.

There are three configurations for the E-2 nose landing gear, two for the E-2B aircraft and one for the E-2C aircraft. The major difference between the E-2B configurations is the inner piston, one being a bottle bore and the latter a straight bore. The inner pistons of the E-2B gears are fabricated from 98BV40 mod. steel, heat treated to 220,000 psi. All the steel components of the E-2B gears were fabricated using the outdated air melt process. The steel components of the E-2C gears were fabricated using the vacuum melt process. The E-2C inner piston is fabricated from 300M steel, heat treated to 280,000 psi and is a straight bore configuration. The E-2C drag brace is fabricated from 7075-T73 aluminum and the remaining gear components are fabricated from 4330 steel, heat treated to 220,000 psi.

The E-2B test specimen was a bottle bore configuration in which the drag brace attachment lugs were modified at the NAVAIRDEVCEN. Photos of the nose gear inner piston, outer cylinder and caster barrel and the drag brace are shown in Figures 1, 2 and 3.

TEST PROGRAM

The test program consisted of three parts, an E-2B nose landing gear (NLG) fatigue test, an E-2C NLG fatigue test and a holdback-receiver assembly fatigue test, performed separately and in that order. Each fatigue test was run until specimen failure. The E-2B NLG and the E-2C NLG fatigue tests were identical with the exception of the shock strut drag brace attachment lugs modification, described below.

As recommended by Grumman Aerospace Corp. (GAC), references (b) and (c), the attachment lugs were modified by boring the lug inner diameter 0.050 inches oversize on the radius, thus opening the lug inner diameter to a maximum of 2.3505 inches. While enlarging the inner diameter the cross sectional area was not allowed to decrease below 0.415 square inches. Figure 4 shows the modified test specimen dimensions. After modification of the lugs, oversize bushings were fabricated to fit with an interference of .0010 to .0015 inches.

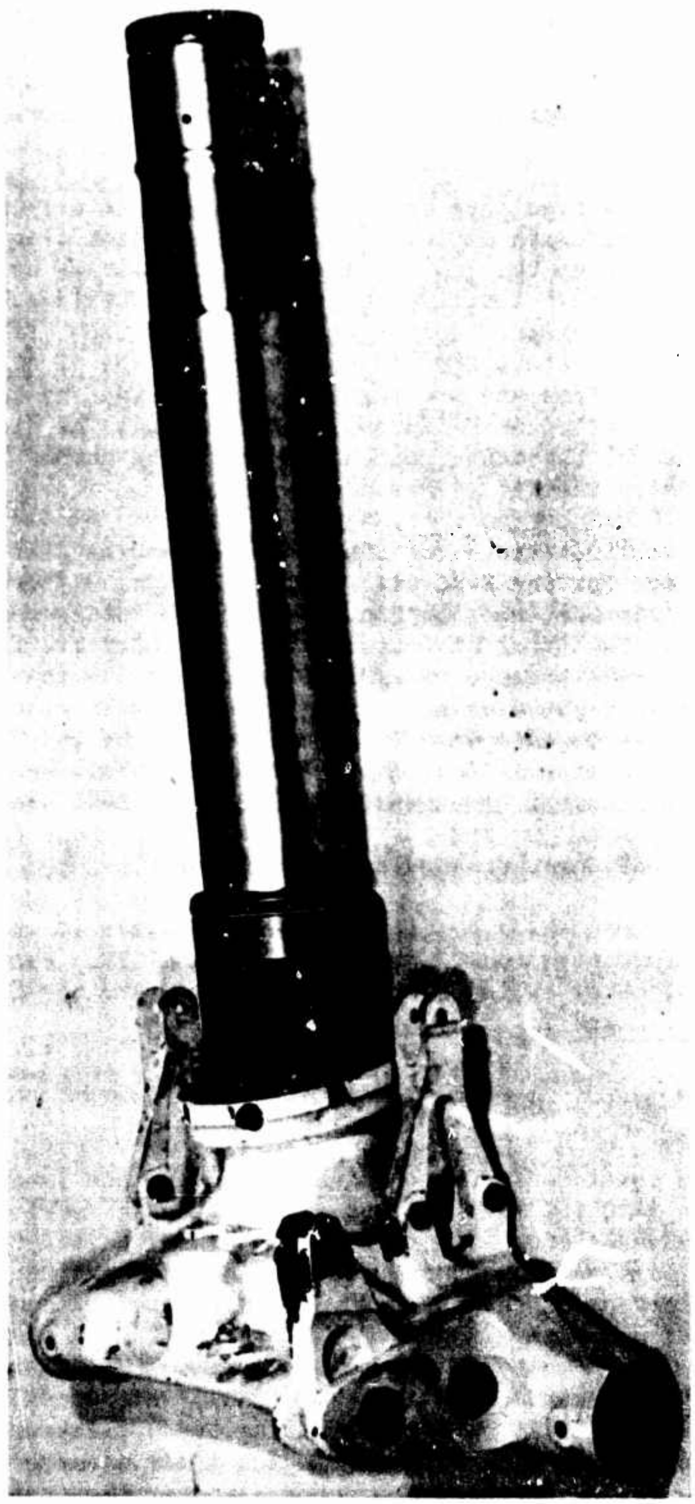


Figure 1. E-2B NLG Test Specimen - Inner Piston

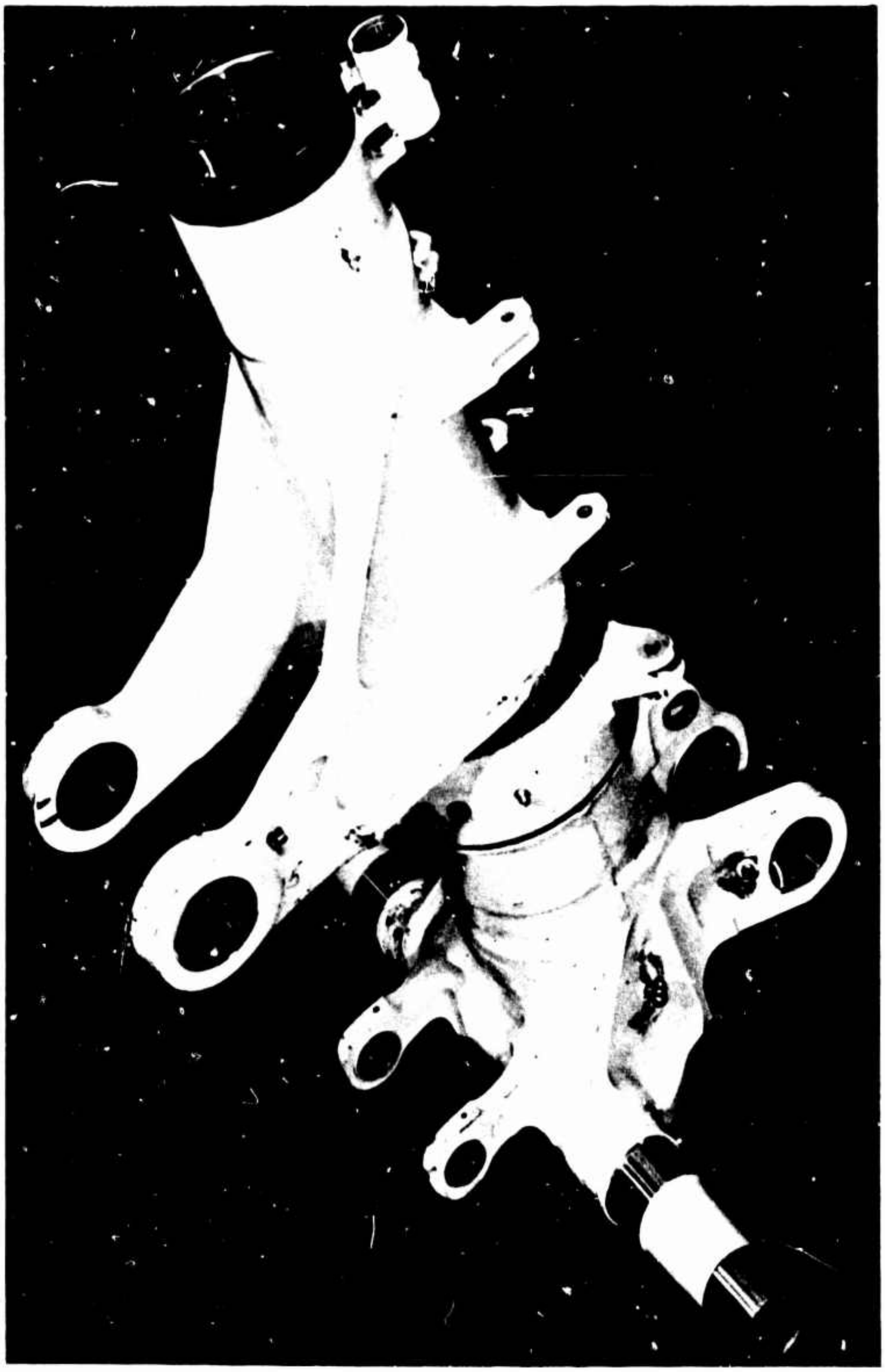
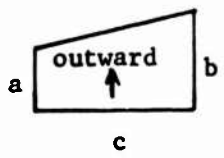
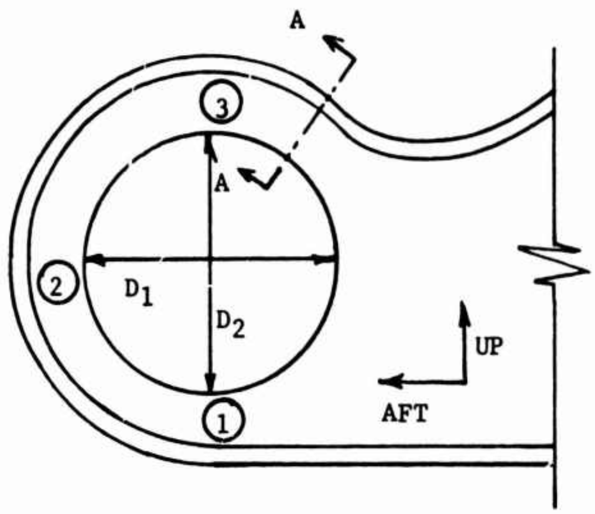


Figure 2. E-2B NLG Test Specimen - Outer Cylinder and Caster Barrel

Figure 3. E-2B NLG Test Specimen - Drag Brace



Section A-A



DRAG BRACE ATTACHMENT LUG

Location	Original Dimensions					Modified Dimensions	
	a in.	b in.	c in.	Cross Section Area, in^2	Hole Diam. D_1 or D_2 in.	Diam. after Boring in.	Final Area in^2
1	.436	.554	.991	.490545	2.2530	2.3505	.442234
Stbd 2	.496	.632	.989	.557796	2.2535	2.3505	.509829
3	.492	.613	.990	.546975	2.2530	2.3505	.498713
1	.405	.507	.989	.450984	2.2525	2.3250	.415130*
Port 2	.507	.612	.988	.552786	2.2540	2.2350	.517715
3	.500	.627	.986	.555611	2.2525	2.3250	.519870
GAC DESIGN	.410	.531	.989	.465000	2.2530 2.2515		

* Critical Area

Figure 4. E-2B NLG Drag Brace Attachment Lugs Modification

Since cracks smaller than 0.040 inches cannot be detected by nondestructive testing techniques and since inspection prior to modification of the lug surfaces revealed no cracks, this modification procedure assumes the removal of any minute fatigue cracks that may have been present.

As a result of reference (d), it was decided to install the lug modification after the application of 600 test cycles, thereby assuring that the test specimen would lead the fleet in number of catapult launches. Since after modification the lugs would essentially be clean metal (crack free), a GAC fatigue analysis based on the remaining material indicates a remaining fatigue life of 1100 calculated launches or a useful life of 550 launches.

The details of each test are as follows:

E-2B/C NLG FATIGUE TEST

To demonstrate the capability to withstand the effects of repeated catapult launches and establish the service life limit of the E-2B/C NLG, simulated carrier landings and catapult launches were applied to the test specimens using the loading conditions found in Appendix A.

The locations of the applied loads and reactions, magnitude and direction are shown in Appendix A, Table A-I and Figures A-2 through A-8. Loads were applied in accordance with the test spectrum determined below.

Total Loading Sequence

Step 1. Apply NLG actuating cylinder load

Step 2. Apply landing sequence

Step 3. Remove NLG actuating cylinder load

Step 4. Apply NLG actuating cylinder load

Step 5. Apply catapult launch sequence

Step 6. Remove NLG actuating cylinder load

The above loading sequence constitutes one carrier landing followed by one carrier catapult launch. Details of the landing sequence (Step 2) and the catapult launch sequence (Step 5) are as follows:

Landing Sequence

Step A. Apply the vertical and aft spin-up loads (Z_{SU} + X_{SU})

Step B. Reduce X_{SU} to zero and apply the forward spring-back load (X_{SB}) as Z_{SU} builds to the vertical spring-back load (Z_{SB}).

Step C. Reduce X_{SB} to zero and apply the aft second cycle spin-up load (X_{SU2}) as Z_{SB}, which equals the vertical second cycle spin-up load (Z_{SU2}), is held constant.

Step D. Reduce all loads to zero.

The above sequence of loading constitutes one carrier landing and is applied using the spectrum of sink speeds (V_S) shown in Table II.

TABLE II

LANDING SPECTRUM

V_S fps	Frequency per 200 Carrier Landings	% of Maximum Applied Load		
		$Z_{SV} = Z_{SB}$	$X_{SU2} = X_{SB}$	$X_{SU} = Z_{SU}$
20.8	1	100	100	100
19.8	2	91	97	97
18.8	7	82	96	95
17.8	12	74	93	92
16.8	178	66	91	90

The frequency of V_S per 200 carrier landings, obtained from reference (b), was truncated at a sink speed of 16.8 fps. All counts of lower sink speed were added to the 16.8 fps sink speed. The above spectrum of sink speeds was repeated every 200 landing cycles as follows:

Landings 1 to 178 at $V_S = 16.8$ fps

Landings 179 to 190 at $V_S = 17.8$ fps

Landings 191 to 197 at $V_S = 18.8$ fps

Landings 198 to 199 at $V_S = 19.8$ fps

Landing 200 at $V_S = 20.8$ fps

Catapult Launch Sequence

For all except the 100th launch

Step A. Apply simultaneously the loads of condition 11 D twice

Step B. Apply simultaneously the loads of condition 11 A once

Step C. Apply simultaneously the loads of condition 11 C once

For each 100th launch the above sequence is preceded by one application of the loads for condition $11D_F$. The above sequence constitutes one catapult launch cycle. During the application of the loads for conditions 11A, 11D, and $11D_F$, the side load is applied first to left, for 100 launches, then to the right for 100 launches. This sequence repeats every 200 launches.

For condition 11C, the loading was varied as follows:

Catapult launch 1 to 9; apply 90% of the maximum tow link and axle loads simultaneously.

Catapult launch 10; apply 100% of the maximum tow link and axle loads simultaneously.

This procedure repeated every 10 launch cycles. During the application of condition 11C, side loads were applied to the tow link at the same percentage of maximum load as the tow load, in the following manner.

Step A. Apply all X and Z loads simultaneously

Step B. Hold X + Z loads; apply side load once to the left then once to the right.

Step C. Reduce X and Z loads to zero.

A typical loading cycle of one carrier landing followed by one catapult launch is shown in Figure 5.

The loading sequence depicted above was repeated until specimen failure occurred. For the E-2B NLG fatigue test, cycling was interrupted after 600 test cycles to install the drag brace attachment lug modification, described previously.

HOLDBACK-RECEIVER ASSEMBLY FATIGUE TEST

To demonstrate the capability to withstand the effects of repeated catapult releases (holdbacks) and establish the service life limit of the holdback assembly (P/N 123LM10085-11 and P/N 123L0074-1), simulated holdback cycles were applied to the test specimens.

Two applications of condition 11D and one application of condition 11A were applied for each holdback cycle. Holdback cycles were applied until specimen failure occurred. A typical holdback cycle is shown below.

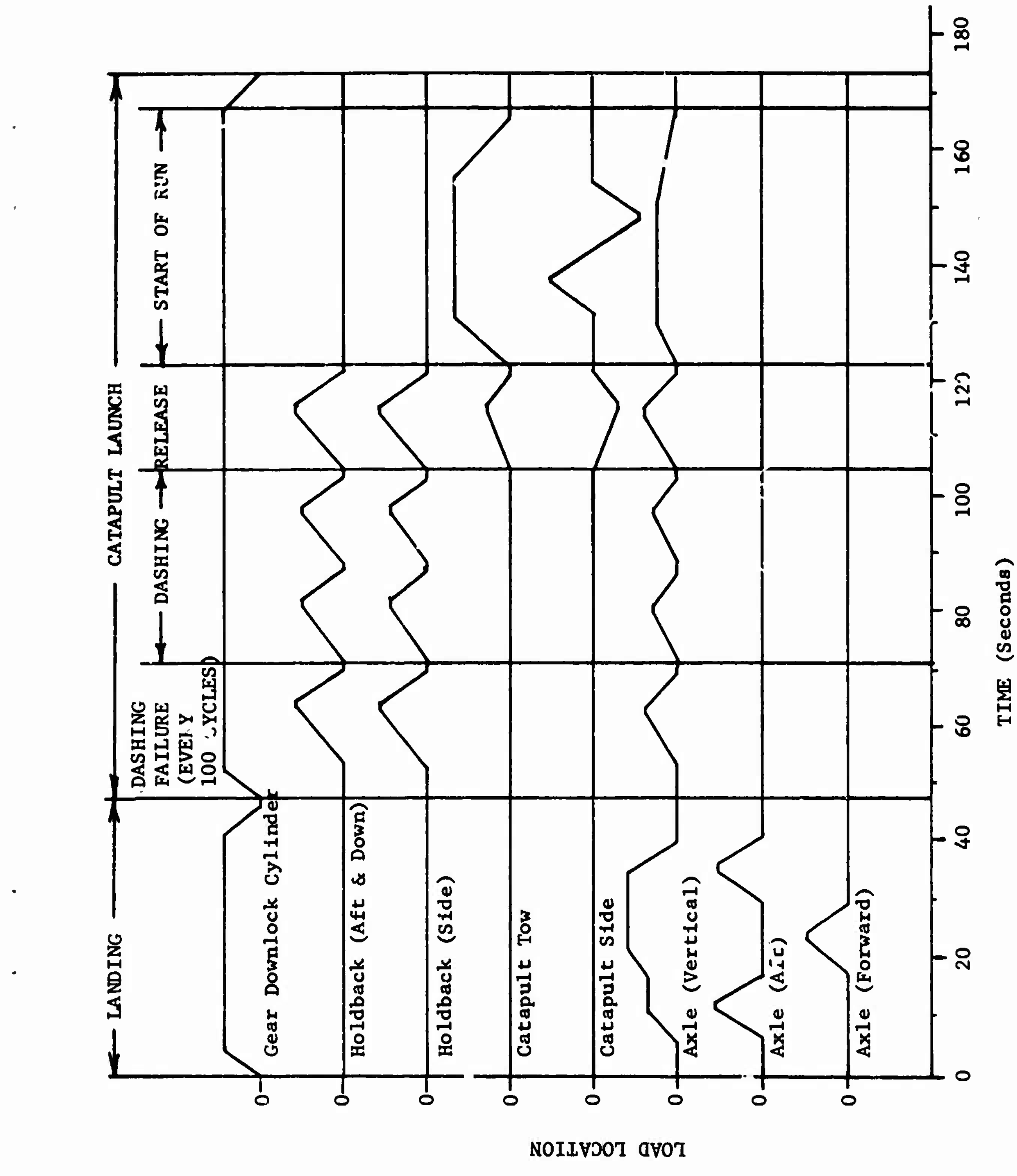
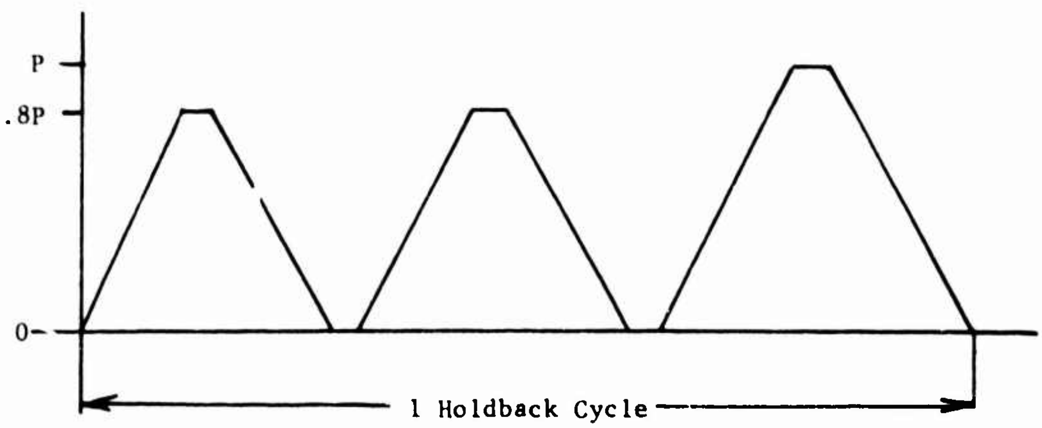


Figure 5. Typical Loading Cycle



T E S T   M E T H O D

E-2B/C NLG FATIGUE TEST

Each test specimen was mounted in an inverted position, in a loading frame. Test loads were reacted at the shock strut upper trunnions and the drag brace trunnions. Steel fixtures were fabricated to simulate the E-2 airplane fuselage fittings for the shock strut and drag brace supports. Adapter fittings were fabricated to apply loads to test specimens at the catapult tow link, holdback lugs and wheel axles. The metering pin was removed from the oleo shock strut and replaced with a plug. The shock strut was then filled with hydraulic fluid to fix the gear in the fully extended static position throughout the test.

Test loads were applied to the specimen with hydraulic actuators which were part of an electro-hydraulic, servo-controlled closed loop loading system. Independent control of each actuator was provided by individual servovalves and servo-controllers. Load direction and phase relationships for the actuators were provided by a multichannel programmer.

Loads were monitored on chart recorders and a multichannel bar graph video display, all of which provided overload protection. Additional and independent overload protection was provided by error detectors on each servocontroller and stroke limit switches on each actuator. Triggering any overload system would immediately dump hydraulic pressure at each actuator and at the hydraulic power supply.

A full NDI (Non Destructive Inspection) of each test specimen was performed prior to the test. Inspections of critical areas were performed throughout the test. Nose gear maintenance and lubrication were also performed at scheduled intervals throughout the test.

Figures 6, 7 and 8 show the final test set-up.

Figure 6. Test Set-Up - View from Right Side

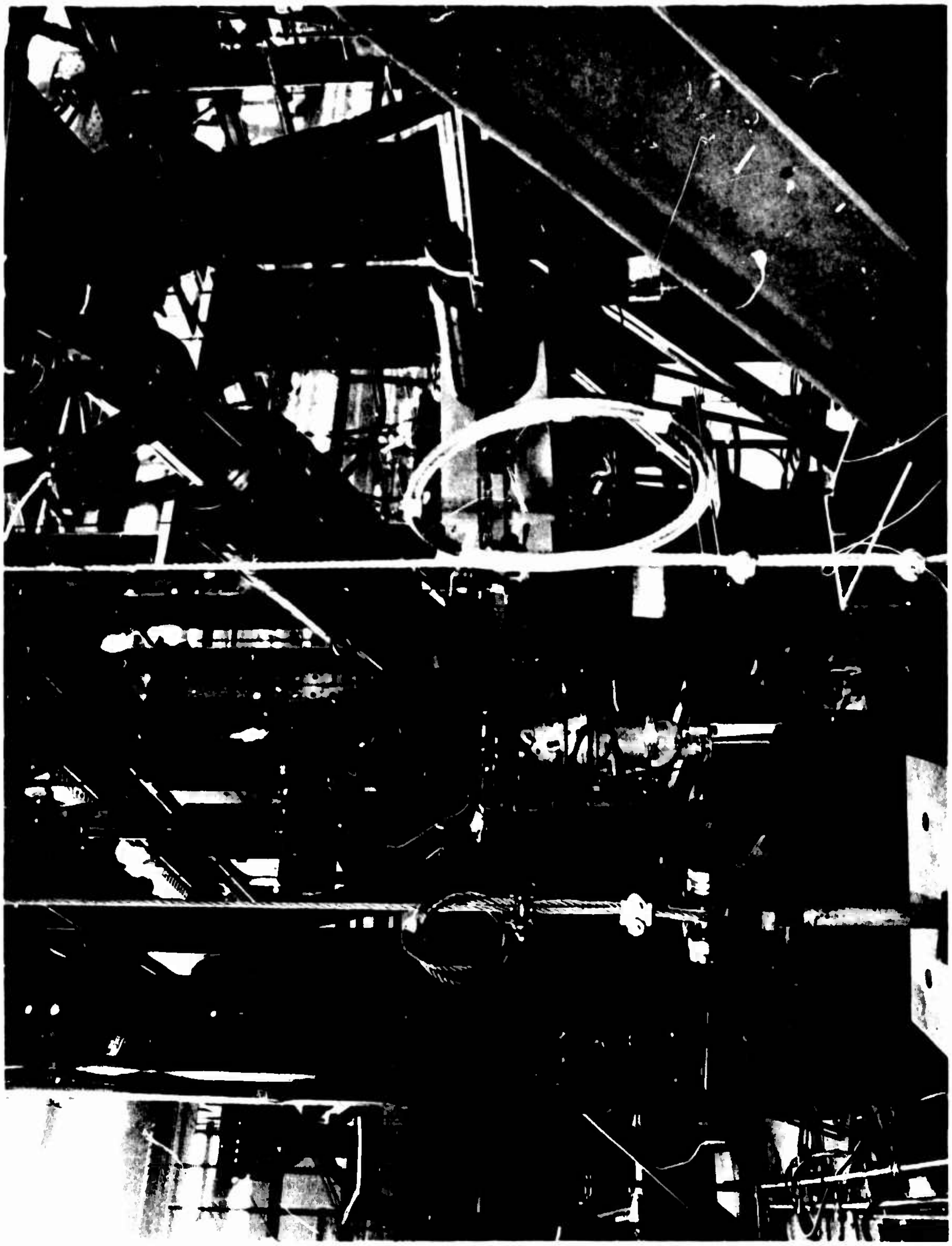


Figure 7. Test Set-Up - View Looking Aft

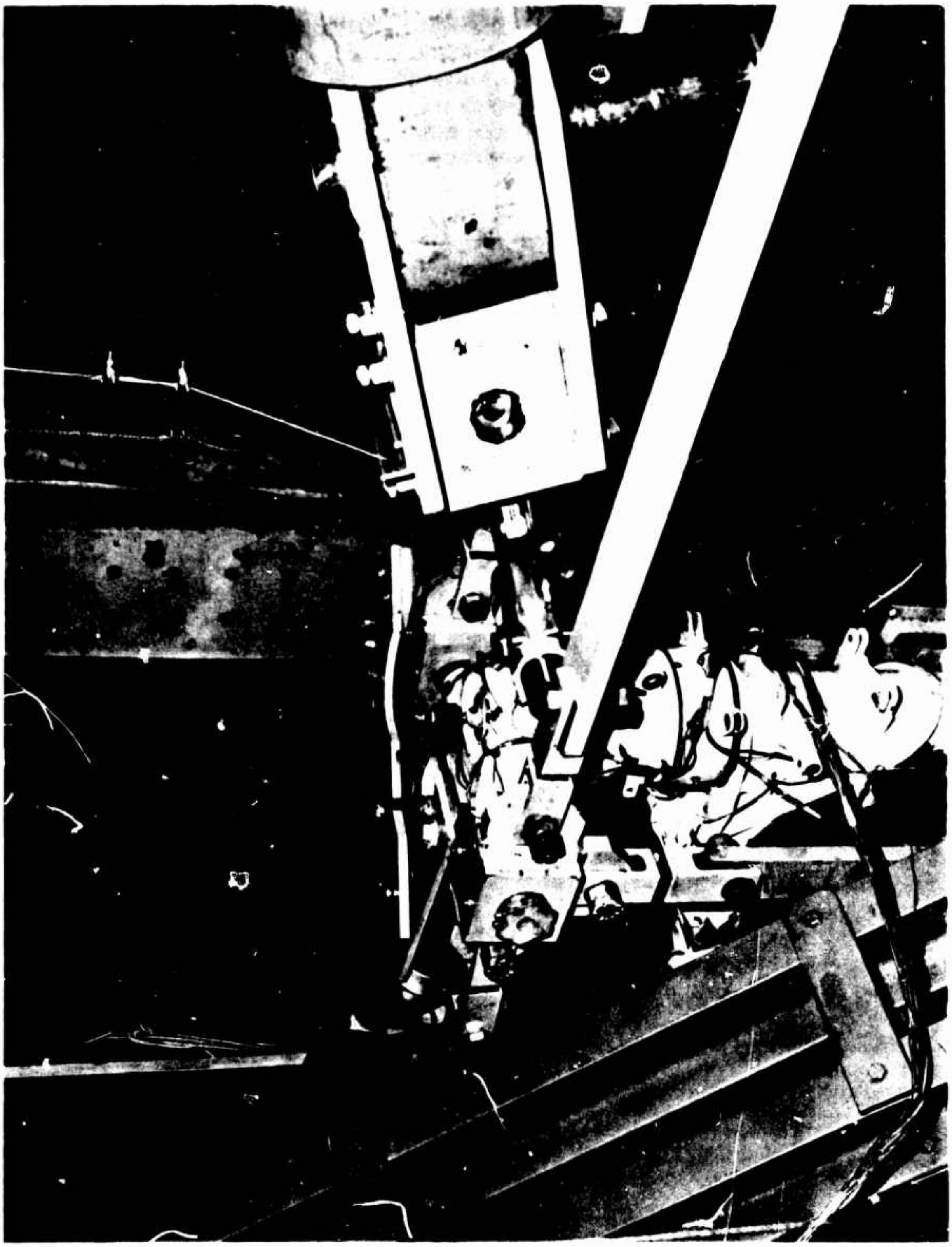


Figure 8. Test Set-Up - View Looking Aft and Down

HOLDBACK - RECEIVER ASSEMBLY FATIGUE TEST

The test specimens were mounted in a 100,000 pound capacity fatigue testing machine. Support and restraint of the test specimens in the test machine were provided by fabricated fixtures in lieu of the actual nose gear holdback lugs and the release element. The dummy release element was made to match the receiver fitting socket in the same manner as the actual frangible release element.

RESULTS

A summary of test results is given in Table III. Significant results of each test are as follows.

TABLE III

SUMMARY OF TEST RESULTS

SPECIMEN	RESULT
E-2B Shock Strut	Holdback lug failure at cycle 3336
E-2C Shock Strut	Outer cylinder crack at cycle 7430 Holdback lug failure at cycle 7540 Test discontinued at cycle 8400 - outer cylinder crack length = 7.5 inches
E-2B Drag Brace #1	Applied 5636 cycles with no failure (860 cycles without holdback loads)
Tow Link #1	Failure after 3200 cycles
Tow Link #2	Failure after 5096 cycles
Tow Link #3	Failure after 2270 cycles
Tow Link #4	Applied 1170 cycles with no failure
Holdback Assembly	Applied 5046 cycles with no failure
Receiver Assembly	Failure after 5046 cycles

E-2B NOSE LANDING GEAR TEST

During the application of cycle 3200, the catapult tow link #1 failed. This tow link, P/N 123LM10189-1, which had no previous usage, was inspected at cycle 2,920 using dye penetrant and found to be crack free. Figures 9 and 10 show the failure. Visual examination of the fracture surfaces indicated two regions of small crack growth prior to failure. One region was approximately 0.1 inches deep and 0.6 inches long. The second region was approximately 0.1

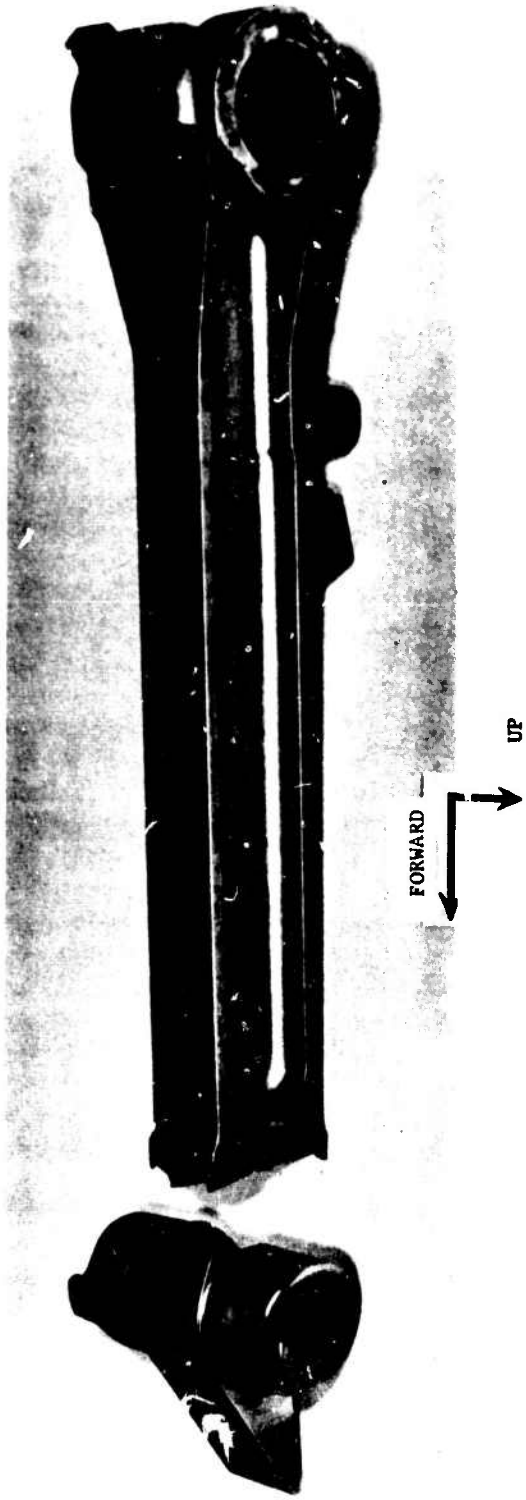


Figure 9. Tow Link #1 Failure

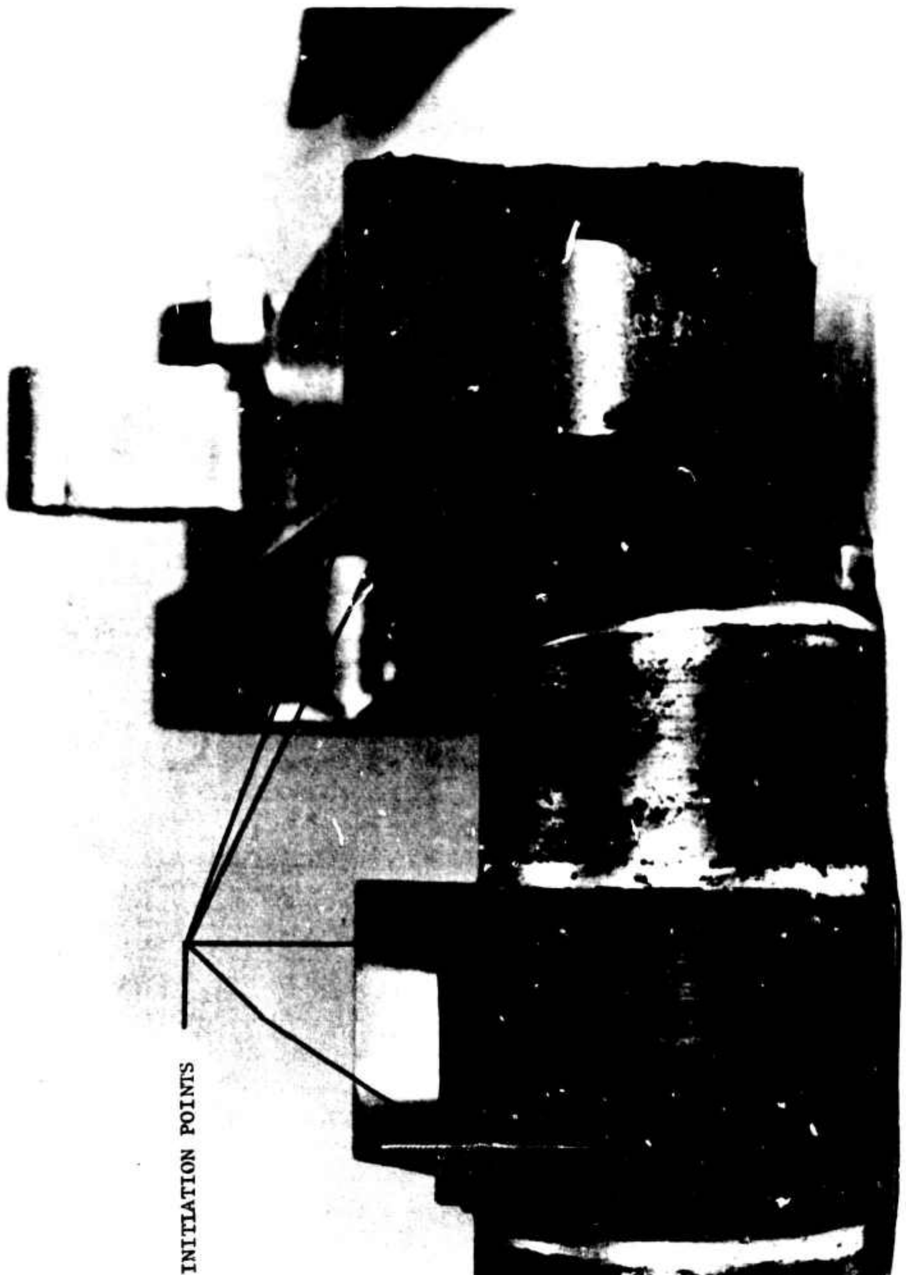


Figure 10. Tow Link #1 Fracture Face

inches deep and 0.2 inches long. A metallurgical examination of the fracture surfaces revealed fatigue striations with transgranular secondary cracks running perpendicular to the striations in the crack growth regions.

The failed tow link was replaced by tow link #2, P/N 123LM10080-3, having an unknown service history. The NLG was disassembled for a detailed inspection, found to be crack free and testing was continued. During the application of cycle 3336 the right hand holdback lug of the shock strut failed. Figures 11 and 12 show the failure.

Upon inspection of the specimen after the holdback lug failure, a hairline crack was found in the left hand drag brace attachment lug. The crack extended across the entire thickness of the lug. A section of the lug encompassing the crack was removed from the specimen and subjected to a slow, continuous load in a testing machine to break open the section, thereby exposing the fracture surface for metallurgical examination. The relative locations of the holdback lug failure and the drag brace attachment lug crack are shown in Figure 13.

Both fracture surfaces showed visual evidence of two stage failures, with fractures originating in the load bearing surfaces. The two stage failure is clearly evident as shown in Figure 14 where a semicircular portion of the flat area adjacent to the load bearing surface is significantly darker than the remainder of the fracture. A metallurgical analysis of each fracture, performed by the Aero Materials Laboratory (AML) of the NAVAIRDEVCEN, considered three distinct fracture zones, designated A, B and C. Zone A consists of the failure initiation and any subsequent crack growth prior to failure. Zone C is the area in which the crack length became critically sized and the remaining lug area failed due to ductile rupture by one cycle of load. Zone B is the transition zone between Zones A and C. Figures 14 and 15 show the distinct zones of each failure.

A scanning electron microscope examination of Zone A of both fracture faces showed the failures were identical but left some uncertainty as to the exact mode of failure. A mixture of intergranular fracture, fatigue and dimple rupture (local ductile fracture) was present. The following explanation has been offered by the AML: An extensive literature survey revealed several cases of fractures identical to the test fractures. These failures were attributed to hydrogen embrittlement and/or stress corrosion. The general belief is that these two modes of failure are identical. The failed NLG lugs were manufactured from air melted 4330 steel which is more susceptible to stress corrosion crack growth than vacuum melted steel. The reason for this is not clear but is likely to be related to the hydrogen content. The evidence indicates that a stress corrosion mechanism initiated the failures and that as the stress intensity increased with crack growth a fatigue mechanism became predominant.

The NLG holdback lugs, drag brace attachment lugs and catapult tow lugs had undergone a detailed inspection, using eddy current and dye penetrant nondestructive testing techniques after tow link #2 failed at cycle 3200 with no detectable cracks. Since failure occurred at cycle 3336, the crack growth rate is seen to be rapid, which is predictable for highly heat treated steels (220-240 KSI). This necessitates short intervals between inspections of the E-2P NLG lugs on carrier based E-2 aircraft.

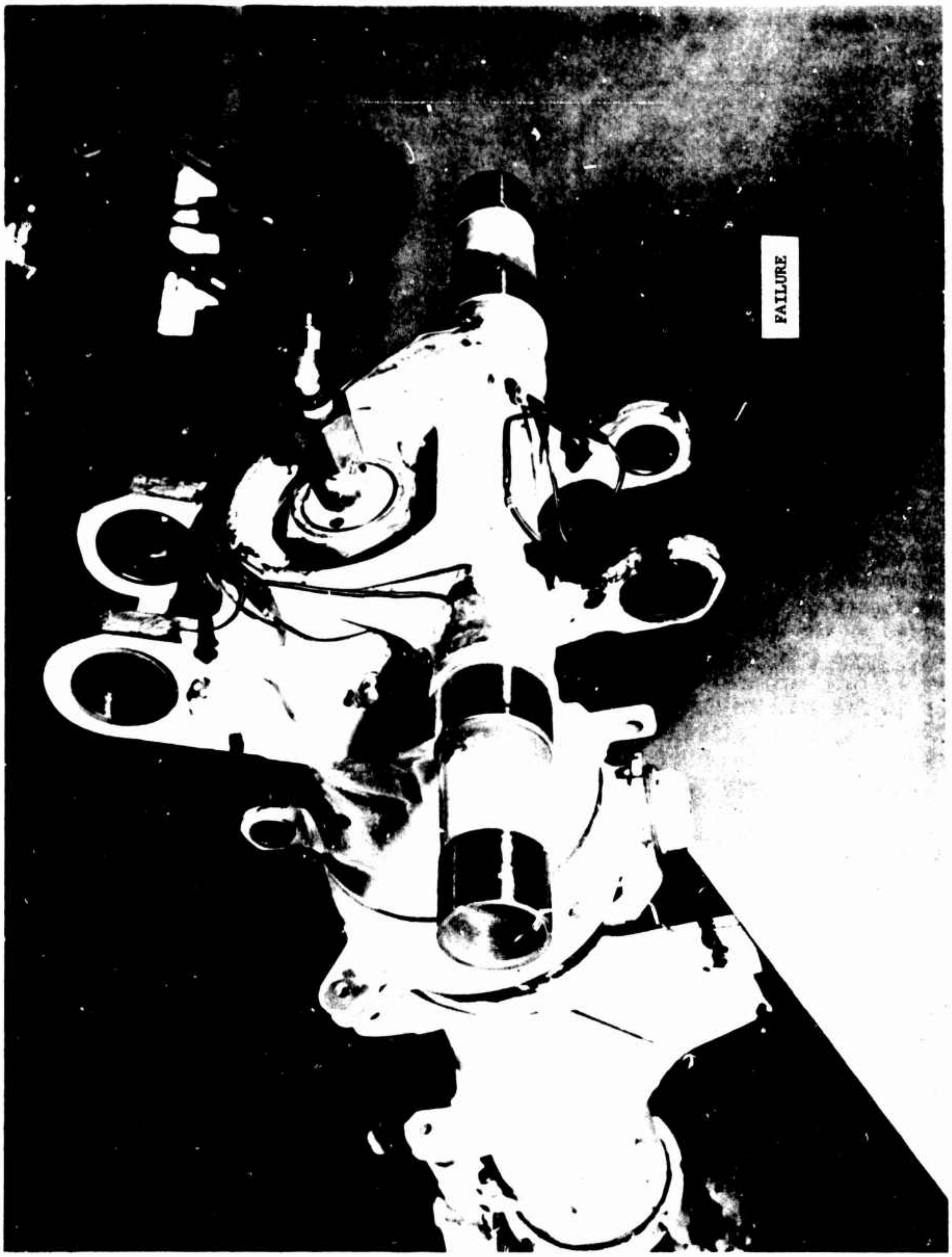


Figure 11. E-2B Holdback Lug Failure

Figure 12. E-2B Holdback Lug Failure - Closeup

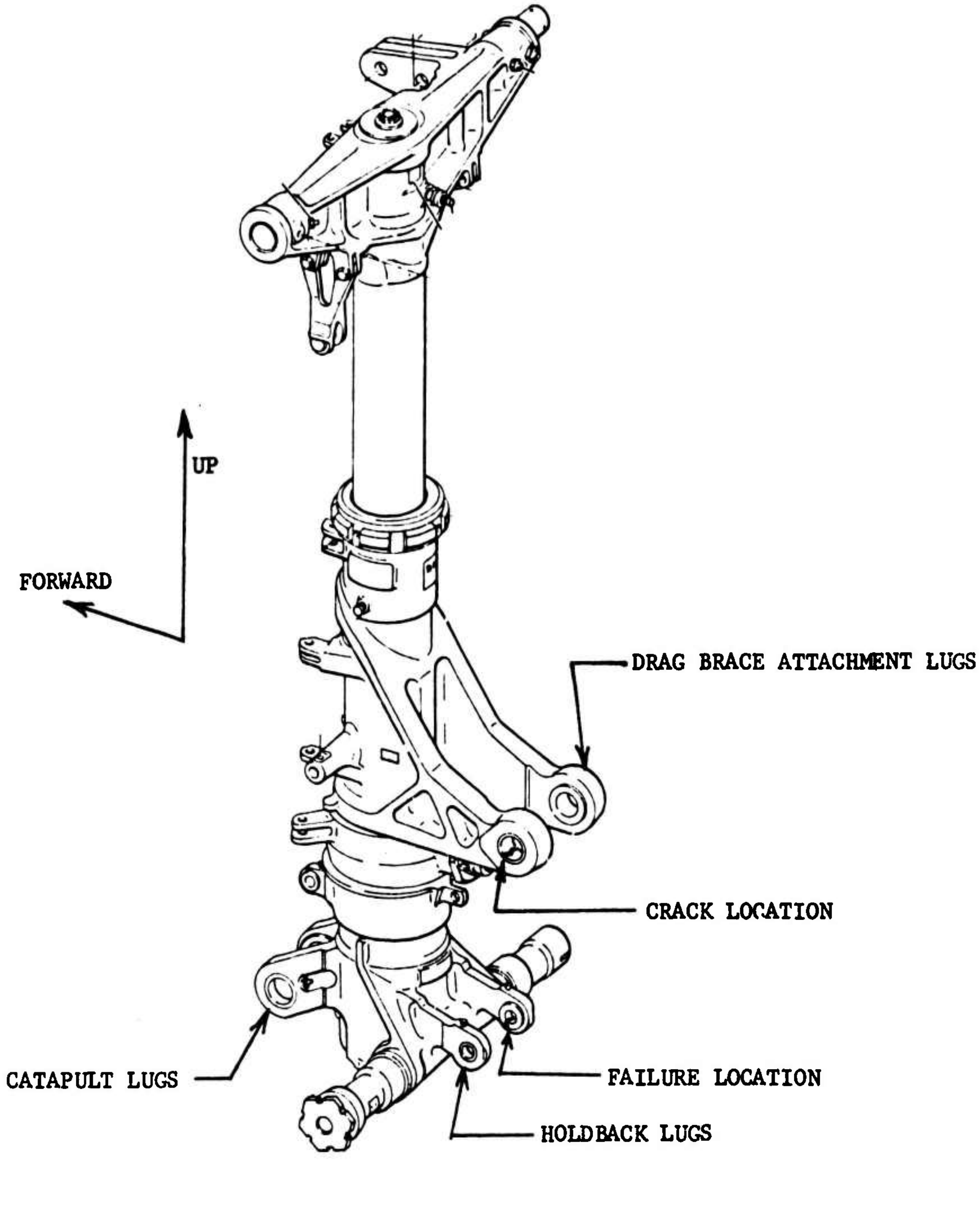


Figure 13. Location of Holdback Lug Failure and Drag Brace Attachment Lug Crack

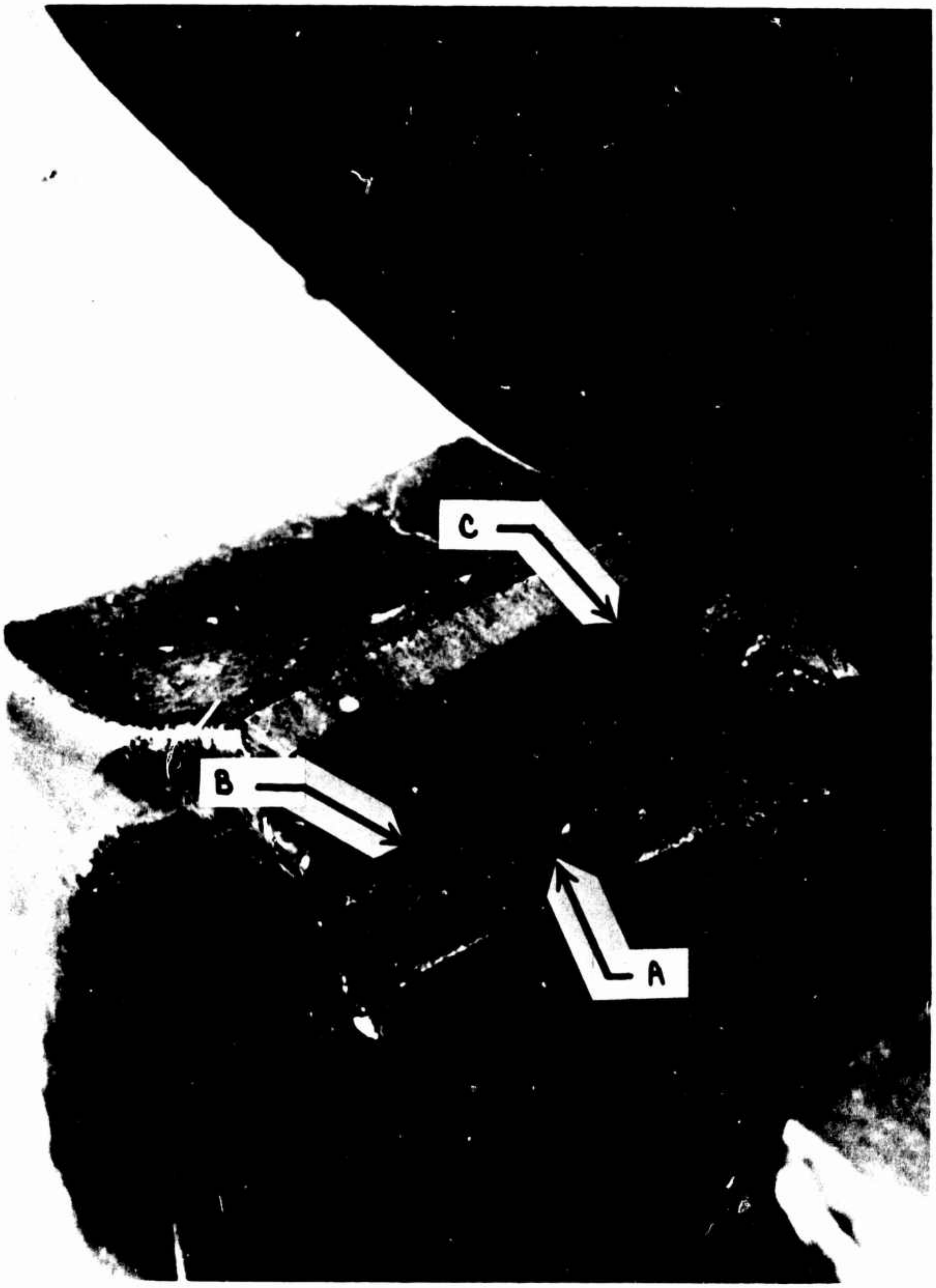


Figure 14. E-2B Holdback Lug Fracture Surface

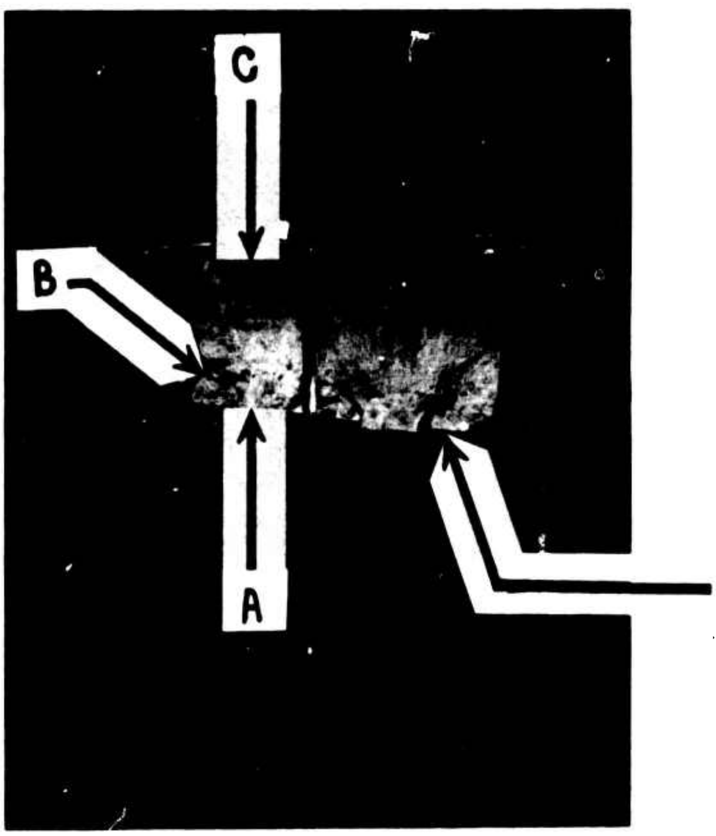


Figure 15. E-2B Drag Brace Attachment Lug Fracture Surface

E-2C NOSE LANDING GEAR TEST

During the application of cycle 2270, catapult tow link #3 failed. This tow link was a new part in which the toe had been removed to conform to the new flush deck catapult shuttles. Figure 16 shows the tow link modification. The mode of failure was identical to tow link #1 and is shown in Figures 17 and 18. The failed tow link was replaced with tow link #2, which was used to complete the E-2B NLG test.

After completion of cycle 2300, drag brace #1 was removed. The drag brace had accumulated 3336 test cycles from the E-2B NLG test and 2300 test cycles from the E-2C NLG test for a total of 5636 test cycles plus an unknown number of service launches. GAC had failed an E-2B drag brace after 6797 test cycles. Since a drag brace failure could have been detrimental to the E-2C shock strut test results, drag brace #1 was replaced by drag brace #2 and testing was continued.

After cycle 7030, tow link #2 was removed and replaced with tow link #4, which was a service used tow link instrumented with strain gages. This was done to affirm the accuracy of the applied catapult tow load due to the already substantially increased fatigue life of the E-2C NLG. After 200 cycles (test cycle 7230) tow link #2 was reinserted and cycling continued.

During cycle 7,430 tow link #2 failed. The tow link had accumulated 5096 test cycles prior to failure plus an unknown number of service launches. The failure was again similar to tow links #1 and #3. At this point, a detailed inspection of the E-2C NLG revealed a crack in the outer cylinder, emanating from under the packing nut and extending down the cylinder approximately two inches as shown in Figures 19 and 20. The time of occurrence of this crack will be used to determine the life of the E-2C NLG. The end of the crack was marked and cycling was continued to investigate the outer cylinder crack growth rate and load carrying capacity. Since it is possible for a similar crack occurrence in service to go unnoticed between NLG inspections, it was desirable to determine whether the NLG could still sustain catapult launch loads.

Upon application of cycle 7540, the right hand holdback lug failed, similar to the E-2B failure. Figure 21 shows the failure. A metallurgical examination of the fracture surface revealed fatigue striations with transgranular secondary cracks running perpendicular to the striations. Unlike the E-2B NLG failure, there is a lack of stress corrosion in the E-2C NLG failure, which is 4330 vacuum melt steel. This is not unexpected since it is known that vacuum melting reduces the stress corrosion crack growth rate but does not substantially affect the fatigue crack growth rate.

The holdback load of the catapult launch cycle was eliminated from the test and cycling was continued to further investigate the crack growth rate of the outer cylinder crack. The crack grew vertically to approximately 4.0 inches and then propagated laterally around the outer cylinder until it achieved a total length of approximately 7.5 inches. At this point it was apparent that a redistribution of the stresses within the specimen stopped

Figure 16. Tow Link Modification

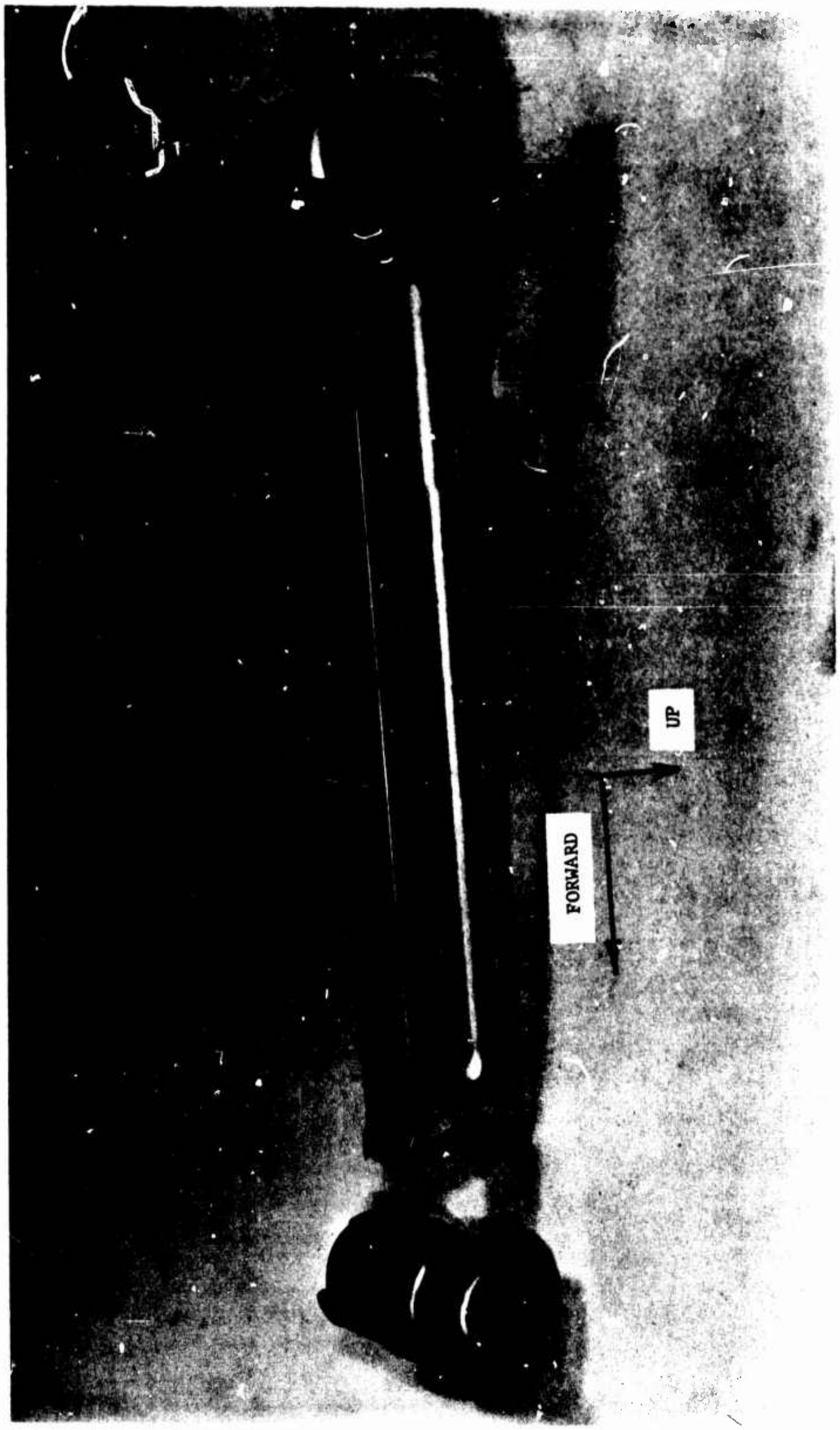


Figure 17. Tow Link #2 Failure

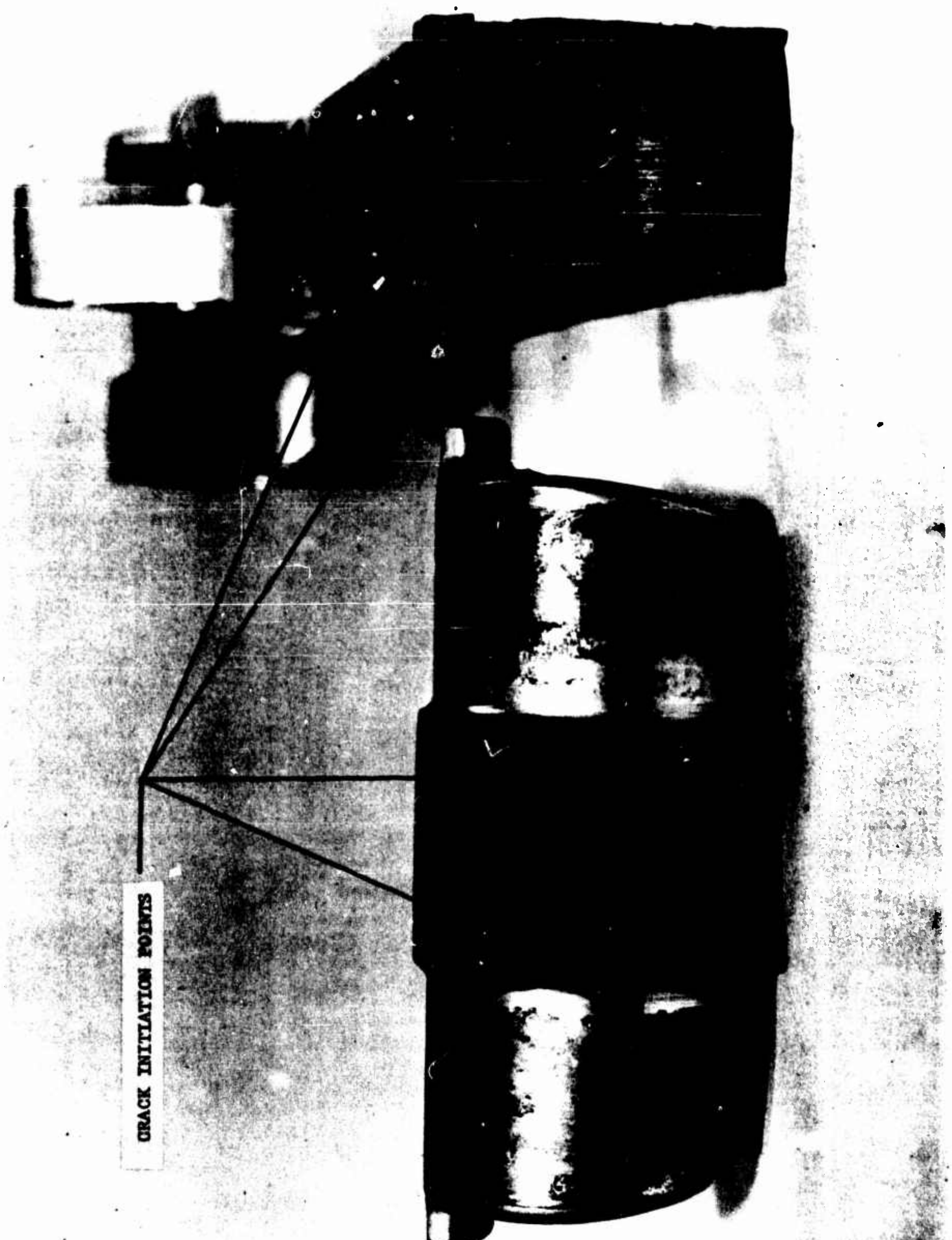


Figure 18. Tow Link #2 Fracture Face

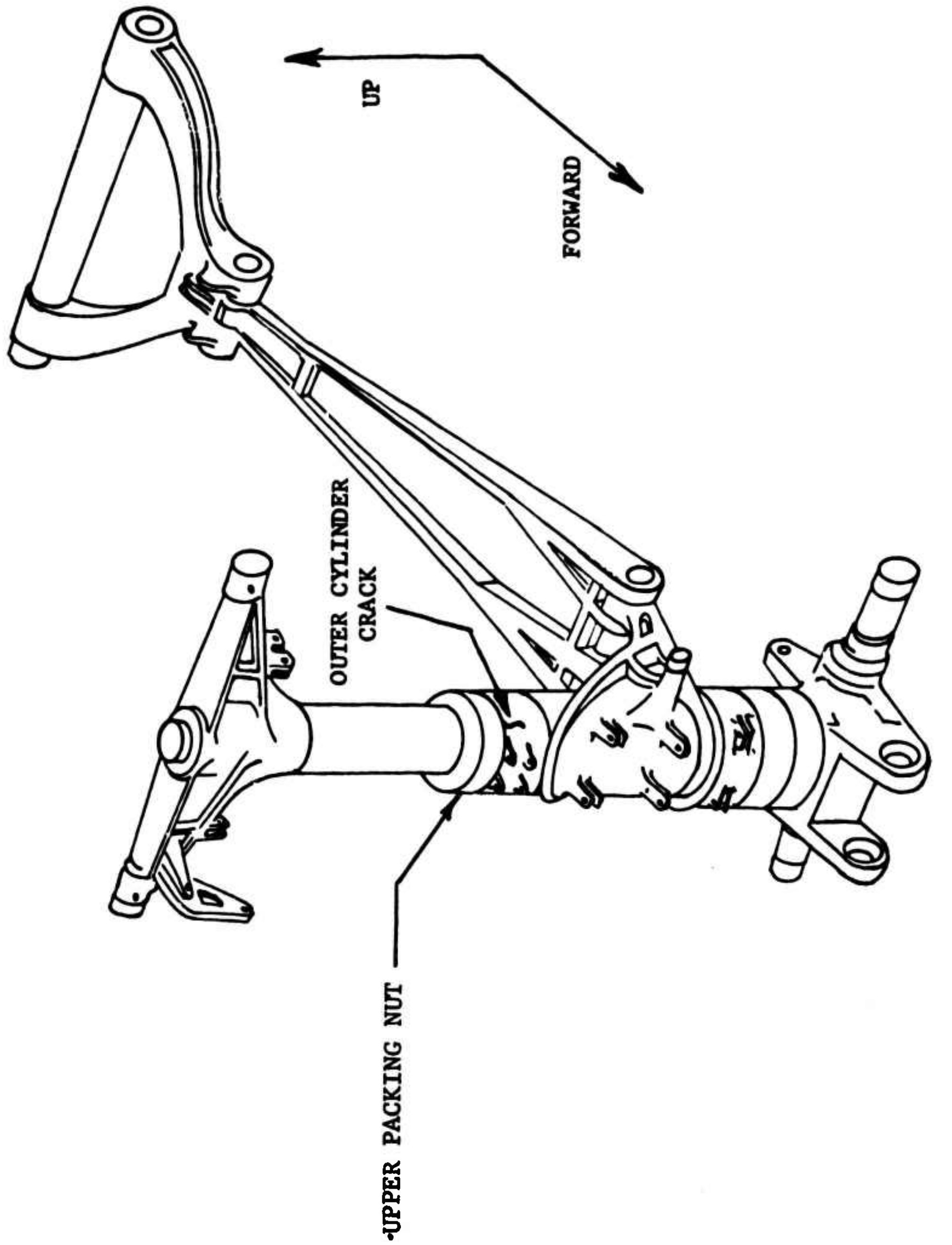


Figure 19. Location of E-2C NLG Outer Cylinder Crack

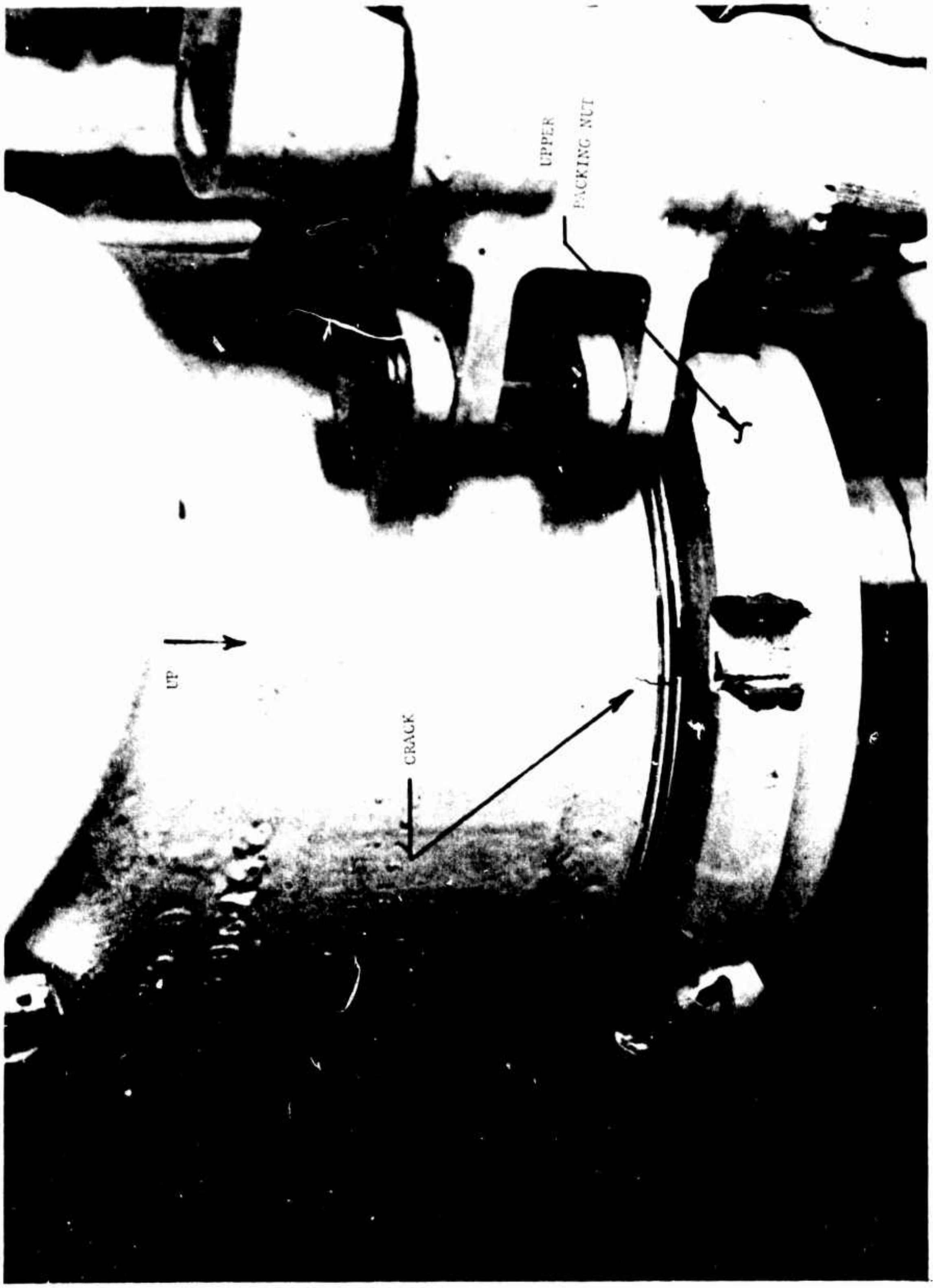


Figure 20. E-2C Outer Cylinder Crack

Figure 21. E-2C Holdback Lug Failure

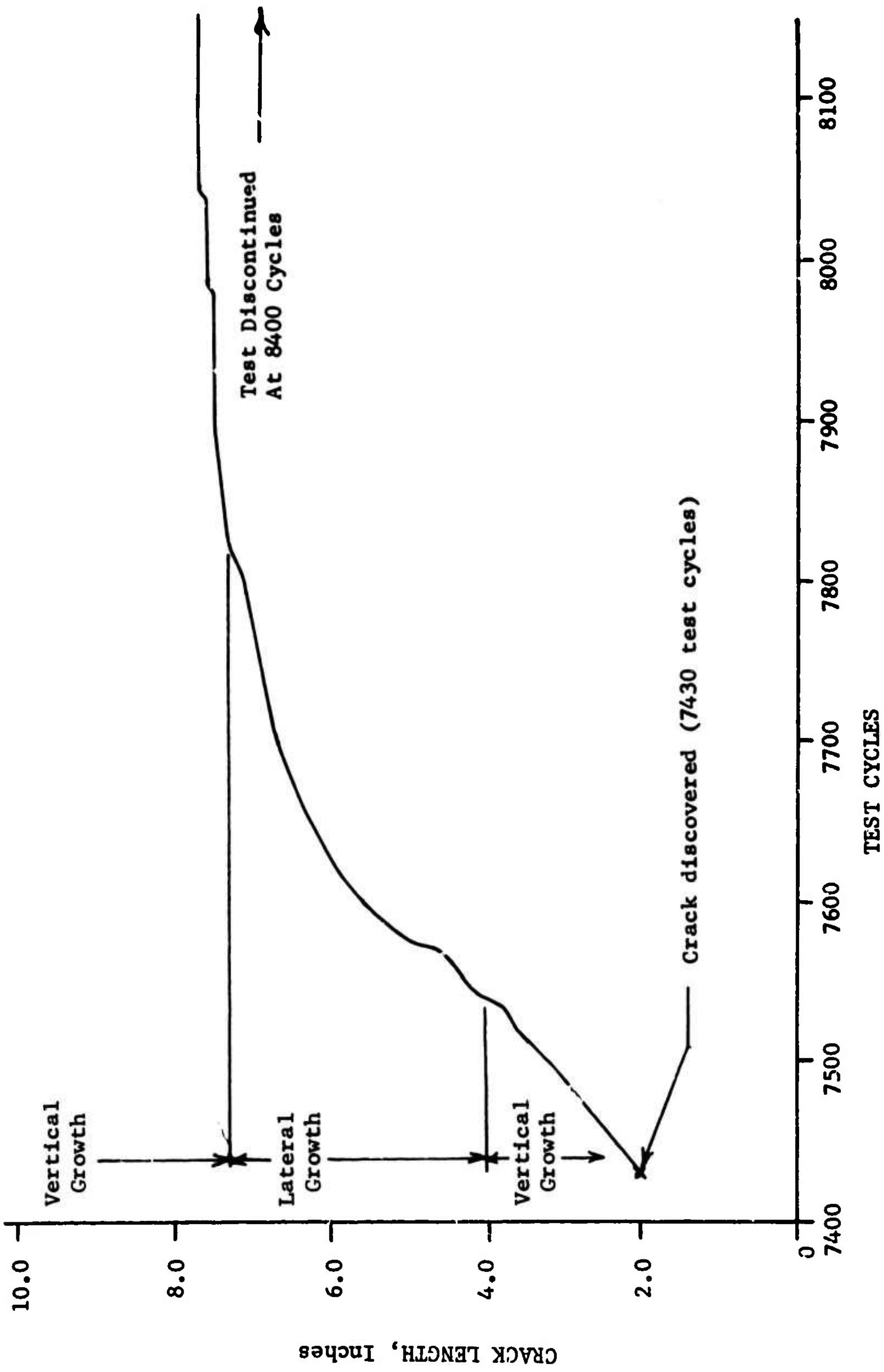


Figure 22. E-2C Outer Cylinder Crack Growth Plot; Crack Length vs. Test Cycles

the crack growth and cycling was discontinued at 8400 cycles, terminating the test. Figure 23 shows a plot of the crack growth (crack length vs. test cycles). Figures 24 and 25 show the outer cylinder crack at its maximum length for zero load and maximum applied catapult tow load, respectively.

HOLDBACK-RECEIVER ASSEMBLY TEST

The dummy release element failed during the application of cycle 1686 and was replaced by a second dummy release element which failed at cycle 4123. The test specimens were inspected and found to be crack free after each dummy release element failure. A third dummy release element was installed and cycling resumed.

During the application of cycle 5046 the holdback receiver assembly (P/N 128L10074-1) failed. The specimen was severed in two as shown in Figure 26. An examination of the fracture surface revealed semicircular areas on both sides of the fracture surface which were determined to be fatigue crack growth as shown in Figure 27.

C O N C L U S I O N S

Based on the results of this fatigue investigation, the E-2B NLG shock strut is capable of sustaining the effects of 1000 additional catapult launches after modification of the outer cylinder drag brace attachment lugs. The test results are applicable to all configurations of the E-2B NLG and assume the modification is installed prior to catapult launch 750. The current authorized limit of 650 catapult launches for the E-2B NLG can therefore be extended to 1750 catapult launches.

The test results also indicate that the 650 catapult launch limit for the E-2C NLG shock strut can be extended to 3,500 catapult launches, with no modifications required. In addition the catapult launch limit for the E-2B drag brace is in excess of 3,000 catapult launches and the E-2B/C holdback-receiver assembly is in excess of 2500 catapult launches. The catapult tow links for all E-2 NLG configurations should remain a replaceable item at 1000 catapult launches.

R E C O M M E N D A T I O N S

As of 1 May 1974, all E-2B NLG were assumed to have 650 launches. It is recommended that the drag brace attachment lugs of the E-2B NLG shock struts be modified within 100 launches of this date. Therefore, after modification, the E-2B NLG will have achieved no more than 750 launches. Based on the test results, it is recommended that an additional 1000 launches be permitted after modification, which extends the original 650 catapult launch limit of the E-2B NLG shock strut to 1750 launches.

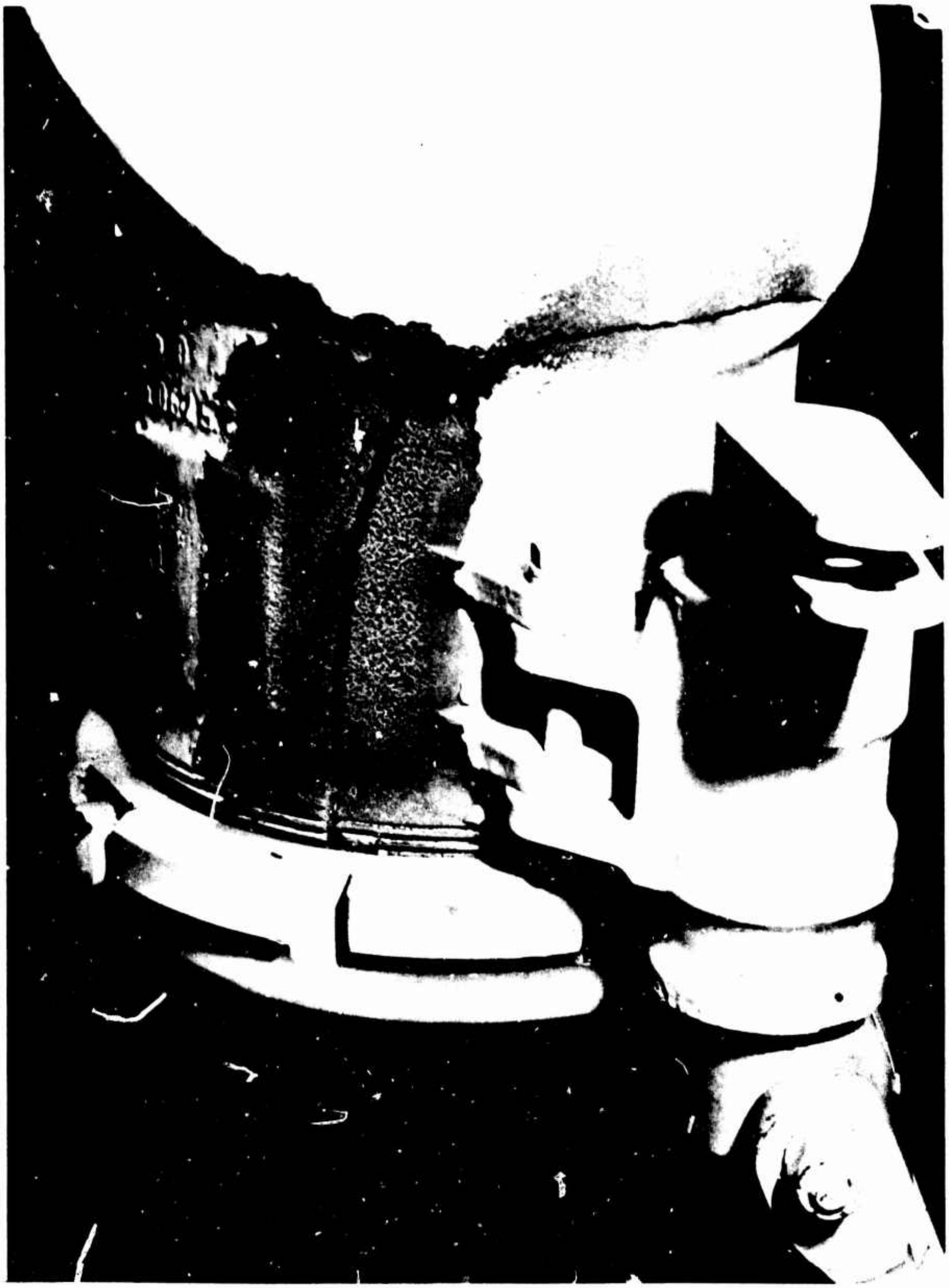


Figure 23. E-2C Outer Cylinder Crack - Maximum Crack Length at Zero Load

Figure 24. E-2C Outer Cylinder Crack - Maximum Crack Length at Maximum Applied Tow Load

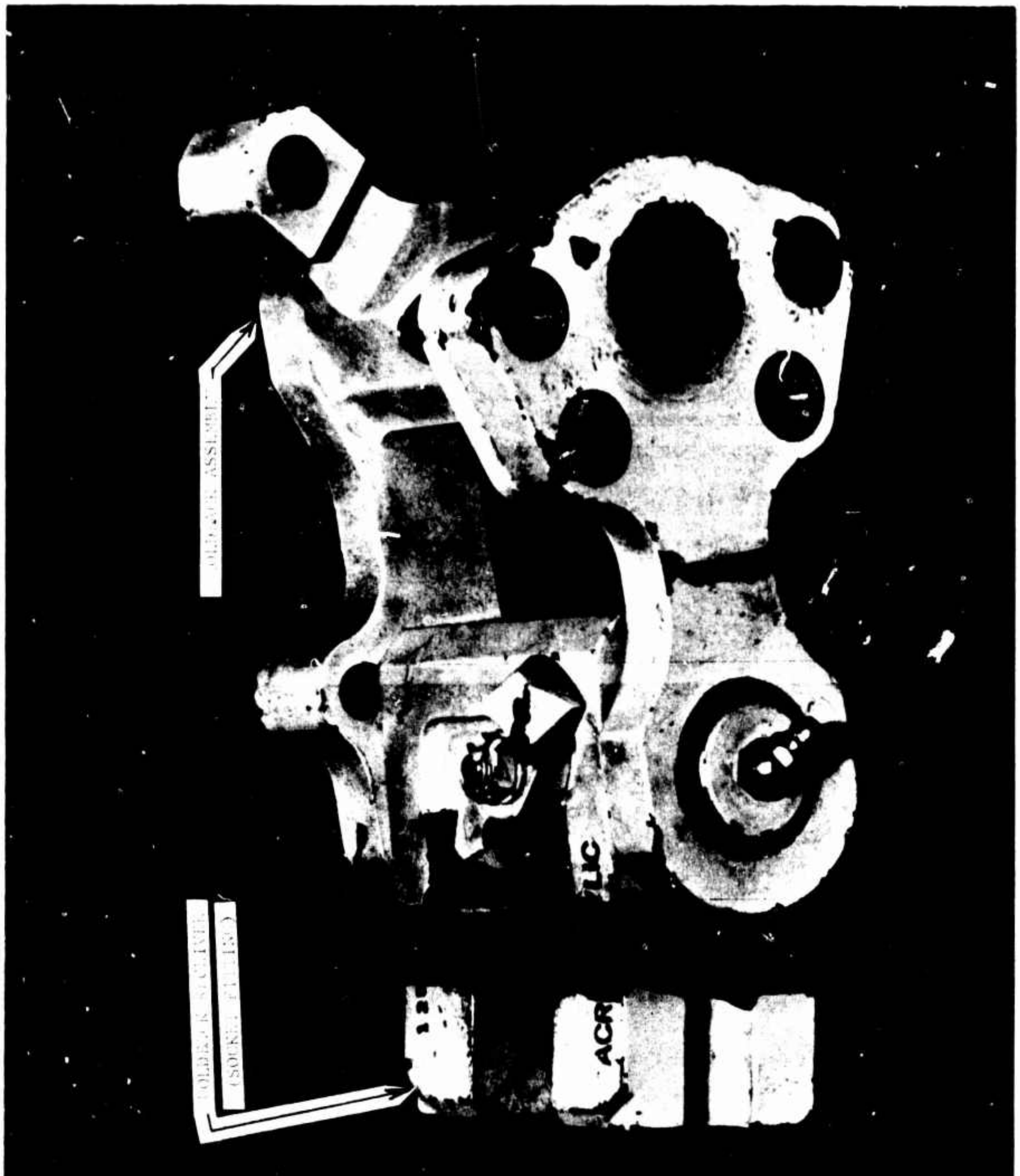


Figure 25. Holdback Receiver Failure

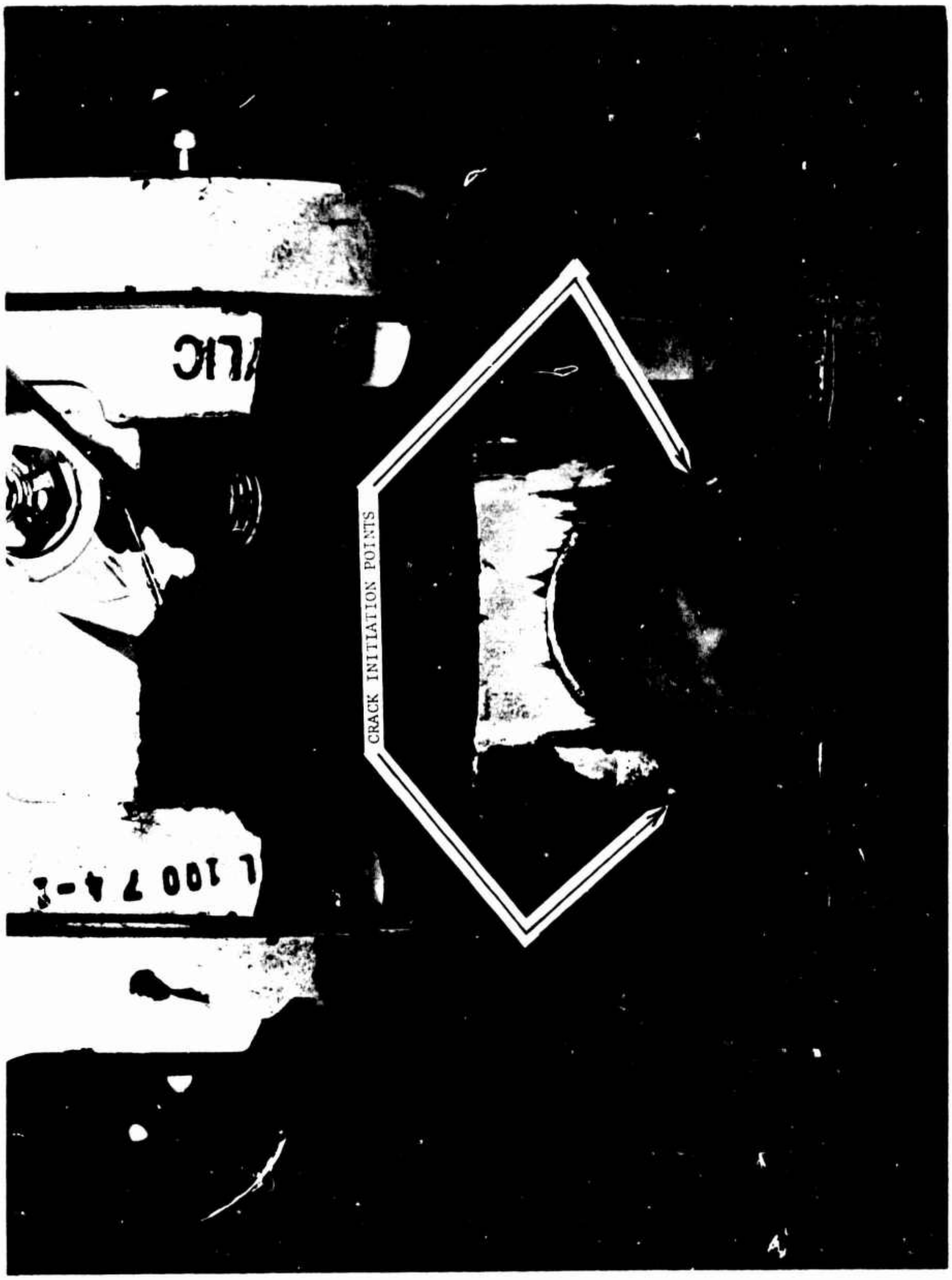


Figure 26. Holdback Receiver Fracture Surface

It is further recommended that the 650 catapult launch limit of the E-2C NLG shock strut be increased to 3,500 launches with no modifications required.

The 1000 launch limit for the tow link with inspections after every 100 launches should not be changed. The drag brace catapult launch limit should be increased to 3000 launches and the holdback-receiver assembly should be increased to 2500 launches.

It is also recommended that the critical areas found in this report be inspected at regular intervals and a method of recording the number of launches of each critical part be initiated.

ACKNOWLEDGMENTS

The author wishes to acknowledge the valuable assistance, during the test program, of Messrs. L. Berman, V. Catone and E. Kautz of the Aero Structures Division and also the Aero Materials Laboratory for performing the metallurgical analysis.

REFERENCES

(a) GAC Report 3839.12, "Results of Catapulting Conditions Fatigue Tests", Rev. 25 Sep 1967.

(b) GAC letter, ENG-E-2C-74-044 of 26 June 1974.

(c) GAC letter, ENG-E-74-046 of 9 July 1974.

(d) NAVAIRDEVCEN, NAVAIREWORKFAC, N.I. and GAC meeting of 15 Aug 1974.

(e) GAC Report 3803.3, "Ground Loading Conditions", Rev. 15 Dec 1970.

APPENDIX A

TEST DATA FOR THE E-2B/C NOSE LANDING GEAR FATIGUE INVESTIGATION

LIST OF FIGURES

LIST OF TABLES

SYMBOLS

All symbols used in this appendix and in the text of the report are as follows:

FS . . . . fuselage station

WL . . . . water line

FRL . . . . fuselage reference line

R_e . . . . resultant load

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.

REFERENCE AXES

X - axis: Lies in the plane of symmetry 100 inches below and parallel to 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

Landing design gross weight - 40,660 pounds

Catapulting design gross weight - 47,940 pounds

Critical Conditions (reference (a))

Landing Conditions . . . . GAC Condition 1SU - 3 point landing, maximum spin-up

GAC Condition 1 SB - 3 point landing, maximum spring-back

GAC Condition 1 SU_2 - 3 point landing, second cycle spin-up

Catapulting Conditions . . GAC Condition 11 D_F - Catapult approach dashing - element failure

GAC Condition 11 D - Catapult approach dashing

GAC Condition 11 A - Catapulting Release

GAC Condition 11 C - Catapult Start of Run

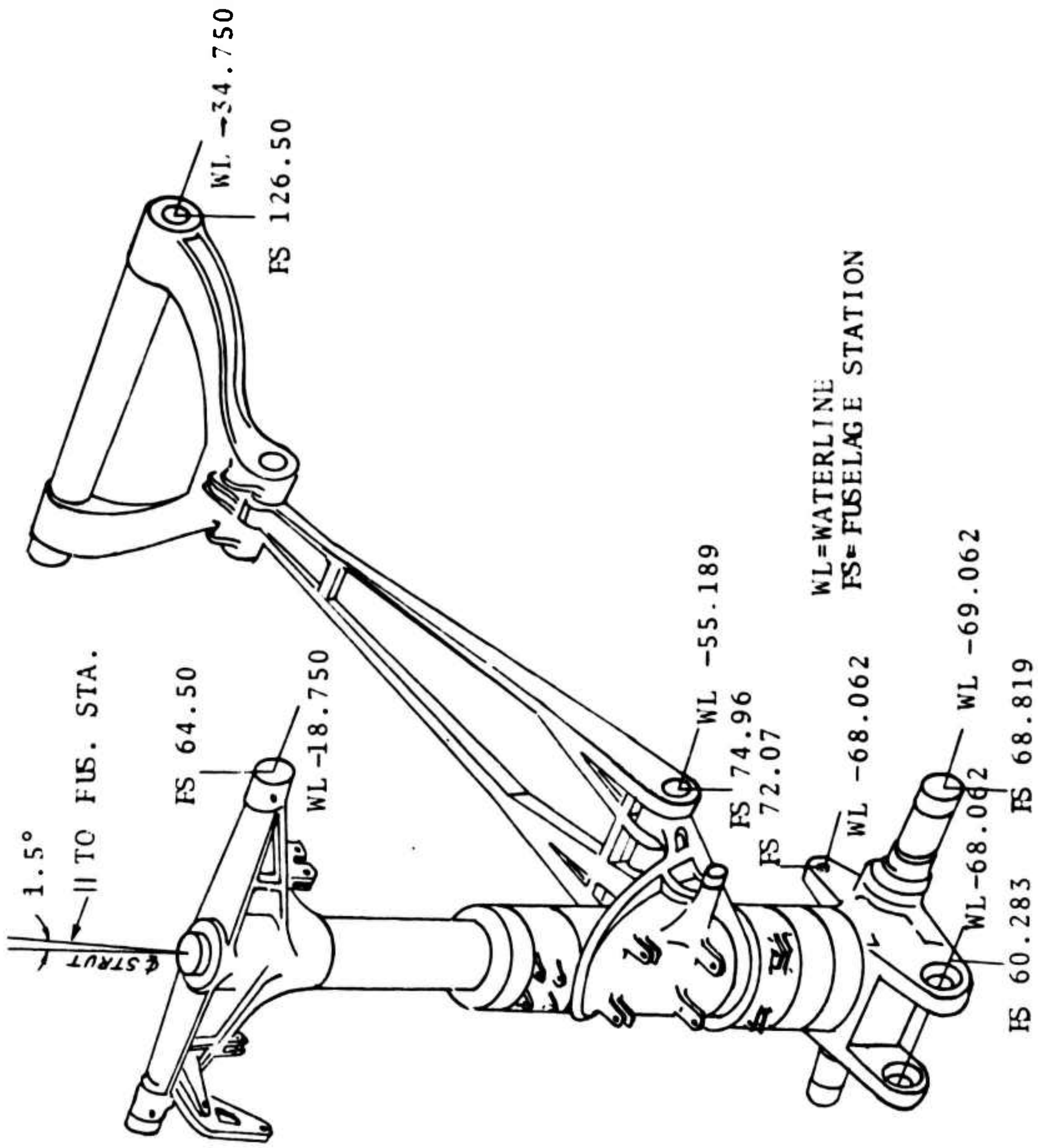


Figure A-1. E-2B/C Nose Landing Gear Geometry

TEST LOADS

All test loads presented in this section are in accordance with those found in references (a) and (b) with the exception of Condition 11 C. The loads for condition 11 C are as presented by NAVAIR 530223 at a meeting on 19 June 1974 and agreed to by GAC and the NAVAIRDEVCEN.

The loads associated with each condition of landing and catapult launch are given in Table A-I. Particular details of each condition are given below.

The down lock actuator load of 8,050 lbs. (reference (c)) was applied for the duration of each landing and catapult launch cycle.

LANDING CONDITIONS

The design landing gross weight of 40,660 lbs., wing lift equal to 2/3 W, maximum sinking speed equal to 20.8 ft/sec and a forward speed equal to 89.6 knots was used for all landing load calculations.

<u>Condition 1-SU</u> - Three point landing, maximum spin up

The nose wheel axle loads relative to the FRL are as follows:

X_{NW} = 21,200 lbs.

Y_{NW} = 0

Z_{NW} = 29,160 lbs.

The load distribution of this condition, direction and magnitude, is given in Figure A-2.

<u>Condition 1-SB</u> - Three point landing, maximum spring back

The nose wheel axle loads relative to the FRL are as follows:

X_{NW} = -17,630 lbs.

Y_{NW} = 0

Z_{NW} = 65,690 lbs.

The load distribution of this condition, direction and magnitude is given in Figure A-3.

<u>Condition 1-SU_2</u> - Three point landing, second cycle spin up

The nose wheel axle loads relative to the FRL are as follows:

TABLE A-I

E-2B NOSE LANDING GEAR FATIGUE INVESTIGATION
APPLIED TEST LOADS

Condition		Point of Load Application	Maximum Applied Loads		
			X	Y	Z
1 SU	3 point landing Maximum spin-up	Axle	21,200	0	29,160
1 SB	3 point landing Maximum spring-back	Axle	-17,630	0	65,690
1 SU_2	3 point landing Second cycle spin-up	Axle	17,850	0	65,690
11 D_F	Catapult approach Dashing, element failure	Holdback Axle	54,140 -480	±1,134 0	-6,170 27,990
11 D	Catapult approach Dashing	Holdback Axle	44,830 -440	±950 0	-5,110 25,700
11 A	Catapulting Release	Holdback Tow Link Axle	54,140 -33,110 -520	±1,134 ∓ 690 0	-6,170 -11,420 30,650
11 C	Catapult Start of Run Upper 90 percentile	Tow Link Axle	-132,300 -170	±2,770 0	-50,270 11,730

NOTES:

(1) All loads will be applied with the shock strut fixed at the static position.

(2) The nose gear actuating cylinder load of 8,050# for the gear in the down and locked position, will be applied for each loading condition.

(3) Positive loads are up and aft.

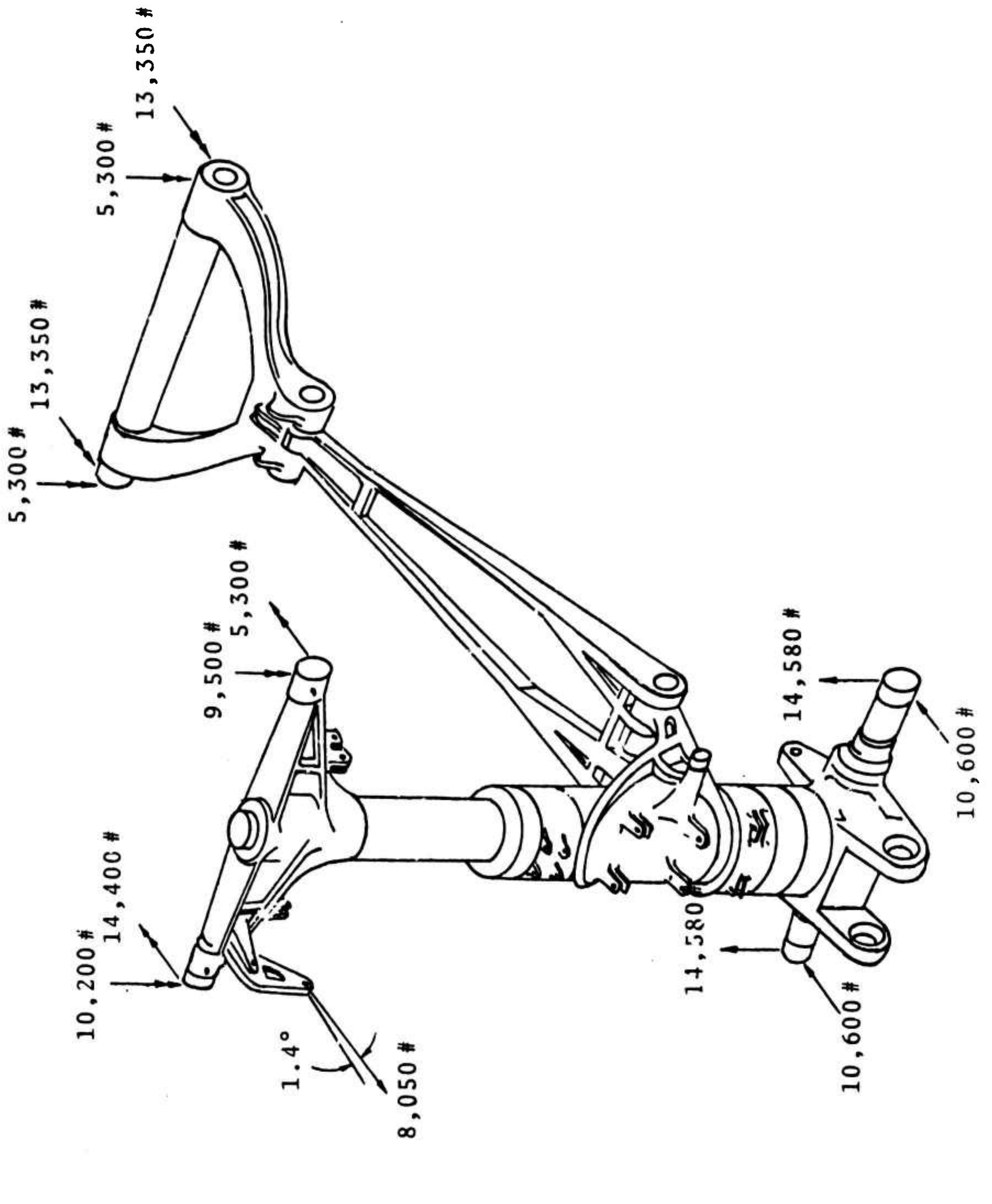


Figure A-2. Condition 1 SU, 3 Point Landing - Maximum Spin Up

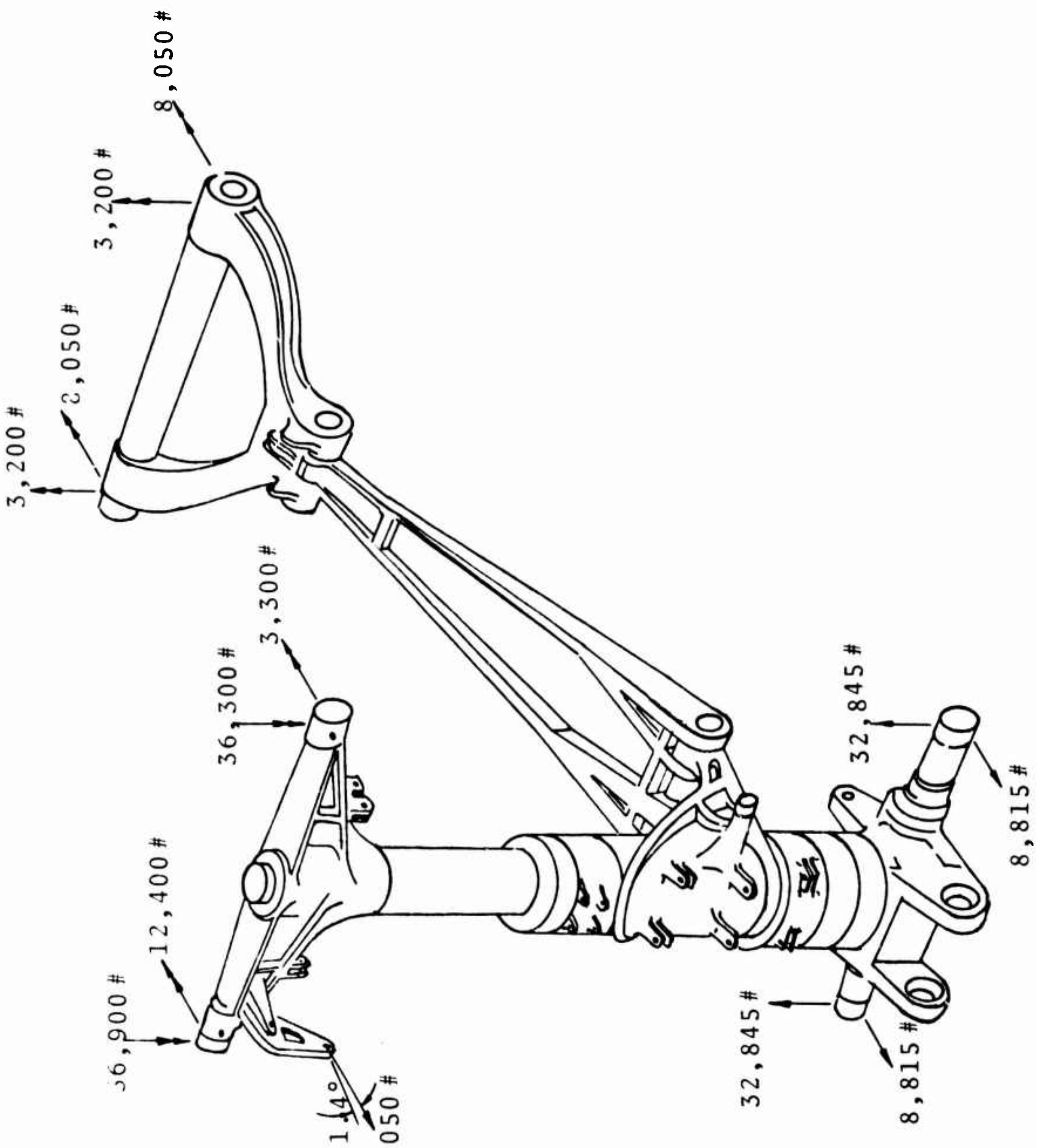


Figure A-3. Condition 1 SB, 3 Point Landing - Maximum Spring Back

X_{NW} = 17,850 lbs.

Y_{NW} = 0

Z_{NW} = 65,690 lbs.

The load distribution for this condition, direction and magnitude is given in Figure A-4.

CATAPULT LAUNCH CONDITIONS

Condition 11 D_F - Catapult approach dashing, element failure

The loads for this condition were derived using the holdback release element failure load of 54,500 lbs. The components of the holdback and nose wheel axle loads are as follows:

Holdback

X = 54,140 lbs.

Y = ±1134 lbs.

Z = -6,170 lbs.

The resultant holdback load acts at an angle of 6.5° down and 1.2° to the left or right of the fuselage reference axes. The side component results from a six-inch off-center spotting of the airplane (reference (d)).

Nose Wheel Axle

X = -440 lbs.

Y = 0

Z = 27,990 lbs.

The resultant nose wheel axle load act normal to the ground with the FRL inclined nose-up at 0.972°. The loading distribution for this condition, direction and magnitude, is given in Figure A-5.

Condition 11 D - Catapult approach dashing

The loads for this condition were derived to produce a design limit compression load of 60,000 lb. in the nose gear drag brace, which was measured during the airplane catapult trials at Patuxent in February 1962. For taxi speeds of 2 to 4 mph and no wheel braking, a holdback trial bar axial load of 45,124 lbs. is required to produce 60,000 lbs. compression in the drag brace. The components of the holdback and nose wheel axle loads are as follows:

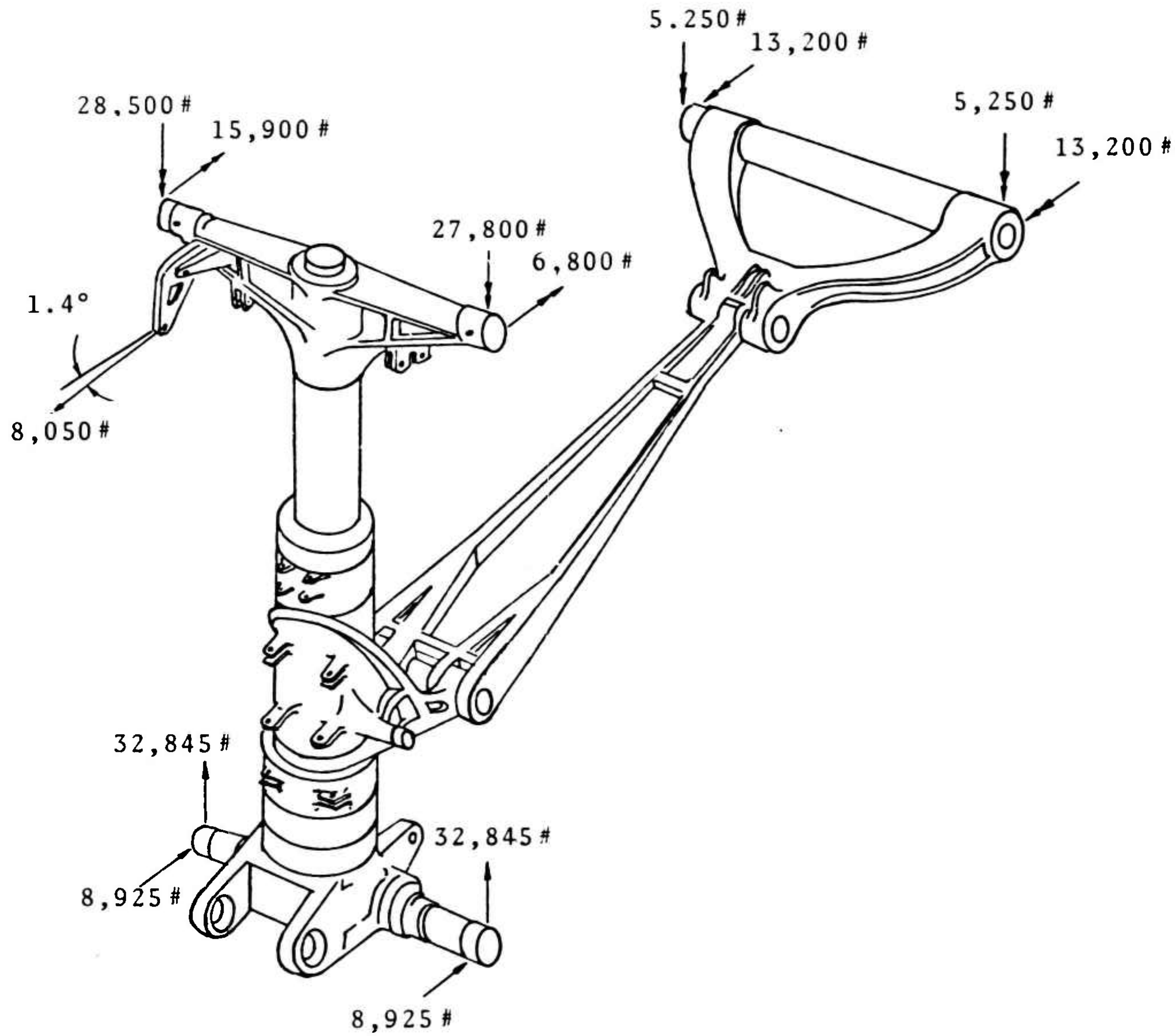


Figure A-4. Condition 1 SU_2, 3 Point Landing - Second Cycle Spin Up

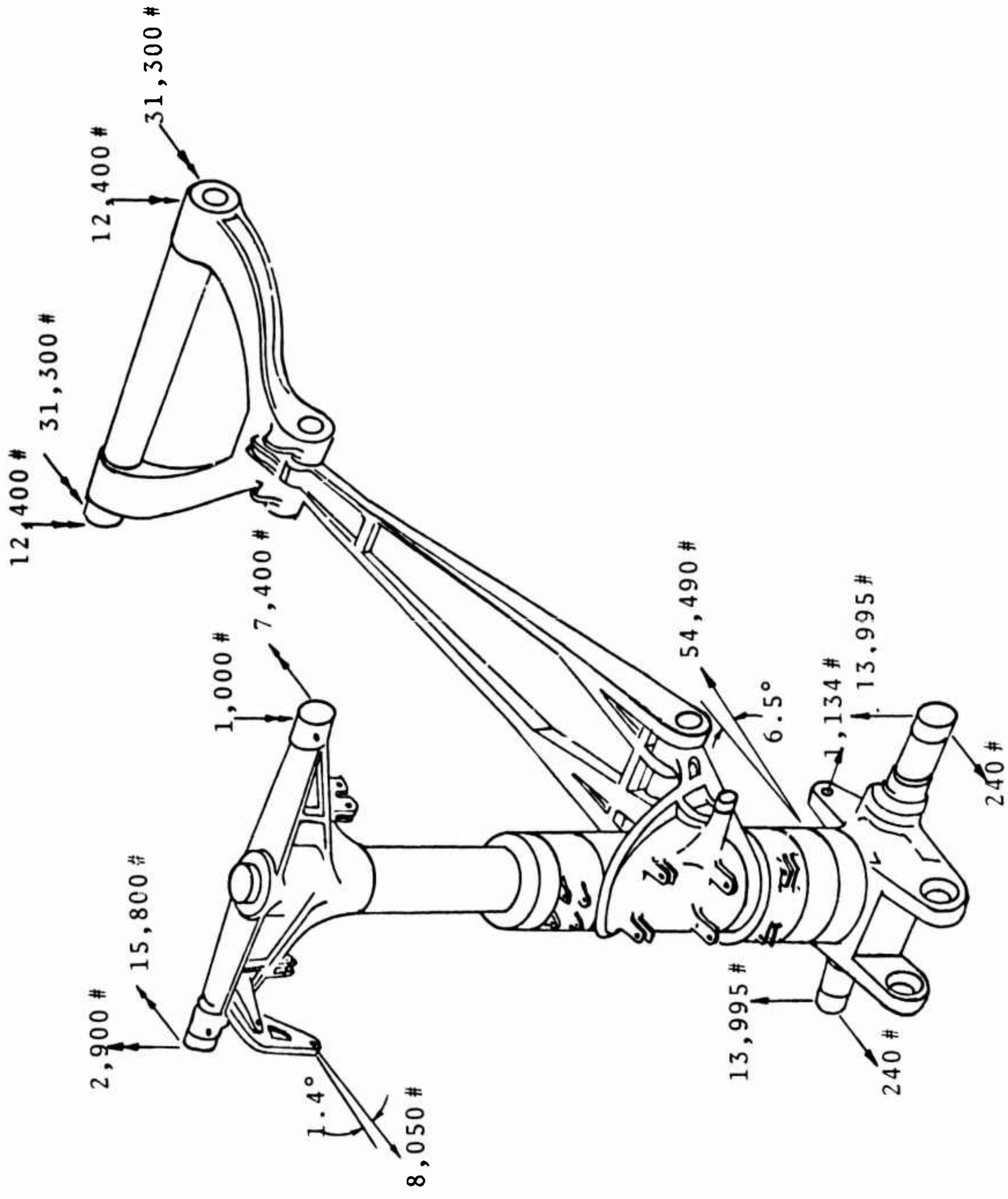


Figure A-5. Condition 11 D_F,

Holdback

X = 44,830 lbs.

Y = ±950 lbs.

Z = 5,110 lbs.

The resultant holdback load acts in the same manner as that indicated for condition 11 D_F.

Nose Wheel Axle

X = -480 lbs.

Z = +27,990 lbs.

The resultant nose wheel load acts normal to the ground with the FRL inclined nose upat 0.97°. The loading distribution for this condition, direction and magnitude is given in Figure A-6.

Condition 11-A - Catapult Release

The loads for this condition were derived using the holdback release element failure load of 54,500 lbs. and a simultaneously applied tow link load of 35,470 lbs. The components of the holdback, tow link and nose wheel axle loads are as follows:

Holdback

X = ±54,140 lbs.

Y = ±1,134 lbs.

Z = -6,170 lbs.

The resultant holdback load acts in the same manner as that indicated for condition 11 D_F.

Tow Link

X =-33,114 lbs.

Y = ±690 lbs.

Z = -11,420 lbs.

The resultant tow link load acts at an angle of 20.97° down and 1.2° to the right or left of the fuselage reference axes.

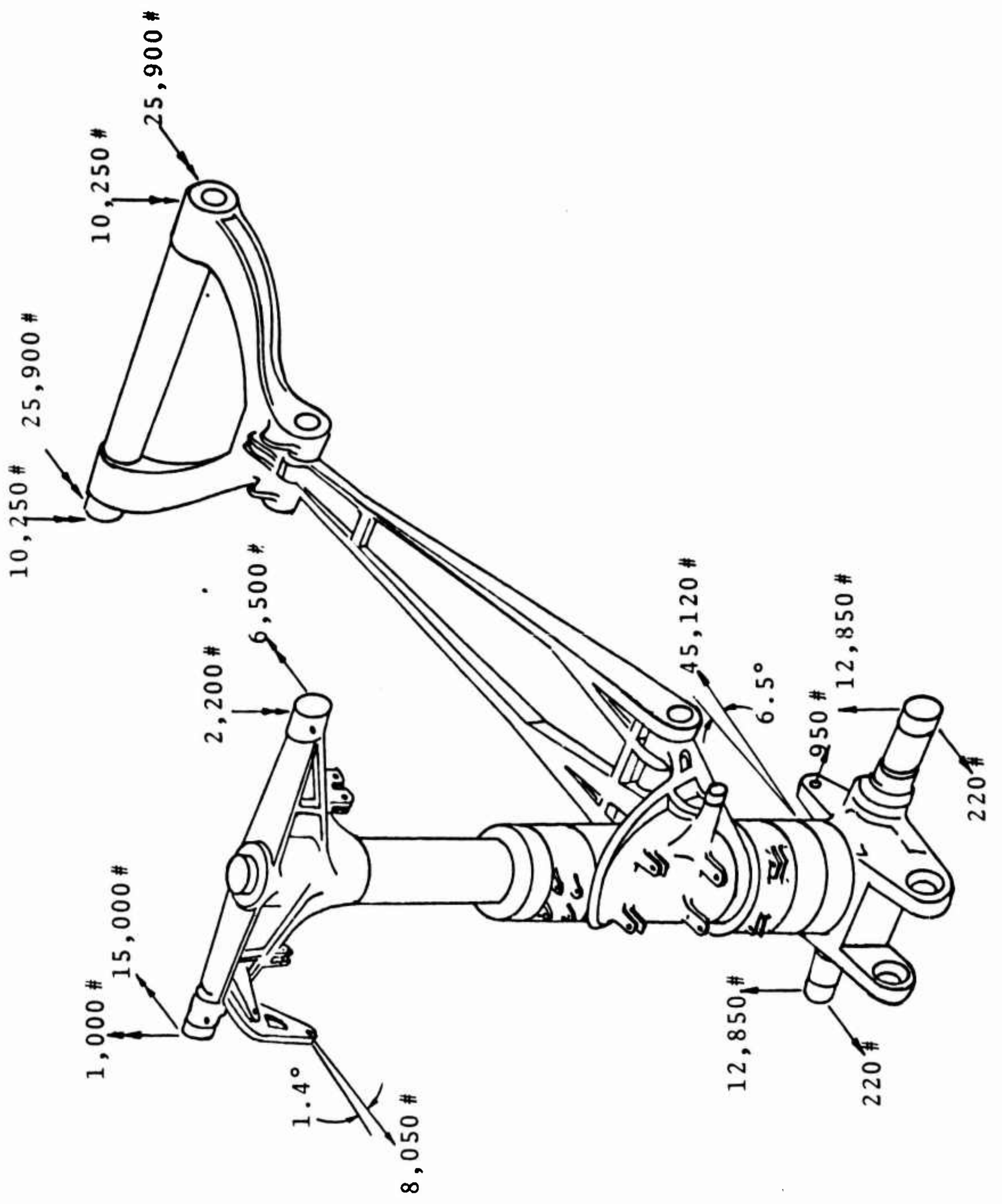


Figure A-6. Condition 11D, Catapult Approach Dashing

Nose Wheel Axle

X = -520 lbs.

Z = +30,650 lbs.

The resultant nose wheel load acts normal to the ground with the FRL inclined nose-up at 0.97°. The loading distribution for this condition, direction and magnitude is given in Figure A-7.

Condition 11 C - Catapult Start of Run

The loads for this condition were derived using a maximum tow force equal to 133,000 lbs. and a mean tow force of 120,000 lbs., applied at the minimum tow link angle of 20° relative to the ground. The components of the maximum tow link and nose wheel axle loads are as follows:

Tow Link

X = +132,300 lbs.

Y = ±2,770 lbs.

Z = -50,270 lbs.

The resultant tow link load acts at an angle of 20.97° down and successively 1.2° to the left and to the right of the fuselage reference axes. The side component of the towing load results from a six inch off-center spotting of the airplanes.

Nose Wheel Axle

X = -165 lbs.

Z = +11,725 lbs.

The resultant nose wheel axle loads acts normal to the ground with the FRL inclined nose-up at 0.97°. The loading distribution for this condition is given in Figure A-8.

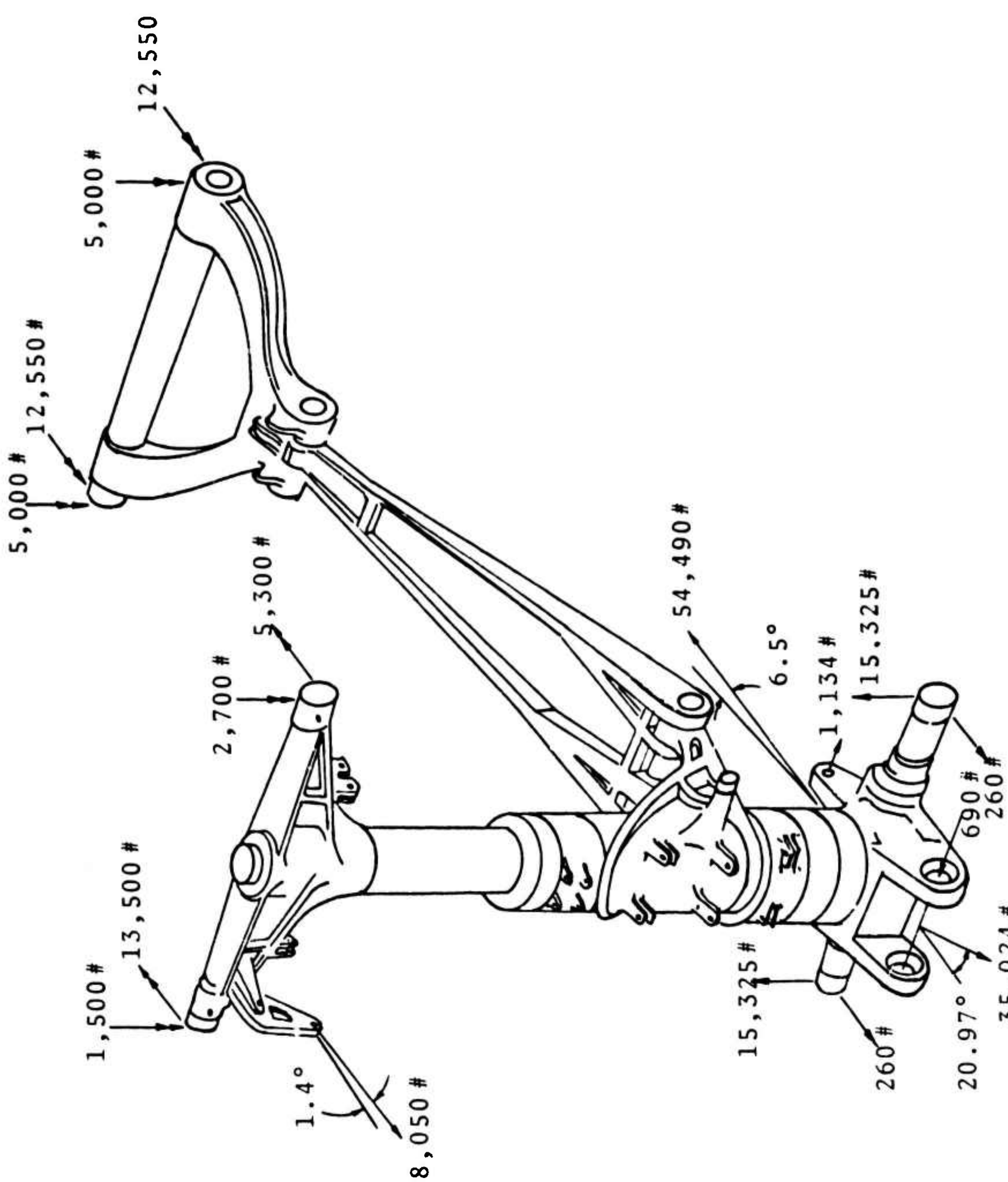


Figure A-7. Condition 11A, Catapult Release

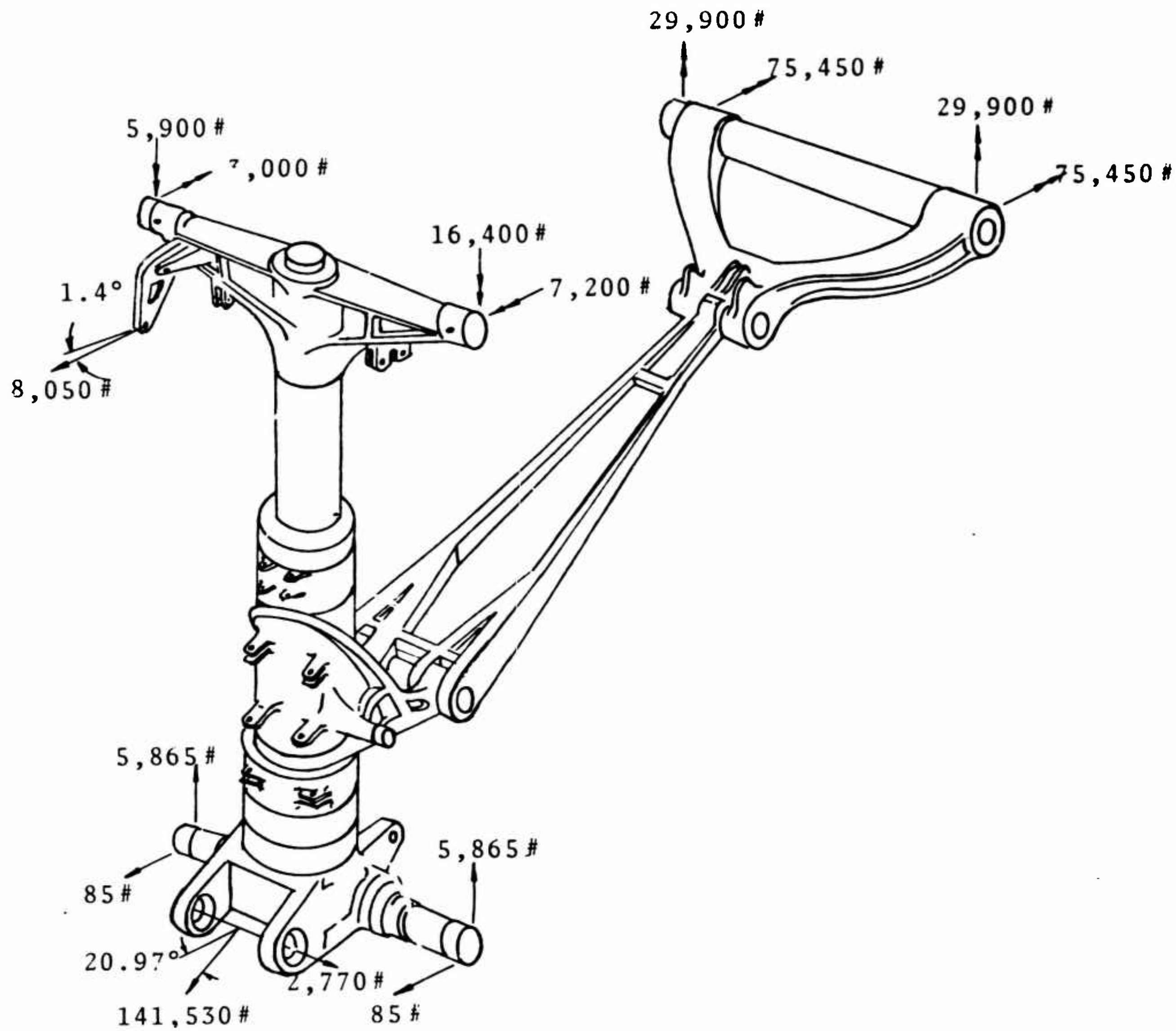


Figure A-8. Condition 11C, Catapult Start-of-Run Maximum Tow Load

REFERENCES

(a) GAC Report 3803.3 Ground Load Condition of 15 Dec 1970.

(b) GAC Report 3839.02 Plan for Catapulting Conditions Fatigue Tests of 13 Aug 1962, Rev. 25 Sep 1967.

(c) Bendix Report 1653 Stress Analysis of the Grumman W2F-1 Nose Gear of 22 Apr 1960, Rev. 15 Dec 1970.

(d) Paragraph 3.1.7.1 of MIL-C-18805A.