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AD905591

STRUCTURAL AND ENVIRONMENTAL
TEST REPORT
FOR THE
NATO SEA SPARROW
FOLDING WING PROGRAM

BR-6253 August 1972

Prepared for
DEPARTMENT OF THE NAVY
Naval Air Systems Command
Washington, D.C. 20360

Contract No. N00019-70-C-0102

RAYTHEON

RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION

RAYTHEON COMPANY

MISSILE SYSTEMS DIVISION

BEDFORD, MASSACHUSETTS

Model No.	Contract No.
Sea Sparrow	N00019-70-C-0102

STRUCTURAL AND ENVIRONMENTAL TEST REPORT FOR THE NATO SEA SPARROW FOLDING WING PROGRAM

Report No.	Date
BR-6253	August 1972

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ABSTRACT

Static structural, dynamic structural and environmental tests were conducted on the NATO Folding Wing Assembly and Torsion Bar. The Folding Wing Assembly and Torsion Bar successfully withstood structural and environmental tests which were conducted under this program.

TABLE OF CONTENTS

LIST OF REFERENCE DRAWINGS

Ref.	Item	Drawing No.	Rev.
a	Wing Assembly, Guided Missile, Folding	E361AS113	C
b	Torsion Bar, Hinge	D361AS100	B
c	Wing Assembly, Guided Missile, Folding	E361AS134	O
d	Torsion Bar, Hinge	D361AS136	O

LIST OF REFERENCE DOCUMENTS

1. Raytheon (Bedford) Report BR-5759, "Structural Test Plan Report For The NATO Sea Sparrow Folding Wing Program" dated March 1970 (Unclassified)
2. Raytheon (Bedford) Report BR-5874, "Environmental Test Plan Report For The NATO Sea Sparrow Folding Wing Program" dated August 1970 (Unclassified)
3. Raytheon (Bedford) Memo No. SM 70-230, "NATO Sea Sparrow Wing Loads" dated 11 September 1970 (Confidential)
4. Raytheon (Bedford) Aerophysics Memo No. HT-041-68, "Sea Sparrow Folding Wing Thermal Analysis" dated 28 February 1968 (Unclassified)
5. "Aerospace Structural Metals Handbook" AFML-TR-68-115 Volume II, 1971 Publication, Mechanical Properties Data Center, Belfour Stulen, Inc., Air Force Materials Laboratory, Air Force System Command, Wright-Patterson Air Force Base, Ohio
6. MIL-STD-810B, "Military Standard - Environmental Test Methods" dated 18 Sept. 1970
7. Federal Test Method Standard No. 151a "Metals; Test Methods" dated 6 May 1959
8. Raytheon (Bedford) Memo No. SM 70-228, "NSSMS GMLS Category I Test Plan" dated 8 September 1970 (Unclassified)
9. Raytheon (Wayland) Report CDRL DSN 086, "NSSMS Category I Test Plan" dated 11 December 1969 (Unclassified)

INTRODUCTION

This test report presents the results of the structural and environmental tests performed under the Navy Contract No. N00019-70-C-0102, NATO Sea Sparrow Folding Wing Program.

The test program, as outlined in the Reference (1) and Reference (2) documents consist of the following structural static tests: a critical loading survey, a static load test, torsion bar endurance and relaxation tests and an influence coefficient study; of the following structural dynamic tests: a random vibration test and a wing ground vibration survey; and of the following environmental tests: a shipboard storage environment test, a temperature-humidity test, a salt spray test, a sand and dust test, ignition impulse tests and shipboard vibration and shock tests.

This report does not contain the results of the wing ground vibration survey and the shipboard vibration and shock tests. The results of the wing ground vibration survey have been included in the Flutter Analysis Report (BR-6352), and the shipboard vibration and shock tests, as stated in the Reference (2) document, are to be conducted and reported in conjunction with the NSSMS GMLS Launcher Qualification Program as outlined in the Reference (8) and (9) documents.

INTRODUCTION (continued)

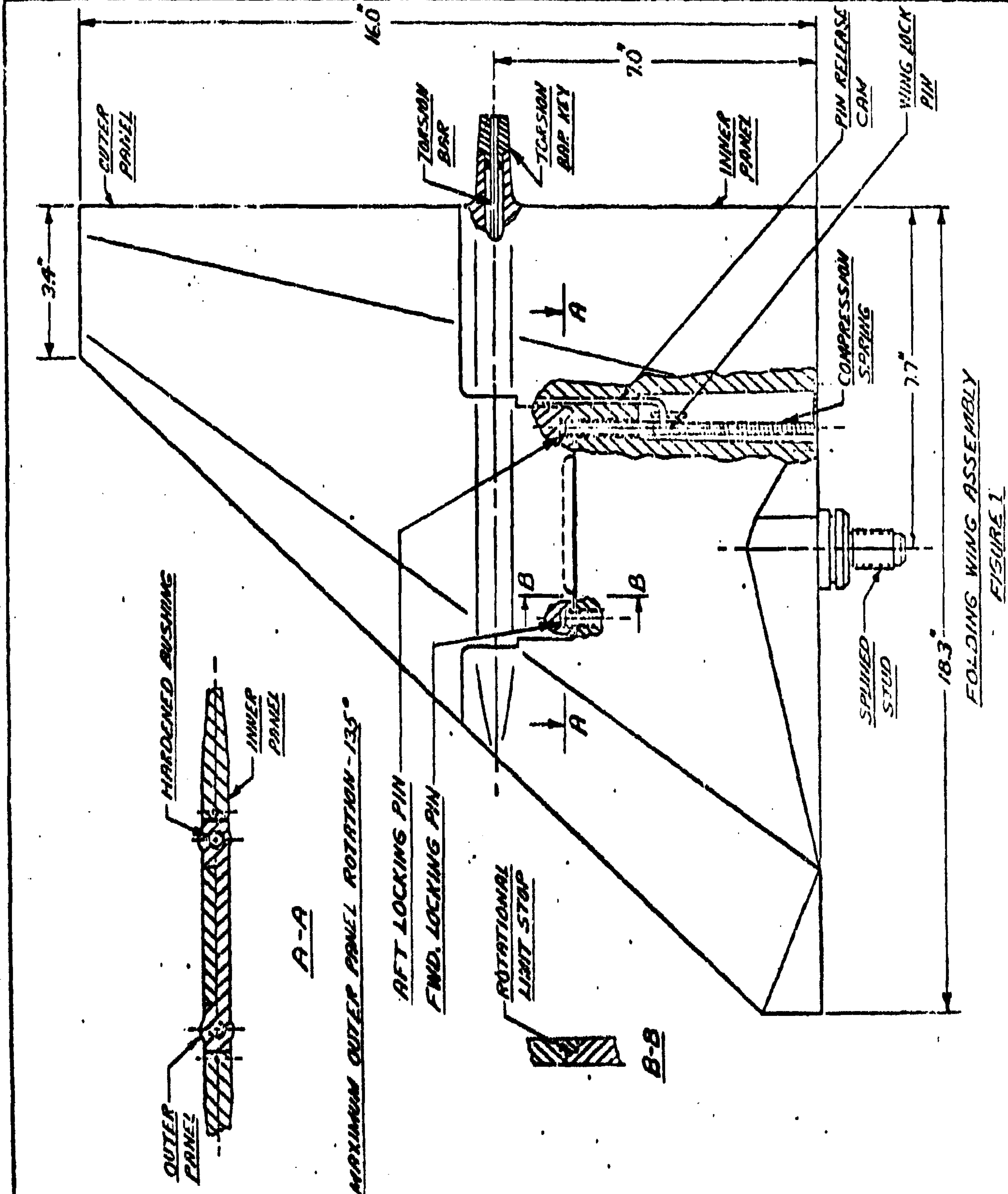
The tests reported herein were conducted between September 1970 and January 1972, in the Structural and Environmental Test Facilities of the Raytheon Mechanical Systems Laboratory at Bedford, Mass. and at the Raytheon Environmental Test Facility at Andover, Mass.

OBJECT

The object of the tests was to verify the folding wing design when exposed to the structural and environmental test conditions specified in the Reference (1) and (2) documents. A sketch of the test article is shown in Figure 1 on page 4.

SUMMARY

The References (a) and (b) Folding Wing Assembly and Torsion Bar, the three modified Folding Wing Assemblies each of which contained a torsion bar of a different diameter, and the References (c) and (d) modified Folding Wing Assembly and Torsion Bar successfully withstood the structural and environmental tests which were conducted under this program.



FOLDING WING ASSEMBLY
FIGURE 1

SECTION 1

STRUCTURAL STATIC TESTS

SECTION 1.1

CRITICAL LOADING SURVEY

CRITICAL LOADING SURVEY

OBJECT

The object of this survey was to determine which condition of lock pin engagement produced the most severe stress levels on the inner panel of the folding wing.

CONCLUSION

It can be concluded from the results of this survey that the most severe stress field on the inner panel of the folding wing was experienced with the aft locking pin engaged and the forward locking pin disengaged.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this survey conformed to the Reference (a) drawing. The inner wing section of the assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of the assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

INSTRUMENTATION

A photoelastic coating was formed and then bonded to one side of the inner wing section of the test article. That coating made it possible to observe and to obtain photographs of the surface stress distribution in the coated area when viewed through a polariscope. Surface stress levels, at specific

INSTRUMENTATION (continued)

locations, were accurately measured by determining the exact number of fringe lines. A fringe line, which was dependent upon the sensitivity of the photoelastic coating used, represented a pre-calibrated stress level of approximately 12,500 psi.

LOADING AND RECORDING APPARATUS

The load was applied to the test article, through suitable loading linkages, by a hydraulic cylinder activated by a hydraulic hand pump. The load developed was measured and recorded with a Baldwin-Lima-Hamilton electric load cell and load recorder combination.

LOADS

A single load was applied to the outer wing section of the test article at the location shown in Figure 2 on page 1.1.5. That load was obtained from the Reference (3) document.

The test article was loaded only until the developing stress pattern, as viewed through the polariscope, could be evaluated. The same load level was applied for all surveys.

TEST ARRANGEMENT

The test arrangement shown in Figure 2 on page 1.1.5, shows the method used in supporting the test article. The test article was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That test fixture was mounted to a rigid test bulkhead.

The test article was mounted with the chord planes of the wing in the vertical position. That test arrangement simplified the test instrumentation setup for viewing and photographing the coated area of the wing.

The test load was applied through a counter-balanced whiffle-tree arrangement with a point contact load at the location shown in Figure 2 on page 1.1.5. A photograph of the test arrangement is shown on page 1.1.6.

TEST PROCEDURE

Three surveys were conducted, each with a different lock pin engagement.

In Survey No. 1, the forward locking pin was disengaged and the aft locking pin was engaged. A single load was applied to the outer wing panel, and slowly increased until the stress in the inner panel was of sufficient magnitude to produce patterns in the photoelastic coating that could be confidently evaluated.

In Survey No. 2, the forward locking pin was engaged and the aft locking pin was disengaged. A single load was applied in the same manner and of the same magnitude as in Survey No. 1.

TEST PROCEDURE (continued)

In Survey No. 3, both locking pins were engaged, and a single load was applied in the same manner and of the same magnitude as in Survey No. 1.

TEST RESULTS

Survey No. 1 (Aft pin engaged, forward pin disengaged)

The stress pattern had sufficiently developed when a load of 450 lbs. had been applied. A photograph of the stress pattern at that load level is shown on page 1.1.7 and the measured stress level at the aft corner, adjacent to the aft pin of the inner wing panel was 49,750 psi.

Survey No. 2 (Forward pin engaged, aft pin disengaged)

A photograph of the stress pattern at an applied load level of 450 lbs. is shown on page 1.1.8, and the measured stress level at the forward corner adjacent to the forward pin of the inner wing panel was 42,500 psi.

Survey No. 3 (Both pins engaged)

A photograph of the stress pattern at an applied load level of 450 lbs. is shown on page 1.1.9. The measured stress level at the forward corner of the inner wing panel was 24,250 psi. The measured stress level at the aft corner of the inner wing panel was 26,000 psi.

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CRITICAL LOADING SURVEY
TEST ARRANGEMENT
& LOAD LOCATION

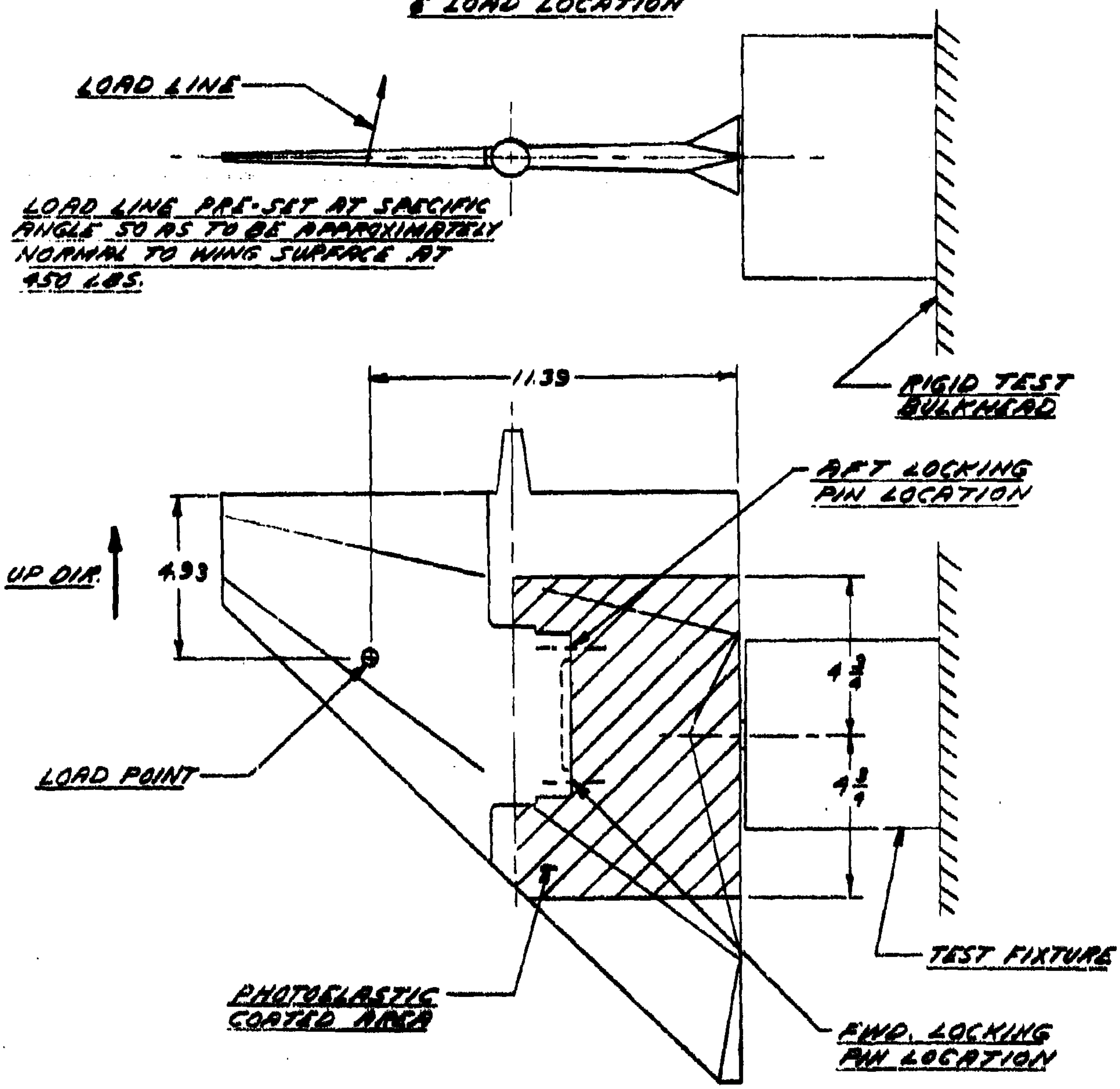
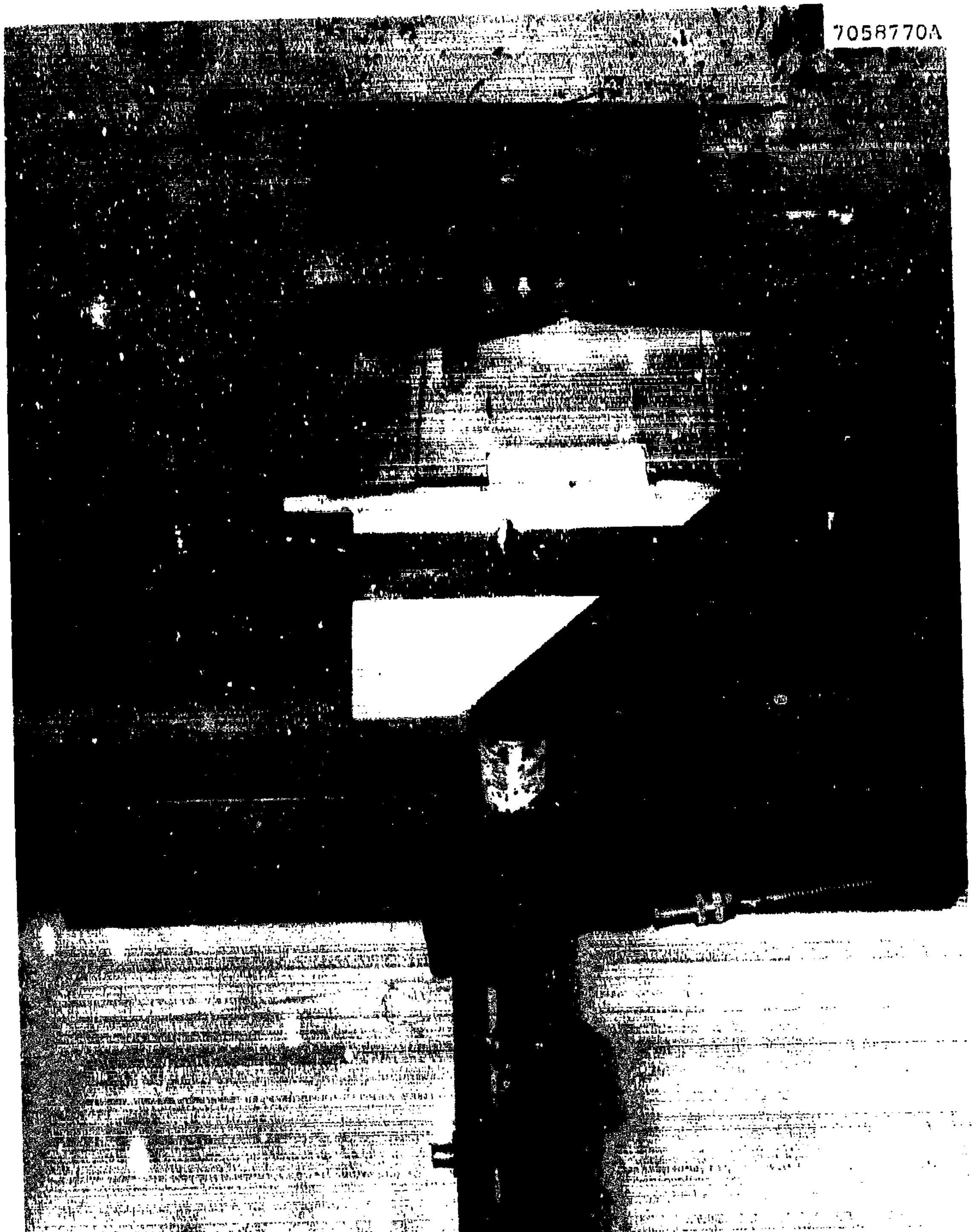


FIGURE 2

Form No. V-1028C

7058770A



Critical Loading Survey - Test Setup

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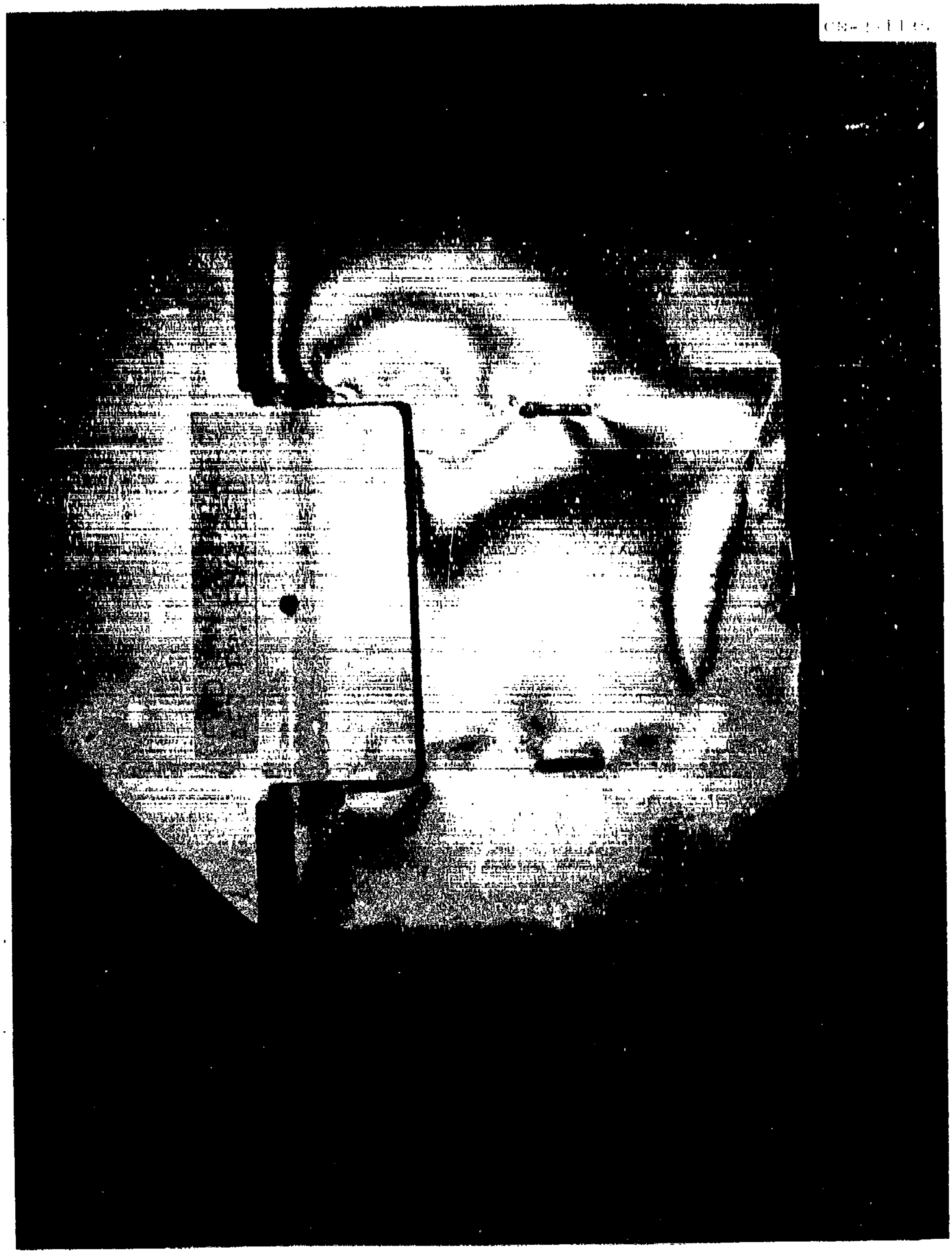
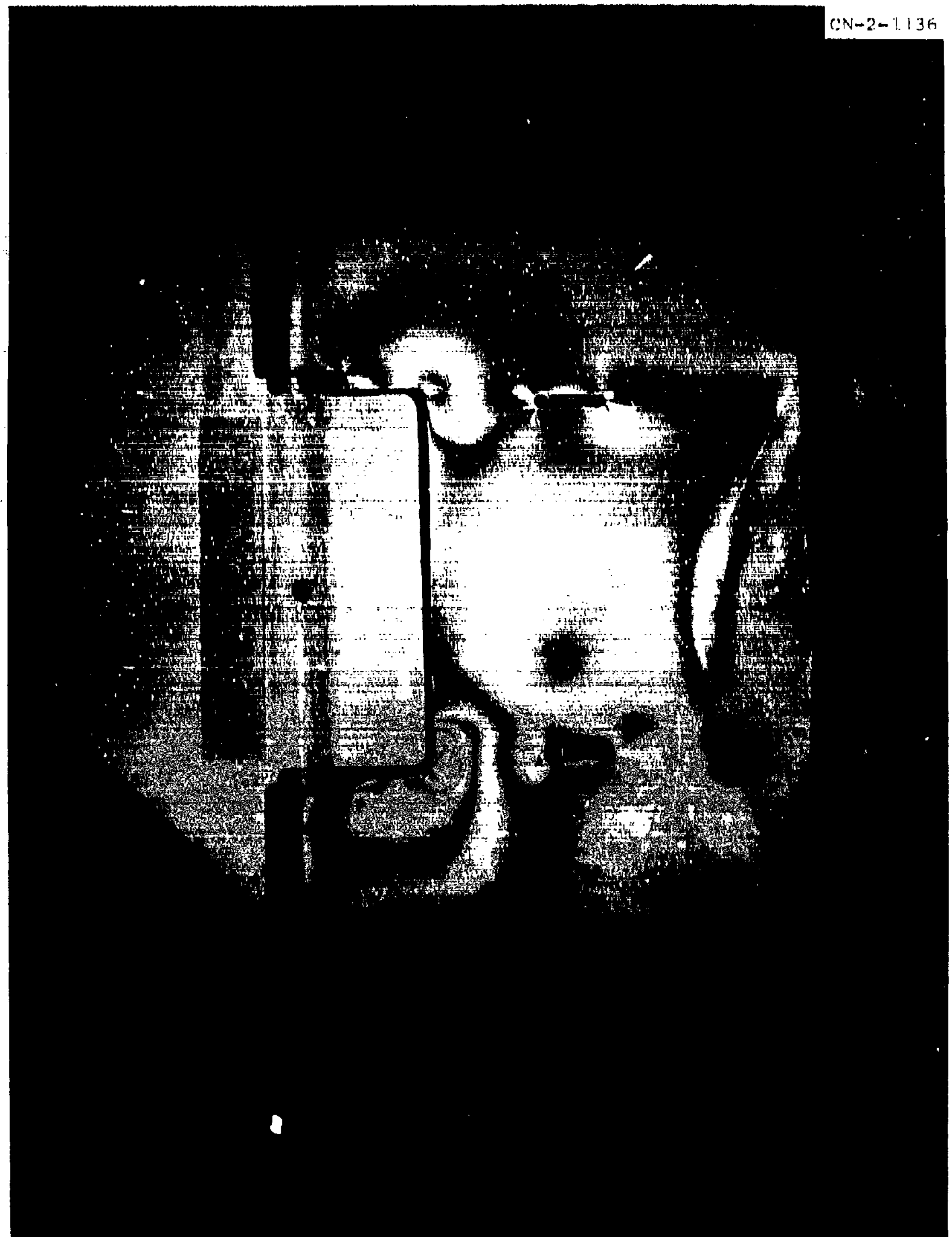


Critical Loading Survey - Aft Pin Engaged, Forward Pin Disengaged

Form No. V-1028

CN-2-1136



Critical Loading Survey - Forward Pin Engaged, Aft Pin Disengaged

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		REPORT NO. BR-6253
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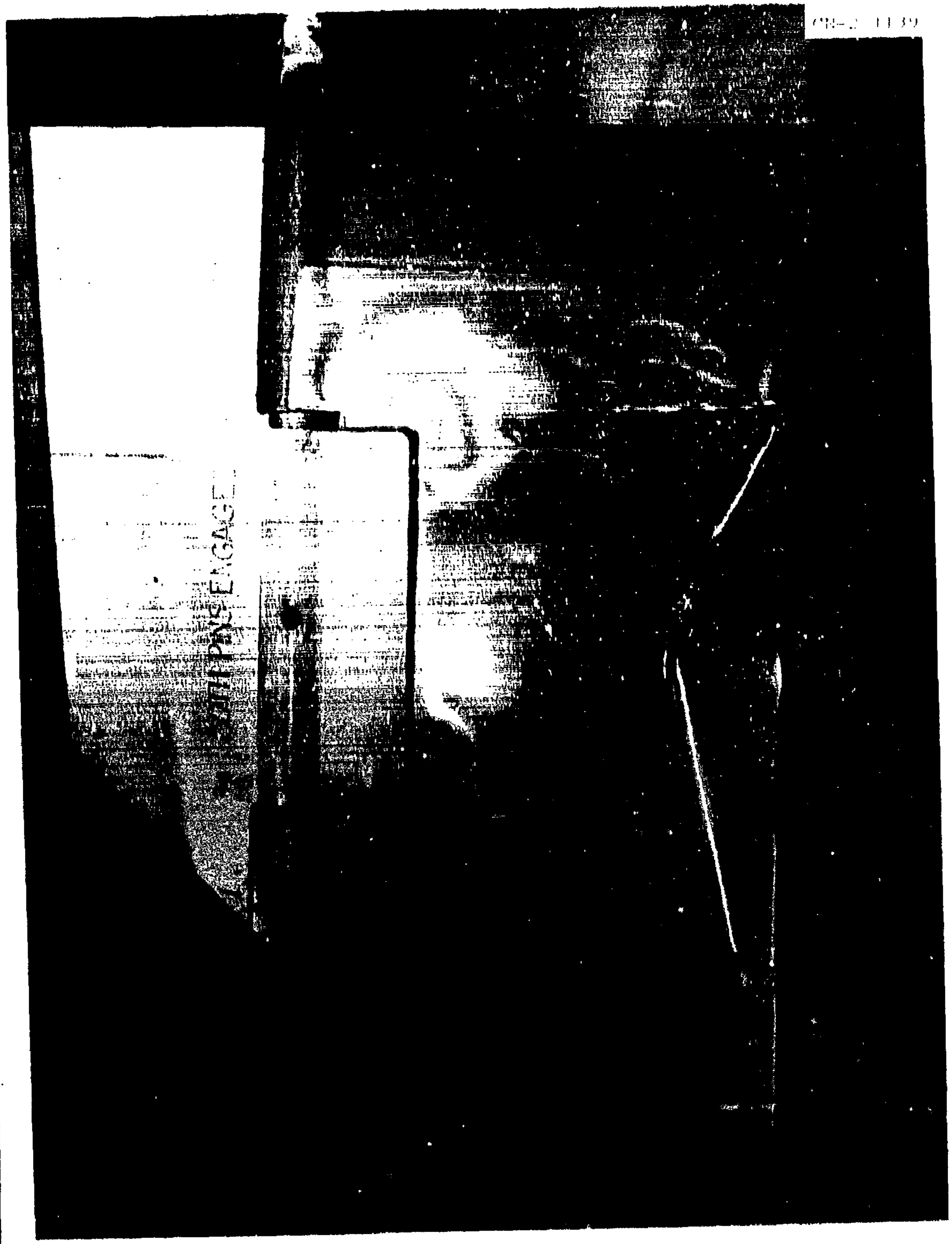

Critical Loading Survey - Both Pins Engaged

Form No. V-1028

SECTION 1.2

STATIC LOAD TEST NO. 1

STATIC LOAD TEST NO. 1

OBJECT

The object of this test was to determine the failing strength of the folding wing with only the aft locking pin engaged, the most critical condition as determined from the critical loading survey.

CONCLUSION

It can be concluded from the results of this test that the folding wing tested, with only the aft locking pin engaged, failed at 129% of the temperature corrected design limit load.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing. The inner wing section of the assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of the assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

INSTRUMENTATION

Deflections of the test article were measured at the locations shown in the sketch of the test arrangement in Figure 3 on page 1.2.6, and in the sketch in Figure 4 on page 1.2.7.

Research Incorporated linear displacement transducers were used to monitor deflections. A B&F Digital Data Acquisition System was used in conjunction with the linear displacement transducers to record the deflection data.

LOADING AND RECORDING APPARATUS

The loads were applied to the test article by the use of a whiffle-tree arrangement, which appropriately distributed to the wing the total load that was applied at one common point by a hydraulic cylinder activated by a hydraulic hand pump. The load developed was measured and recorded with a Baldwin-Lima-Hamilton electric load cell and load recorder combination.

LOADS AND TEMPERATURE

The loads were applied to the test article at the locations shown in the sketch of the test arrangement in Figure 3 on page 1.2.6, and in the sketch in Figure 5 on page 1.2.8. The design limit loads at those locations are shown on page 1.2.8, also. Those load values and locations, which simulate the airload distribution, both chord-wise and span-wise, on the folding wing, were obtained from the Reference (3) document.

The static load test was conducted at room temperature. The in-flight temperature at the maximum thickness area of the outer panel of the folding wing is 159°F, as shown in the Reference (4) document. That location where the aft locking pin engages the outer panel, analytically is the most critical area. To reflect the degradation on the material properties of the outer panel, the applied loads were increased by 6% as shown in the Reference (5) document.

TEST ARRANGEMENT

The test arrangement shown in Figure 3 on page 1.2.6, shows the method used in supporting the test article. The test article was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That test fixture was mounted to a rigid test bulkhead.

The test article was mounted with the chord planes of the wing in the horizontal position. That test arrangement simplified the setup for the instrumentation and the loading linkages.

The test loads consisted of eleven concentrated loads which were connected to a common load point by means of a whiffle-tree arrangement as shown in the photographs of the test arrangement on pages 1.2.9, and 1.2.10.

To apply the loads to the folding wing, steel wire cables with swaged ball-end fittings on one end were used. Those wire cables were passed through holes which were drilled in the folding wing at the load points. A spherical ball end-mill was used to countersink one side of the holes. Those holes were small and had a negligible effect on the strength of the folding wing. The load on the outer panel of the folding wing was much greater than the other individual loads, and to prevent any local failure at that point, a 2-inch diameter steel pad with a rubber washer was used to distribute that load.

TEST PROCEDURE

The loads were applied to the test article in accordance with the loading schedule shown on the data sheets on pages 1.2.13 and 1.2.14, and deflections were recorded at each increment of load. At selected load levels, the load was reduced to a base reference load, and deflections were recorded in order to insure that no anomalies occurred during test.

TEST RESULTS

The folding wing, with only the aft locking pin engaged, failed at 129% of the temperature corrected design limit load, as the outer panel ruptured in the area of the aft locking pin engagement. The values at failure for the shear and bending moment at the root of the folding wing were 3020 lbs. and 22,640 in-lbs., respectively. Photographs of the failure are shown on pages 1.2.11 and 1.2.12.

A table of the raw deflection data is shown on page 1.2.13, and a table of the corrected deflection data is shown on page 1.2.14. That corrected deflection data reflects the actual deflection of the folding wing using the deflection location point 14 as a zero reference point, thereby eliminating fixture movement. Also, 10% design limit load (temperature corrected) is used as zero deflection because the dead weight of the test fixture loading linkages prevent obtaining an accurate zero load reading.

TEST RESULTS (continued)

Curves of % Limit Load vs. Deflection are shown on pages 1.2.15, 1.2.16, 1.2.17 and 1.2.18. Curves for deflection location points 11, 12 and 13 were not plotted because of the extremely small wing movement at those locations.

Span-wise deflection curves for selected percentages of limit load are shown on page 1.2.19. Those curves give a clearer indication of how the folding wing reacts under load with only the aft locking pin engaged. As is evident from the curves, there is a rotation, about the hinge center line, of the outer wing panel in respect with the inner wing panel.

STATIC LOAD TEST NO. 1
TEST ARRANGEMENT

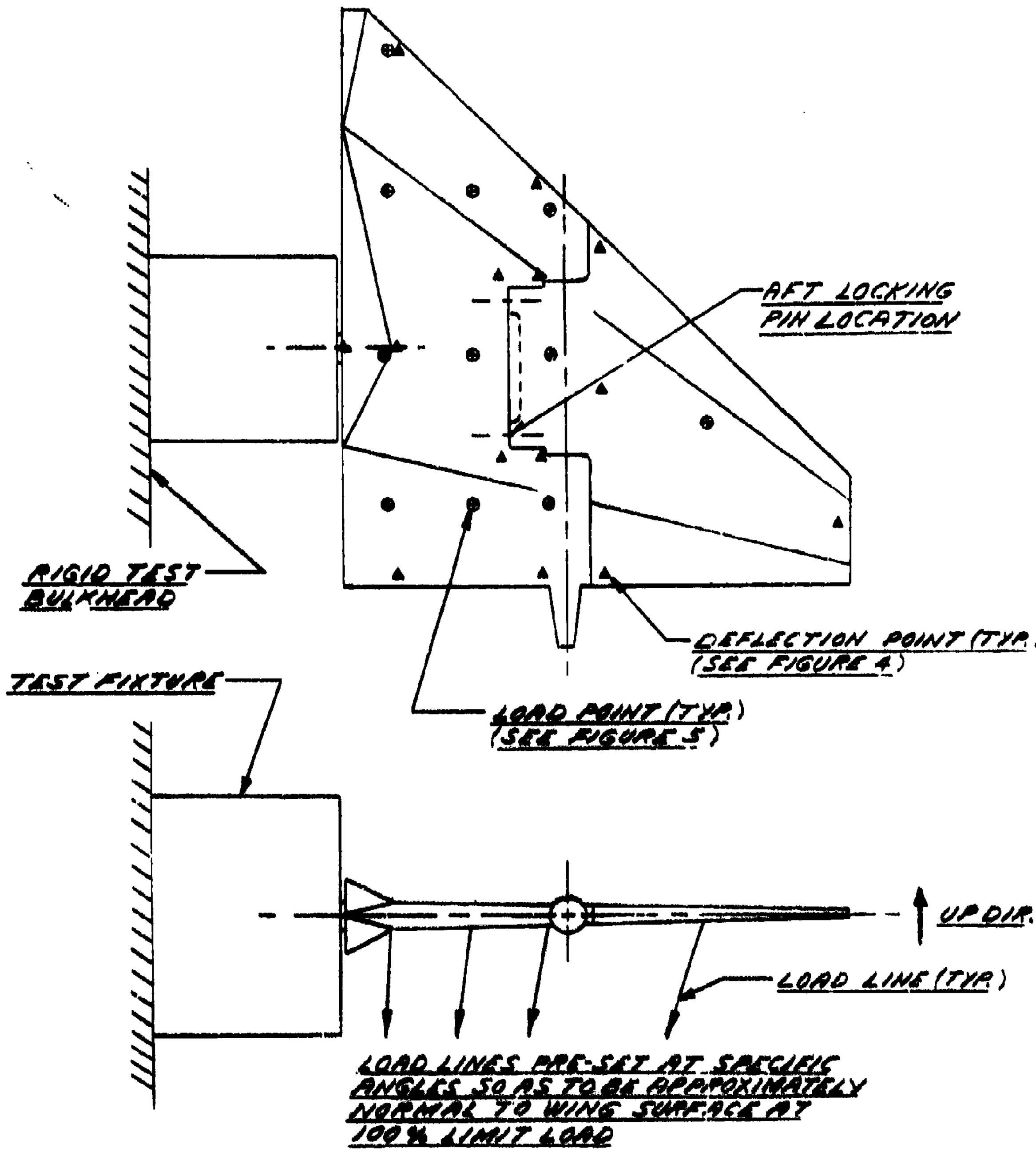

FIGURE 3

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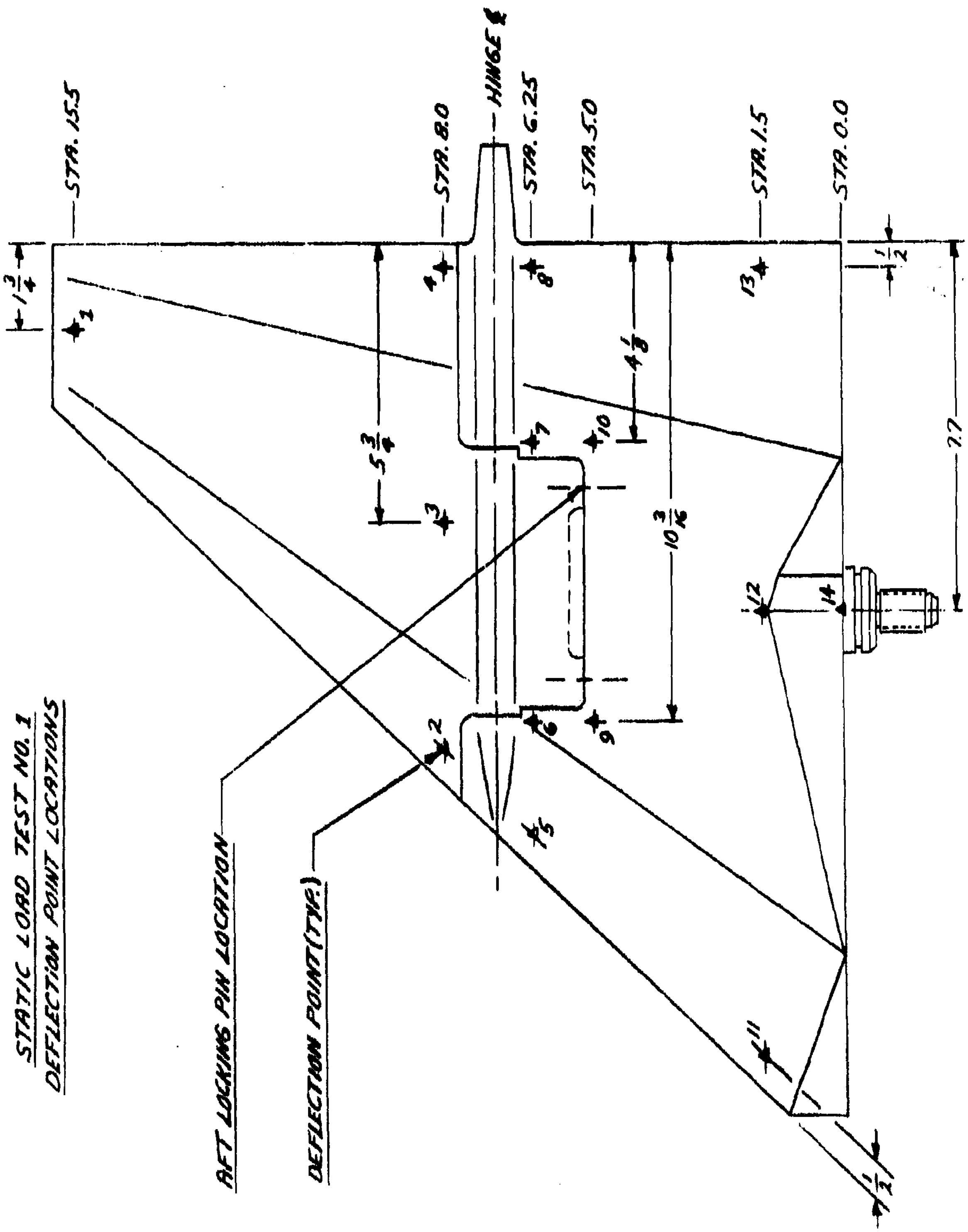


FIGURE 4

Form No. V-1028C

STATIC LOAD TEST NO.1
LOAD LOCATIONS

LOAD LOC.	LIMIT LOAD (LBS.)	X (INS.)	Y (INS.)
1	45.4	2.38	1.33
2	55.6	2.41	3.99
3	57.8	2.43	6.45
4	108.6	7.39	1.33
5	141.8	7.41	3.99
6	150.4	7.41	6.45
7	152.0	12.85	1.33
8	92.6	16.77	1.33
9	204.2	12.86	3.99
10	109.9	11.53	6.45
11	1078.7	4.93	11.39

TOTAL LIMIT LOAD = 2197 LBS.
(UNCORRECTED FOR TEMP.)

TOTAL LIMIT LOAD = 2337 LBS.
(CORRECTED FOR TEMP.)

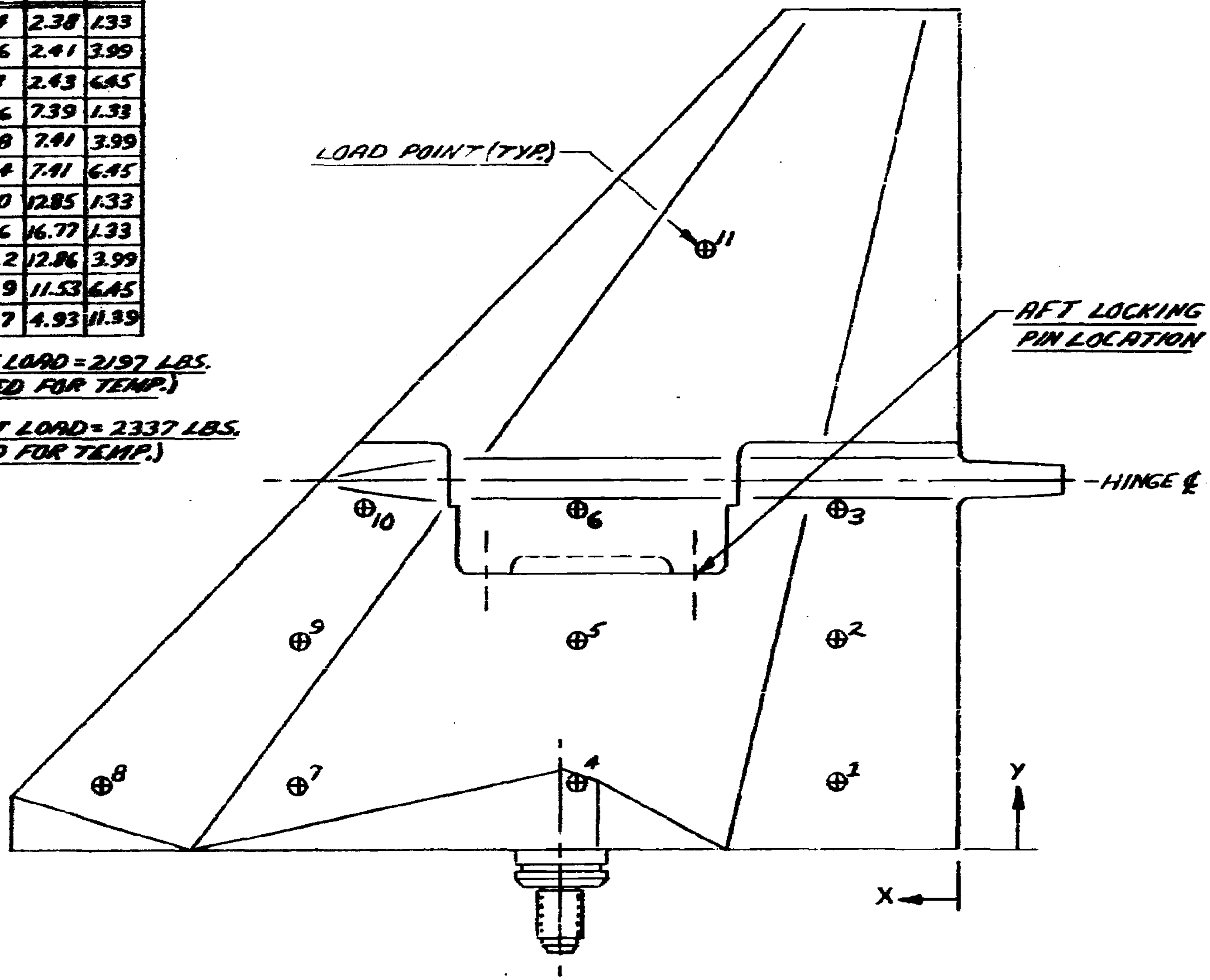
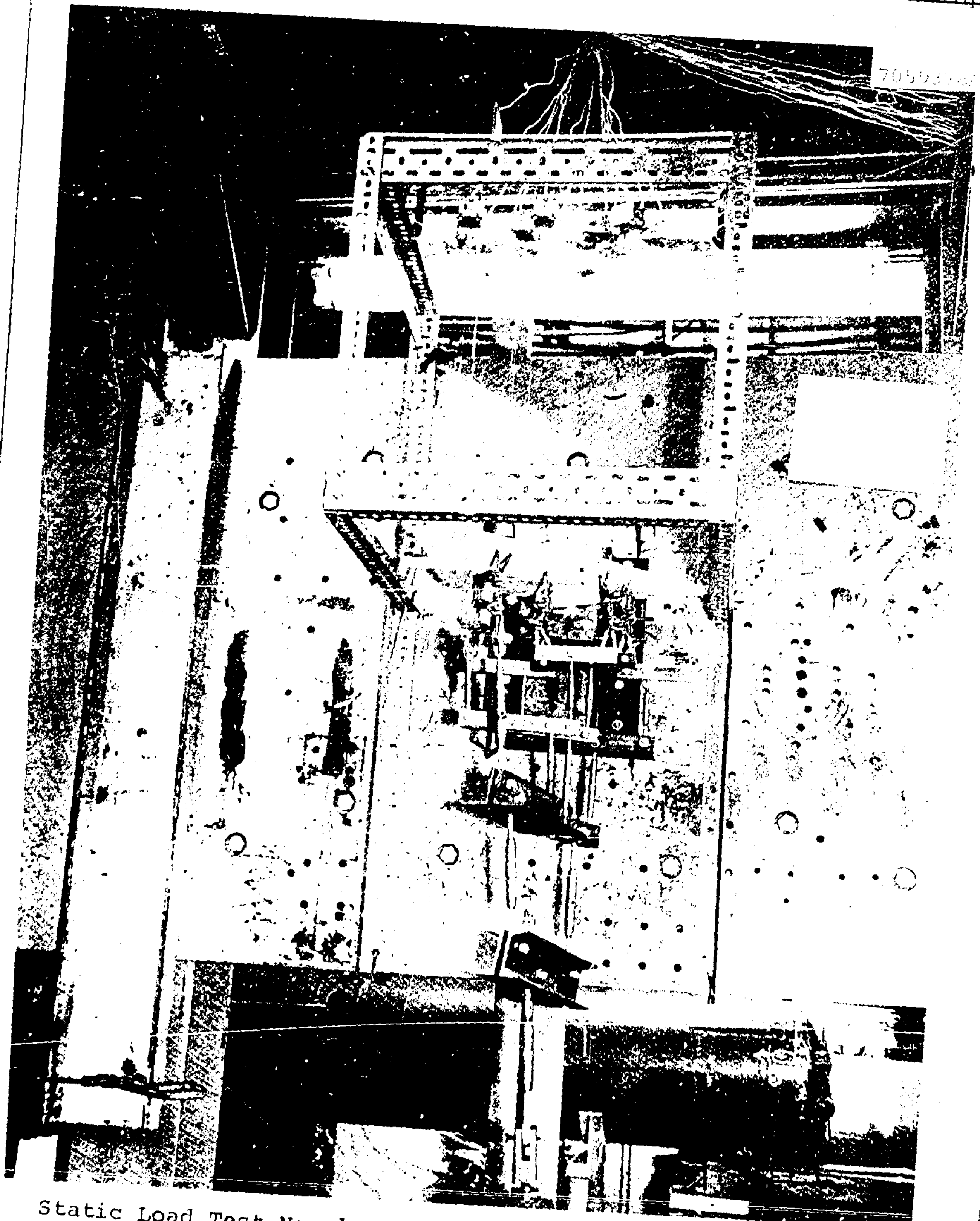
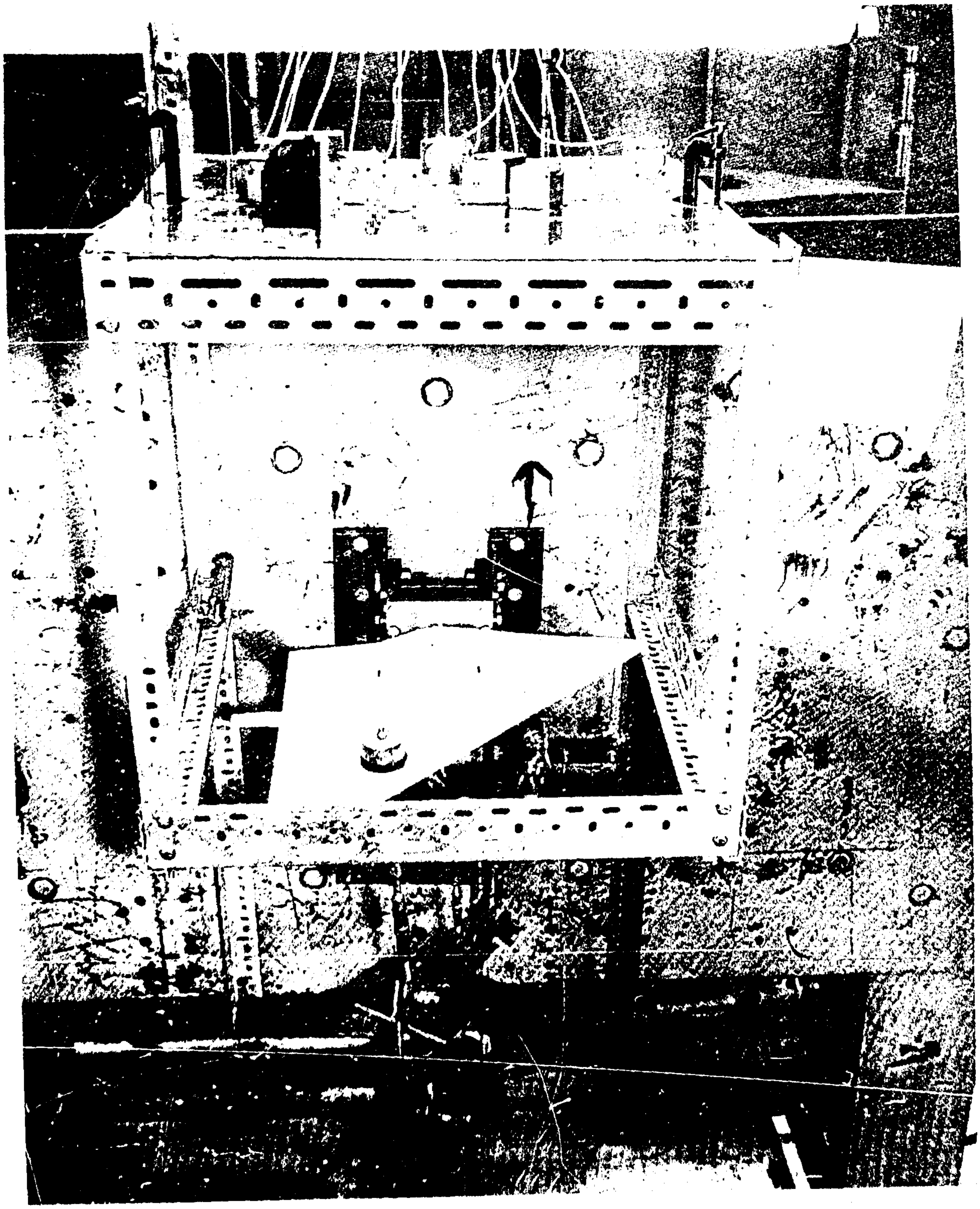


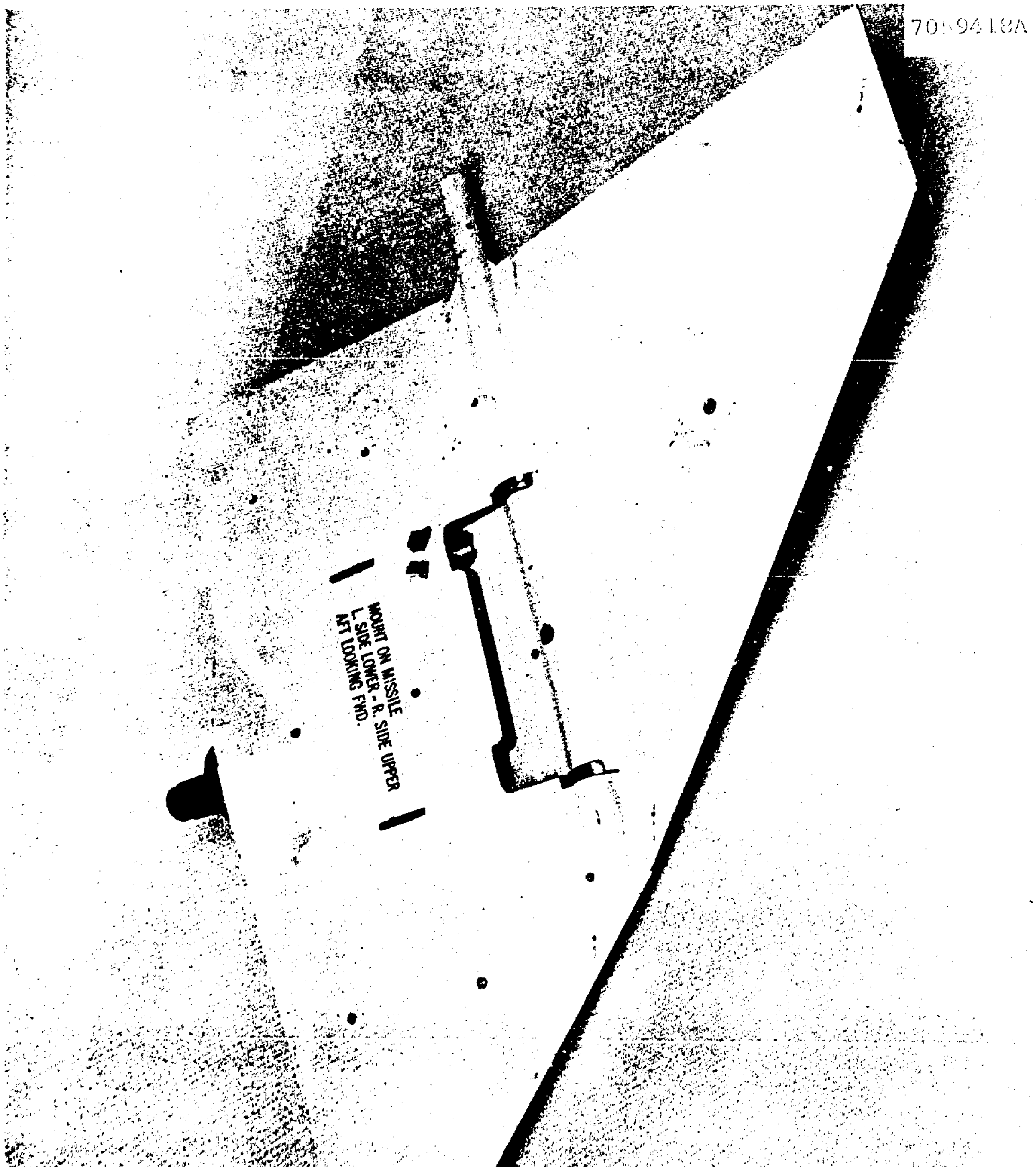
FIGURE 5



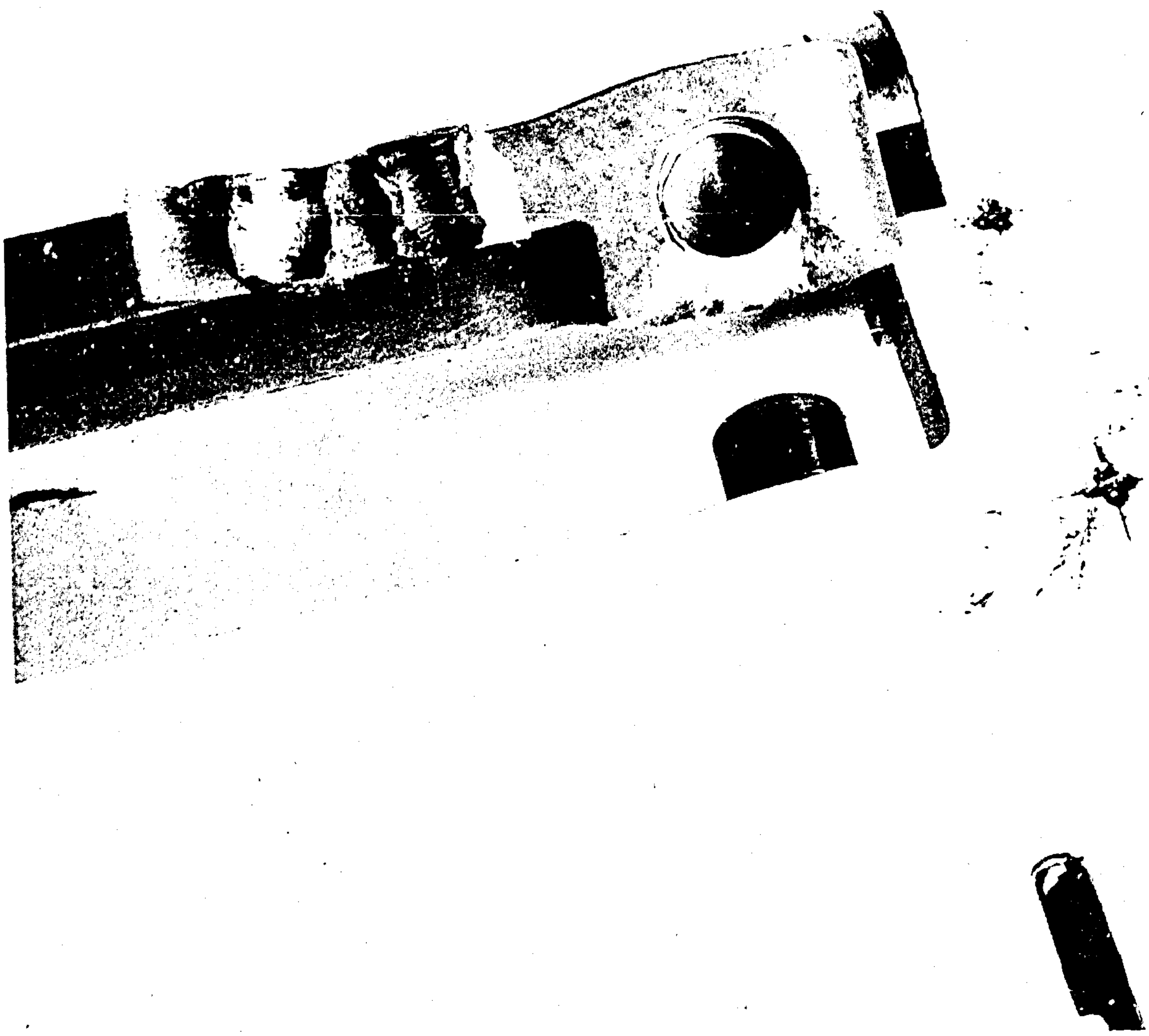
Static Load Test No. 1 - Test Setup - Overall View



Static Load Test No. 1 - Test Setup - Top View



Static Load Test No. 1 - Failure of Outer Wing Panel



Static Load Test No. 1 - Closeup of Failure of Outer Wing Section

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STATIC LOAD TEST NO. 1

TABLE OF DEFLECTION DATA READINGS (RAW DATA)

% LIMIT LOAD (TEMP. CORR.)	TOTAL APPLIED LOAD (LBS.)	DEFLECTION LOCATIONS DEFLECTION ~ INS.													
		LOC. 1	LOC. 2	LOC. 3	LOC. 4	LOC. 5	LOC. 6	LOC. 7	LOC. 8	LOC. 9	LOC. 10	LOC. 11	LOC. 12	LOC. 13	LOC. 14
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	235	.2839	.0552	.0767	.1007	BAD	.0311	.0492	.0577	.0199	.0396	.0005	.0046	.0014	.0000
20	470	[illegible]	.0870	.1305	.1641	GAGE	.0502	.0854	.0908	.0374	.0591	.0011	.0084	.0026	.0012
30	700	.6259	.1120	.1706	.2265		.0701	.1168	.1251	.0505	.0795	.0015	.0130	.0044	.0018
40	935	.8050	.1424	.2261	.2898		.0902	.1482	.1603	.0616	.1003	.0019	.0166	.0058	.0027
10	235	.3031	.0556	.0827	.1076		.0317	.0541	.0597	.0232	.0399	.0002	.0056	.0018	.0002
50	1170	1.0037	.1743	.2838	.3583		.1077	.1810	.1974	.0726	.1229	.0028	.0199	.0086	.0036
60	1400	1.1835	.2055	.3313	.4206		.1253	.2109	.2291	.0842	.1399	.0036	.0232	.0106	.0045
70	1635	1.3875	.2367	.3806	.4930		.1431	.2422	.2676	.1004	.1642	.0035	.0278	.0105	.0054
10	235	.4259	.0685	.1126	.1462		.0373	.0680	.0770	.0257	.0472	-.0003	.0675	.0029	.0009
80	1870	1.6098	.2742	.4420	.5735		.1607	.2736	.3055	.1140	.1891	.0034	.0317	.0121	.0062
90	2105	1.8742	.3115	.5045	.6512		.1783	.3066	.3379	.1268	.2129	.0042	.0361	.0132	.0072
100	2335	2.1381	.3490	.5687	.7337		.1959	.3382	.3688	.1449	.2310	.0049	.0398	.0143	.0090
10	235	.6818	.0871	.1543	.2142		.0396	.0775	.0779	.0314	.0506	-.0009	.0152	.0065	.0009
110	2570	2.4479	.3927	.6400	.8271		.2136	.3738	.4003	.1576	.2596	.0051	.0435	.0154	.0089
120	2805	2.8129	.4424	.7185	.9276		.2373	.4069	.4323	.1692	.2776	.0056	.0481	.0165	.0126
125	2920	3.0303	.4625	.7604	.9842		.2431	.4240	.4434	.1767	.2842	.0064	.0500	.0169	.0135
10	235	[illegible]	.1228	.2196	.3023		.0472	.0854	.0831	.0413	.0582	-.0912	.0211	.0066	.0036
129	3020	WING FAILURE													

NOTE: + IS DOWN DIRECTION, - IS UP DIRECTION

Form No. V-1028

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STATIC LOAD TEST NO. 1

TABLE OF CORRECTED DEFLECTION DATA READINGS

% LIMIT LOAD (TEMP. CORR.)	TOTAL APPLIED LOAD (LBS)	DEFLECTION LOCATIONS DEFLECTION-INS.													REF. PT.
		LOC. 1	LOC 2	LOC. 3	LOC. 4	LOC 5	LOC. 6	LOC. 7	LOC 8	LOC 9	LOC 10	LOC. 11	LOC 12	LOC 13	LOC 14
0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	235	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	470	.1787	.0366	.0526	.0622	BAD	.0179	.0350	.0319	.0163	.0233	-.0006	.0026	.0000	.0012
30	700	.3402	.0559	.1001	.1200	GAGE	.0302	.0658	.0656	.0288	.0381	-.0008	.0066	.0012	.0018
40	935	.5184	.0865	.1467	.1864		.0564	.0963	.0989	.0390	.0680	-.0013	.0093	.0017	.0827
10	235	.0190	.0042	.0658	.0067		.0004	.0097	.0008	.0031	.0051	-.0005	.0008	.0002	.0002
50	1170	.7162	.1155	.2035	.2540		.0730	.1282	.1361	.0491	.0847	-.0013	.0117	.0036	.0036
60	1400	.8961	.1458	.2581	.3154		.0897	.1572	.1665	.0598	.0998	-.0014	.0141	.0047	.0045
70	1635	1.0382	.1761	.2985	.3869		.1066	.1876	.2095	.0751	.1242	-.0024	.0178	.0037	.0054
10	235	.1418	.0124	.0350	.0436		.0063	.0179	.0104	.0049	.0117	-.0017	.0020	.0006	.0009
80	1870	1.3187	.2128	.3591	.4666		.1294	.2182	.2446	.0879	.1403	-.0031	.0209	.0045	.0062
90	2105	1.5831	.2491	.4246	.5433		.1400	.2502	.2730	.0997	.1711	-.0035	.0243	.0046	.0072
100	2335	1.8302	.2860	.4830	.6240		.1558	.2800	.3021	.1160	.1874	-.0046	.0262	.0039	.0090
10	235	.3970	.0310	.0767	.1126		.0076	.0274	.0193	.0166	.0151	-.0023	.0097	.0042	.0009
110	2570	2.1591	.3276	.5534	.7165		.1726	.3147	.3327	.1278	.2101	-.0053	.0298	.0041	.0099
120	2805	2.5464	.3746	.6292	.8143		.1936	.3451	.3620	.1367	.2304	-.0075	.0309	.0025	.0126
125	2920	2.7329	.3900	.6702	.8700		.1985	.3613	.3722	.1433	.2361	-.0076	.0319	.0020	.0135
10	235	.8398	.0646	.1393	.1590		.0125	.0326	.0218	.0178	.0200	-.0053	.0129	.0016	.0036
129	3020	WING	FAILURE												

NOTE: 1. + IS DOWN DIRECTION, − IS UP DIRECTION
2. DEFLECTIONS CORRECTED TO REFLECT ACTUAL DEFLECTION OF WING. LOCATION POINT 14 IS USED AS ZERO REFERENCE POINT. ALSO, 10% LIMIT LOAD IS USED AS ZERO DEFLECTION BECAUSE THE DEAD WEIGHT OF THE TEST FIXTURE LOADING LINKAGES PREVENT OBTAINING A TRUE ZERO LOAD READING

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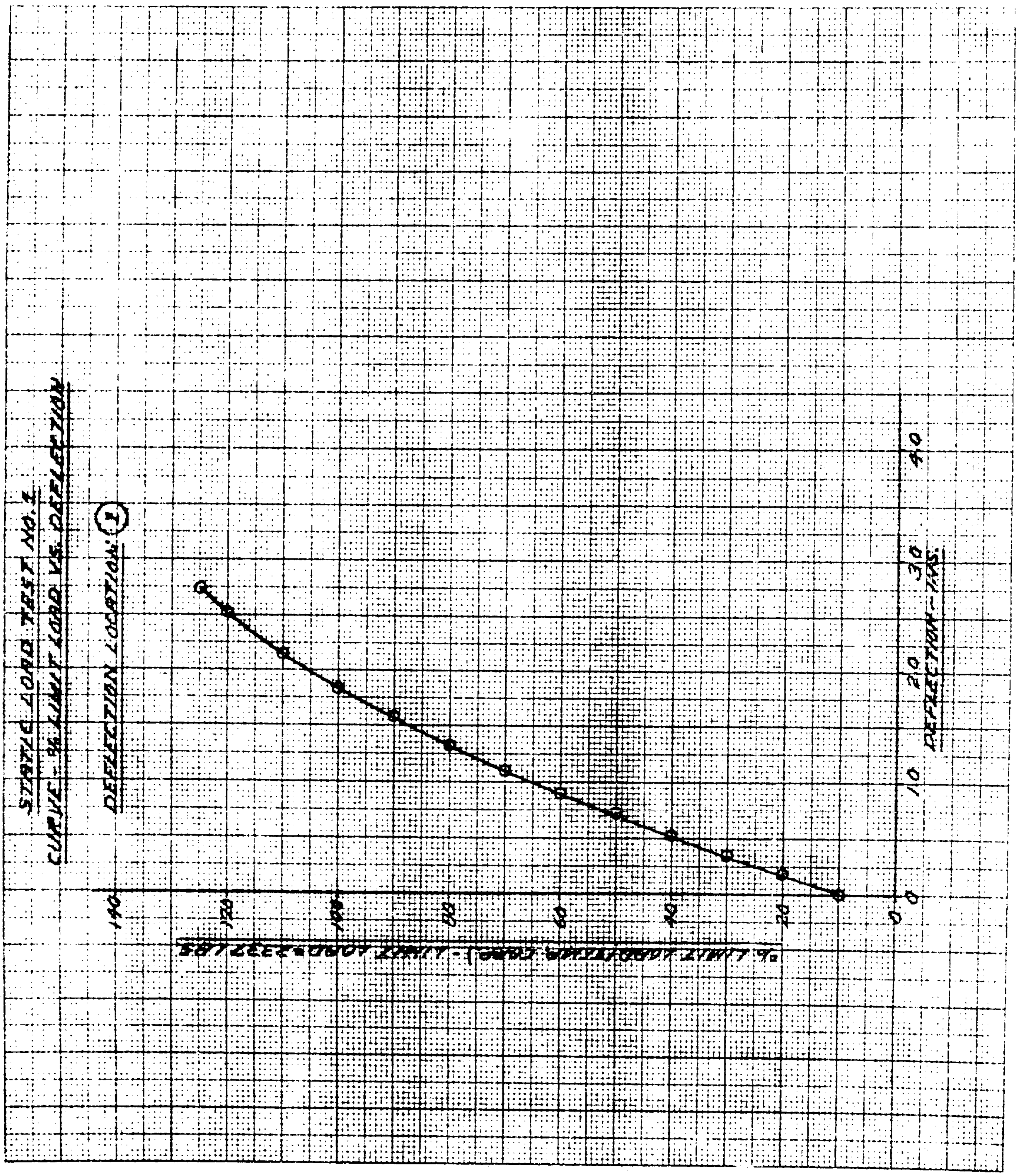

ENGINEER J. Younis	**RAYTHEON COMPANY**	PAGE NO. 1.2.16
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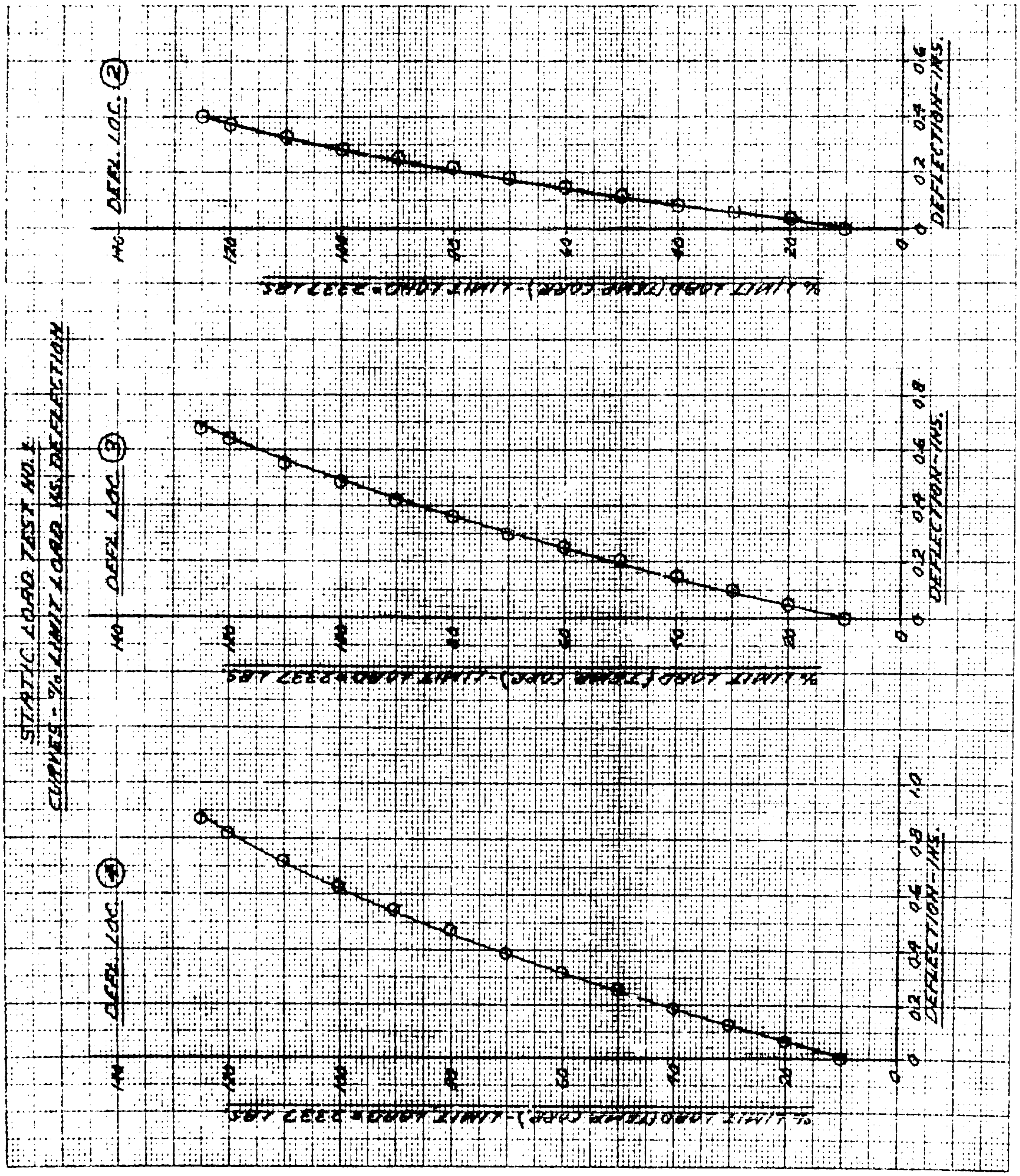

ENGINEER J. Younis	RAYTHEON COMPANY	PAGE NO. 1.2.17
CHECKER	MISSILE SYSTEMS DIVISION	REPORT NO. BR-6253
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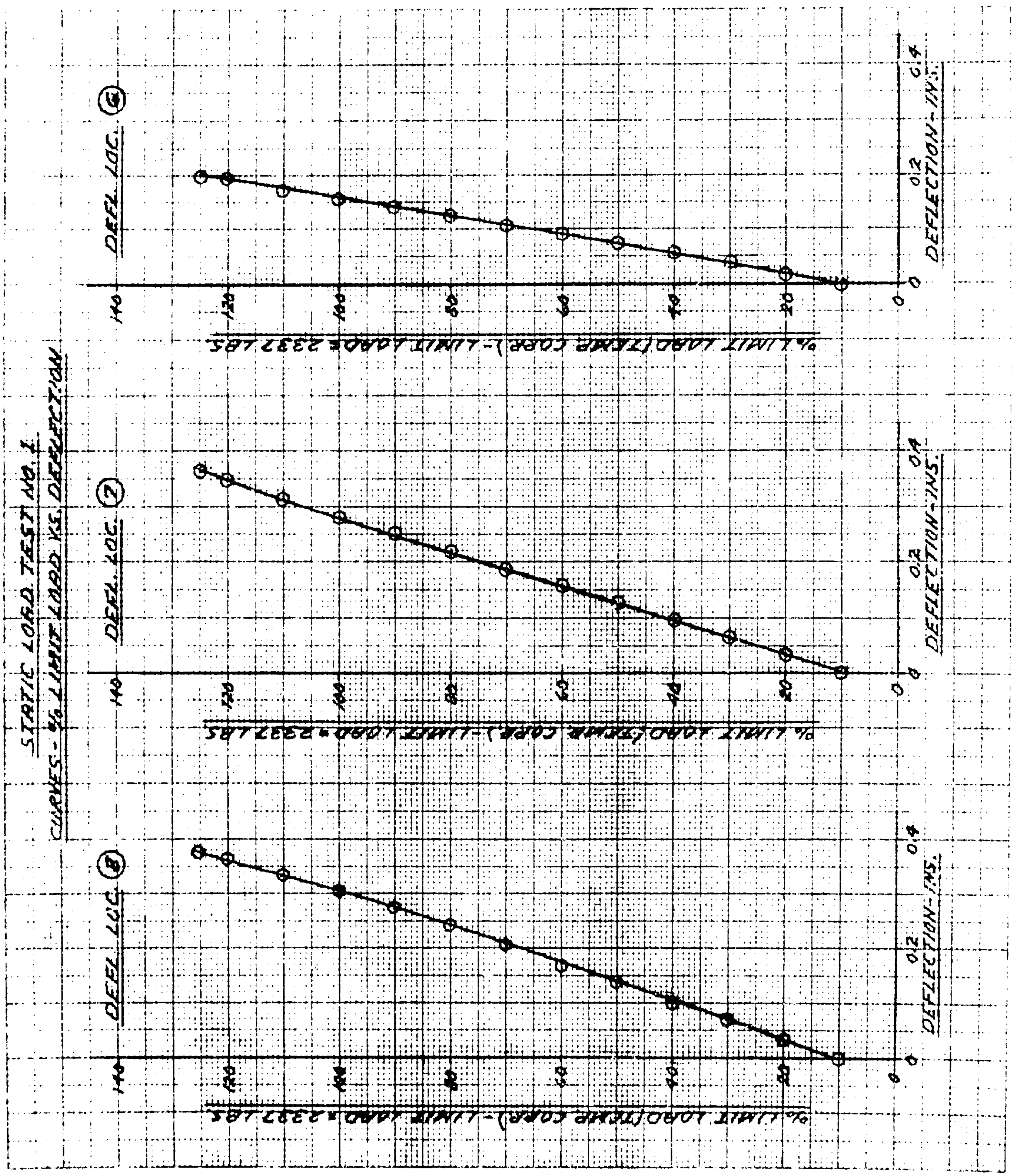

ENGINEER J. Younis	RAYTHEON COMPANY MISSILE SYSTEMS DIVISION	PAGE NO. 1.2.18
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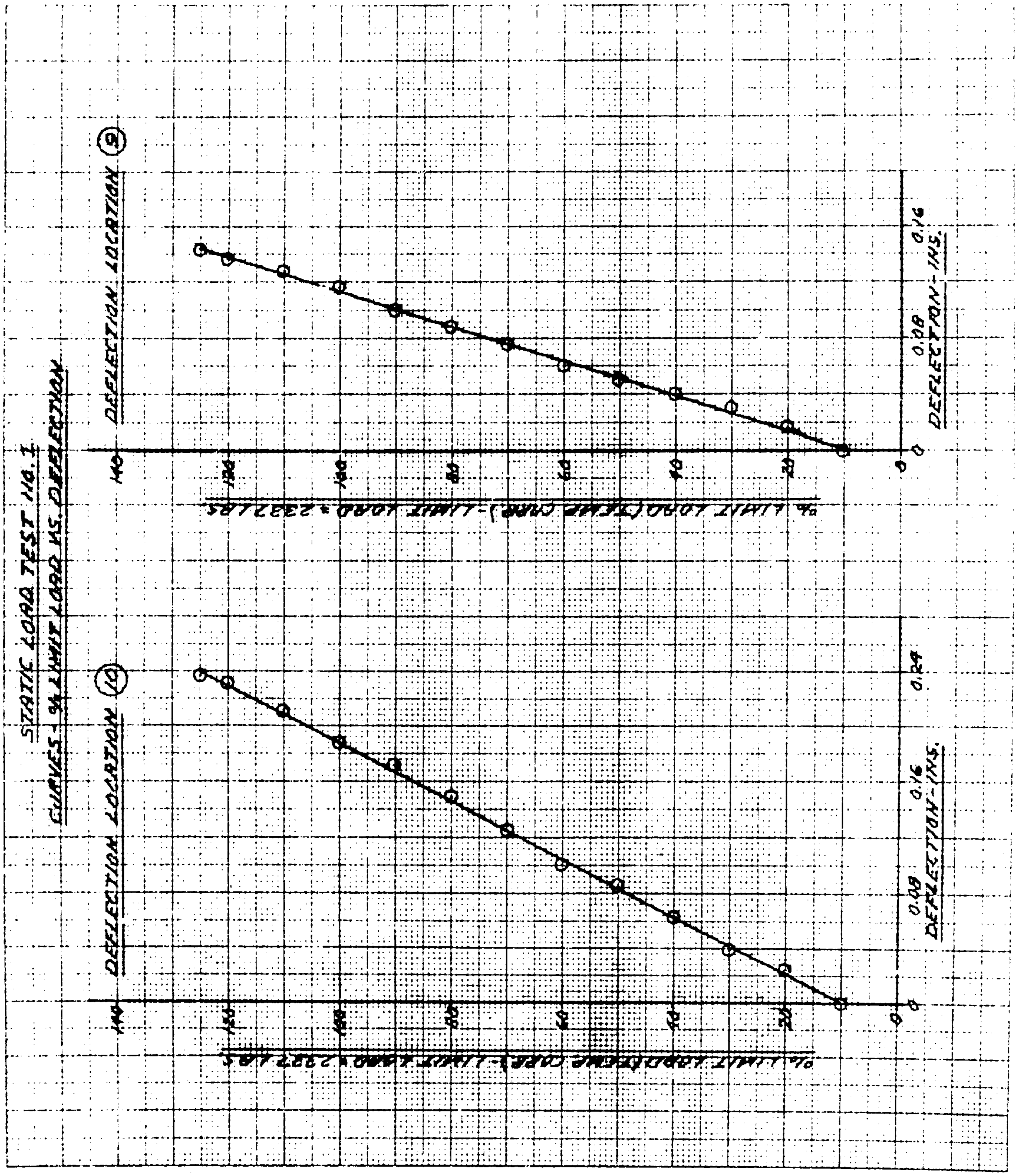

ENGINEER J. Younis	RAYTHEON COMPANY MISSILE SYSTEMS DIVISION	PAGE NO. 1.2.19
CHECKER		REPORT NO. BR-6253
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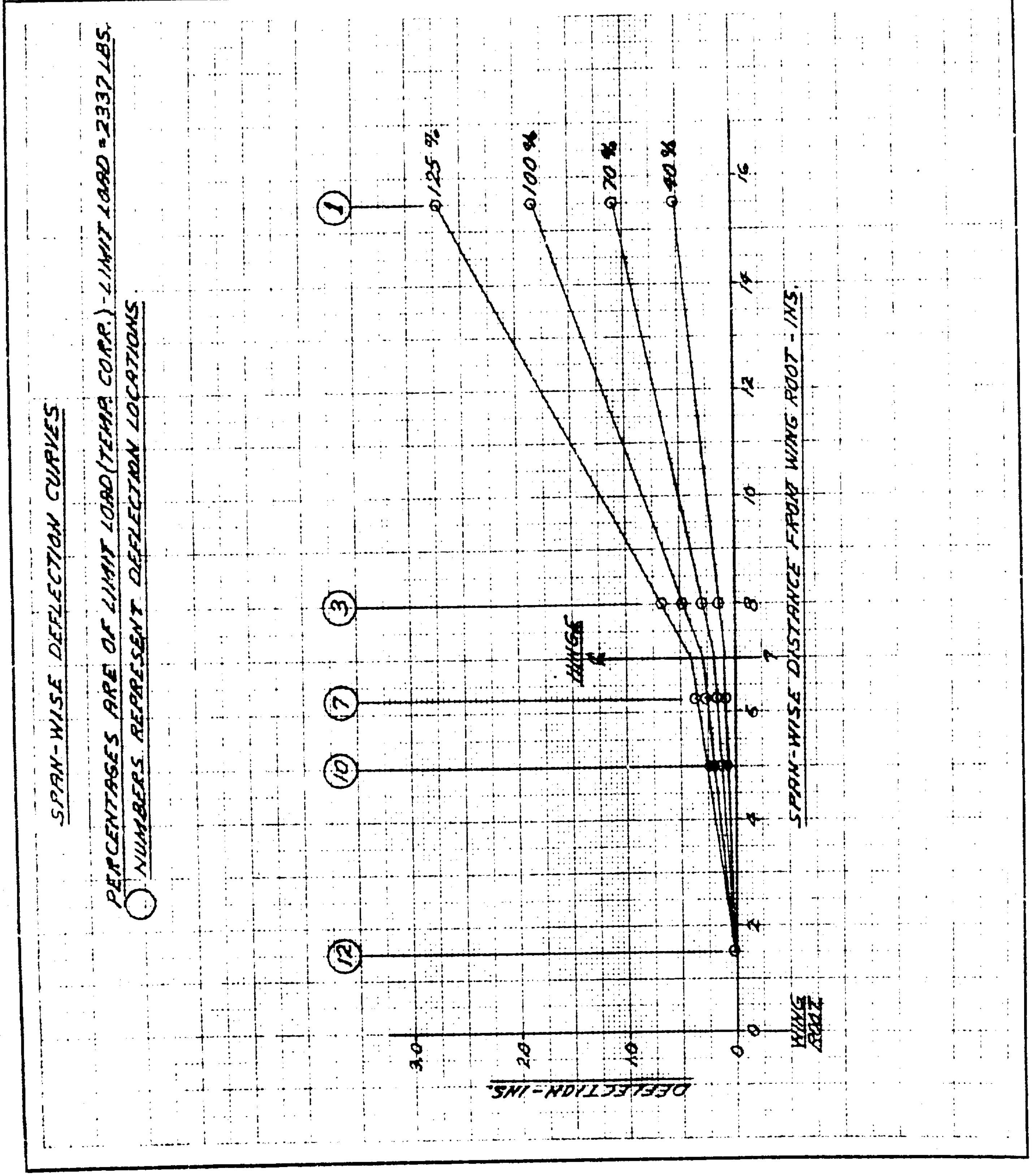

SECTION 1.3

STATIC LOAD TEST NO. 2

STATIC LOAD TEST NO. 2

OBJECT

The object of this test was to determine the failing strength of an additional folding wing with only the aft locking pin engaged, the most critical condition as determined from the critical loading survey, and to obtain photographs showing the general overall pattern of how the stresses developed throughout the inner wing panel.

CONCLUSION

It can be concluded from the results of this test that the folding wing tested, with only the aft locking pin engaged, failed at 122% of the temperature corrected design limit load.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing, and is the same folding wing used for the critical loading survey.

INSTRUMENTATION

The folding wing had a photoelastic coating on the inner wing panel bonded during the previous critical loading survey. That coating was observed and photographed at specific load levels to obtain the general overall stress pattern of the inner wing panel.

LOADING AND RECORDING APPARATUS

The loads were applied to the test article by the use of a whiffle-tree arrangement, which appro-

LOADING AND RECORDING APPARATUS (continued)

priately distributed to the wing the total load that was applied at one common point by a hydraulic cylinder activated by a hydraulic hand pump. The load developed was measured and recorded with a Baldwin-Lima-Hamilton electric load cell and load recorder combination.

LOADS AND TEMPERATURE

The loads were applied to the test article at the locations shown in Figure 6 on page 1.3.5. The design limit loads at those locations are shown on page 1.3.5, also. Those load values and locations, which simulate the airload distribution, both chord-wise and span-wise, of the folding wing, were obtained from the Reference (3) document.

The static load test was conducted at room temperature. The in-flight temperature at the maximum thickness area of the outer panel of the folding wing is 159°F, as shown in the Reference (4) document.. That location, where the aft locking pin engages the outer panel, analytically is the most critical area. To reflect the degradation on the material properties of the outer panel, the applied loads were increased by 6% as shown in the Reference (5) document.

TEST ARRANGEMENT

The test arrangement shown in Figure 6 on page 1.3.5, shows the method used in supporting the test article. The test article was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That test fixture was mounted to a rigid test bulkhead.

TEST ARRANGEMENT (continued)

The test article was mounted with the chord planes of the wing in the vertical position. That test arrangement simplified the test instrumentation setup for viewing and photographing the coated area of the wing.

The test loads consisted of eleven concentrated loads which were connected to a common load point by means of a counter-balanced whiffle-tree arrangement as shown in the photograph of the test arrangement on page 1.3.6.

To apply the loads to the folding wing, steel wire cables with swaged ball-end fittings on one end were used. Those wire cables were passed through holes which were drilled in the folding wing at the load points. A spherical ball end-mill was used to countersink one side of the holes. Those holes were small and had a negligible effect on the strength of the folding wing. The load on the outer panel of the folding wing was much greater than the other individual loads, and to prevent any local failure at that point, a 2-inch diameter steel pad with a rubber washer was used to distribute that load.

TEST PROCEDURE

The loads were applied to the folding wing in 10% increments of the temperature corrected design limit load. At selected levels, photographs of the developing stress pattern were taken.

TEST RESULTS

The folding wing, with only the aft locking pin engaged, failed at 122% of the temperature corrected design limit load as the outer panel ruptured in the area of the aft locking pin engagement. The values at failure for the shear and bending moment at the root of the folding wing were 2840 lbs. and 21,290 in-lbs., respectively. Photographs of the failure are shown on pages 1.3.7 and 1.3.8.

Photographs of the developing stress pattern were taken at 30%, 50%, 70% and 100% of the temperature corrected design limit load. Those photographs are shown on pages 1.3.9, 1.3.10, 1.3.11 and 1.3.12, respectively. Unfortunately, the photoelastic material developed a crack at the highly stressed aft corner after 50% design limit load had been attained. However, the photographs do show the general overall picture of how the stresses developed throughout the inner panel.

LOAD LOC.	LIMIT LOAD (LBS.)	X (INS.)	Y (INS.)
1	45.4	2.38	1.33
2	55.6	2.41	3.99
3	57.8	2.43	6.45
4	108.6	7.39	1.38
5	141.8	7.41	3.99
6	150.4	7.41	6.45
7	152.0	12.85	1.33
8	32.6	16.77	1.38
9	204.2	12.86	3.99
10	103.3	11.53	6.45
11	1078.7	4.93	11.39

STATIC LOAD TEST NO. 2 TEST ARRANGEMENT & LOAD LOCATIONS

TOTAL LIMIT LOAD = 2197 LBS. (UNCORRECTED FOR TEMP.)

TOTAL LIMIT LOAD = 2397 LBS. (CORRECTED FOR TEMP.)

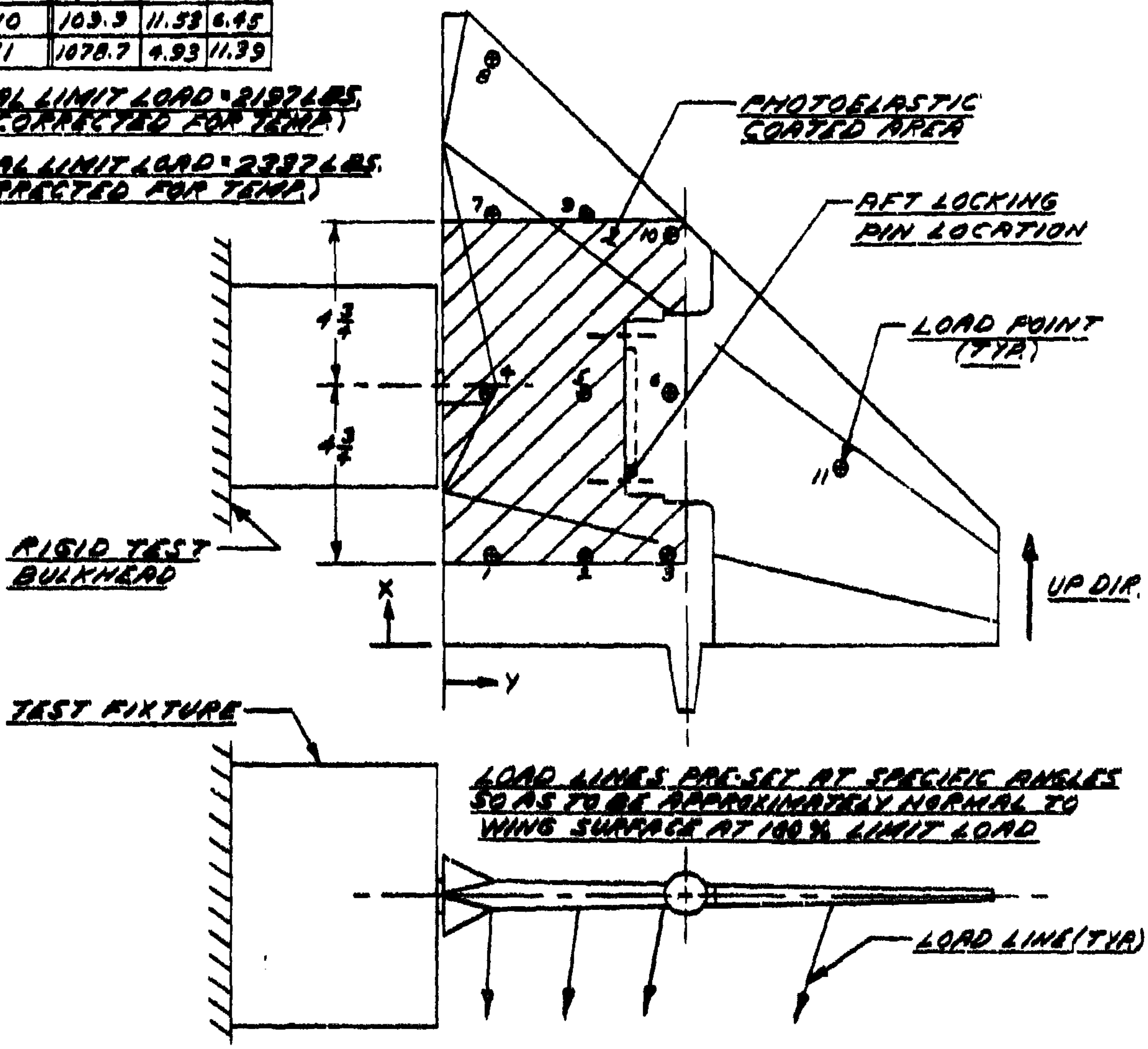

FIGURE 6

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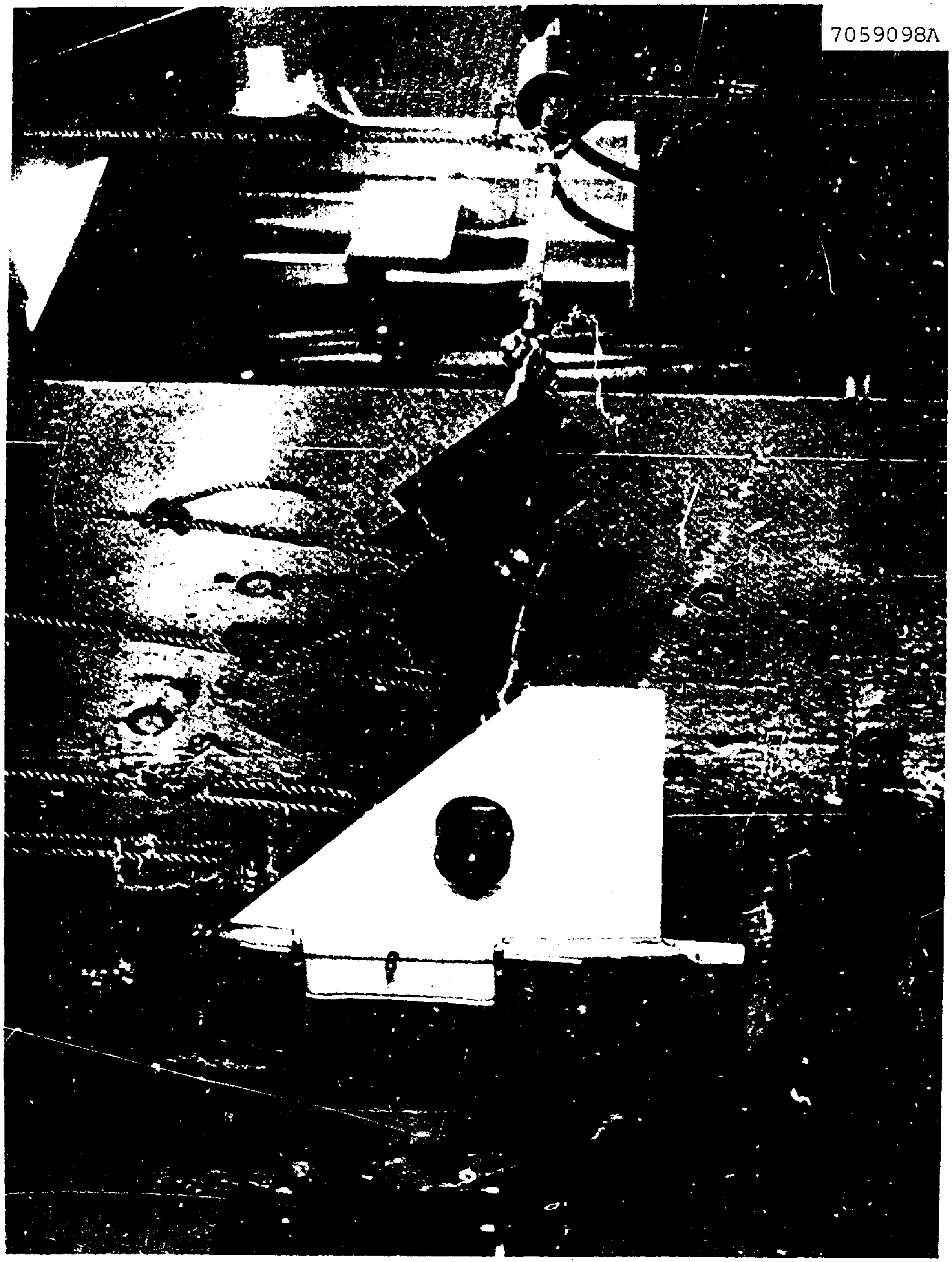

Static Load Test No. 2 - Test Setup

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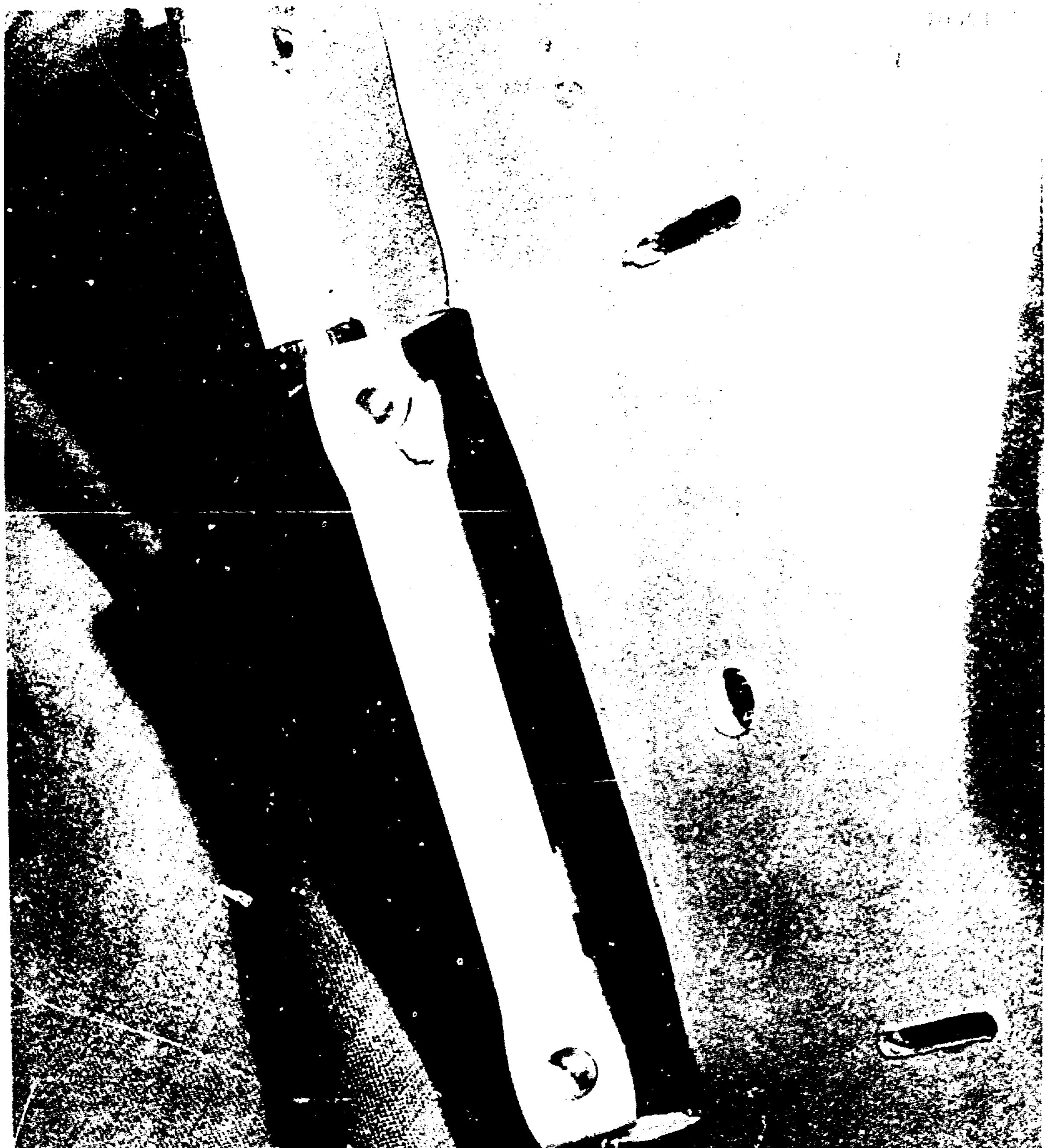

Static Load Test No. 2 - Failure of Outer Wing Section

Form No. V-1028

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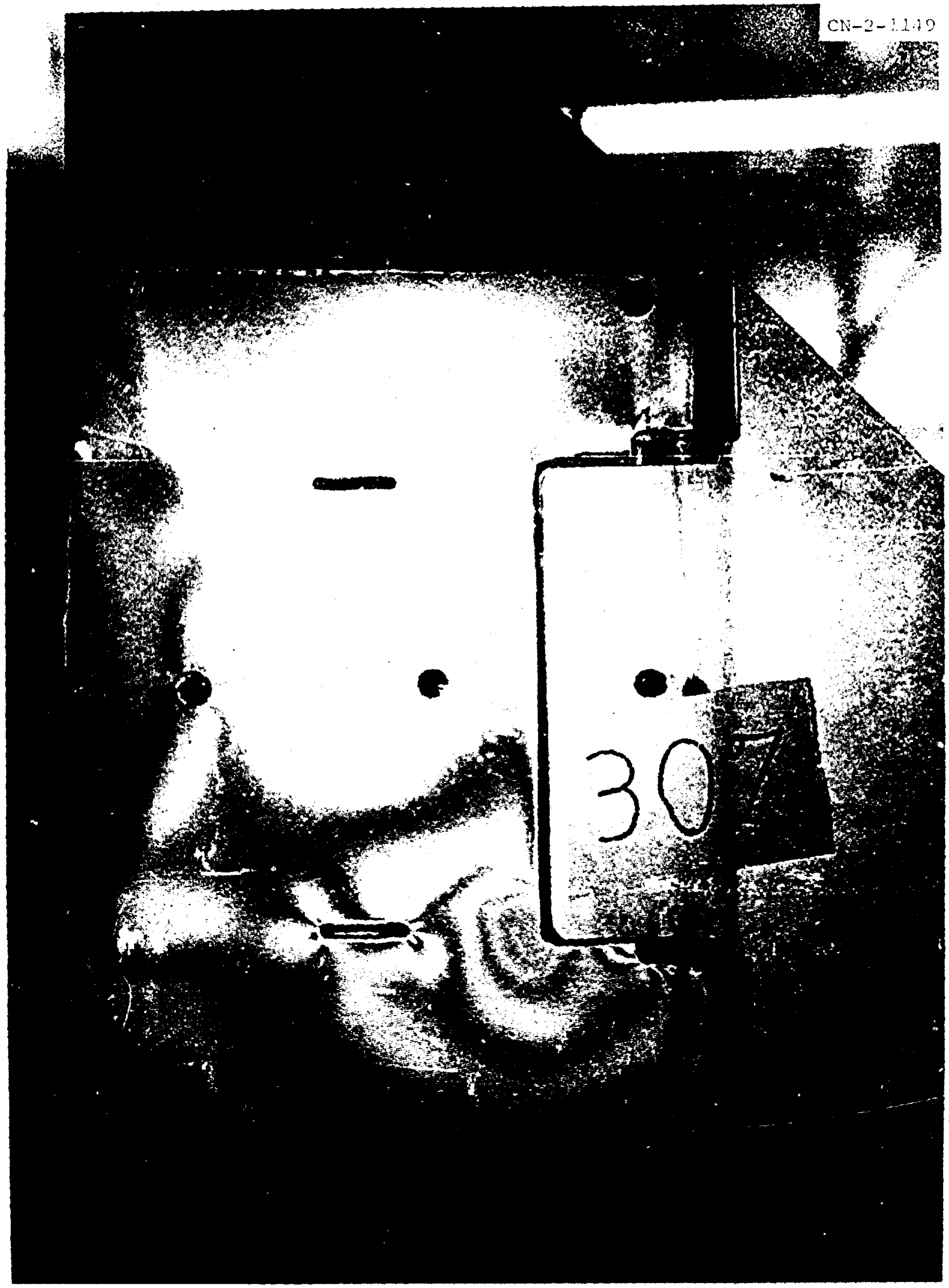
Static Load Test No. 2 - Closeup of Failure of Outer Wing Section



Static Load Test No. 2 - 30% Limit Load

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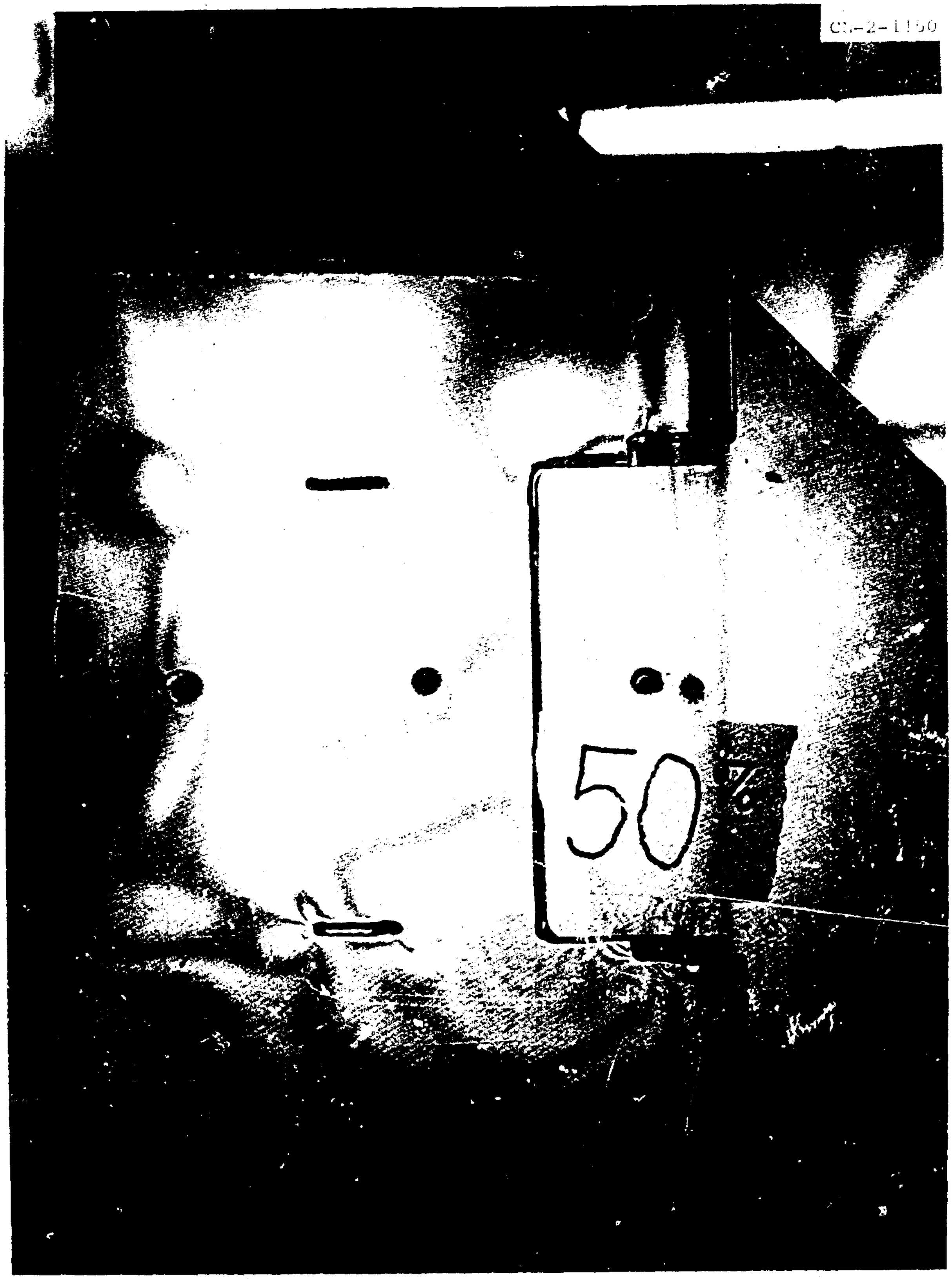
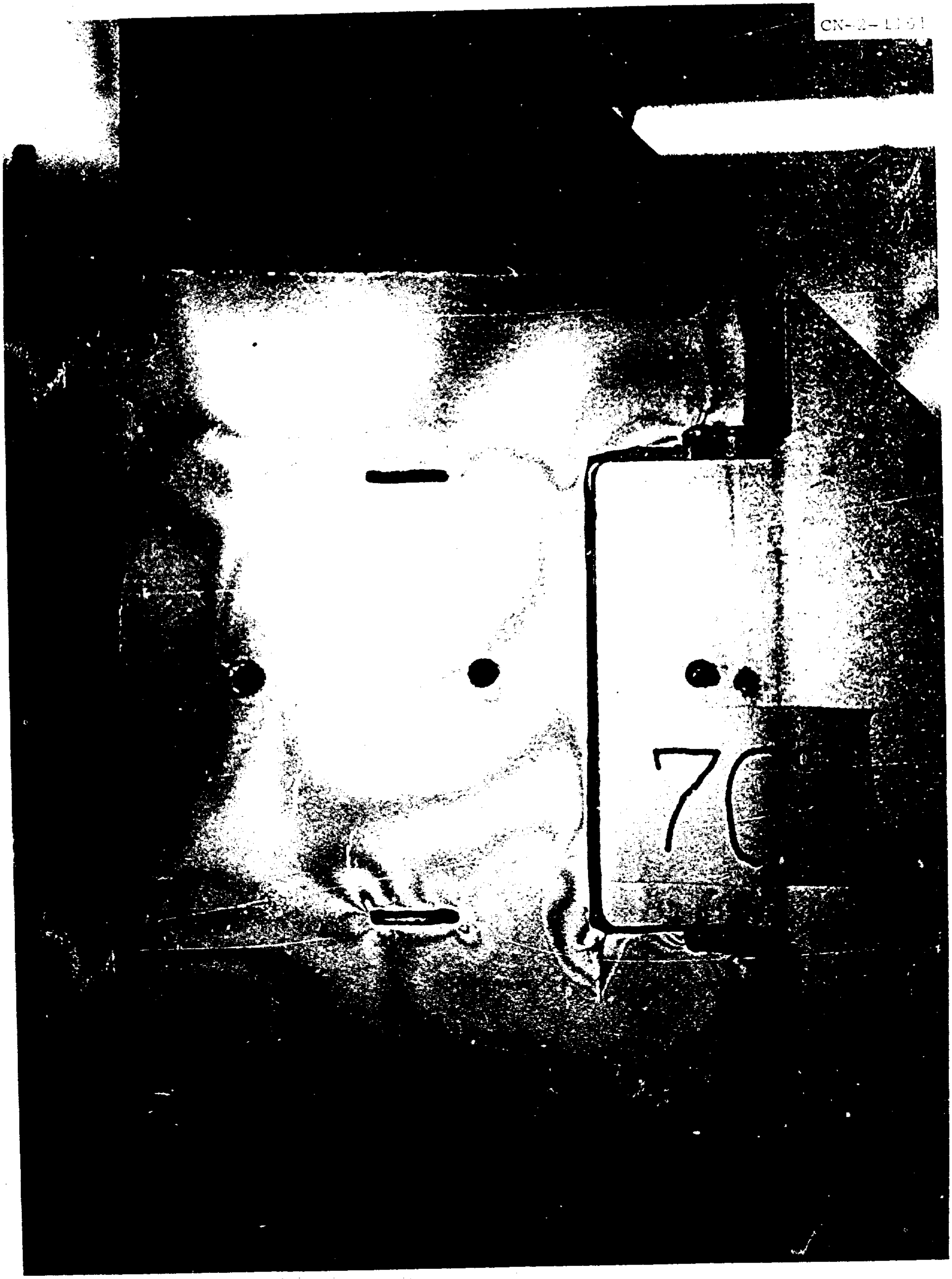


Static Load Test No. 2 - 50% Limit Load

Form No. V-1028



Static Load Test No. 2 - 70% Limit Load

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Static Load Test No. 2 - 100% Limit Load

Form No. V-1028

SECTION 1.4

TORSION BAR ENDURANCE AND RELAXATION TESTS

TORSION BAR ENDURANCE AND RELAXATION TESTS

OBJECT

The object of these tests was to determine the number of cycles the folding wing torsion bar could sustain prior to failure when subjected to selected torsional shear stress levels, and to determine if any relaxation trends occur after repeated cycling.

CONCLUSION

It can be concluded from the results of this test that there are no significant relaxation trends in the torsion bar, for the torsional shear stress levels attained during test.

DESCRIPTION OF TEST ARTICLES

The torsion bars, which are integral parts of the folding wing assemblies, conformed to the Reference (b) drawing. The torsion bars are fabricated from 1890 nickel maraging alloy steel, grade 350, and are heat treated to RC 57-61. A sketch of the torsion bar is shown in Figure 7 on page 1.4.5.

INSTRUMENTATION

Micro-measurements foil-type strain gages were bonded to each torsion bar. Those strain gages were wired to a Bristol punch-type strip chart strain recorder, which was operated continuously during the test. The sole purpose of the strain gages was to record when failure occurred, where a condition of zero strain indicated failure. The number of cycles to cause

INSTRUMENTATION (continued)

failure of each torsion bar was then determined, knowing the paper speed of the strip chart strain recorder and the frequency of the applied loads.

LOADING AND RECORDING APPARATUS

The loads were applied to four torsion bars simultaneously by means of a rack and pinion gear arrangement, which are an integral part of the test fixture. A hydraulic power supply was used to activate a hydraulic actuator which in turn drove the rack gear. The hydraulic actuator was driven by servo valves which were controlled by means of an electronic console. A Hewlett-Packard low frequency generator was used to obtain the desired frequency and amplitude.

LOADS

The torsion bars were subjected to selected maximum torsional shear stress levels of approximately 120,000 psi, 140,000 psi, 160,000 psi and 180,000 psi.

TEST ARRANGEMENT

A test fixture was designed and fabricated so that four torsion bars could be tested simultaneously. A photograph of the test arrangement is shown on page 1.4.6.

TEST ARRANGEMENT (continued)

The loads were applied to one end of the four torsion bars simultaneously by means of the rack and pinion gear arrangement. The other ends of the torsion bars were locked in place at specific pre-set angles, which are the differences between the maximum outer wing panel rotation of 135 degrees and the calculated angles required to attain the selected maximum torsional shear stress levels. The pre-set angles induced a selected negative stress so that when the test was conducted, the torsion bars were cycled between the selected negative stress levels and the selected maximum positive stress levels.

The angles required to attain the selected maximum positive torsional shear stress levels were calculated using the formulas shown in the enclosure on page 1.4.7. Also shown are the calculated torques required to attain the maximum positive stress levels and the pre-set angles.

TEST PROCEDURE

Prior to testing, the torques required to twist the torsion bars to the specific angles required to attain the selected stress levels were measured and recorded for each torsion bar. The torsion bars were then locked in position at their

TEST PROCEDURE (continued)

specific pre-set angles. The torsion bars were cycled at the maximum outer wing panel rotation of 135 degrees at a frequency of 0.1 cycles per second. At each half-hour interval, until failure occurred, the endurance test was stopped and the torques required to twist the torsion bars to the specific angles required to attain the selected stress levels were measured and recorded for each torsion bar.

TEST RESULTS

Four torsion bars were tested and a table of the test results is shown on page 1.4.7. Also, a S-N curve of the maximum torsional shear stress vs. the number of cycles to failure is shown on page 1.4.8.

It should be noted that the torques required to twist the torsion bars to the specific angles required to attain the selected stress levels, which were measured and recorded prior to the test and at each half-hour interval, remained constant throughout the entire test.

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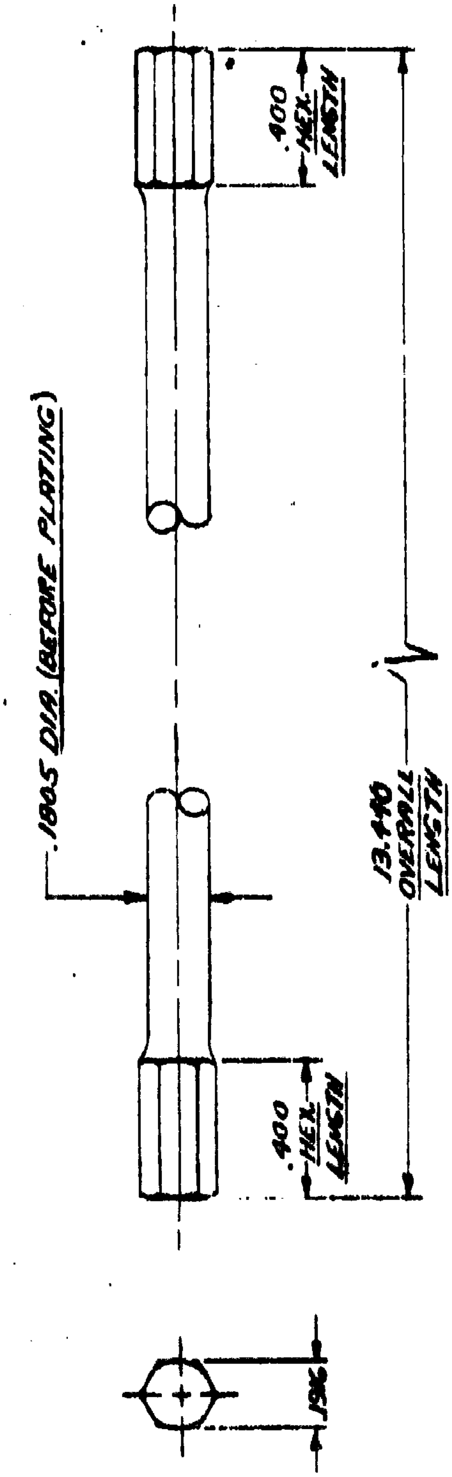
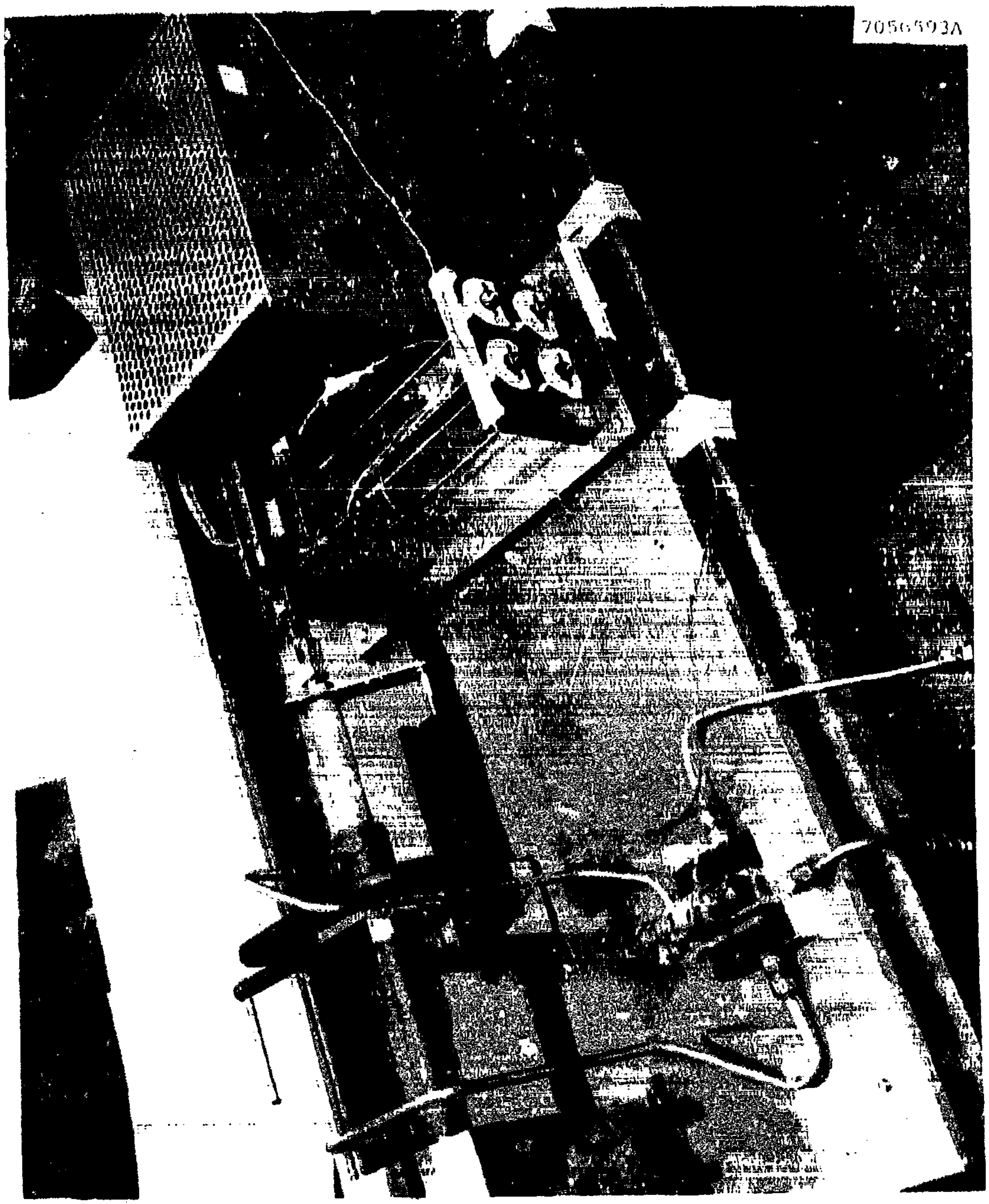


TORSION BAR

FIGURE 7



Torsion Bar Endurance and Relaxation Test Setup

TABLE OF TEST RESULTS

TORSION BAR	SELECTED MAX. STRESS LEVEL (psi)	CALCULATED ANGLE FOR MAX. STRESS	PRE-SET ANGLE	CALCULATED TORQUE FOR ANGLE OF MAX. STRESS (IN.-LBS.)	TEST DATA: MEASURED ‡ TORQUE FOR ANGLE OF MAX. STRESS (IN.-LBS.)	TEST DATA: NUMBER OF CYCLES TO FAILURE
A	180,000	135°	0°	208	205	7450
B	160,000	120°	15°	185	190	9790
C	140,000	105°	30°	162	160	10,090
D	120,000	90°	45°	139	130	10,630

$$\sigma_s^{*} = \frac{\mathcal{T} r}{J}\,; \qquad \theta^{*} = \frac{\mathcal{T} L}{G J}\,; \qquad J^{*} = \frac{\pi r^4}{2}$$

BY SUBSTITUTION

$$\mathcal{T} = \frac{\sigma_s \pi r^3}{2} \quad \text{AND} \quad \theta = \frac{\sigma_s L}{G r}$$

WHERE:

σ_s = TORSIONAL SHEAR STRESS - psi

$\mathcal{T}$ = TORSION (TORQUE) - IN.-LBS.

r = RADIUS - IN. (.09025)

J = POLAR MOMENT OF INERTIA - IN.^{4}

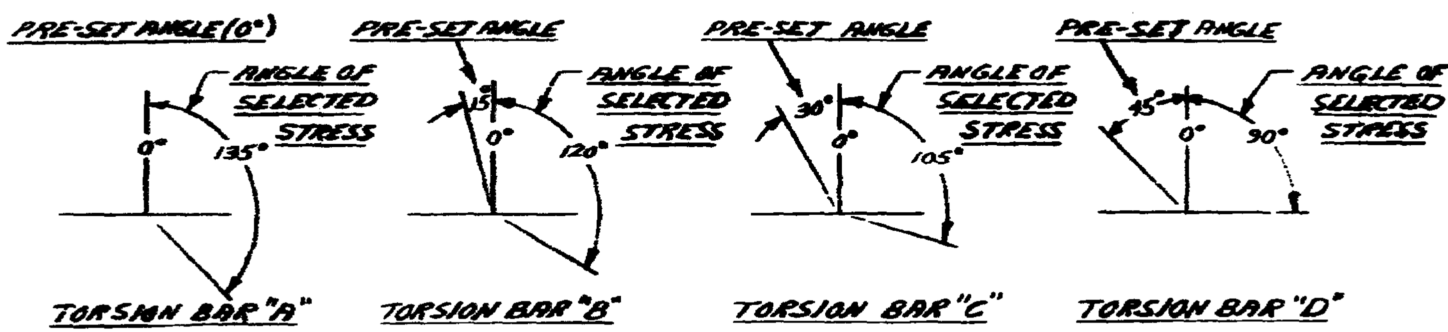
θ = ANGLE OF TWIST - RADIANS

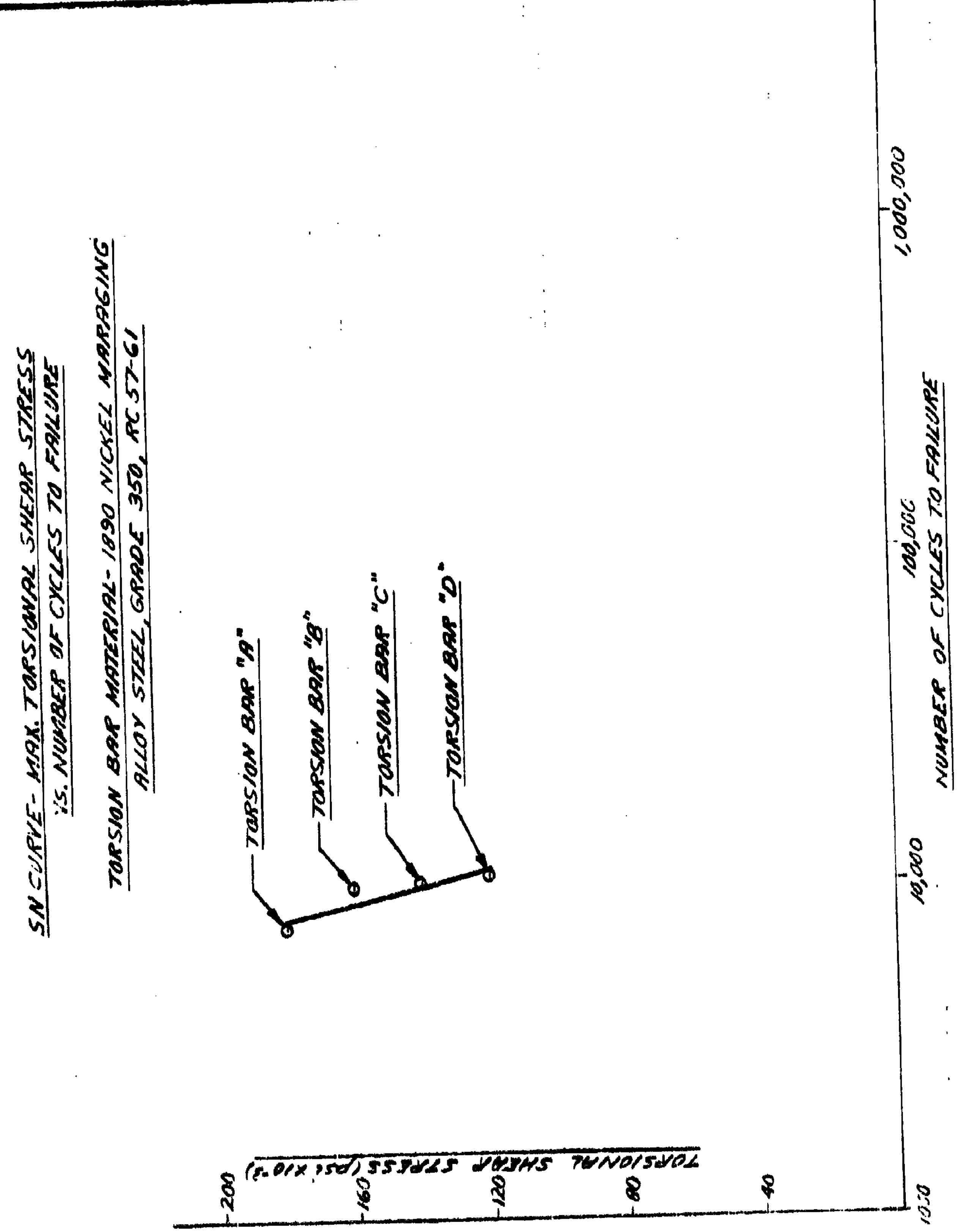
L = EFFECTIVE LENGTH - INS. (12.640)

G = MODULUS OF SHEAR - psi (10.7×10^6)

* REF. - "STRENGTH OF MATERIALS" TEXT BOOK

‡ THE TORQUES, MEASURED EVERY HALF HOUR FOR EACH TORSION BAR, WERE CONSTANT THROUGHOUT THE ENTIRE TEST





SN CURVE - MAX. TORSIONAL SHEAR STRESS
VS. NUMBER OF CYCLES TO FAILURE
TORSION BAR MATERIAL - 18% NICKEL MARAGING
ALLOY STEEL, GRADE 350, RC 57-61
TORSION BAR "A"
TORSION BAR "B"
TORSION BAR "C"
TORSION BAR "D"
TORSIONAL SHEAR STRESS (PSI x10^3)
200
160
120
80
40
1000
10,000
100,000
1,000,000
NUMBER OF CYCLES TO FAILURE

SECTION 1.5

INFLUENCE COEFFICIENT STUDY

INFLUENCE COEFFICIENT STUDY

OBJECT

The object of this study was to obtain Load vs. Deflection measurements at various locations on the folding wing so that an influence coefficient matrix could be generated.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this study conformed to the Reference (a) drawing. The inner wing section of the assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of the assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

INSTRUMENTATION

Deflections of the test article were measured at the locations shown in the sketch in Figure 8 on page 1.5.4. Ames dial indicators were used to measure deflections.

LOADS

A single 100-pound dead weight load was suspended from each of the load locations shown in the sketch in Figure 8 on page 1.5.4.

TEST ARRANGEMENT

The test article was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That test fixture was mounted to a rigid test bulkhead.

The test article was mounted with the chord planes of the wing in the horizontal position. That test arrangement simplified the setup for the instrumentation and the loading linkages.

The influence coefficients of the folding wing were determined for a 35-point grid network as shown in the sketch in Figure 8 on page 1.5.4. Deflections at all the grid coordinates were measured and recorded for all combinations of a single load applied at one location at a time.

To apply the load to the folding wing, steel wire cables (1/16 inch diameter) with swaged ball-end fittings on one end were used. Those wire cables were passed through small holes which were drilled in the folding wing at the load and deflection points. A spherical ball end-mill was used to countersink one side of the holes. Those holes were small (No. 36 drill) and had a negligible effect on the folding wing stiffness.

Deflections were measured by means of Ames dial indicators which were secured to a rigid framework. Small stranded steel wires (.015 inch diameter) were attached to those deflection indicators. The

TEST ARRANGEMENT (continued)

other ends of the steel wires were attached to short pieces of aluminum-alloy tubing. Those pieces of tubing straddled the ball-end fittings of the loading cables, and were bonded directly to the top surface of the folding wing.

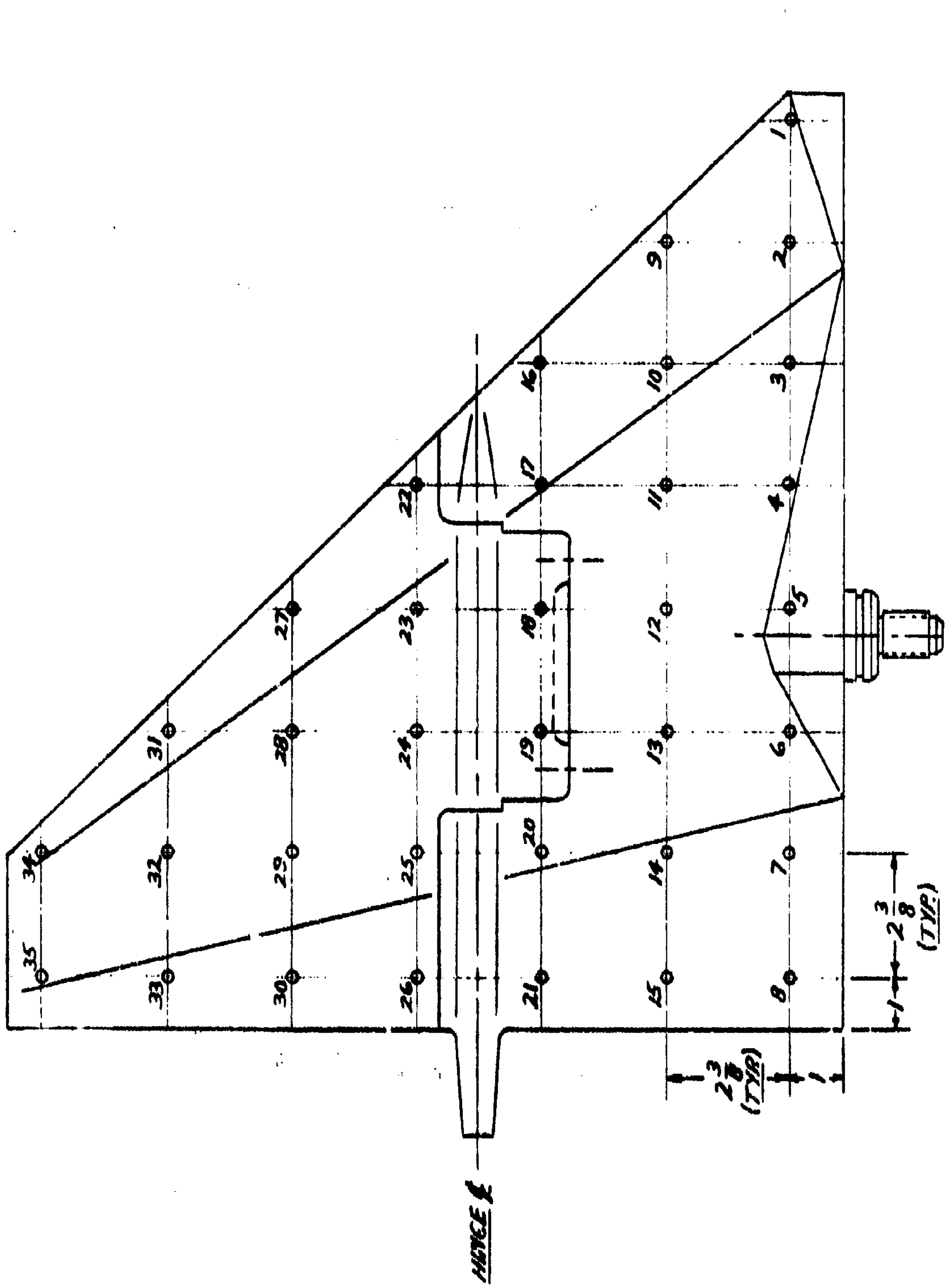
Photographs of the test arrangement are shown on pages 1.5.5 and 1.5.6.

TEST PROCEDURE

The following test procedure was performed at each of the 35 loading points to eliminate possible errors from test fixture movement: A 100-pound dead weight load was hung from a loading point and then removed. After recording zero-load deflection readings, the load was again applied and deflection measurements at all points were recorded. The load was then removed and the zero-load deflection readings recorded again prior to the next load application.

TEST RESULTS

A matrix showing the net deflections occurring at all loading points, due to the application of the 100-pound dead weight load, is shown on page 1.5.7.



INFLUENCE COEFFICIENT STUDY-LOAD & DEFLECTION PT. LOCATIONS

FIGURE 8

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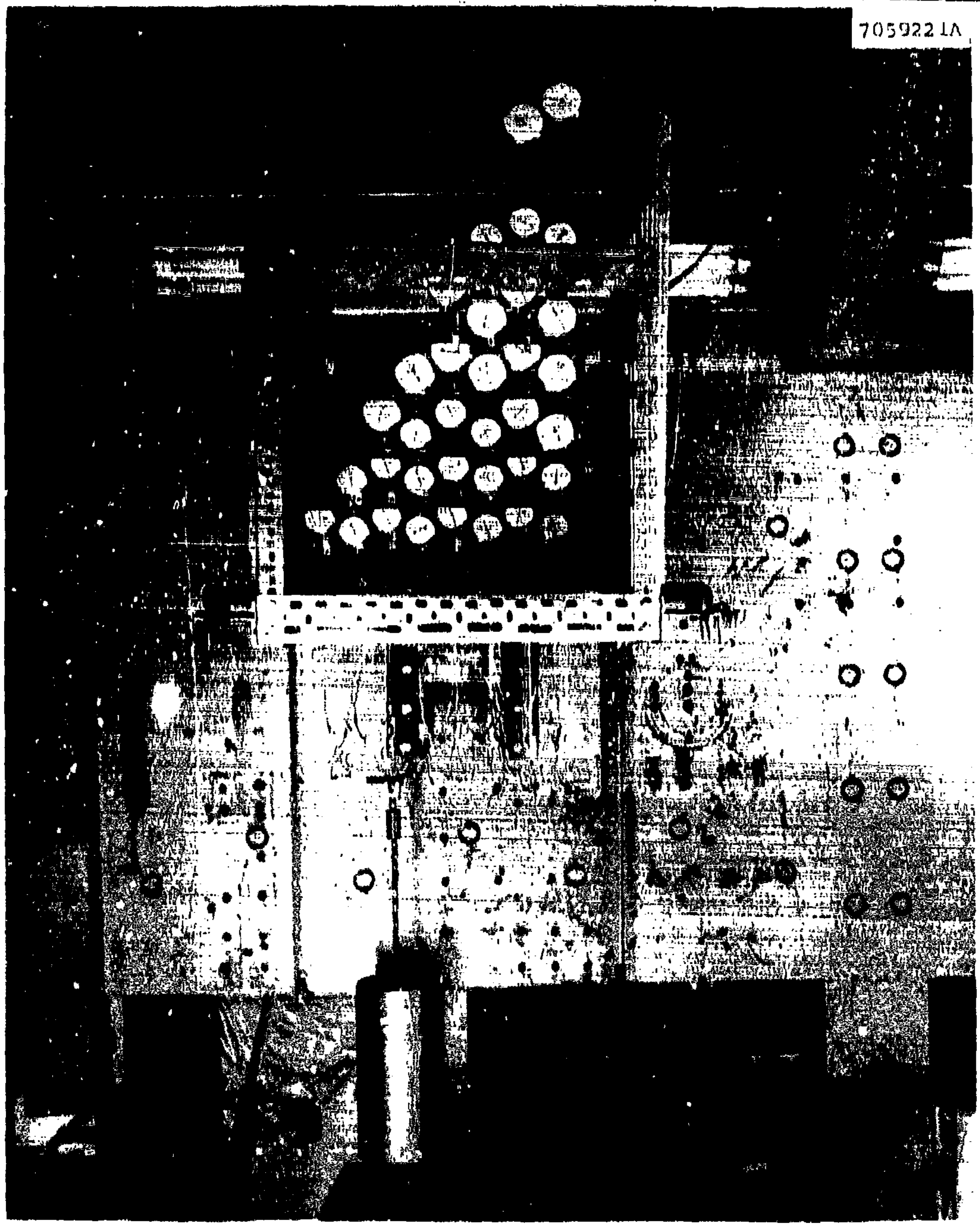
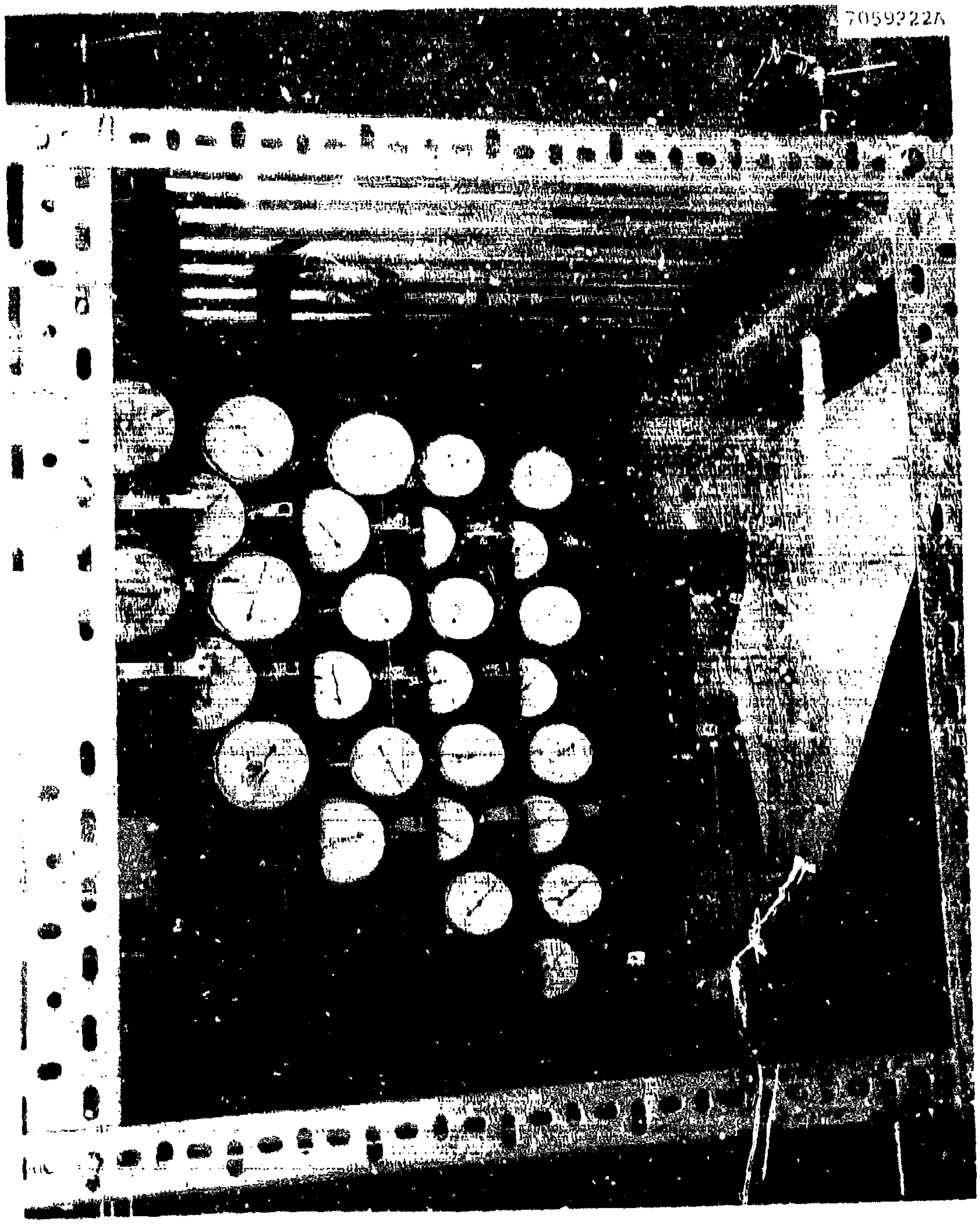


Influence Coefficient Study - Test Setup - Overall View

Form No. V-1028



Influence Coefficient Study - Test Setup - Top View

ENGINEER	P. KNUDIT-JONES	RAYTHEON COMPANY	PAGE NO.	1.5.7
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DATE	APRIL 1972	STRUCT. & ENVIR. TEST REPORT	MODEL	SEA SPARROW

INFLUENCE COEFFICIENT STUDY
LOAD-DEFLECTION MATRIX BASED ON A 100 LB. LOAD

DEFLEC. \ LOAD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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SECTION 2

STRUCTURAL DYNAMIC TEST

RANDOM VIBRATION TEST

OBJECT

The object of this test was to determine the dynamic characteristics and the vibrational stress integrity of the folding wing assembly.

CONCLUSION

It can be concluded from the results of this test that the folding wing assembly can successfully withstand the random vibration environment specified in the Reference (6) document.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing. The inner wing section of the assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of the assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

INSTRUMENTATION

Instrumentation for the test consisted of three Endevco minature accelerometers, one fixed to the wing in the root area and used as the control accelerometer, one fixed to the wing in the tip area and one fixed to the wing at the hinge line. The control accelerometer output was plotted to show the equalized white noise input spectrum and the dynamic characteristics of the folding wing at the control location.

INSTRUMENTATION (continued)

The two read-out accelerometer outputs were plotted to show the power spectral density response spectrums. A tape recorder and an X-Y-Y' recorder were used to plot the data.

TEST EQUIPMENT

The following test equipment was used during the test.

1 Ling Model A275-Vibrator
1 Ling Model 40/60 - Amplifier
1 MB Model T589 - 3K Hz Random Equalizer/Analyzer
3 MB Model N-400 - Zero Drive Signal Conditioning Amplifiers
1 Endevco Model 2271 - Accelerometer (control)
2 Endevco Model 220C - Accelerometers (readout)
3 Ballantine Model 300 - Voltmeters
1 Precision Instruments Model PS-207A - Tape Recorder
1 Honeywell Model 540 - X-Y-Y' Recorder

TEST ARRANGEMENT

The folding wing was mounted to an operational AIM-7E Hydraulic Control Section Shell in order to include proper wing hydraulic restraints and any wing-body coupling effects. The Hydraulic Control Section was hard mounted at two locations to a test fixture, which was secured to the vibrator.

Photographs of the test arrangements for the random vibration tests along each of the three principal axes of the folding wing are shown on pages 2.0.6, 2.0.7 and 2.0.8. To ensure stability of the

TEST ARRANGEMENT (continued)

of the test support shell during test, an additional uninstrumented folding wing was mounted to the Hydraulic Control Section Shell directly opposite to the instrumented folding wing for the transverse and longitudinal random vibration tests.

Random vibration tests were conducted along each of the three principal axes of the folding wing to the levels specified in the Reference (5) document.

TEST PROCEDURE

The folding wing, along each of its three principal axes, was subjected to an equalized white noise wide band random vibration spectrum of 0.04 g^2/Hz over the frequency bandwidth of 100 Hz to 1000 Hz with a 6 db/octave roll off between 10 Hz to 100 Hz and between 1000 Hz to 2000 Hz. The random vibration was applied for a time duration of 5 minutes along each of its three principal axes. The outputs from the control accelerometer and the two read-out accelerometers were tape recorded.

TEST RESULTS

The tape recordings from each random vibration tests were played back through the Random Equalizer/ Analyzer and X-Y plots were made of the power spectral density spectrum (g^2/Hz) input and response accelerations by means of the X-Y-Y' recorder.

TEST RESULTS (continued)

Those plots of the random vibration test in the vertical direction are shown on pages 2.0.9, 2.0.10 and 2.0.11. Those plots of the random vibration test in the lateral direction are shown on pages 2.0.12, 2.0.13, and 2.0.14. Those plots of the random vibration test in the longitudinal direction are shown on page 2.0.15, and 2.0.16 and 2.0.17.

The data for all random vibration tests were plotted on the semi-logarithmic graph paper recommended for use with the X-Y-Y' recorder. The Y-axis, which is logarithmic represents the power spectral density spectrum (g^2/Hz) and the X-axis represents the frequency.

To better understand the frequency scale factor it should be noted that the 3000 Hz Random Equalizer/ Analyzer contains eighty (80) filters which represent full scale from 0 Hz to 3000 Hz on the X-axis. Those filters are not identical and vary in band width from 12.5 Hz (filters 1 to 16), 25 Hz (filters 17 to 32) and 50 Hz (filters 33 to 80). Each filter represents 0.1 inch on the X-axis and to determine the frequency at a specific location on the X-axis, that distance should be physically measured and then the summation of the frequencies of the specific filters within that distance will determine the frequency at that location.

A plot of the input at the folding wing root has been superimposed on each of the response plots so as to obtain a clearer picture of the dynamic characteristics at the hinge and tip area of the folding wing.

TEST RESULTS (continued)

Visual inspections of the folding wing were made after each of the random vibration tests. In each case no visual damage was evident.

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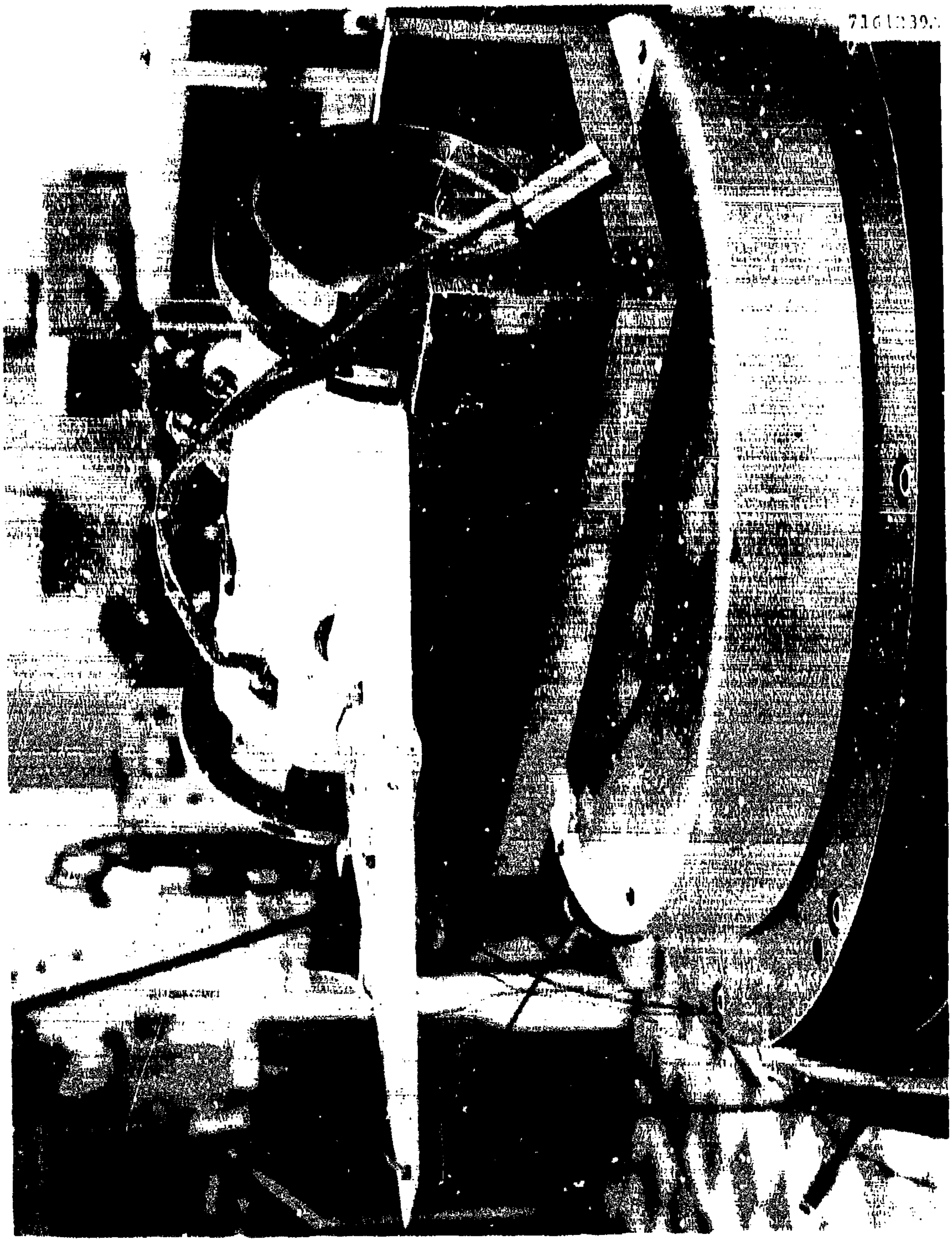
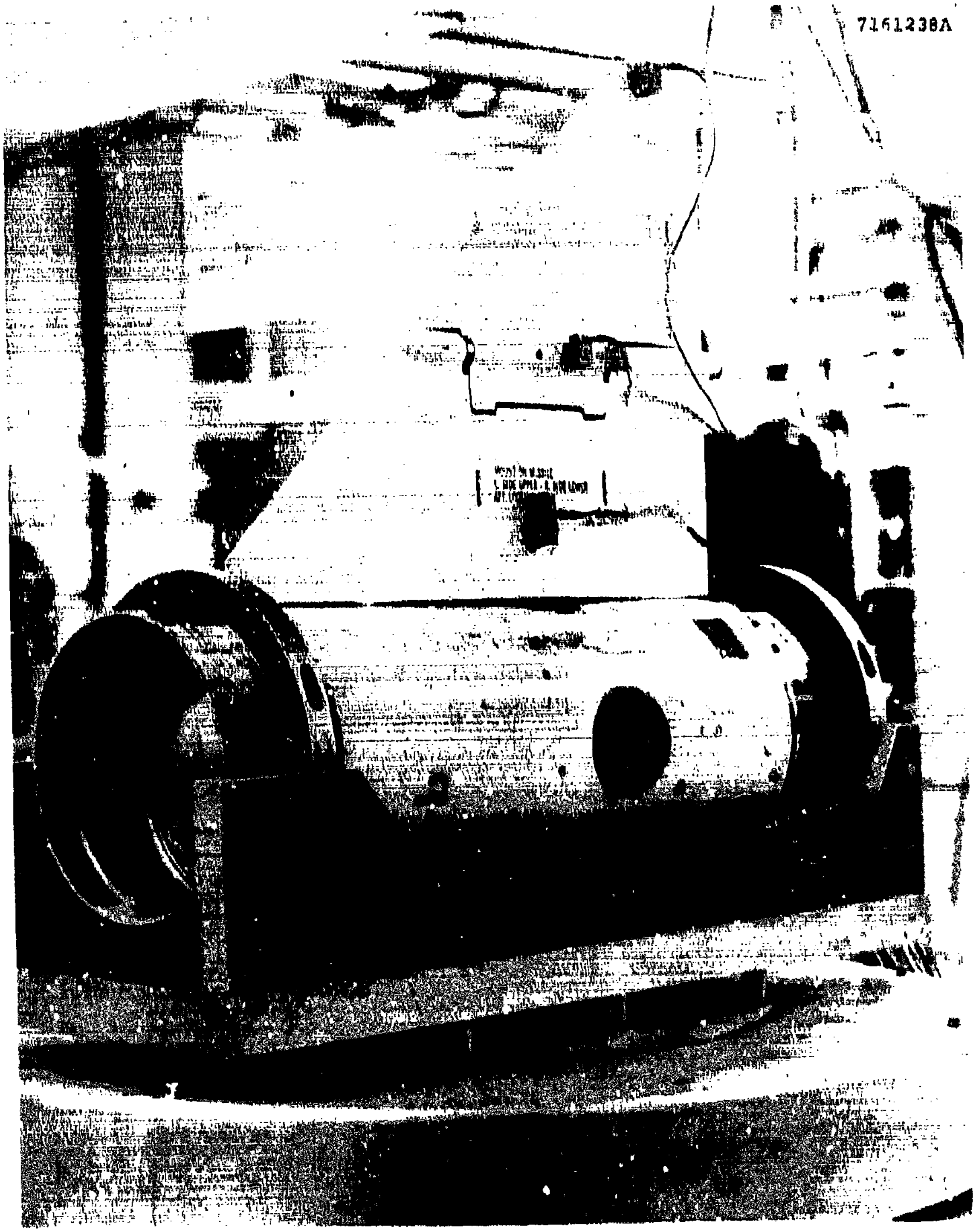
	MISSILE SYSTEMS DIVISION	REPORT NO. BR-6253
DATE April 1972	Struct. & Envir. Test Report	MODEL NO. Sea Sparrow



Random Vibration Test - Vertical Axis

ENGINEER J. Younie	RAYTHEON COMPANY	PAGE NO. 2.0.7
	MISSILE SYSTEMS DIVISION	REPORT NO. BR-6253
DATE April 1972	Struct. & Envir. Test Report	MODEL NO. Sea Sparrow



Random Vibration Test - Lateral Axis

Form No. V-1028

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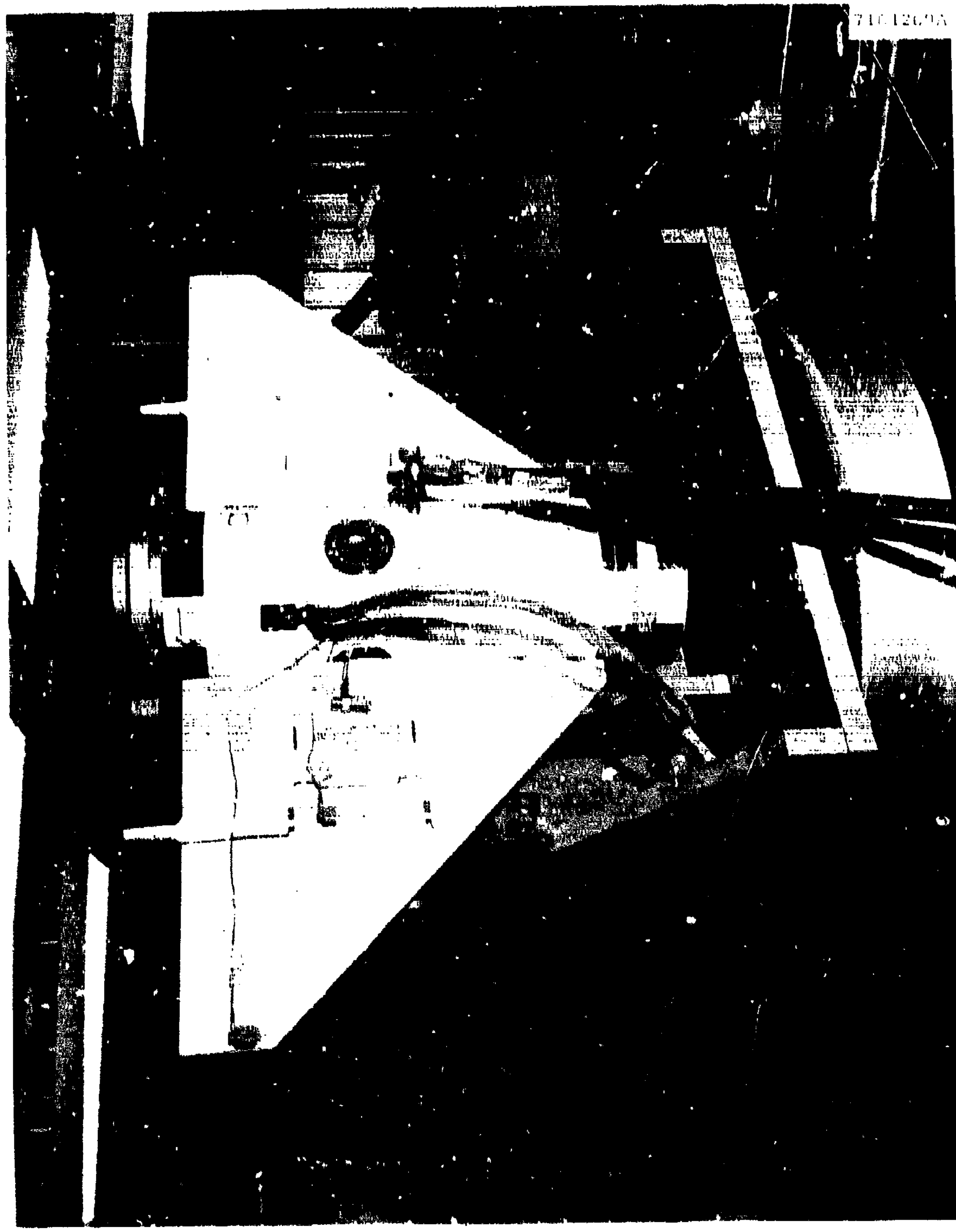
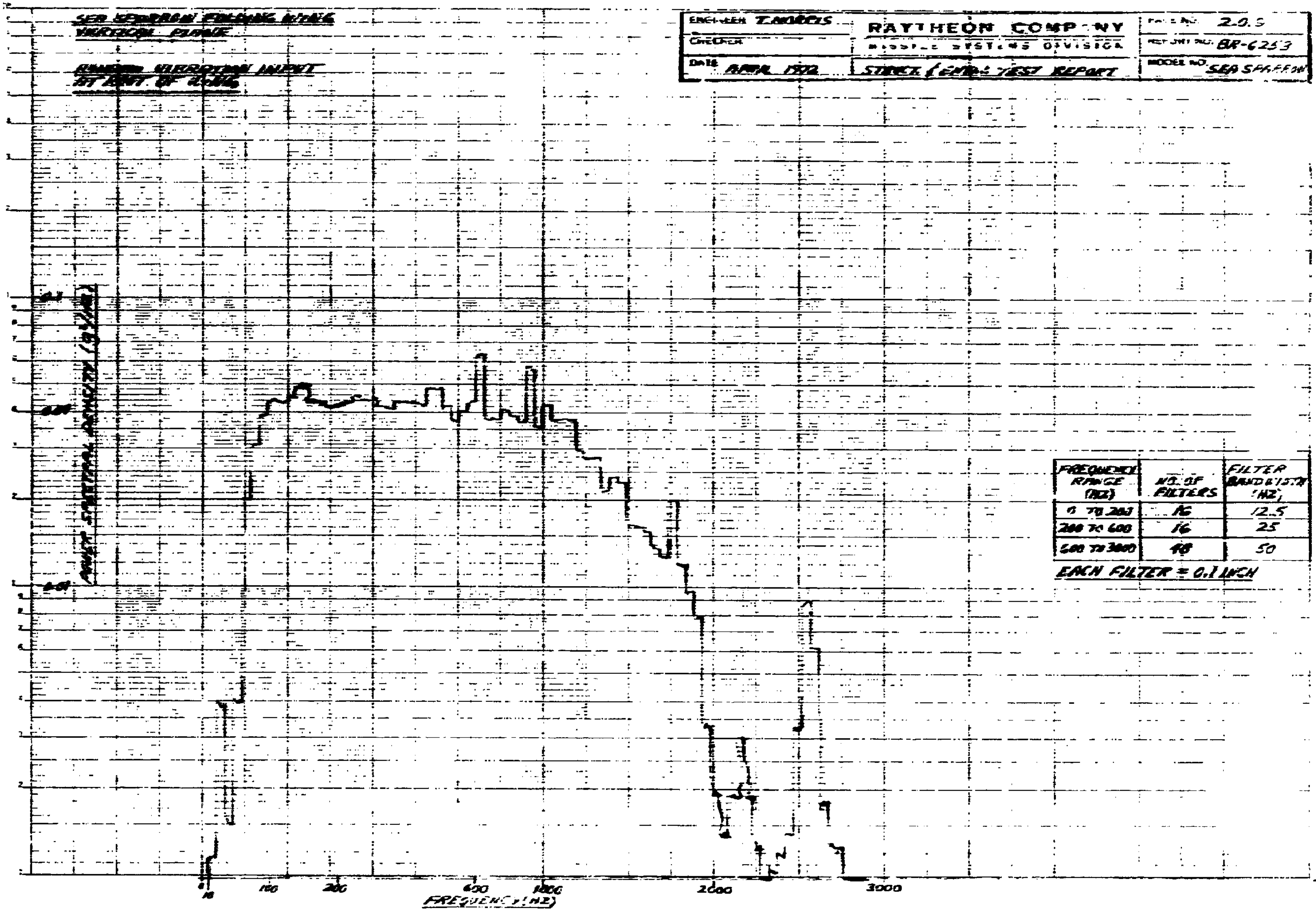
	MISSILE SYSTEMS DIVISION	REPORT NO. BR-6253
DATE April 1972	Struct. & Envir. Test Report	MODEL NO. Sea Sparrow



Random Vibration Test - Longitudinal Axis

Form No. V-1028


RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
ENGINEER T. NORRIS
CHECKER
DATE APRIL 1972
FIG. NO. 2.0.5
REPORT NO. BR-6253
MODEL NO. SEA SPARROW
VERTICAL PLANE
RANDOM VIBRATION INPUT
FREQUENCY RANGE (HZ)
NO. OF FILTERS
FILTER BANDWIDTH (HZ)
0 TO 200
16
12.5
200 TO 600
16
25
600 TO 3000
48
50
EACH FILTER = 0.1 INCH
.1
.01
10
100
200
600
1000
2000
3000
FREQUENCY (HZ)

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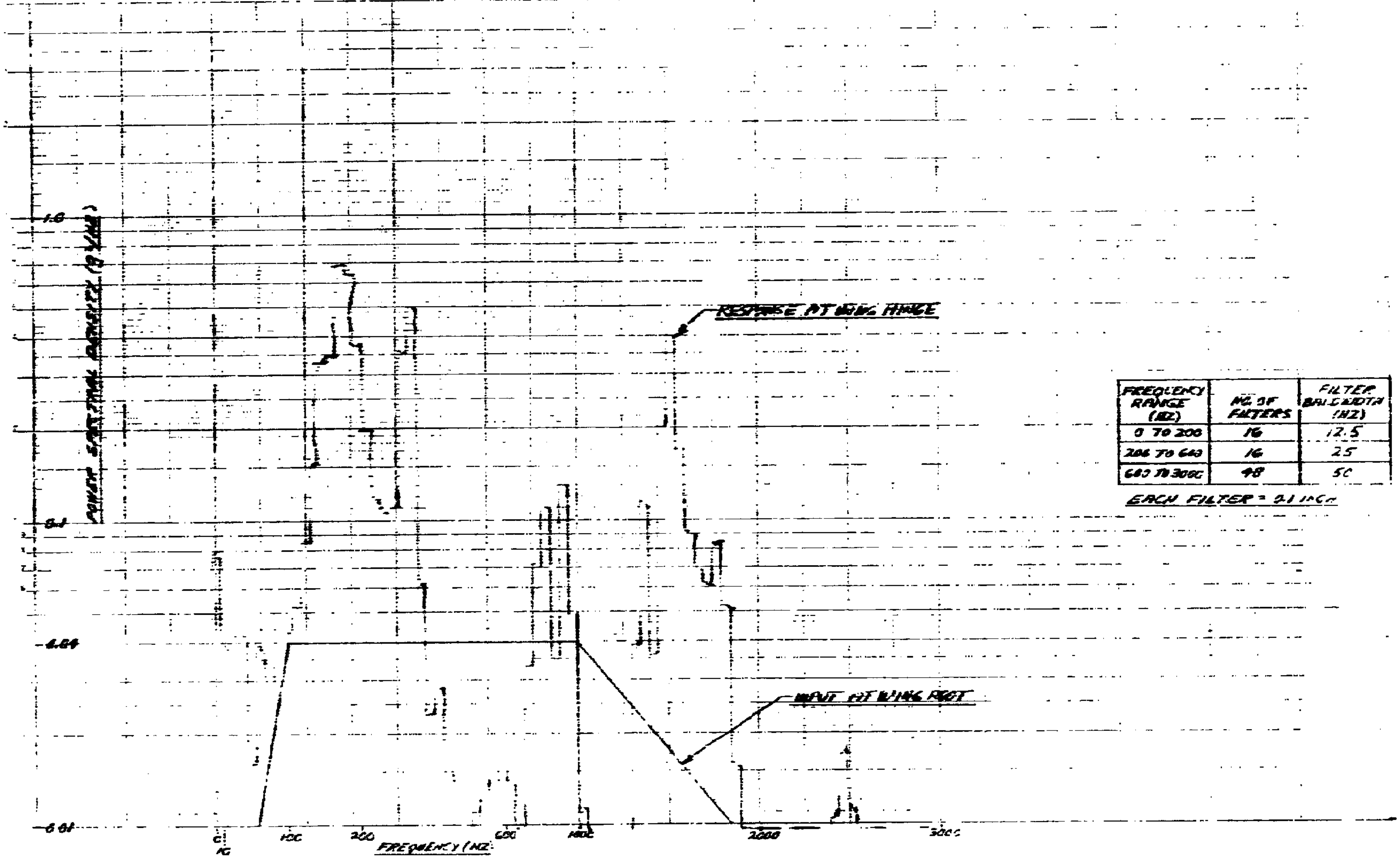
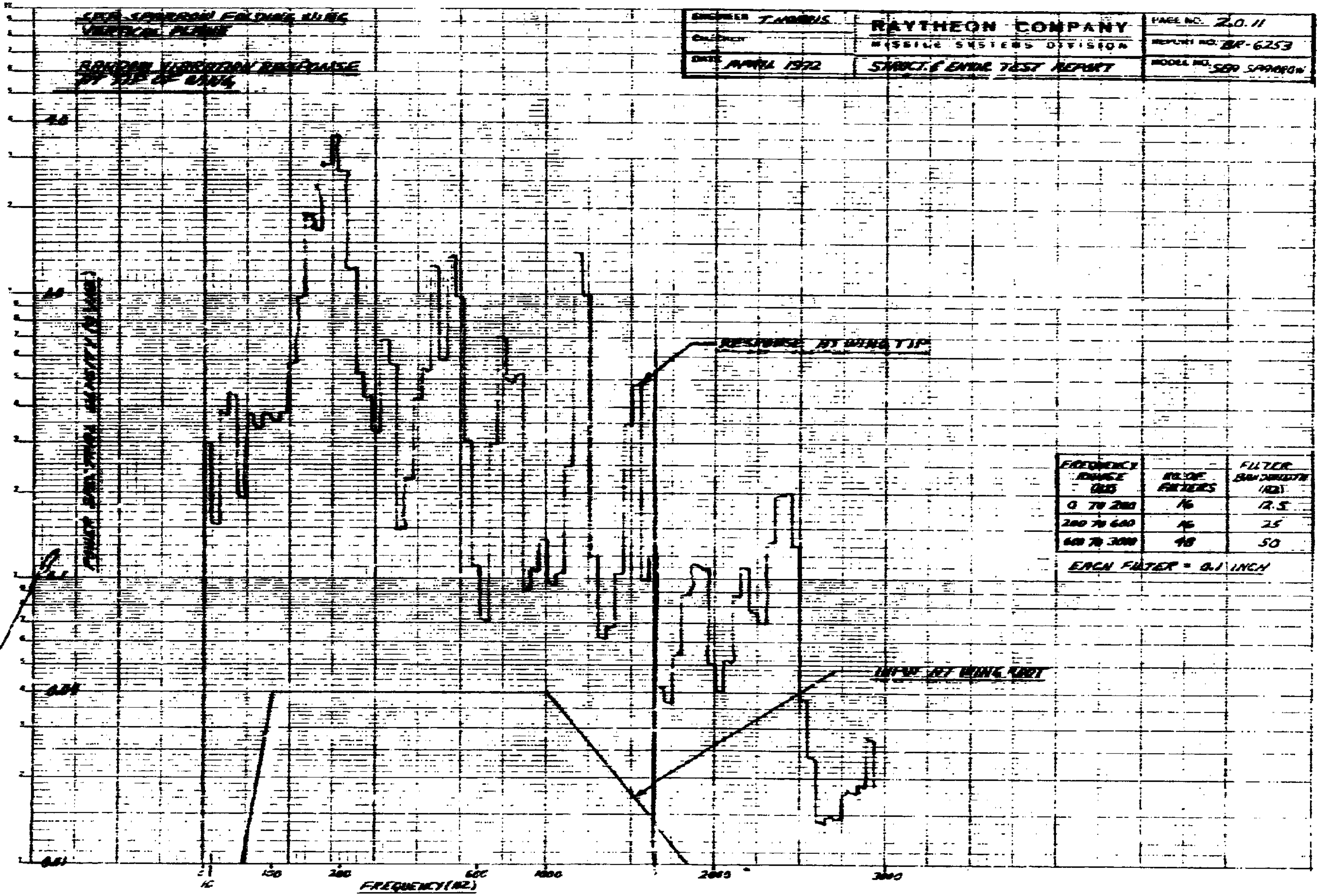
SEA SPARROW FOLDING WING
VERTICAL PLANE

RANDOM VIBRATION RESPONSE
AT HINGE OF WING



FREQUENCY RANGE (HZ)	NO. OF FILTERS	FILTER BANDWIDTH (HZ)
0 TO 200	16	12.5
200 TO 640	16	25
640 TO 3000	48	50

EACH FILTER = 0.1 INCH


ENGINEER T. HARRIS
DATE APRIL 1972
RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
STRUCT. & ENVIR. TEST REPORT
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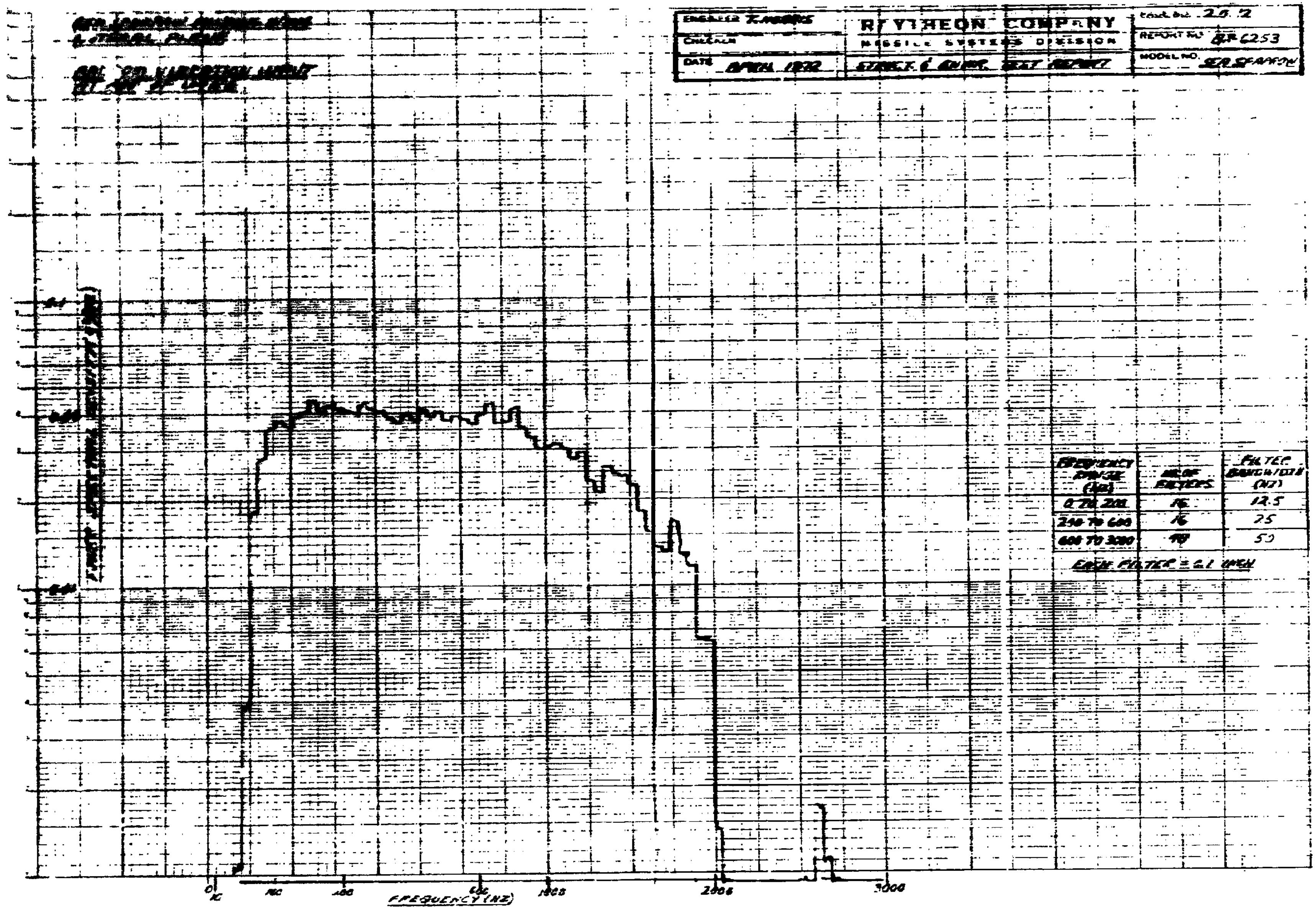
REPORT NO. BR-6253
MODEL NO. SEA SPARROW
SEA SPARROW FOLDING WING
VERTICAL PLANE
RANDOM VIBRATION RESPONSE
AT TIP OF WING
1.0
0.1
0.01
RESPONSE AT WING TIP
INPUT AT WING ROOT
FREQUENCY RANGE (HZ)
NO. OF FILTERS
FILTER BANDWIDTH (HZ)
0 TO 200
16
12.5
200 TO 600
16
25
600 TO 3000
48
50
EACH FILTER = 0.1 INCH
100
200
600
1000
2000
3000
FREQUENCY (HZ)



RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
STRUCT. & ENVIR. TEST REPORT
REPORT NO. BR 6253
MODEL NO. SEA SPARROW
DATE APRIL 1972
FREQUENCY RANGE (HZ)
NO. OF FILTERS
FILTER BANDWIDTH (HZ)
0 TO 200
16
12.5
240 TO 600
16
25
600 TO 3000
48
50
EACH FILTER = 0.1 INCH
FREQUENCY (HZ)
1000
2000
3000

SEA SPARROW FOLDING WING
LATERAL PLANE

RANDOM VIBRATION RESPONSE
AT HINGE OF WING

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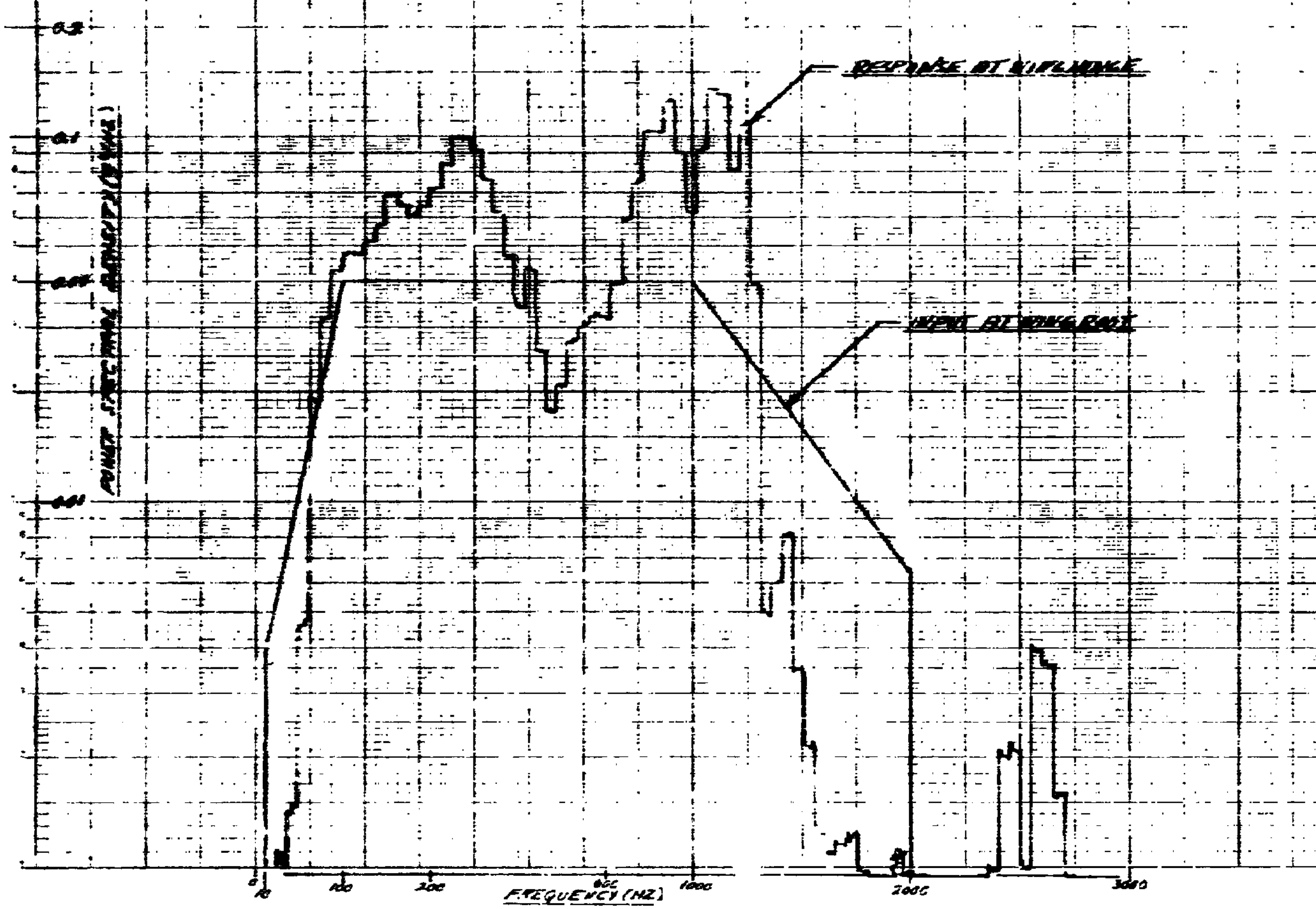
DATE APRIL 1972	STRUCT & ENVIR. TEST REPORT	MODEL NO SEA SPARROW



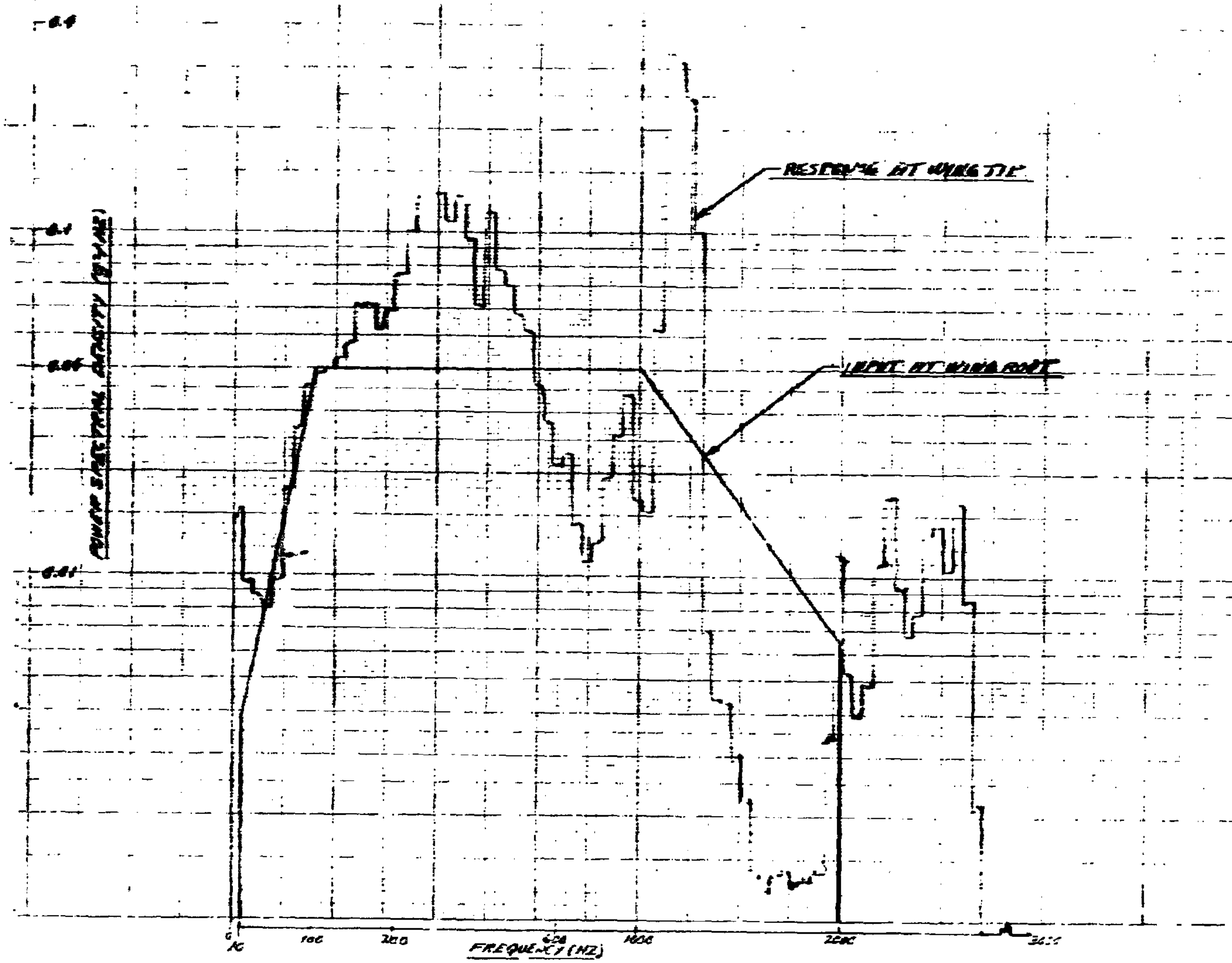
FREQUENCY RANGE (HZ)	NO. OF FILTERS	FILTER BANDWIDTH (HZ)
0 TO 200	16	12.5
200 TO 600	16	25
600 TO 3000	48	50

EACH FILTER = 0.1 [illegible]

SEA SPARROW FOLDING WING
LATERAL PLANE

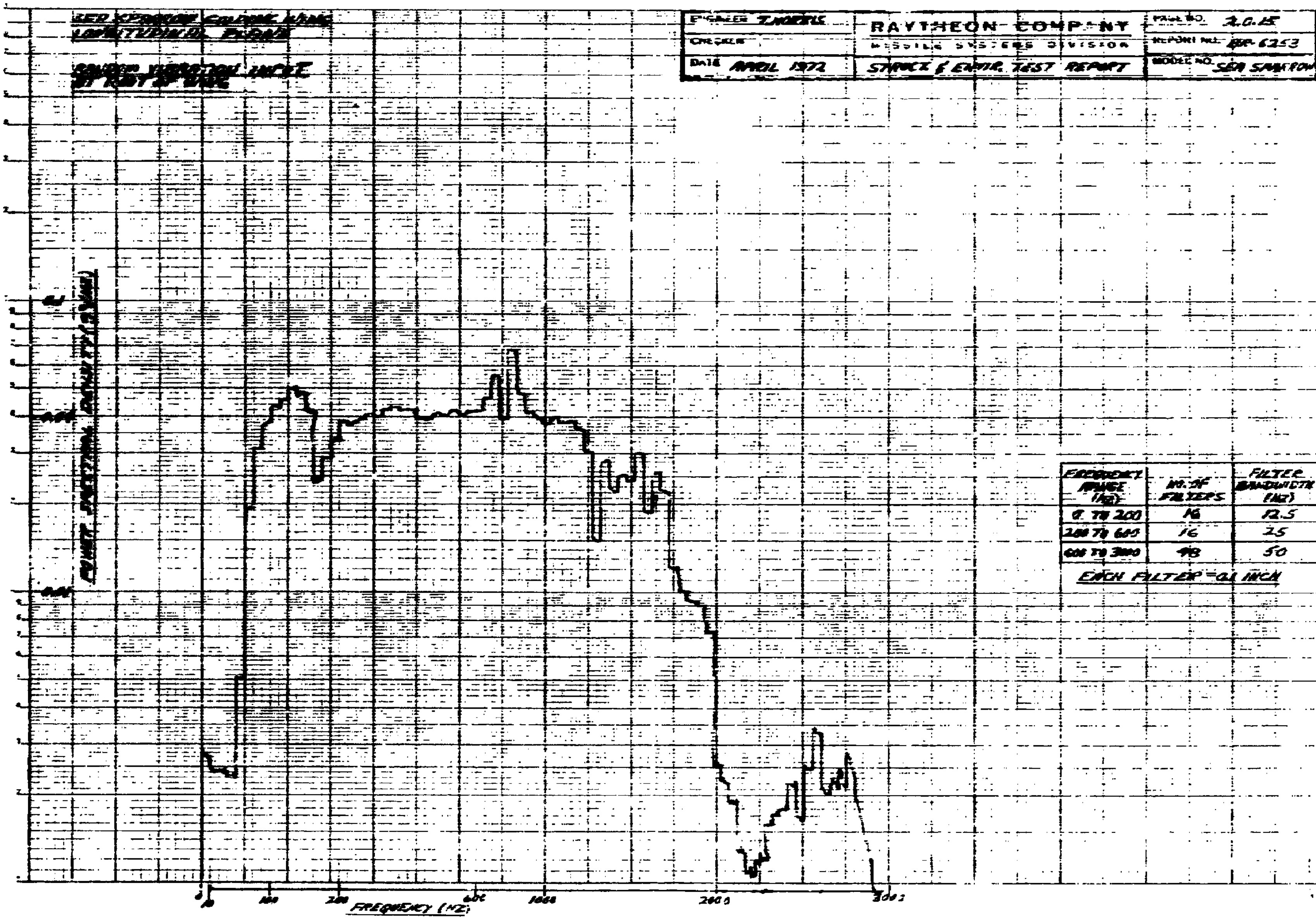
RANDOM VIBRATION RESPONSE
AT TIP OF WING

ENGINEER T. NORRIS	RAYTHEON COMPANY	PAGE NO. 2.3.M
CHECKER	MISSILE SYSTEMS DIVISION	REPORT NO. BR-6253
DATE APRIL 1972	STRUCT. & ENVIR. TEST REPORT	MODEL NO. SEA SPARROW

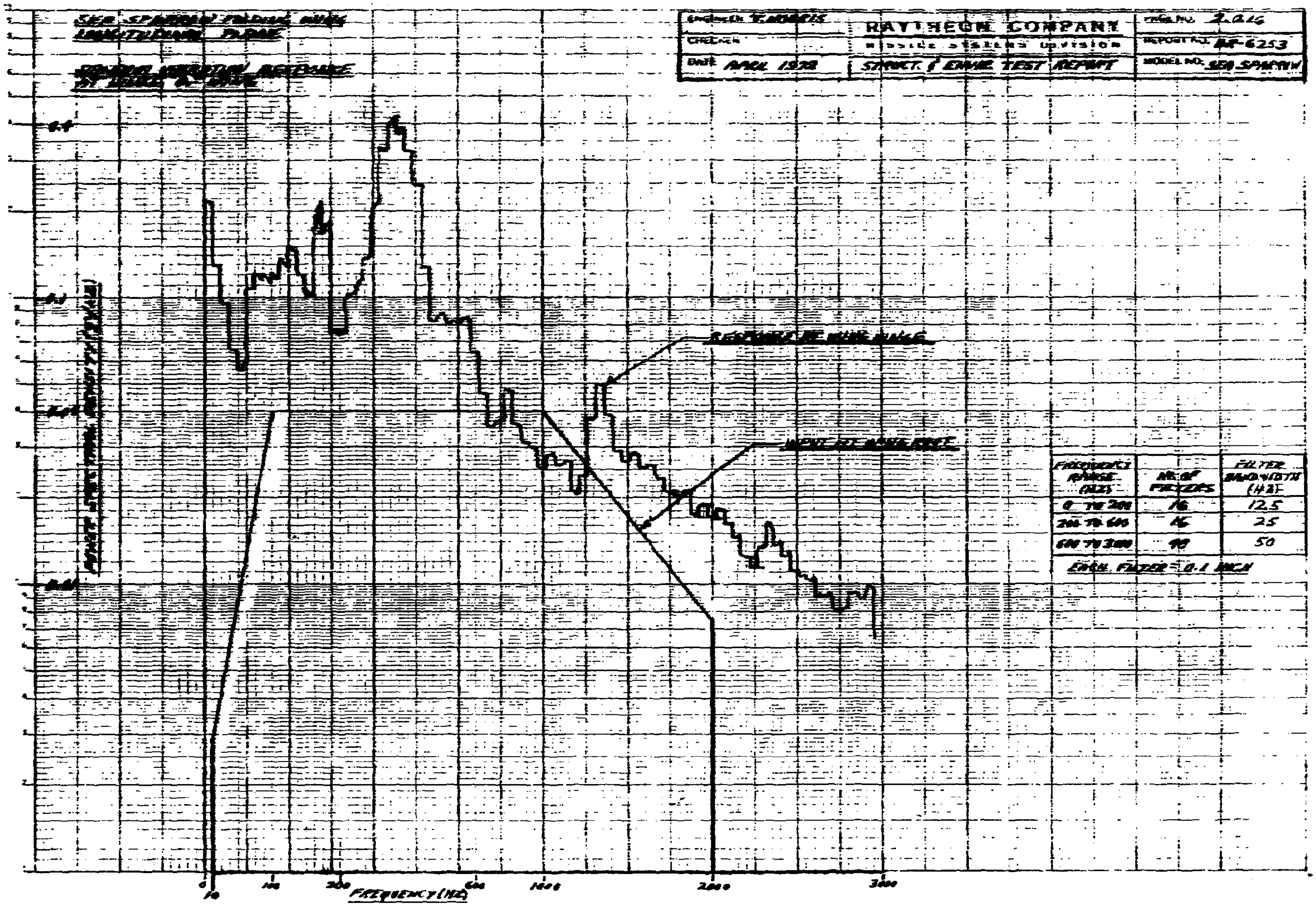


FREQUENCY RANGE (HZ)	NO. OF FILTERS	FILTER BANDWIDTH (HZ)
0 TO 200	16	12.5
200 TO 600	16	25
600 TO 3000	48	50

EACH FILTER = 3.1 INCH



ENGINEER T. NORRIS
CHECKER
DATE APRIL 1972
RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
STRUCT. & ENVIR. TEST REPORT
PAGE NO. 2.0.15
REPORT NO. BR-6253
MODEL NO. SEA SPARROW
POWER SPECTRAL DENSITY (G²/HZ)
FREQUENCY (HZ)
0
100
200
600
1000
2000
3000
FREQUENCY RANGE (HZ)
NO. OF FILTERS
FILTER BANDWIDTH (HZ)
0 TO 200
16
12.5
200 TO 600
16
25
600 TO 3000
48
50
EACH FILTER = 0.1 INCH


SEA SPARROW FOLDING WING
LONGITUDINAL PLANE
RANDOM VIBRATION RESPONSE
ENGINEER
CHECKER
DATE APRIL 1972
RAYTHEON COMPANY
MISSILE SYSTEMS DIVISION
STRUCT. & ENVIR. TEST REPORT
PAGE NO. 2.216
REPORT NO.
MODEL NO. SEA SPARROW
POWER SPECTRAL DENSITY (G²/HZ)
0.4
0.1
0.04
0.01
RESPONSE AT WING HINGE
INPUT AT WING ROOT
FREQUENCY RANGE (HZ)
NO. OF FACTORS
FILTER BANDWIDTH (HZ)
0 TO 200
16
12.5
200 TO 600
16
25
600 TO 3000
48
50
EQUAL FILTER = 0.1 INCH
0
10
100
200
FREQUENCY (HZ)
600
1000
2000
3000

ENGINEER T. MORRIS	RAYTHEON COMPANY	PAGE NO. 2.617
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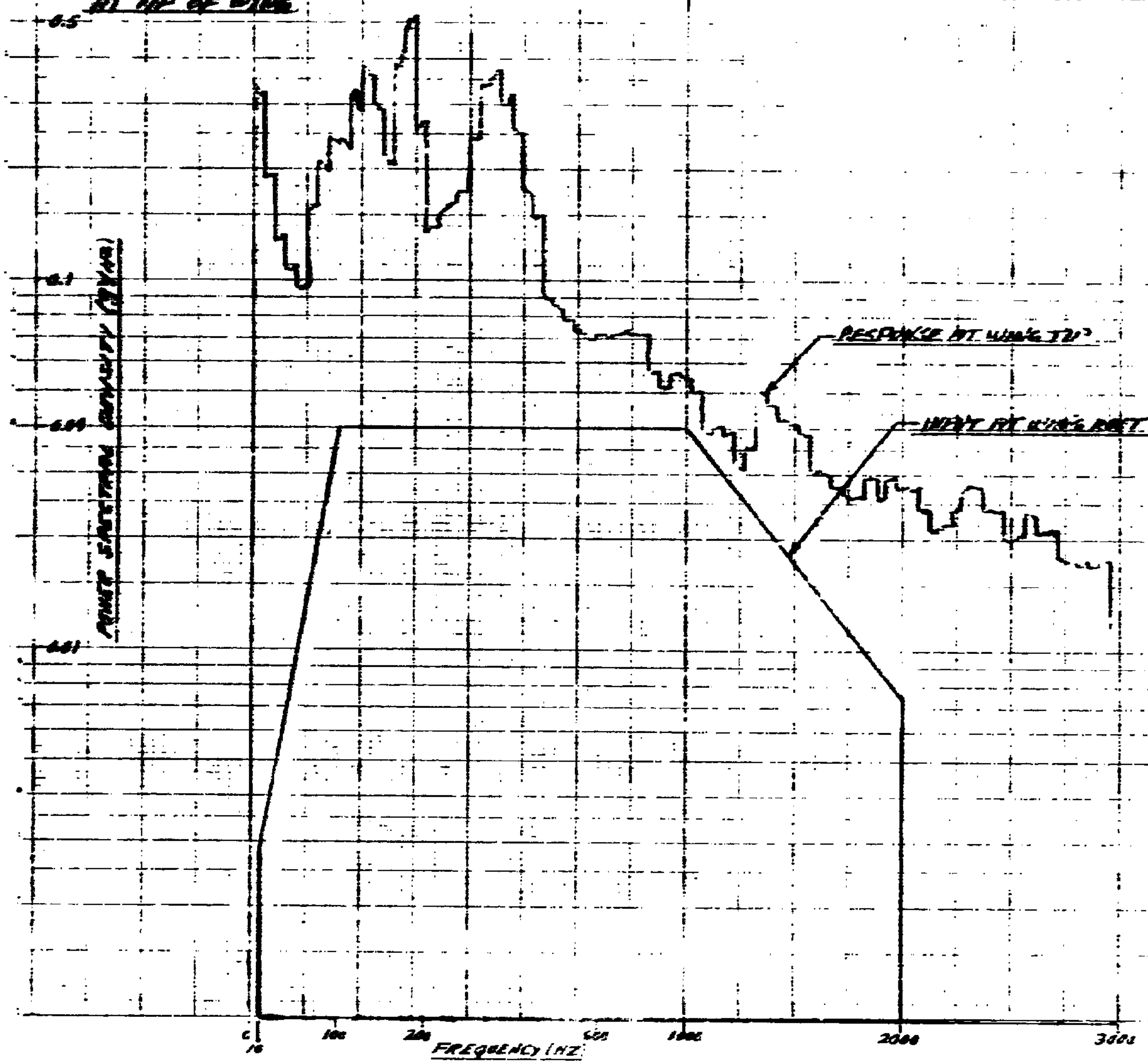
DATE APRIL 1972	STRUCT. & ENVIR. TEST REPORT	MODEL NO. SEA SPARROW



FREQUENCY RANGE (HZ)	NO. OF FILTERS	FILTER BANDWIDTH (HZ)
3 TO 200	16	12.5
200 TO 600	16	25
600 TO 3000	48	50

EACH FILTER - 0.1 INCH

SECTION 3

ENVIRONMENTAL TESTS

SECTION 3.1

SHIPBOARD STORAGE ENVIRONMENT TEST

SHIPBOARD STORAGE ENVIRONMENT TEST

OBJECT

The object of this test was to evaluate the effects of exposure on the folding wing assembly after it had been subjected to a shipboard storage environment for a 6-month period. The primary interest was in the interaction of high stress and environment on the torsion bar.

CONCLUSION

It can be concluded from the results of this test that the 6-month shipboard storage environment had no visible effects on the components or the deployment capability of the folding wing.

DESCRIPTION OF TEST ARTICLES

Four Folding Wing Assemblies were used for this test. Those folding wings conformed to the Reference (a) drawing. The inner wing section of an assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of an assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

The torsion bar, which is an integral part of a folding wing assembly, conformed to the Reference (b) drawing. The torsion bar was fabricated from 1890 nickel maraging alloy steel, grade 350, and was heat treated to RC 57-61.

INSTRUMENTATION

No instrumentation was required for the shipboard storage environment test.

TEST ARRANGEMENT

A complete dummy AIM-7E missile, equipped with the four folding wing assemblies, was stored in a modified MK 128 Mod 0 launch cell. That launch cell was modified so that the four folding wings were restrained in the folded position. The mounting geometry was similar to that for the NSSMS GMLS Launcher.

The shipboard environment for the test was provided by the USS Norton Sound (AVM-1). The installation of the dummy missile in the modified launch cell was performed at the Naval Missile Systems Engineering Station at Port Hueneme, California. The test was conducted for a period of 6 months during the normal operations of the AVM-1, commencing on the date of installation of the dummy missile in the modified MK 128 Mod 0 launch cell.

TEST PROCEDURE

At the completion of the 6-month shipboard storage period, the Hydraulic Control Section Shell, with the four Folding Wings restrained in the folded position, was disassembled from the dummy missile, crated and shipped to Raytheon Company, Bedford, Massachusetts.

TEST PROCEDURE (continued)

Each folding wing was deployed on the test sled at velocity levels simulating the actual launch conditions. The wing deployment times were monitored electronically. A complete description of the sled tests is given in Section 3.5 of this report.

At the completion of the sled tests, the folding wings were disassembled, and each component inspected for adverse environmental effects.

TEST RESULTS

The four folding wings deployed and locked successfully on the test sled. A complete table of the sled test results is presented in Section 3.5 of this report.

Also, a visual inspection of each component of the four folding wings showed no adverse environmental effects.

SECTION 3.2

TEMPERATURE-HUMIDITY TEST

TEMPERATURE-HUMITITY TEST

OBJECT

The object of this test was to determine if the folding wing assembly could be deployed and locked successfully after being subjected to the temperature-humidity environment specified for a period of 96 hours.

CONCLUSION

It can be concluded from the results of this test that the folding wing assembly can be successfully deployed and locked after sustaining the temperature-humidity environment specified for a period of 96 hours.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing. The inner wing section of the assembly is a casting fabricated from AMS 4229 aluminum-alloy (KO-1) tempered to a T7 condition. The outer wing section of the assembly is a casting fabricated from A356 aluminum-alloy tempered to a T6 condition.

INSTRUMENTATION

No instrumentation was required for the temperature-humidity test.

TEST EQUIPMENT

A model 64 STR-100200 (Tenney Engineering, Inc.) High and Low Temperature and Humidity Chamber was used for this test. Accessories to control the

TEST EQUIPMENT (continued)

temperature and humidity are part of the chamber, also, The temperature range of the chamber is -75°F to +350°F. The humidity range of the chamber is 20% to 95%.

TEST ENVIRONMENT

The folding wing assembly was subjected to a temperature-humidity test for a period of 96 hours in accordance with the Reference (6) document with the following modification: The low temperature of the temperature cycle was -65°F. The folding wing assembly was cycled between the temperature extremes of +160°F to -65°F. The relative humidity control was set for 95% at the high temperature level and was not controlled for the low temperature level.

TEST ARRANGEMENT

The folding wing assembly was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. A linkage arm was attached to the test fixture in such a manner that it could be positioned to restrain the folding wing in the folded position. A piece of nylon cord was attached to the linkage arm so that the folding wing could readily be deployed without removing the test setup from the chamber. A photograph of the test arrangement is shown on page 3.2.4.

TEST PROCEDURE

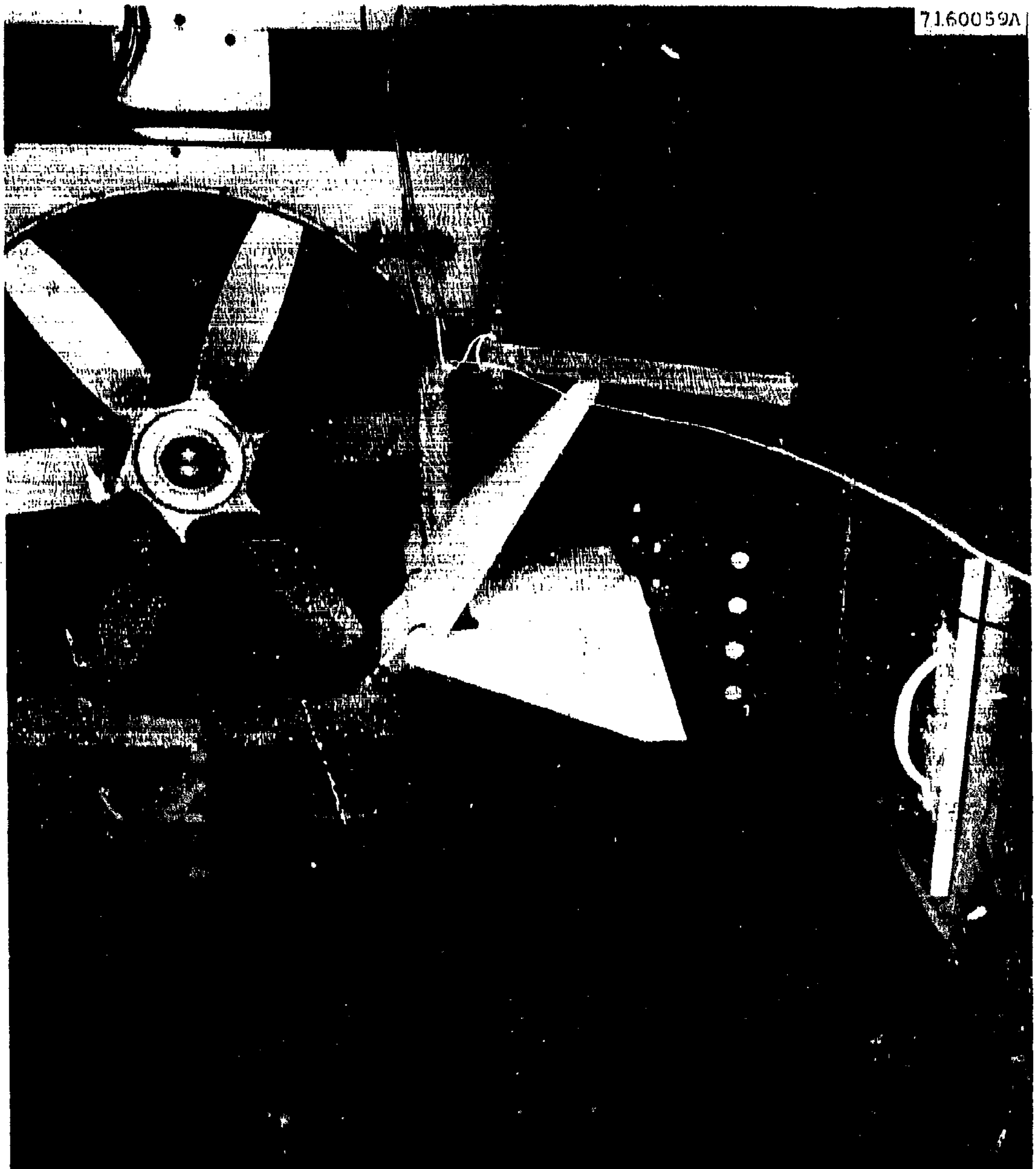
The folding wing assembly test setup was positioned in the test chamber so that the wing deployment could be tested without having to reposition the test setup.

The chamber temperature was increased gradually from ambient to 160°F, and the relative humidity control was set for 95%. This condition was maintained for a period of 16 hours. Then, the chamber temperature was lowered gradually to -65°F, and the relative humidity was not controlled. This condition was maintained for a period of 16 hours, also. Three complete cycles of the above two test conditions were conducted in order to complete this phase of the test.

At the completion of the three cycles the chamber was returned gradually to 160°F, and the folding wing was tested within the chamber for satisfactory wing deployment and panel locking. Then, the chamber was returned gradually to ambient temperature, the folding wing was reset in the folded position and deployed again. The folding wing was reset in the folded position again and the chamber temperature was lowered gradually to 30°F. The folding wing was deployed for the third time to complete this test.

TEST RESULTS

The folding wing assembly deployed and locked successfully each time it was checked during the test, and at the completion of the test.



Temperature - Humidity Test Setup

SECTION 3.3

SALT SPRAY TEST

SALT SPRAY TEST

OBJECT

The object of this test was to determine if the folding wing assembly could be deployed and locked successfully after being subjected to the salt spray environment specified for a period of 48 hours.

CONCLUSION

It can be concluded from the results of this test that the folding wing assembly can be successfully deployed and locked after sustaining the salt spray environment specified for a period of 48 hours.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing, and is the same folding wing that had sustained the temperature-humidity environment.

INSTRUMENTATION

No instrumentation was required for the salt spray test.

TEST EQUIPMENT

A Model SS-3-8 (Associated Testing Laboratory, Inc.) Salt Fog Chamber was used for this test. Accessories to control temperature and percentage of salt solution are part of the chamber, also.

TEST ENVIRONMENT

The folding wing assembly was subjected to a salt spray environment for a period of 48 hours, with the test chamber temperature set at 95°F and the salt solution set at 5%, as specified in the Reference (7) document.

TEST ARRANGEMENT

Due to the physical limitations of the Salt Fog Chamber, the folding wing could not be secured within a mock-up launcher cell section as specified in the Reference (2) document. Therefore, the folding wing assembly was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. A linkage arm was attached to the test fixture in such a manner that it could be positioned to restrain the folding wing in the folded position. A piece of nylon cord was attached to the linkage arm so that the folding wing could readily be deployed without removing the test setup from the chamber. That test arrangement was more severe than that specified in the Reference (2) document, since the folding wing was directly exposed to the salt spray stream. A photograph of the test arrangement is shown on page 3.3.4.

TEST PROCEDURE

The folding wing assembly test setup was positioned in the test chamber so that the wing deployment could be tested without having to remove the test setup from the chamber.

TEST PROCEDURE (continued)

The chamber controls were set to maintain an internal chamber temperature of 95°F and a 5% salt solution. Those test conditions were maintained for a period of 48 hours.

At the completion of the test, the folding wing was tested for satisfactory wing deployment and panel locking.

TEST RESULTS

The folding wing assembly deployed and locked successfully at the completion of the test.

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Salt Spray Test Setup

SECTION 3.4

SAND AND DUST TEST

SAND AND DUST TEST

OBJECT

The object of this test was to determine if the folding wing assembly could be deployed and locked successfully after being subjected to the sand and dust environment specified for a period of 4 hours.

CONCLUSION

It can be concluded from the results of this test that the folding wing assembly can be successfully deployed and locked after sustaining the sand and dust environment specified for a period of 4 hours.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (a) drawing, and is the same folding wing that had sustained the temperature-humidity and the salt spray environments.

INSTRUMENTATION

No instrumentation was required for the sand and dust test.

TEST EQUIPMENT

A Model 375 (Nucledyne Company) Sand and Dust Chamber was used for this test. Accessories to control the dust (fine sand) concentration, velocity, temperature and humidity of the dust laden air are part of the chamber, also.

TEST ENVIRONMENT

The folding wing assembly was subjected to the sand and dust environment for a period of 4 hours in accordance with the Reference (6) document. The test was conducted with the chamber controls set to maintain a chamber temperature of 73°F and a relative humidity of less than 22%.

TEST ARRANGEMENT

The folding wing assembly was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That configuration was contained within a mock-up of a section of the launcher cell. The test fixture was mounted on a platform which had the capability of sliding in and out of the mock-up launcher cell section, which was open at both ends. The folding wing was restrained in the folded position in the launcher cell section by means of a simulated launcher rail section.

TEST PROCEDURE

The complete test setup configuration was positioned in the test chamber so that the open ends of mock-up launcher cell section were not directly exposed to the dust stream.

The chamber controls were set to maintain an internal chamber temperature of 73°F and a relative humidity of less than 22%. The air velocity was adjusted to 500 ± 200 feet per minute. The dust

TEST PROCEDURE (continued)

feeder was adjusted to control the dust concentration at 0.3 ± 0.2 grams per cubic foot. Those test conditions were maintained for a period of 4 hours.

At the completion of the test, the folding wing was tested for satisfactory wing deployment and panel locking by sliding the test fixture out of the cell until the wing was no longer restrained by the simulated launcher rail section.

TEST RESULTS

The folding wing assembly deployed and locked successfully at the completion of the test.

SECTION 3.5

IGNITION IMPULSE TESTS

IGNITION IMPULSE TESTS

OBJECT

The objects of these tests were to determine if the folding wing assemblies, after exposure to several environmental conditions, could be deployed and locked successfully when accelerated down the test track during ignition impulse tests, and to determine if there was any degradation in folding wing deployment.

CONCLUSION

It can be concluded from the results of these tests that the folding wing assemblies can deploy and lock successfully and are not appreciably degraded, after being exposed to the environmental conditions contained in this report.

DESCRIPTION OF TEST ARTICLES

Six Folding Wing Assemblies were used for this test. Those folding wings conformed to the Reference (a) drawing. Four of the folding wings were previously subjected to the Shipboard Storage Environment, and one of the folding wings was previously subjected to the Temperature-Humidity, Salt Spray, and Sand and Dust Environmental Tests. The sixth folding wing was not exposed to any environmental test conditions.

INSTRUMENTATION

The pre-load required for the acceleration device to simulate the missile launch velocity, was measured and recorded with a Baldwin-Lima-Hamilton electric load cell and load recorder combination.

INSTRUMENTATION (continued)

Photo-electric cells, positioned at selected stations along the track, were used to measure the time required for the folding wing to fully deploy. An electronic digital counter was used to measure the deployment time.

TEST EQUIPMENT

An acceleration test track, to simulate missile launch velocity, was used for this test. The test track is 30 feet long and contains a carriage that can slide along the track.

TEST ARRANGEMENT

The folding wing was conventionally attached to an AIM-7E actuator shaft which was contained within a segment machined from a missile hub block. That hub block was mounted to the carriage which could slide along the 30-foot track.

The folding wing test setup was accelerated along the track by means of a 3/4-inch diameter bungee cord pre-loaded to produce a velocity profile similar to the actual missile launch velocity. The transient thrust at ignition of the AIM-7E rocket motor which causes a high intensity, low duration impulse to the missile, was simulated by means of two compression springs which were compressed when the test setup was initially positioned prior to test. Upon release of the test setup, the compression springs subjected the folding wing to a longitudinal aft to forward shock of no less than a 30 g peak for a minimum duration of 2 milliseconds.

TEST ARRANGEMENT (continued)

As the test setup traveled along the track, it uncoiled a 21-foot nylon rope, which when it became taut, decelerated the sled.

An aluminum tube guide rail dimensionally simulating the location of the missile launch cell rail, was mounted adjacent to the track against which the folded outer wing panel was restrained. The guide rail could be mounted on either side of the track, depending on whether the folding wing being tested deployed to the left or to the right. The folding wing when released would initiate deployment as the trailing edge of the outer wing panel cleared the end of the aluminum tube guide rail.

A photograph of the test arrangement is shown on page 3.5.6. The photograph, however, does not show the final positioning of the photo-electric cells used to obtain the wing deployment time. In actuality, one photo-electric cell was positioned at the end of the guide rail, so that the folding wing would break the beam, and activate the electronic digital counter, as it started to deploy. Another photo-electric cell was positioned down the track so that the tip of the folding wing, when locked in position, would break the beam and de-activate the digital counter.

TEST PROCEDURE

The folding wing test setup, with the wing restrained in the folded position by the guide rail was pinned to the track at the initial starting position. The bungee cord was stretched until the desired pre-load of 450 pounds was attained. The pin securing the sled to the track was then released allowing the folding wing test setup to accelerate along the track. The maximum time of travel required for the wing to fully deploy was measured and recorded.

TEST RESULTS

A total of six folding wings were accelerated down the test track. Four of the wings were previously subjected to the Shipboard Storage Environment and had been kept restrained in the folded position. One of the wings was previously subjected to the Temperature-Humidity, Salt Spray, and Sand and Dust Environmental Tests. The sixth folding wing had not been exposed to any environmental test conditions and was tested so as to obtain a comparison of the time required to deploy the wings. The results of the test are as follows:

	Folding Wing	Max. Time to Deploy
Shipboard Storage	1	65.21 milliseconds
	2	66.46 milliseconds
	3	64.48 milliseconds
	4	65.38 milliseconds
T-H, SS, S&D	5	63.10 milliseconds
New	6	62.50 milliseconds

TEST RESULTS (continued)

The tests were conducted as the folding wings became available, therefore, the spread in deployment times can be partially attributed to the tolerances in repositioning the photo-electric cells. Also, an additional reason for the spread in deployment times can be attributed to the tolerances when applying the 450-pound pre-load.

At the completion of the tests, folding wings 1 to 5 were disassembled, and each component was visually inspected. No adverse environmental effects were evident.

Ignition Impulse Test Setup - Side View

ADDENDUM

INTRODUCTION

The Reference (a) folding wing assembly, which contains the Reference (b) torsion bar, successfully withstood the structural and environmental testing program reported herein. However, the results of the wing deployment wind tunnel tests was intended to provide the basis for the final selection of the torsion bar dimensions.

To satisfy the 70 knot wind tunnel test condition, it was found that a larger diameter torsion bar was needed. A larger diameter torsion bar will experience a higher torsional shear stress when the folding wing is restrained in the folded position in the launch cell. Since long term storage under stress in a shipboard environment is a normal operational requirement of the folding wing, additional environmental tests were performed.

Those environmental tests which are pertinent to the torsion bar and are required for the folding wing qualification are the six-month shipboard storage environment test, the salt spray environment test, the temperature-humidity environment test and the torsion bar endurance test.

The following environmental tests were performed on three folding wing assemblies, each of which contained a torsion bar of a different diameter.

INTRODUCTION (continued)

Direct salt spray environmental tests were conducted on three unprotected folding wings similar to the salt spray test in Section 3.3 of this report, and then followed by temperature-humidity environmental tests using the same folding wings. The folding wings were kept restrained in the folded position at all times. The tests were conducted without cleaning the folding wings of any foreign matter that had accumulated. At the completion of the tests, the folding wings were stored for one month in an uncontrolled ambient environment. The folding wings were not cleaned and were kept restrained in the folded position throughout the one-month storage period. Thut sequence of testing was selected to cause the highest probability of salt solution contamination of the torsion bars. At the completion of the one-month storage period, the folding wings were tested for wing deployment and locking on the acceleration test track.

In addition, the endurance capability of the final torsion bar configuration was determined by conducting a torsion bar endurance test.

It should be noted that the folding wing assembly, containing the final torsion bar configuration, will be subjected to a shipboard storage environment for a 6-month period in the near future during the NATO Missile System Operational Test and Evaluation Program.

ENVIRONMENTAL TESTS

OBJECT

The object of these tests was to determine if the three modified folding wing assemblies, with the three candidate torsion bars, after being exposed to direct salt spray and temperature-humidity environments could be deployed and locked successfully when accelerated down the test track during ignition impulse tests.

CONCLUSION

It can be concluded from the results of these tests that the three modified folding wing assemblies, with the three candidate torsion bars, will deploy and lock successfully after being exposed to direct salt spray and temperature-humidity environments.

DESCRIPTION OF TEST ARTICLES

The three folding Wing Assemblies used for these tests are similar to the Reference (a) Folding Wing Assembly except that each assembly contained a different size torsion bar. The Reference (b) torsion bar has a 0.180 inch diameter, whereas the three candidate torsion bars have 0.190 inch, 0.200 inch and 0.210 inch diameters. Also, the individual wing components (hinge tube and end fittings) that interface with the Reference (b) torsion bar were modified to insure compatibility.

INSTRUMENTATION

No instrumentation was required for the direct salt spray and temperature-humidity tests.

For the ignition impulse tests, the pre-load required for the acceleration device was measured and recorded with a Baldwin-Lima-Hamilton electric load cell and load recorder combination.

TEST EQUIPMENT

The test equipment used for the direct salt spray, the temperature-humidity and the ignition impulse tests are the same as for the previous tests and are identified in Sections 3.3, 3.2 and 3.5.

TEST ARRANGEMENT

The test arrangements are the same as for the previous tests and are explained in detail in Sections 3.3, 3.2 and 3.5.

The exceptions to the similarities of the test arrangements was that no nylon cords were attached to the linkage arms restraining the wings in the folded position, and no photo-electric cells were used for the ignition impulse tests.

TEST PROCEDURE

The direct salt spray environmental tests were conducted first. The test procedure was the same as the previous salt spray environmental test except that the folding wings were kept restrained in the folded position and not tested for satisfactory wing deployment.

TEST PROCEDURE (continued)

At the completion of the salt spray environmental tests, the temperature-humidity environmental tests were conducted. The test procedure was the same as the previous temperature-humidity environmental test except that again, the folding wings were kept restrained in the folded position and not tested for satisfactory wing deployment.

At the completion of the temperature-humidity environmental tests, the folding wings, still restrained in the folded position and still contaminated by foreign matter from both environmental tests, were stored for one month in an uncontrolled room ambient environment.

At the completion of the one-month storage period, the folding wings, still restrained in the folded position and still contaminated, were set up and accelerated down the test track. The test procedure was the same as the previous ignition impulse tests except that no photo-electric cells were used to obtain the deployment time.

Photographs of one of the folding wings after the completion of the one-month storage period and prior to deployment are shown on pages A.2.4, A.2.5 and A.2.6.

TEST RESULTS

The three modified folding wings, with the three candidate torsion bars, which were still contaminated from the previous environmental tests, deployed and locked successfully when accelerated down the test track.

TEST RESULTS (continued)

At the completion of the final test, the folding wings were disassembled and each component was visually inspected. A photograph of one of the disassembled folding wings showing all the disassembled components is shown on page A.2.7. There was evidence of contamination on some of the components and on the inner and outer wing panels that had been directly exposed to the test environments, however, the three candidate torsion bars and hinge tubes showed no visual indications of adverse environmental effects.

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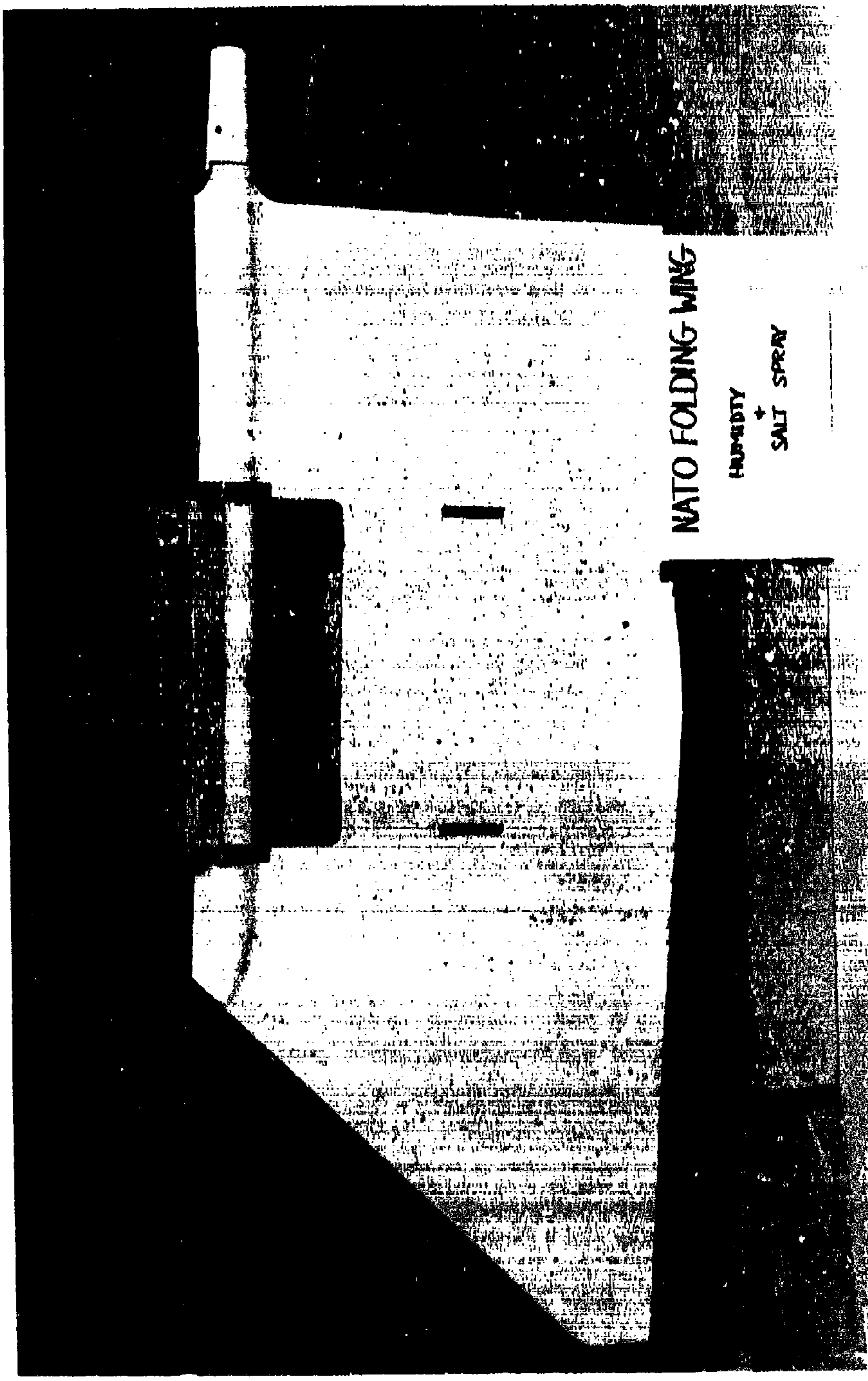

7163138A

Modified Folding Wing After Salt Spray and Temp.-Hum. Tests

Form No. V-1028

7163139A

Closeup of Modified Folding Wing After Salt Spray and Temp. - Hum. Tests

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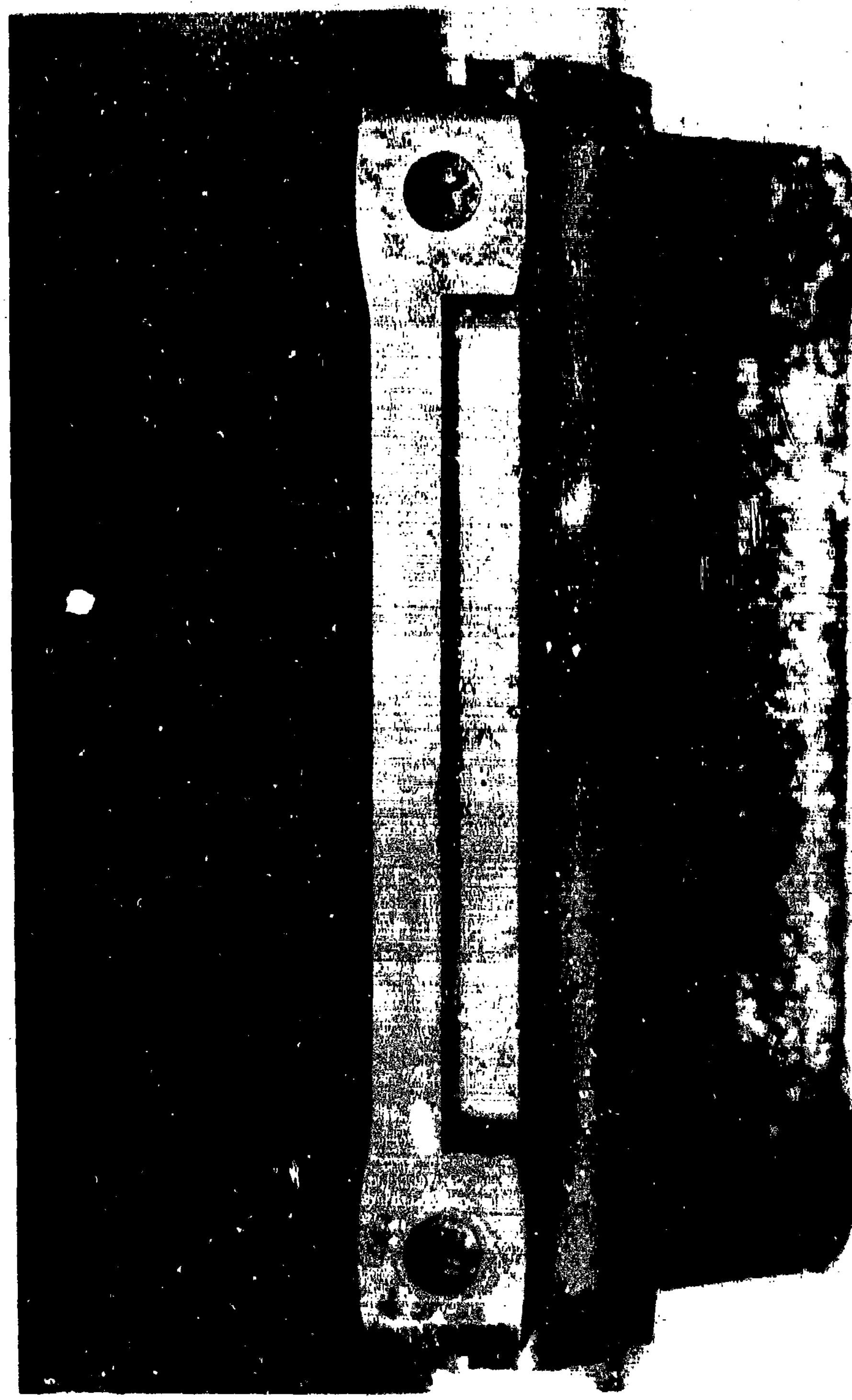

7163140A

Closeup of Modified Folding Wing After Salt Spray and Temp. - Hum. Tests

Form No. V-1028

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Modified Folding Wing - Disassembled After Final Test

Form No. V-1028

TORSION BAR ENDURANCE TEST

OBJECT

The object of this test was to determine the number of cycles the modified folding wing, with the final (0.230 diameter) torsion bar, could sustain prior to failure of the torsion bar, when subjected to a fluctuating torsional shear stress which the torsion bar would experience when the folding wing is restrained within the launch cell.

CONCLUSION

It can be concluded from the results of this test that the final torsion bar can sustain in excess of 600,000 cycles without failure, when subjected to the fluctuating torsional shear stress that the folding wing would experience when restrained within the launch cell.

DESCRIPTION OF TEST ARTICLE

The Folding Wing Assembly used for this test conformed to the Reference (c) drawing. The torsion bar, which is an integral part of the folding wing assembly, conformed to the Reference (d) drawing and is shown in Figure 9 on page A.3.3.

The only differences between the References (c) and (d) test articles and the previous References (a) and (b) test articles are that the Reference (d) torsion bar has a larger diameter (0.230 inch vs. 0.180 inch), and the individual wing components that interface with the Reference (b) torsion bar were modified to be compatible with the Reference (d) torsion bar.

INSTRUMENTATION

No instrumentation was required for the torsion bar endurance test.

TEST EQUIPMENT

An adjustable speed motor driven mechanical vibrator was used for this test.

LOADS

Due to shipboard motion, the missile will rotate within the tolerance extremes of the missile to launch rail interface, resulting in a fluctuating torsional shear stress in the torsion bar.

A 10 degree rotation of the outer wing panel was selected as the test condition. That represents a conservative lateral translation of the missile within the launch cell. The fluctuating torsional shear stress component was superimposed on the nominal steady state torsional shear stress in the torsion bar by cycling the folding wing between 125 degrees and 135 degrees, where 135 degrees is the maximum outer wing panel rotation.

TEST ARRANGEMENT

The modified folding wing assembly was secured to a test fixture which contained an actual AIM-7E missile wing shaft assembly. That test fixture was secured to a rigid test fixture in such a manner that the outer wing panel would be in a horizontal position when rotated 130 degrees. A photograph of the test arrangement is shown on page A.3.4, and as can be noted the outer wing panel was restrained by a clamp and turnbuckle arrangement which was attached to the mechanical vibrator.

TEST PROCEDURE

The mechanical vibrator was adjusted so that the outer wing panel would be cycled $\pm$ 5 degrees from the horizontal position of 130 degrees.

The folding wing was cycled at a frequency of 2.6 cycles per second, the slowest capability of the mechanical vibrator, as compared to the shipboard vibration environment of 6 to 9 cycles per minute.

At each half-hour interval, the endurance test was stopped and the folding wing checked for failure of the torsion bar.

TEST RESULTS

After 617,760 cycles had been completed, with the final torsion bar still functioning satisfactorily, the test was stopped.

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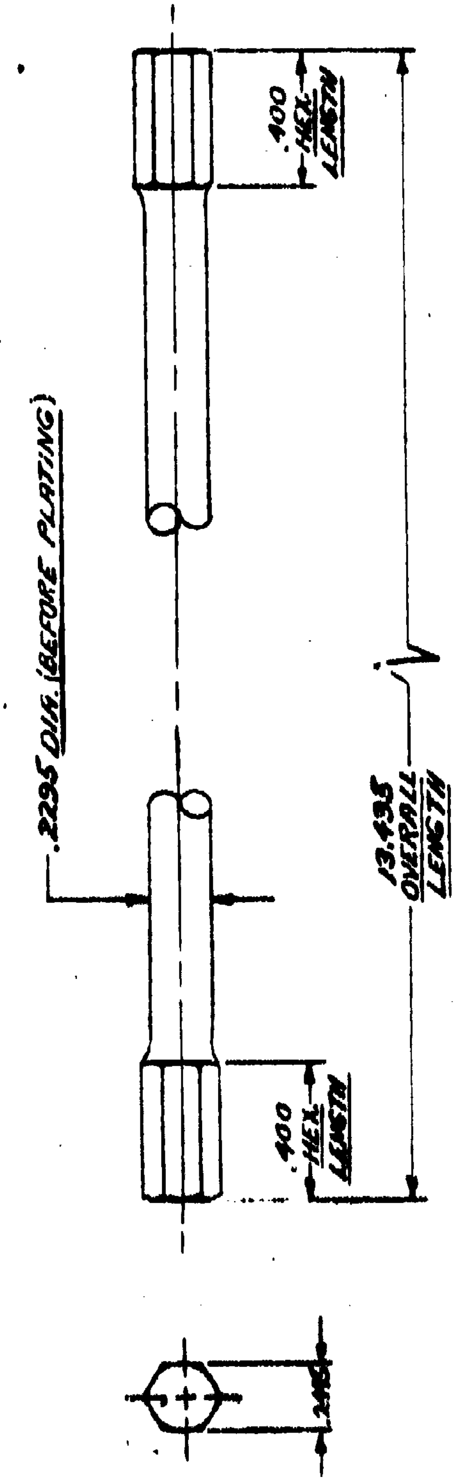

TORSION BAR

FIGURE 9

Form No. V-1028C

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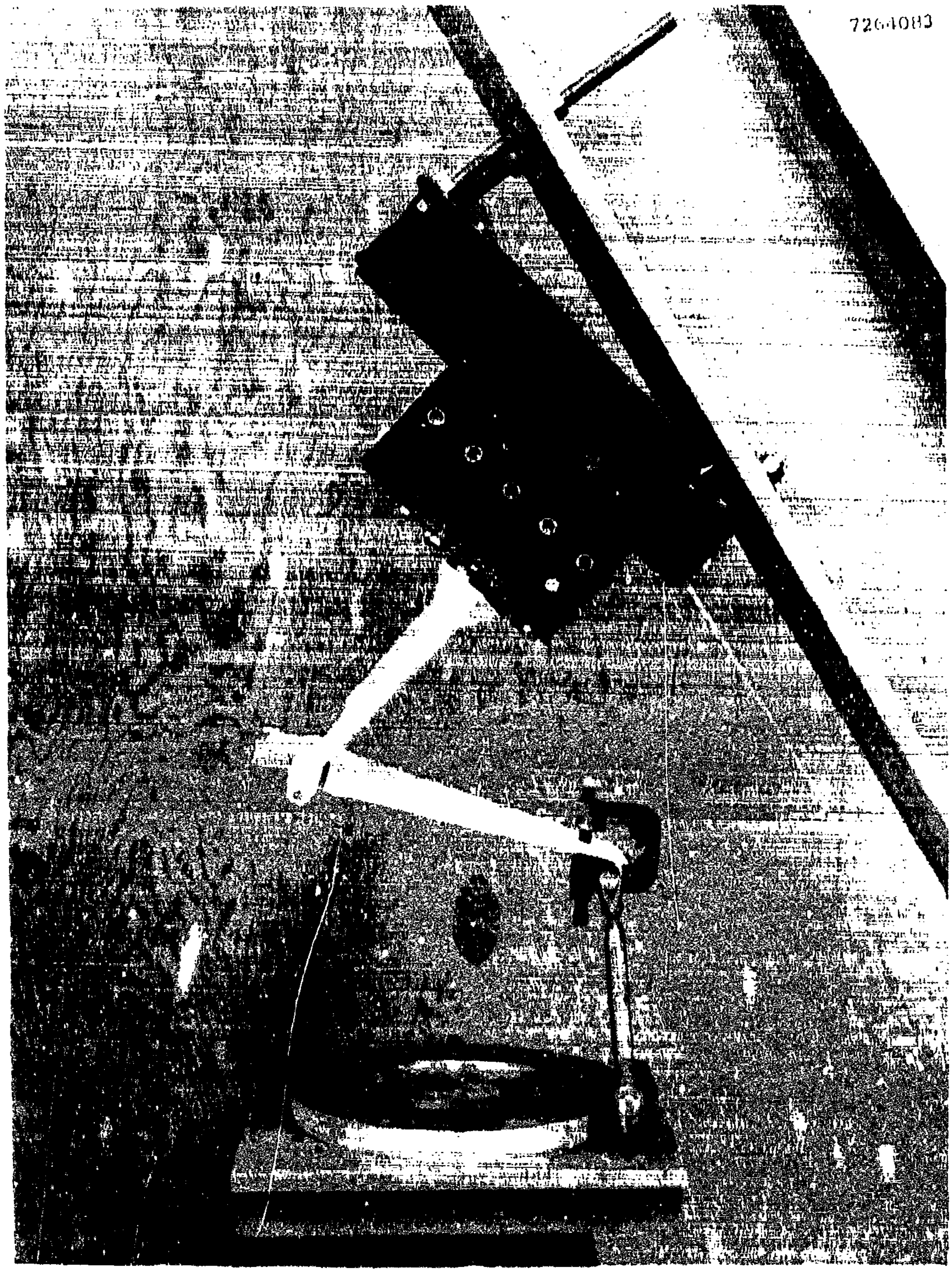

Torsion Bar Endurance Test Setup .