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RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

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5-6-66	JF	Added Section K_1, Pages K_1-1 to K_1-31 Added pages 2.9 and 2.10 to Table of Contents	A
8-9-66	JF	Added Section Q, Pages Q-1 to Q-35 Added Page 2.17 to Table of Contents	B
10-20-66	EM	Added Section T, Pages T-1 to T-30 Added Page 2.20 to Table of Contents	C
12-12-66	EM	Added Section S, Pages S-1 to S-13 Added Page 2-19 to Table of Contents	D
1-6-67	MB	Added Section B, Pages B-1 to B-14. Added Page 2.1 to Table of Contents	E
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4-5-67	MB	Added Section P, pages P1-P70. Added Page 2.16 to Table of Contents	G

TEST RESULTS FOR THE LEM LANDING GEAR

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TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

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TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

PREFACE

This report contains the results of all tests described in LTP-904-10001, Pl n for the Landing Gear Component Development Tests. The report is submitted in accordance with Paragraph 5.5 of Exhibit E to Contract NAS 9-1100.

The format of this report is essentially the same as that of LTP-904-10001. Section A of the report corresponds to Section A of the plan, etc. Since some tests extend over a longer period of time than others, the sections of this report are not published in their proper alphabetical sequence.

Information concerning the dates of the test, and the particular test hangar at the Grumman Facility in Bethpage where the tests were conducted, are included in the individual sections of this report.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

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RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

REFERENCES

Grumman Drawings

LSK 320-10508	Cartridge Assembly - Primary Strut
LSK 320-10523	Cartridge Assembly - Primary Strut
LSK 320-10525	Cartridge Assembly - Primary Strut
LSK 320-10540	Cartridge Assembly - Secondary Strut
LSK 320-10541	Cartridge Assembly - Secondary Strut

Grumman Test Plans

LTP 904-10001 Section B	Crushable Cartridges - Intermediate and Full Size

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

INTRODUCTION

This section contains the results of tests performed in accordance with LTP 904-10001, Section B "Crushable Cartridges - Intermediate and Full Size Specimens."

Prior to the release of this report an earlier report was issued by the Mechanical Design Group containing the test results pertinent to their design effort. Upon review of this earlier report, it was felt that additional reporting of detailed test results, data, etc. would be needless duplication. For this reason, and with the cognizance of the Design Group, the earlier report is included in full as an addendum to this report.

The text of this section is limited to a summary of results, detailed description of test apparatus, procedures, and instrumentation. All tests were conducted in the Grumman Structural Test Laboratory in Bethpage, N.Y. The period of testing lasted from June 1964 until June 1965.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

1.0 PURPOSE OF TEST

The over-all objective of the test program is the development of impact energy-absorbers within the load levels and dimensional confines of the LEM Landing Gear Assembly. The present phase was concerned more specifically with the evaluation of crushable cartridges which, when contained within the landing gear struts, would stroke or compress at Lunar Vehicle Touchdown.

2.0 TEST RESULTS SUMMARY

Because the afore mentioned report covers the design parameters, the summary here will be concerned with testing methods and requirements.

2.1 As a result of the initial phase of the test program, it was determined that aluminum honeycomb core offered the best development potential as a landing gear energy-absorber. The "Spiral Wrap" and "Truss-Grid" intended for use in the secondary strut cartridge would require further investigation.

2.2 The data obtained while being repeatable under static conditions exhibited some differences under dynamic and environmental extremes. For this reason it was considered necessary to investigate the basic construction of the honeycomb itself and to separate the effects of cell size, foil thickness, physical configuration and other properties. This consequently indicated the need for a large number of test specimens and duplicate testing for a complete evaluation.

2.3 From a structural standpoint, the ability of the cartridge to retain its basic shape and crush in a normal pattern seemed to depend on the consistency of the cell size, the domed end shape, and the separating plate between each stage.

2.4 After the start of the test program, it was learned that during the cartridge manufacturing process (at the vendor's) various heat treatments ~~were~~ used to adjust the cartridge crush load. The long term effects of these treatments were evident but not well defined and tended to obscure the final results. This fact indicates the need of a complete time history-treatment record of the honeycomb in order to insure the uniformity and condition of the final product.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

2.0 TEST RESULTS SUMMARY - continued

2.5 Based on the previous conclusions, it can be said that on a qualitative level honeycomb acts in a fairly predictable manner, but quantitatively it is definitely dependent on the total combination of material, shape, bonding, and techniques used in fabrication. Unless these factors are known, the energy-absorption characteristics of the honeycomb cannot be determined with any degree of repeatability.

3.0 DESCRIPTION OF TEST ARTICLES

At the beginning of the test program the test specimens consisted of a wide variety of honeycomb-type materials and configurations, many of which were eliminated quite early. After this opening phase, the effort was concentrated on the following types:

1. Honeycomb Aluminum - Type 3003 and 5052 of various cell sizes
2. Spiralgrid-Aluminum - 1/8 -5052-.0015P General Grid Corp.
3. Trussgrid-Aluminum - 1/8 -5052-.0015P General Grid Corp.

The diameters varied from 1½ to 8 inches and the lengths from 2 to 40 inches.

The testing of the aluminum honeycomb was then expanded to include several types of aluminum, foil thickness and cell size. Some of the honeycomb was manufactured into the final cartridge assemblies while the rest was in the form of cartridge components. A complete description of all the test specimens is provided in Para. 4.0 on page of the Addendum to this report. Photographs of representative samples are included in Figures and on pages B-[illegible] and B-12 of this report.

4.0 DESCRIPTION OF TEST

4.1 Test Program

This program exists as a parallel effort with the development of the landing gear itself. For this reason the early phase of the program was concerned with determination of design parameters and selection of materials and not with prototype designs.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

4.0 DESCRIPTION OF TEST - continued

4.1 Test Program - continued

Since the testing was largely exploratory it resulted in the use of a wide variety of materials, test methods and apparatus which were continuously being modified. After the initial phase in which the less promising types were eliminated a more defined program was set-up which is the basis of this report.

The basic program set up to test the cartridges was as follows:

4.1.1 Pre-crush the cartridges to eliminate the peak load and establish a constant crush level. This prepares the cartridge for the machining of the domed head on one end if desired.

4.1.2 Static crush a number of the cartridges fully under ambient conditions to establish constancy of crush load level and amount of energy-absorption available in the cartridge.

4.1.3 Static crush the cartridges fully under the specified environmental conditions (temperature, vacuum, and combined) as in Para. 2.0. The initial temperature range was from +200°F to -200°F. The vacuum level desired was 100 microns of Hg or better.

4.1.4 Dynamically crush the cartridges with a suitable weight at impact velocities of up to 25 feet per second under ambient conditions.

4.1.5 Dynamically crush the cartridges at impact velocities up to 25 feet per second under the environmental conditions listed in the static tests.

It was intended to perform the above sequence on several samples of the various types of cartridges. In some cases this was not possible due to a lack of test specimens.

4.2 Test Set-Up

Although most of the testing was to be done under ambient conditions the need to subject the cartridges to some environmental tests required the design and fabrication of special temperature-vacuum chambers. For comparison purposes all tests were then conducted using these chambers. The various chamber combinations are shown in drawing LSP 915-549 and in Figure 3 on page [illegible] The testing is separated into two categories as follows:

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

4.0 DESCRIPTION OF TEST - continued

4.2 Test Set-Up - continued

4.2.1 Static Tests

The static testing was accomplished by installing the chamber containing the cartridge in the Baldwin Testing Machine and proceeding to apply a compressive load. The chamber itself approximated the primary strut in internal geometry and configuration. It consisted of a 6.3" I.D. cylindrical chamber open at one end to a movable shaft and piston. Several pistons were made to adapt to the various cartridge end conditions. A load cell positioned at the bottom of the chamber was used to measure the crush load. To measure the stroke, a linear potentiometer was connected to the movable shaft giving an electrical readout. A plot of the load vs. stroke was obtained on an X-Y recorder. The environmental conditions were established by using either liquid nitrogen for low temperatures or the Wyle temperature control unit (with hot air) for the high temperatures.

4.2.2 Dynamic Tests

The set-up for the dynamic tests consisted of a 33-foot high drop tower, a weighted carriage and a chamber similar to the static test with the suitable instrumentation. The carriage had a loading capacity of 10,000 lbs. and a maximum drop height of approximately 15 ft. By adjusting the carriage weight and drop height, the desired impact energy could be obtained and consequently the load stroke could be generated. In this case the stroke was measured by a shaft-mounted rack driving a pinion and helipot giving an electrical readout. A load cell was used to measure the dynamic crush load with both load and stroke recorded on a direct writing recorder. The impact velocity was measured by the breaking of a pencil lead circuit at the point of impact (i.e. measuring the time to fall through a set distance).

As with the static tests, the environmental conditions were established by circulating either hot air (+200°F) or liquid nitrogen (-200°F) through a Wyle temperature control unit and around the chamber. The surface temperature of the cartridge was monitored by using thermocouples and a temperature bridge.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

4.0 DESCRIPTION OF TEST - continued

4.2 Test Set-Up - continued

4.2.2 Dynamic Tests - continued

An additional test was done to check the outgassing effects on the cartridge. The "outgassing" was accomplished by soaking the cartridges in a thermal-vacuum chamber for a period of 72-84 hours (simulating Lunar mission). The conditions were a vacuum of less than 1×10^{-6} mm Hg and temperatures of either +175°F or -175°F. The cartridges were then crushed at either the high or low temperature as in the soak period.

4.3 Test Procedure

The normal procedure used, as outlined in the test plan was as follows:

4.3.1 Static Test

4.3.1.1 Set up test chamber (LSK 915-549) on Baldwin Machine suitable for applying compressive load.

4.3.1.2 Record cartridge identification number and pre-crush load.

4.3.1.3 Insert cartridge in test chamber in accordance with drawing LSK 915-549 . For primary cartridge assemblies it is necessary to position the honeycomb so that the softer end (6000# stage longer cartridge) is in the movable upper piston of the cartridge. This will insure the load will be transmitted to the lower cartridge through the separation plate.

4.3.1.4 Check instrumentation (X-Y recorder, potentiometer, etc.) for proper operation.

4.3.1.5 Proceed to apply compressive load using the Baldwin testing machine. The load should be applied at a medium rate of speed or approximately 1000#/minute.

4.3.1.6 The load is applied for any pre-determined length or to the limit of the uniform crushing.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

4.0 DESCRIPTION OF TEST - continued

4.3 Test Procedure - continued

4.3.1.7 The cartridge is removed from the chamber and examined for any deviations from the normal crush pattern.

Environmental Tests

4.3.1.8 For temperature tests, prior to installation of the cartridge in the chamber, two thermocouples are attached to the test specimen and also one thermocouple to the load cell. These thermocouples are brought out through the electrical connector and monitored on a temperature bridge.

4.3.1.9 Using the temperature control unit (Wyle), the chamber is brought to its final level and allowed to soak for one hour before crushing the cartridge.

4.3.1.10 For outgassed cartridges the procedure is identical only occurring after 68-72 hours soak period.

4.3.2 Dynamic Test

4.3.2.1 Determine load-stroke and energy-absorption from the pre-crush value and the type of cartridge being tested.

4.3.2.2 Load the drop carriage with the appropriate weight and raise to the required height to give the desired impact energy.

4.3.2.3 Install cartridge in test chamber as shown in drawing LSK 915-549 (See Figure 3 on page B-13 of this report).

4.3.2.4 Check the instrumentation for proper resistance calibration (R.C.) for the expected load and stroke.

4.3.2.5 Release safety machanism and drop carriage.

4.3.2.6 Remove cartridge from chamber and examine for any deviations from normal crush pattern.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION B: CRUSHABLE CARTRIDGES - INTERMEDIATE AND FULL SIZE

4.0 DESCRIPTION OF TEST - continued

4.3 Test Procedure - continued

4.3.2 Dynamic Test - continued

Environmental Tests

4.3.2.7 The method used for the temperature tests is the same as that of the static test (Step 8, etc.)

4.3.2.8 For conducting vacuum tests at temperature, raise the temperature of the cartridge to the desired level and evacuate the chamber and allow it to stabilize.

4.3.2.9 After soaking for a minimum of one hour, proceed to crush as in the ambient test.

At the conclusion of all testing and data reduction all the various sequences of test points are plotted so that the characteristics of individual cartridges can be identified and compared.

5.0 INSTRUMENTATION

Instrumentation was provided for each test to obtain or derive the following information:

5.1 Static Tests

1. Axial Load - Strain Gage Load Cell (0-25,000 lbs.)
2. Stroke - Bourns or Helipot potentiometer (0-40 in.)
3. Plot of Load - Stroke - X-Y Recorder
4. Temperature - Thermocouples - Minimite Bridge ±200°F

5.2 Dynamic Tests

1. Axial Impact Load - Strain Gage Load Cell (0-25,000 lbs.)
2. Stroke - Rack - Gear - Helipot (0-60 in.)
3. Plot - Dynamic Load - Time (also Stroke - Time Direct Readout Oscillograph
4. Impact Velocity - Pencil Lead Circuit - Event Marker
5. Acceleration - Accelerometer (0-100 g's)
6. Temperature - Thermocouples - Minimite Bridge
7. Vacuum - Thermocouple Gauge

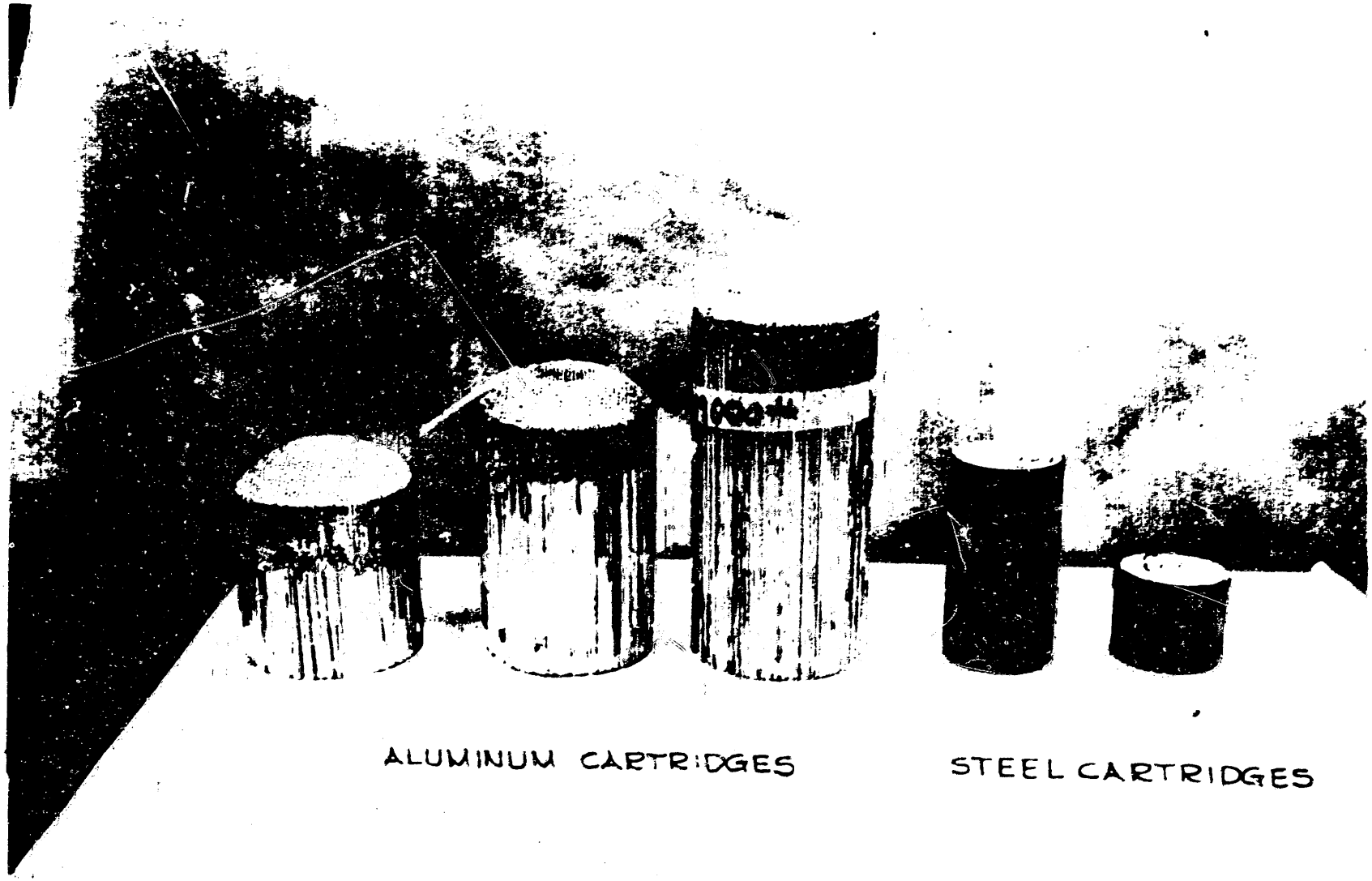


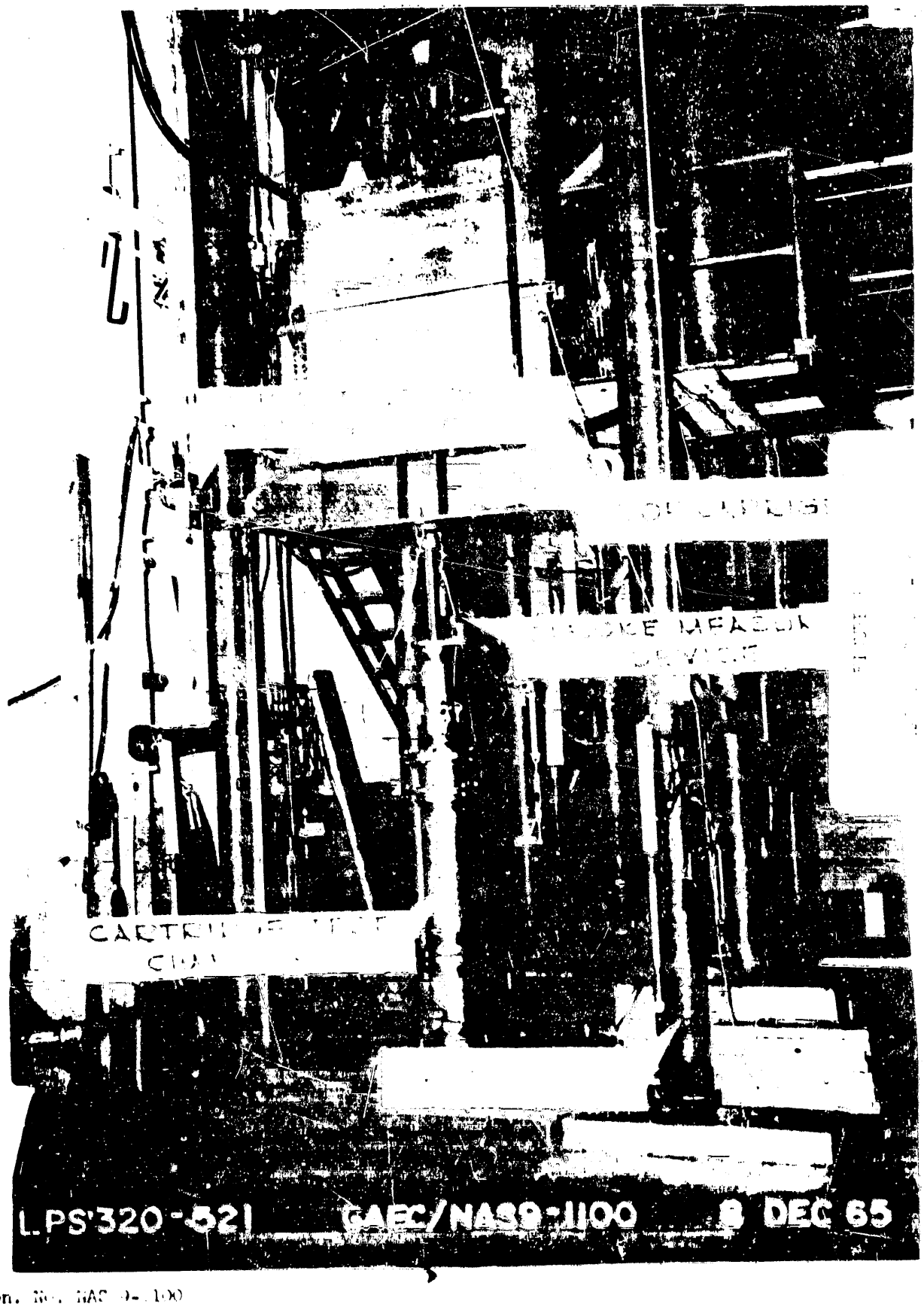
FIGURE 1

CAPTRIDGE SAMPLES

FIGURE 2

160 INCH HONEYCOMB PRIMARY

CARTRIDGE



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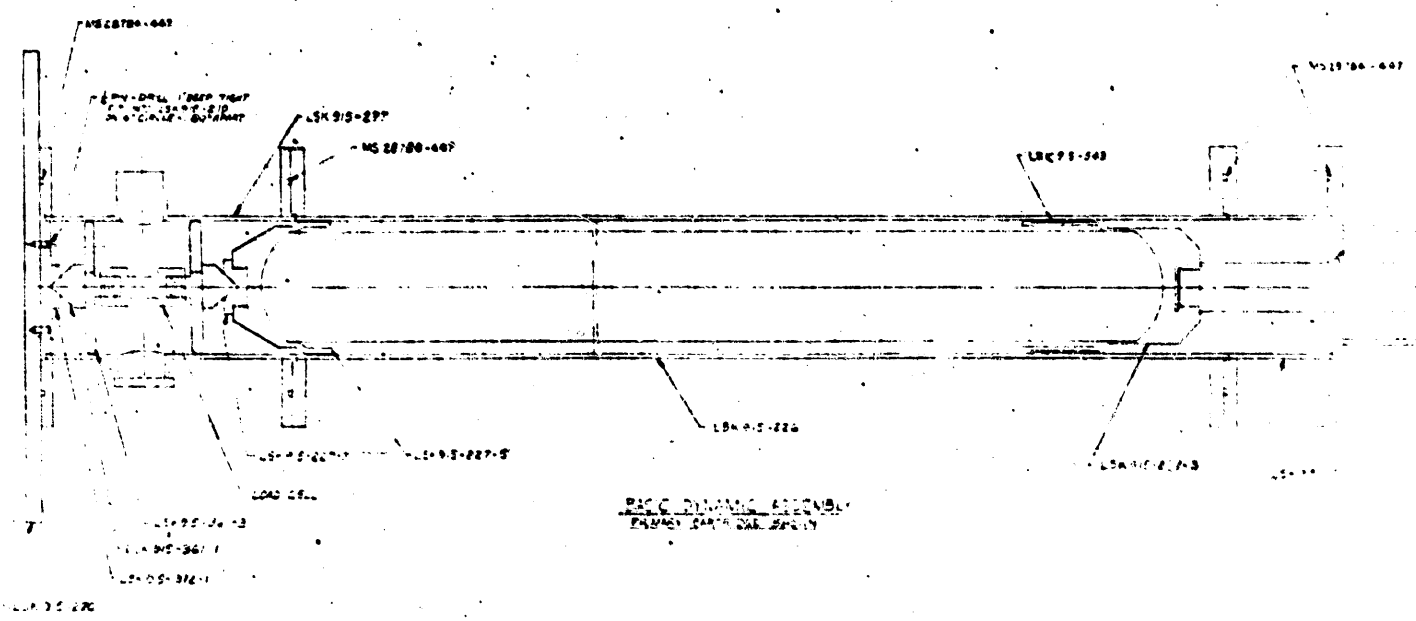
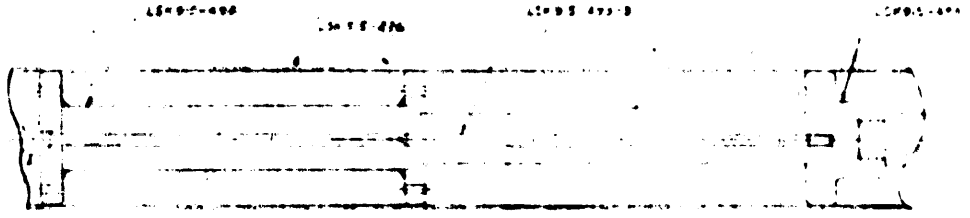
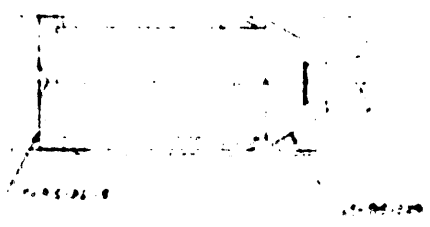
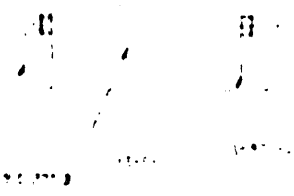
Primary No. 511

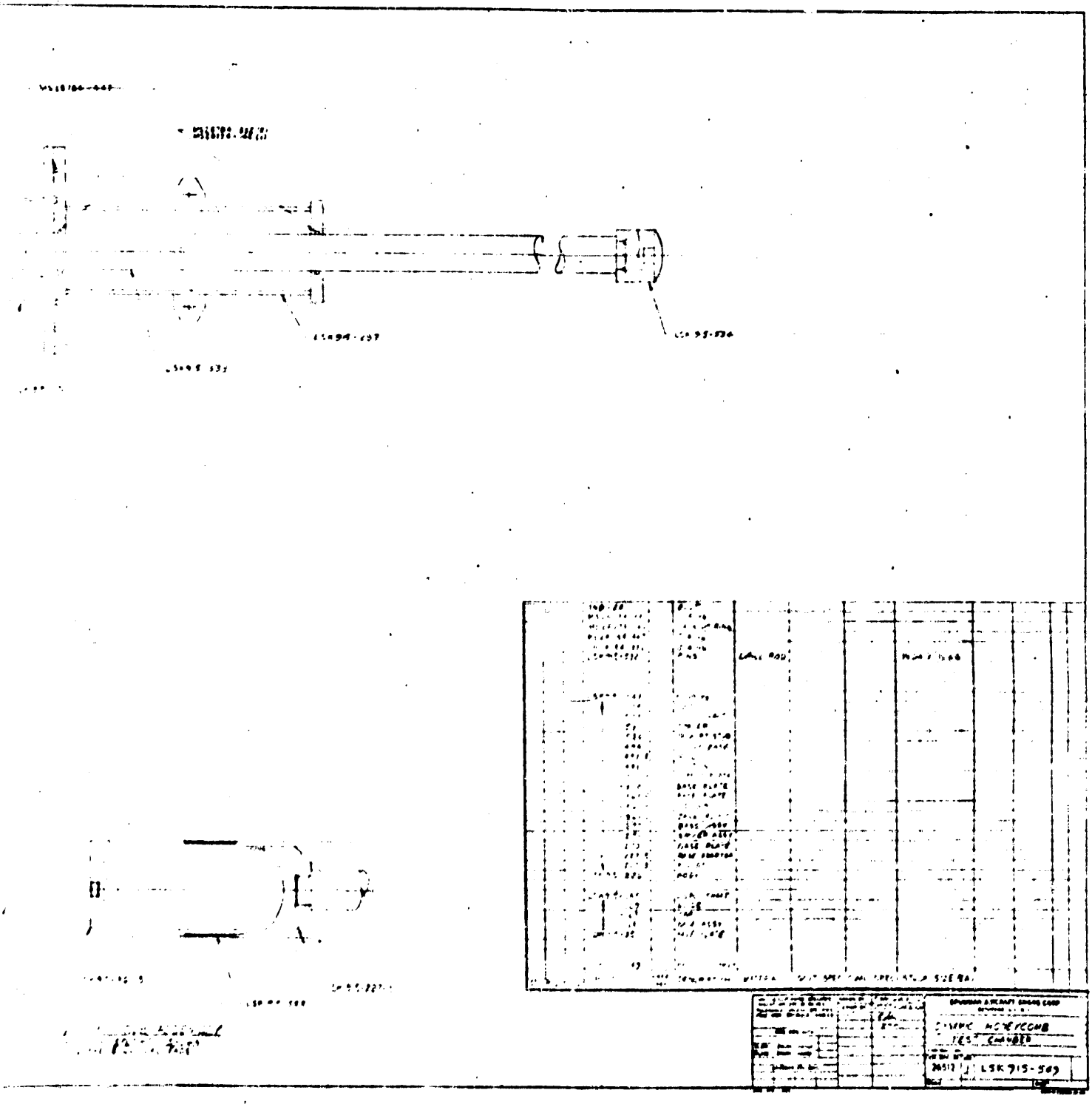


BASIC DYNAMIC ASSEMBLY









RESULTS OF THE LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION C - RESULTS OF THE PRIMARY STRUT ASSEMBLY TESTS (180" SEMI-TREAD)

PREPARED BY:
B. DeBlasio

CHECKED BY:
R. L. Makemson

RESULTS OF THE LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION C - RESULTS OF THE PRIMARY STRUT ASSEMBLY TESTS (180" SEMI-TREAD)

1.0 PURPOSE OF TEST

1.1 This section of the report contains the results of initial development tests which were performed to verify the calculated stresses of the landing gear primary shock strut under static loading conditions, and to investigate operational and dimensional characteristics of the strut under load. Axial and transverse loads were applied to the strut assembly to obtain this verification and to complement the analytical studies for the final strut design.

1.2 These tests were conducted in partial fulfillment of the requirements of Contract No. NAS 9-1100.

2.0 DESCRIPTION OF TEST SPECIMEN

2.1 The strut, designed for test purposes only, (Figure 1, page C- 11), had an initial length of 108", and weighed 17.5 lbs. without an insert.

2.2 The tests were conducted using the following three strut assembly conditions:

a. Unloaded, that is there was no insert in the strut

b. An aluminum honeycomb energy absorber was installed in the strut for another portion of the test. For one test a single stage, (one crushing level), honeycomb cartridge was used, and for several other tests a two stage honeycomb cartridge was inserted. (Refer to Section 6, Summary of Test Results).

c. For a section of this test, the honeycomb shock attenuator was replaced with various wooden spacer blocks so that the strut was prevented from stroking. The blocks were of such lengths so as to restrain the strut at stroke positions where maximum strut stresses occur.

RESULTS OF THE LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION C - RESULTS OF THE PRIMARY STRUT ASSEMBLY TESTS (180" SEMI-TREAD)

2.0 DESCRIPTION OF TEST SPECIMEN - continued

2.3 The Moment of Inertia of the strut assembly was determined with a 96" strut length and a wooden spacer block weighing 3.81 lbs. The Moment of Inertia was found to be 2.62 slug-ft^2.

3.0 TEST SET-UP AND PROCEDURE

3.1 The test set-up and procedure were as described in the test plan.Report No. LTP 904-10001, Section C. The test set-up is shown in Figure 2, Page C-14.

3.2 Vibration Mode Survey

3.2.1 For all vibration mode survey tests, the S-131 Shaker was placed on the inner cylinder, at a distance of 23" from the centerline of the uniball end fitting. For one section of this test the ends of the strut were pinned while for other portions of the test an axial load was applied.

3.2.2 For all vibration tests, wooden spacer blocks were used to obtain the required lengths, and the weights of these blocks were considered in evaluating the test results.

3.3 Static Test

3.3.1 All static tests were conducted in the test rig shown in Figure 2, Page C-12

3.3.2 The transverse loads were applied as follows: Rubber straps were positioned at calculated locations on the strut to insure the correct load distribution; these rubber straps were secured to a plywood base, and the method of loading was to rest shot bags on the base until the required magnitude of load was obtained. (The load distribution details are shown on Figure 3, Page C-13). The weight of the strut and the weight of the fixtures required to apply the desired transverse loads were considered in establishing the load distribution.

RESULTS OF THE LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION C - RESULTS OF THE PRIMARY STRUT ASSEMBLY TESTS (180" SEMI-TREAD)

3.0 TEST SET-UP AND PROCEDURE - continued

3.3 Static Test - continued

3.3.3 Figure 3, Page C- , shows the locations of the strain gauges along the strut and indicates also the positioning of the "linear motion potentiometer" that were used to measure strut deflections during the test.

3.3.4 Transverse loads were determined using a nominal strut weight of 25.0 lbs. However, the strut assembly was tested using various inserts of different weights, so that the lateral load is expressed nominally in "g's", and the exact weight of the side loads recorded.

4.0 TEST CONDITIONS

4.1 All tests were conducted at ambient environmental conditions.

5.0 DISCUSSION OF TEST RESULTS

5.1 The 180" semi-tread was superceded by the 160" semi-tread landing gear while the 180" tests were in progress. For this reason, the 180" primary strut test program was relatively brief and the results were used to verify design conditions.

5.2 Vibration Mode Survey

5.2.1 All vibration tests were conducted in the test fixture shown in Figure 2, Page C-

5.2.2 The vibration mode survey was conducted under 6 conditions:

Condition	Strut Length	Axial Load
1	96 inches	0 lbs.
2	96 inches	4000 lbs.
3	96 inches	8000 lbs.
4	96 inches	12,300 lbs.
5	88 inches	0 lbs.
6	88 inches	12,300 lbs.

RESULTS OF THE LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION C - RESULTS OF THE PRIMARY STRUT ASSEMBLY TESTS (180" SEMI-TREAD)

5.0 DISCUSSION OF TEST RESULTS - continued

5.2 Vibration Mode Survey - continued

5.2.3 With the strut length at 96" and both ends fixed, the first Mode Resonant Frequency was found to be 54.9 cps.

5.2.4 A summary of all vibration mode survey test results is shown in Section 6.1.

5.3 Static Tests

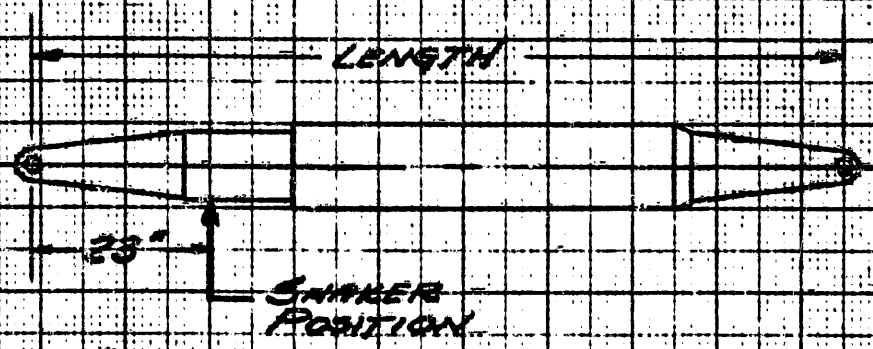
5.3.1 Test No. 3 was conducted to determine the axial load required to overcome friction. The axial load was found to be approximately 750 lbs. at 35 "g" side load, and approximately 950 lbs. at 50 "g" side load.

5.3.2 Maximum strut centerline deflection was recorded at ultimate conditions and a strut length of 108", (Test No. 8), and measured 0.5888 in.

5.3.3 A summary of all static tests is included in Section 6.2.

Section 6 SUMMARY OF TEST RESULTS

Section 6.1 Summary Of Vibration, Mode Survey Test Results

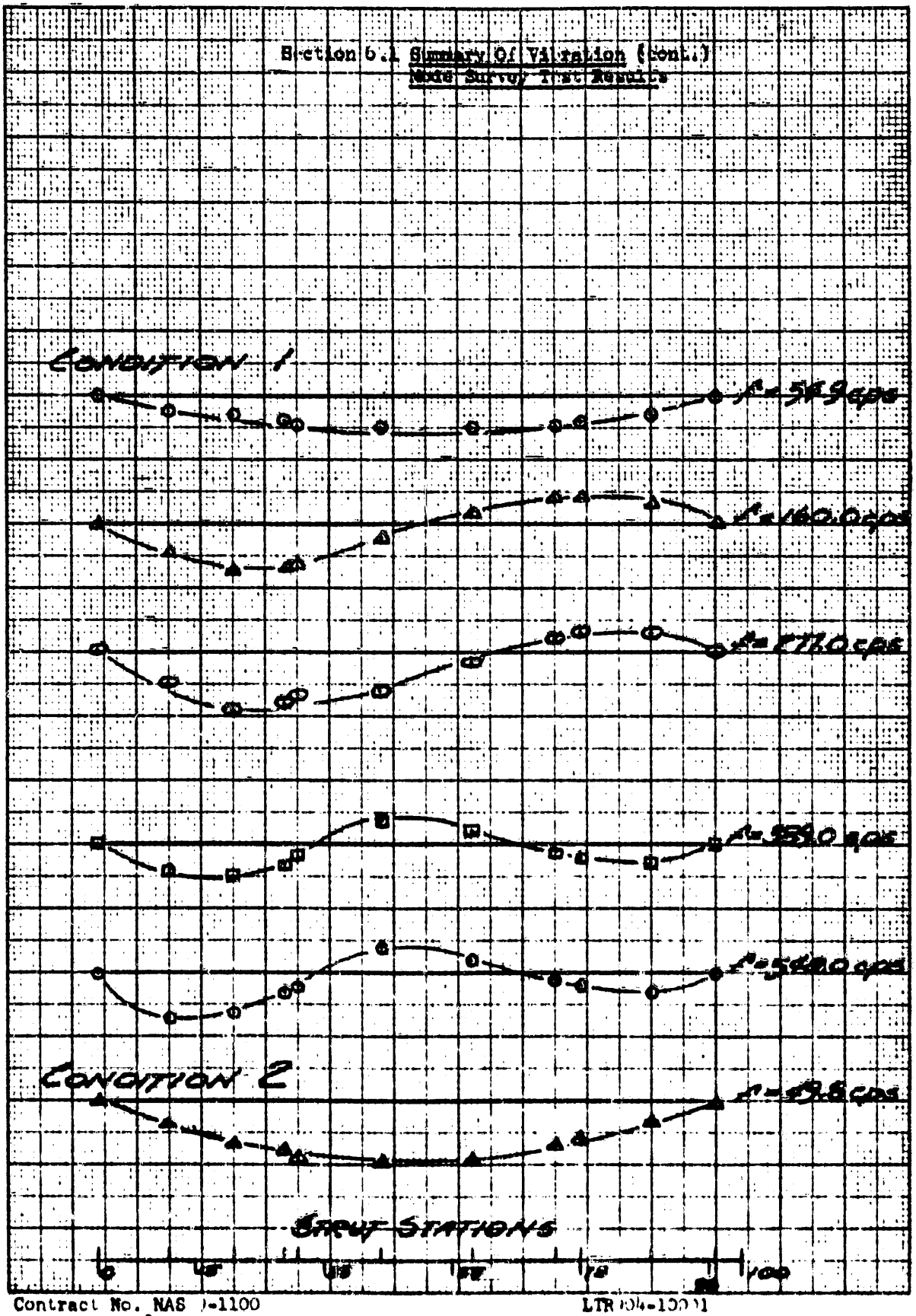


CONDITION	STRUT LENGTH	AXIAL LOAD
1	96"	0
2	96"	4000 LBS
3	96"	8000 LBS
4	96"	18,300 LBS
5	88"	0
6	88"	18,300 LBS

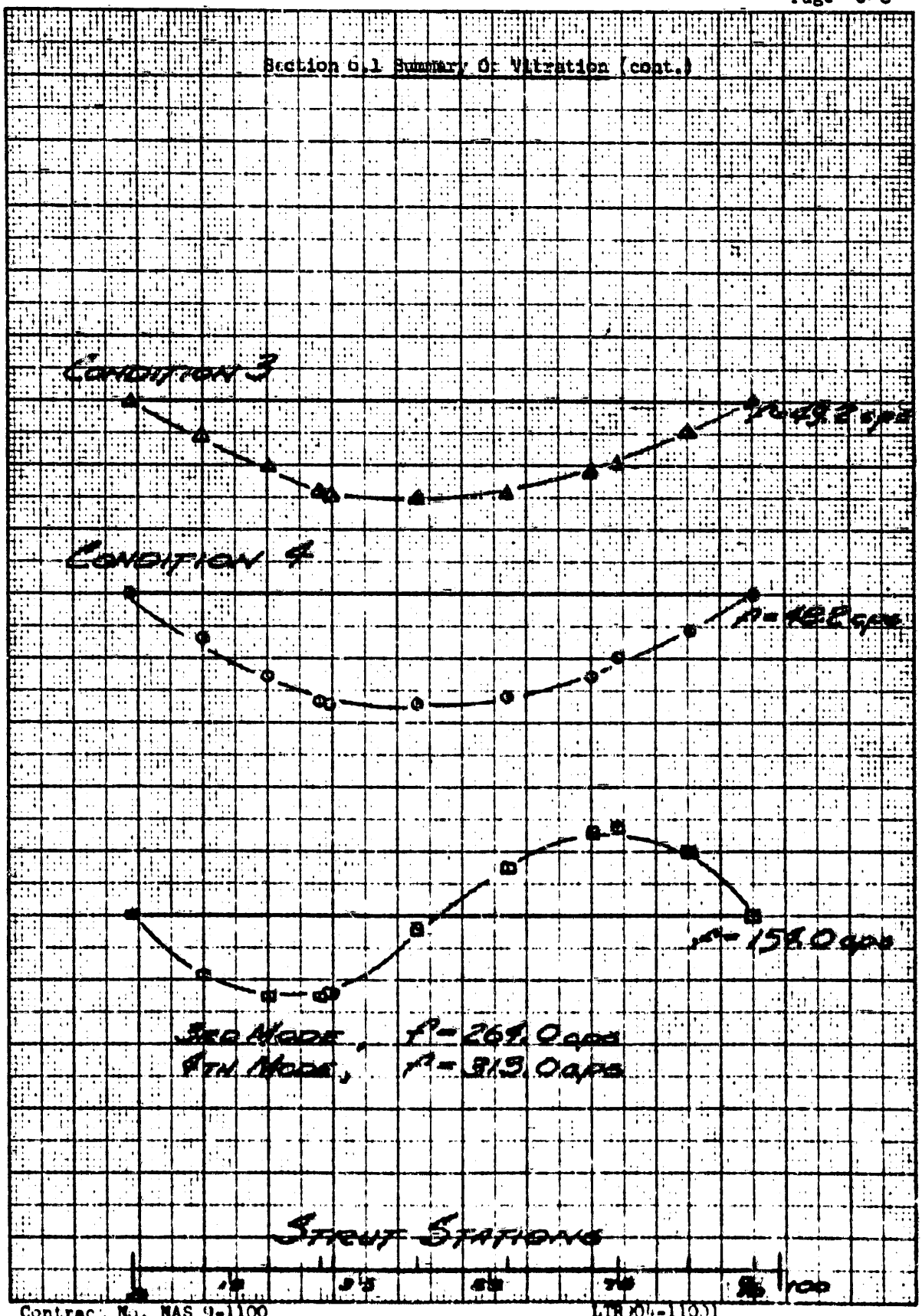
6 January 1964

K&E 10 X 10 TO THE 1/2 INCH 359T-11 KEUFFEL & ESSER CO.

Section 6.1 Summary Of Vibration (cont.)
Mode Survey Test Results

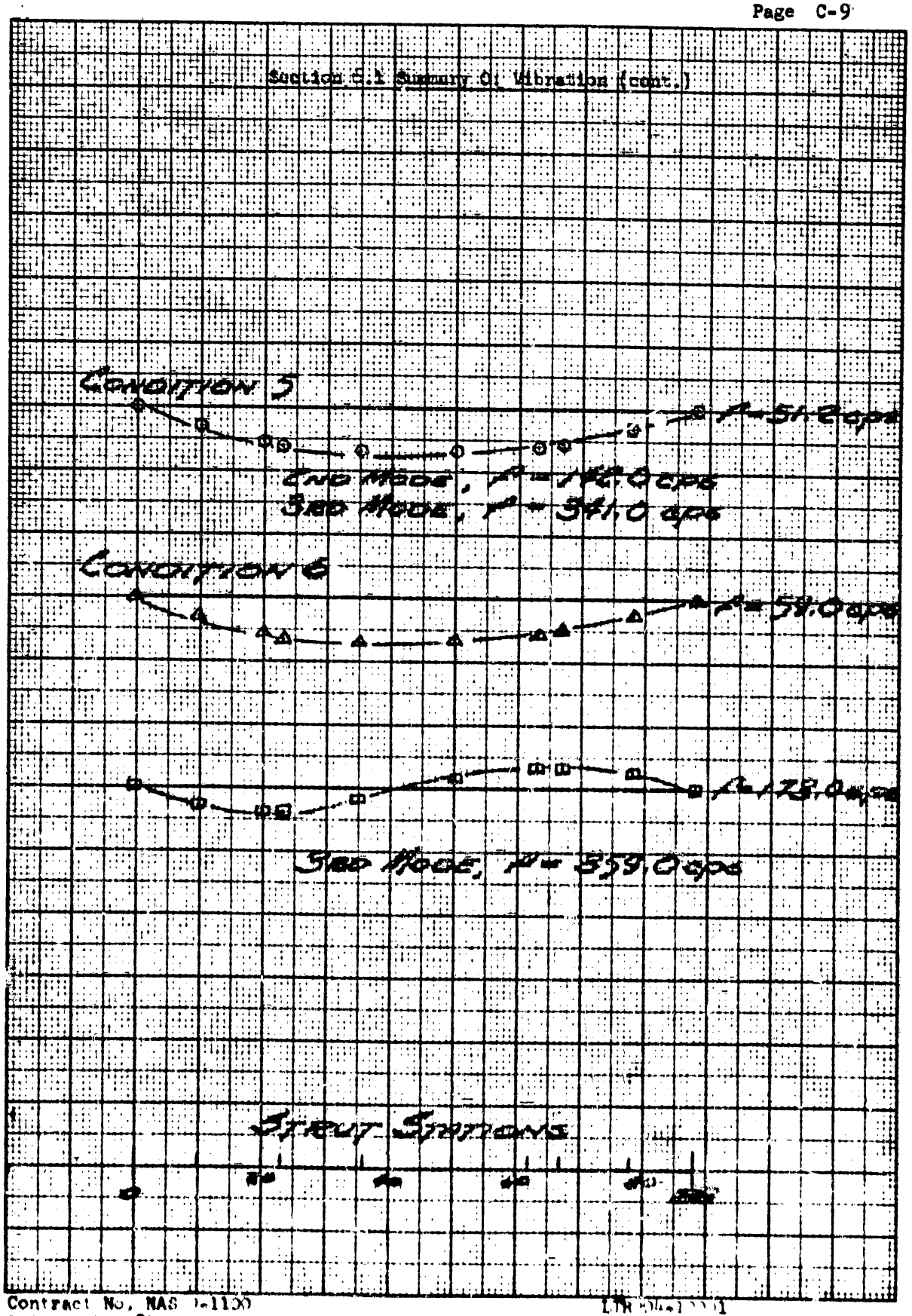


Section 6.1 Summary Of Vibration (cont.)



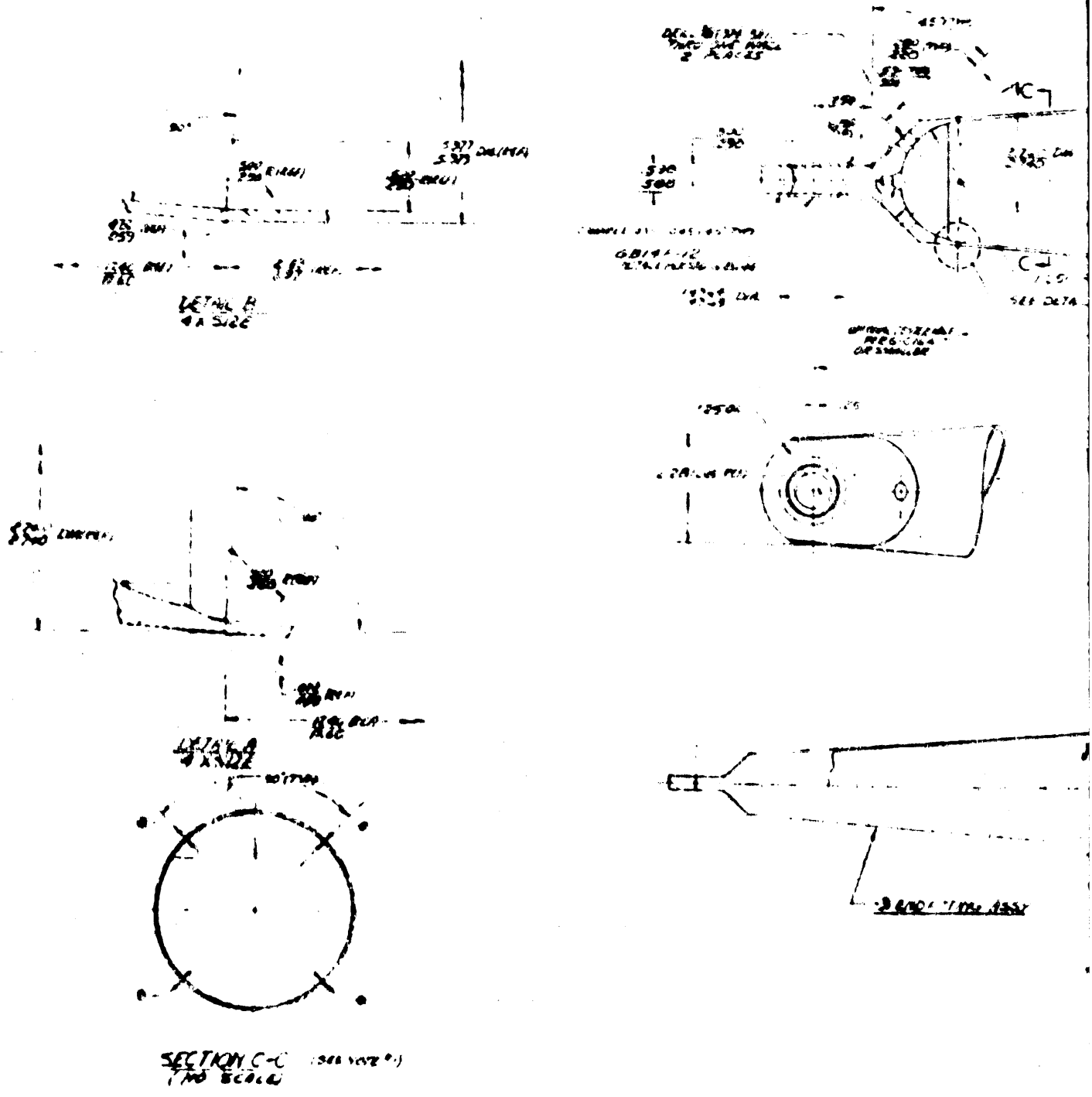
K+E 10 X 10 TO THE ½ INCH 359T-11
KEUFFEL & ESSER CO.
ALBANENE

Section 5.1 Summary Of Vibration (cont.)



6.2 SUMMARY OF STATIC TESTS

TEST NO.	DATE	INSERT TYPE	INITIAL STRUT LENGTH	TRANSVERSE LOAD "G"	TRANSVERSE LOAD Lbs.	AXIAL LOAD	REMARKS
1.	22 Jan. '64		96"	0	0	12,300 lbs	Set side load & apply axial load. Limit conditions at this length.
		Wood	96"	10	232	"	
		Block	96"	20	477	"	
			96"	35	837	"	
2.	23 Jan "64		96"	0	0	See Remarks	Set side load & apply axial to start of crush.
		Honeycomb	96"	10	232		
			96"	20	477		
			96"	35	837		
3.	5 June '64	No	108"	35	837	See Remarks	Set side load & apply axial load to motion.
	[illegible] June '64	Insert	108"	50	1225		
4.	8 June '64	Honeycomb	108"	0	0	3400lbs	A. Crush 1 in. at 0 "G"
		No. 1057	107"	35	837	4000 lbs (approx.)	B. Crush Stage 1
			96"	35	837	15,000 lbs (approx)	C. Crush Stage 2
5.	8 June '64	Honeycomb	108"	0	0	3400 lbs	A. Crush 1 in. at 0 "G"
		No. 1058	107"	35	837	4000 lbs (approx)	B. Crush Stage 1
			96"	35	837	15,000 lbs (approx)	C. Crush Stage 2
6	9 June '64	Honeycomb	108"	0	0	3400 lbs	A. Crush 1 in. at 0 "G"
		No 1060	107"	50	1225	4000 lbs (approx)	B. Crush Stage 1
			96"	50	1225	15,000 lbs (approx)	C. Crush Stage 2
7.	9 June '64	Honeycomb	108"	0	0	3400 lbs	A. Crush 1 in. at 0 "G"
		No. 1064	107"	50	1225	4000 lbs (approx)	B. Crush Stage 1
			96"	50	1225	15,000 lbs (approx)	C. Crush Stage 2
8.	9 June '64	Wood Block	108"	50	1225	6750 Lbs.	Ultimate conditions at this length
9.	9 June '64	Wood Block	96"	50	1225	18,750 lbs	Ultimate conditions at this length



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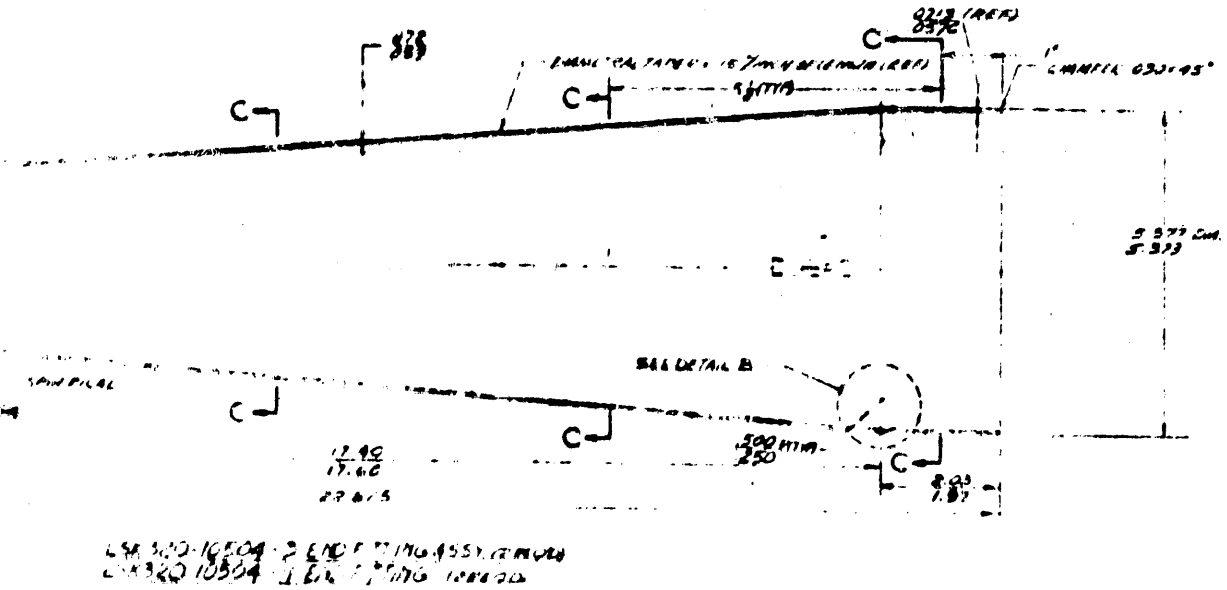
PRIMARY No. [illegible]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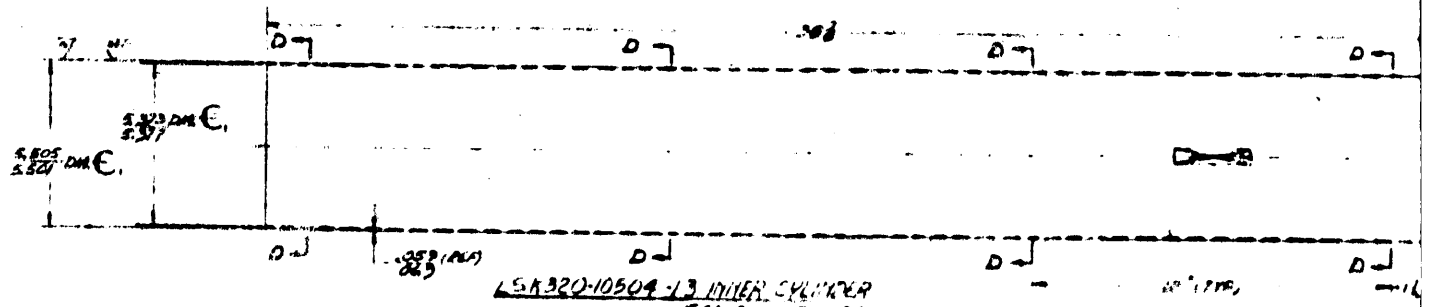
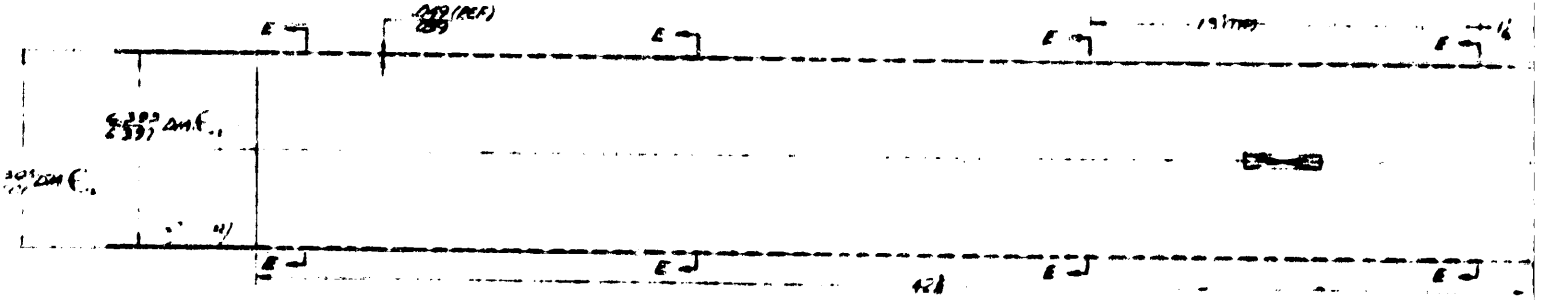


LSK320-10504-13 INNER CYLINDER
SCALE HALF SIZE



LSK320-10504-15 OUTER CYLINDER
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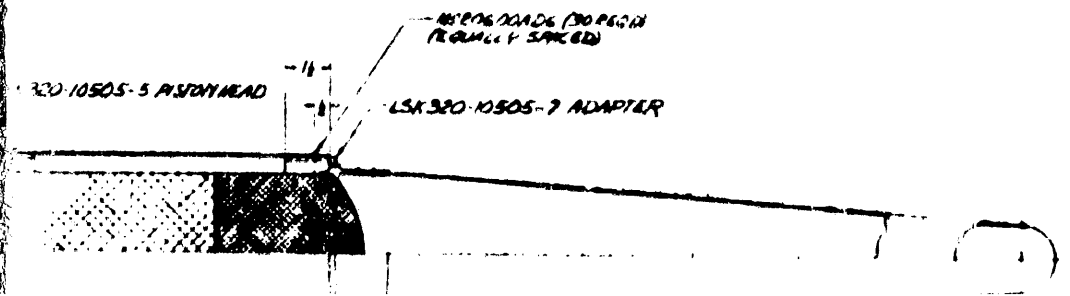

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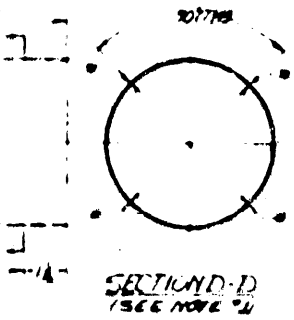
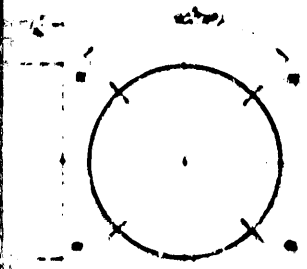


SECTION D-D
(SEE NOTE #1)



SECTION E-E
(SEE NOTE #1)

* IN SECTIONS C-C, D-D & E-E RECORDED BY INSPECTION.

RECORD DRAWINGS AND E.O.'S

MANUFACTURING OPERATIONS

RESPONSIBILITY

DATE

RECORD DRAWINGS AND E.O.'S

DRAWING CHANGES

PROCESSES

FACTURING OPERATIONS

REPORT LTR-ACC 10001

DATE [illegible] FEBRUARY, 1966

PRIMARY STRUT ASSY (TESTS)

LANDING GEAR

VSA 3P0-10504

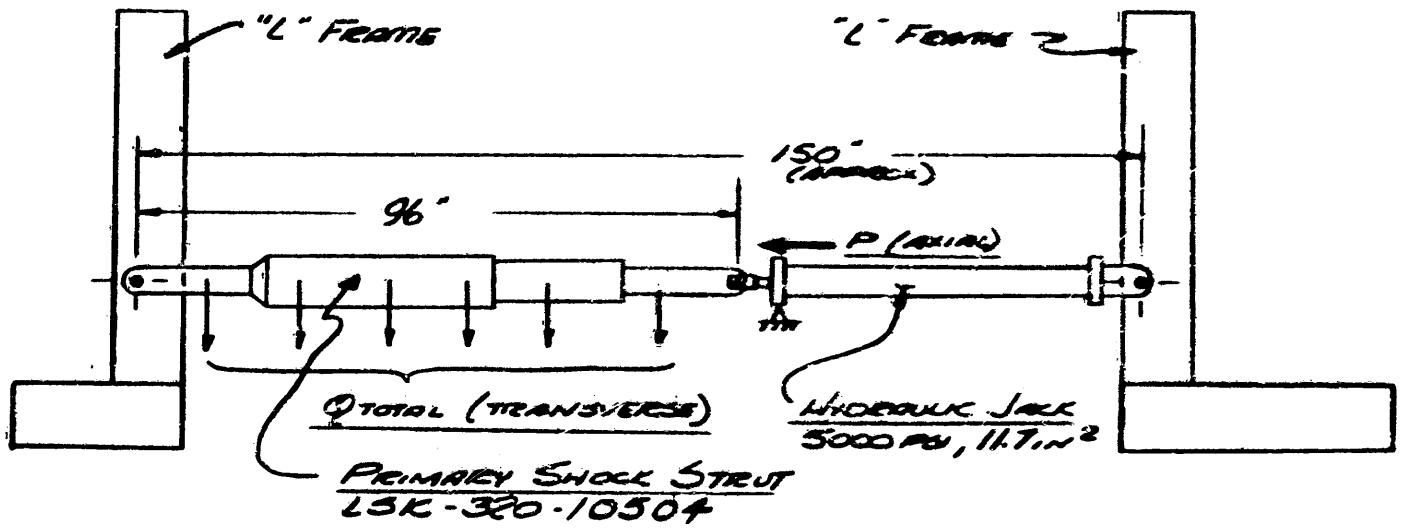
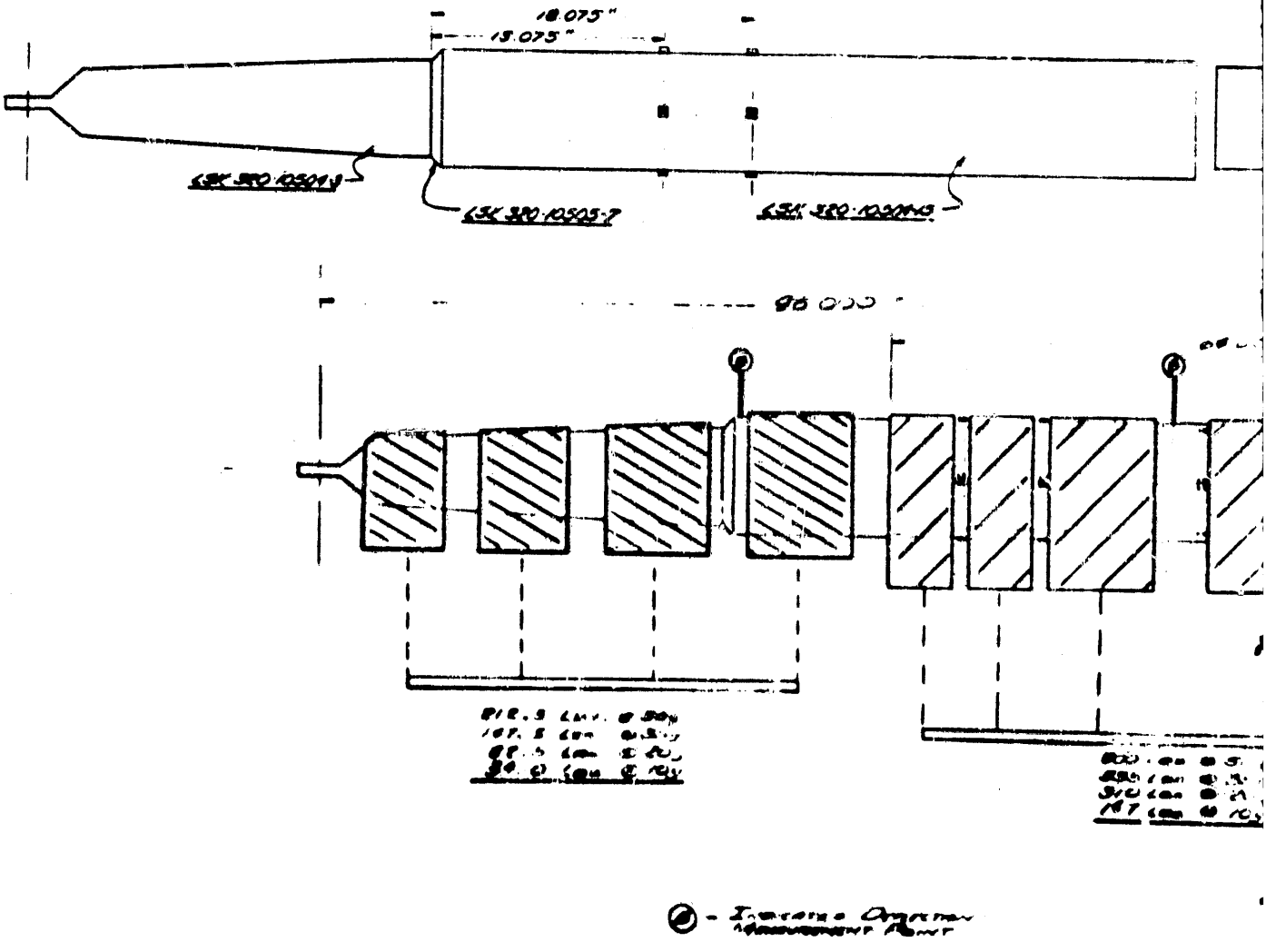


FIG 2: TEST SET-UP

Figure 1



Contract No. NAS 9-1100
Primary No. 81

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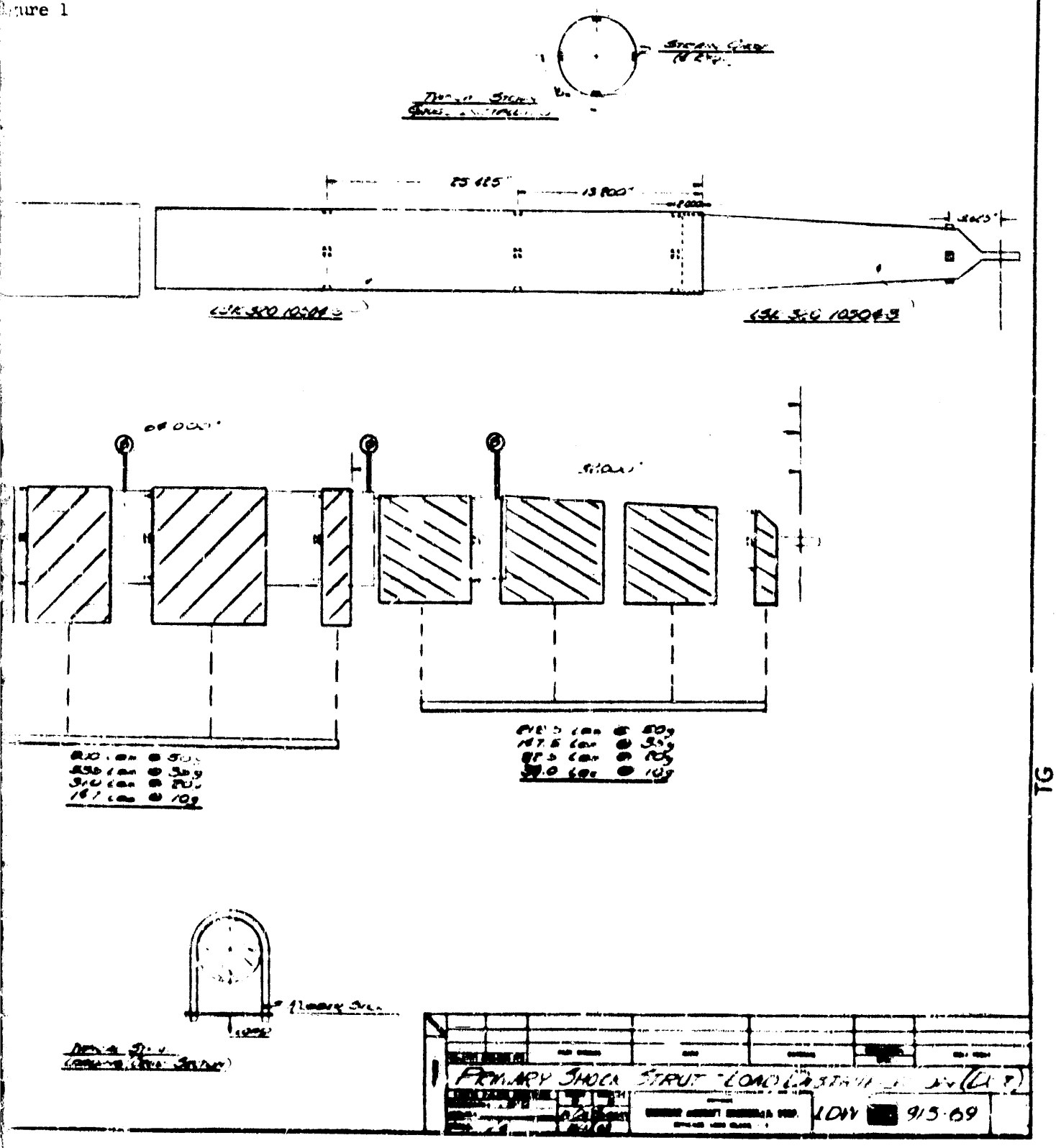

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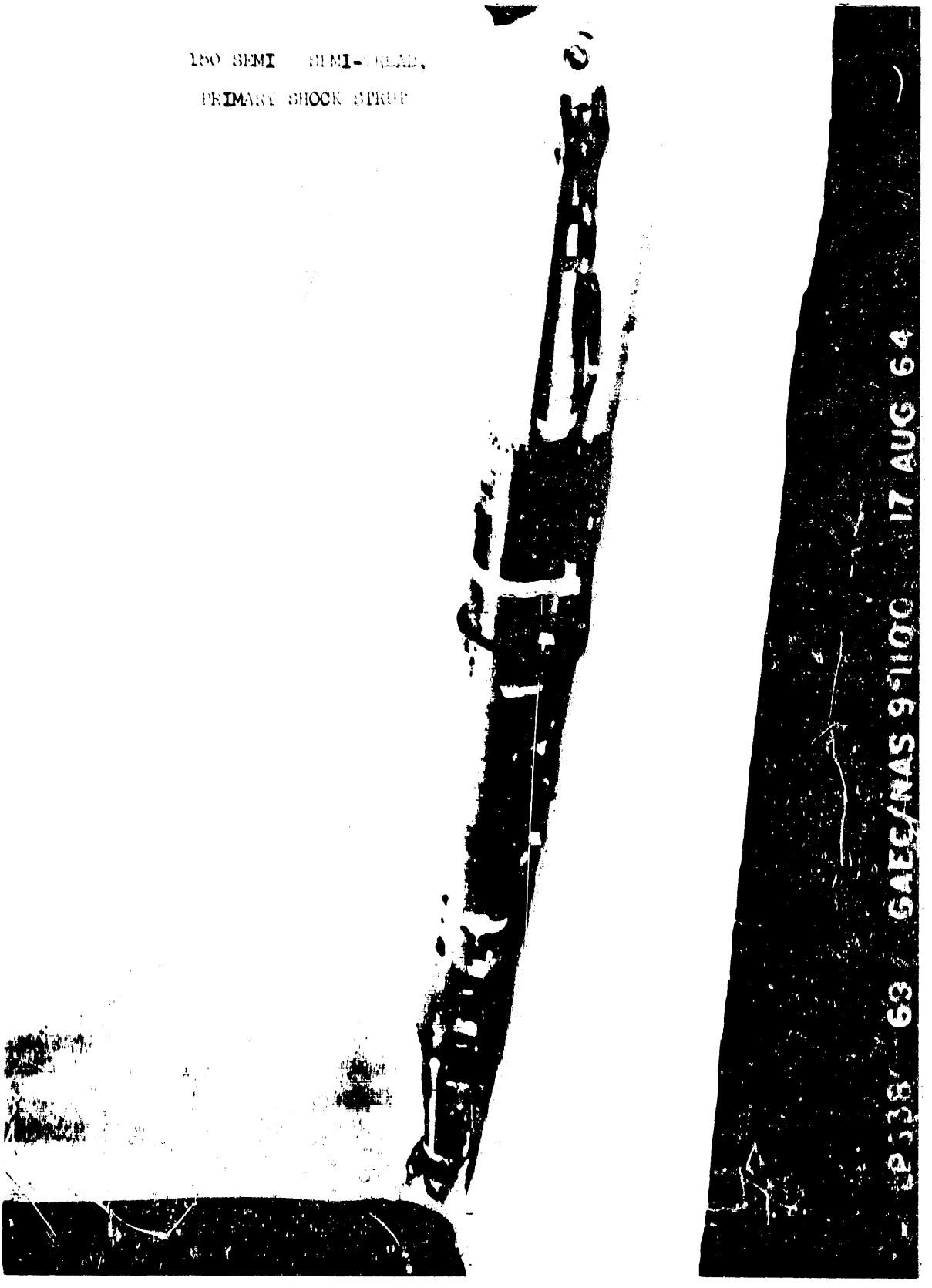
160 SEMI SEMI-REAR,

PRIMARY SHOCK STRUT



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Report [illegible]
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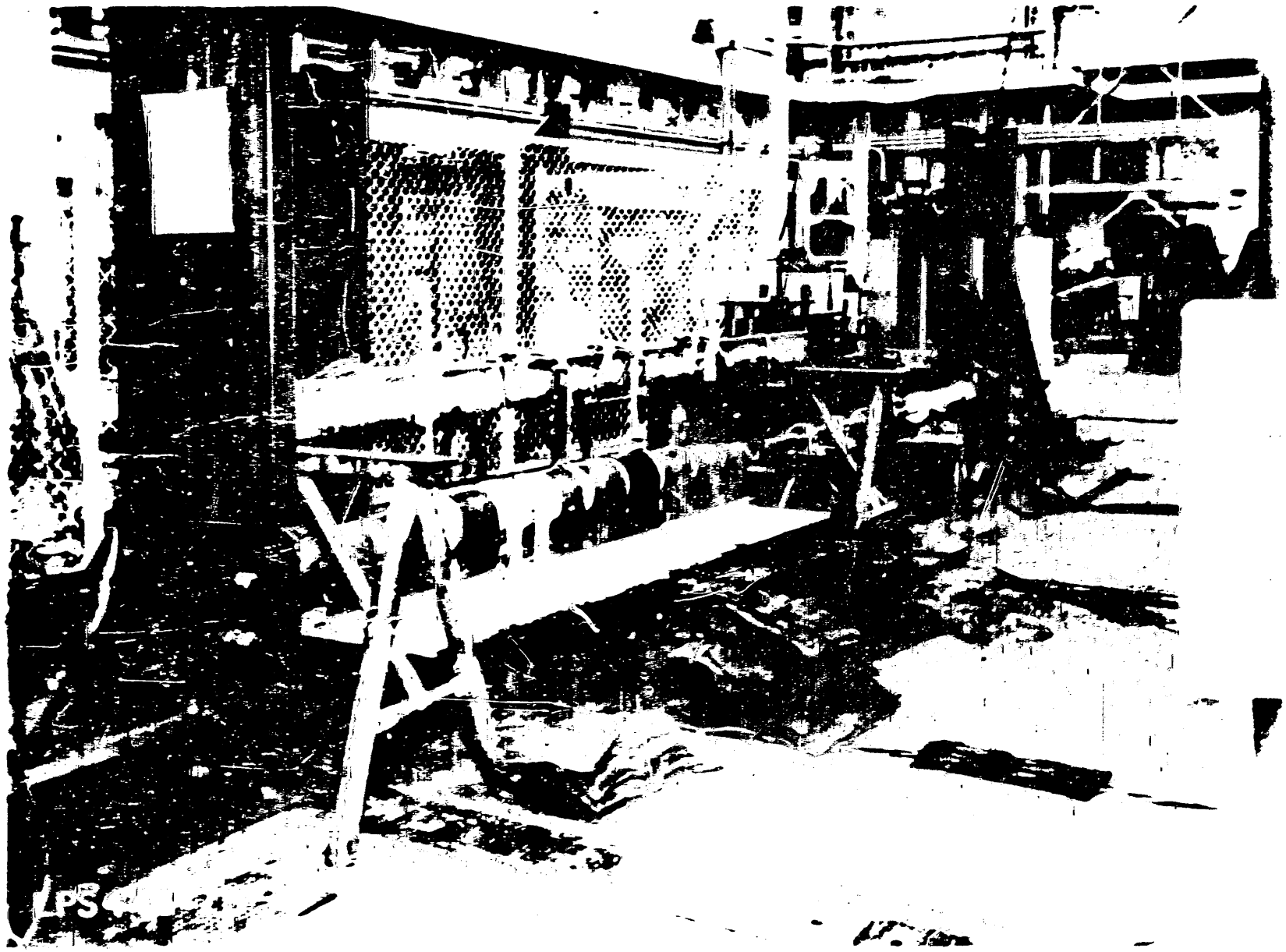

CALIBRATION OF PRIMARY

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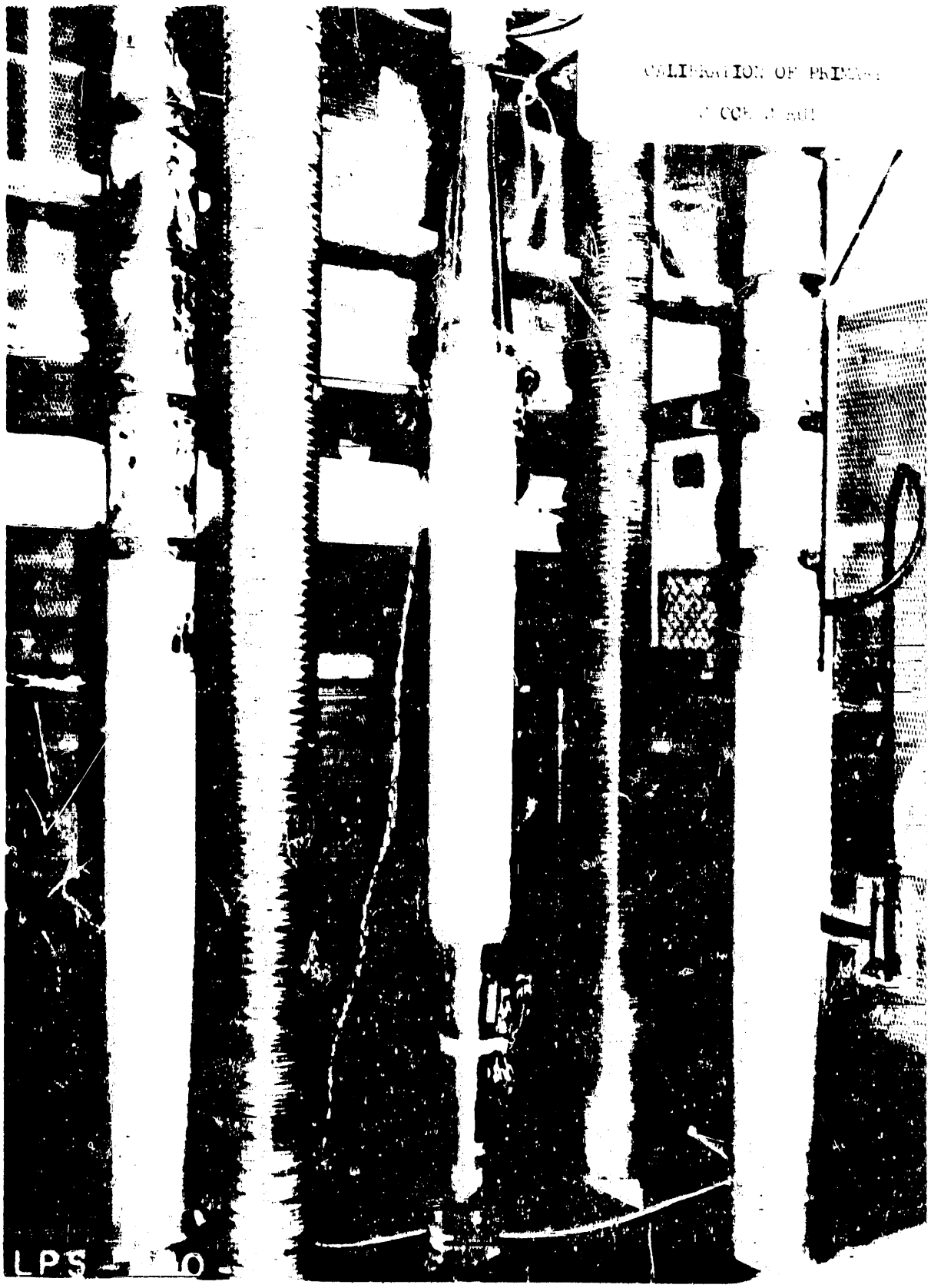

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TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10702

PREPARED BY:
M. Gartenschlaeger

CHECKED BY:
R. L. Makemson

TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10702

INTRODUCTION

This section of the report contains the results of all tests conducted on the LEM Landing Gear Footpad LSK-320-10702. It was found that the footpad satisfactorily withstood the Design Normal Load of 12 psi and exhibited satisfactory lateral crushing characteristics.

Refer to LTP-904-10001 - Section D - Plan for the Static Test of Footpad LSK-320-10702.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10702

1.0 PURPOSE OF TEST

1.1 The purpose of these tests was to determine the strength of the footpad when subjected to a uniformly distributed normal load and to evaluate the load-stroke characteristics during lateral crushing of this preliminary footpad design for use on the LEM landing gear.

1.2 As described in Test Plan LTP-904-10001 - Section D, the tests were separated into two phases:

Phase I - Normal Load Tests

a) Proof Test (Design Normal Load)

b) Failure Test

Phase II - Transverse Load Tests

2.0 DESCRIPTION OF TEST ARTICLE

2.1 The test specimens were 36 inches in diameter and of a shallow dish configuration (Refer to Figure 1). Construction was of bonded aluminum honeycomb. The core was 5052 aluminum foil (0.0015 thick and 3/16 inch cell size). The skins were of 7075-T6 aluminum and were tapered to the outer edge to produce desirable lateral crush characteristics.

2.2 Four pads conforming to Drawing LSK-320-10702 were supplied for testing. One footpad was used for Phase I - Normal Load Test and three pads were used for Phase II - Transverse Load Test.

TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD 1SK-320-10702

3.0 TEST CONDITIONS

3.1 The tests were conducted under ambient environmental conditions. In all tests, the pad was installed in a horizontal attitude.

3.2 The surface loading during the Normal Load Tests was essentially static in that no attempt was made to achieve a particular rate of pressure loading.

3.3 During the Transverse Load Tests, no attempt was made to attain a specific rate of loading but rather a uniform rate of loading. The footpads were crushed into hard fixed bearing surfaces having configurations of a flat surface, inside 90° corner and an outside 90° corner.

4.0 TEST SET-UP AND PROCEDURE

4.1 The test set-up and procedure was essentially as described in Test Plan LTP-904-10001 - Section D (Paragraph 5.0 - Test Description). Loading the footpad incrementally through a compression jack, as stated in the test plan, was not considered practical nor representative of a lunar landing. Therefore, the design normal load of 12 psi and an uprated proof load of 13 psi was applied to the footpad using an inflatable rubber bladder. The load was reacted by a rigid compression member incorporating a strain gage load cell. The failure test was identical with the above. See Photograph LPS-560-123, Page D-33.

4.2 Strain gages were installed on the footpad as shown on Figure 1. The pressure was measured with a pressure transducer at the inlet port of the bladder and the load cell was installed above the ball and socket joint as described in Paragraph 4.1.

TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10702

4.0 TEST SET-UP AND PROCEDURE - continued

4.3 Prior to the Transverse Load Tests, the jig was system calibrated to determine the friction forces inherent in the jig. This calibration resulted in an applied load vs. corrected load curve which may be seen on page D-17. The pad was crushed into the three obstacle configurations (Paragraph 3.3 - Test Conditions) at a slow uniform rate. The load-stroke profiles were obtained from these tests. Refer to Photographs LPS-560-109, 129, 131.

5.0 RESULTS AND CONCLUSIONS

5.1 Under the conditions described in Paragraph 3.2, the pad withstood a normal pressure loading of 12 psi. Visual inspection under this load showed no damage. It was then decided to increase the normal pressure loading to 13 psi. which resulted in skin buckling and consequently bond separation in localized areas on the footpad. Photograph LPS-560-126 is representative of this damage.

5.2 The above test was repeated. The footpad was to be subjected to an increasing pressure load until failure. The pad, however, failed at 11.5 psi. Failure occurred by extensive bond separation of the core to skin on the inner side of the pad and subsequent collapse of the skin in compression. This failure at a pressure less than that sustained previously may be attributed to the local bond failures incurred in Test 1. A comparison of the strain data from the two tests supports this conclusion. The erratic behavior of the gages in Test #2 (particularly gages #1 and #2) is attributed to local buckling of the skin, now unsupported because of the local bond failures. Refer to Figures 3A through 3D - Pressure vs. Strain (Test #1) and Figures 4A through 4D - Pressure vs. Strain (Test #2).

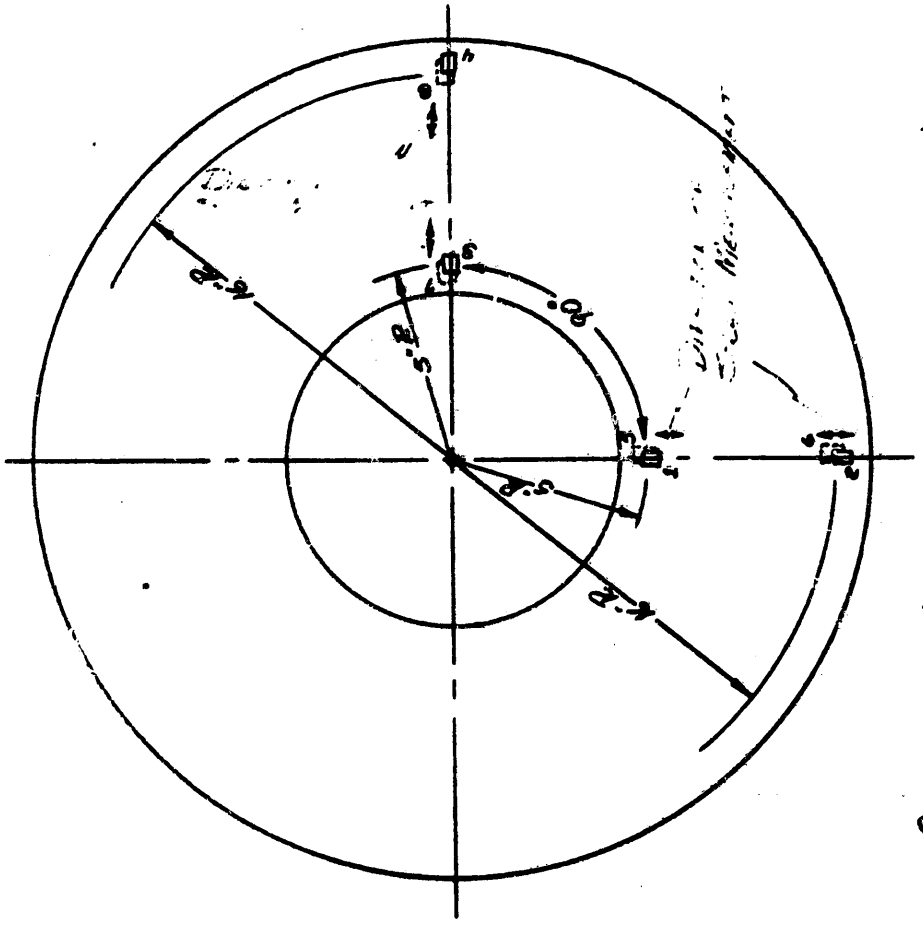
TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION D - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10702

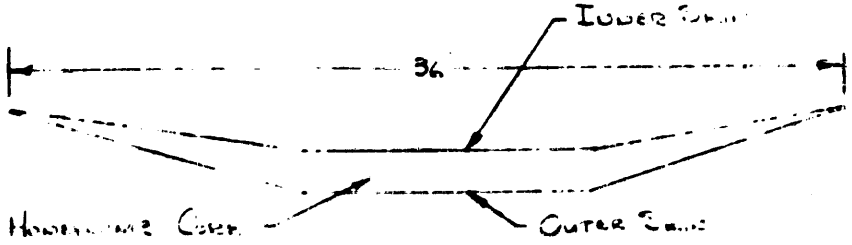
5.0 RESULTS AND CONCLUSIONS - continued

5.3 Load-Stroke characteristics were obtained during lateral crushing into the three obstacle configurations described in Paragraph 3.3. The characteristic curves are presented in the form of Applied Load vs. Stroke which are duplications of the traces obtained directly on the X-Y recorder The Corrected Load vs. Stroke curves show the actual characteristics of the pad and were derived using the Applied Load vs. Corrected Load curve. Variations in crush characteristics reflect the sensitivity of each pad to the shape of the obstacle. This sensitivity is given in efficiency percentages and is presented with the Corrected Load-Stroke curves, Pages D-18 through D-27 . It should be noted that one pad was used for Tests #1 and #2. Refer to Photograph LFS-560-108 showing crush mode of the pad for a flat plate. A second pad was used for Test #3 which resulted in damage to the major area of the footpad. Therefore, this pad was used for one test only. Refer to Photograph LFS-560-130 showing the crush mode of the pad for an inside 90° obstacle. The third footpad was used for Tests #4 and #5. Refer to Photograph LFS-560-133 showing crush mode of the pad for an outside 90° obstacle. The Energy Absorbed vs Stroke curves are the results of the integration of the Load-Stroke curves and may be seen on Pages D-28 through D-32.



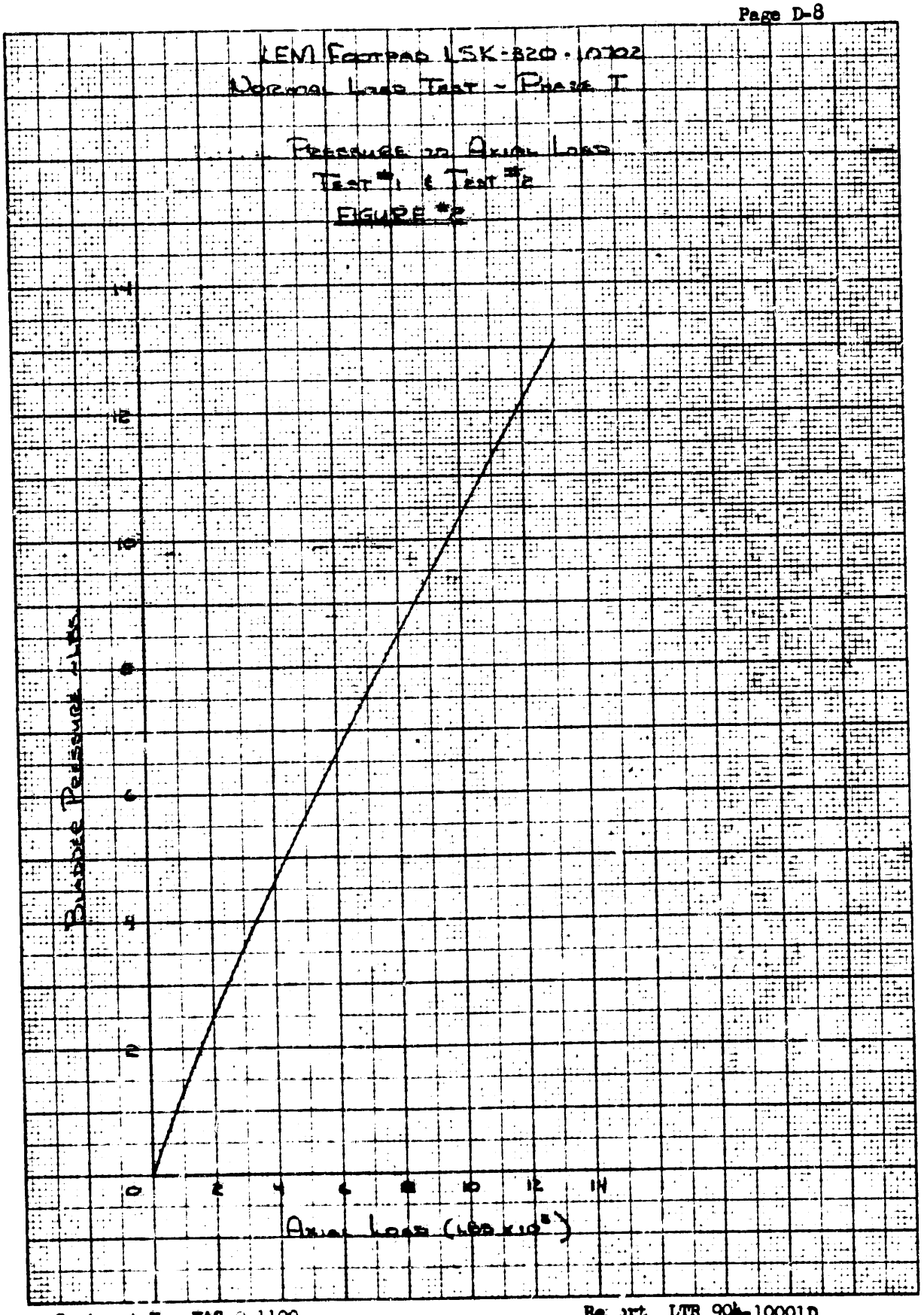
NOTE: STRAIN GAGES 1, 5, 2 & 6 ARE LOCATED ABOVE & BELOW CEMENTED SPLICE OF TRIANGULAR SECTIONS OF HONEYCOMB. REFER TO DWG. LSK-320-10702 FOR DETAILS OF HONEYCOMB INSTALLATION.

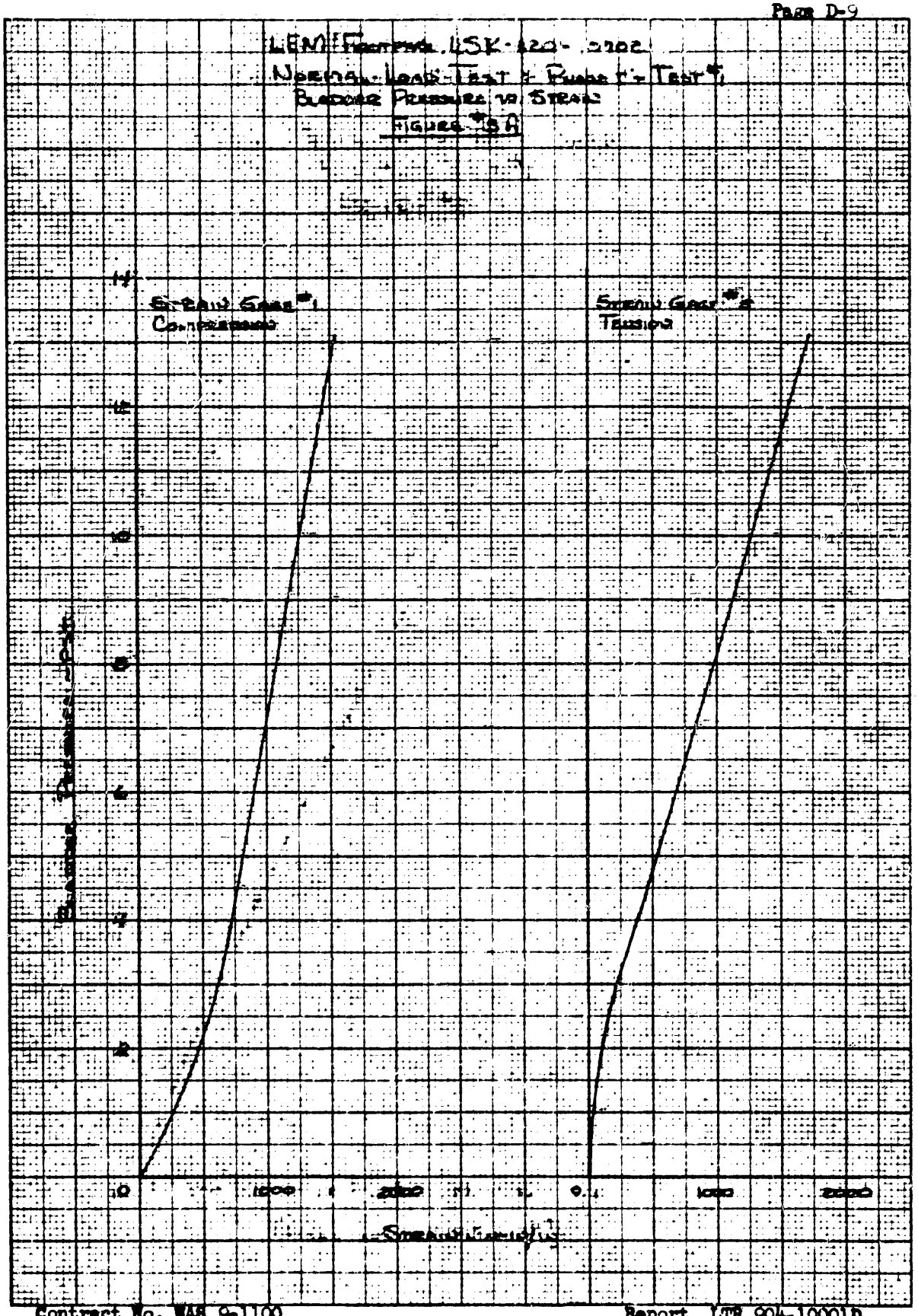
DRAWING NAME: LEM FOOTPAD; STRAIN GAGE INSTALLATION		ISSUED	PROJECT ENGINEER	GOVT. APPROVAL
DRWG NO: FIG. 2	MODEL	BY: [illegible]		
		DATE: 8/10/64		

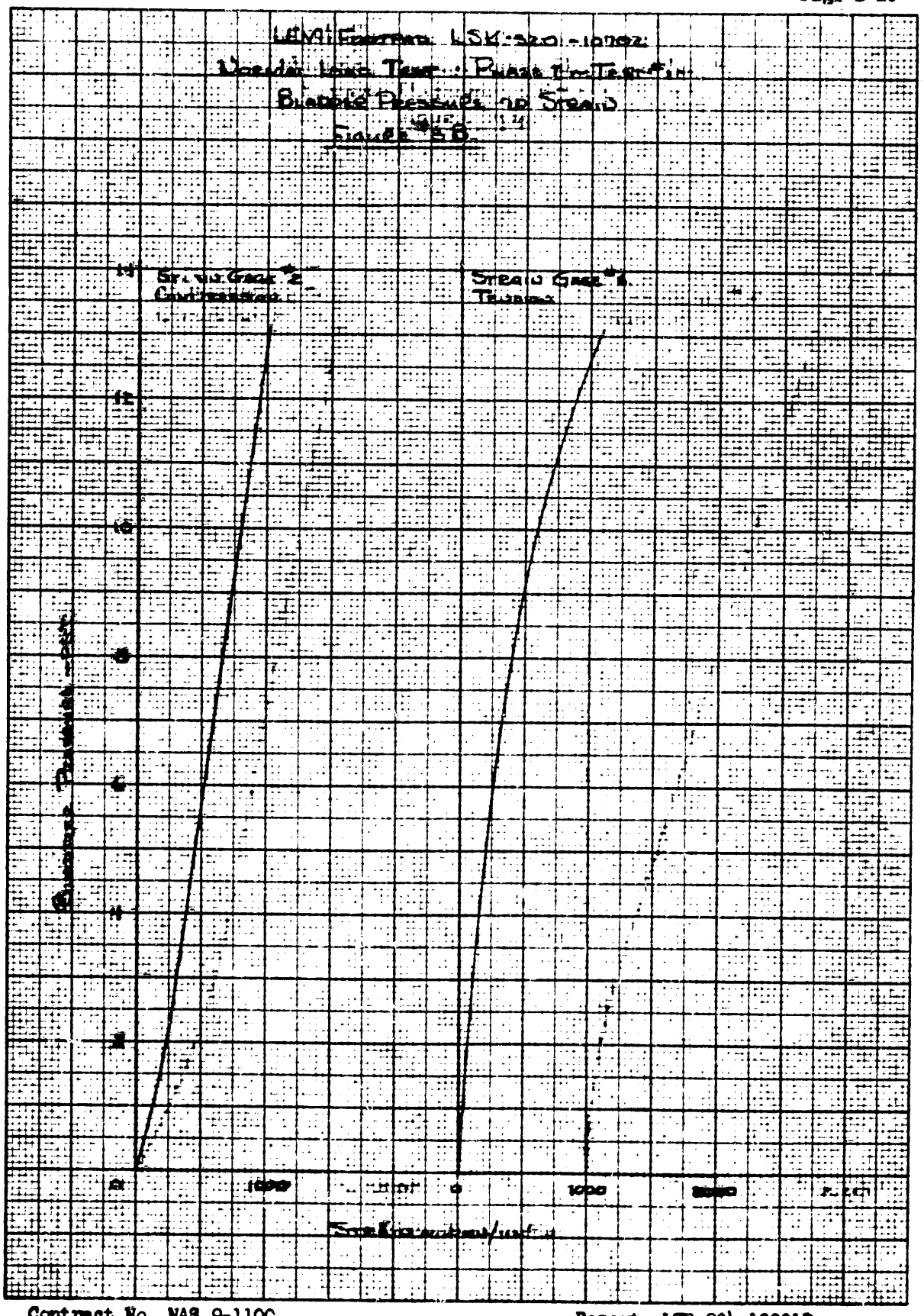


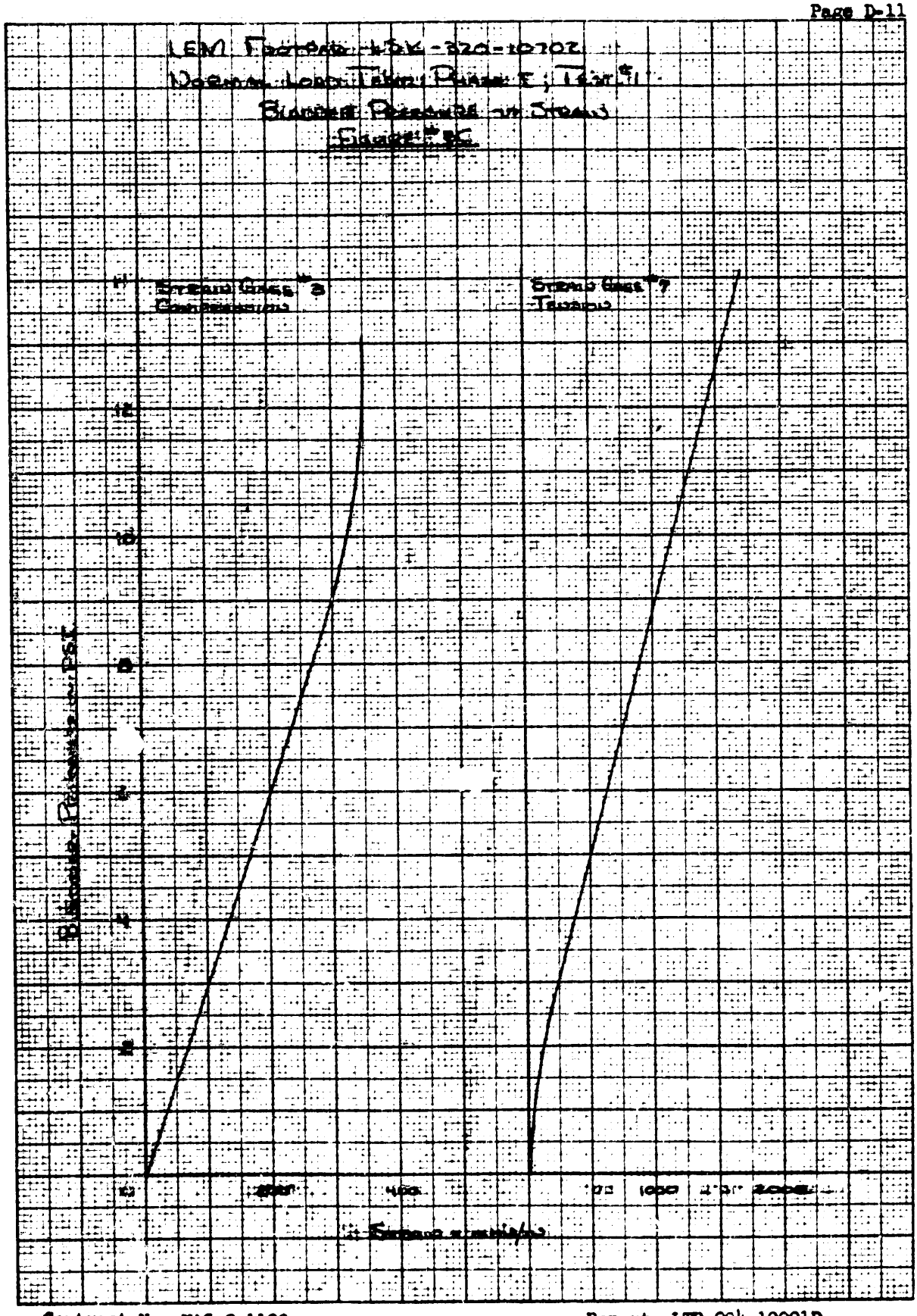
LEM Footpad LSK-320-10702
Normal Load Test - Phase I

Pressure vs Axial Load
Test #1 & Test #2
FIGURE #2




LEM Footpad LSK-120-2702
Normal Load Test & Phase I - Test #1
Bladder Pressure vs Strain
Figure #3A
Strain Gage #1
Compression
Strain Gage #2
Tension
14
12
10
8
6
4
2
0
1000
2000
0
1000
2000
Strain Gage #1


Strain Gage #2
Compression
Strain Gage #1
Tension
14
12
10
8
6
4
2
0
1000
0
1000



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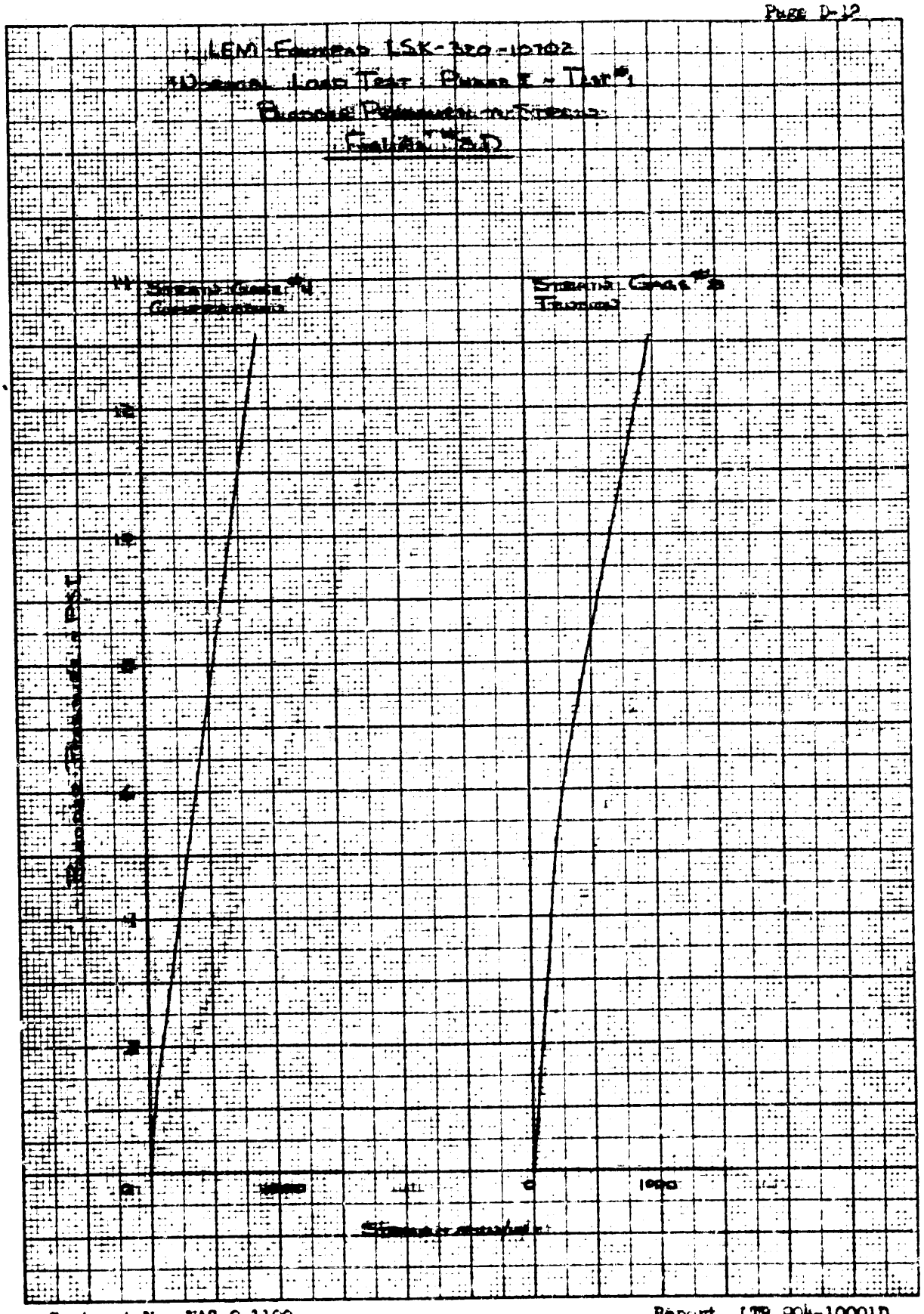
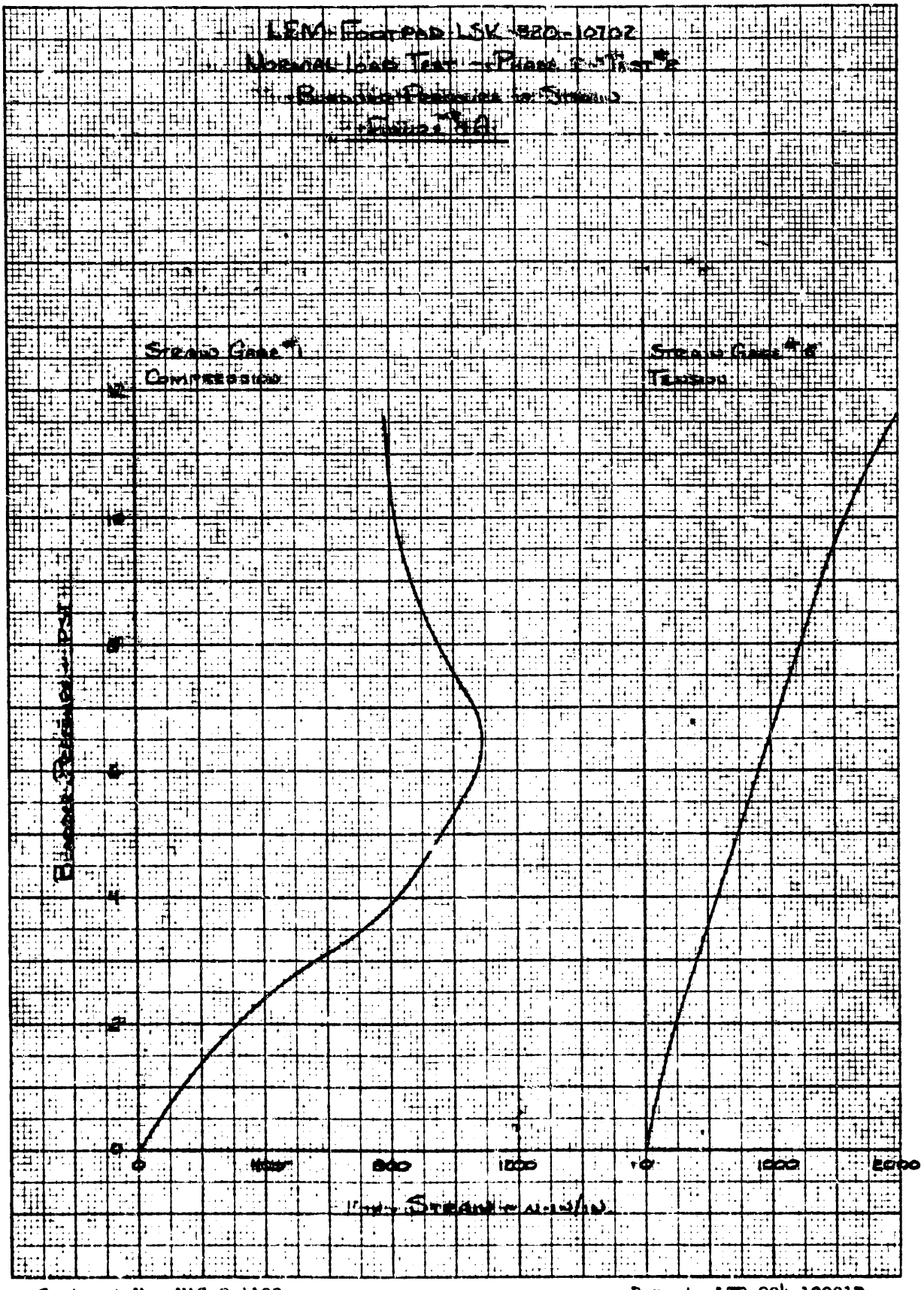
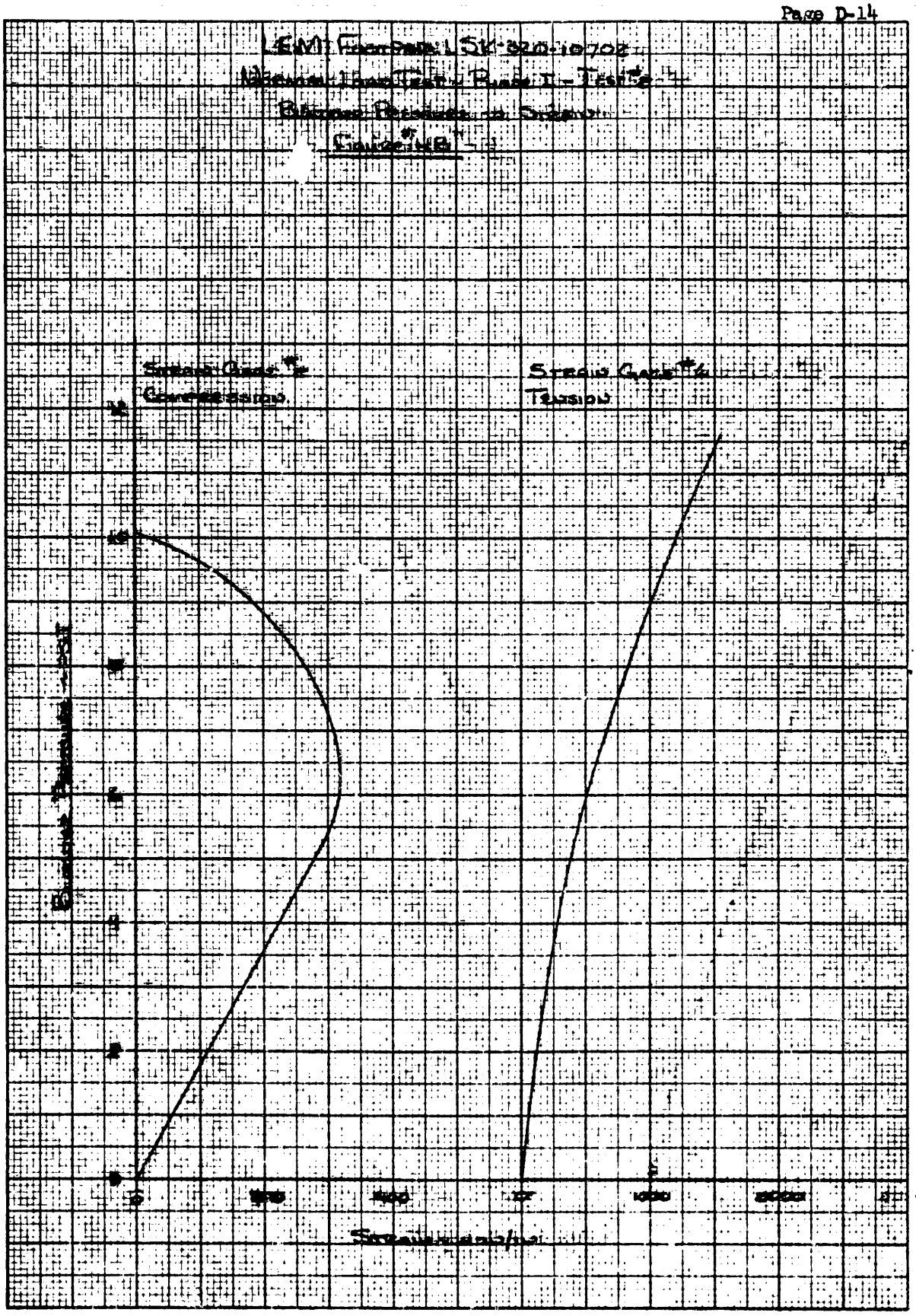
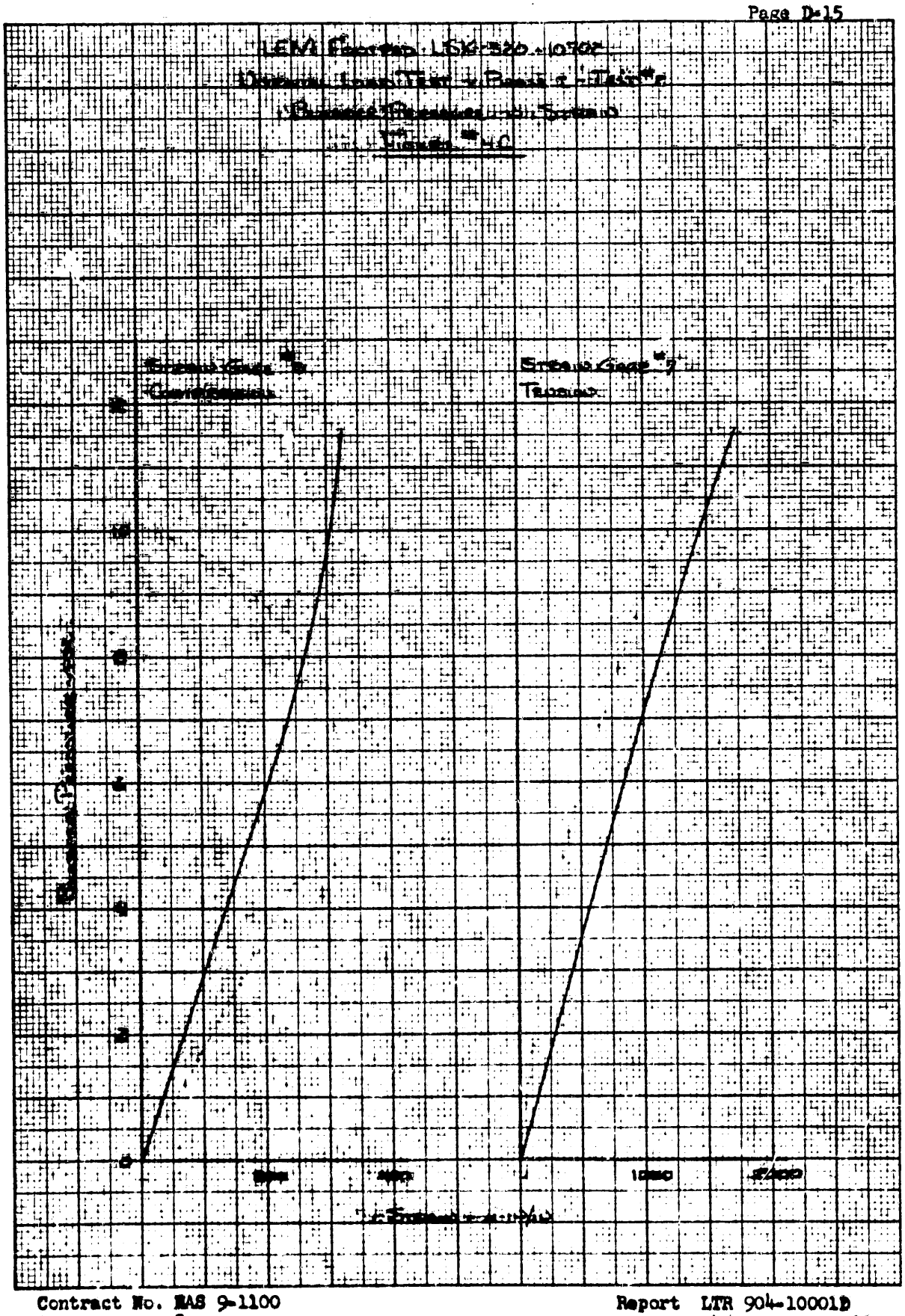


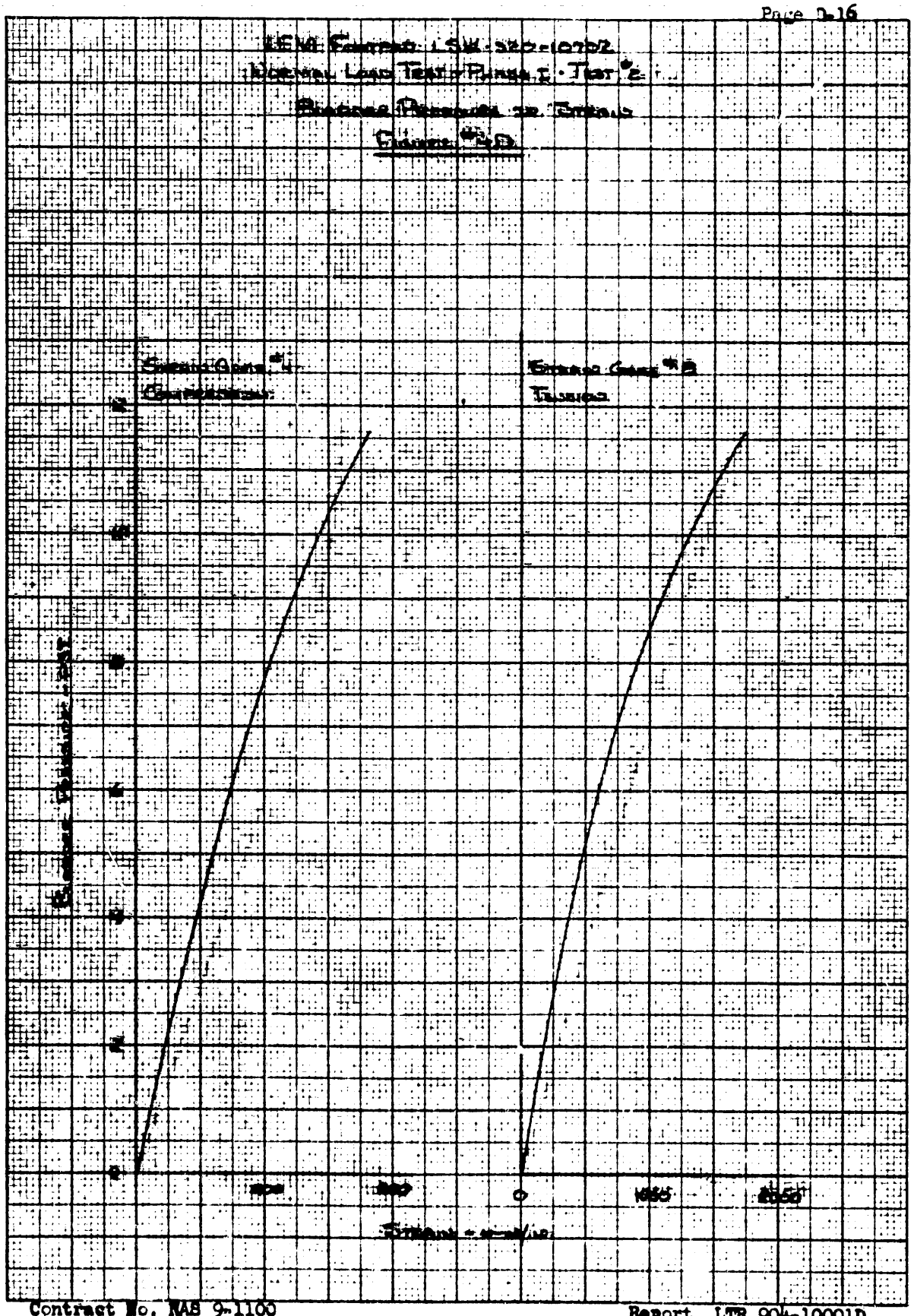
Contract No. NAS 9-1100
Primary Code 811

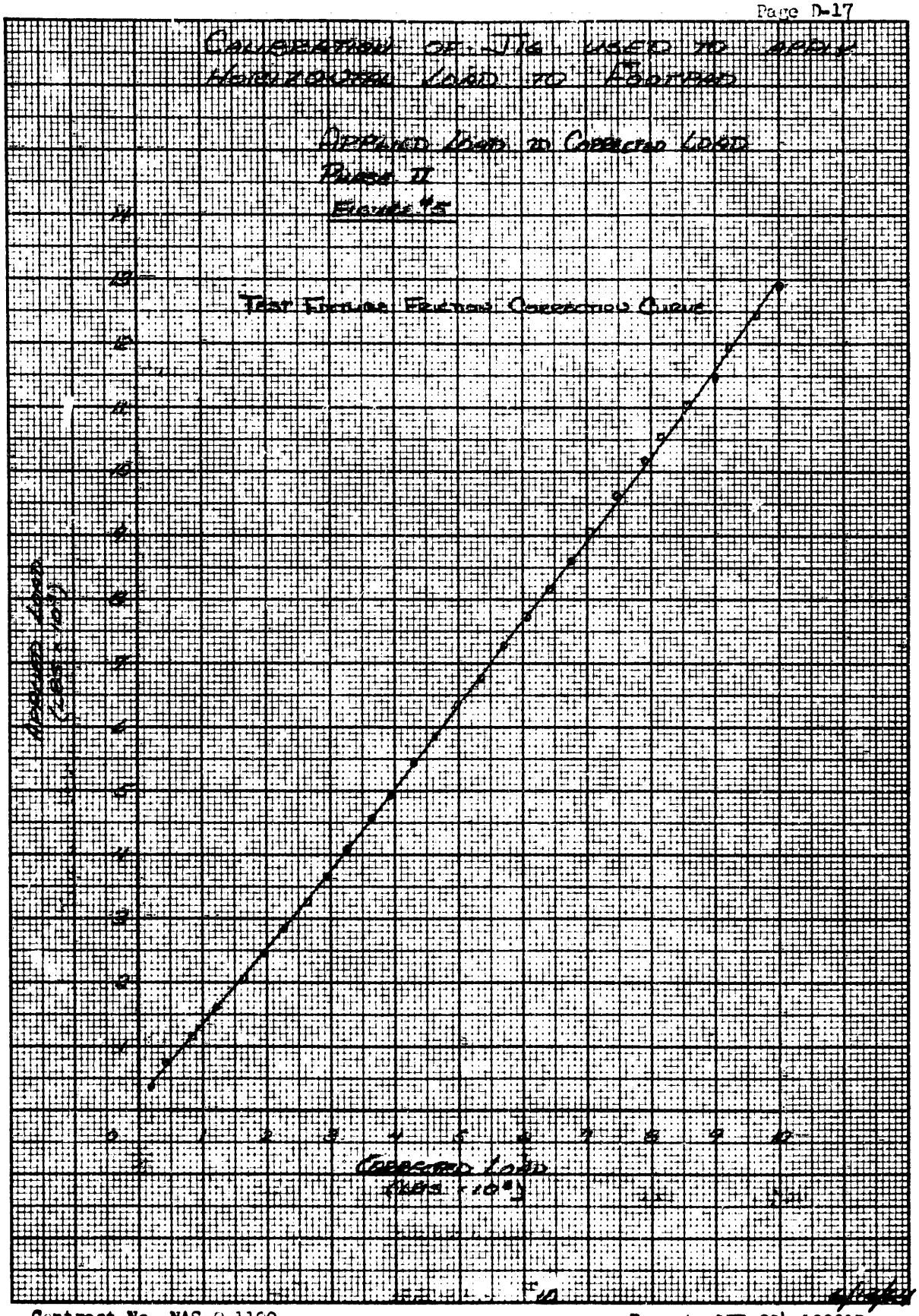
Report LTR 904-10001D
Date 14 February 1966


LEM FOOTPAD LSK 320-10702
NORMAL LOAD TEST - PHASE I - TEST #2
BLADDER PRESSURE - STRAIN
STRAIN GAGE #1
COMPRESSION
STRAIN GAGE #8
TENSION
BLADDER PRESSURE - PSI
0
2
4
6
8
10
12
0
400
800
1200
1000
2000
STRAIN - IN-IN/IN


Strain Gage #4
Compression
Strain Gage #4
Tension

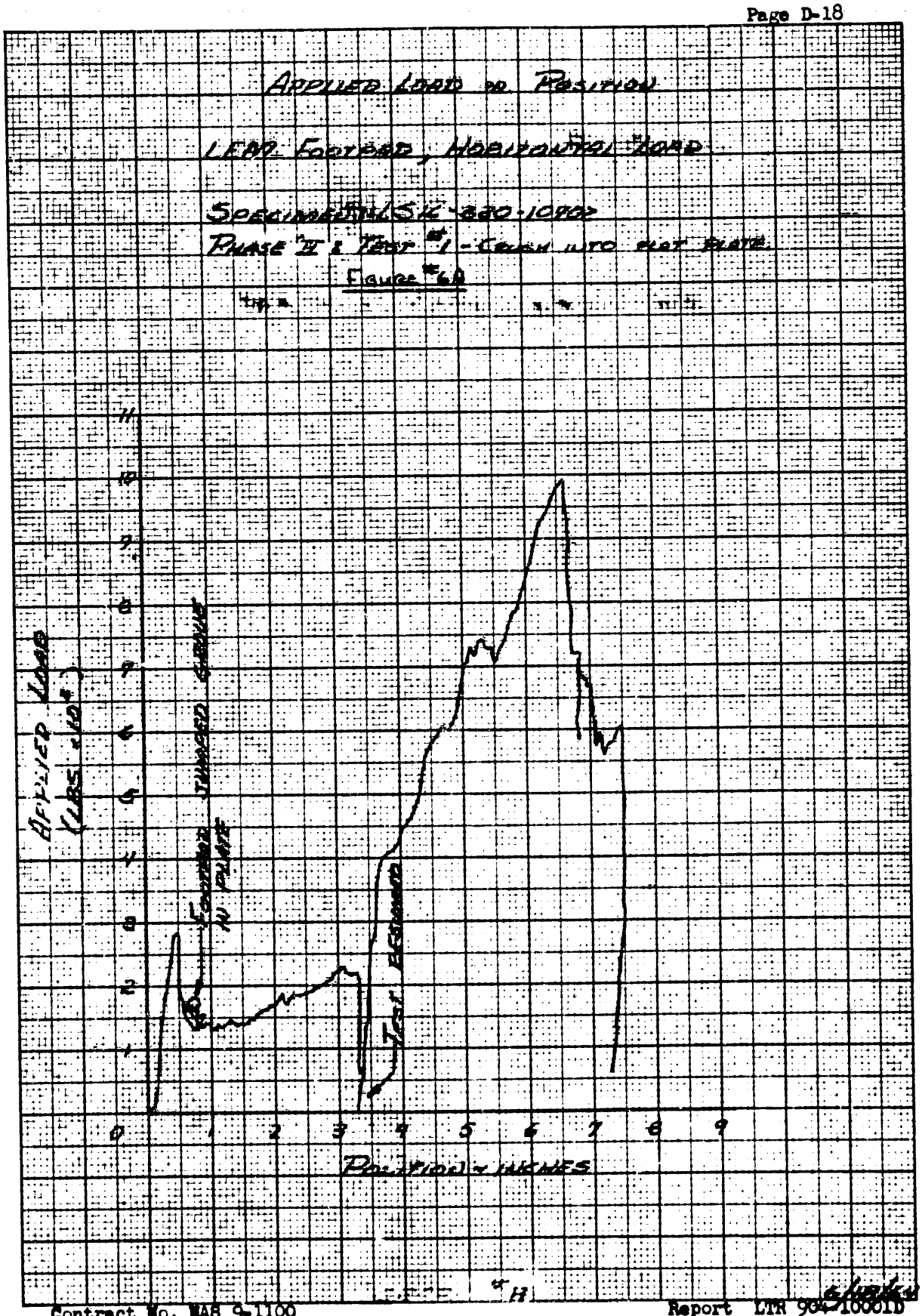

Strain Gage #7
Tension
1000
2000

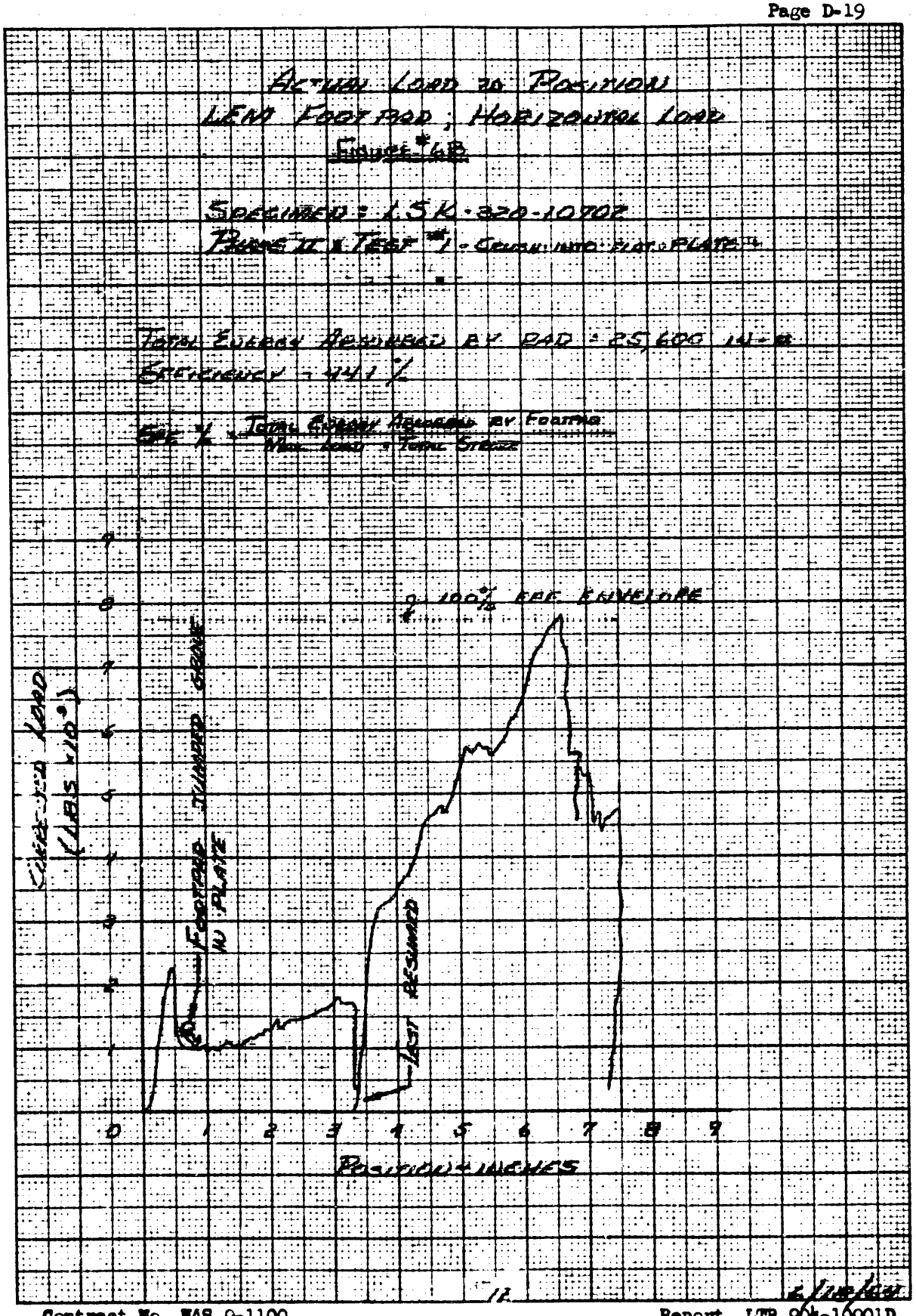

Strain Gage #4
Compression
Strain Gage #3
Tension
0

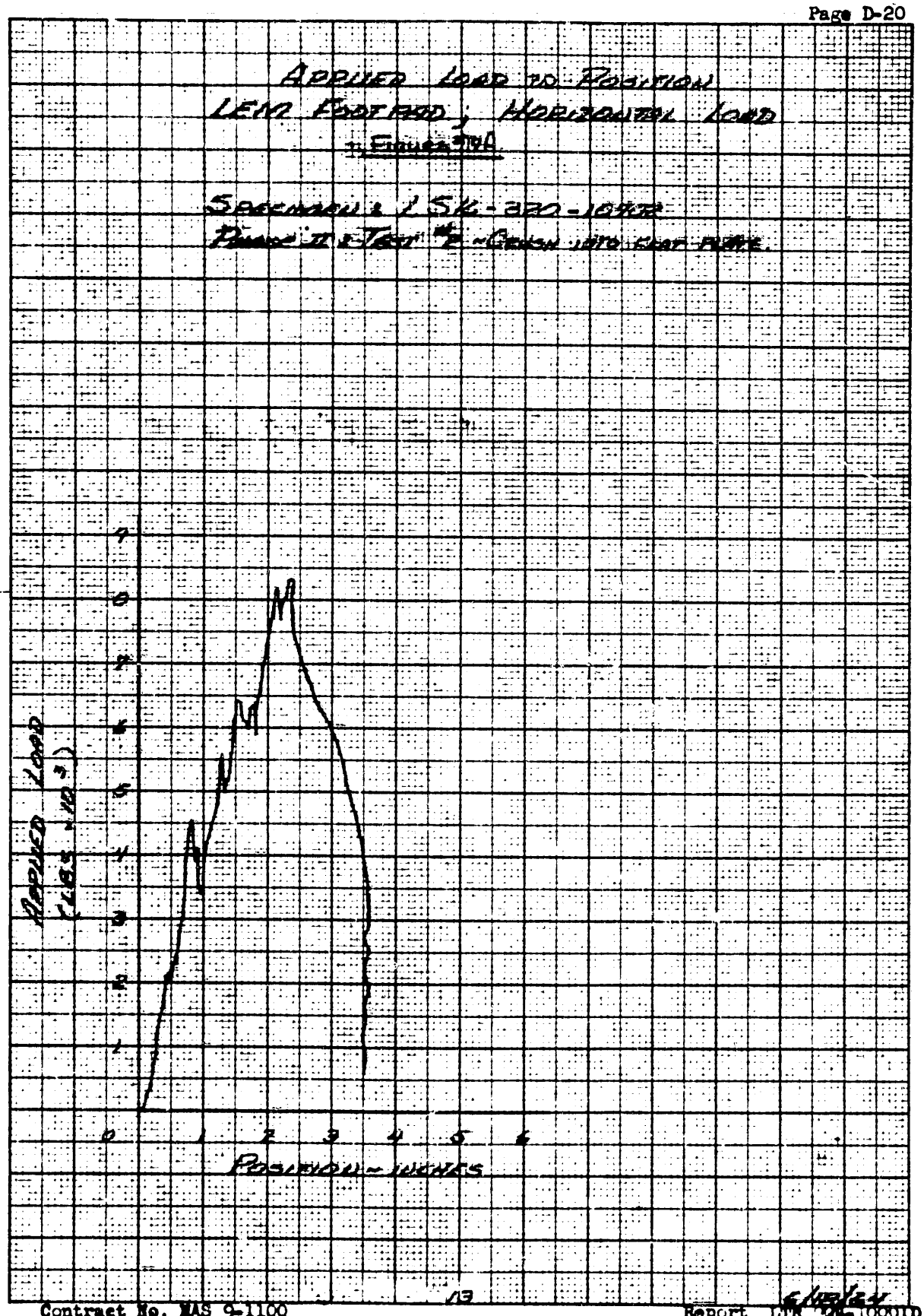


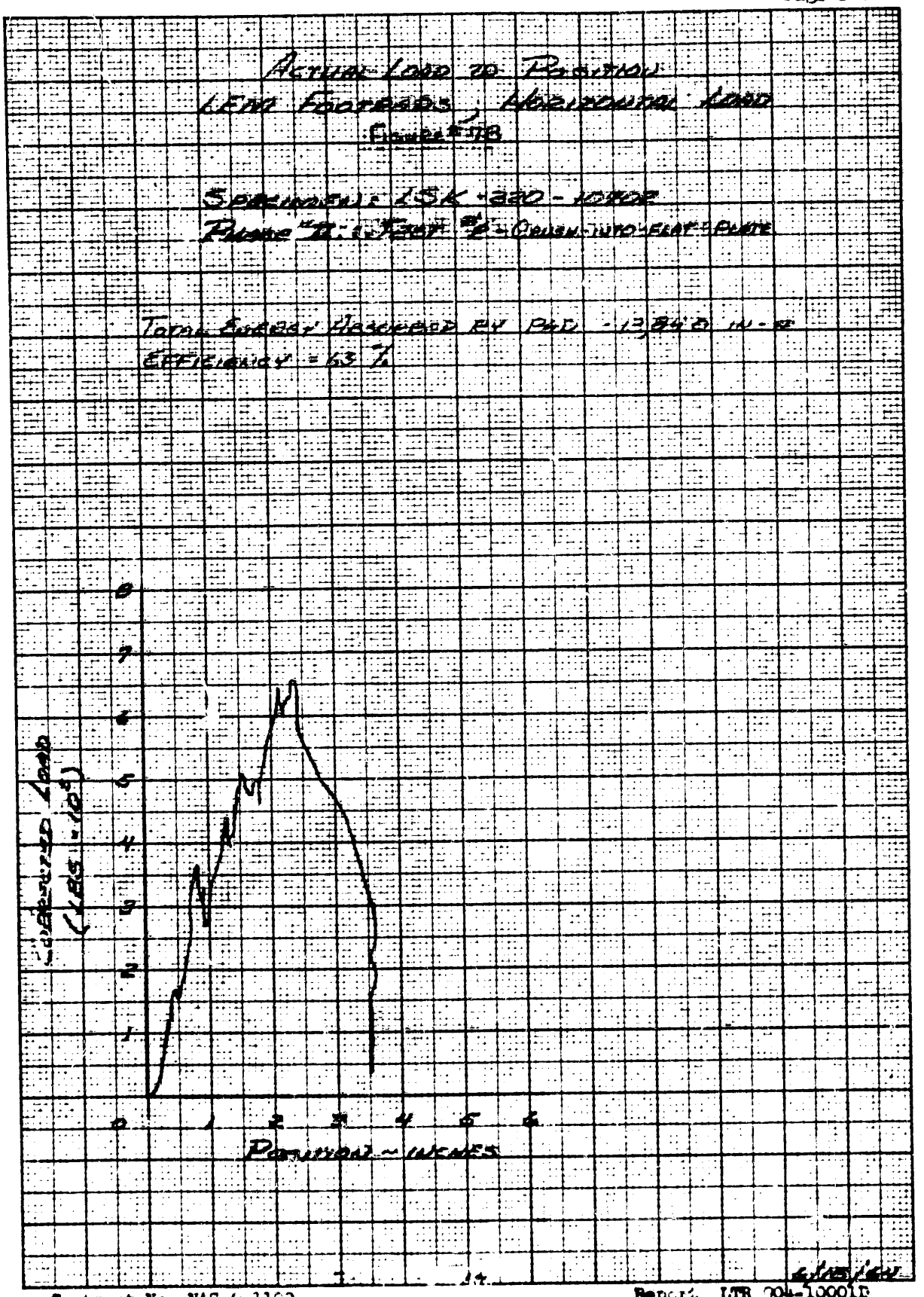
Contract No. NAS 9-1100
Primary Code 811

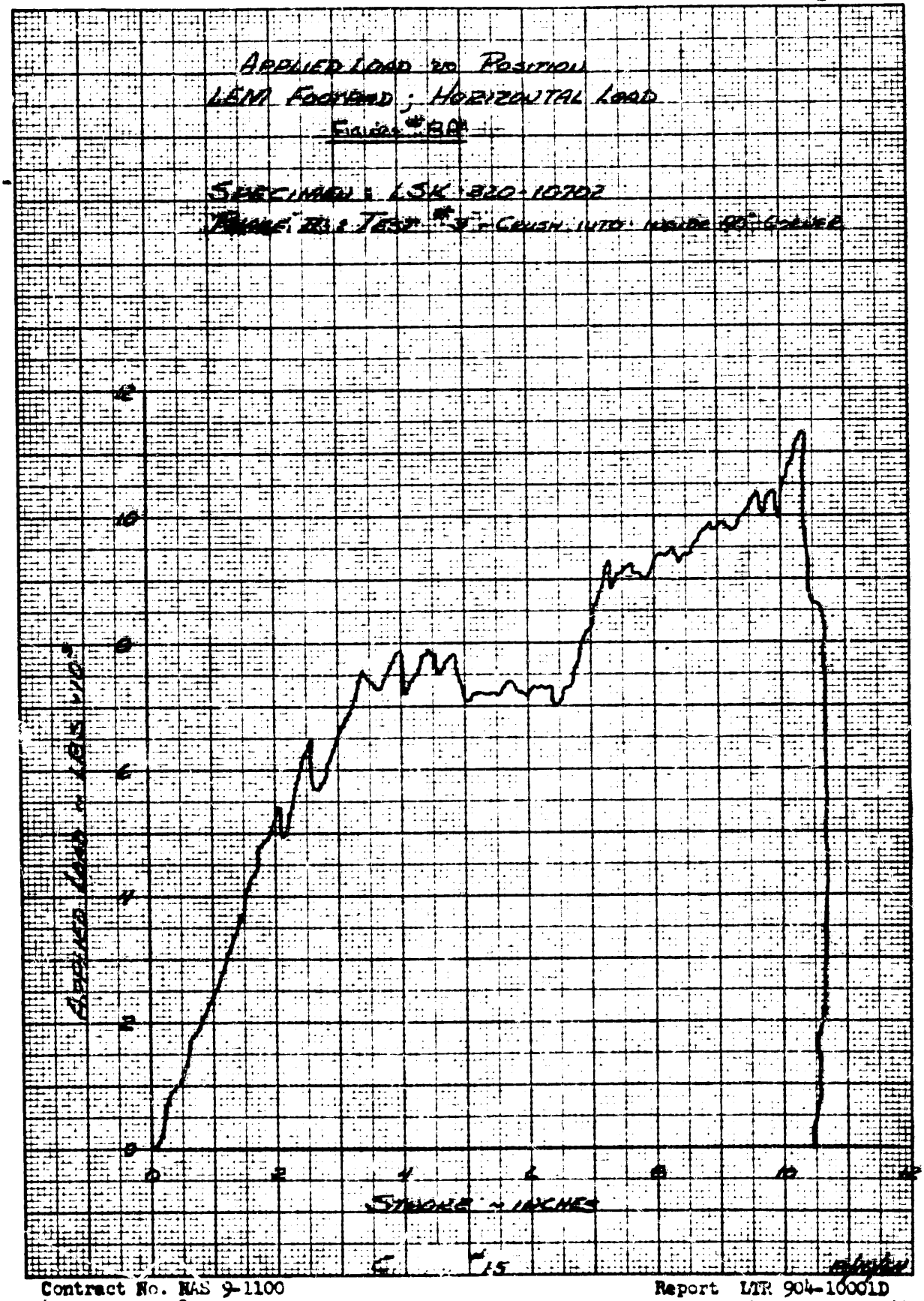
Report LTR 904-10001D
Date 14 February 1966


APPLIED LOAD vs POSITION
LEM FOOTPAD, HORIZONTAL LOAD
SPECIMEN #1 (SK-320-10902)
PHASE II & TEST #1 - CRUSH INTO FLAT PLATE
FIGURE #6A
APPLIED LOAD (LBS x 10⁴)
FOOTPAD JUMPED GROUND IN PLATE
TEST RESUMED
POSITION ~ INCHES
0
1
2
3
4
5
6
7
8
9
10
11


ACTUAL LOAD VS POSITION
LEM FOOTPAD; HORIZONTAL LOAD
FIGURE #6B
SPECIMEN: LSK-320-10702
PHASE II x TEST #1 - CRUSH INTO FLAT PLATE
TOTAL ENERGY ABSORBED BY PAD = 25,600 IN-#
EFFICIENCY = 44.1 %
EFF % = TOTAL ENERGY ABSORBED BY FOOTPAD / MAX LOAD × TOTAL STROKE
100% EFF. ENVELOPE
FOOTPAD JUMPED GROVE IN PLATE
TEST RESUMED
CORRECTED LOAD (LBS × 10³)
POSITION - INCHES
0
1
2
3
4
5
6
7
8
9

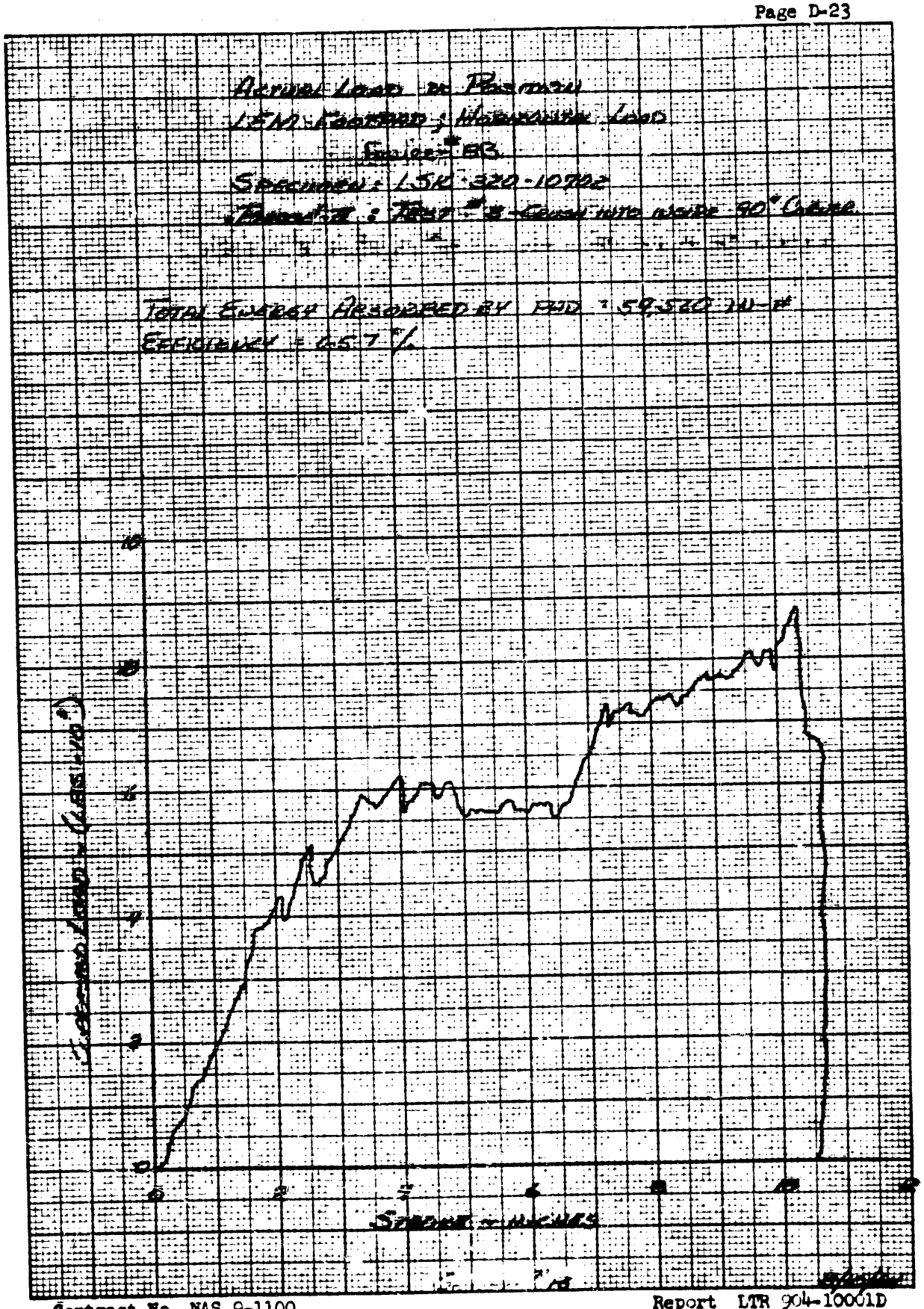

APPLIED LOAD TO POSITION
LEM FOOTPAD; HORIZONTAL LOAD
Figure 9A
SPECIMEN: LSK-320-10402
PHASE II: TEST #2 - CRUSH INTO FLAT PLATE.
APPLIED LOAD (LBS x 10³)
POSITION - INCHES
0
1
2
3
4
5
6
7
8
9


ACTUAL LOAD TO POSITION
LEM FOOTPADS, HORIZONTAL LOAD
FIGURE #78
SPECIMEN: LSK-320-10702
PHASE "II": TEST #2 - CRUSH-INTO-FLAT PLATE
TOTAL ENERGY ABSORBED BY PAD - 13,840 IN-#
EFFICIENCY = 63 %
CORRECTED LOAD (LBS × 10³)
POSITION ~ INCHES
0
1
2
3
4
5
6
7
8

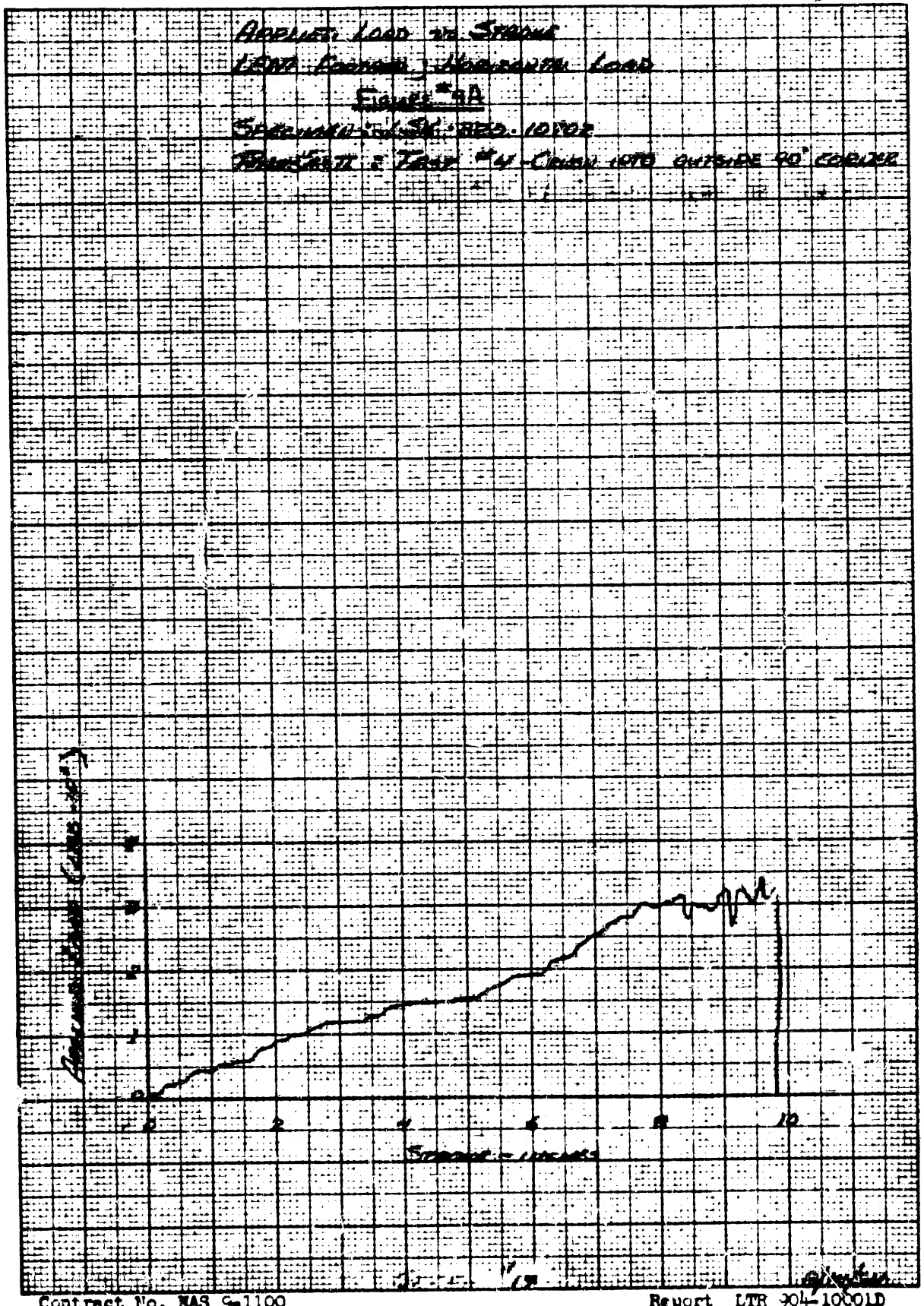


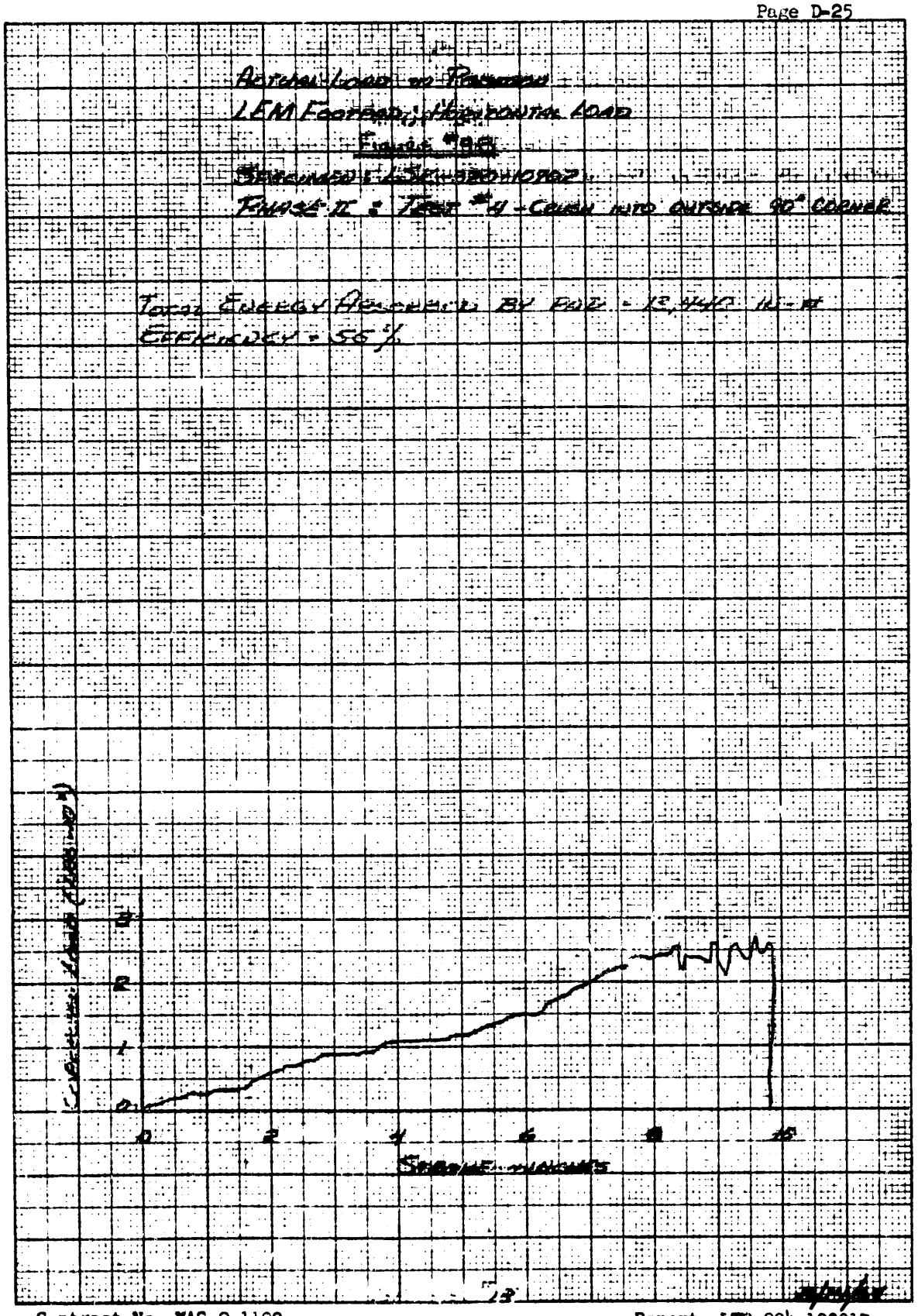
Contract No. NAS 9-1100
Primary Code 811

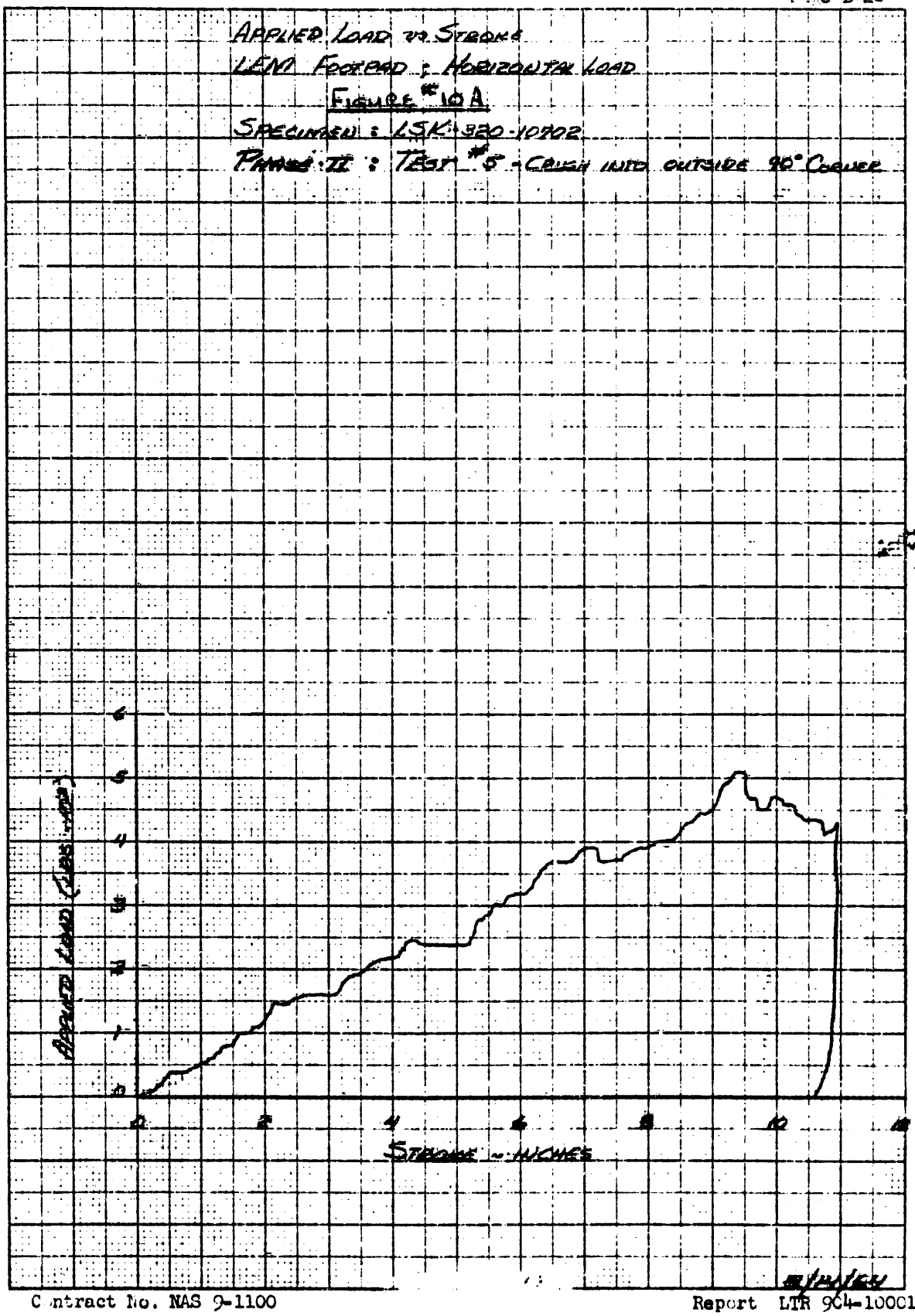
Report LTR 904-10001D
Date 14 February 1966

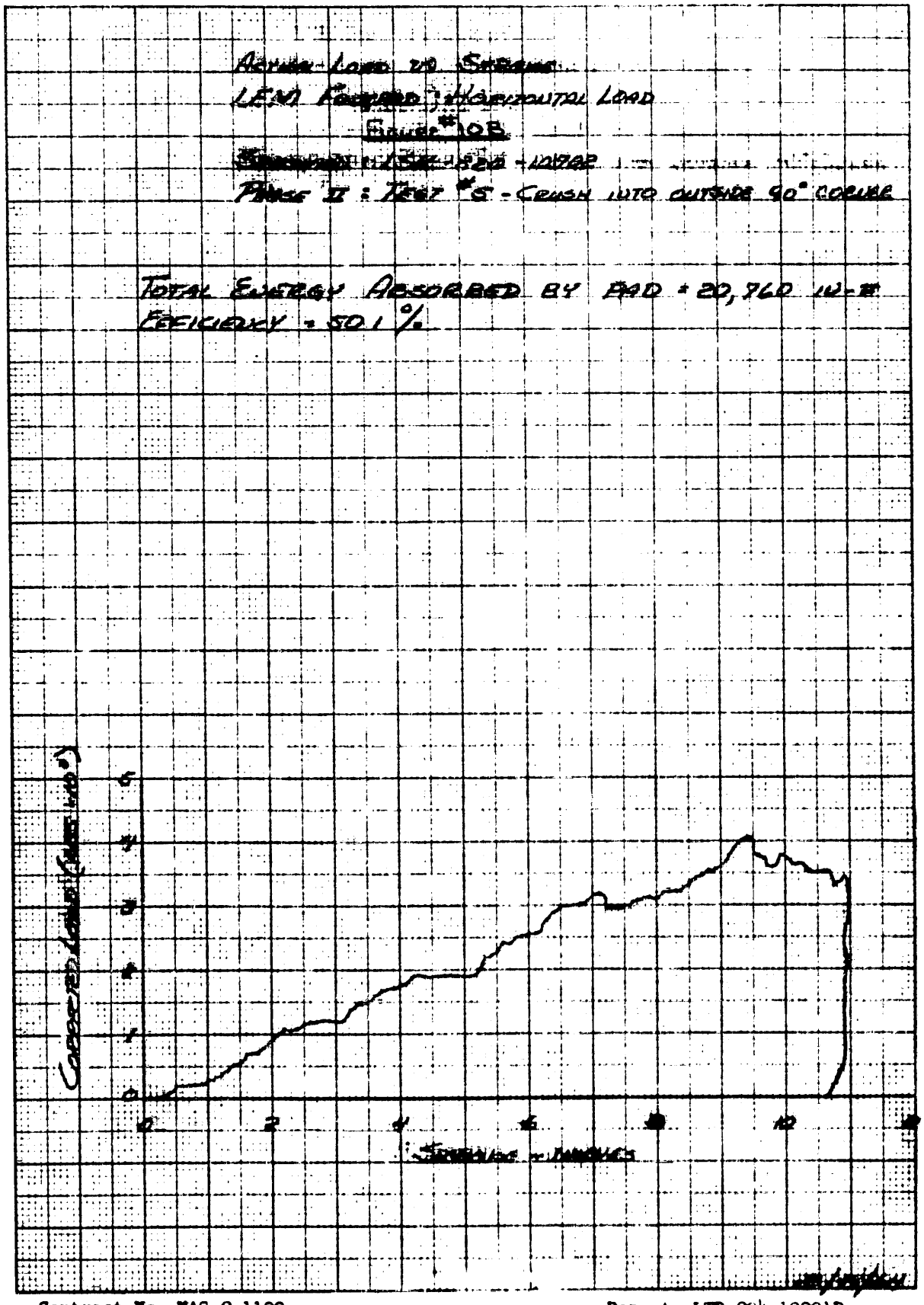


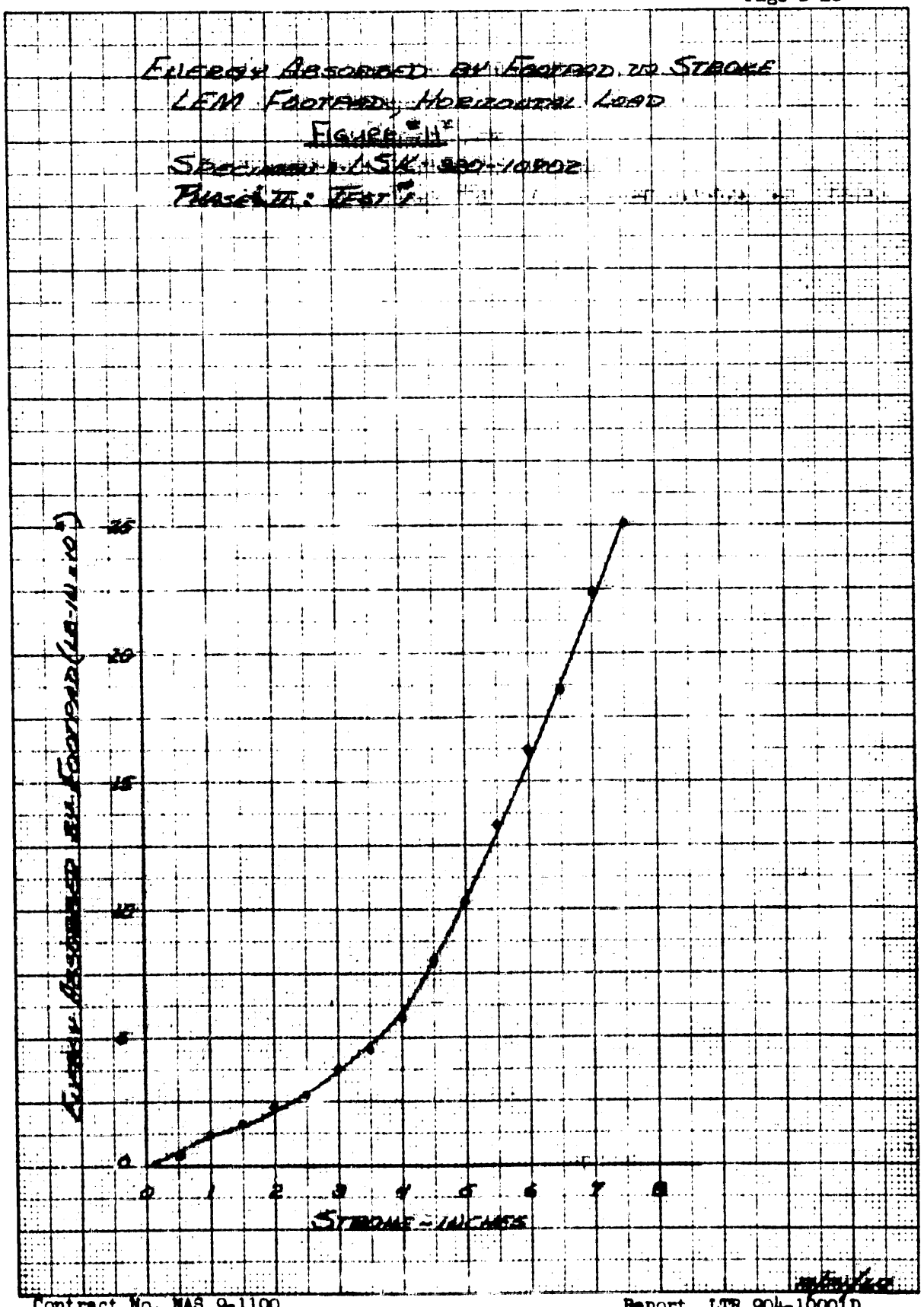
K+E 10 X 10 TO THE ½ INCH 359T-11
KEUFFEL & ESSER CO.

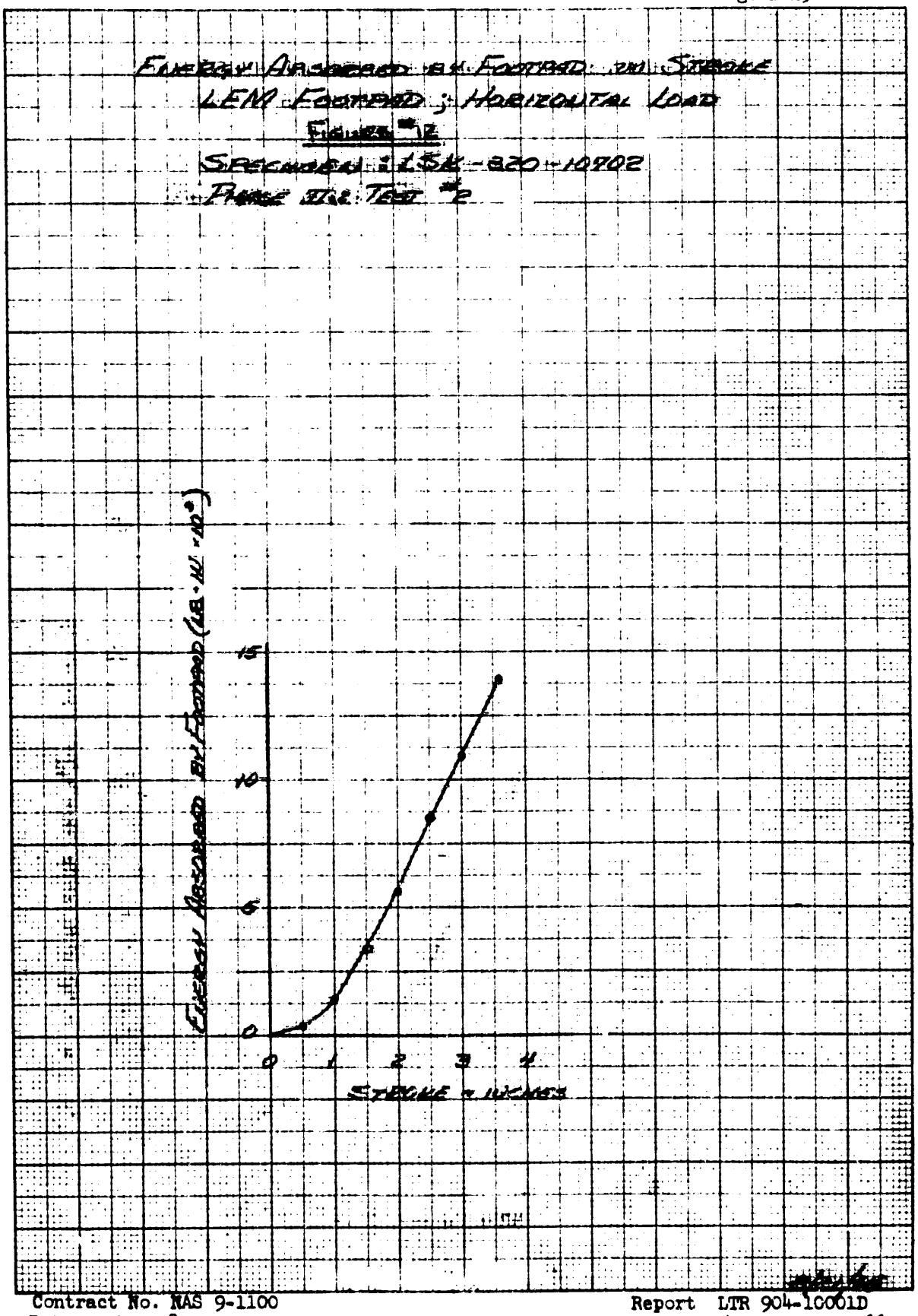

Applied Load vs Stroke
Left Footing Horizontal Load
Figure #9A
Specimen: LSK-320-10702
Transmit: Test #4 - Crush into outside 90° corner
Applied Load (Lbs-in²)
0
1
2
3
4
0
2
4
6
8
10
Stroke - inches

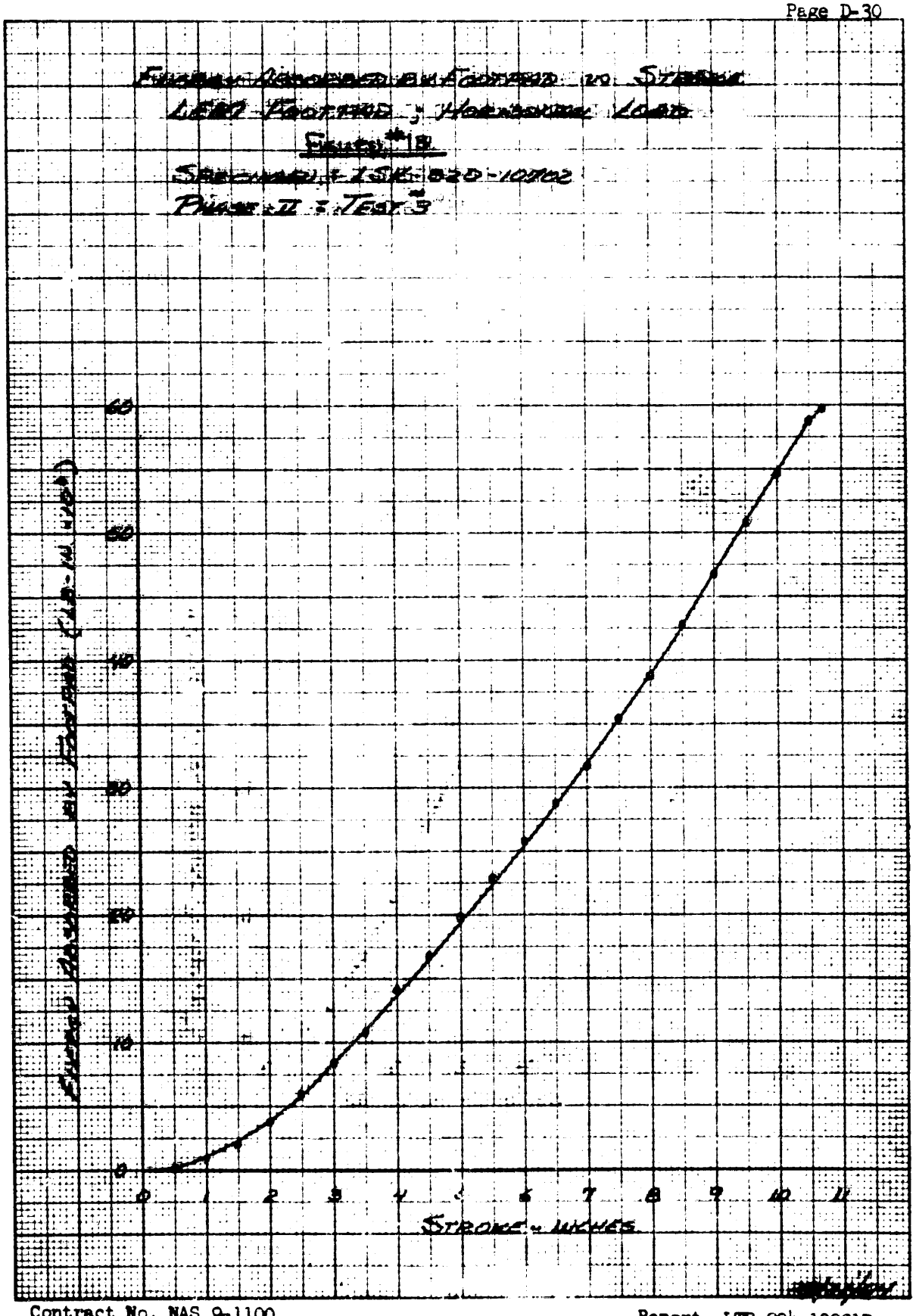

Actual Load on Pressure
LEM Footpad; Horizontal Load
Figure #98
Specimen: LSK-320-10702
Phase II: Test #4 - Crush into outside 90° corner
Total Energy Absorbed by Pad - 13,440 in-#
Efficiency - 56%
Capacity Load (lbs-in)
0
1
2
3
0
2
4
6
8
10
Stroke - inches

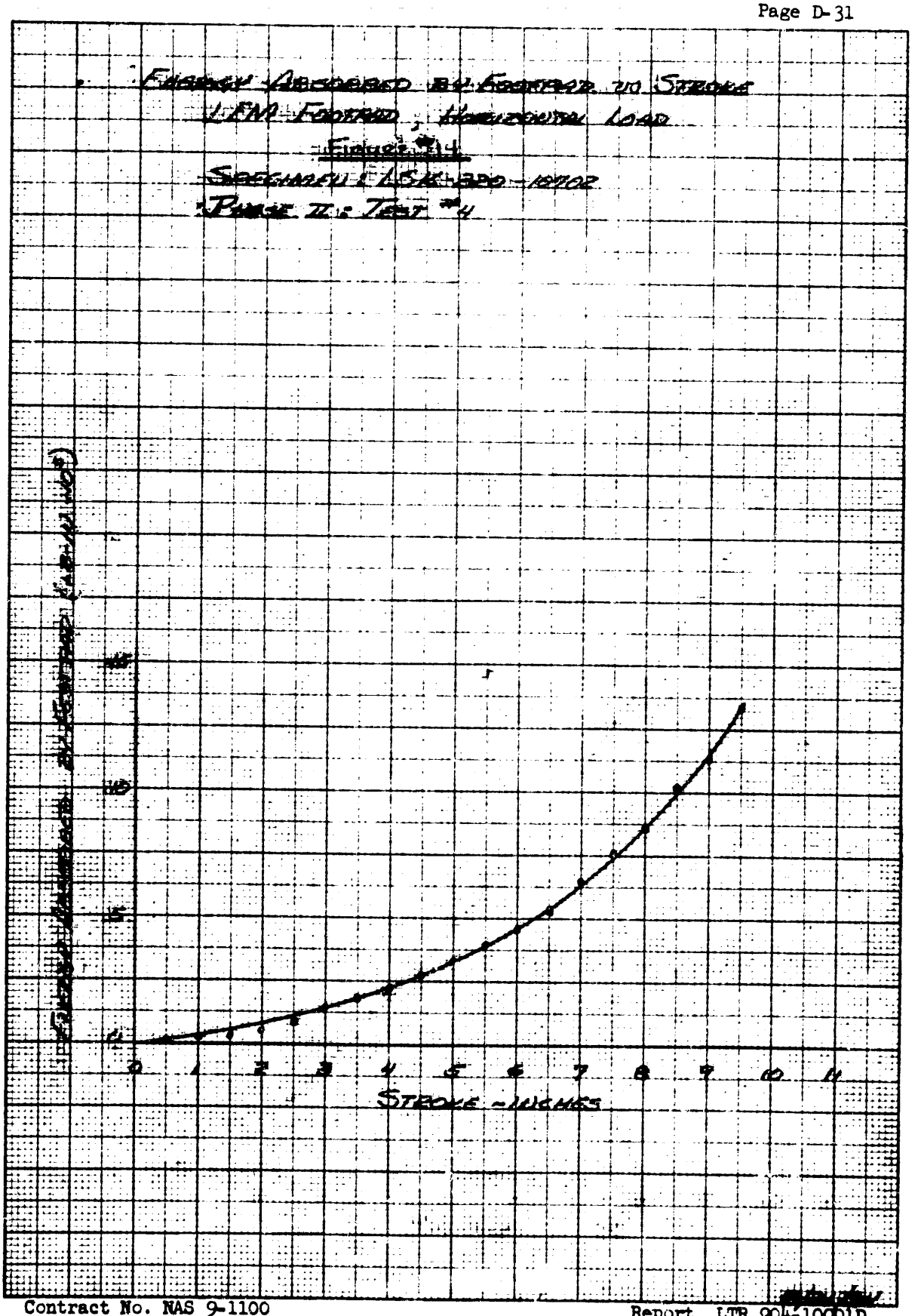

APPLIED LOAD vs. STROKE
LEM FOOTPAD ; HORIZONTAL LOAD
FIGURE #10A
SPECIMEN : LSK-320-10702
PHASE II : TEST #5 - CRUSH INTO OUTSIDE 90° CORNER
APPLIED LOAD (LBS x 10³)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
STROKE ~ INCHES

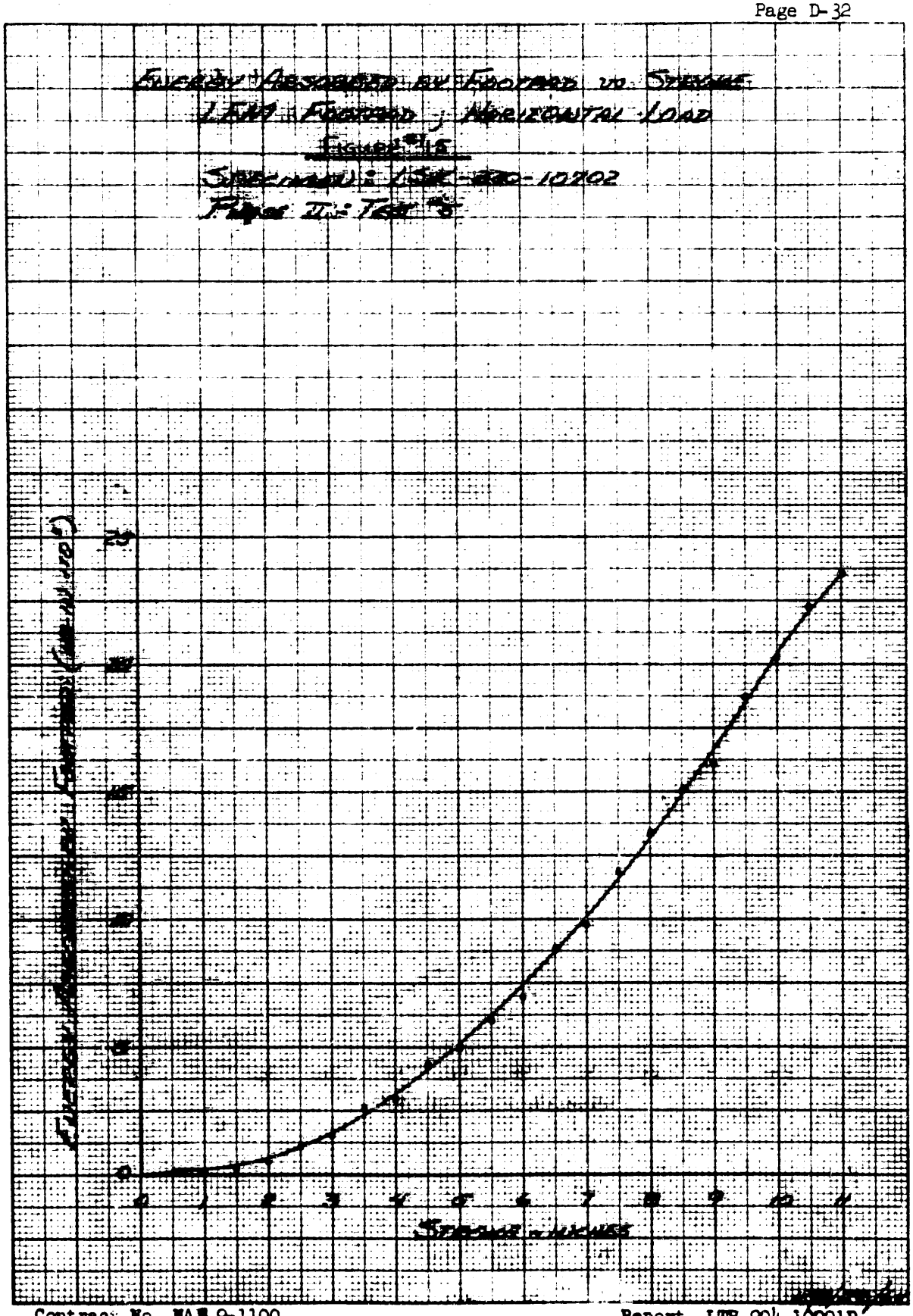

LEM FORWARD; HORIZONTAL LOAD
FIGURE #10B
PHASE II : TEST #5 - CRUSH INTO OUTSIDE 90° CORNER
TOTAL ENERGY ABSORBED BY PAD = 20,760 IN-#
EFFICIENCY = 50.1 %
0
1
2
3
4
5
0
2
4
6
8
10
12

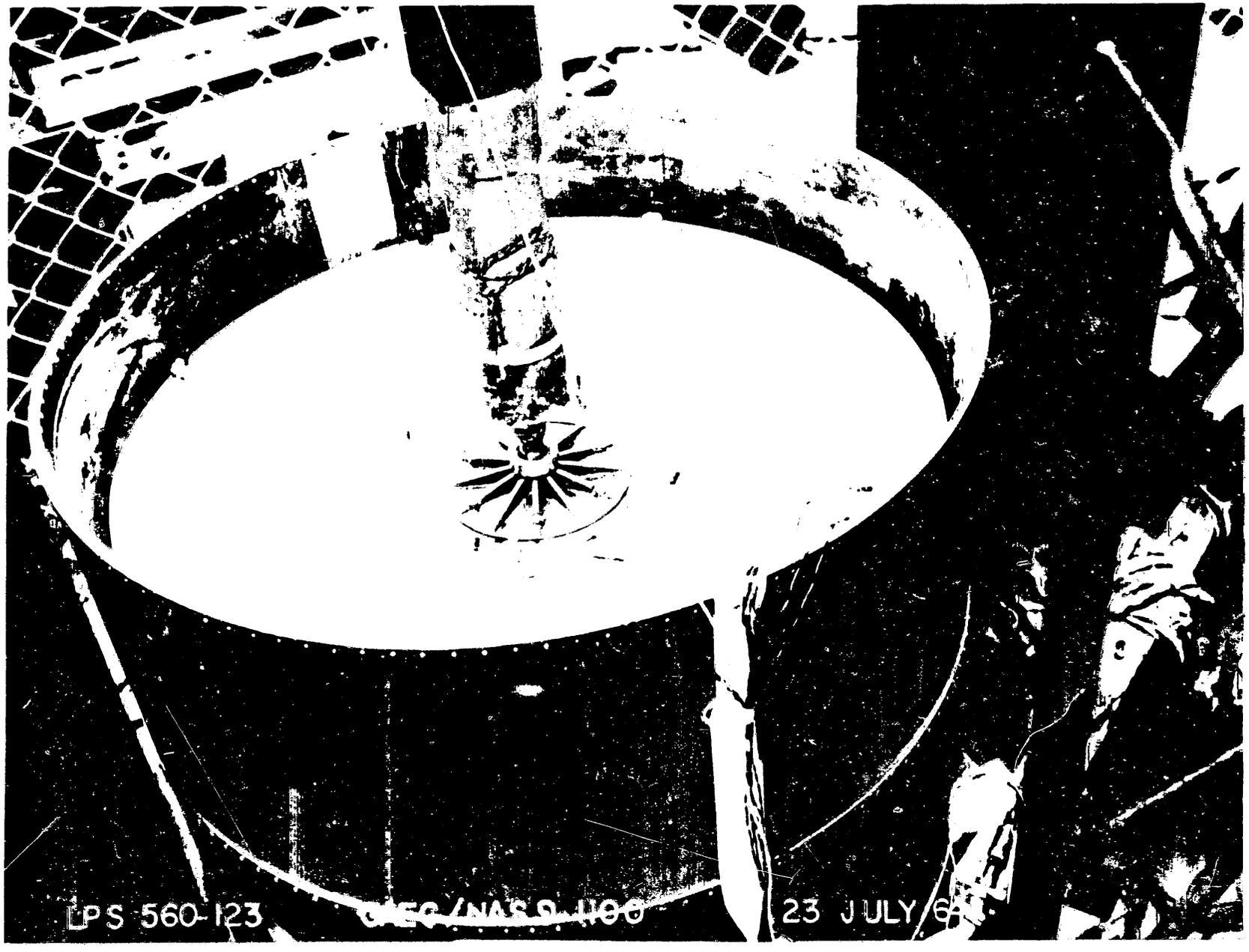

ENERGY ABSORBED BY FOOTPAD VS STROKE
LEM FOOTPAD, HORIZONTAL LOAD
FIGURE #11
SPECIMEN: LSK 380-10902
PHASE II: TEST #1
ENERGY ABSORBED BY FOOTPAD (LB-IN x 10³)
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
STROKE - INCHES

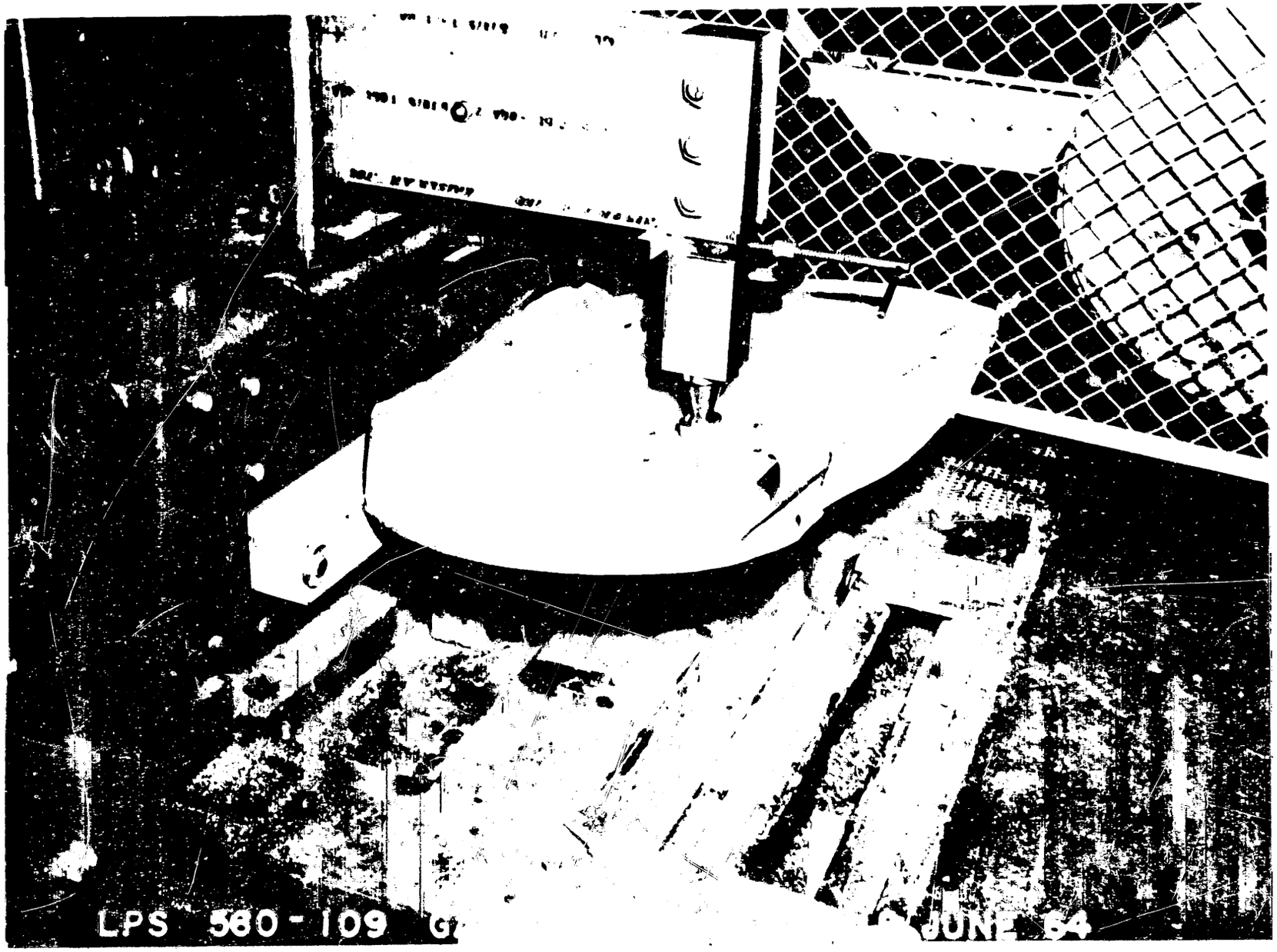

ENERGY ABSORBED BY FOOTPAD IN STROKE
LEM FOOTPAD ; HORIZONTAL LOAD
FIGURE #2
SPECIMEN : LSK-820-10702
PHASE III: TEST #2
ENERGY ABSORBED BY FOOTPAD (LB-IN-10³)
15
10
5
0
0
1
2
3
4
STROKE - INCHES

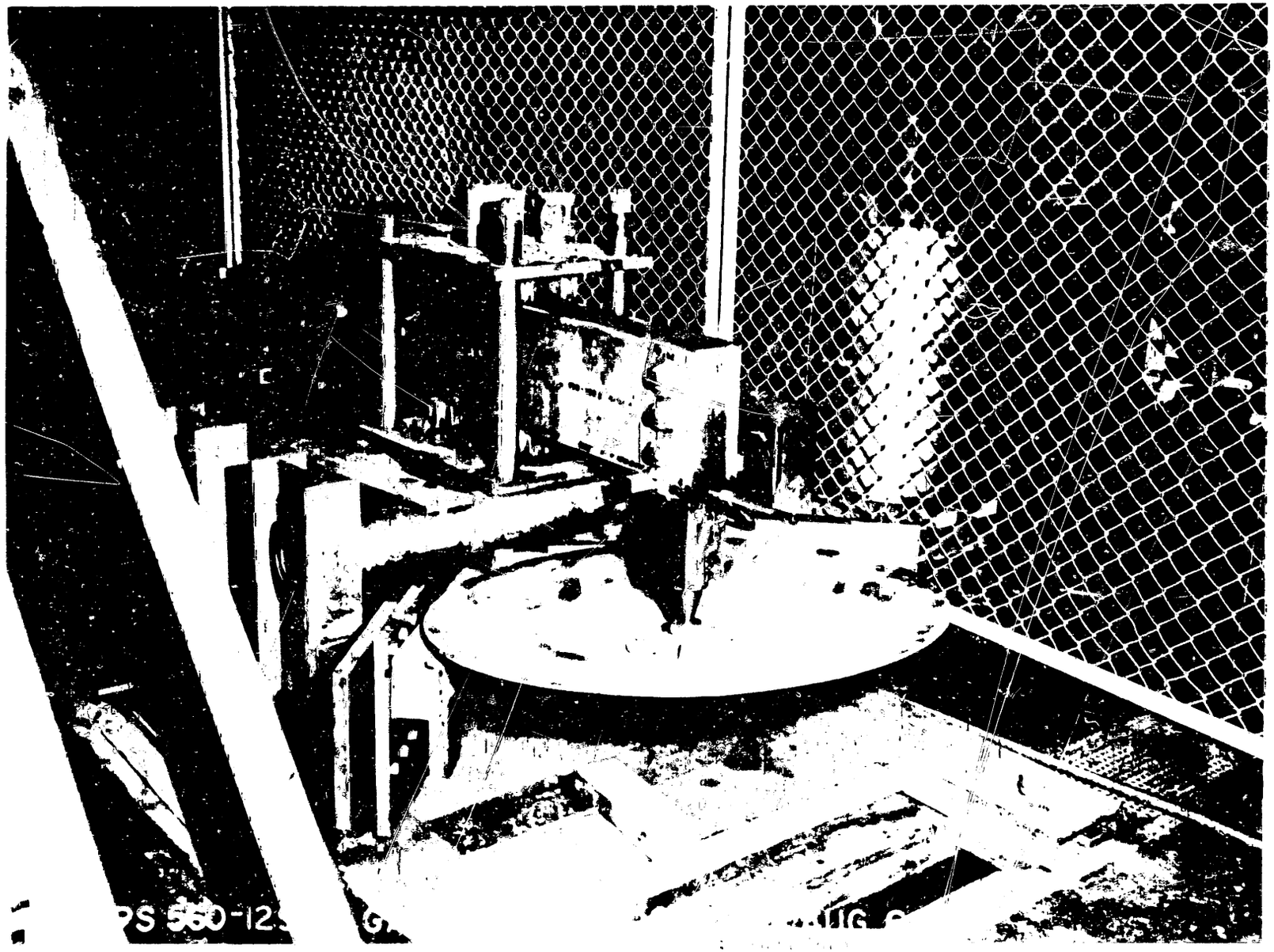

Energy Absorbed by Footpad vs Stroke
LEM Footpad ; Horizontal Load
Figure #18
Specimen : ISK-320-10702
Phase II : Test #3
Energy Absorbed by Footpad (LB-IN x 10⁴)
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
8
9
10
11
Stroke - Inches


ENERGY ABSORBED BY FOOTPAD VS STROKE
LEM FOOTPAD, HORIZONTAL LOAD
FIGURE #14
SPECIMEN: LSK-320-10702
PHASE II: TEST #4
0
1
2
3
4
5
6
7
8
9
10
11
STROKE - INCHES


Energy Absorbed by Footrad vs Stroke
LEM Footrad ; Horizontal Load
Figure #15
Specimen: LSK-220-10702
Phase II: Test #5
0
1
2
3
4
5
6
7
8
9
10
11
Stroke - Inches


LPS 560-123
23 JULY 6


LPS 580-109 G
JUNE 64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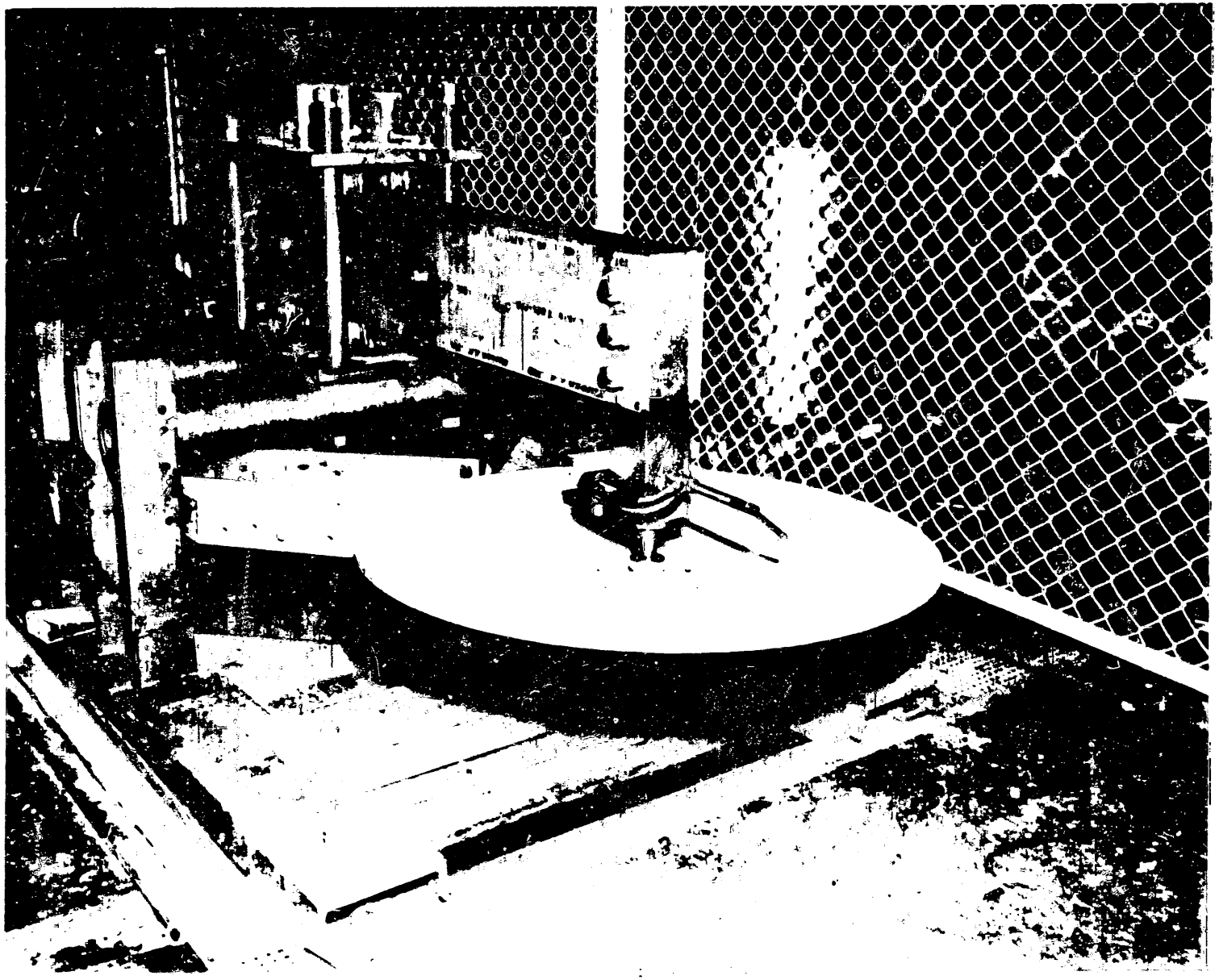
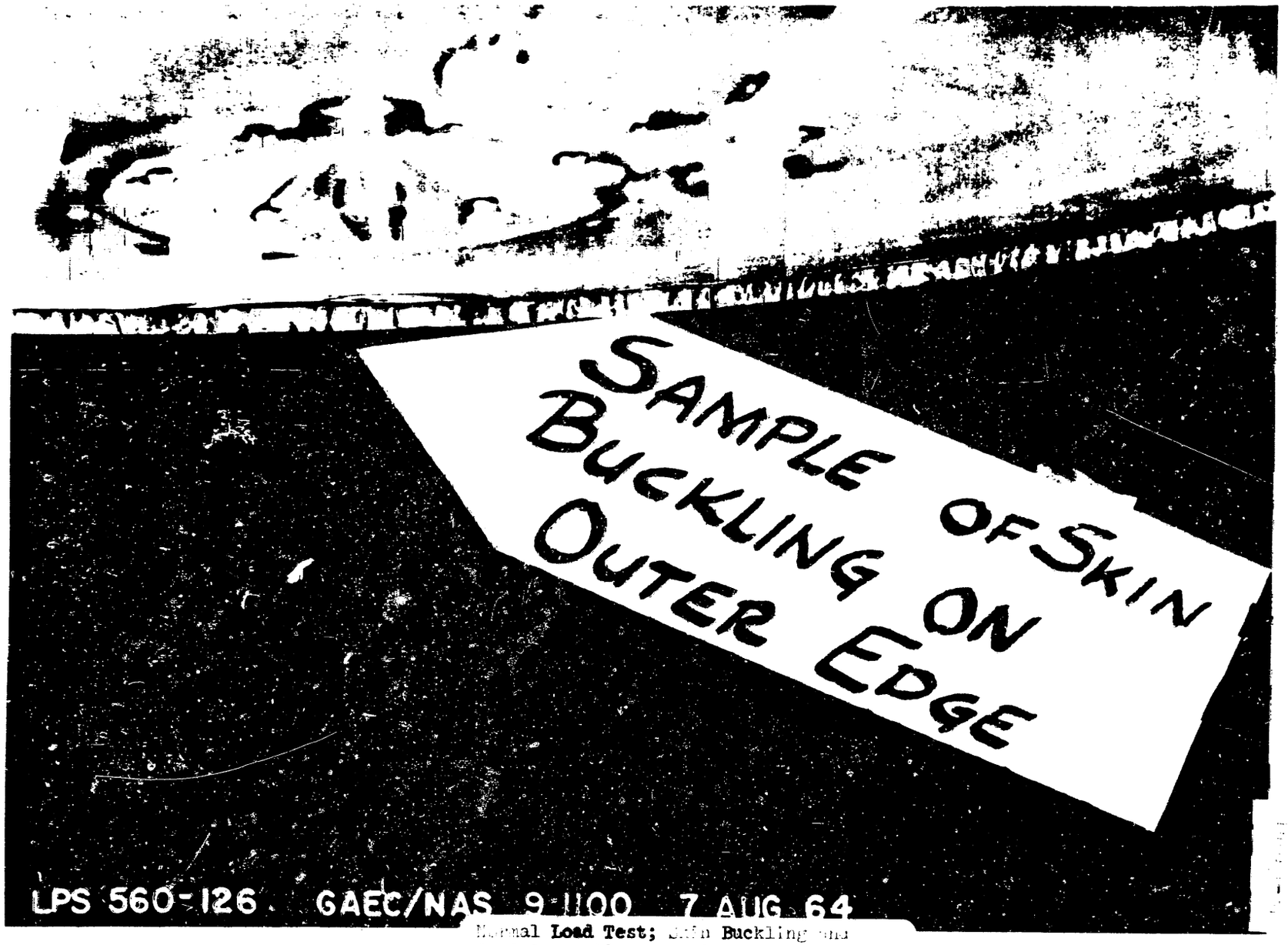
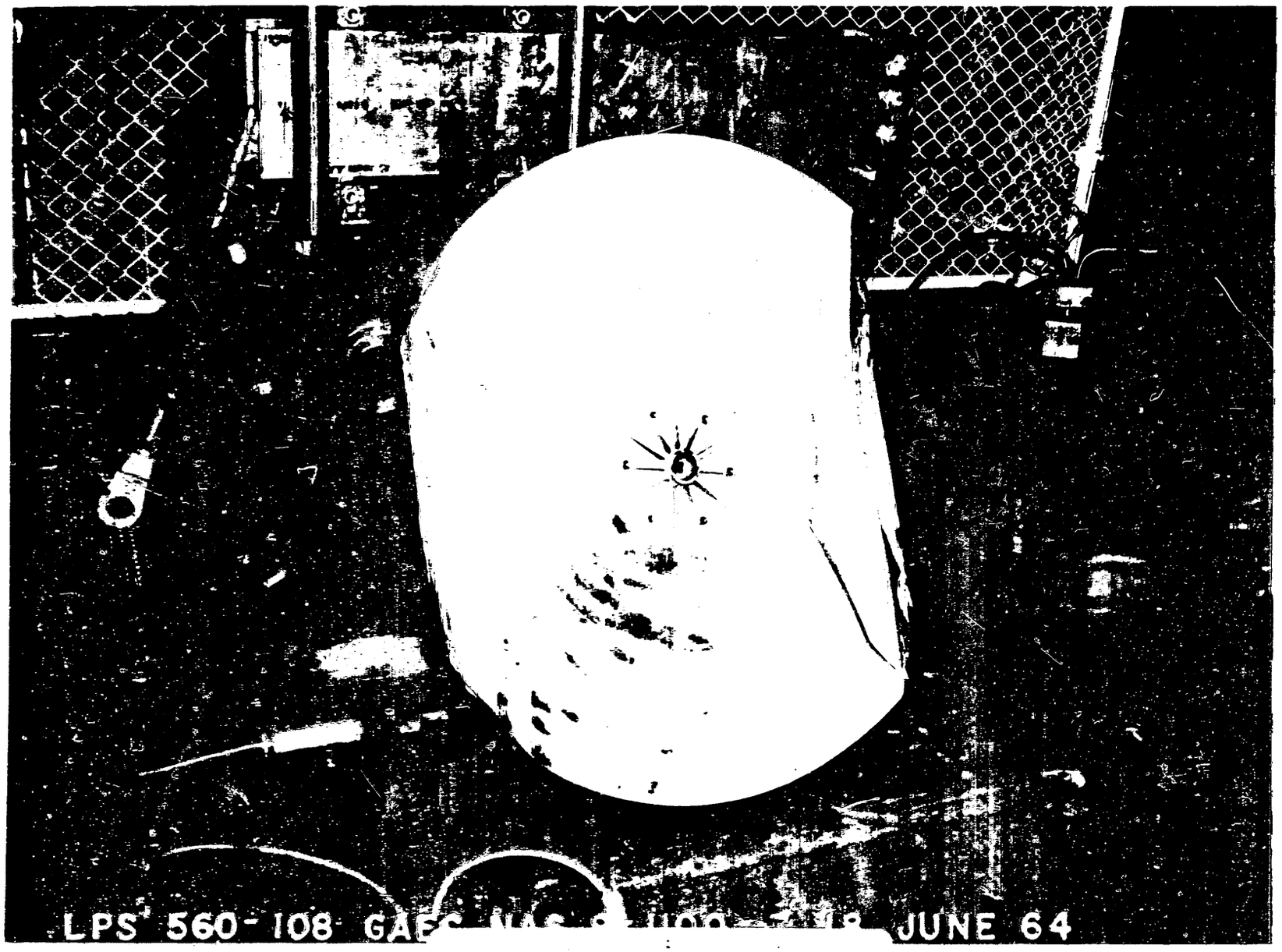




Normal Load Test; Skin Buckling and
Bond Separation on Outer Edge of Component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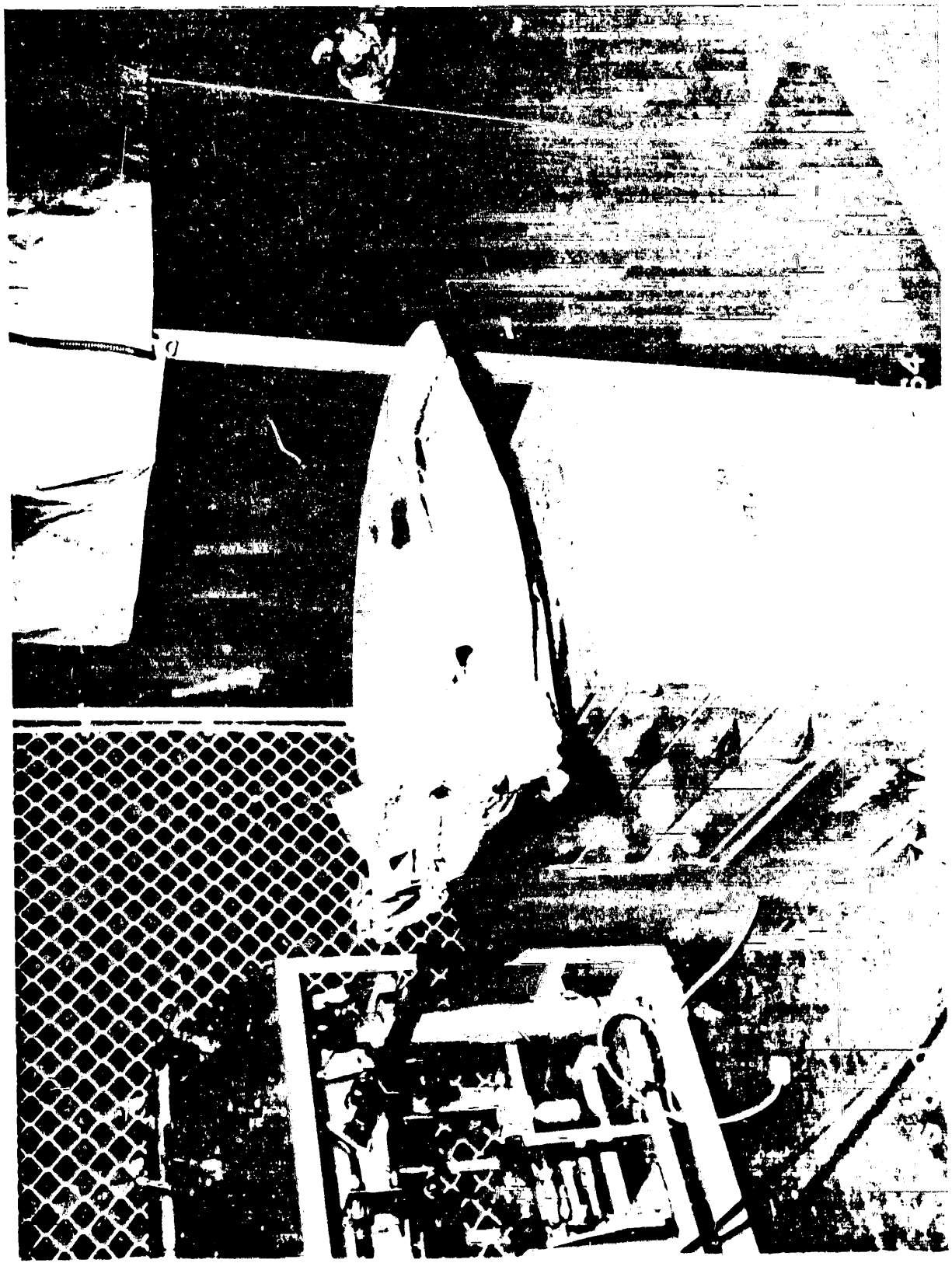

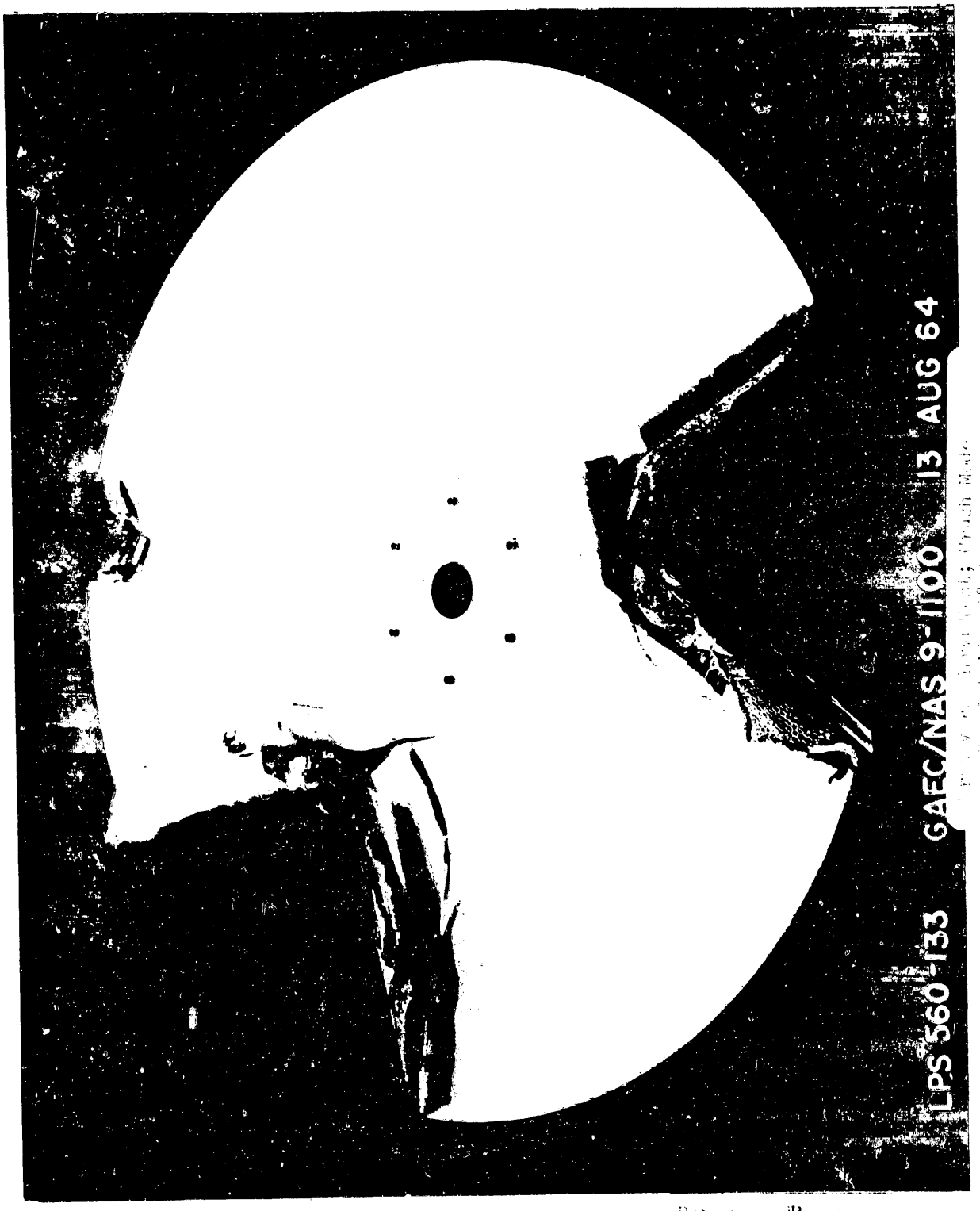
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GAEC/NAS 9-1100
13 AUG 64

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

L. Tosto
PREPARED BY:
L. Tosto

R. L. Makemson
CHECKED BY:
R. L. Makemson

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

1.0 PURPOSE OF TEST

1.1 This section contains the results of honeycomb cartridge development tests conducted to develop the cartridges for the landing gear of the LEM 1/6 scale model: MKII. This model will be used to investigate the landing stability characteristic for the LEM vehicle. The purpose of these tests was to evaluate various core materials, cartridge configuration and fabrication techniques for honeycomb cartridges.

1.2 These tests were conducted in partial fulfillment of the requirements of Contract No. NAS 9-1100.

2.0 DESCRIPTION OF HONEYCOMB CARTRIDGES

2.1 Honeycomb cartridges were fabricated from structural honeycomb material made by either the "expanded core" or "lay-up" method. The core material was supplied by the Hexcel Corporation (expanded core method) and Honeycomb Corporation of America (lay-up method).

2.2 Core material is identified by cell size, foil thickness and material in this order. Insertion of P after the foil thickness specifies the use of perforated foil.

Example - 1/8-7P (5052-H39) denotes 1/8" cell size, .0007 inches thick foil (perforated) and 5052 aluminum alloy with a heat treat value of H39.

Honeycomb material used had the following characteristics:

a. Cell Size - Ranges from 1/8" - 3/16"

b. Foil Thickness - .0007 - .002"

c. Material - 3003-H19 or 5052-H39

2.3 Honeycomb cartridges were pre-crushed to eliminate initial peak loads. Cartridge characteristics are shown on Figures 2,3, and 4. Additional information on cartridges may be obtained from drawings LSK 320-10106, LSK 320-101070 and LSK 320-10115F.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

3.0 TEST CONDITIONS

3.1 All tests were conducted under ambient environmental conditions

3.2 Cartridge designs with crushing loads, which most closely approach the required nominal values will be used in the landing gear of the LEM 1/6 scale model: MKII. The required nominal values are shown below.

Type of Strut	Model Nominal Loads (lbs)	LEM Prototype Loads (lbs)
A - Primary Strut		
1 - First Stage	125	4500
2 - Second Stage	378	13600
B - Secondary Strut		
1 - Single Stage	104	3750

4.0 TEST SET-UP AND PROCEDURE

4.1 The test set-up and procedures were as described in test plan LTP 904-10001, Section E. Static tests were conducted in the Riehle Test Machine and a stress-strain plotter was used to record crushing loads. The sketch (Figure 1) shows the essential features of the dynamic test apparatus. Dynamic loads were recorded on an oscilloscope ; equipped with a polaroid camera.

5.0 DISCUSSION OF TEST RESULTS

5.1 Static Tests

5.1.1 Static tests were considered a necessary preliminary to the dynamic tests. The primary purpose of static crushing tests, was to derive quickly a materials and cartridge geometry combination which would approximate the required cartridge properties both from maximum load and energy absorption considerations.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

5.0 DISCUSSION OF TEST RESULTS - continued

5.1 Static Tests - continued

5.1.2 The first batch of cartridges tested were made from core manufactured by the Honeycomb Corporation using the "lay-up" method of construction. Five cartridges of each type were statically crushed and the average crushing loads are tabulated below. The required nominal strut loads are also shown for comparison. The characteristics of these cartridges were as shown in Figure 2.

Type of Cartridge*	Crushing Load (lbs) (Static)	Required Nominal Strut Load (lbs) (Dynamic)
-1	179	125
-3	181	125
-5	277	378
-7	355	378
-9	175	104
-11	143	104

5.1.3 A second batch of honeycomb cartridges identical to those of batch #1 were made using different blocks of similar core material. Results of these tests are shown below.

Type of Cartridge*	Crushing Load (lbs) (Static)	Required Nominal Strut Load (lbs) (Dynamic)
-1	132	125
-3	78	125
-5	340	378
-7	420	378
-9	120	104
-11	228	104

(*Ref. Dwg. LSK 320-10106)

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

5.0 DISCUSSION OF TEST RESULTS - continued

5.1 Static Tests - continued

5.1.4 Comparison of these test results show that the second batch of cartridges had a noticeably different crushing load from the first. This indicates that cartridges made from different blocks of similar core material will not necessarily have the same crushing load. Therefore in order to maintain uniform properties all cartridges of any one type should be made from the same block of core material.

5.1.5 Two methods of adjusting the load levels were adopted:

a. Reducing core material by cutting a hole down the center of each cartridge.

b. Increasing or decreasing cartridge diameter..

Static testing of adjusted cartridges revealed that the first method impaired the structural integrity of the cartridge. While some of these cartridges were tested, no further use was made of this method, and the results are not presented. Cartridges with adjusted diameters which most closely approach the required crush loads, yielded results as shown below: Cartridge characteristics were as shown on Figure 3.

Type of Cartridge*	Actual Crushing Load (lbs) (Static)	Nominal Strut Load (lbs) (Dynamic)
-13	110	125
-19	371	378
-25	390	378
-29	91	125

* (Ref. LSK 320-101026)

5.1.6 The static results obtained from these later tests indicated that cartridges conforming to these final characteristics (LSK 320-10107) (-13,-19,-25,-29) approached the desired load levels with sufficient accuracy to permit a start to be made on the dynamic test program.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

5.0 DISCUSSION OF TEST RESULTS - continued

5.2 Dynamic Tests

5.2.1 Dynamic tests were conducted to ascertain that under conditions simulating actual usage of the cartridge in the 1/6 LEM model landing gear that they would function satisfactorily. The criteria defining satisfactory operation are load, energy absorption and cartridge stability. Cartridges which most closely approach the nominal strut loads as defined in paragraph 3.2 and also exhibit satisfactory energy absorption and stability properties will be acceptable.

5.2.2 The first batch of cartridges dynamically tested were made from core manufactured by either the "lay up" or "expanded core" method. Cartridge characteristics were as shown in Figure 3. At least five cartridges of each type were dynamically crushed and the average crushing loads are shown on Table I.

5.2.3 Test results showed that a high proportion of the cartridges made from core material manufactured by the lay-up method were structurally unstable and exhibited inconsistent crushing loads. However cartridges made from core manufactured by the expanded core method were comparatively stable, and possessed more consistent load values. All subsequent tests will therefore be conducted on cartridges using core material manufactured by the expanded core method.

5.2.4 Results also indicated that the method of cartridge fabrication was not adequate to realize acceptable load tolerances. In an attempt to approach more closely the nominal strut loads, specific cartridges types (LSK 320-10107 -31, -37 and -41) were modified by controlling the number of cells in the most advantageous arrangement possible **The number of cells used and the results obtained are shown in the following table.**

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

5.0 DISCUSSION OF TEST RESULTS - continued

5.2 Dynamic Tests - continued

Dash No.	Core Mat	Number of Cells	Drop Velocity (in/sec)	Average Crushing (lbs)	Nominal Strut Loads
-31	1/8-15P (3003)	27	130	426	378
-37	1/8-7P (3003)	38	118	100	104
-41	1/8-7P (5052)	37	118	100	125

5.2.5 Five specimens of -31 and -41, and 4 specimens of -37 configuration were tested (all modified to cell count indicated). While the cartridge loads are not close enough to the required values, these configurations exhibited a much smaller spread in crush loads than any previous group. The number of cells were adjusted in subsequent cartridges (Figure 4) to obtain the desired loads.

Dash No.	Core Mat	Number of Cells	Drop Velocity (in/sec)	Average Crushing (lbs)	Nominal Strut Loads
-1	1/8-7P (5052)	40	130	120	125
-3	1/8-15P (3003)	24	130	377	378
-5	1/8-7P (3003)	43	118	100	104

5.2.6 Observation of crushed cartridges revealed that occassionally raw edges appear at the periphery of the cartridge. The uncertainty of these edge effects was eliminated by leaving 1/2 the cell wall intact at each side as shown on Figure 4, (Dwg. LSK 320-10115F).

5.2.7 These final dynamic test results as tabulated above illustrate that cartridge types conforming to Dwg. No. LSK 320-10115F are suitable for use in the LEM 1/6 scale model: MKII drop tests.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION E - HONEYCOMB CARTRIDGE DEVELOPMENT TESTS 1/6 SCALE MODEL: MKII

5.0 DISCUSSION OF TEST RESULTS - continued

5.2 Dynamic Tests - continued

5.2.7 The final design of the three cartridges to be used are as follows:

LSK 320-10115	-1	Primary Strut, First Stage, Nominal Crush Load, 125 lbs.
LSK 320-10115	-3	Primary Strut, Second Stage, Nominal Crush Load, 378 lbs.
LSK 320-10115	-5	Secondary Strut, Single Stage, Nominal Crush Load, 104 lbs.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

TABLE I

Dash No.	Core Material	Dia. of Cartridge	Drop Velocity (in/sec)	Average Crushing Load (lbs)	Nominal Strut Load (lbs)	Manufacturer of Core Material	Remarks
-1	1/8-10P (3003)	13/16	130	152	125	Honeycomb Corp. (Lay-up Method)	Inconsistent loads and Structurally unstable
-9	1/8-10P (3003)	3/9	130	84	104	Honeycomb Corp. (Lay-up Method)	Inconsistent loads and Structurally unstable
-13	3/16-15P (3003)	1	130	118	125	Honeycomb Corp. (Lay-up Method)	Inconsistent loads and Structurally unstable
-19	3/16-20P (5052)	1 1	130	321	378	Honeycomb Corp. (Lay-up Method)	Inconsistent loads and Structurally unstable
-23	1/8-15P (3003)	1	130	550	378	Honeycomb Corp. (Lay-up Method)	Cart. load extremely high. Cart. eliminated from future testing.
-25	3/16-15P (3003)	15/16	118	112	104	Honeycomb Corp. (Lay-up Method)	Relatively consistent loads
-29	3/16-15P (3003)	7/8	118	84	104	Honeycomb Corp. (Lay-up Method)	Relatively consistent loads
-31	1/8-10P (3003)	13/16	130	456	378	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-37	1/8-7P (3003)	1	130	107	104	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-39	1/8-7P (5052)	7/8	130	110	104	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-41	1/8-7P (5052)	15/16	130	150	125	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

TABLE I - continued

Dash No.	Core Material	Dia. of Cartridge	Drop Velocity (in/sec)	Average Crushing Load (lbs)	Nominal Strut Load (lbs)	Manufacturer of Core Material	Remarks
-31*		27 cells	130	426	378	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-37*		38 cells	130	100	104	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-41*		37 cells	130	100	128	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-1**		40	130	120	125	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-3**		24	130	377	378	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable
-5**		43	130	100	104	Hexcel Corp. (Expanded Core)	Relatively consistent load levels and structurally stable

NOTES: * - modified
** - (LSK 320-10115)

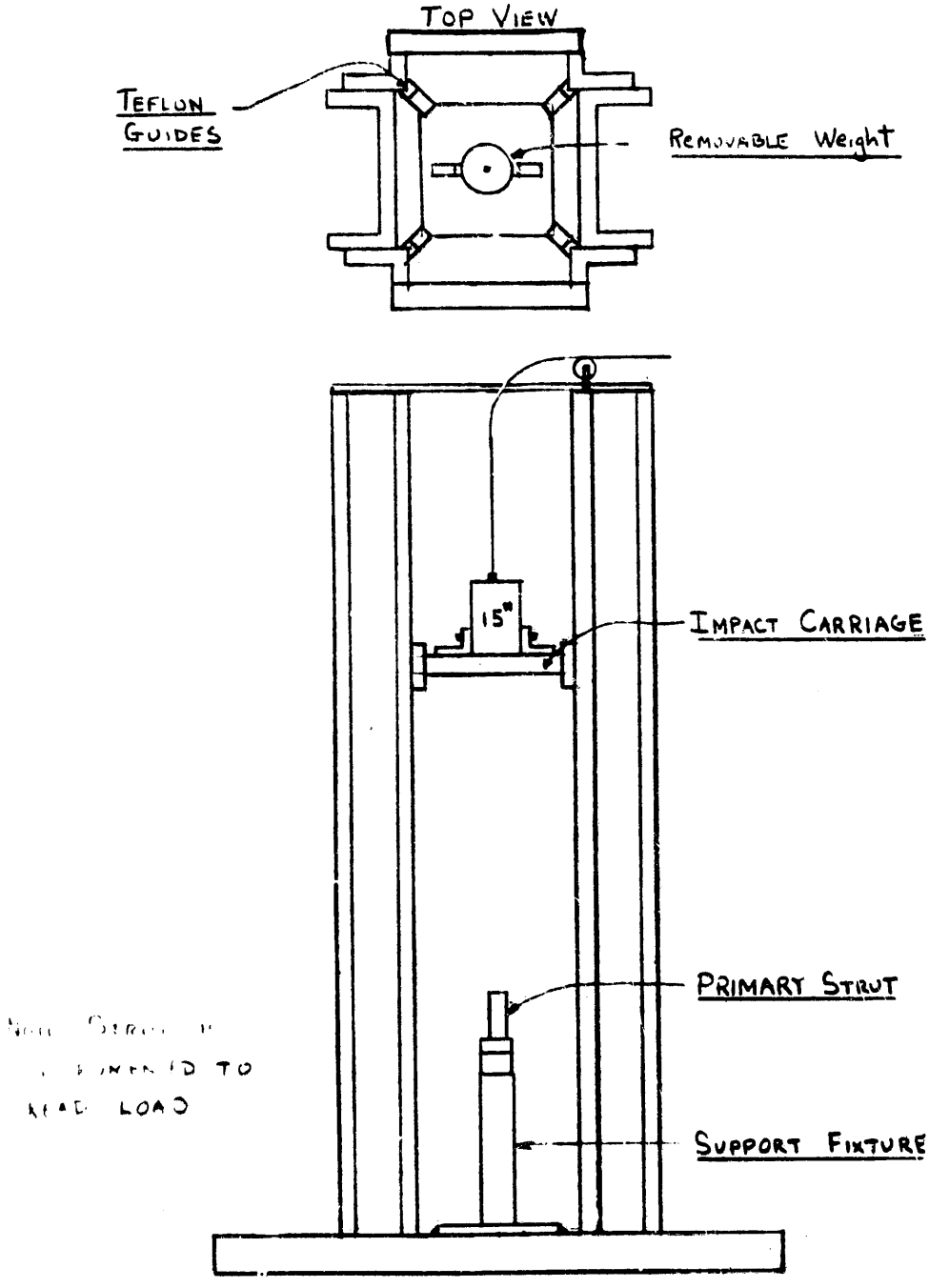
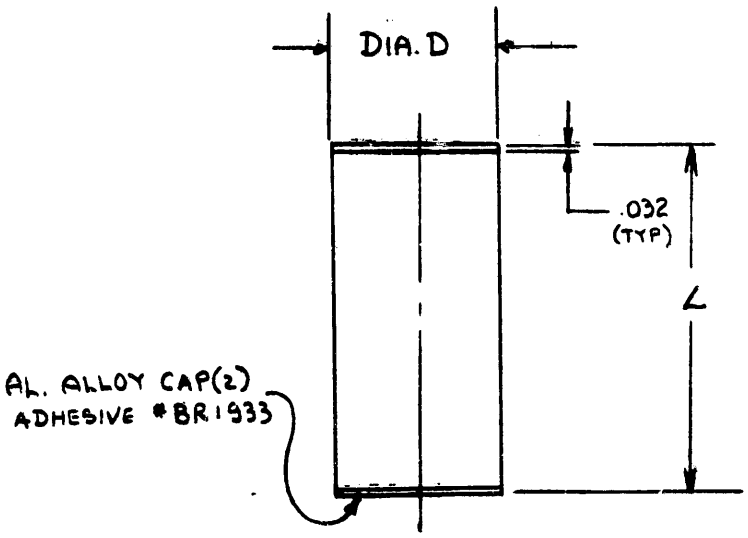


FIG. 1 IMPACT TOWER – HONEYCOMB CRUSHING



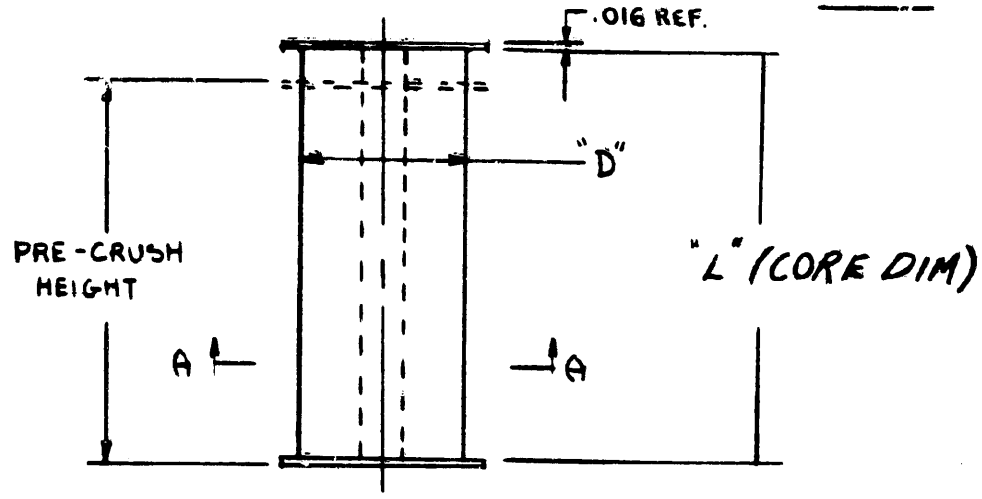
DASH NO	CORE MAT	DIA D	L
-1	$\frac{1}{8}$-10P(3003)	$\frac{13}{16}$	$2\frac{9}{16}$
-3	$\frac{3}{16}$ -15P(3003)	$\frac{7}{8}$	$2\frac{9}{16}$
-5	$\frac{3}{16}$ -20P(5052)	$\frac{1}{8}$	$4\frac{9}{16}$
-7	$\frac{1}{8}$-20P(3003)	$\frac{15}{16}$	$1\frac{9}{16}$
-9	$\frac{1}{8}$ -10P(3003)	$\frac{3}{4}$	$2\frac{9}{16}$
-11	$\frac{3}{16}$ -10P(3003)	1	$2\frac{9}{16}$

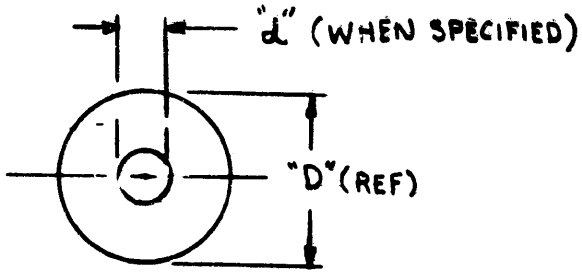
FIG. #2 INITIAL CARTRIDGE CONFIGURATION

REF. DWG. LSK 320-10106

FIG. #3 INTERIM CARTRIDGE CONFIGURATION - REF. LSK 320-10107C

SHEET 1





SECT. A-A

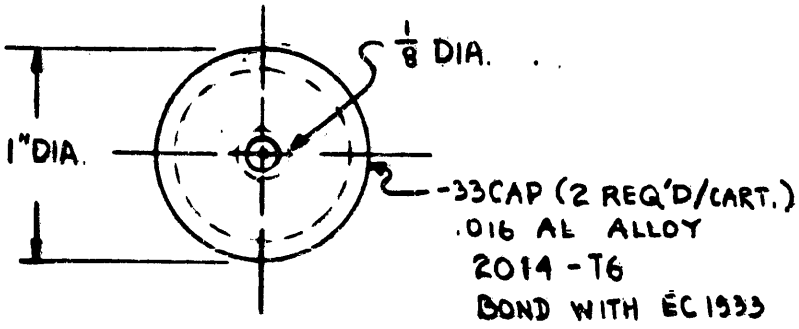
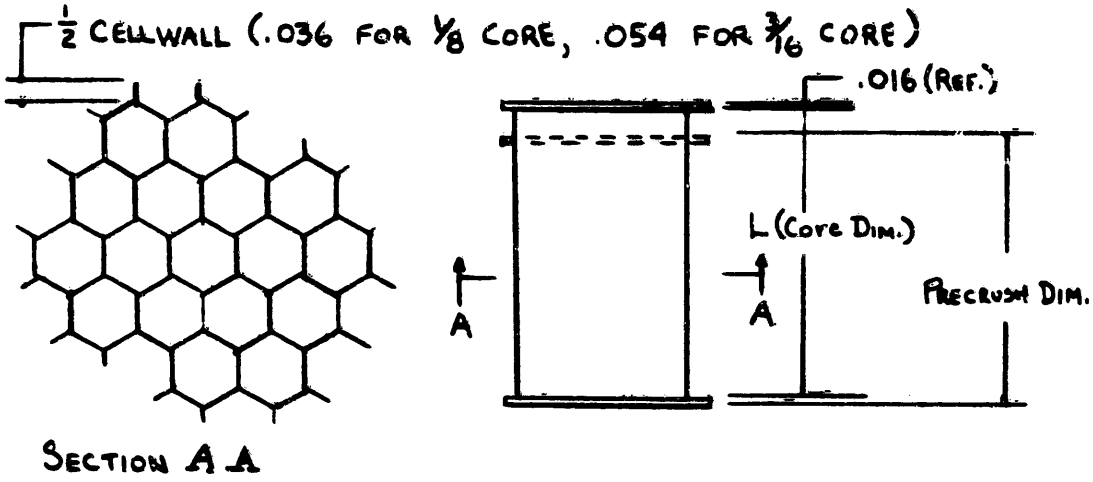


FIG. #3 INTERIM CARTRIDGE CONFIGURATION - REF. LSK 320-10107C SHEET 2

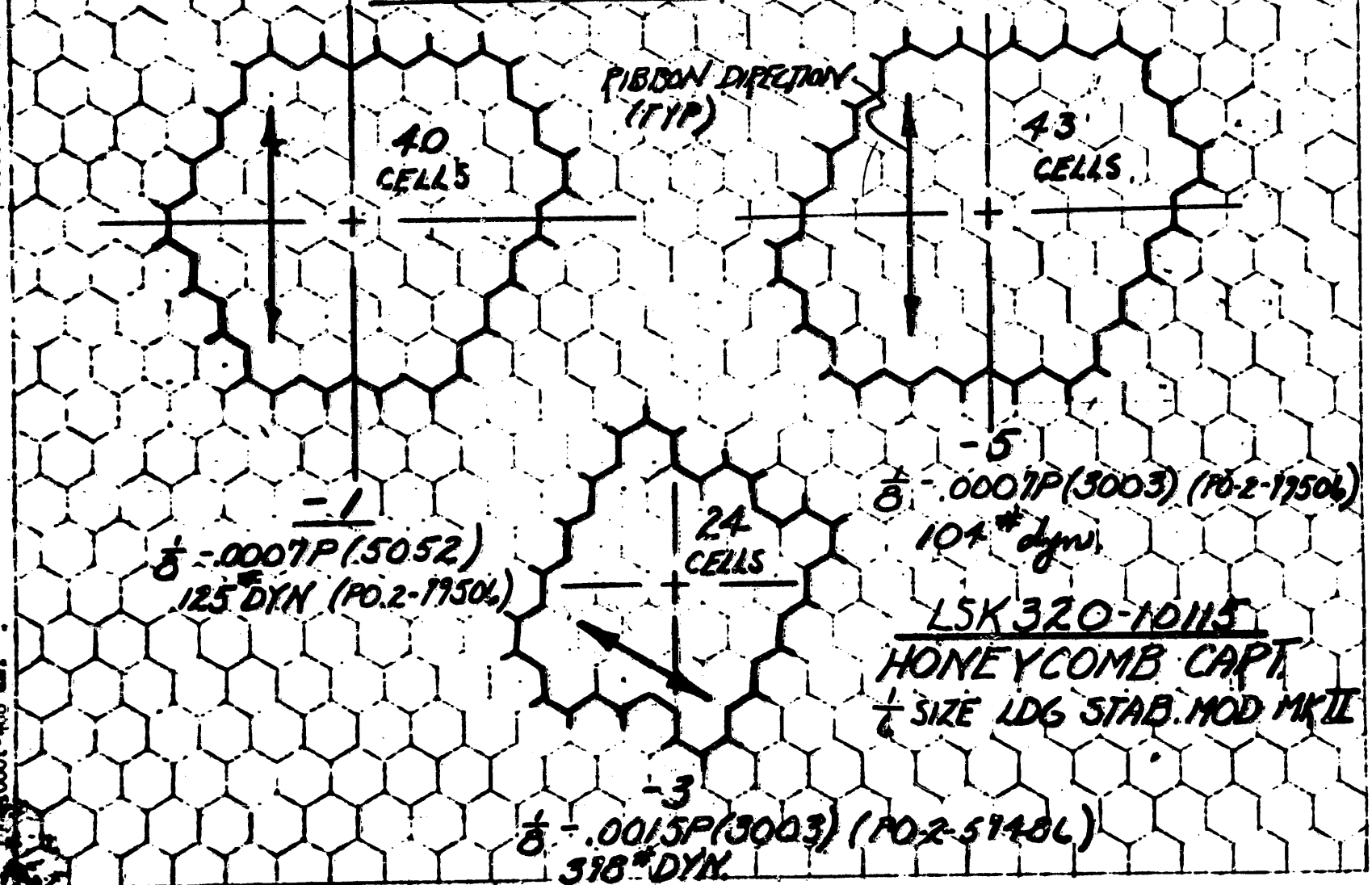
DASH NO.	CORE MAT.	DIA. "D"	DIA "d"	DIM "L"	PRE-CRUSH HEIGHT
-1	1/8 -10P (3003)	13/16	~	2 9/16	2 15/32
-3	3/16 - 15 (3003)	7/8	~	2 9/16	2 15/32
-5	3/16 -20P (5052)	7/8	~	1 5/8	1 17/32
-7	1/8 -20P (3003)	15/16	~	1 5/8	1 17/32
-9	1/8 -10P (3003)	3/4	~	2 19/32	2 5/16
-11	3/16 -10P (3003)	1	~	2 19/32	2 9/16
-13	3/16 - 15P (3003)	1	~	2 19/32	2 15/32
-15	3/16 - 15P (3003)	1	1/4	2 19/32	2 15/32
-17	3/16 - 15P (3003)	1	3/8	2 19/32	2 15/32
-19	3/16 -20P (5052)	1	~	1 5/8	1 17/32
-21	1/8 -20P (3003)	7/8	1/4	1 5/8	1 17/32
-23	1/8 - 15P (3003)	1	~	1 5/8	1 17/32
-25	3/16 - 15P (3003)	15/16	~	2 19/32	2 9/16
-27	3/16 - 15P (3003)	15/16	1/4	2 19/32	2 9/16
-29	3/16 - 15P (3003)	7/8	~	2 19/32	2 9/16
-31	1/8 - 15P (3003)	13/16	~	1 5/8	1 17/32
-35	1/8 -20P (3003)	7/8	~	1 5/8	1 17/32
-37	1/8 - 7P (3003)	1	~	2 19/32	2 9/16
-39	1/8 -7P (5052)	7/8	~	2 19/32	2 9/16
-41	1/8 -7P (5052)	15/16	~	2 9/16	2 15/32

FIG. 4 FINAL CARTRIDGE CONFIGURATION - REF LSK 320-10115F (Sheet 1)



DASH NO.	CORE MATERIAL	P.O. NO.	NO. OF CELLS	NOMINAL STRUT LOAD	DIM "L"	PRECRUSH DIM.
-1	⅛ - 7P (5052)	2-79506	40	125*	2⅝	2 15/32
-3	⅛ - 15P (3003)	2-57486	24	378*	1 9/32	1 7/32
-5	⅛ - 7P (3003)	2-79506	43	104*	2⅝	2 9/16

Fig. 4 — Final Configuration Of Cartridges Developed For MK II Drop Test Program (Sheet 2)



TEST RESULTS FOR THE LEM LANDING GEAR

COMPONENT DEVELOPMENT TESTS

SECTION F - RESULTS OF THE CANTILEVER PRIMARY STRUT ASSEMBLY TEST (160 INCH SEMI-TREAD)

PREPARED BY:

W. De Blasio

CHECKED BY:

R. L. Makemson

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION F - RESULTS OF THE CANTILEVER PRIMARY STRUT ASSEMBLY TEST (160 INCH SEMI-TREAD)

1.0 Purpose of Test

1.1 This section of the report contains the results of the initial development tests conducted on the primary strut of the 160 inch cantilever landing gear. The tests were performed to verify the calculated stresses, demonstrate the structural integrity, and to check the mechanical operation of the strut.

1.2 These tests were conducted in partial fulfillment of the requirements of Contract No. NAS 9-1100.

2.0 Description of Test Specimen

2.1 The strut, an earlier design now superseded by the 167 inch semi-tread design, had an initial length of 108.25" at its fully extended position and a fully stroked length of 83.25".

2.2 All bearings were replaceable so that the effects of different bearing materials and shapes upon strut operational characteristics could be determined.

2.3 Dwg. LSK 320-10910, shows the entire strut assembly used for the tests, and is included as Fig. 1.

3.0 Test Set-Up and Procedures

3.1 General

3.1.1 The test set-up and procedure were as described in the test plan, Report No. LTP904-10001, Section F. except where noted.

3.1.2 Figure 4, Dwg. LSK 915-191, locates and identifies both the individual strain gauges on the strut reading axial strain and the strain gauge circuits used to measure axial and bending loads.

3.1.3 The axial and bending load circuits were calibrated prior to testing by applying known loads to the strut and recording the corresponding strain gauge circuit outputs. Photograph LF3 ~~340~~-77 shows the strut during axial load calibration.

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION F - RESULTS OF THE CANTILEVER PRIMARY STRUT ASSEMBLY TEST (160 INCH SEMI-TREAD)

3.2 Vibration Mode Survey

3.2.1 For all vibration mode survey tests, the strut was installed in the fixture of Figure 3, Dwg LSK 915-189. The S-131 shaker was positioned on the outer cylinder approximately 37" from the centerline of the universal end and oriented as shown in Photographs LPS 380-67 and -68.

3.2.2 The secondary strut pick-up collar fitting, load link, etc., which were used for the dynamic side load tests, remained attached during the vibration survey. This was so the frequencies and modes determined would reflect the strut behavior under the same conditions as the dynamic side load tests, and permit correlation of data from the two tests.

3.3 Static Tests

3.3.1 The static tests included the bearing friction tests and the structural tests, and were conducted in the fixture of Figure 2, Dwg LSK 915-188, and Photographs LPS 560-137 and -138.

3.3.2 Strut centerline deflection was measured at the midpoint of the secondary strut attachment collar in the direction of the resultant side load force. Measurement was by means of a linear motion potentiometer.

3.3.3 Side loads were positioned to insure the correct loading geometry, and the weights of the jacks counter-balanced.

3.3.4 The axial load applied for each limit load test was determined by adding the theoretical friction load and the nominal cartridge crushing load for the particular strut length.

3.4 Dynamic Side Load Tests

3.4.1 For tests 1 through 21, strut deflection was measured as explained in 3.3.2. For Series II, deflection measurements were taken at the four positions where the bending moment circuits were located. (Ref. Figure 4).

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION F - RESULTS OF THE CANTILEVER PRIMARY STRUT ASSEMBLY TEST (160 INCH SEMI-TREAD)

3.4.2 The load cell, plunger, honeycomb side load absorber, etc., were positioned to insure maximum side load in a direction perpendicular to the strut centerline.

3.4.3 All honeycomb side load absorbers were precrushed before use. Their nominal static or dynamic crushing loads are indicated in the log of tests, Figure 11, Page F-11

4.0 Test Conditions

4.1 All tests were conducted at ambient environmental conditions.

5.0 Discussion of Test Results

5.1 Vibration Mode Survey

5.1.1 At a strut length of 105.25 inches with both ends pinned, vertical excitation produced a first mode resonant frequency of 31.2 CPS and a structural damping coefficient of .115.

5.1.2 Under the same conditions as listed in 5.1.1, diagonal excitation produced a first mode resonant frequency of 29.3 CPS and a structural damping coefficient of .115.

5.1.3 The results of all vibration mode survey tests are shown in Figure 5, Page F-10

5.2 Bearing Friction Tests

5.2.1 The recorded results of several parameters from bearing friction test No. 32 are tabulated in Figure 6, Page F-11. Run 32 was selected because it is a typical representation of the friction tests.

5.2.2 The coefficient of friction for each test was determined by solving for the reactions at each primary strut sleeve bearing, (Refer to Figure 1, part numbers LGK 320-10[illegible]-1 and -3), summing these two to find the "total normal" force and measuring the axial force required to stroke the inner cylinder.

5.2.3 The coefficient of friction for the solid teflon bearings used for Tests 22 to 41, ranged approximately from u=0.33 to u=0.38

TEST RESULTS FOR THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION F - RESULTS OF THE CANTILEVER PRIMARY STRUT ASSEMBLY TEST (160 INCH SEMI-TREAD)

5.3 Structural Tests

5.3.1 Figure 7, Page F-12, lists the strain gauge outputs of Run No. 42, limit load conditions at a strut length of 108.25".

5.3.2 Maximum strut centerline deflection for this test was 1.475 inches, measured at the midpoint of the collar.

5.3.3 Since the strut was at the fully extended position, maximum bending was experienced during this test.

5.4 Dynamic Side Load Tests

5.4.1 Figures 8, 9 and 10, Pages F-13 to F-15 , show the recorded results of several dynamic side load tests. The tests shown and discussed were selected as being representative of the dynamic tests.

5.4.2 For the first series of tests, strut length, cartridge crushing load and drop weight were constant and the impact velocity was varied.

5.4.3 The effect of impact velocity (or drop height), is shown in Figure 9, Page F-14 . Bending moment and strut deflection are seen to increase with increases of drop height.

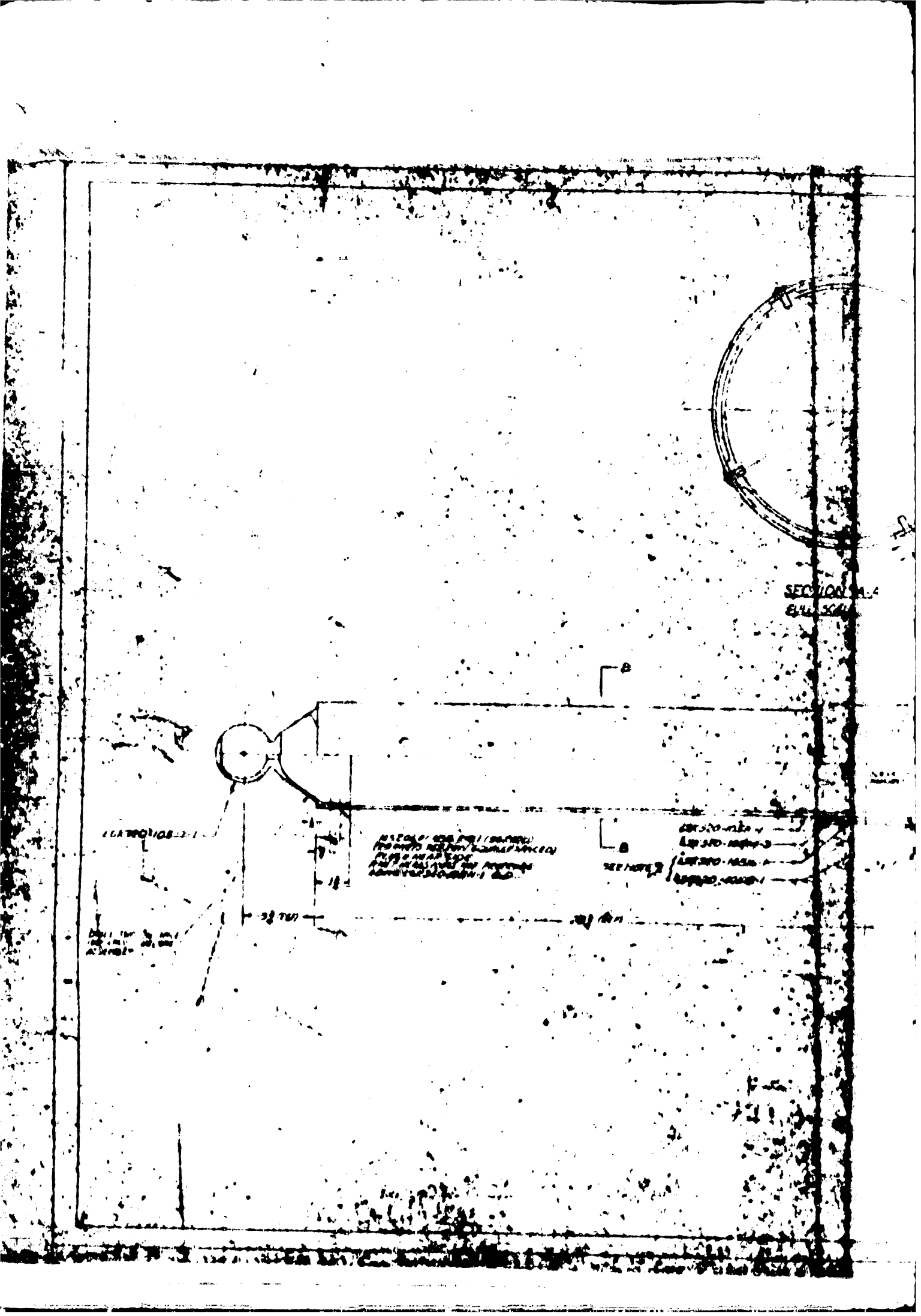
5.4.4 It should be noted here, and when a similar situation occurs as discussed in paragraph 5.4.6, that the ratio of increase in moment is not the same at all locations. Also, that the moment ratio at a particular location is not the same as the corresponding deflection ratio. This is due to the fact that the strut "telescopes" as it changes length, and that there is slippage between the inner and outer cylinder at the collar bearing.

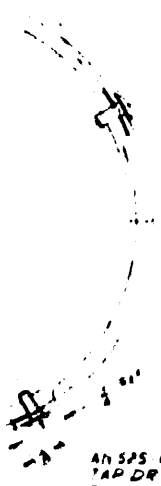
5.4.5 For Series II, impact velocity remained a constant, and strut length, cartridge crushing load and drop weight were varied.

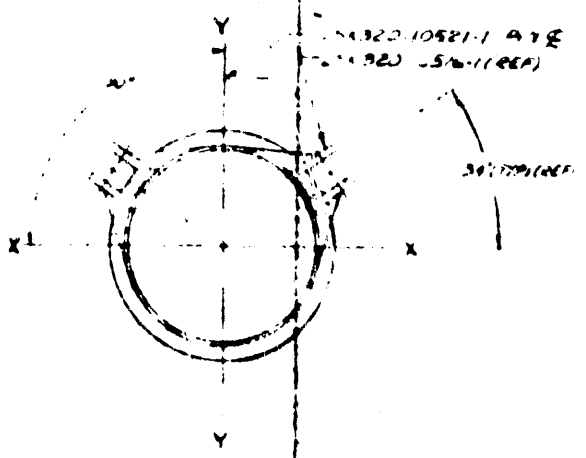
5.4.6 Figure 10, Page F-15, indicates the apparent dynamic magnifications, (ratios), determined in drop No. II-7.

5.4.7 Series II was conducted to help ascertain the maximum bending loads and strains that might occur during dynamic loading.

5.4.8 The results of Series I and II generally indicate that the dynamic magnification ratio varies directly with impact velocity and inversely with applied load.



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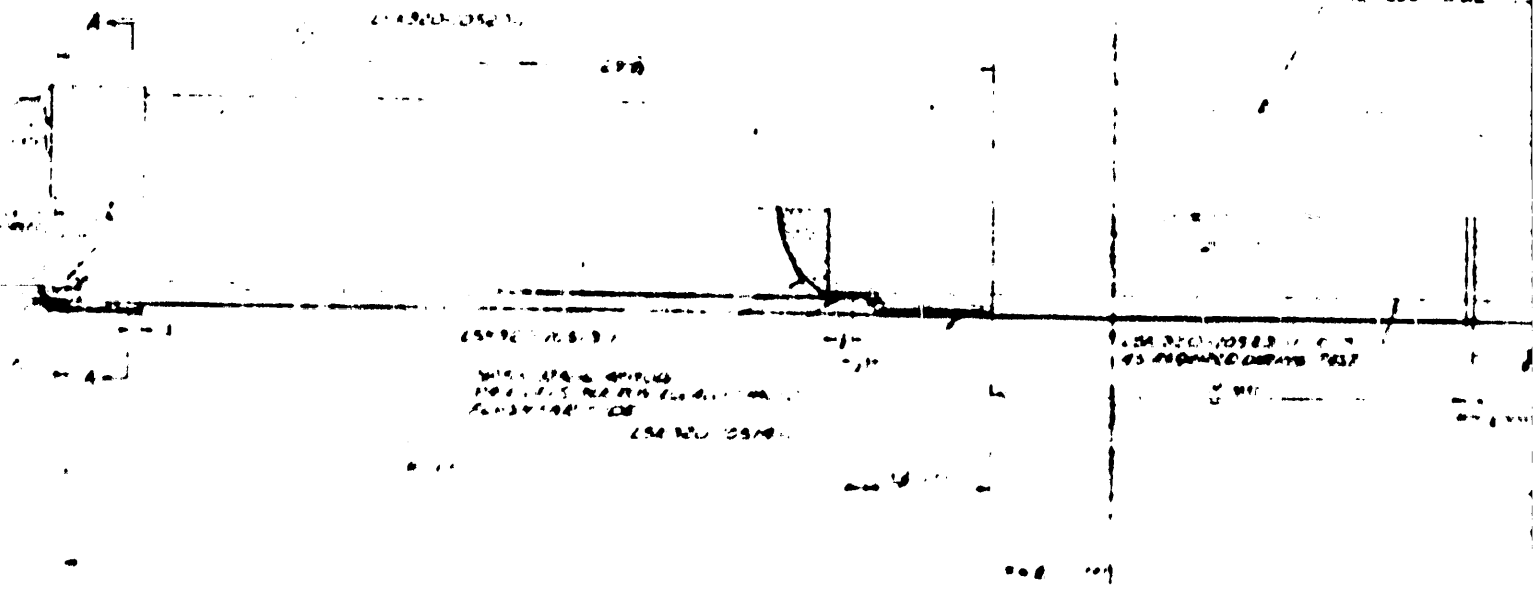
SECTION B-B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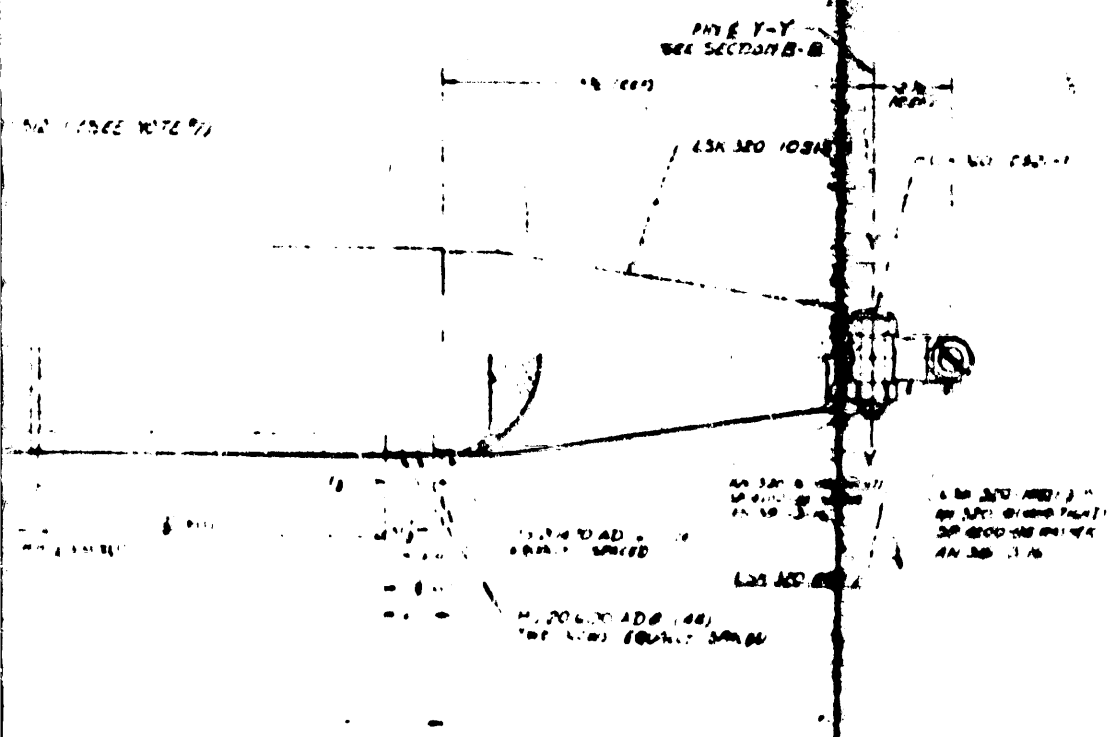
NOTES:

1. PRIOR TO TAP DRILL THRU LSK320-10516 & LSK320-10512, SHOULDER OF LSK320-10516 MUST BE IN CONTACT WITH LSK320-10512 AND LSK320-10516 MUST BE IN CONTACT WITH LSK320-10518.

2. STRUT COMPONENTS TO BE INSTRUMENTED AFTER RIVET HOLES ARE DRILLED BUT BEFORE RIVETS ARE INSTALLED.



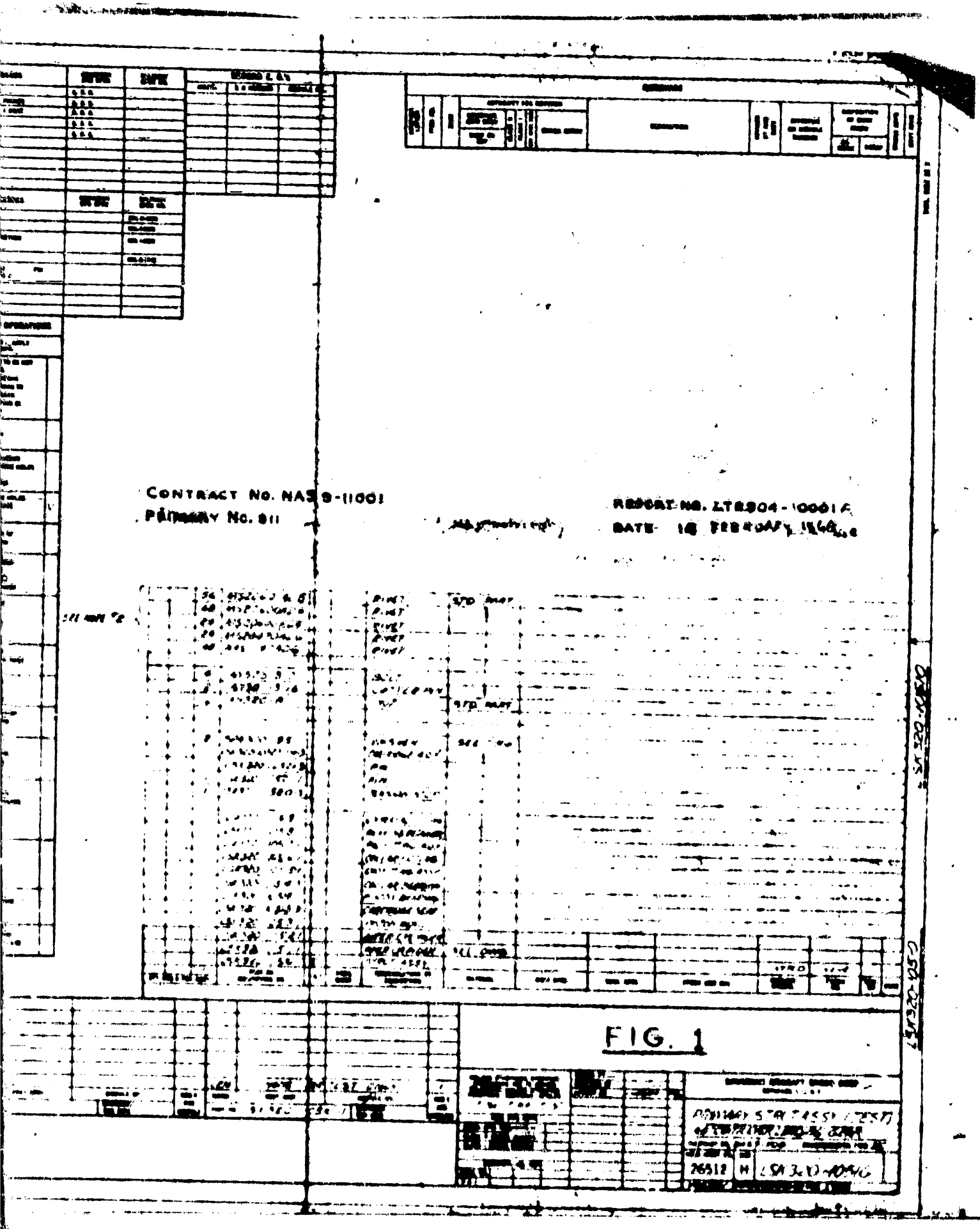
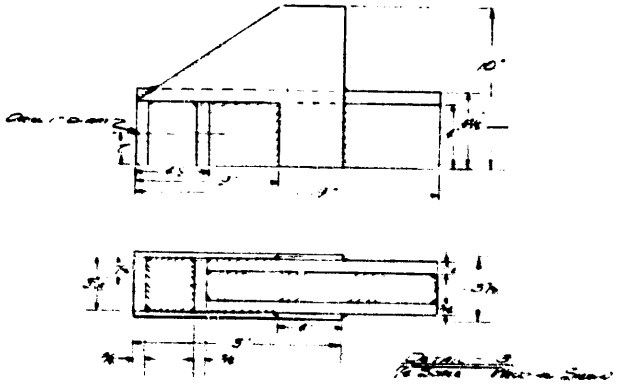
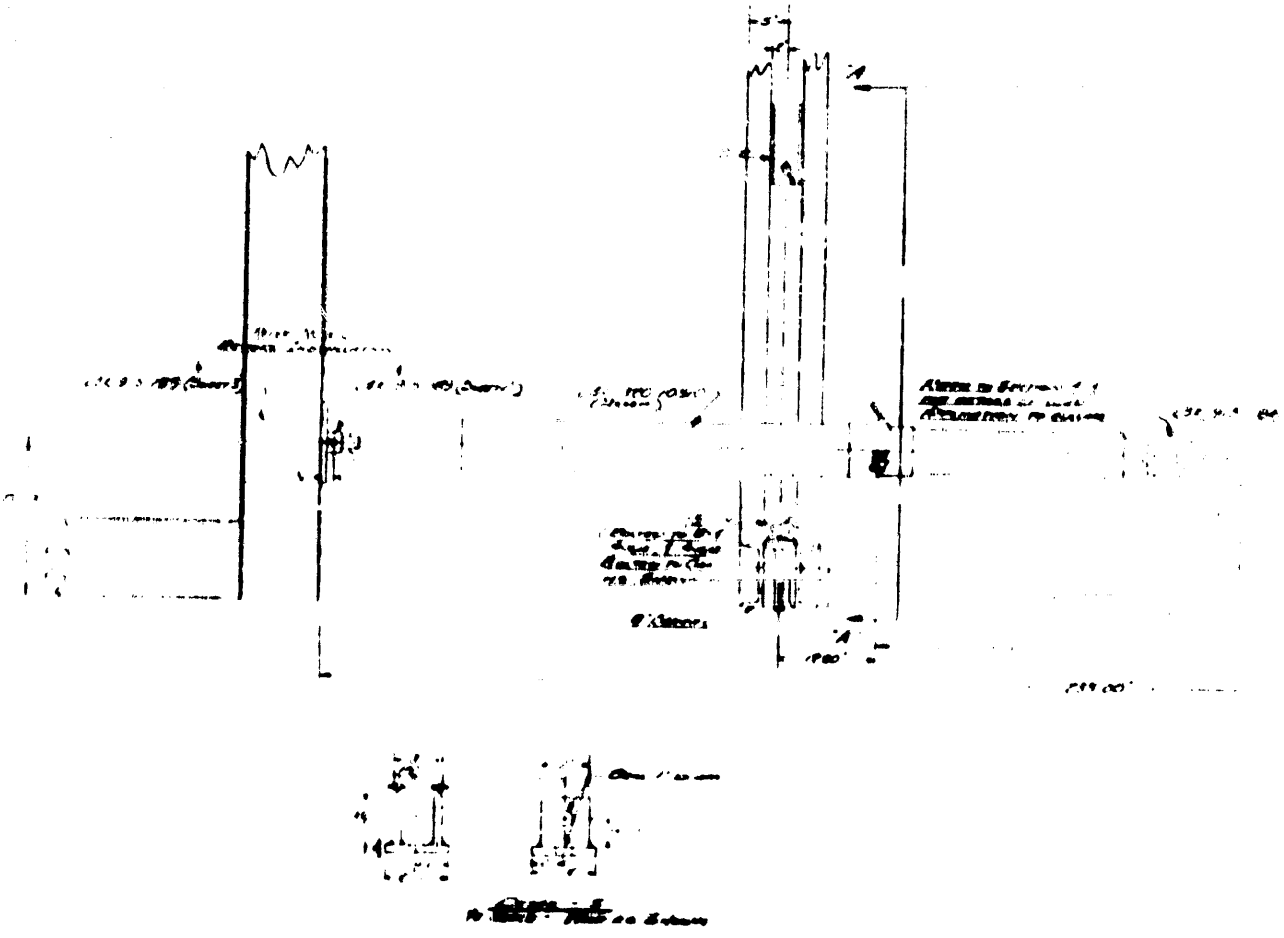
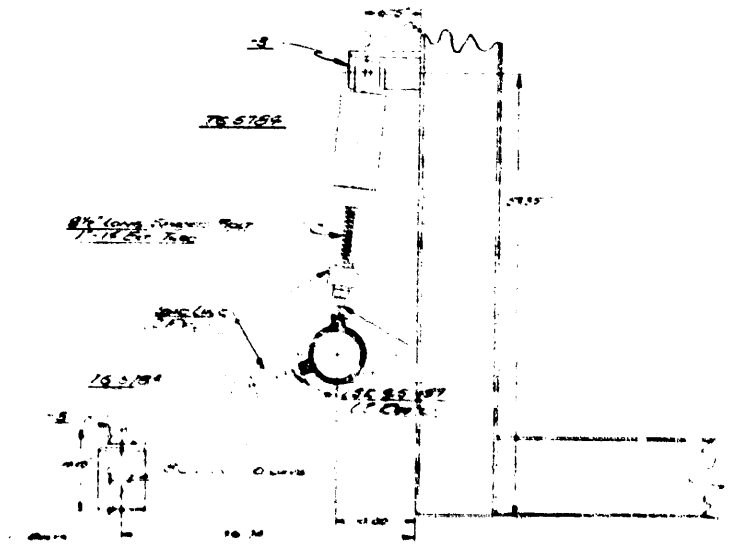

CONTRACT NO. NAS 9-11001
PRIMARY No. 811
REPORT NO. LTR904-10001A
DATE 18 FEBRUARY 1968
STD PART
STD PART
LSK320-10510
LSK320-1050

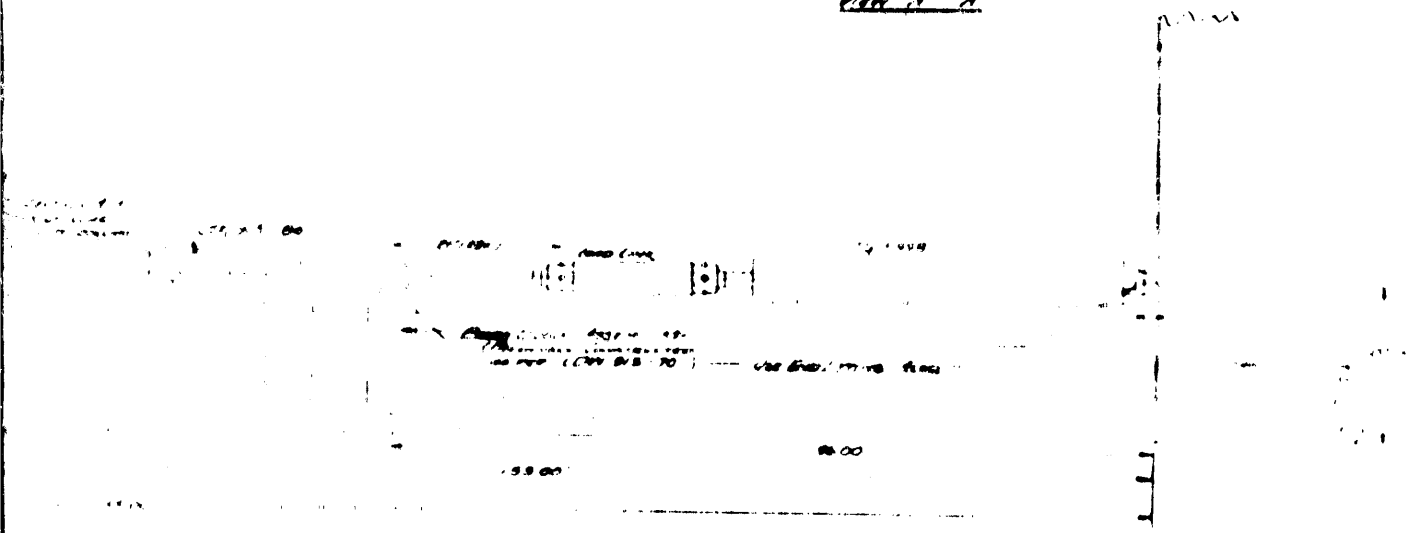
FIG. 1

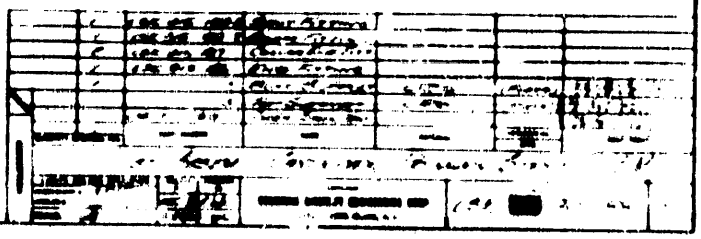


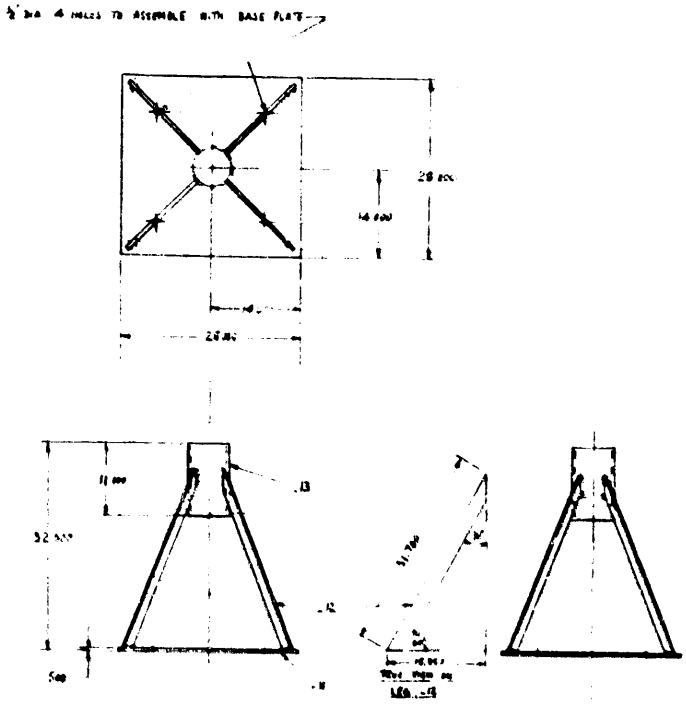


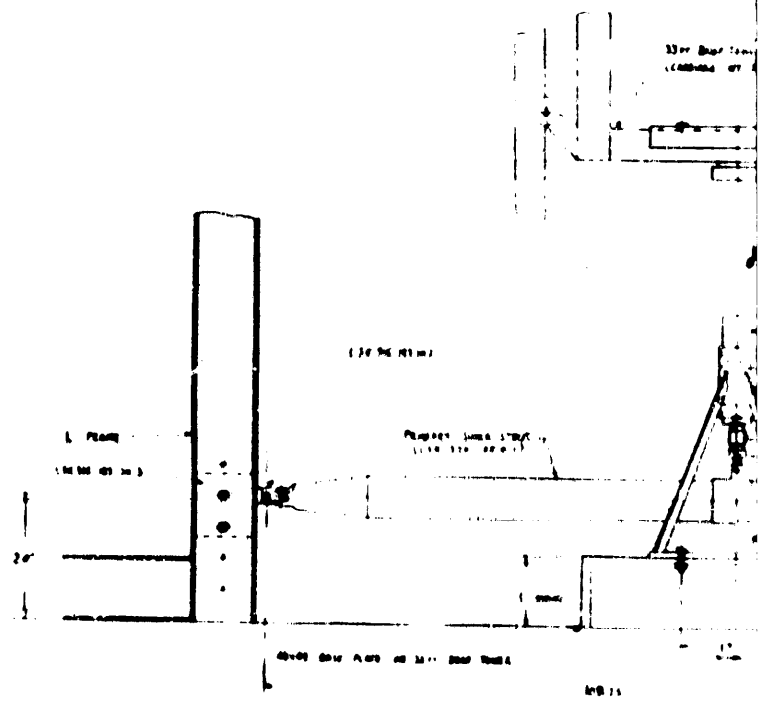
NOTES:

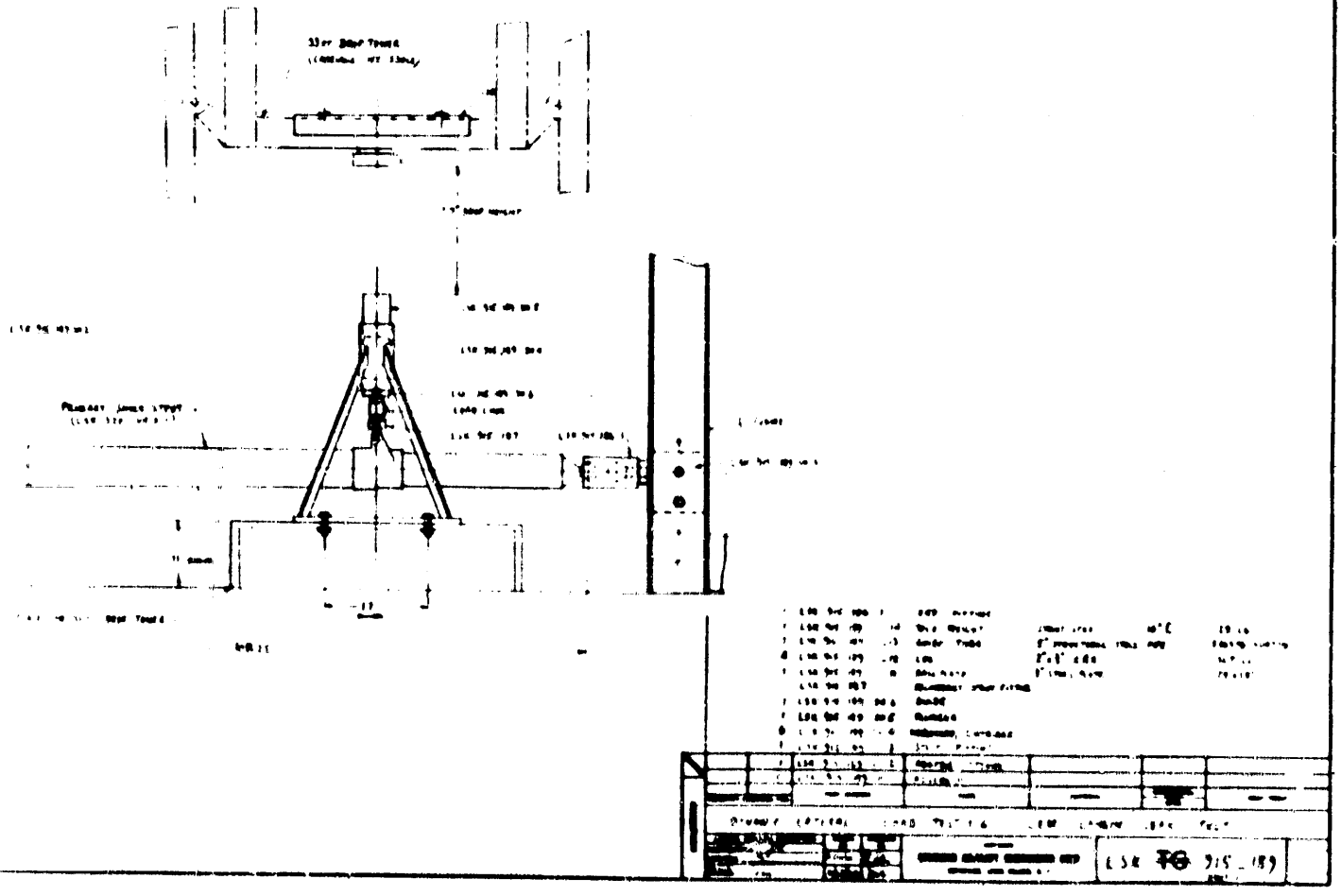


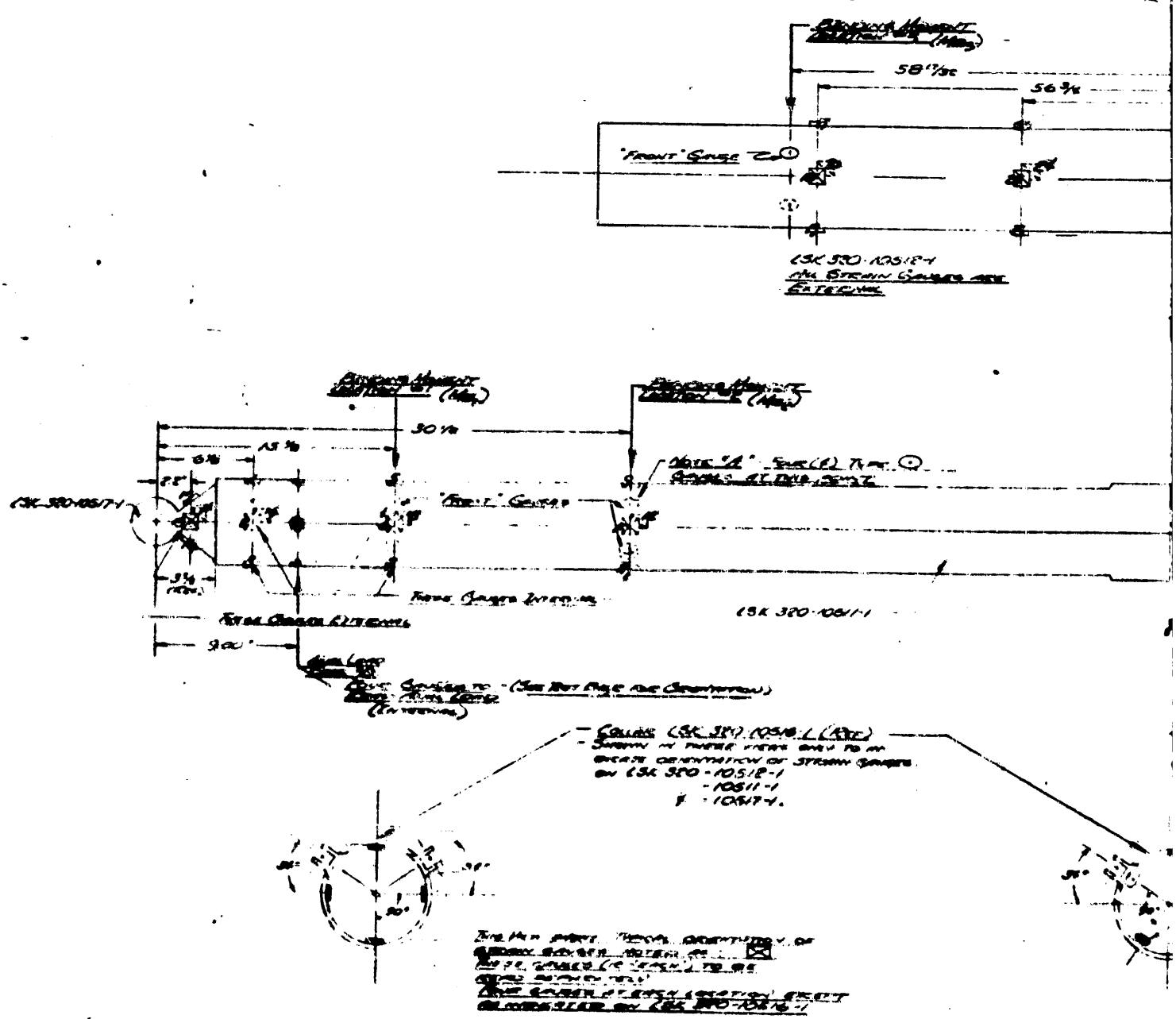




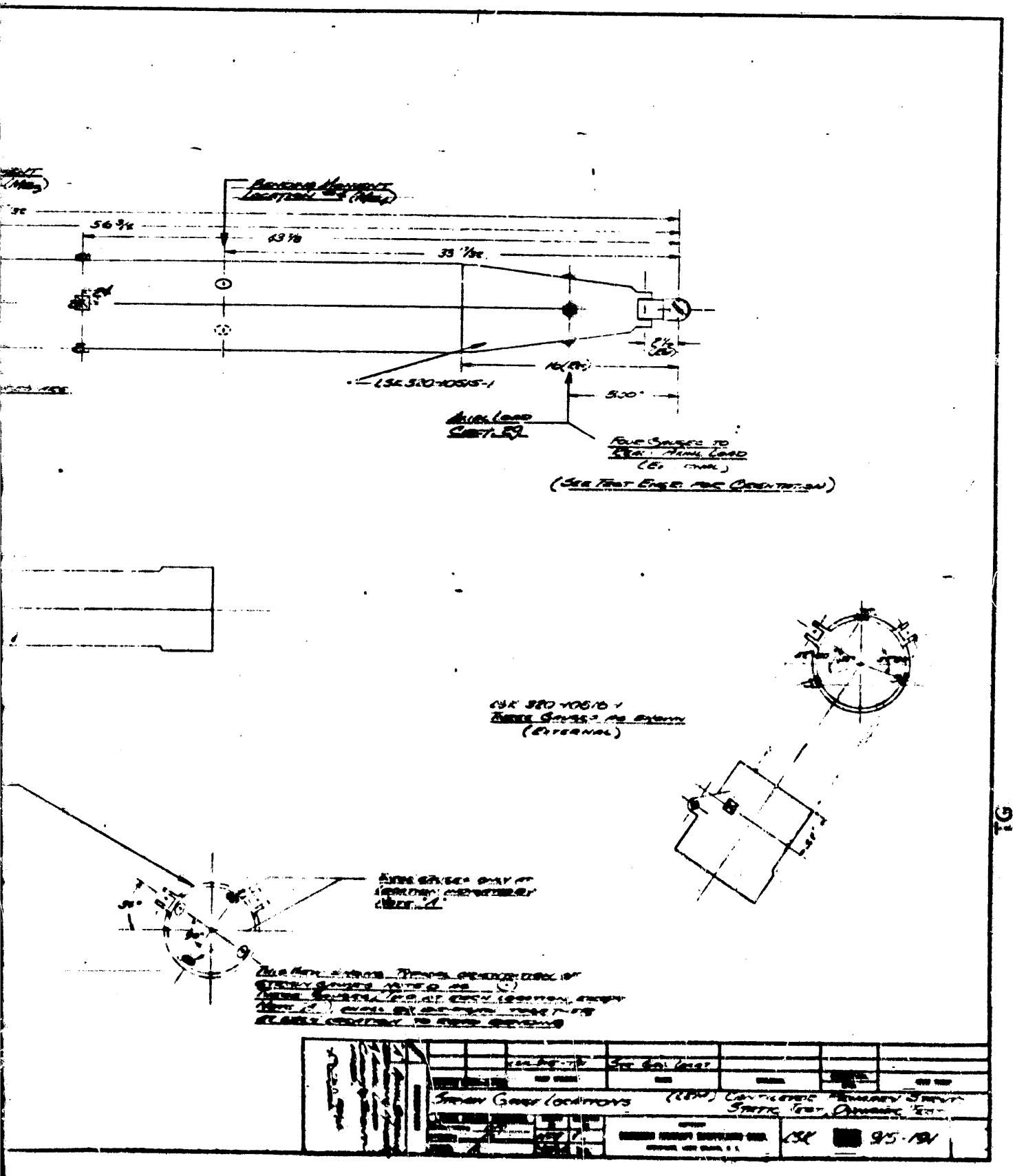

4 HOLES TO ASSEMBLE WITH BASE PLATE







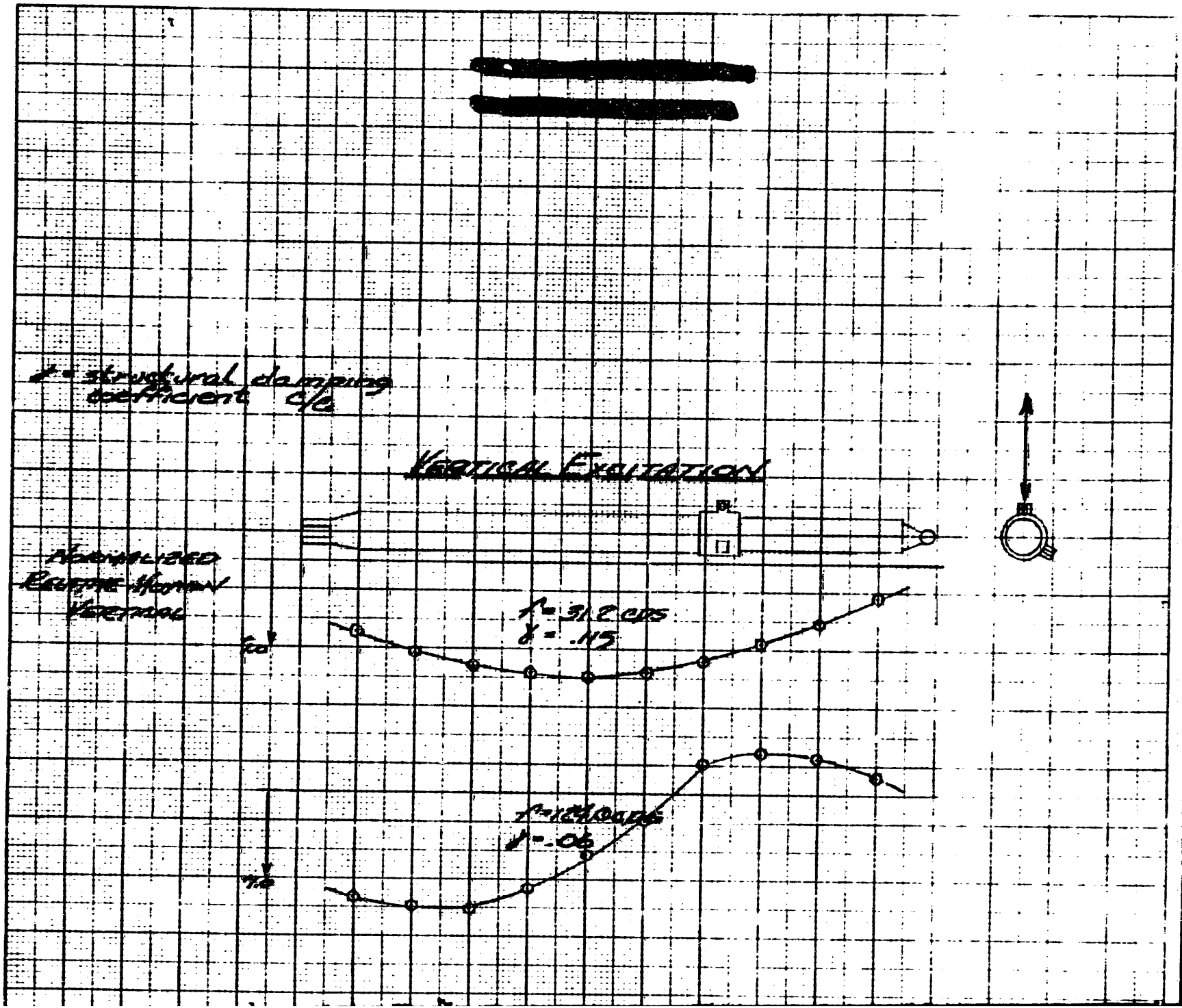
58 17/32
56 3/4
"FRONT" GAUGE
LSK 320-10512-1
ALL STRAIN GAUGES ARE EXTERNAL
30 1/8
15 5/8
6 1/8
2.2"
LSK 320-10517-1
"FRONT" GAUGES
NOTE "A" FOUR (4) TYPE GAUGES AT THIS POINT
3 1/4 (REF.)
THESE GAUGES INTERNAL
THESE GAUGES EXTERNAL
LSK 320-10511-1
9.00"
(INTERNAL)
COLLAR LSK 320-10516-1 (REF)
SHOWN IN THESE VIEWS ONLY TO AN EXACT ORIENTATION OF STRAIN GAUGES ON LSK 320-10512-1
-10511-1
-10517-1.
30°


56 3/16
63 7/8
33 7/32
LSK 320-10515-1
5.00"
(See Test Engr. for Orientation)
(External)
Strain Gauge Locations
Static Test
Dynamic Test
LSK
915-191

TG

[redacted]

γ = structural damping coefficient c/c_c



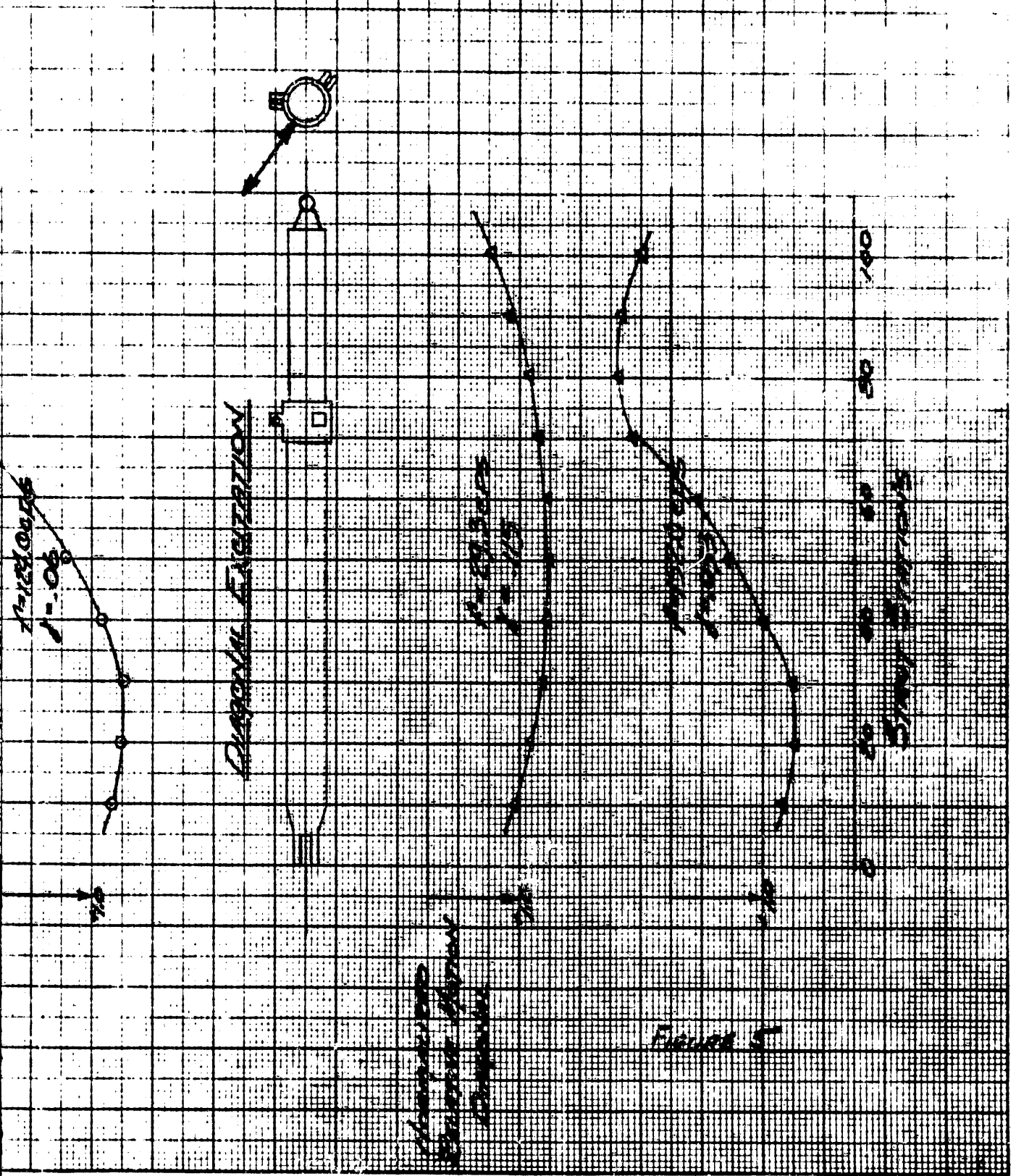


FIGURE 5

RUN #32 - [illegible]

(.030 Crown [illegible])

GAUGE	0"	1"	[illegible]	[illegible]	[illegible]	[illegible]	12"	24"
9	150 IN-IN/IN	150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-[illegible]
10	3100	2800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	100	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	3150	3000	3050	[illegible]	[illegible]	[illegible]	[illegible]	200
12	2600	2700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	600

	0"	10"	15"	16"	17"	18"	20"	24"
5	25	100	0	500	200	-200	-50	-50
7	200	0	100	-500	-400	+100	-100	-200

	0"	10"	15"	20"	22"	23"	24"
2	1000	1200	1250	1300	1250	1350	1150
3	100	25	0	0	0	0	300

	0"	5"	10"	15"	20"	24"
Load 29B	6750 LB	5250	4500	3500	2250	1500

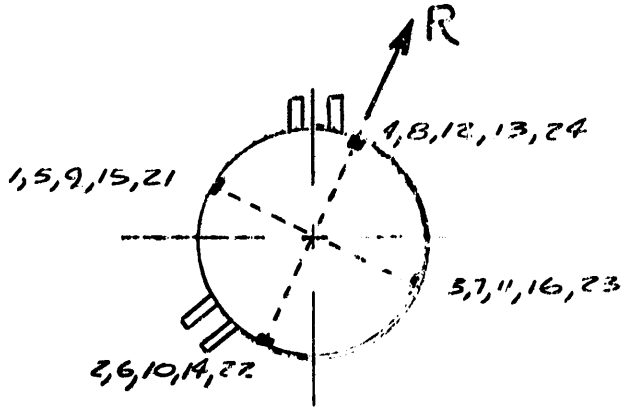


Figure 7

Run #42 Limit Load at 108.2°F

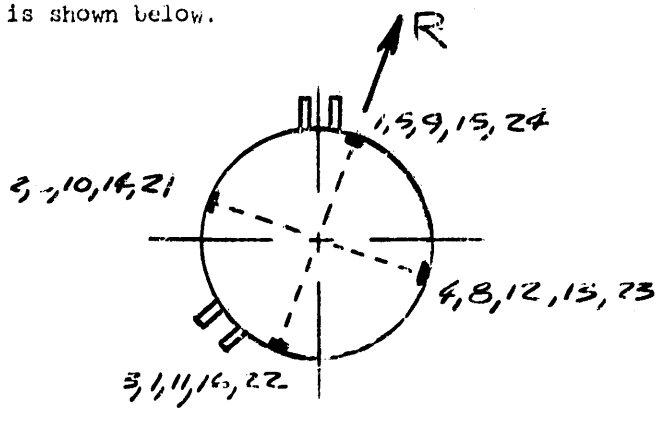
Compressive Side Load - 5000 LB

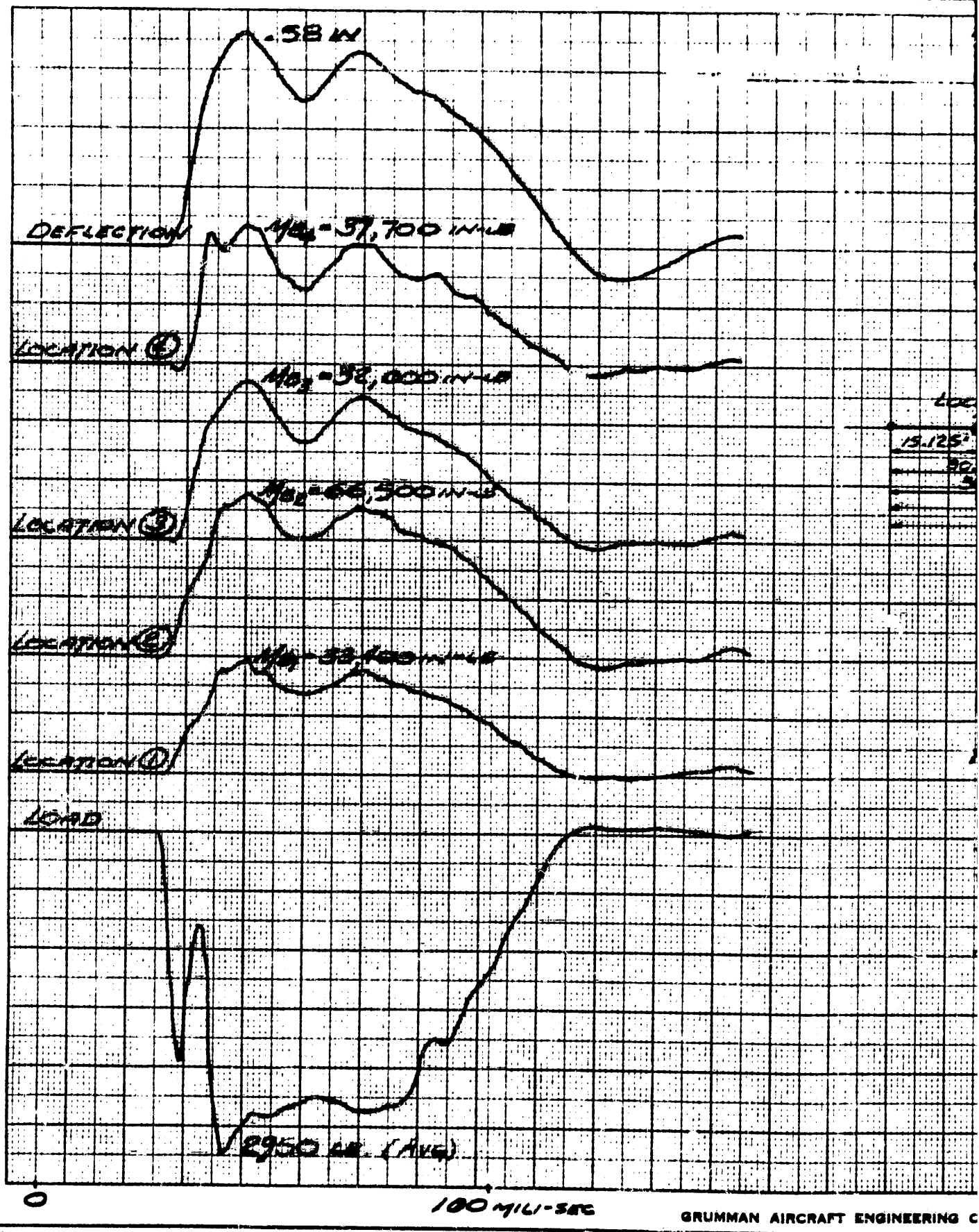
Tensile Side Load - 3000 LB

Axial Load - 8800 LB

Gauge No.	Strain Output (μin/in)
1	500
2	200
3	1100
4	350
5	1600
6	2250
8	4500
9	2100
10	400
11	600
12	375
21	150
22	3150
23	800
24	2700

For locations of gauges refer to Figure 4, Page E-16 . Orientation of gauges is shown below.




.58 IN
DEFLECTION
M_{B_4} = 37,700 IN-LB
LOCATION ④
M_{B_3} = 32,000 IN-LB
LOCATION ③
M_{B_2} = 66,500 IN-LB
LOCATION ②
M_{B_1} = 33,400 IN-LB
LOCATION ①
LOAD
2950 LB. (AVG)
0
100 MILI-SEC
15.125'

TEST NO. 1 108.25 IN.
5.0" DROP HT. 600 LB WT.

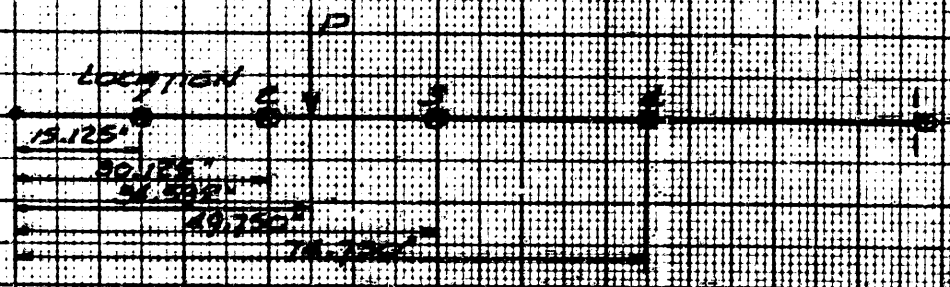


FIGURE 8

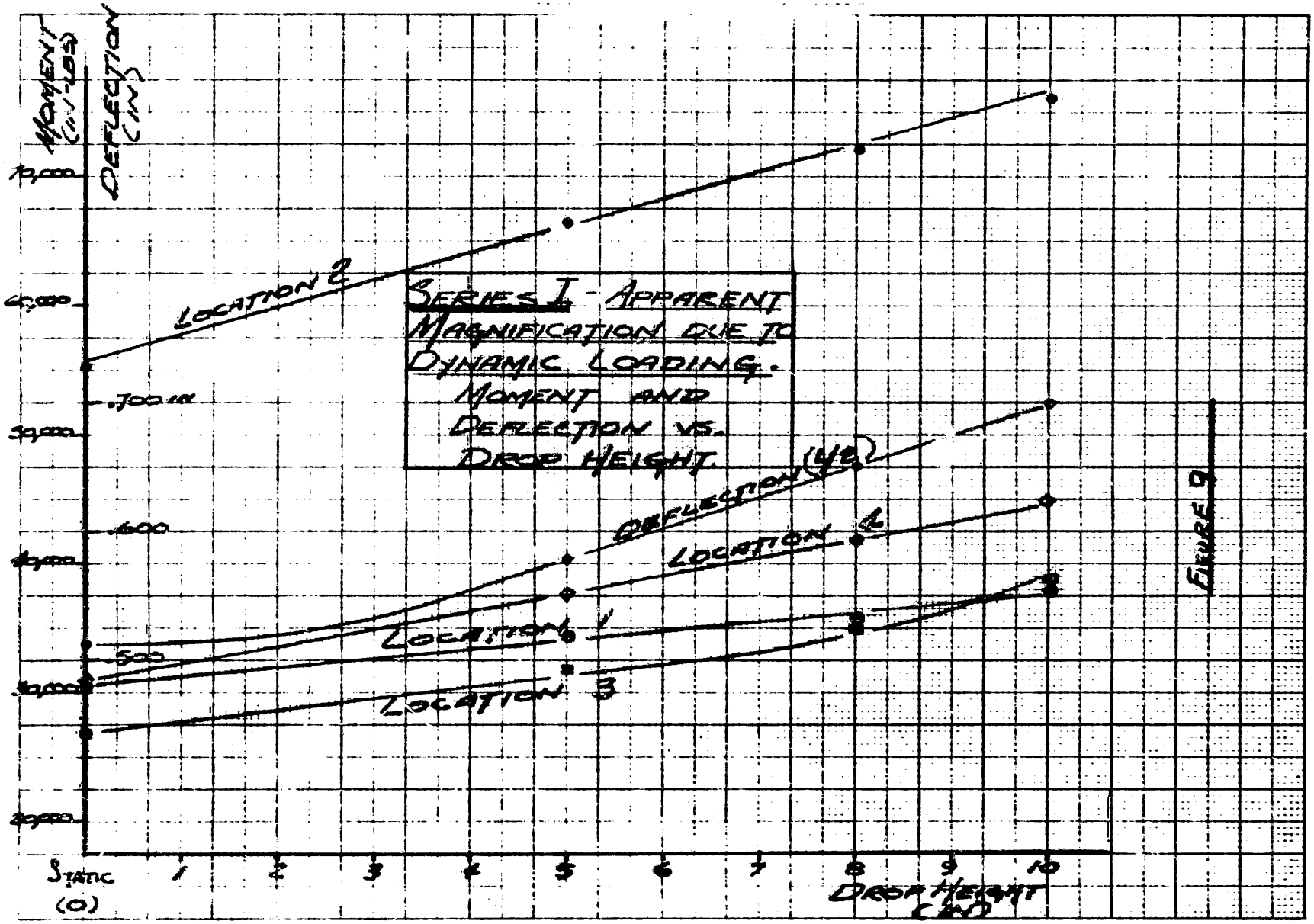
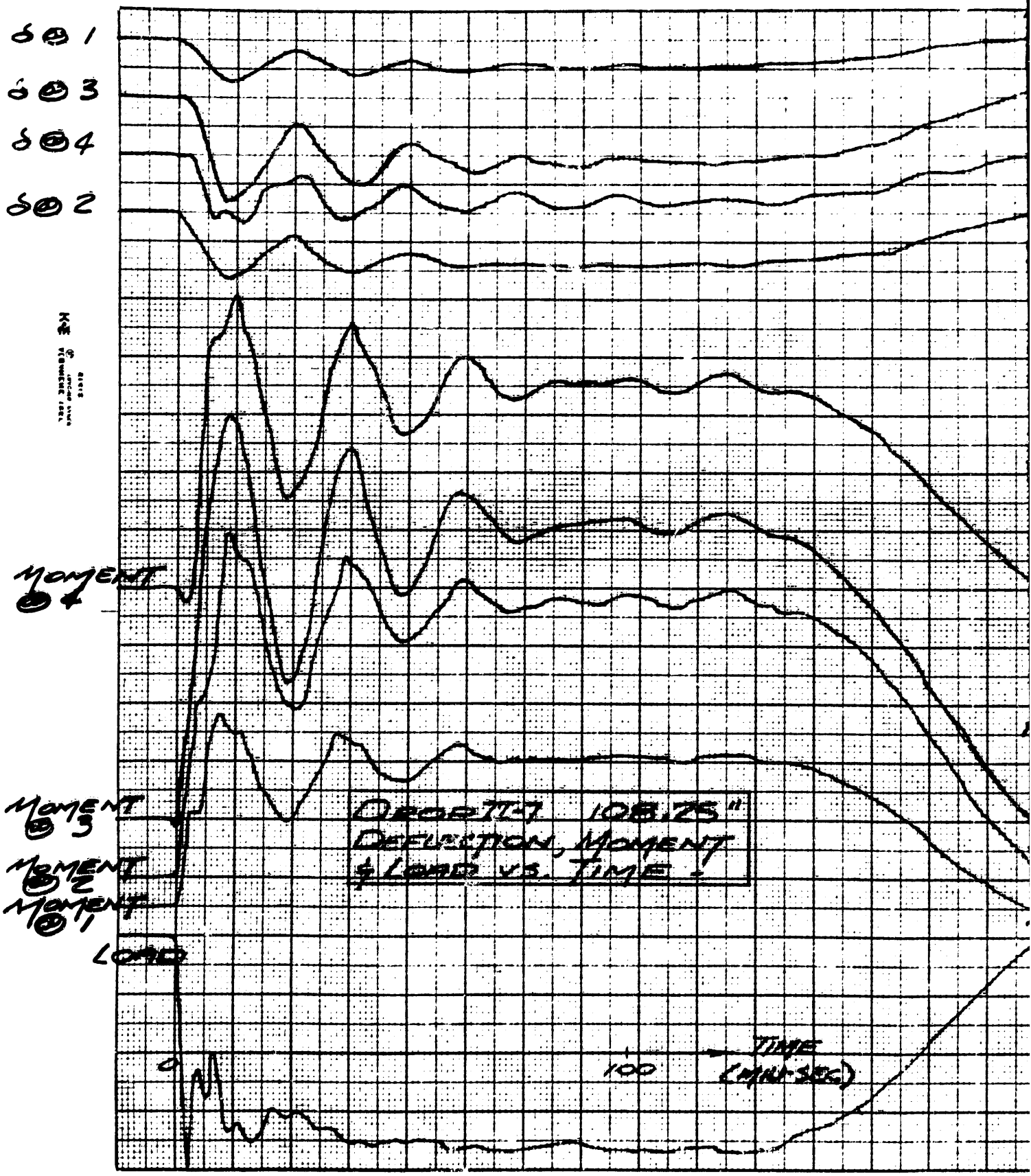

MOMENT (IN-LBS)
DEFLECTION (IN)
SERIES I - APPARENT MAGNIFICATION DUE TO DYNAMIC LOADING. MOMENT AND DEFLECTION VS. DROP HEIGHT.
LOCATION 2
DEFLECTION (1/2)
LOCATION 1
LOCATION 3
.700 IN
.600
.500
STATIC (0)
1
2
3
4
5
6
7
8
9
10
DROP HEIGHT (IN)

FIGURE 9


δ @ 1
δ @ 3
δ @ 4
δ @ 2
MOMENT @ 4
MOMENT @ 3
MOMENT @ 2
MOMENT @ 1
LOAD
0
100
TIME (MILLI-SEC)
DROP HT 108.75"
DEFLECTION, MOMENT & LOAD VS. TIME

LOAD AVG = 4475 LB

LOCATION	DEFLECTION DYN. PEAK	DEFLECTION *EQUIV. STAT. AVG.	DEFLECTION RATIO	MOMENT DYN. PEAK	MOMENT *EQUIV. STAT. AVG.	MOMENT RATIO
1	.480 IN	.270	1.78	62,900	45,600	1.38
2	.775	.662	1.17	105,800	91,200	1.16
3	1.120	.820	1.37	56,700	41,100	1.38
4	.825	.550	1.50	62,600	46,700	1.34

* - STATIC VALUE BASED ON 4475 LB.

Figure 11

Test No.	Date	Type of Test	Cartr. No.	Drop Height	Drop Weight	Strut Length	Specimen Length Original	Specimen Length Final
1	7/30/64		1	5.0"	600 LB	108 1/4"	6 3/4	5 9/16
2	7/30/64		1	5.0"	600 LB	108 1/4"	5 9/16	4 19/32
3	7/30/64		1	5.0"	600 LB	108 1/4"	4 19/32	3 3/4
4	7/30/64		1	5.0"	600 LB	108 1/4"	3 3/4	3
5	7/30/64		2	10.0"	600 LB	108 1/4"	6 7/8	4 5/8
6	7/30/64	Dynamic	2	8.0"	600 LB	108 1/4"	4 5/8	3 1/8
7	8/3/64	Tests	3	10.0"	600 LB	108 1/4"	6 13/16	4 9/16
8	8/3/64		3	8.0"	600 LB	108 1/4"	4 9/16	3 1/32
9	8/12/64		4	5.0"	600 LB	108 1/4"	6 3/4	5 11/16
10	8/12/64		4	5.0"	600 LB	108 1/4"	5 11/16	4 5/8
11	8/12/64		4	5.0"	600 LB	108 1/4"	4 5/8	3 3/4
12	8/12/64		4	5.0"	600 LB	108 1/4"	3 3/4	2 7/8
13	8/12/64		4	5.0"	600 LB	108 1/4"	2 7/8	1 3/4
14	8/12/64		5	5.0"	600 LB	108 1/4"	6 3/4	5 5/8
15	8/12/64		5	5.0"	600 LB	108 1/4"	5 5/8	4 1/2
16	8/12/64		5	5.0"	600 LB	108 1/4"	4 1/2	3 7/16
17	8/12/64		5	5.0"	600 LB	108 1/4"	3 7/16	2 1/2
18	8/12/64		5	5.0"	600 LB	108 1/4"	2 1/2	1 1/4
19	8/18/64		6	10.0"	600 LB	108 1/4"	6 13/16	4 13/32
20	8/18/64		6	8.0"	600 LB	108 1/4"	4 13/32	2 11/16
21	8/18/64		6	5.0"	600 LB	108 1/4"	2 11/16	1 9/16

Test No.	Date	Type of Test	Insert	Side Compr.	Load Tension	Strut Length	Stroke Velocity	Axial Load
22	8/31/64	Friction	None	2500 LB	3000 LB	108 1/4"	.9 in/sec	
23	10/27/64	Friction	None	2500 LB	3000 LB	108 1/4"	.9 in/sec	
24	10/27/64	Friction	None	2500 LB	3000 LB	108 1/4"	.9 in/sec	
25	10/27/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
26	10/28/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
27	11/6/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
28	11/6/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
29	11/6/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
30	11/6/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
31	11/6/64	Friction	None	5000 LB	6000 LB	108 1/4"	.9 in/sec	
32	11/10/64	Friction	None	5000 LB	6000 LB	108 1/4"	.75 in/sec	
33	11/10/64	Friction	None	5000 LB	6000 LB	108 1/4"	.75 in/sec	
34	11/10/64	Friction	None	5000 LB	6000 LB	108 1/4"	.75 in/sec	
35	11/10/64	Friction	None	5000 LB	6000 LB	108 1/4"	.75 in/sec	

Specimen Length Original	Final	Δ	Remarks
3/4	5 9/16	1 3/16	General: Honeycomb Static Crushing Load = 2460 LBS;
9/16	4 19/32	31/32	No insert in strut.
3/32	3 3/4	27/32	
3/4	3	3/4	
7/8	4 5/8	2 1/4	
5/8	3 1/8	1 1/2	
3/16	4 9/16	2 1/4	Load cell flush against impact plate
9/16	3 1/32	1 17/32	
3/4	5 11/16	1 1/16	Oscilloscope missed peak
1/16	4 5/8	1 1/16	Oscilloscope missed peak
5/8	3 3/4	7/8	
3/4	2 7/8	7/8	
7/8	1 3/4	1 1/8	
3/4	5 5/8	1 1/8	
1/8	4 1/2	1 1/8	
1/2	3 7/16	1 1/16	
7/16	2 1/2	15/16	
1/2	1 1/4	1 1/4	
3/16	4 13/32	2 13/32	Straps on block at foot-pad end
3/32	2 11/16	1 23/32	Straps on block at foot-pad end
1/16	1 9/16	1 1/8	Straps on block at foot-pad end

Stroke Velocity	Axial Load	Bearing Type	Remarks
in/sec		Teflon	Load vs. stroke plot, inconsistent
in/sec		Teflon	
in/sec		Teflon	Tests 23-26, gauges not in line with side load resultant
in/sec		Teflon	
in/sec		Teflon	
in/sec		Teflon	
in/sec		Teflon	
in/sec		Teflon	
in/sec		Teflon	
in/sec		Teflon	
in/sec		.030 Crown	
in/sec		(LSK 915-	
in/sec		1027-13 &	
in/sec		-3)	

Figure 11

Test No.	Date	Type of Test	Insert	Side Load Compr.	Side Load Tension	Strut Length	Stroke Velocity	Axial Load
36	11/11/64	Friction	None	5000	6000	108 1/4	-5 in/sec	
37	11/11/64	Friction	None	5000	6000	108 1/4	-5 in/sec	
38	11/11/64	Friction	None	5000	6000	108 1/4	-5 in/sec	
39	11/11/64	Friction	None	5000	6000	108 1/4	-5 in/sec	
40	11/16/64	Limit	Wood	5000	6000	108 1/4	None	8800
41	11/16/64	Limit	Wood	5000	6000	108 1/4	None	8800
42	11/16/64	Limit	Wood	5000	6000	108 1/4	None	8800
43	11/16/64	Limit	Wood	5000	6000	93 1/4	None	13,800
44	11/16/64	Limit	Wood	5000	6000	93 1/4	None	13,800
45	11/16/64	Limit	Wood	5000	6000	93 1/4	None	13,800
46	11/18/64	Limit	Wood	5000	6000	83 1/4	None	13,500
47	11/18/64	Limit	Wood	5000	6000	83 1/4	None	13,500
48	11/18/64	Limit	Wood	5000	6000	83 1/4	None	13,500
49	11/19/64	Friction	None	5000	6000	108 1/4	.9 in/sec	
50	11/19/64	Friction	None	5000	6000	108 1/4	.9 in/sec	
51	11/19/64	Friction	None	5000	6000	108 1/4	.9 in/sec	

Series No. II

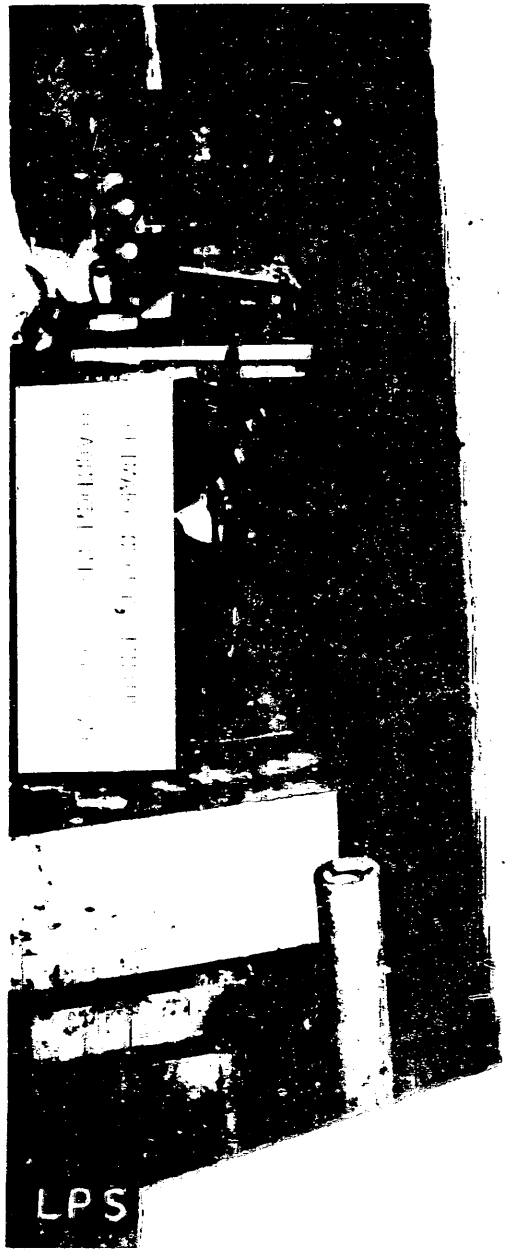
Test No.	Date	Type of Test	*Cartr. No	Drop Height	Drop Weight	Strut Length	Specimen Length Original	Specimen Length Final
II-1	1/25/65	↑	2000-2	18.75"	590 LB	108.25"	13 11/16	7 3/4
II-2	1/25/65		2000-3	18.75"	590 LB	93.25"	13 3/4	7 7/16
II-3	1/28/65		2000-4	18.75"	590 LB	83.25"	13 3/4	7 5/16
II-4	1/28/65	Dynamic	4000-2	18.75"	1275 LB	83.25"	13 7/8	5 13/16
II-5	1/28/65	Tests	4000-3	18.75"	1275 LB	93.25"	13 13/16	6 1/8
II-6	1/28/65		4000-4	18.75"	1275 LB	108.25"	13 3/4	6 3/8
II-7	1/29/65	↓	4000-5	18.75"	1275 LB	108.25"	13 3/4	6 3/8
II-8	2/2/65		6000-2	18.75"	1725 LB	83.25"	13 13/16	6 15/16
II-9	2/2/65		6000-3	18.75"	1725 LB	93.25"	13 7/8	7 1/16
II-10	2/2/65		6000-4	18.75"	1725 LB	108.25"	13 7/8	7
II-11	2/3/65		6000-5	18.75"	1725 LB	108.25"	13 3/4	7

*The 1st part of the Cartridge No. indicates the approximate static crushing load.

Stroke Velocity	Axial Load	Bearing Type	Remarks
-5 in/sec			
-5 in/sec			
-5 in/sec			
-5 in/sec			
None	8800 LB		
None	8800 LB	"Molycoat"	
None	8800 LB	(LSK 915-1027-11)	
None	13,800 LB		
None	13,800 LB		
None	13,800 LB		
None	13,500 LB		
None	13,500 LB		
None	13,500 LB		
.9 in/sec		.040 Crown	
.9 in/sec		(LSK 915-1027-15	
.9 in/sec		and -5)	

Specimen Length Original	Final	Δ	Remarks
13 11/16	7 3/4	5 15/16	General: No insert in strut, foot-pad
13 3/4	7 7/16	6 5/16	End supported
13 3/4	7 5/16	6 7/16	
13 7/8	5 13/16	8 1/16	
13 13/16	6 1/8	7 11/16	
13 3/4	6 3/8	7 3/8	
13 3/4	6 3/8	7 3/8	
13 13/16	6 15/16	6 7/8	No picture
13 7/8	7 1/16	6 13/16	
13 7/8	7	6 7/8	
13 3/4	7	6 3/4	

LPS340-
GAE
SA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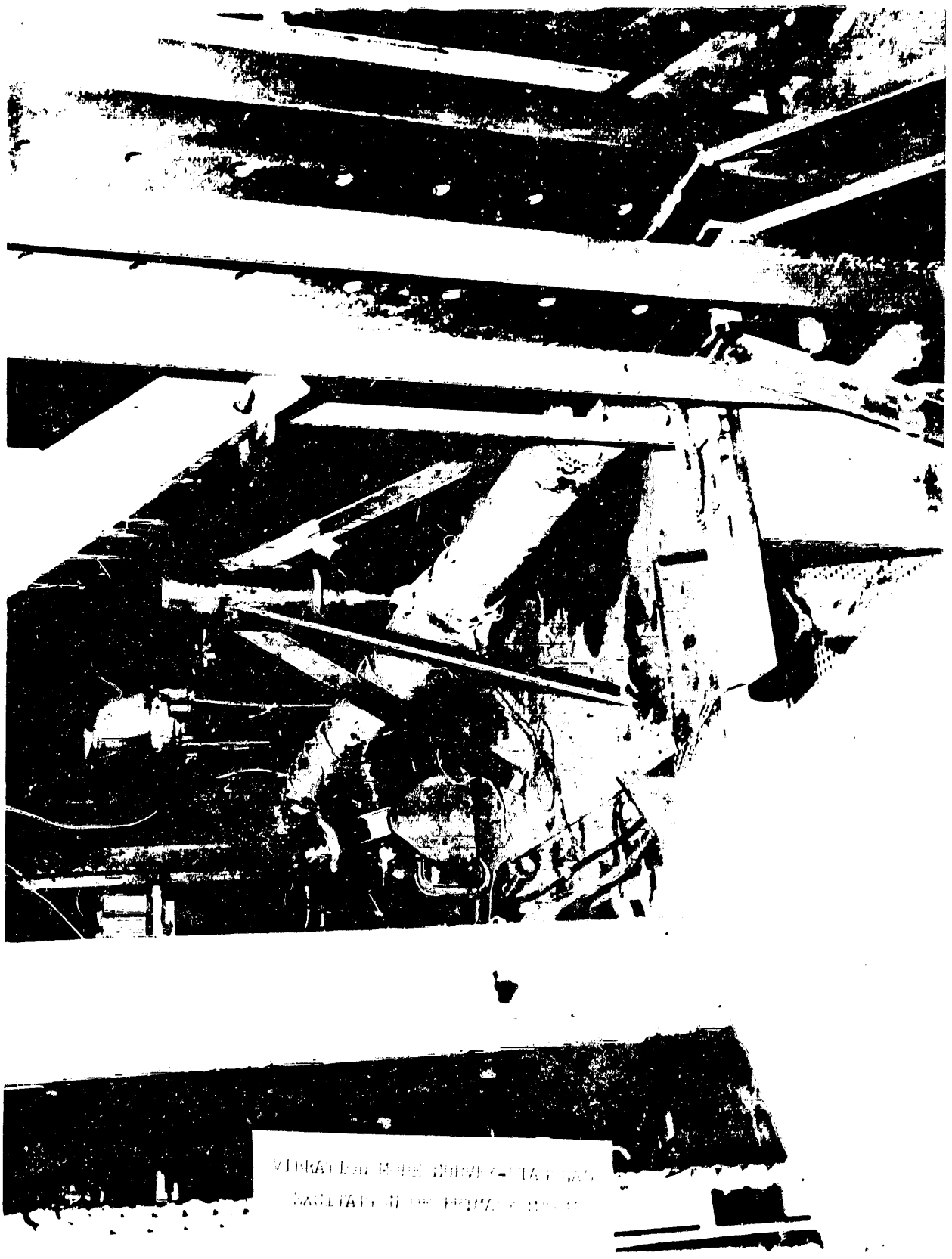
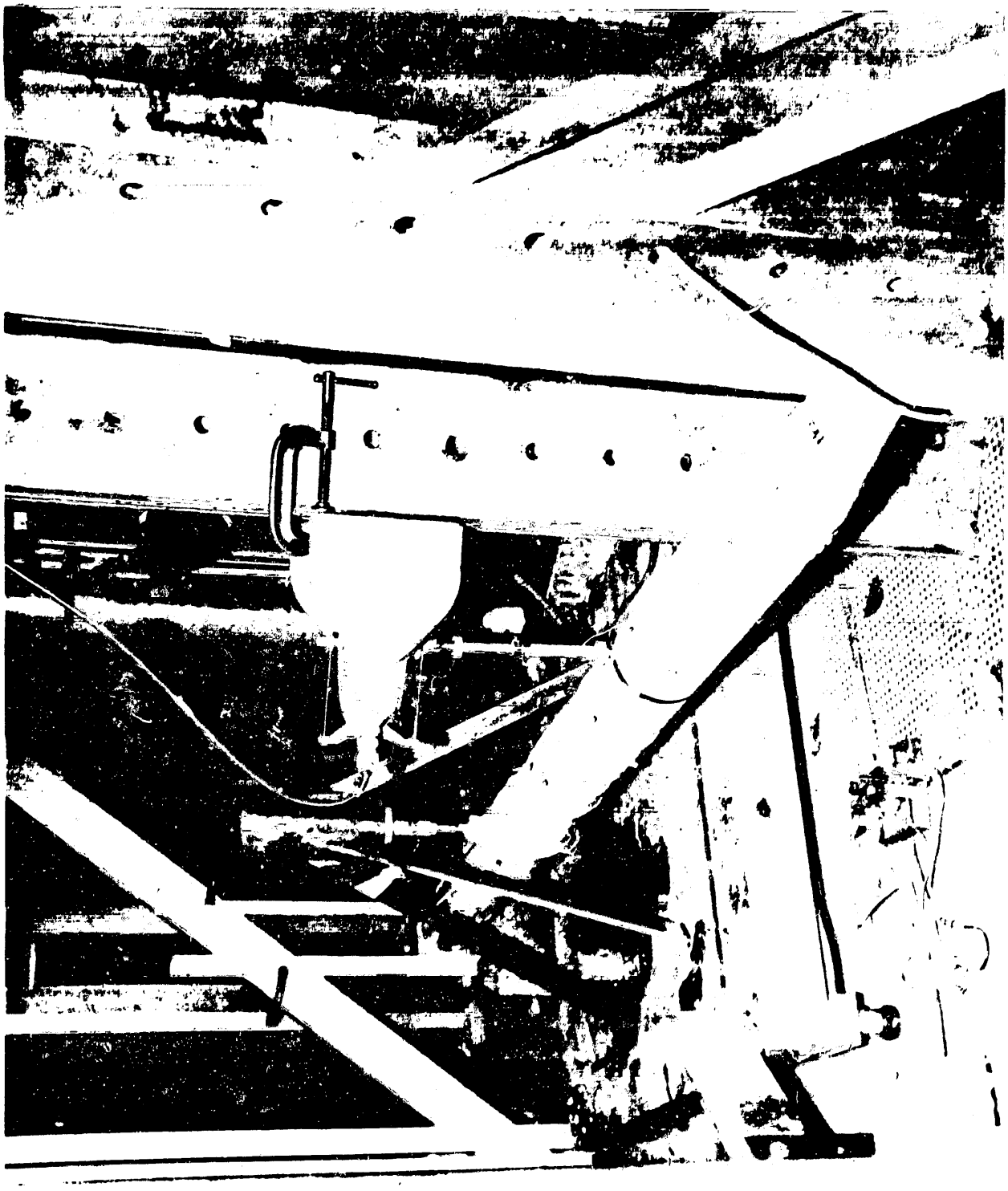
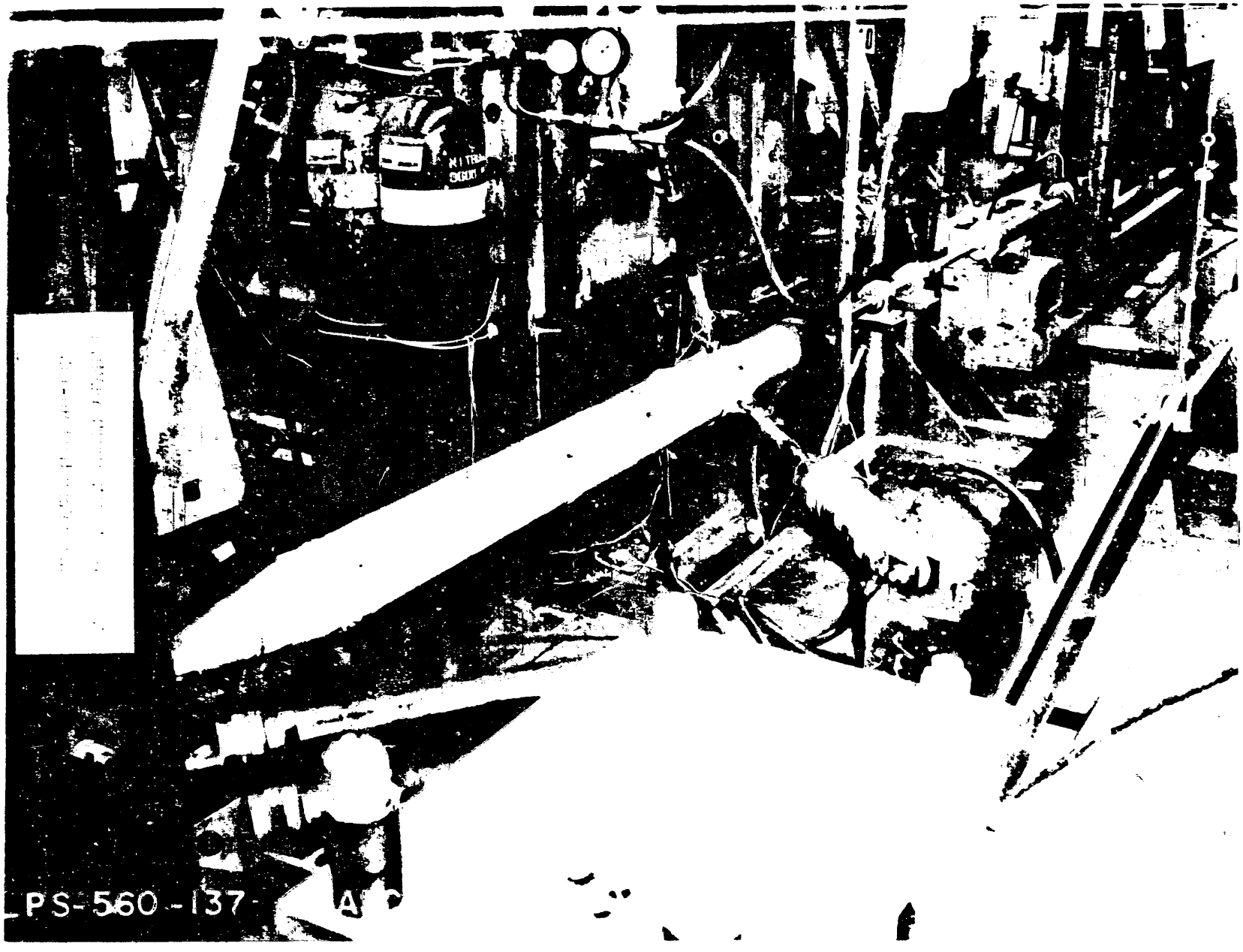
JULY 64



VIBRATION MODE SURVEY-FLAT GAS
EXCITATION OF PRIMARY MODES




PS-560-137
A

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

PREPARED BY:
R. GARTENSCHLAEGER

CHECKED BY:
R. L. MAKEMSON

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

INTRODUCTION

This section of the report contains the results of all tests conducted on the LEM Landing Gear Footpad LSK-320-10704. It was found that the footpad satisfactorily withstood the design normal load of 12 psi at both ambient and 225°F temperature. The pad also exhibited satisfactory lateral crushing characteristics.

This is a continuation of the footpad development program. The results of previous tests were presented in Section D of this report.

Refer to LTP-904-10001, Section J, Plan for the Static Test of the LEM Landing Gear Footpad LSK-320-10704.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

1.0 PURPOSE OF TEST

1.1 The purpose of these tests was to verify the structural integrity of the footpad when subjected to a uniformly distributed normal load at ambient and 225°F temperature conditions and to evaluate the load-stroke characteristics during lateral crush of this footpad design for use on the LEM landing gear. A test to failure under normal pressure load was conducted to establish the design safety margins.

2.0 DESCRIPTION OF TEST SPECIMEN

2.1 The test specimens were 37 inches in diameter and of the configuration shown on Figure 1. Construction was of bonded aluminum honeycomb. The core was a composite of 5052 aluminum foil (0.0010 inch thick and 3/16 inch cell size) and of 2024-T81 aluminum foil (0.0015 inch thick and 3/16 inch cell size) assembled as shown on Dwg. LSK-320-10704. The skins were of 7075-T6 aluminum and were tapered to the outer edge to produce desirable lateral crush characteristics.

2.2 Four pads conforming to Dwg. LSK-320-10704 were supplied for testing. One footpad was used for Phase I - Normal Load Tests and three pads were used for Phase II - Transverse Load Tests.

3.0 TEST CONDITIONS

3.1 In all tests described below, the pad was installed in a horizontal attitude.

3.2 Phase I - Normal Load Test

3.2.1 Test 1 - Proof Test (Design Normal Load): conducted under ambient environmental conditions.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

3.0 TEST CONDITIONS - continued

3.2 Phase I - Normal Load Test - continued

3.2.2 Test 2 - Proof Test and Failure Test: conducted under 225° ± 10°F temperature.

3.2.3 It should be noted that the pad is designed to a zero safety margine (i.e.) limit and ultimate design load have the same value of 12 psi.

3.2.4 The surface loading during these tests was essentially static in that no attempt was made to achieve a particular rate of pressure loading.

3.3 Phase II - Transverse Load Test

3.3.1 During these tests, no attempt was made to attain a specific rate of loading but rather a uniform rate of loading. The footpads were crushed into hard fixed bearing surfaces having configurations of a flat plate, inside 90° corner and an outside 90° corner.

4.0 TEST SET-UP AND PROCEDURE

4.1 The design normal load was applied to the footpad using an inflatable rubber bladder (Refer to Paragraph 3.2.1). The load was reacted by a rigid compression member incorporating a strain gage load cell. The proof test and failure test (Para. 3.2.2) was essentially identical with the above. The pad was heated to 225°F. temperature prior to being subjected to the pressure loading.

4.2 Strain gages were installed on the footpad as shown on Figure 1. The pressure was measured with a pressure transducer at the inlet port of the bladder and the strain gage load cell was installed above the ball and socket joint as described in Paragraph 4.1.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

4.0 TEST SET-UP AND PROCEDURE - continued

4.3 Prior to the Transverse Load Tests, the jig was system calibrated to determine the friction forces inherent in the jig. The calibration resulted in an Applied Load vs. Corrected Load curve which may be seen on Figure 2. The pad was crushed into the three obstacle configurations at a slow uniform rate. Load-stroke profiles were obtained from these tests. Refer to Photographs LPS-560-213, 230 and 320.

5.0 RESULTS AND CONCLUSIONS

5.1.1 Under the conditions described in Paragraph 3.2.1, the pad withstood a normal pressure loading of 12 psi. A visual inspection under this load showed no damage or skin buckling.

5.1.2 The above test was repeated at 225°F as described in Paragraph 3.2.2. Visual inspection of the pad while under the normal pressure load of 12 psi showed no damage or skin buckling. The pressure in the bladder was slowly increased. Audible cracking occurred at 14 psi and complete failure at 16.7 psi. Sectioning and subsequent internal inspection of the pad showed that a vertical shear failure of the core had occurred circumferentially around the hub at approximately 6 inches from the pad center. This failure is shown in Photograph LPS-560-524. Extensive failure of the core to skin had also occurred (Photograph LPS-560-527). It was not possible to definitely identify the primary failure (i.e. vertical shear of the core or core to skin separation) but vertical shear of the core was thought the more probable.

5.1.3 Recorded strains in both ambient and elevated temperature were of a low order (i.e. 1000μ-in/in or less) and have therefore not been presented in this report.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

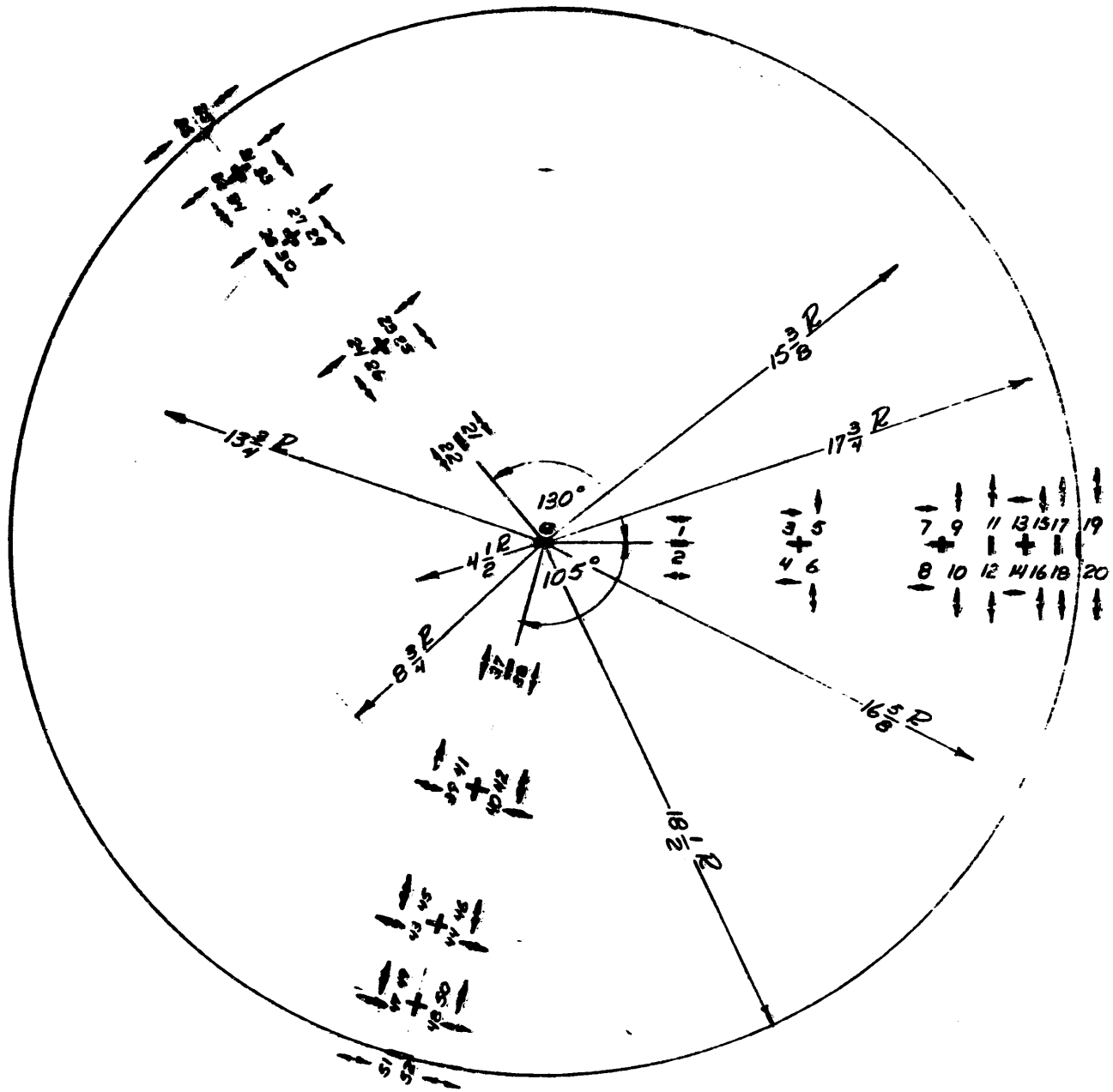
SECTION J - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10704

5.0 RESULTS AND CONCLUSIONS - continued

5.2 Load-stroke characteristics were obtained during lateral crushing into the three obstacle configurations described in Paragraph 3.3. The characteristic curves are presented in the form of Applied Load vs. Stroke (Figures 3A-7A) which are duplications of the traces obtained directly on the X-Y recorder. The Corrected Load vs. Stroke curves (Figures 3B-7B) show the actual characteristics of the pad and were derived using the Applied Load vs. Corrected Load curve. Variations in crush characteristics reflect the sensitivity of each pad to the shape of the obstacle. This sensitivity is given in efficiency percentages and is presented with the Corrected Load-Stroke curves. It should be noted that one pad was used for Tests #1 and #2. Refer to Photograph LPS-560-216 showing crush mode of the pad for a flate plate. A second pad was used for Tests #3 and #4. Refer to Photograph LPS-560-319 showing the crush mode of the pad for an inside 90° obstacle. The third footpad was used for Test #5. Refer to Photograph LPS-560-233 showing crush mode of the pad for an outside 90° obstacle.

STRAIN GAGE INSTALLATION OF FOOTPAD LSK-320-10704

NORMAL LOAD TEST



Contract No. NAS 9-1100
Drawing No. 011

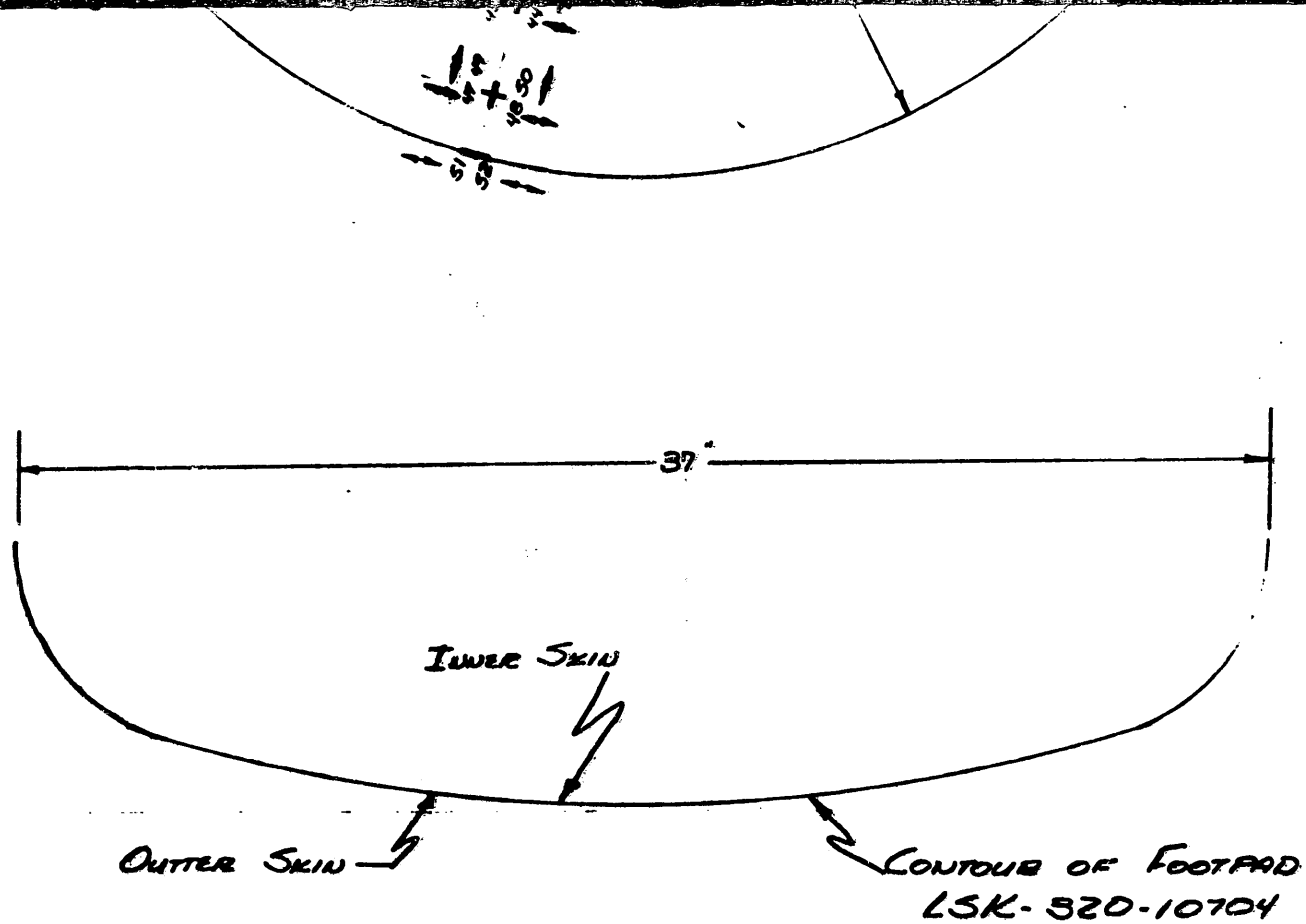


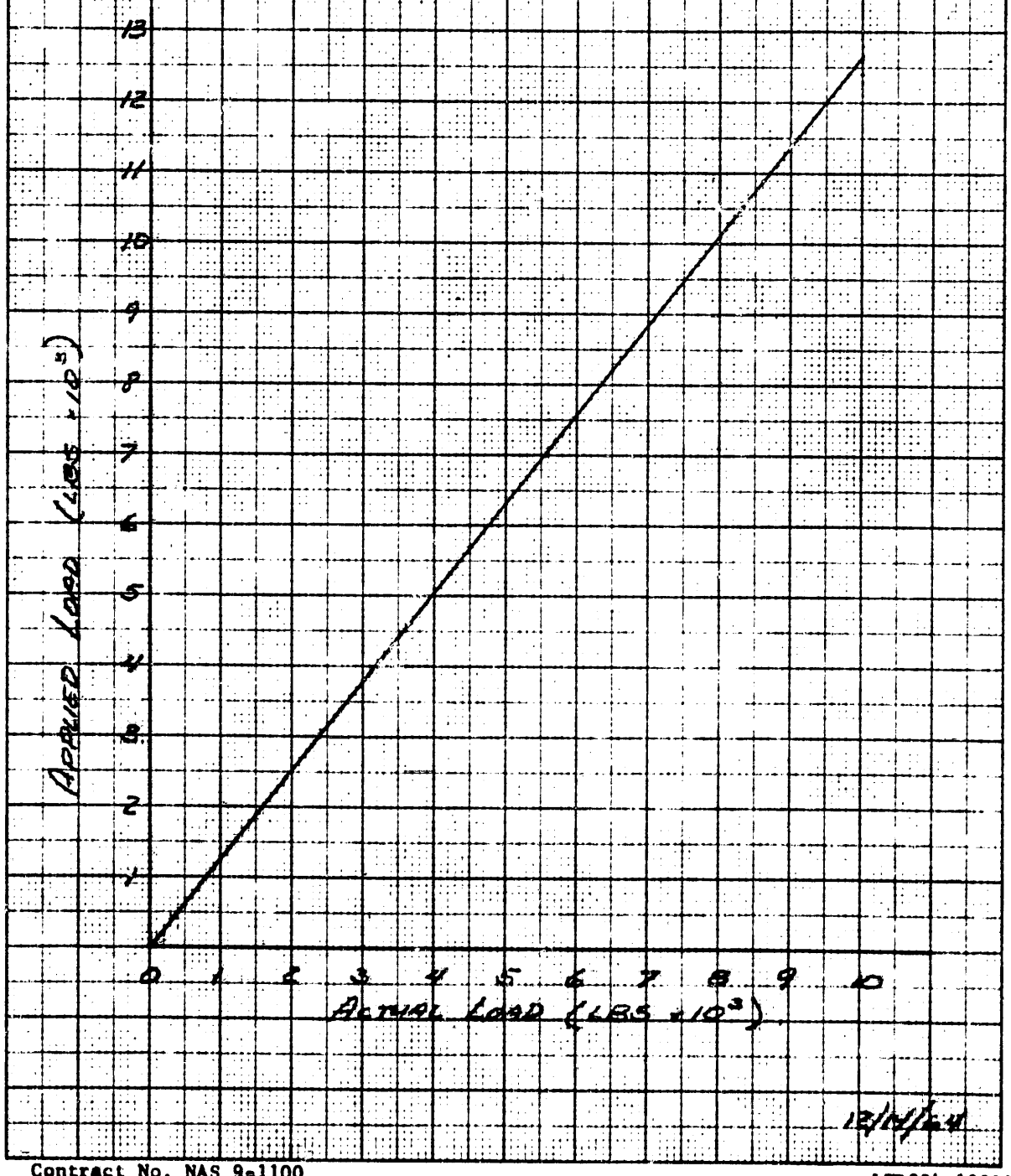
FIGURE - #1

NOTES:

1. ODD NUMBERED GAGES ARE LOCATED ON INNER SKIN. (GAGE 53 ON BOTTOM SKIN)
2. EVEN NUMBERED GAGES ARE LOCATED ON OUTTER SKIN.
3. ARROW ON TOP OR BOTTOM OF NUMBER DENOTES THE DIRECTION OF THE SENSITIVE AXIS OF THE STRAIN GAGE

PHASE II: TEST FIXTURE FRICTION CORRECTION
LEM FOOTPAD, TRANSVERSE LOAD

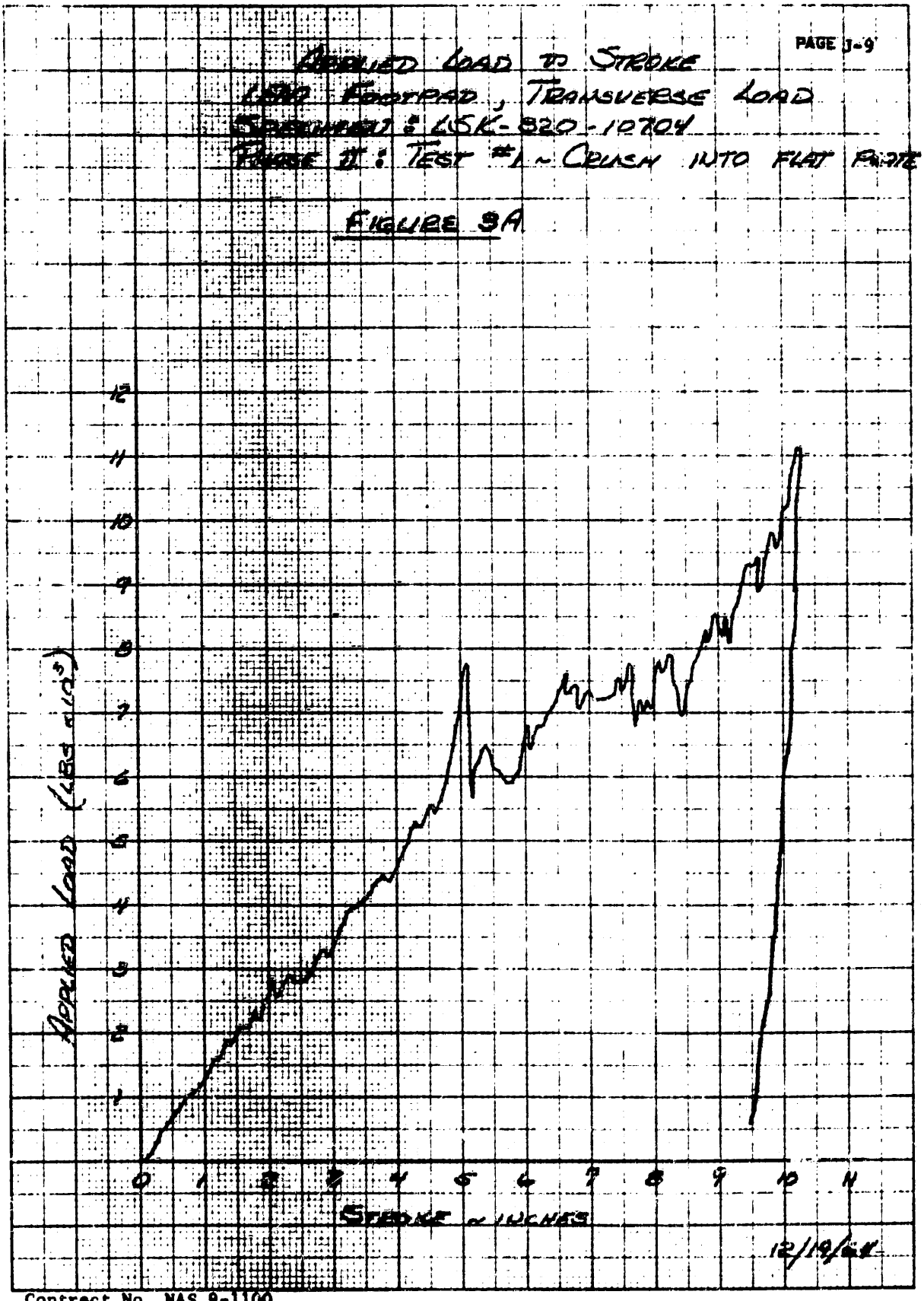
FIGURE 2



12/14/64

APPLIED LOAD VS STROKE
LEG FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LSK-820-10704
PHASE II: TEST #1 ~ CRUSH INTO FLAT PLATE

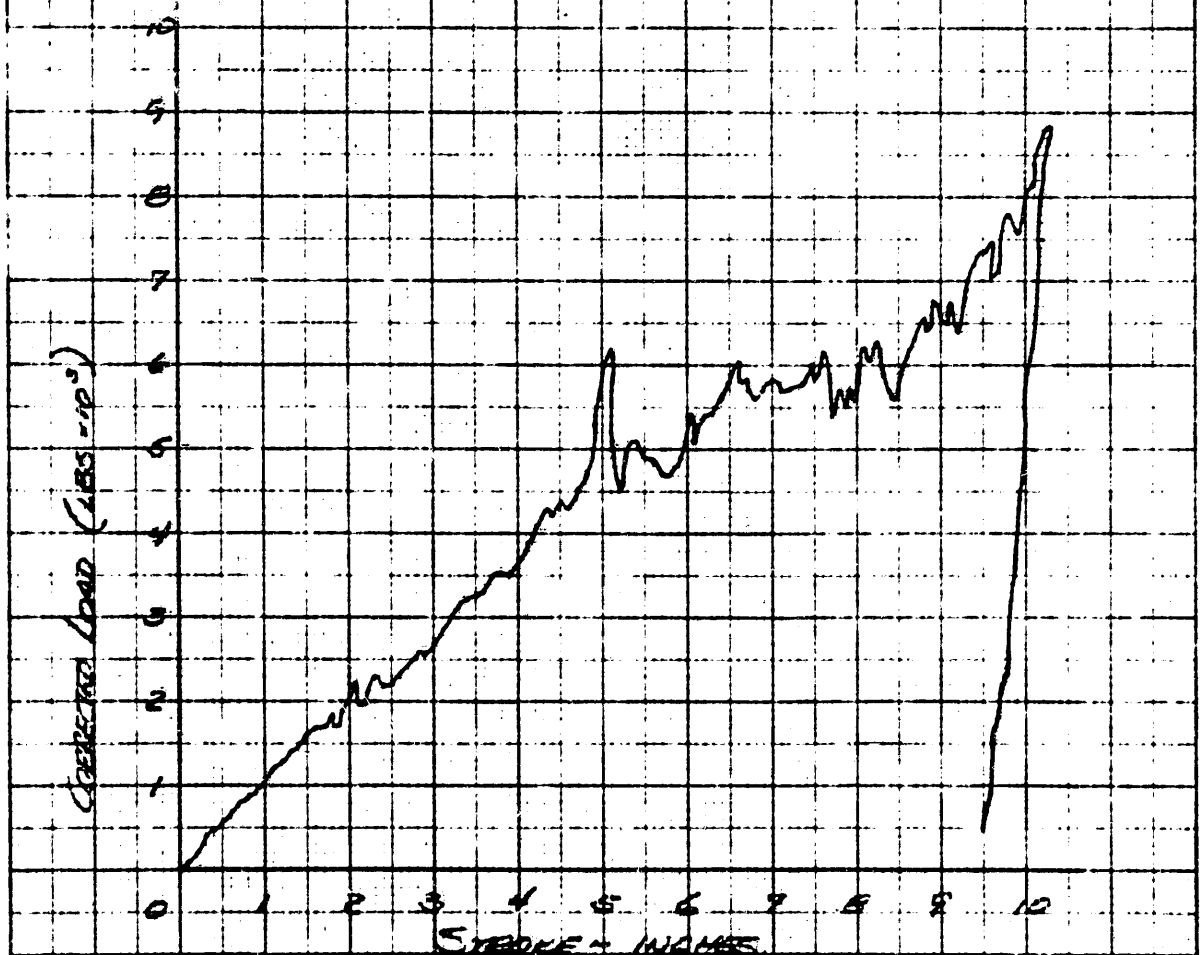
FIGURE 9A



CORRECTED LOAD VS STROKE
LEM FOOTPAD, TRANSVERSE LOAD.
SPECIMEN: 45K-820-10704-1
PHASE II: TEST #1 - CRUSH INTO FLAT PLATE.

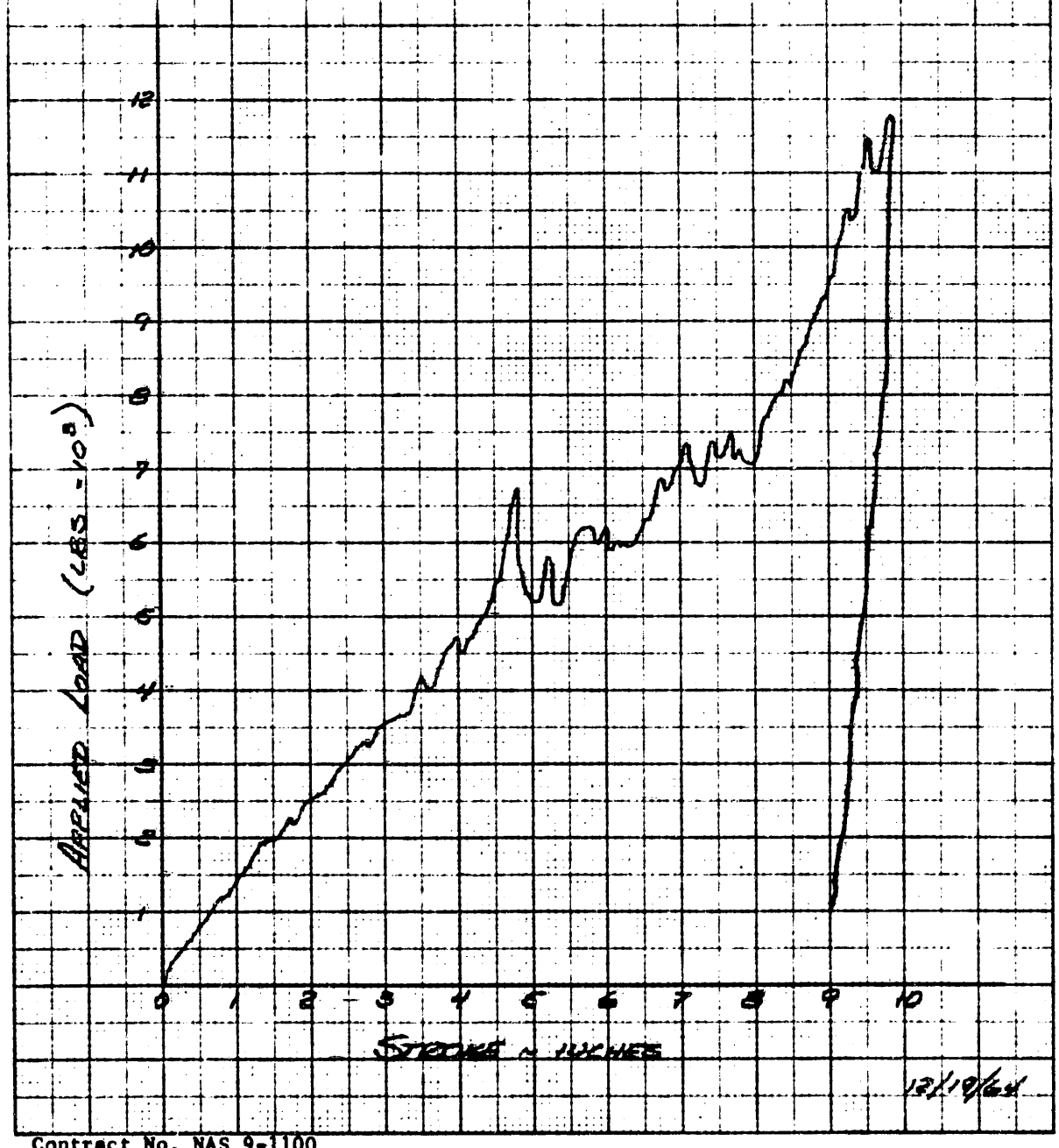
FIGURE 9B

TOTAL ENERGY ABSORBED BY FOOTPAD = 37416 IN-LBS.
EFFICIENCY = 52.0 %



APPLIED LOAD vs STROKE
LEM FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LSK-320-10704
PHASE II: TEST #2 CRUSH INTO FLAT PLATE

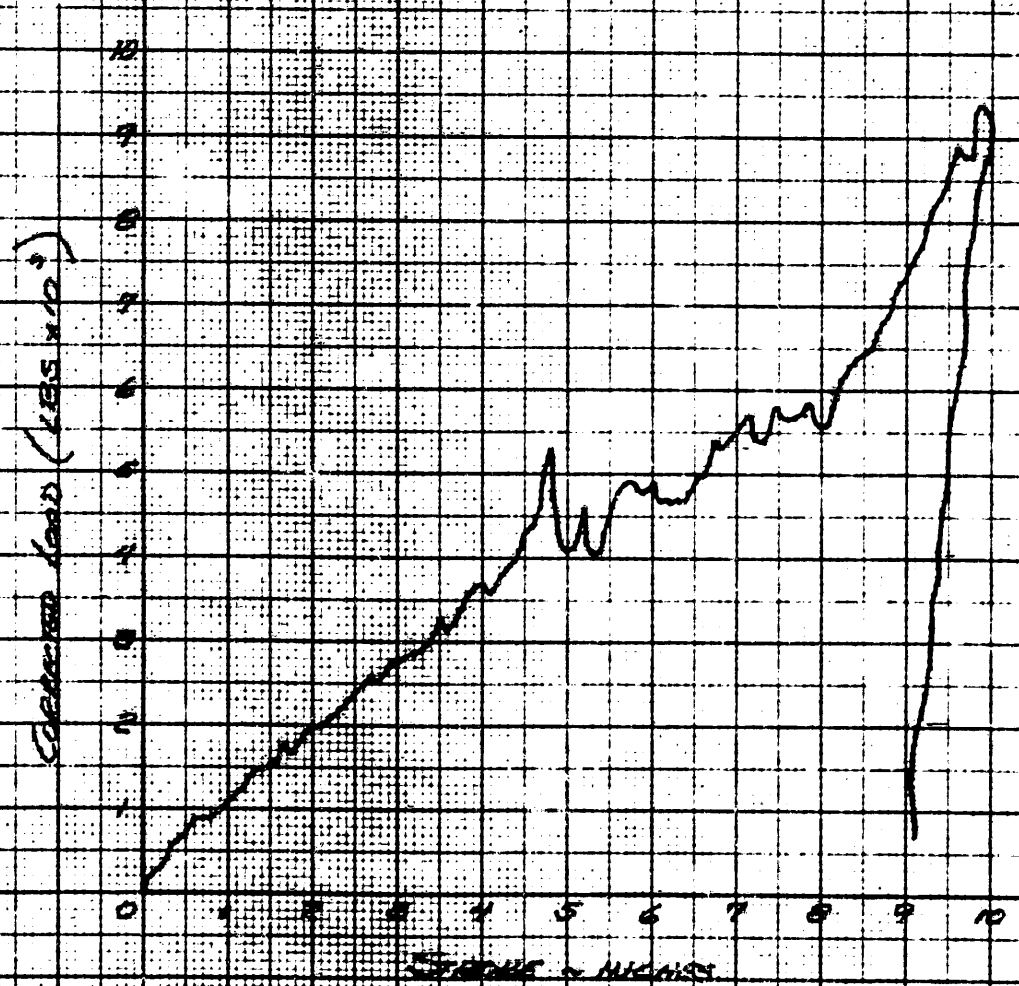
FIGURE 4A



CORRECTED LOAD VS STROKE
LSM FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LSK-320-10704-1
PHASE II: TEST #2 - CRUSH INTO FLATE PLATE

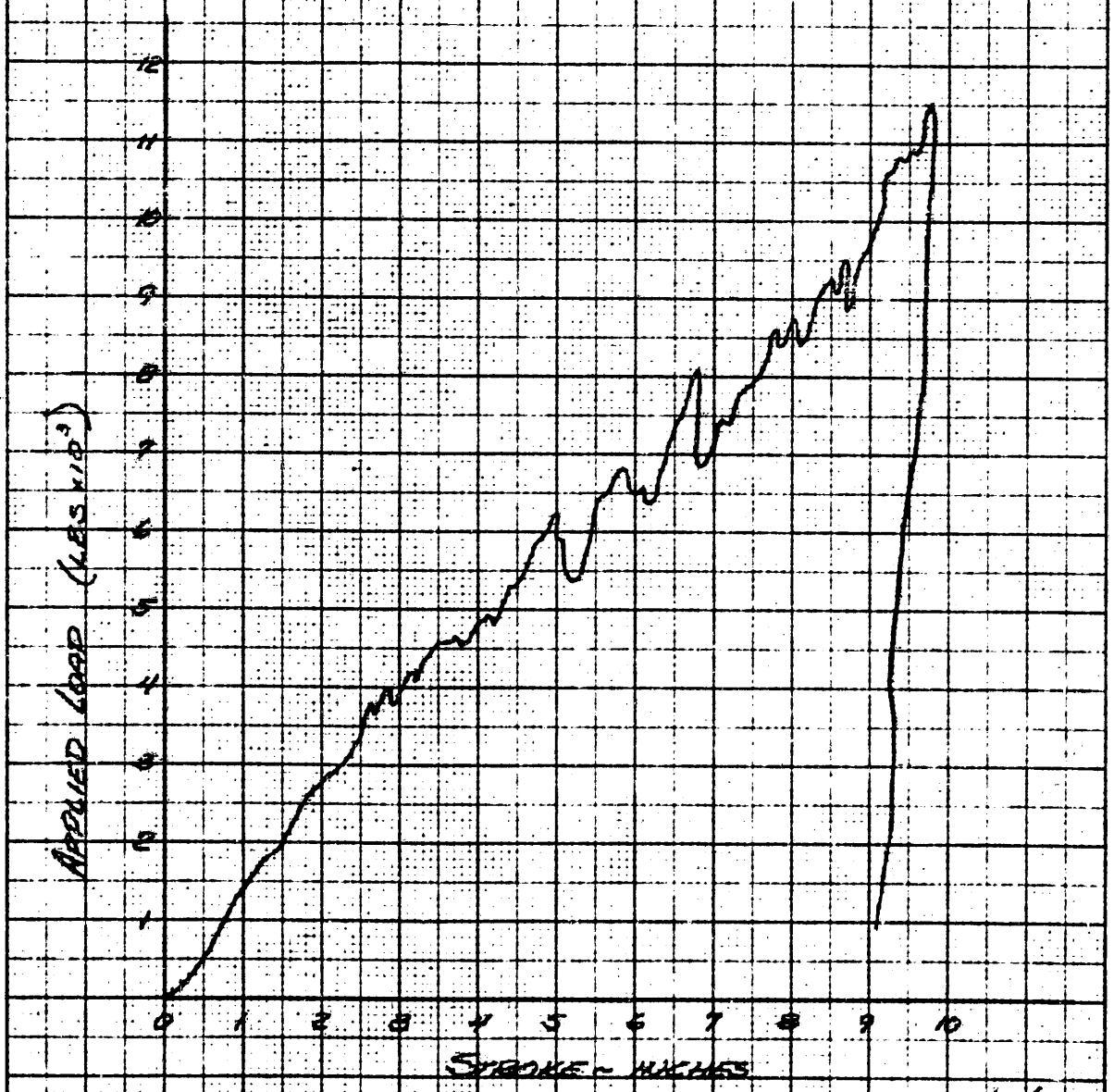
FIGURE 4B

TOTAL ENERGY ABSORBED BY FOOTPAD = 41,500 IN-#
EFFICIENCY = 46.2%



APPLIED LOAD TO STROKE
LEM FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LCK-820-10704
PHASE II: TEST #3 ~ CRUSH INTO INSIDE 90° CORNER

FIGURE 5A

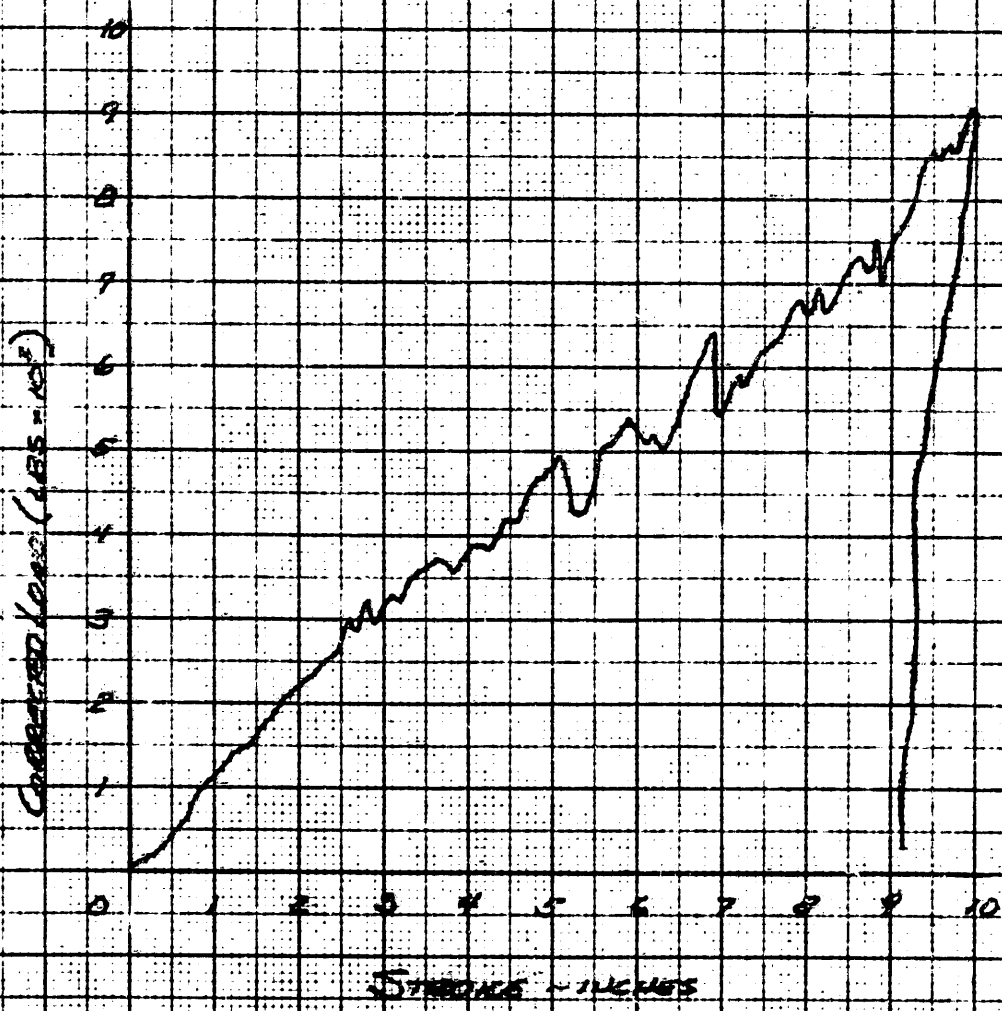


3/9/65

CORRECTED LOAD VS STROKE
LEM FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LSK-820-10704-3
PHASE II: TEST #3 - CRUSH INTO INSIDE 90° CORNER

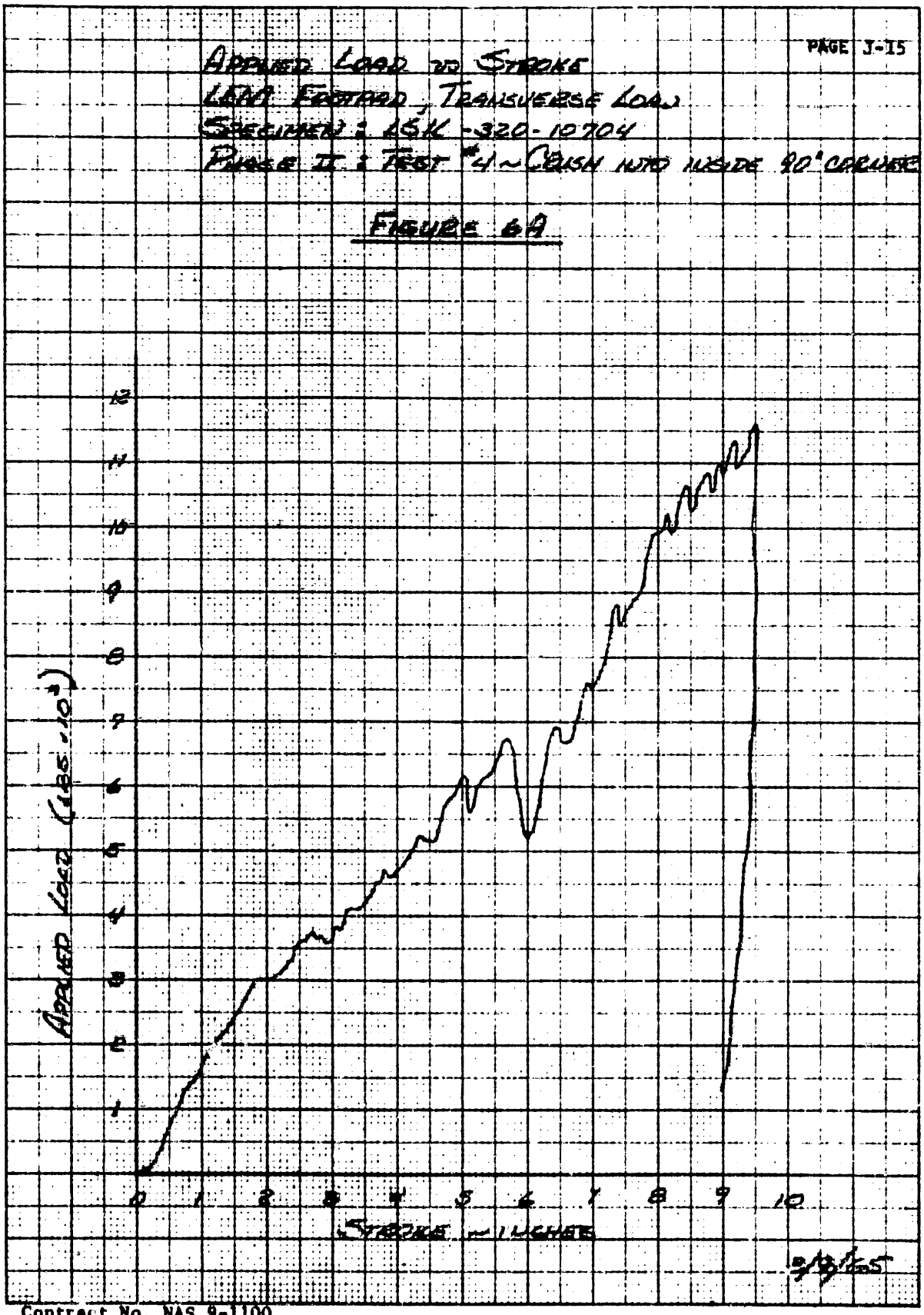
FIGURE 58

TOTAL ENERGY ABSORBED BY FOOTPAD = 42,300 IN-LBS
EFFICIENCY = 42%



APPLIED LOAD VS STROKE
LEAD FORWARD, TRANSVERSE LOAD
SPECIMEN: 65K-320-10704
PHASE II: TEST #4 ~ CRUSH INTO INSIDE 90° CURVE

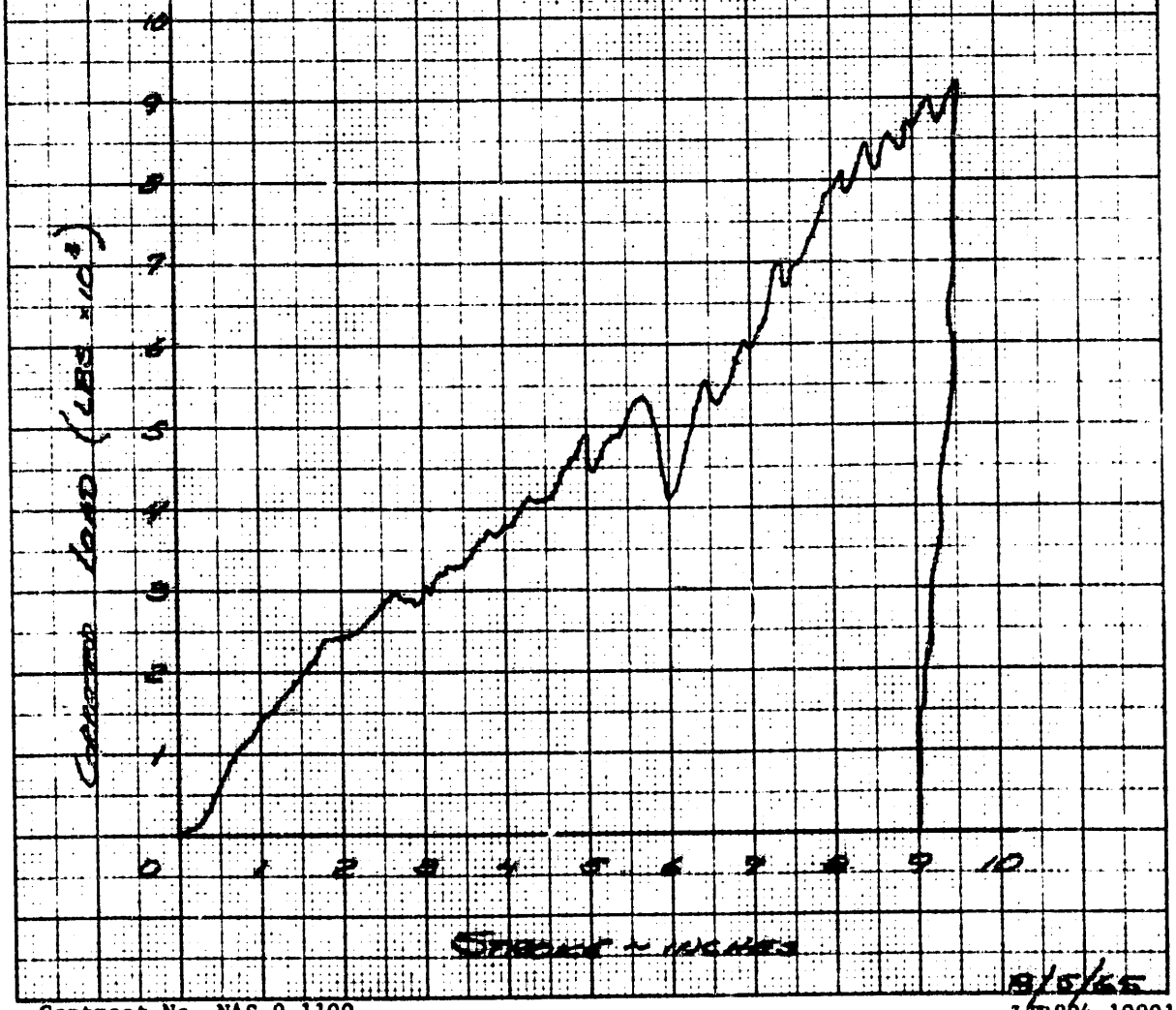
FIGURE 6A

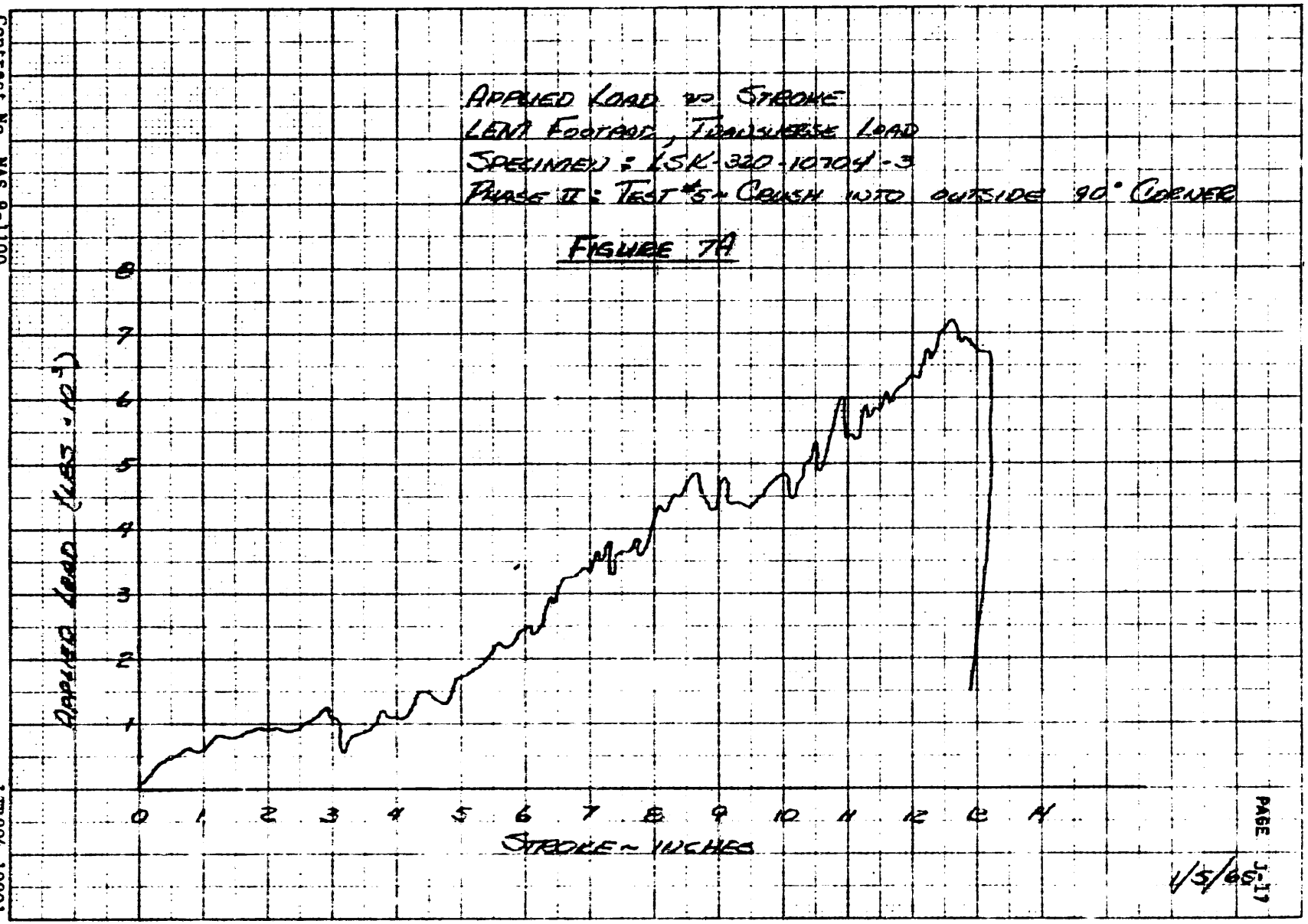


Crushed Load vs Stroke
LEM Footpad, Transverse Load
Specimen # L5K-500-10704-3
Phase II: Test #4 - Crush with inside 90° corner

Figure 68

Total Energy Absorbed by Footpad = 40800 in-#
Efficiency = 44.0 %

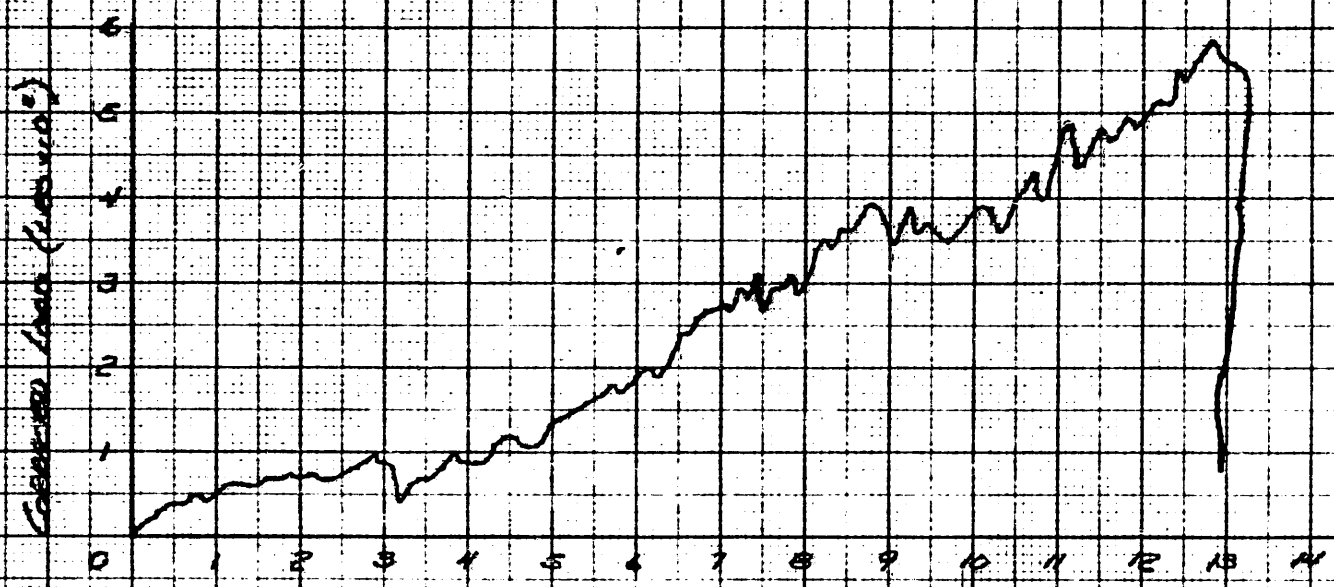


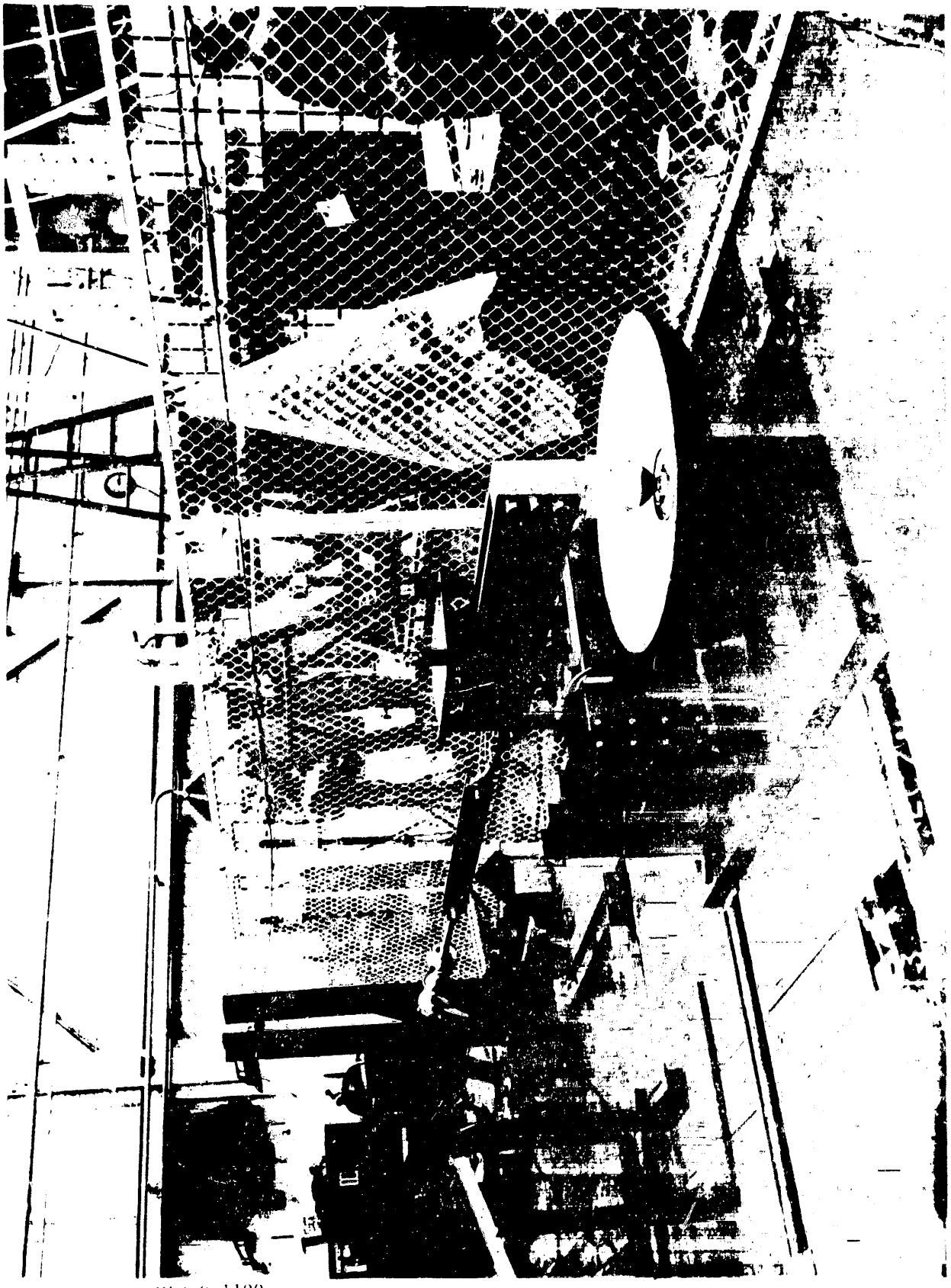

APPLIED LOAD VS STROKE
LEM FOOTPAD, TRANSVERSE LOAD
SPECIMEN: LSK-320-10704-3
PHASE II: TEST #5 - CRUSH INTO OUTSIDE 90° CORNER
FIGURE 7A
APPLIED LOAD (KLBS · 10³)
1
2
3
4
5
6
7
8
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
STROKE ~ INCHES
1/5/65

CORRECTED LOAD TO STROKE
LEM FOOTPAD TRANSVERSE LOAD
SPECIMEN: LSK-320-10704-3
PHASE II - TEST #5 - CRUSH INTO OUTSIDE 90° CORNER

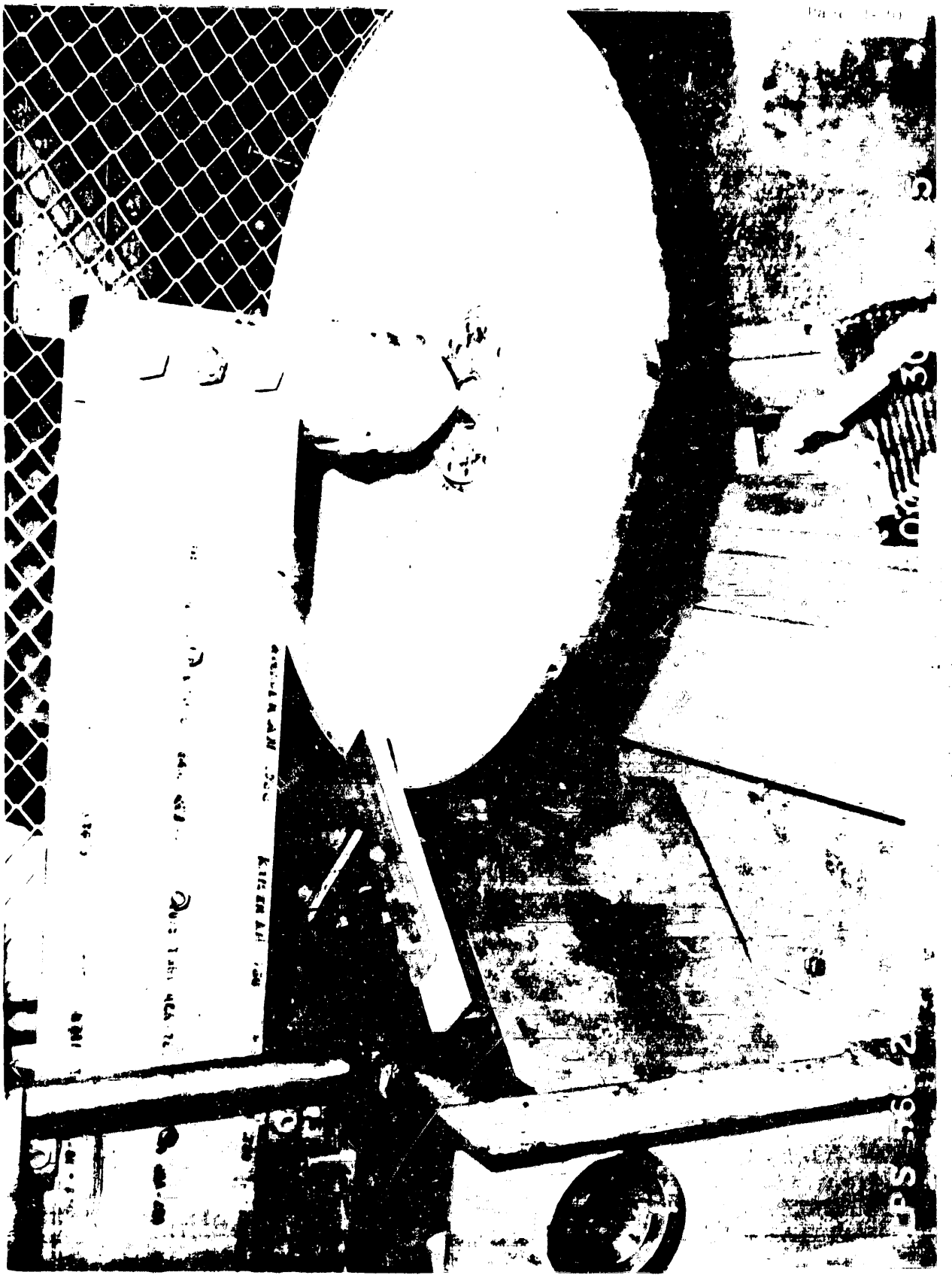
FIGURE 7B

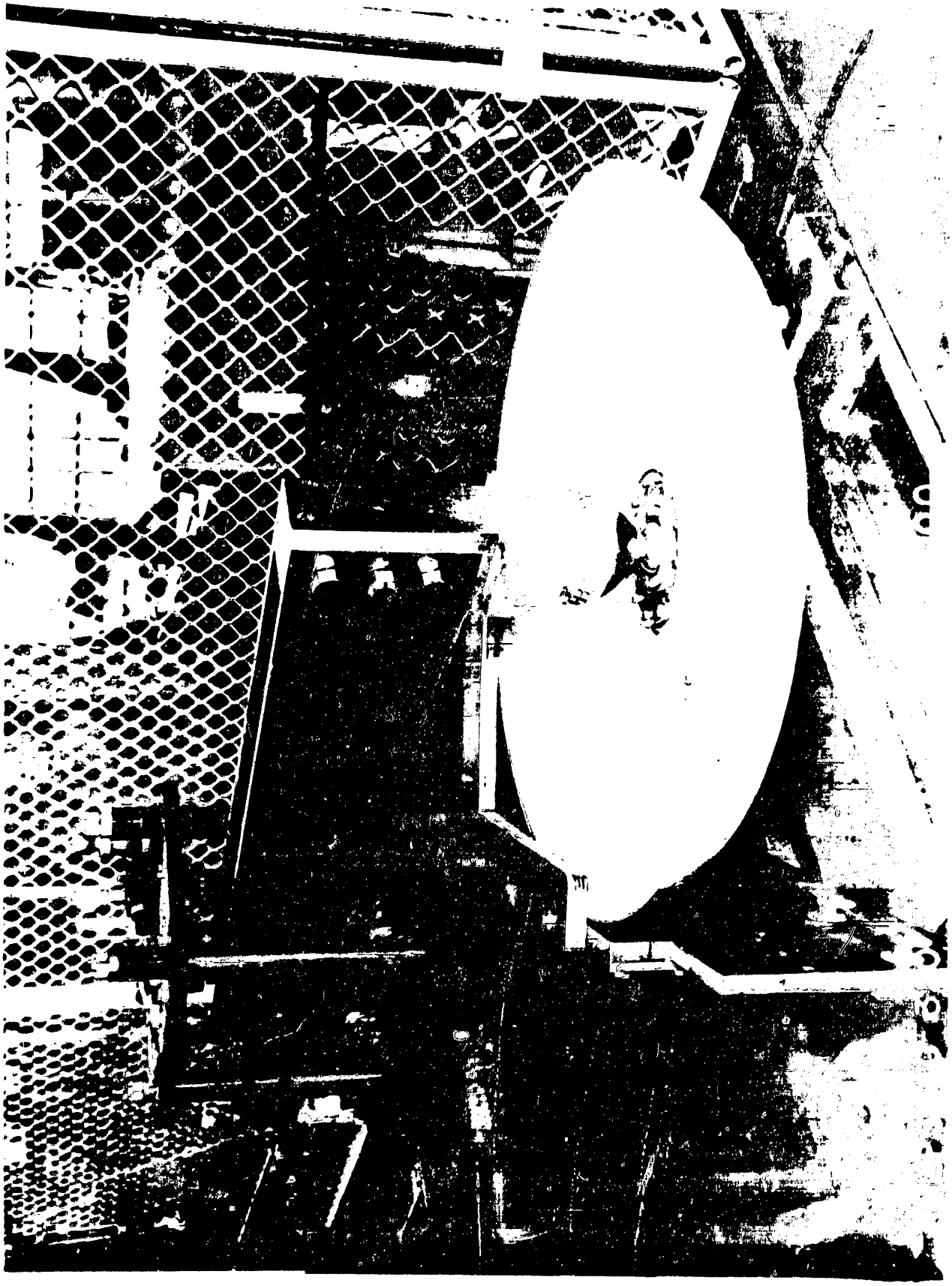
TOTAL ENERGY ABSORBED BY FOOTPAD = 35,600 IN-LBS
EFFICIENCY = 48.8 %

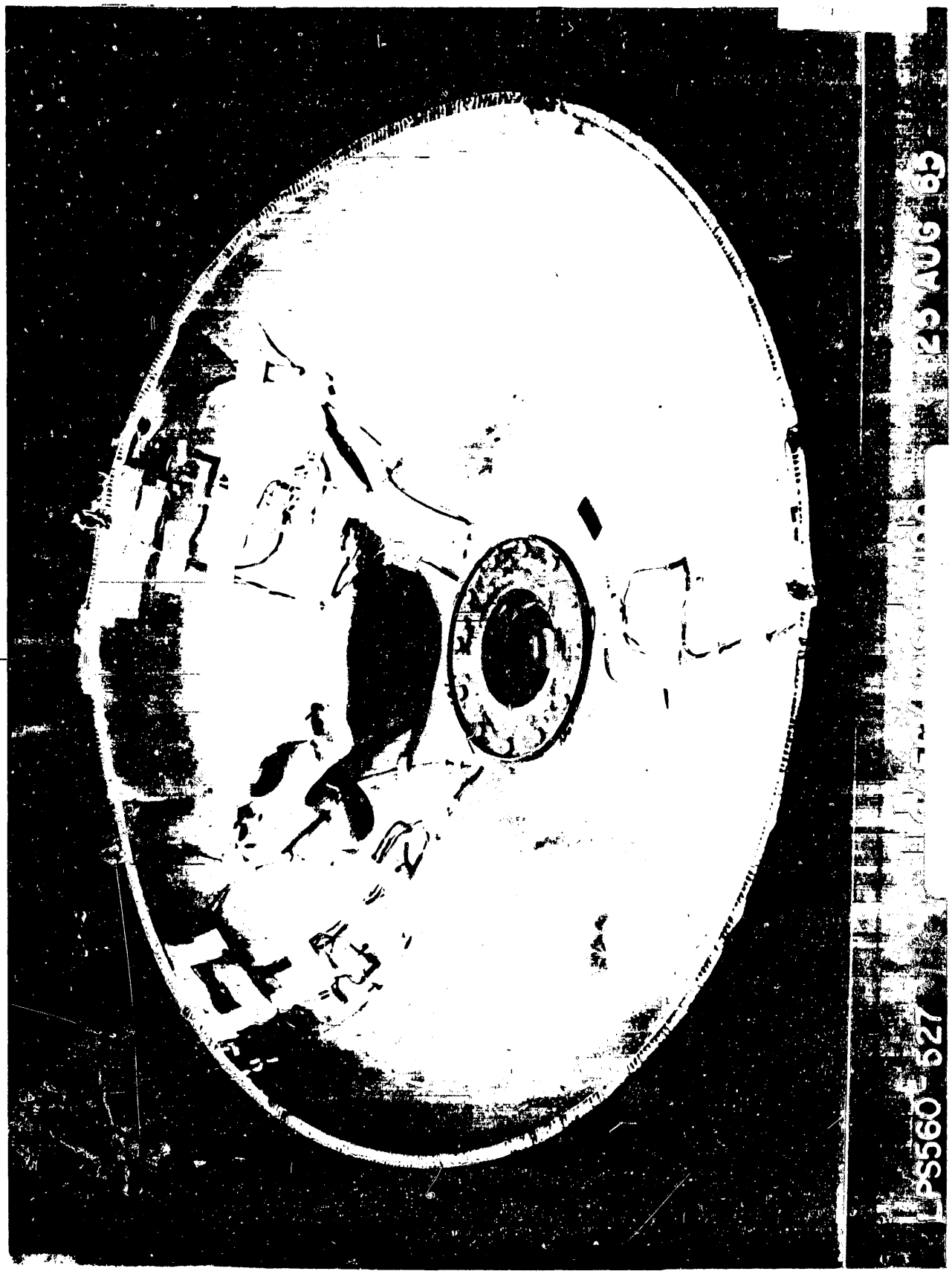


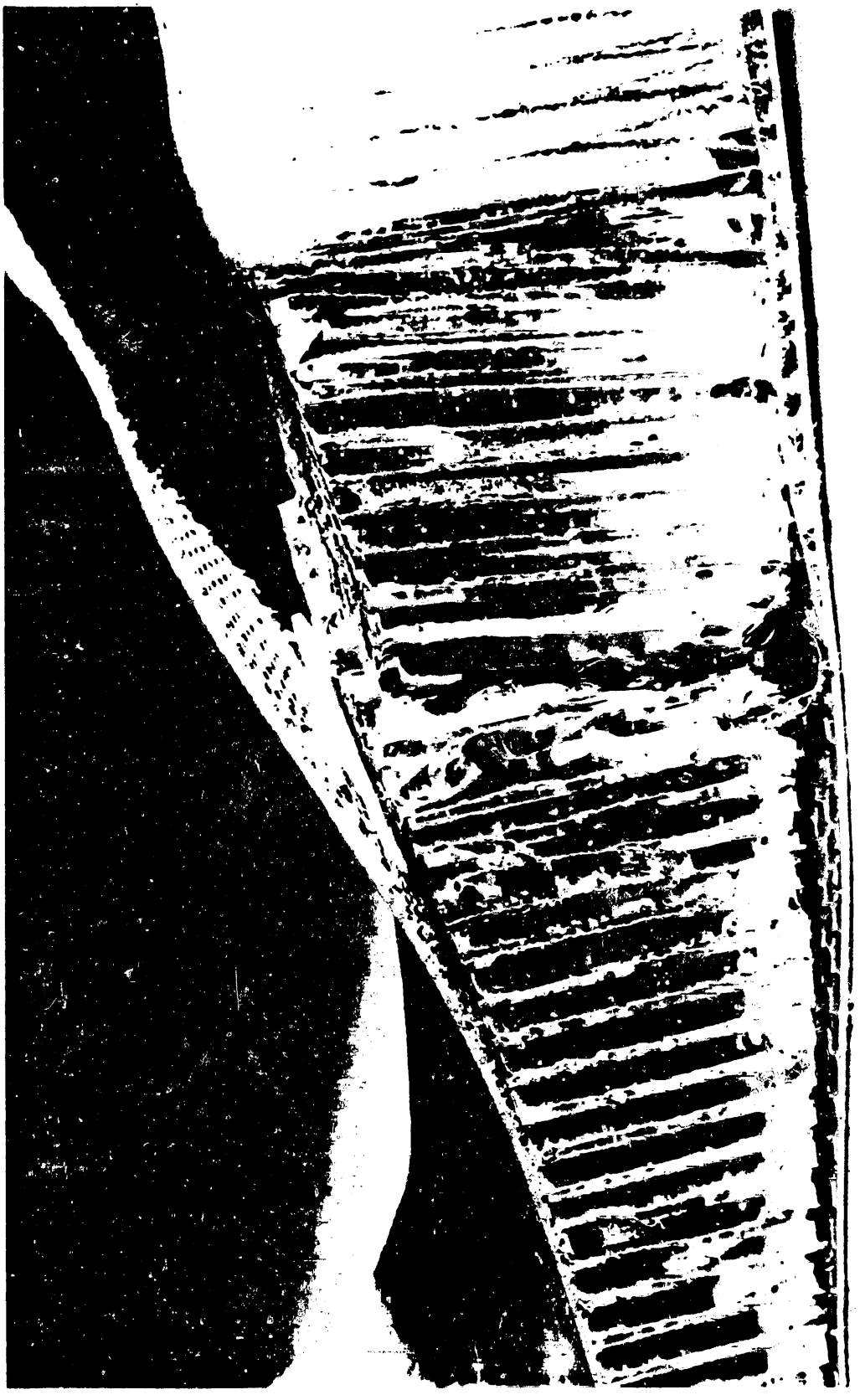


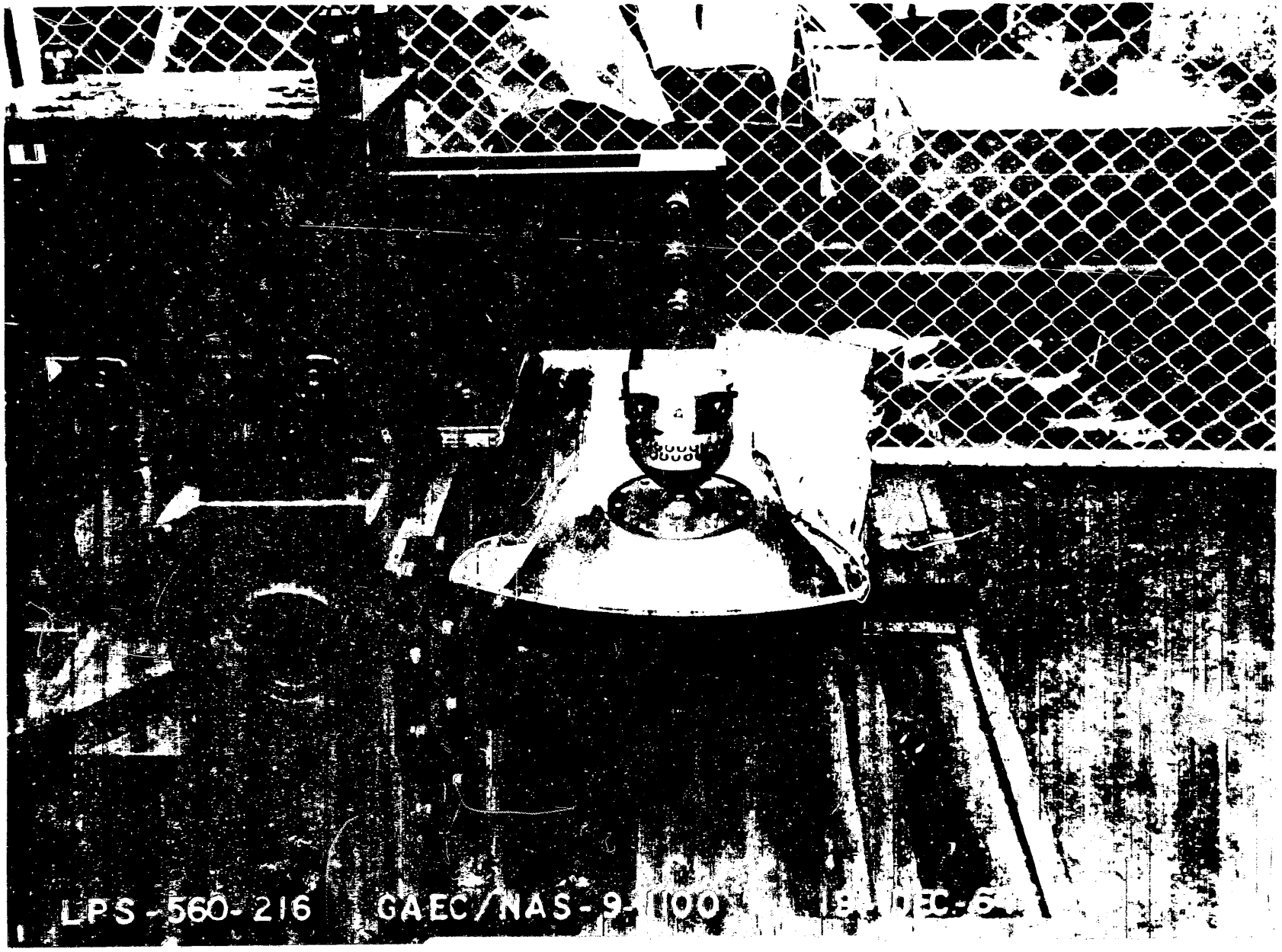
Contract No. NAS 9-1100
Project No. 811

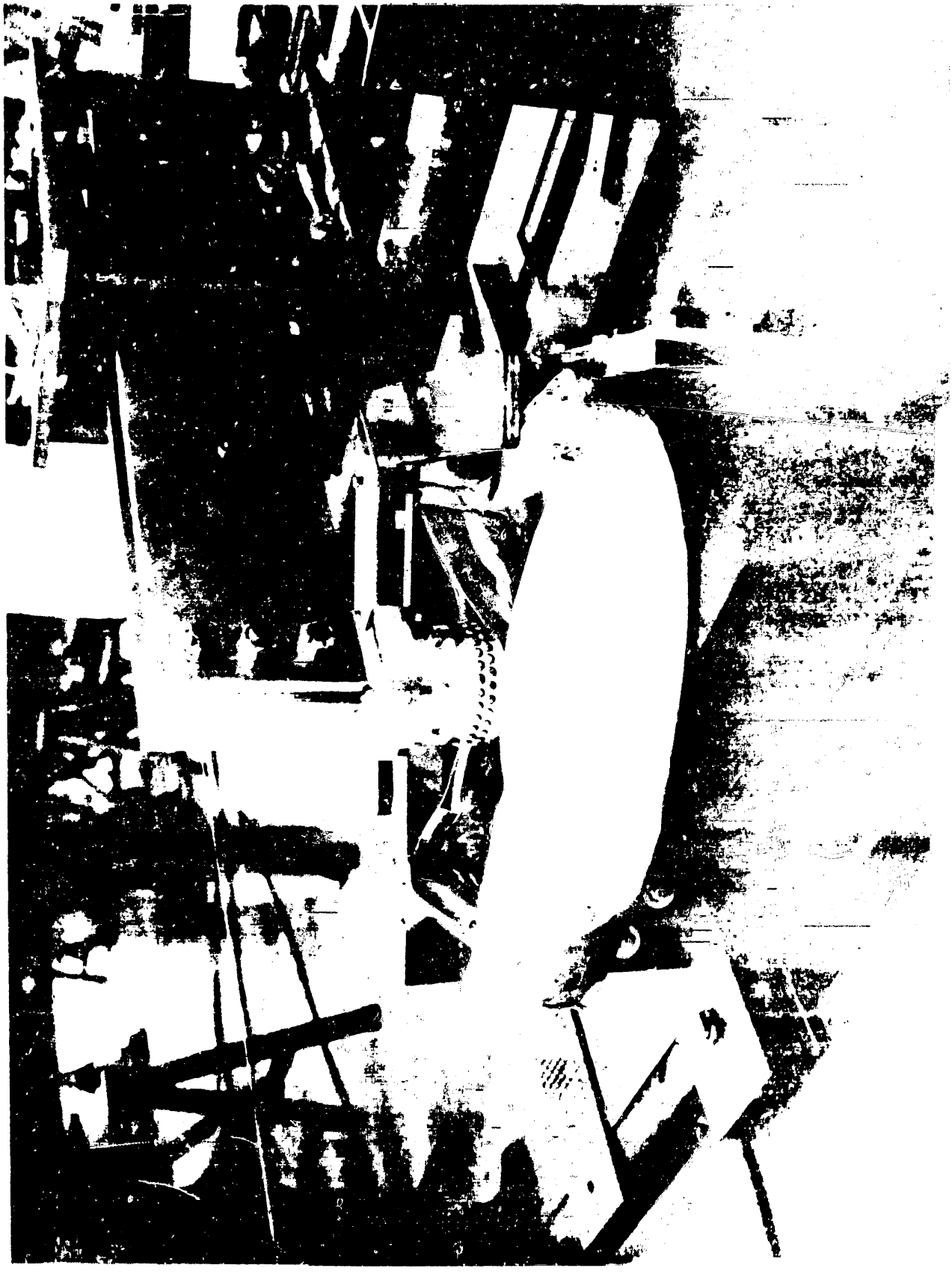





LPS560-527
AUG 65




LPS-560-216 GAEC/NAS-9-1100



PS560-2

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_1 CROSSOVER FITTING TEST

Jack Feldman
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R. L. Makemson
CHECKED BY:
R. L. Makemson

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_1 - CROSSOVER FITTING TEST

INTRODUCTION

This section of the report contains the results of tests conducted upon the Deployment Truss Crossover Fitting (LTM320-M-50903). The test demonstrates the structural capability of the Crossover Fitting under design conditions set forth in LTP904-10001C, Section K. In the final test, the Crossover Fitting failed in buckling at 130% of its design ultimate load.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_1- CROSSOVER FITTING TEST

1.0 PURPOSE OF THE TEST

The purpose of the tests reported in this section was to verify the structural integrity of the deployment truss crossover fitting. A test to failure under the critical loading condition established the actual safety margin.

2.0 DESCRIPTION OF THE TEST ARTICLE

The test article was a crossover fitting in accordance with LTM320-M-50903 except that the crossover fitting tested was provided with dummy end fittings (LSK915-617 and LSK915-618) which duplicated the actual tube to fitting attachment. The design of the deployment truss is such that incorporation of the crossover fitting in one of the truss tranverse members (LTM320-50902) permits the other member (LTM320-50901) to penetrate it in plane with no interconnection of the two members; this preserves the truss as an essentially determinant structure.

3.0 TEST CONDITIONS

3.1 Design limit load for the fitting is 8600 lbs compression applied at specified eccentricities about the longitudinal centroidal axis of the fitting. Eccentricities in two mutually perpendicular planes were specified as noted on Figure 2. For descriptive purposes in this report, these loading axes have been designated axis A and axis B.

3.2 The factor of safety used in the LEM landing gear design is:

limit load x 1.35 = ultimate load = 11,600 lbs.

3.3 Ultimate transverse inertia loads on the fitting were simulated by the application of a 36 lb. concentrated load at the center of the fitting. This load was applied in a direction such that the induced bending was additive to that due to the eccentricity.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION K_1 - CROSSOVER FITTING TEST

3.0 TEST CONDITIONS - continued

3.4 All tests were conducted at ambient temperatures except the final ultimate load and overstress test which was conducted at 285°F. A scheduled test at 200°F was omitted after it was determined that its results would be superfluous.

4.0 TEST SET-UP AND PROCEDURE

4.1 The test article was set up in a universal type test machine enclosed in a temperature chamber designed for use in conjunction with this machine. The test arrangement is shown in Figure 3 (page K1-28) and in Photograph No. LPS-560-521 (page K1-29). Strain measurements were plotted directly by B and F strain recorders.

4.2 The required test procedure, as described in the test plan (LTP904-10001 Section K) was as follows:

(a) At room temperatue the ultimate transverse inertia load of 36 lbs. was applied.

(b) The limit load of 8600 lbs. compression was applied to axis A in 10% increments reading strains at each increment. See Figure 2 for axis location.

(c) Repeat of b with load applied to axis B.

After this test a manufacturing descrepancy of the fitting was discovered. After repair of the fitting as described in paragraph 5.2.2 an additional limit load test was run on axis A to determine the effect of the repair. All remaining tests were conducted on the repaired fitting.

(d) From results of b and c axis A was selected as the critical axis for use in the remainder of the tests.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION K_1 - CROSSOVER FITTING TEST

4.0 TEST SET-UP AND PROCEDURE - continued

4.2 (e) At room temperature the ultimate load of 11,600 lbs. compression was applied in the 10% increments reading strains at each increment.

(f) Repeat of e at 200°F. This test was omitted as noted in paragraph 3.4 above.

(g) At +285°F the ultimate load of 11,600 lbs. was applied in 10% increments.

(h) At +285°F loading was increased until failure of the fitting occurred.

5.0 TEST RESULTS

5.1 Presentation of Results

The results are presented as follows:

a. Log of limit load test on Axis A (page K_1-8).

b. Strain gage results and calculated stresses for Axis A (pages K_1-9) and K_1-10).

c. Log of limit load test on Axis B (page K_1-11).

d. Strain gage results and calculated stresses for Axis B (pages K_1-12 through K_1-13).

e. Comparison of results of Axis A and Axis B limit load tests (pages K_1-14 through K_1-17).

f. Results of limit load retest on Axis A after rework of fitting (page K_1-18).

g. Log of ultimate load test on axis A (page K_1-19)

h. Strain gage results and calculated stresses for ultimate load test (pages K_1-20 and K_1-21).

i. Strain level plots for critical gages for ultimate load test on axis A (page K_1-22 and K_1-23).

j. Summary of critical results of ultimate load test on axis A (page K_1-24).

k. Log of failure test at +285°F (page K_1-25).

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION K_1 - CROSSOVER FITTING TEST

5.0 TEST RESULTS - continued

5.2 Discussion of Results

5.2.1 Strain readings recorded during the limit load tests indicating significant strain levels (in the order 2000μ in/in or greater) are plotted on pages K_1-14 through K_1-17. Comparison of these strains shows that with the exception of gage #2 axis A was always more critical than axis B.

5.2.2 High strain levels were indicated at gage locations 2 and 4 and an inspection of the fitting showed that the required wall thickness of .045/.040 inches at the locations of gages 2 and 4 had been undercut to .022 inches; this is shown in Materials Review Report No. 66626. A tool mark of .030 inch radius within the undercut and extending over the entire circumference was also discovered. As corrective action the undercut was blended without decreasing the wall thickness of the fitting any further. A collar (MRR 66626-1) machined from 7079-T651/52 aluminum alloy was inserted into the fitting over the blended surface. This installation is shown in pages 2 and 3 of MRR No. 66626 and can also be seen on Photograph LPS 320-431, page K_1-31.

5.2.3 After rework of the fitting the limit load test was repeated on axis A to determine the effect of the corrective action. For this test gages 3 and 4 were selected as being representative of the strains in the area of the reinforcing collar and are plotted on page K_1-18) together with those from the original (axis A) test. It will be noted that the strain levels on gage #4 have been significantly reduced. Strains indicated by all other gages agreed with those obtained from the first limit load test on axis A. The rework of the fitting was thus considered adequate for testing purposes. Two additional gages identified as numbers 71 and 72 were added to the fitting for the ultimate load tests. These gages were read in place of gages 1 and 2 which had been destroyed during rework of the fitting. Gages 71, 72, 46, 48, 20, 23, 26, and 29 indicated the highest strains and have been plotted on pages K_1-22 and K_1-23. A summary of critical strain results is shown on page K_1-24.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TEST

SECTION K_1 - CROSSOVER FITTING TEST

5.0 TEST RESULTS - continued

5.2.4 The failing load test was run at a temperature of +285°F to simulate actual landing conditions. This test was designed to determine the margin of safety of the cross-over fitting. The specimen failed in plastic instability at an applied compression load of 15,140 lbs. This represents a margin of safety of 30% over the design ultimate load.

5.2.5 In cases where 45° strain rosettes were applied, the arithmetically greater principle stress has been calculated from the strains measured at limit or ultimate loads and is reported in the tables of strain gage results. The direction of the stress has also been noted as clockwise (C.W.) or counterclockwise (C.C.W.) from a referenced strain gage axis.

6.0 CONCLUSIONS

This series of tests shows the Deployment Truss Crossover Fitting to have a margin of safety of 30% over design ultimate load and to be structurally adequate for the specified design criteria. The experimentally measured strains (stresses) correlate those derived by analysis.

SECTION K_1^T : CROSSOVER FITTING TEST

LOG OF TEST

Test Conditions

Room temperature

Limit load on axis A (8600#)

DATE
8/11/65

RUN NO	% of Limit Load	Test Load (Lbs.)		Remarks
		Inertia	Compression	
1	0	0	0	
2	0	36	0	
3	10		860	
4	20		1720	
5	30		2580	
6	40		3440	
7	50		4300	
8	60		5160	
9	70		6020	
10	80		6880	
11	90		7740	
12	100	36	8600	Design Limit Load
13	0	0	0	

STRAIN GAGE RESULTS

Test Item LTM 3201-50903 Condition LIMIT LOAD-AXIS A Test Date 8/11/65

~~Ult.~~ LIM Test Press. 8600 ## Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	~~Ult.~~ LIM Strain μin/in	~~Ult.~~ LIM Stress PSI
Recorder No. 1			Recorder Identification				
1	1	SEE FIGURE 1	A1		10.4	-2975	-30,900
2	2					-3275	-34,100
3	3					-500	-5,200
4	4					-3025	-31,500
5	5					+1360	+14,125
6	6					+520	+5410
7	7					+530	+5520
8	8					+1380	+16,600
9	9	Rosette				+110	16° CW
10	10					-180	FROM GAGE 8
11	11					+1300	+15,600
12	12	Rosette				+105	14° CCW
13	13					-270	FROM GAGE 11
14	14					-530	-5350
15	15	Rosette				-185	2° CCW
16	16					-220	FROM GAGE 14
Recorder No. 2			Recorder Identification				
1	17		A1		10.4	-600	-6300
2	18	Rosette				-200	9.4° CW
3	19					+180	FROM GAGE 17
4	20					-3100	-38,700
5	21	Rosette				+190	18° CW
6	22					+725	FROM GAGE 20
7	23					-3050	-37,900
8	24	Rosette				+335	19° CW
9	25					+780	FROM GAGE 23
10	26					+1900	+23,800
11	27	Rosette				-110	20° CW
12	28					-280	FROM GAGE 26
13	29					+2010	+24,200
14	30	Rosette				-220	19° CW
15	31					-490	FROM GAGE 29
16	32					+330	+7400
Recorder No. 3			Recorder Identification				
1	33	Rosette	A1		10.4	-518	36½° CW
2	34					-60	FROM GAGE 32
3	35					+400	+8400
4	36	Rosette				-496	36° CW
5	37					-80	FROM GAGE 35
6	38					-1050	-10,900
7	39					+230	+2390
8	40					-1120	-11,650
9	41					-900	-9350
10	42					+64	+665
11	43					-910	+9450
12	44					+1270	+13,200
13	45					+1490	+15,500
14	46					+2700	+28,100
15	47					+1790	+18,600
16	48					+2625	+27,300

Model LEM
Cont. No. NAS 9-1100

Report LTR 904-10001
Date 6 May 1966

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
ENGINEERING DEPARTMENT

ENG 698 11-63

STRAIN GAGE RESULTS

Test Item LTM 320M-50023 Condition LIMIT LOAD-AXIS A Test Date 3/11/65

~~Ult.~~ LIM. Test Press. 9600 # Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	~~Ult.~~ LIM. Strain μin/in	~~Ult.~~ LIM. Stress PSI
Recorder No. 4			Recorder Identification				
1	49	SEE FIGURE 1	A1		10.4	+150	+1560
2	50					+1280	+13,310
3	51					−840	−8740
4	52					−1700	−17690
5	53					−520	−5400
6							
7							
8							
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16							
Recorder No.			Recorder Identification				
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GRUMMAN AIRCRAFT ENGINEERING CORPORATION
ENGINEERING DEPARTMENT

ENG 898 11-63

SECTION K : CROSSOVER FITTING TEST

LOG OF TEST

Test Conditions
Room temperature
Limit load test on axis B (8600#)

Date
8/11/65

RUN No.	% of LIMIT Load	Test Load (Lbs.) Inertia	Test Load (Lbs.) Compression	Remarks
1	0	0	0	
2	0	36	0	
3	10	↓	860	
4	20		1720	
5	30		2580	
6	40		3440	
7	50		4300	
8	60		5160	
9	70		6020	
10	80		6880	
11	90		7740	
12	100	36	8600	Design Limit Load
13	0	0	0	

STRAIN GAGE RESULTS

Test Item LTM 320M-50903 Condition LIMIT LOAD-AXIS B Test Date 8/11/65

~~ULT~~ LIM Test Press. 3600 # Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	~~ULT~~ LIM Strain μin/in	~~ULT~~ LIM Stress PSI
Recorder No. 1			Recorder Identification				
1	1	SEE FIGURE 1	A1		10.4	-1525	-15,880
2	2					-4900	-51,000
3	3					-590	-6,130
4	4					-2200	-22,900
5	5					+680	+7,070
6	6					+600	+6,240
7	7					-450	+4,675
8	8					+1610	+18,520
9	9	Rosette				-190	13° CW
10	10					-200	FROM GAGE 8
11	11					+2325	+24,600
12	12	Rosette				-100	15° CCW
13	13					-495	FROM GAGE 11
14	14					-940	-10,650
15	15	Rosette				-30	14° CCW
16	16		✓		✓	-250	FROM GAGE 14
Recorder No. 2			Recorder Identification				
1	17		A1		10.4	-316	-3700
2	18	Rosette				-30	17½° CW
3	19					-90	FROM GAGE 17
4	20					-2175	-24,700
5	21	Rosette				-430	22½° CCW
6	22					-610	FROM GAGE 20
7	23					-1860	-20,600
8	24	Rosette				+400	22½° CW
9	25					+470	FROM GAGE 23
10	26					+1160	+15,500
11	27	Rosette				-300	24° CW
12	28					-30	FROM GAGE 26
13	29					+1100	-7,300
14	30	Rosette				-310	21° CW
15	31					-400	FROM GAGE 29
16	32		✓		✓	-40	-4020
Recorder No. 3			Recorder Identification				
1	33	Rosette	A1		10.4	-520	42° CCW
2	34					+52	FROM GAGE 32
3	35					+240	+2600
4	36	Rosette				-476	41° CW
5	37					54	FROM GAGE 35
6	38					-650	-6850
7	39					0	0
8	40					-1120	-11,650
9	41					-120	-1,650
10	42					-270	-2,700
11	43					-610	-6,350
12	44					+904	+9,420
13	45					+[illegible]	+2,820
14	46					+2050	+21,300
15	47					+1140	+11,850
16	48		✓	✓	✓	+1600	+16,650

Model LTM
Cont. No. NAS 9-1100

Report LTR 904-10001
Date 6 May 1966

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
ENGINEERING DEPARTMENT

ENG 658 1143

STRAIN GAGE RESULTS

Test Item LTM 320M-50903 Condition LIMIT LOAD-AXIS B Test Date 8/11/65

~~UTS~~ LIM. Test Press. 3600# Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	~~UTS~~ LIM. Strain μin/in	~~UTS~~ LIM. Stress PSI
Recorder No. 1			Recorder Identification				
1	49	SEE FIGURE 1	A1		10.4	+100	+1040
2	50					+2400	+25000
3	51					-1500	-15,200
4	52					-1690	-17,450
5	53					+40	+4160
6							
7							
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16							
Recorder No.			Recorder Identification				
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Recorder No.			Recorder Identification				
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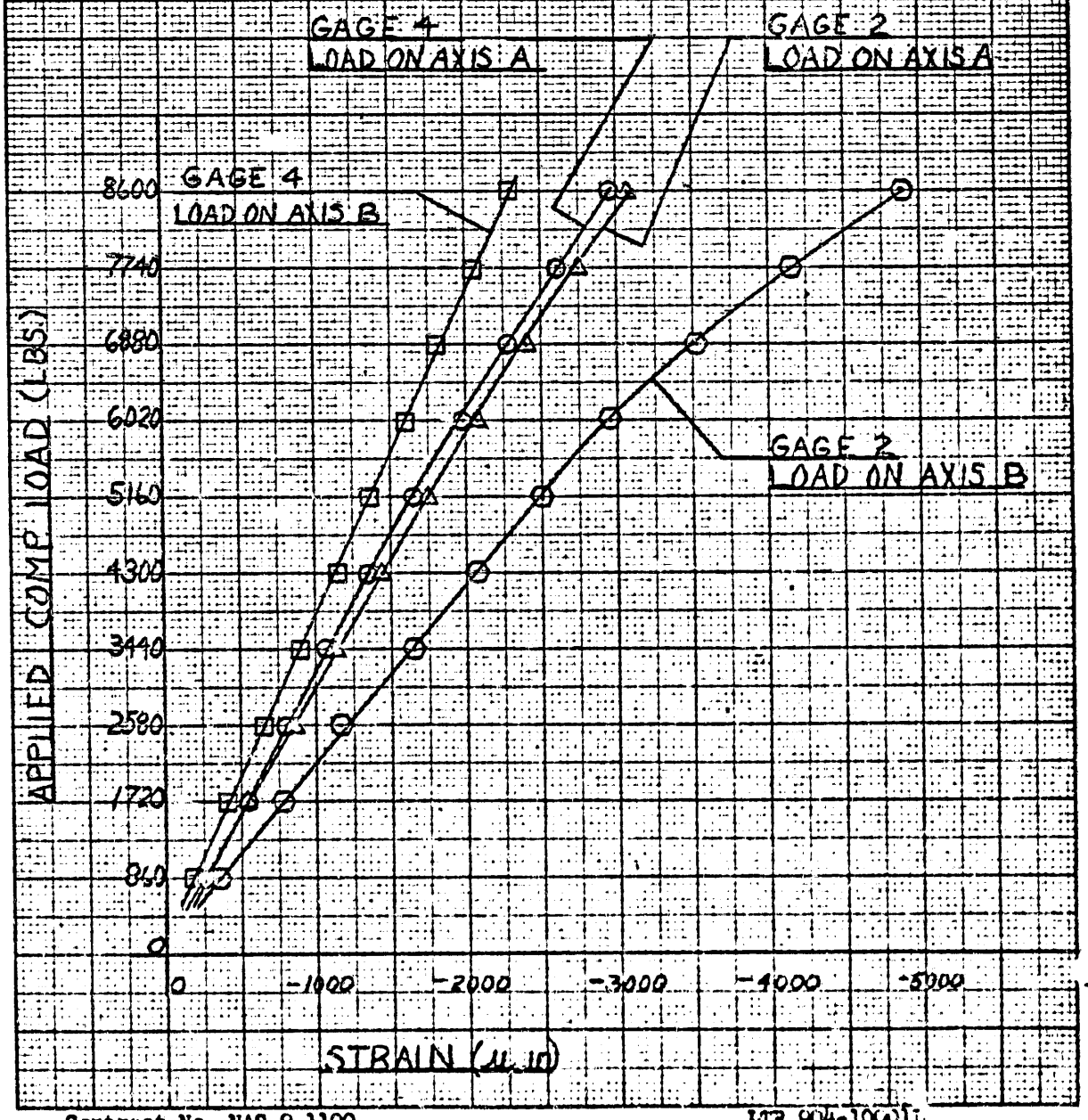
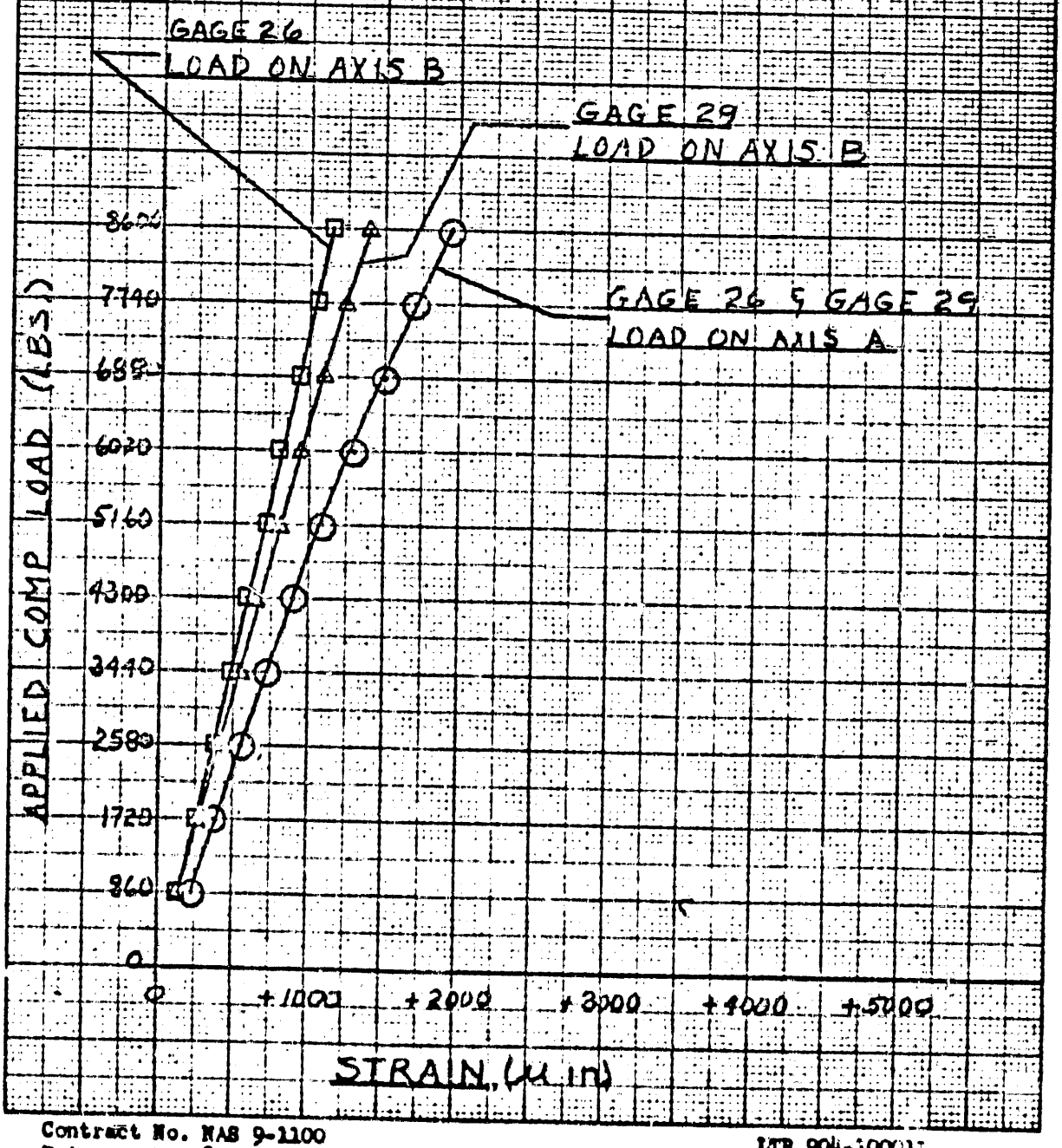
GRUMMAN AIRCRAFT ENGINEERING CORPORATION
ENGINEERING DEPARTMENT

SECTION E: CROSSOVER FITTING TEST
APPLIED COMP LOAD vs STRAIN
FOR CRITICAL POINTS
LIMIT LOAD TESTS - AXIS A & B

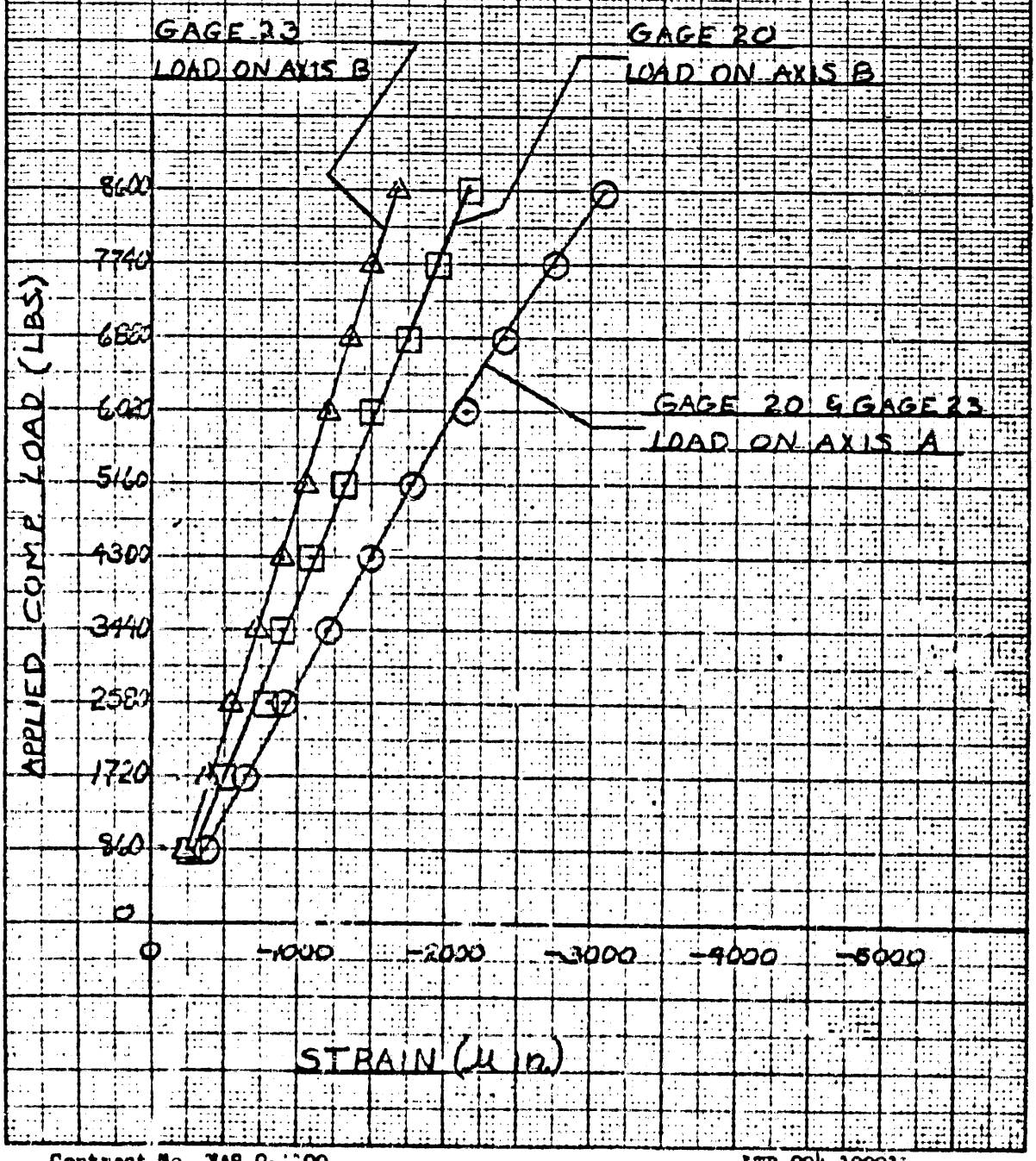


SECTION E CROSSOVER FITTING TEST

APPLIED COMP. LOAD vs. STRAIN
FOR CRITICAL POINTS
LIMIT LOAD TESTS - AXIS A & AXIS B

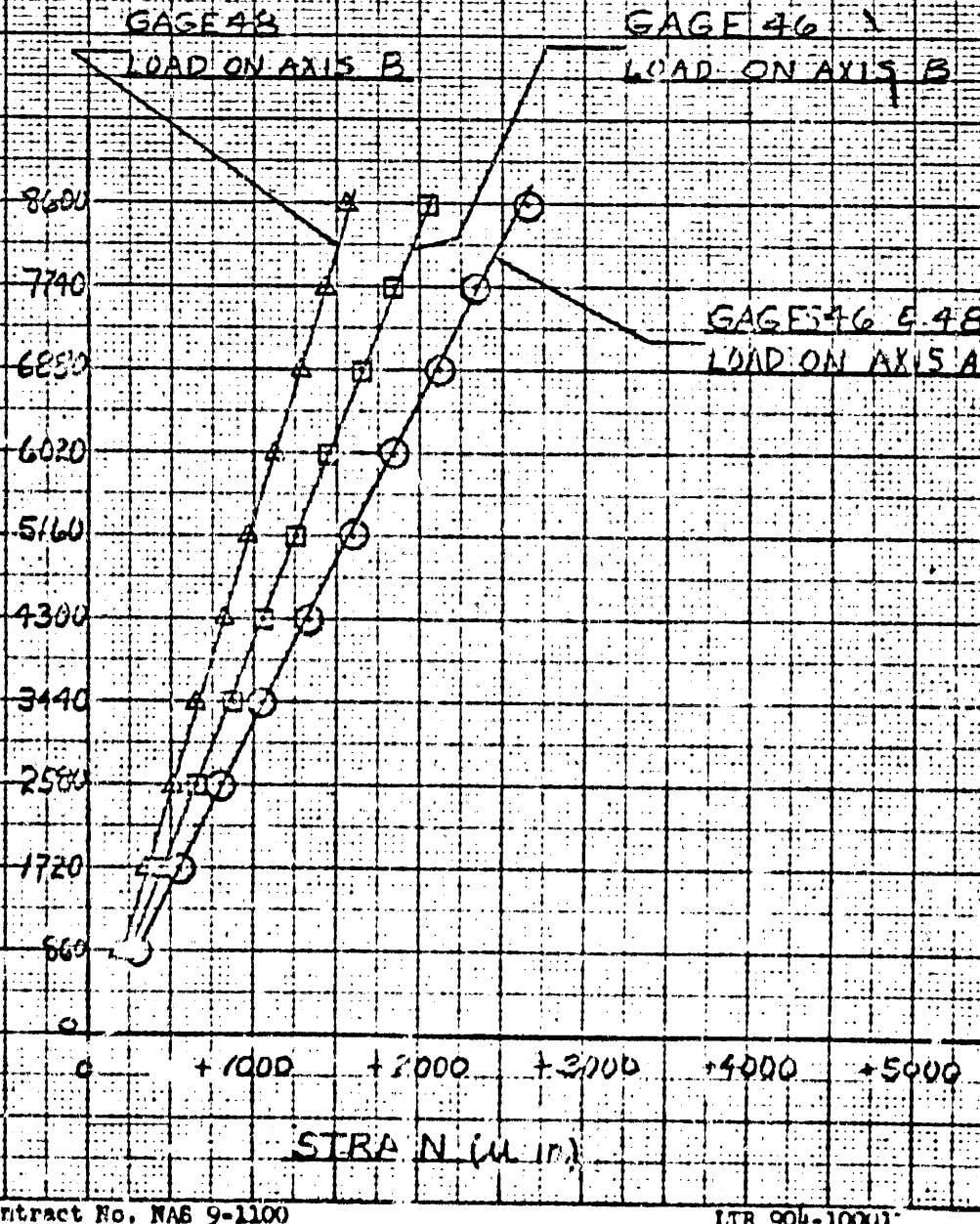


SECTION 5 : CROSSOVER FITTING TEST
APPLIED COMP LOAD VS. STRAIN
FOR CRITICAL POINTS
LIMIT LOAD TESTS - AXIS A & AXIS B



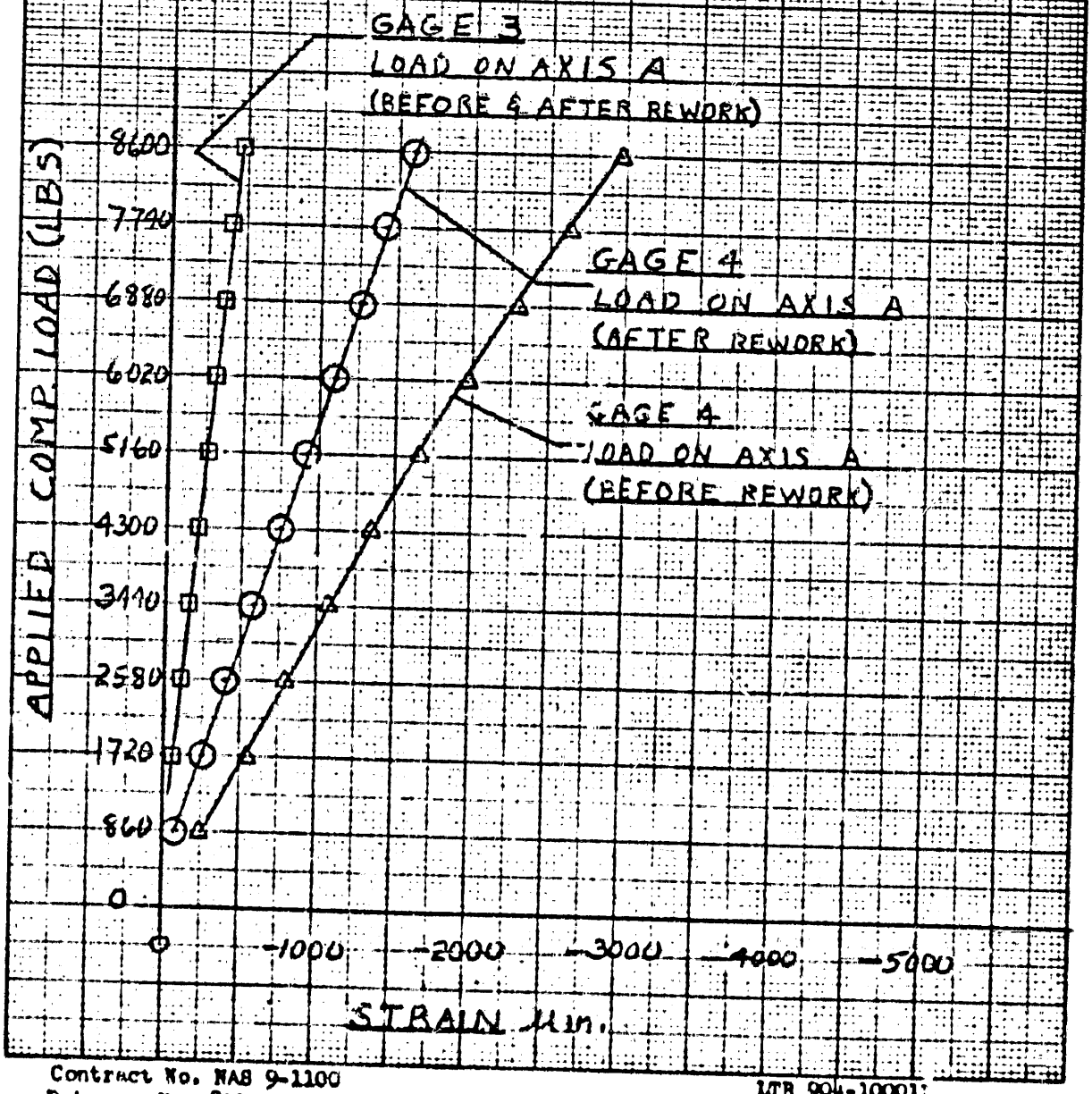
SECTION K CROSSOVER FITTING TEST

APPLIED COMP. LOAD vs. STRAIN
FOR CRITICAL POINTS
LIMIT LOAD TESTS - AXIS A & AXIS B



SECTION K CROSSOVER FITTING TEST

APPLIED LOAD vs. STRAIN
FOR GAGES 3&4 ON REPAIRED SPEC.
LIMIT LOAD TEST - AXIS A



SECTION K_1 : CROSSOVER FITTING TEST

LOG OF TEST

Test Conditions

Room temperature

Ultimate load test on axis A (11,600#)

Date

9/21/65

RUN NO	% of Limit Load	Test Load (Lbs.)		Remarks
		Inertia	Compression	
1	0	0	0	
2	0	36	0	
3	10		1160	
4	20		2320	
5	30		3480	
6	40		4640	
7	50		5800	
8	60		6960	
9	70		8120	
10	80		9280	
11	90		10440	
12	100		11600	Design Ultimate Load
13	0	36	0	
14	0	0	0	

STRAIN GAGE RESULTS

Test Item LTM320M-50903 Condition ULT. LOAD-AXIS A Test Date 9/21/65
Ult. Test Press. 11,600# Axial Stress = E x Strain; Shear Stress = E x Strain/2.66
A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	Ult. Strain μin/in	Ult. Stress PSI
Recorder No. 1			Recorder Identification				
1	71	See Figure 1	A1		10.4	-5250	-54,500
2	72					-4650	-49,300
3	3					-600	-6250
4	4					-2190	-22,600
5	5					+1980	-20,600
6	6					-700	+7280
7	7					+725	+7550
8	8					+1875	-22,550
9	9	Rosette				-135	16° CW
10	10					-250	From Gage 9
11	11					-1810	-22,000
12	12	Rosette				+120	4° CCW
13	13					-350	From Gage 11
14	14					-760	-7,000
15	15	Rosette				-300	3½° CCW
16	16		✓		✓	+300	From Gage 14
Recorder No. 2			Recorder Identification				
1	17		A1		10.4	-960	-10,000
2	18	Rosette				-224	[illegible]
3	19					-300	Gage 17
4	20					-4250	-51,000
5	21	Rosette				+235	[illegible]
6	22					+1000	From Gage [illegible]
7	23					-4000	-51,000
8	24	Rosette				+[illegible]	[illegible]
9	25					+1130	From Gage 23
10	26					+2705	[illegible]
11	27	Rosette				-200	[illegible]
12	28					-[illegible]	From Gage [illegible]
13	29					+2750	+[illegible]
14	30	Rosette				-[illegible]	[illegible]
15	31					-[illegible]	From Gage 29
16	32		✓		✓	+420	+10,000
Recorder No. 3			Recorder Identification				
1	33	Rosette	A1		10.4	-735	36½° CW
2	34					-100	From Gage 32
3	35					+540	+11,300
4	36	Rosette				-705	36° CCW
5	37					-65	From Gage 35
6	38					-1440	[illegible]
7	39					-225	[illegible]
8	40					-1545	[illegible]
9	41					-1255	-3,050
10	42					+105	[illegible]
11	43					-1275	-13,250
12	44					+1800	+18,700
13	45					+2075	+21,600
14	46					+3725	+38,750
15	47					+2550	+26,500
16	48		✓		✓	+3660	+38,000

Model LEM
Cont. No. NAS 9-1100

Report LER 904-10001
Date 6 May 1966

ENGINEERING DEPARTMENT

STRAIN GAGE RESULTS

Test Item LTM 320M-50903 Condition ULT. LOAD- AXIS A Test Date 9/21/65
Ult. Test Press. 11,600# Axial Stress = E x Strain; Shear Stress = E x Strain/2.66
A1, A2: Axial Gage; S1, S2: Shear Gage

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	Ult. Strain μin/in	Ult. Stress PSI
Recorder No. 4			Recorder Identification				
1	48	See Figure 1	A1		10.4	+200	+2080
2	50					+1822	+18,920
3	51					-1120	-11,520
4	52					-2270	-24,600
5	53					-690	-7,170
6							
7							
8							
9							
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16							
Recorder No.			Recorder Identification				
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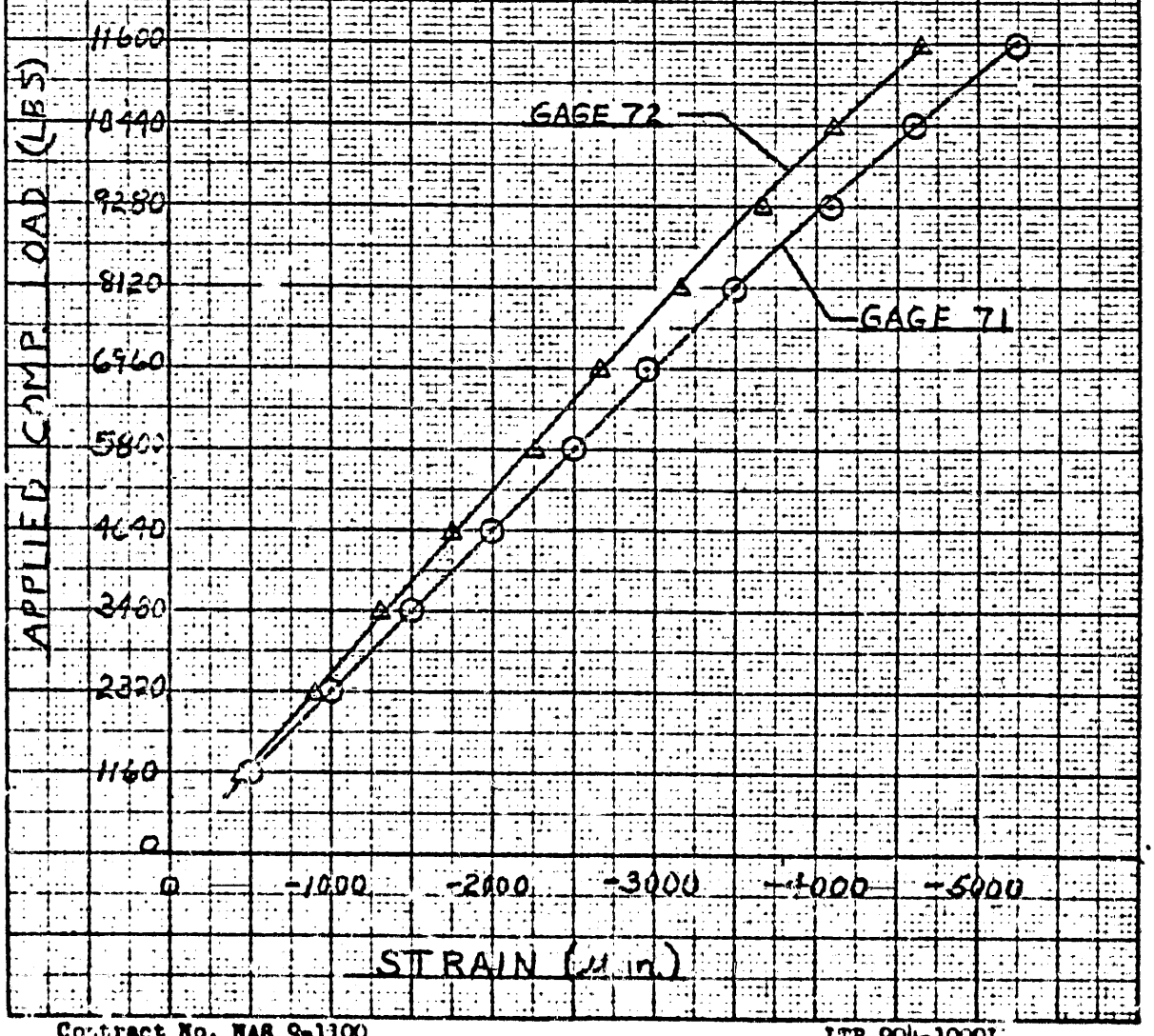
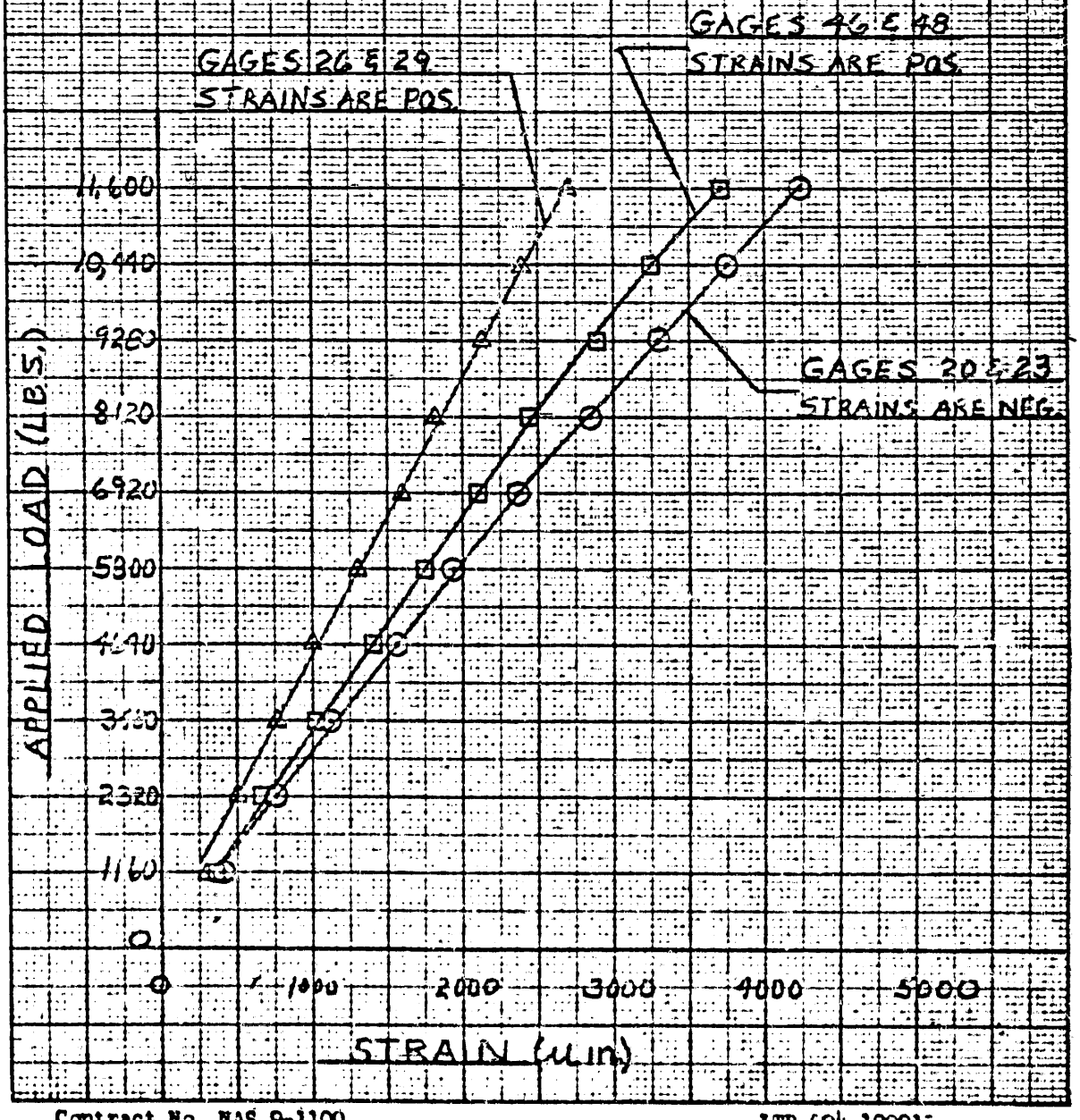
SECTION K CROSS OVER FITTING TEST

APPLIED COMP. LOAD VS. STRAIN
FOR CRITICAL POINTS
ULTIMATE LOAD TEST - AXIS A



SECTION E CROSSOVER FITTING TEST

APPLIED COMP LOAD vs. STRAIN
FOR CRITICAL POINTS
ULTIMATE LOAD TEST - AXIS A



SECTION K_1: CROSSOVER FITTING TEST

Summary of Critical Results of Ultimate Load Test

Gage No	Ultimate Strain	Ultimate Stress ($E = 10.4 \times 10^{6}$ PSI, $\mu = .333$)
71	− 5250 μ	− 54,500 PSI
72	− 4650 μ	− 48,300 P.S.I.
20	− 4250 μ	− 51,000 P.S.I
21	+ 235 μ	
22	+ 1900 μ	
23	− 4200 μ	− 51,000 P.S.I.
24	+ 450 μ	
25	+ 1130 μ	
26	+ 2725 μ	+ 34,400 P.S.I
27	− 200 μ	
28	− 400 μ	
29	+ 2750 μ	+ 33,000 P.S.I
30	− 200 μ	
31	− 700 μ	
46	+ 3725 μ	+ 38,750 P.S.I
48	+ 3600 μ	+ 38,000 P.S.I.

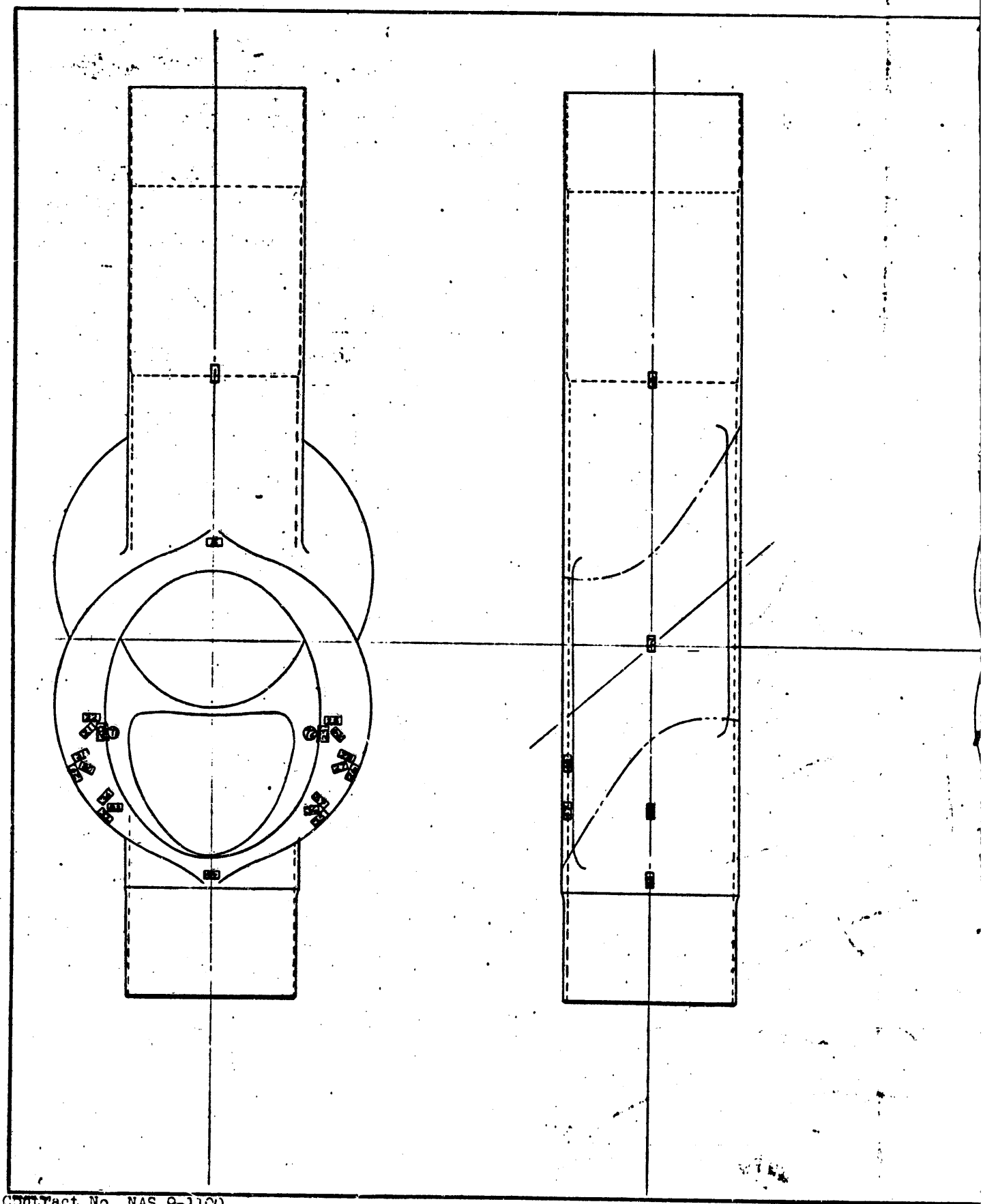
SECTION K_1 CROSSOVER FITTING TEST

LOG OF TEST

Test Conditions
+285° F
Failure test on axis A

Date
9/21/65

RUN NO.	% of Ultimate Load	Test Loads (Lbs)		Remarks
		Inertia	Compression	
1	0	0	0	
2	0	36	0	
3	20		2320	
4	40		4640	
5	60		6960	
6	70		8120	
7	80		9280	
8	90		10440	
9	100		11660	Design Ultimate Load
10	105		12240	
11	110		12820	
12	115		13400	
13	120		13980	
14	125		14560	
15	130	36	15,140	Failure occurs at 130% Ult. Load



Contract No. NAS 9-1100
Primary No. 811

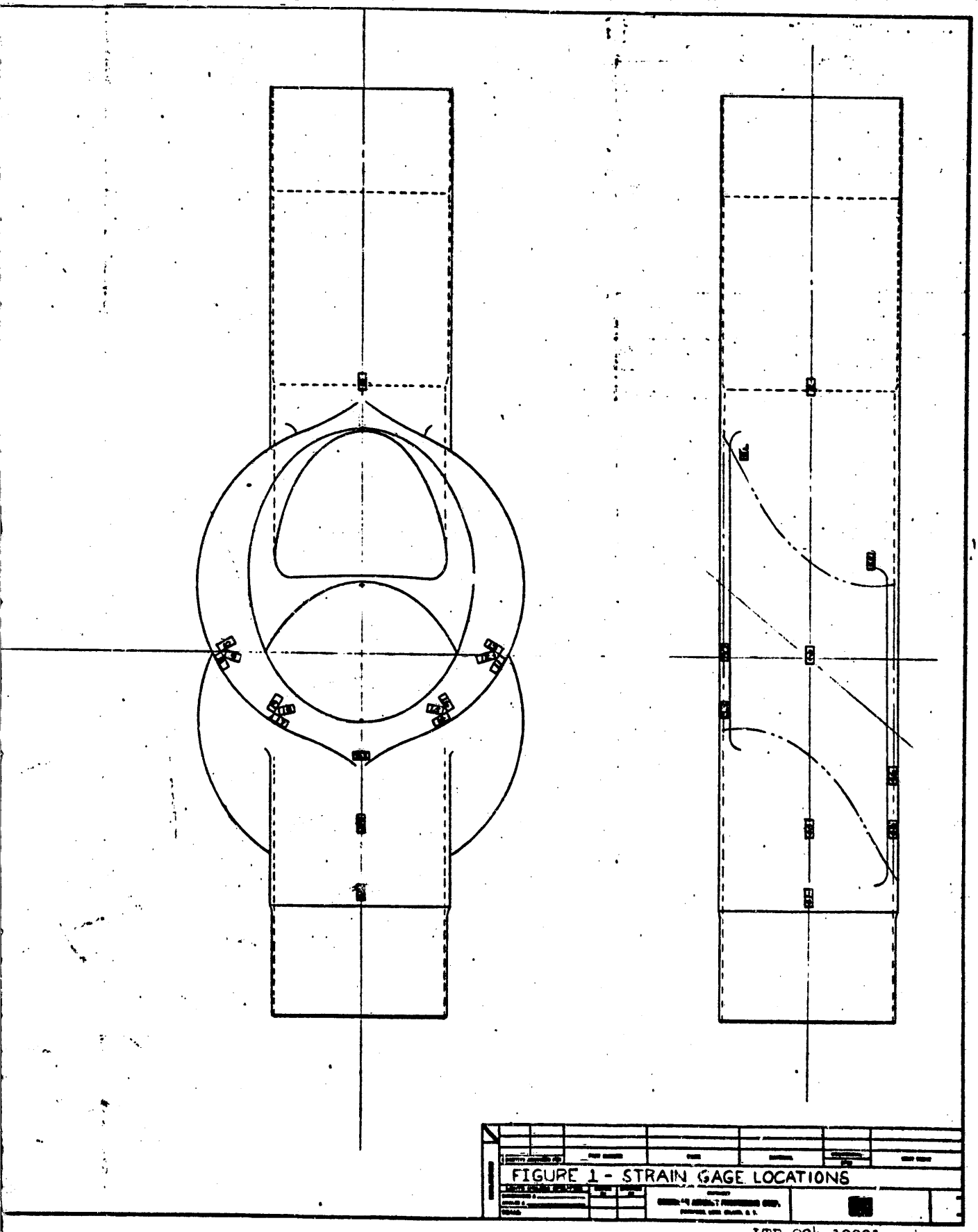
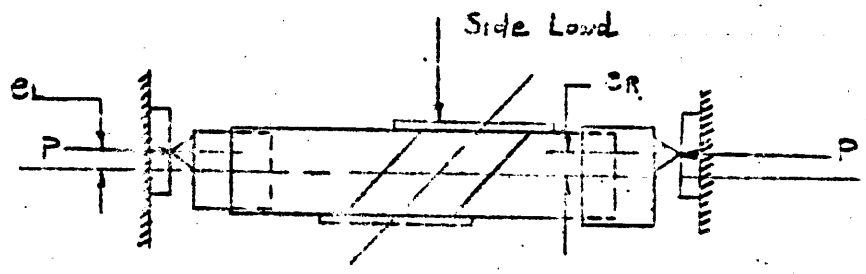


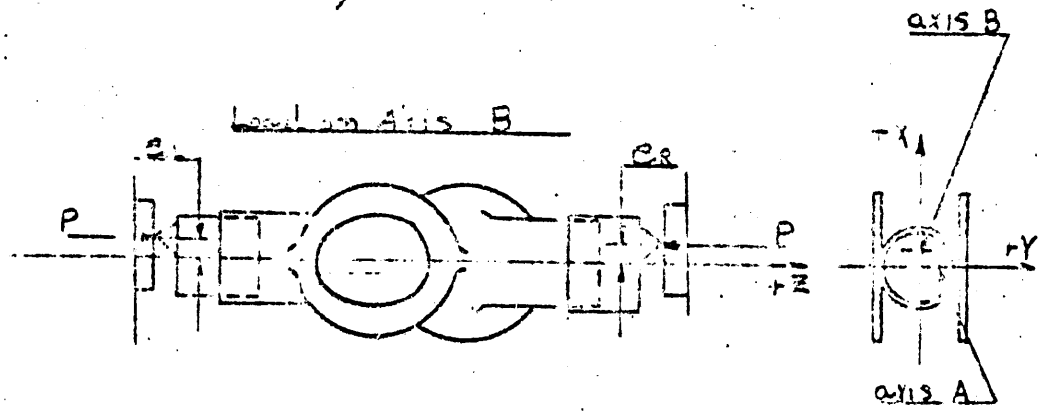
FIGURE 1 - STRAIN GAGE LOCATIONS

Figure 2
Location of Axes

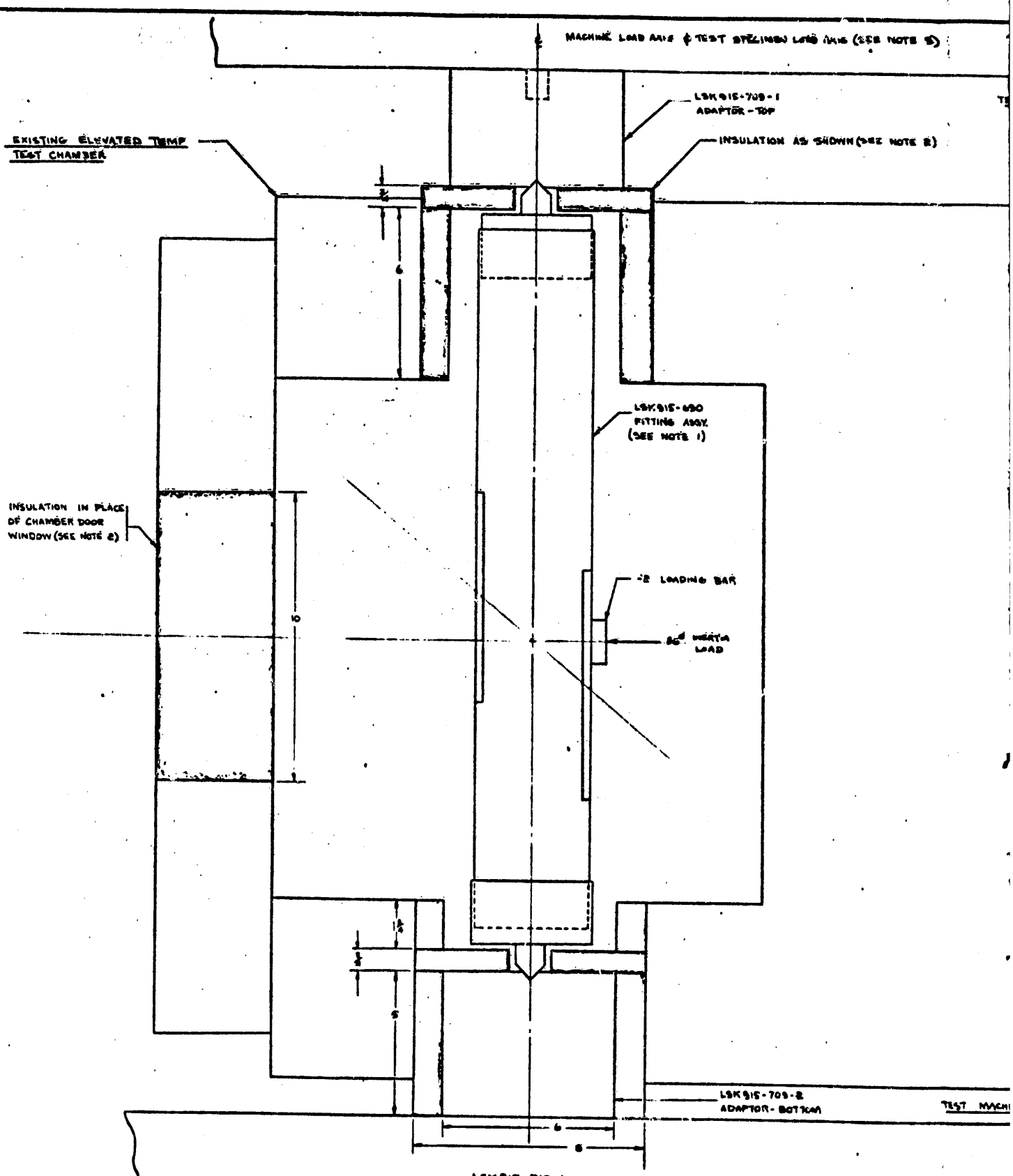
Load on Axis A



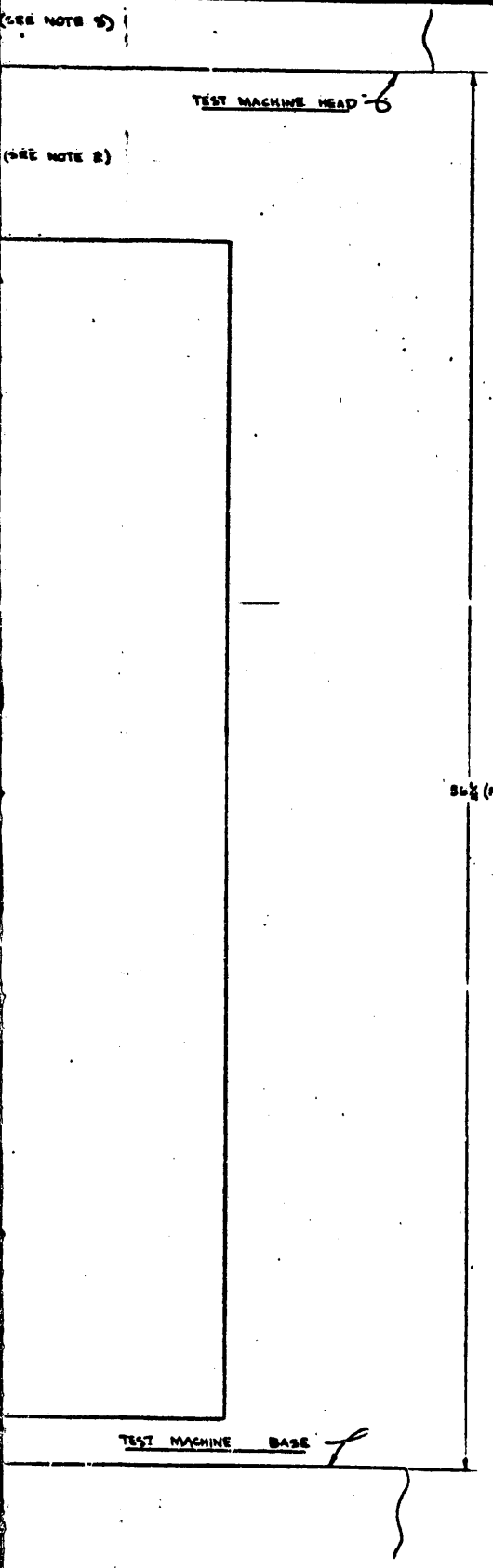
Load on Axis B



e_R = .450"
e_L = .340"



LSK 915-710-1
CHAMBER SET-UP
(VIEW LOOKING IN FROM LEFT SIDE)



NOTE:

1) LSK 915-690 FITTING TO BE ORIENTED AS SHOWN (FEMALE END PLUG DOWN) REGARDLESS OF TEST AXIS.
2) INSULATION TO BE SIMILAR TO THAT SHOWN ON DWG. BUT NEED NOT BE EXACTLY AS SHOWN. INSULATING MATERIAL MAY BE CAST IN PLACE OR CUT TO FIT.
3) SPECIMEN LOAD AXIS & GEOMETRIC CENTER ARE NOT COINCIDENTAL

QUANTITY REQUIRED FOR	PART NUMBER	NAME	MATERIAL	COMMERCIAL SPEC	HEAT TREAT
1	LSK 915-710-2	LOADING BAR	½ x 1½ x 8	7075-T6	NONE
AS REQ'D		INSULATION	SEE NOTE 2		
1	LSK 915-690	FITTING ASSY	SEE DWG.	—	—
1	LSK 915-709-2	ADAPTOR - BOTTOM	SEE DWG.	—	—
1	LSK 915-709-1	ADAPTOR - TOP	SEE DWG	—	—
	LSK 915-710-1	SET-UP	—	—	—
-1					

CROSSOVER FITTING TEST - CHAMBER SET-UP (FIGURE 3)

LIMITS UNLESS SPECIFIED
DIMENSIONS ±
ANGLES ±
SCALE: HALF

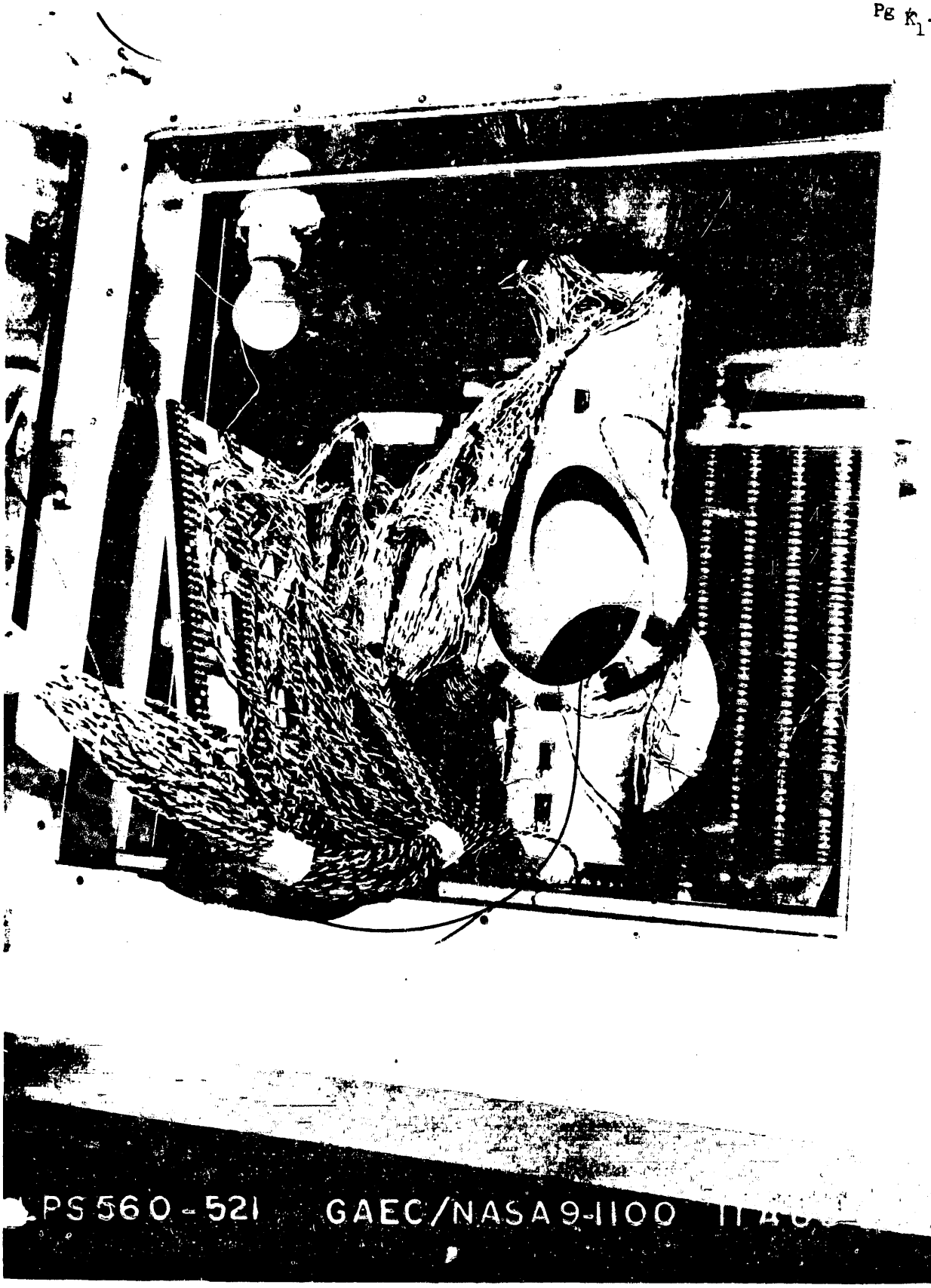
DRAWN BY: DOWNEY

DOCUMENT
GRUMMAN AIRCRAFT ENGINEERING CORP.
BETHPAGE, LONG ISLAND, N.Y.

LSK 915 [redacted] -710
(FIGURE 3)

LTR 904-10001

LSK 915 [redacted] -710



Test Chamber Set-Up

Results of Buckled F ing

Results of Buckled Fitting

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

M. Bonner

PREPARED BY: M. BONNER

R. L. Makemson

CHECKED BY: R. L. MAKEMSON

FORM 0328 REV 1 8-64

Contract No. NAS 9-1100
Primary No. 811

REPORT LTR924-10001
DATE 26 May 1967

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
CODE 26512

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

INTRODUCTION

This report contains the results of tests conducted to demonstrate the structural characteristics of the 160" Gear Deployment Truss as a complete assembly. This section in conjunction with the previous section (K_1 - Crossover Fitting Tests) defines the truss capabilities under the specified loading conditions. All tests were conducted in accordance with LTP 904-10001 Section L. The time period was from August through December 1965, and the testing took place in the Grumman Structural Test Laboratory at Bethpage, New York.

REFERENCES

(1) LTP 904-10001 Rev. E Plan for LM Landing Gear Component Development Tests, Section K "Deployment Truss (160-inch Cantilever LM Landing Gear) Structural Tests".

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

1.0 PURPOSE OF TEST

The purpose of these tests was to demonstrate the structural integrity of the 160" landing gear deployment truss assembly. The originally scheduled vibration mode survey was deleted at the direction of the test requestor.

2.0 DESCRIPTION OF TEST ARTICLE

The test article consists of the two similar frame assemblies which comprise the 160" deployment truss assembly. Reference is made to Figure 7 for designation of individual truss members. The frame assemblies are essentially summetrical, the only difference being that the transverse member in one frame contains the crossover fitting as shown in Figure 7. This crossover fitting permits the transverse member of the other frame to penetrate it in-plane thus preserving the truss as a simple determinant structure. Because of the similarity and for expediency in testing only the transverse member was changed in the test sequence and therefore only one set of side support members was tested. To insure proper end conditions however, the second set of members was installed on the fixture for the test duration.

3.0 TEST CONDITIONS

This series of tests subjected the various members of the truss to critical loading conditions. The principal loads simulated are end loads either tension or compression, applied through the secondary struts when the energy absorbing cartridges are crushed. In addition transverse inertia loads developed during vehicle deceleration (20 g's) were distributed over the lengths of the members. The sequence of tests was conducted at ambient conditions and then repeated at a temperature of 200°F to simulate the solar and engine heat input during descent.

RESULTS OF LANDING GEAR COMPONENT

DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT

TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

3.0 TEST CONDITIONS - continued

The applied loads (magnitude and direction) for the test conditions are as noted in Figure 1 on page 9 . The factors of safety used in the landing gear design were as follows:

(Limit Load) x 1.35 = Ultimate Load

(Limit Load) x 1.15 = Proof Load.

Since this truss was scheduled for use in the landing gear drop tests afterwards, it was necessary to insure that no damage be inflicted upon it. For this reason only the proof load (85% ultimate load) was applied.

4.0 TEST SET-UP AND PROCEDURE

Each frame assembly of the truss was installed in turn in the test fixture as shown in Figure 2. The inertia loads were to be applied in the weakest bending plane of the member. Since all the members, with the exception of the crossover fitting member are symmetrical the load was applied by distributing shot bags along the length of the members. For the crossover member the load was applied in the plane of the truss as shown in Figure 7 . The secondary strut loads were applied by a hydraulic cylinder attached to a movable L-frame (see Figure 2). This facilitated loading in the four positions required due to the geometry changes in the strut-truss configuration. These positions were determined such that each member could be critically loaded in sequence while the other members developed non-critical loads.

Dial gauges were used to measure the deflections at the loading points and at the mid-points of the critical member during the test.

RESULTS OF LANDING GEAR COMPONENT

DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT

TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

4.0 TEST SET-UP AND PROCEDURE - continued

Strain gages were located at various points on each tube and on the crossover fitting for verification of the stress analysis of the truss assembly. The strain gage locations for each of the positions are shown in Figures 4, 5, and 6.

The step-by-step procedure utilized in the test was as outlined in para. 5.3.2 of the test plan (see reference 1 on page 2). The only addition to the given procedure was that in Position III (see Figure 1) both tubes #1 and #2 were critical and the test was repeated to obtain both sets of data.

5.0 TEST RESULTS AND CONCLUSIONS

These tests demonstrated that the individual truss frames, and hence the complete truss assembly were capable of sustaining the applied "proof" loads under both ambient and elevated temperature conditions. The loads critical to each member were derived from a computer - based on analysis of the many possible landing gear geometries at lunar impact. By utilizing a positioned hydraulic cylinder and adding the appropriate "inertia" weights, each truss member was loaded in sequence to a critical load. The critical load was limited to 85% of ultimate design load because the truss was needed in subsequent tests.

The detailed test results verify the design and stress analysis in that the actual critical stresses are in close agreement with the predicted stresses. One variation from the test plan exists in the detailed results in regard to the temperature tests. The requirement for recording the strains and deflections was waived because of inherent problems at high temperature with both the strain gauge adhesive and the deflection measuring equipment. The applied load was monitored and the truss characteristics were compared to the ambient tests with no significant differences resulting.

RESULTS OF LANDING GEAR COMPONENT

DEVELOPMENT TESTS

SECTION K_2 - STRUCTURAL TEST OF DEPLOYMENT

TRUSS ASSEMBLY FOR THE 160" LANDING GEAR

5.0 TEST RESULTS AND CONCLUSIONS - continued

The 160" landing gear design has been superseded by subsequent designs with some modifications to the deployment truss. It is anticipated that in a later phase of the test program, a complete evaluation of the redesigned truss will be made in terms of ultimate load and mode of failure.

This table lists the detailed test results and the pages on which they may be found for each of the test positions.

Parameter	Position Number I	II	III	IV	III
	Critical For Tube # 4	3C	1	3T	2
1. Strain Gauge Readings & Calc. Stresses	14	21	26	36	27
2 Deflect Readings at Proof Load	45	46	49	55	50
3 Eccentricity Curves Normal & In-Plane	15	22,23	51,52	37	51,52
4 Applied Load vs. Strain @ Mid-Span	17	39	28	38	30
5 Applied Load vs. Deflect. Normal & In-Plane	16,18	47,48	29,53	56,57	31,52
6 Temperature Data	19	24	32	40	33
7 Stress & Strain Individual Members	20	25	34	41	35

In addition to these results tables of limit loads & predicted stresses are included for comparison purposes on pages 7 and 8

TEST LOADS:

POSITION	LIMIT LOADS (lbs.) TUBE 1	TUBE 2	TUBE 3	TUBE 4
I	+7000	—	-2370	-3300
II	+6020	—	-8370	+1230
III	-8540	—	+7670	-50
IV	-7440	—	+11260	-2960
III	—	-8540	+7670	-50

CRITICAL TUBE

POSITION	PREDICTED (P/A) STRESSES @ MID-SPAN * TUBE 1	TUBE 2	TUBE 3	TUBE 4
I	+14350	—	-8950	-23300
II	+12350	—	-31600	+8700
III	-17500	—	+29000	-353
IV	-15250	—	+42500	-20900
III	—	-17500	+29000	-353
AREA VARIATION	.497-.561	.497-.561	.261-.305	.131-.163

* BASED ON
1- MAX. AREA
2- LIMIT LOAD x 1.15 = PROOF LOAD

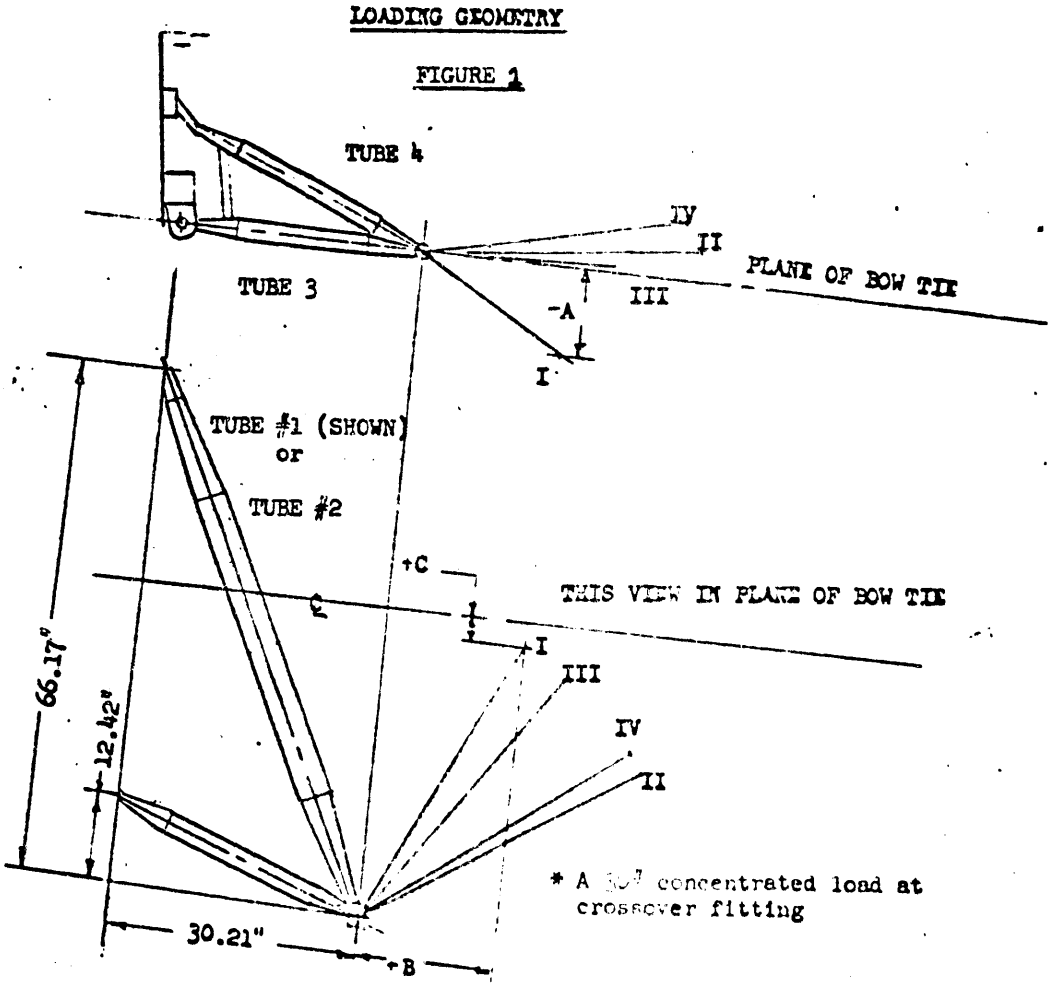
SUMMARY OF PREDICTED/ACTUAL MID-SPAN STRESSES

POSITION	APPLIED CRIT LOAD	PREDICTED STRESS	ACTUAL STRESS
	#	PSI	PSI
POSITION I			
TUBE 1		+14350	13500
" 2		—	—
" 3		-5250	9560
" 4	-3330	-23300	21800
POSITION II			
TUBE 1		+12550	+12,250
" 2		—	—
" 3	-8370	-31600	-32100
" 4		+8700	+13700
POSITION III			
TUBE 1	-8540	-17500	-18000
" 2		—	—
" 3		+27000	+26600
" 4		-353	~
POSITION IV			
TUBE 1		-15250	14000
" 2		—	—
" 3	+11260	+42500	+40,600
" 4		-20,900	-20,300
POSITION III			
TUBE 1		—	—
" 2	-8540	-17500	+16,900
" 3		+27000	+26,500
" 4		-353	~

SECTION K_2 DEPLOYMENT TRUSS STRUCTURAL TEST 160" GEAR

LOADING GEOMETRY

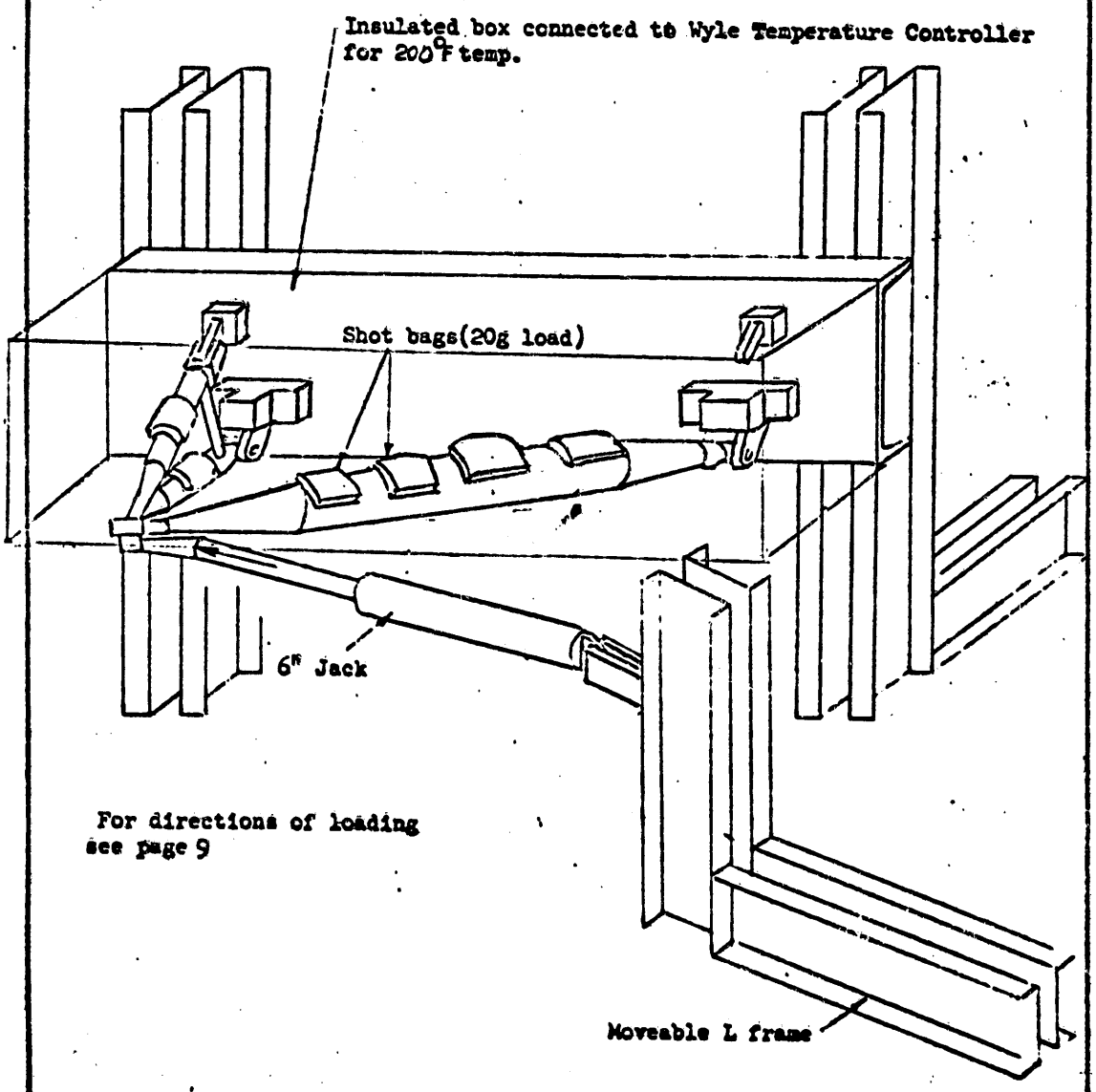
FIGURE 1



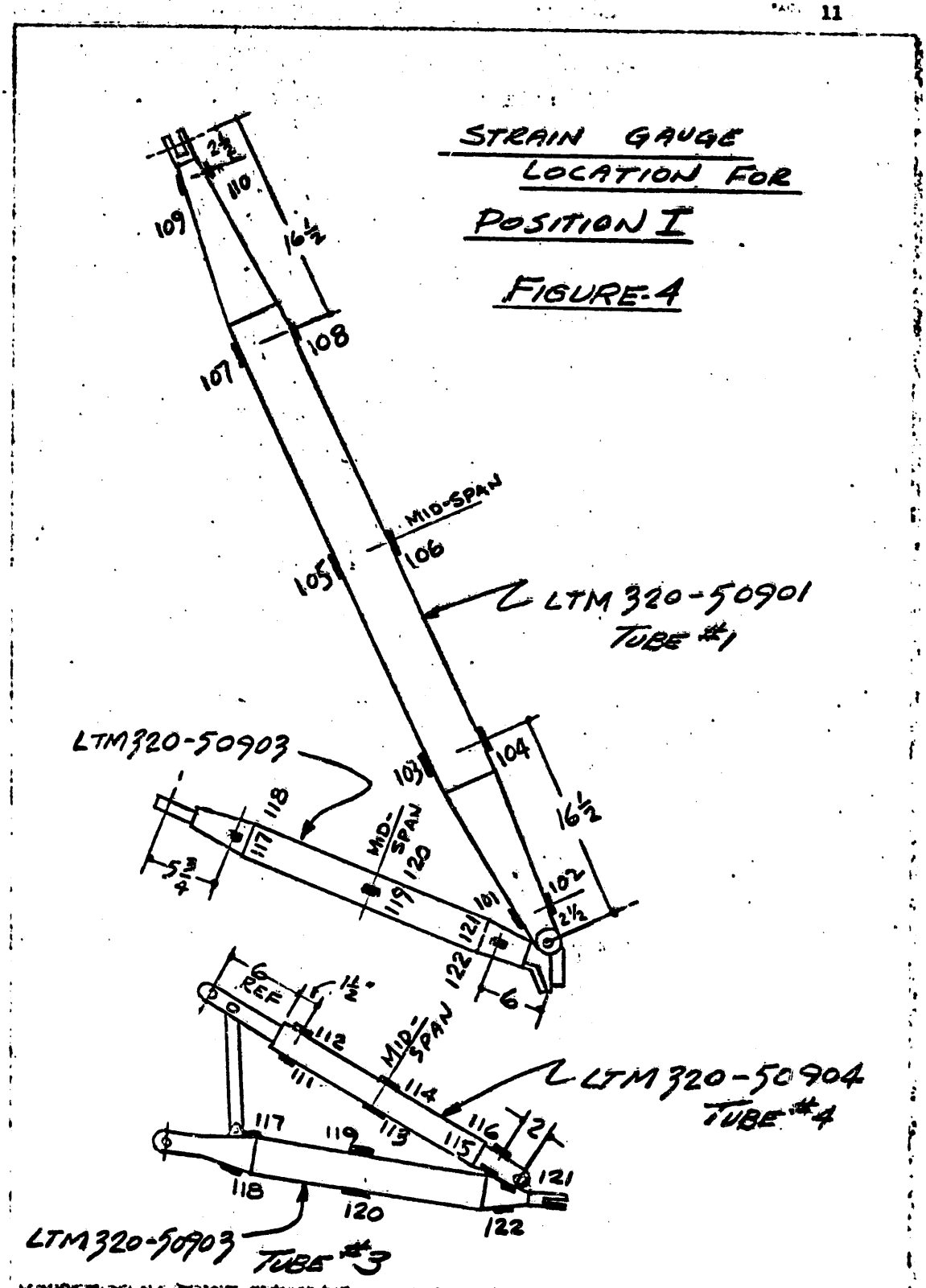
POSITION	DIMENSIONS (INCHES)			PROOF LOADS (LBS)				
	A	B	C	SECONDARY STRUT	INERTIA ON TUBE			
					[illegible]	# 2 *	# 3	#4
I	-10.00	17.74	3.42	-5800	74	80	52	26
II	4.48	40.16	13.04	-5800	74	80	52	26
III	.25	35.50	-10.50	+7000	74	80	52	26
IV	10.75	46.32	3.42	+7000	74	80	52	26

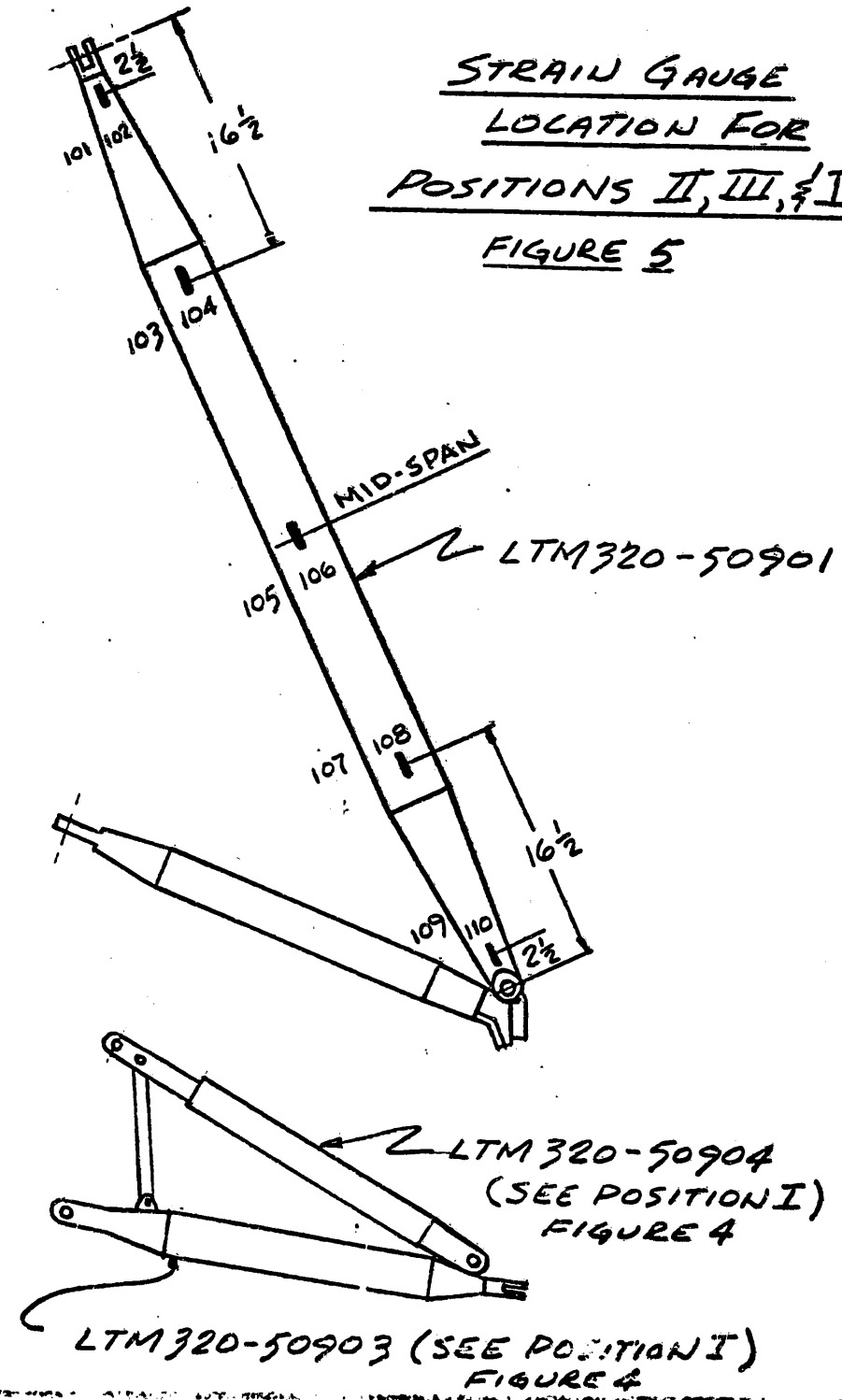
SECTION K_2- DEPLOYMENT TRUSS STRUCTURAL TEST 160" GEAR.

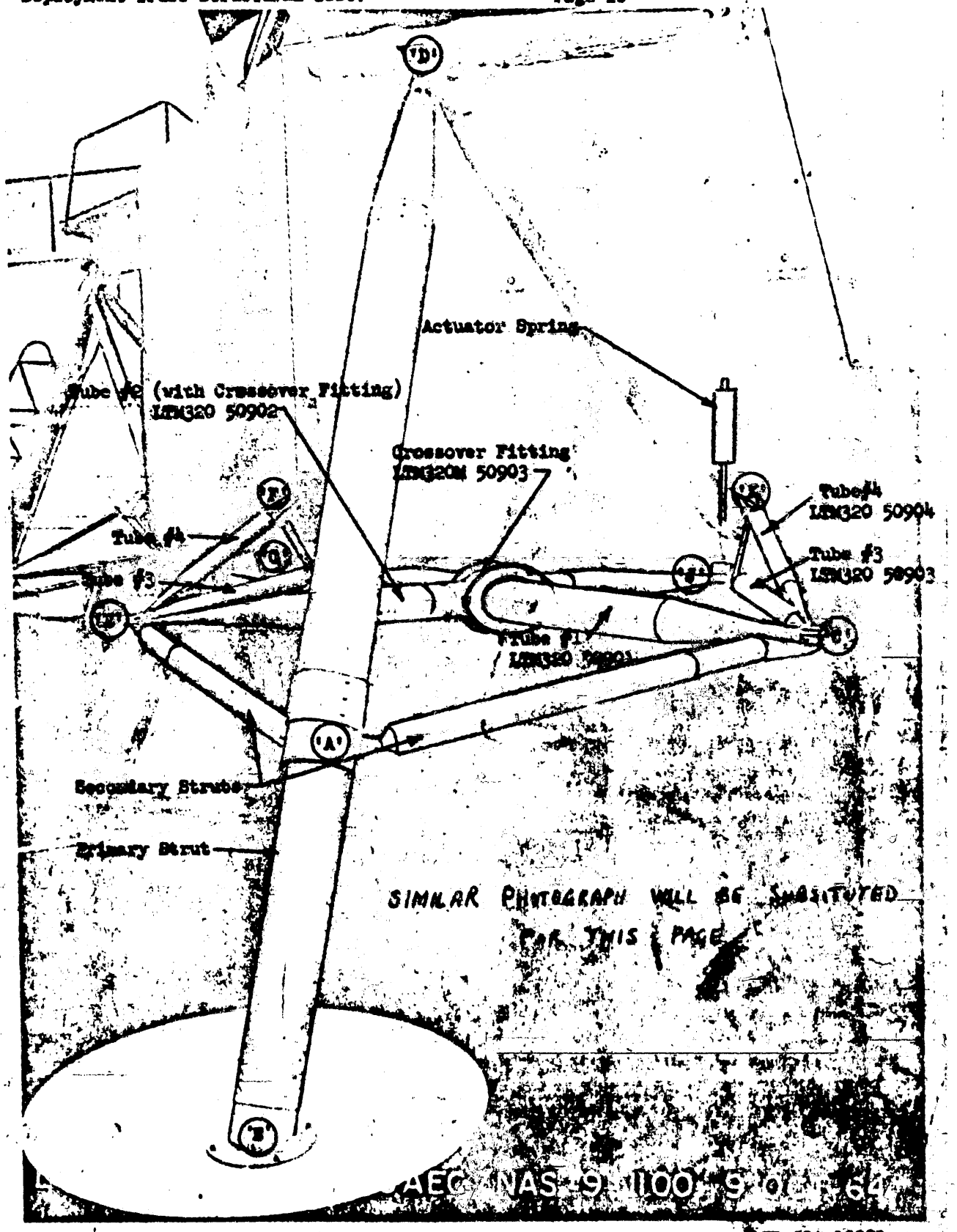
Figure 2



For directions of loading see page 9


STRAIN GAUGE
LOCATION FOR
POSITION I
FIGURE-4
MID-SPAN
LTM 320-50901
TUBE #1
LTM320-50903
MID-SPAN
LTM 320-50904
TUBE #4
LTM320-50903
TUBE #3

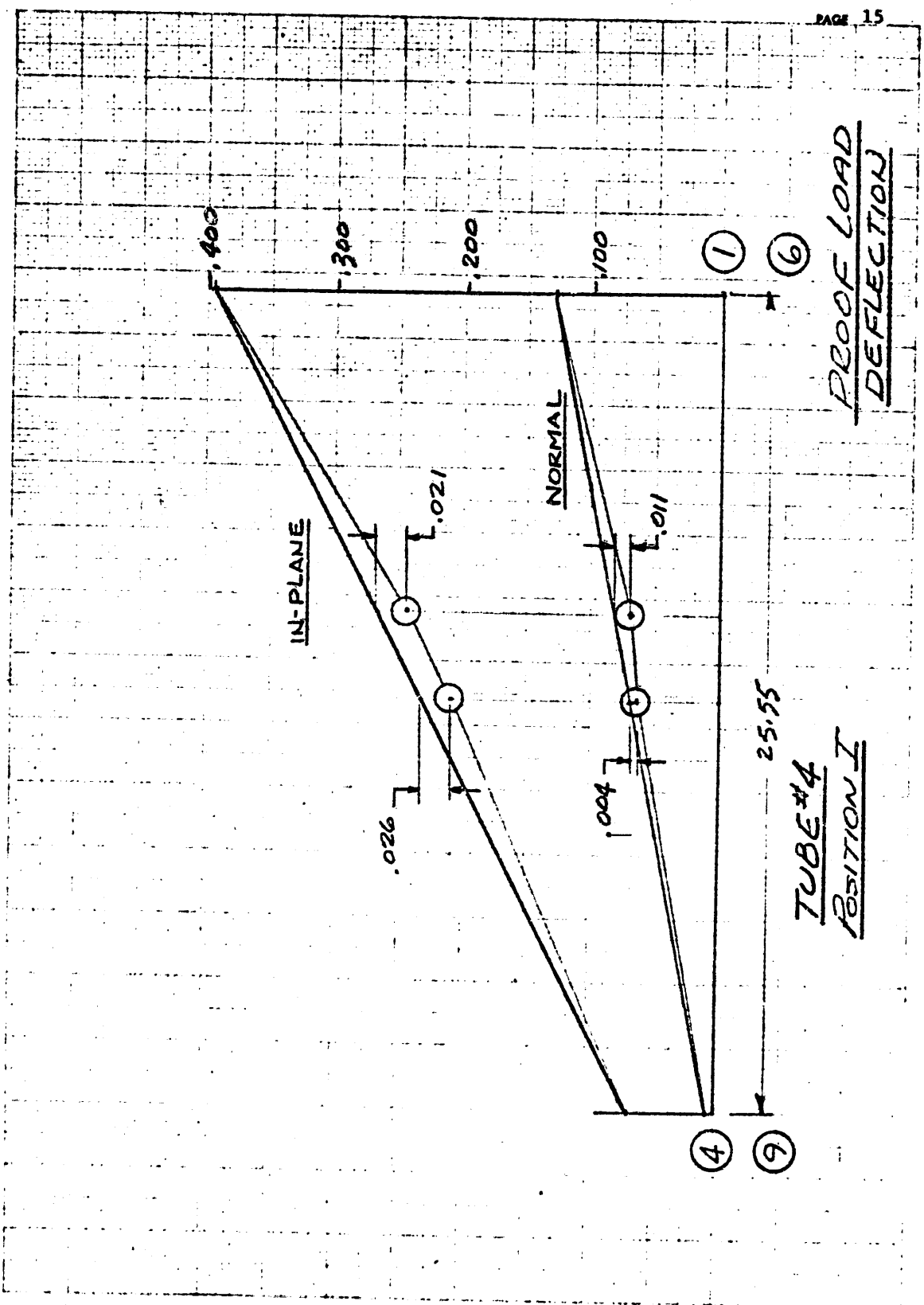

STRAIN GAUGE
LOCATION FOR
POSITIONS II, III, & IV
FIGURE 5
2½
16½
101
102
103
104
MID-SPAN
105
106
LTM320-50901
107
108
16½
109
110
2½
LTM320-50904
(SEE POSITION I)
FIGURE 4
LTM320-50903 (SEE POSITION I)
FIGURE 4

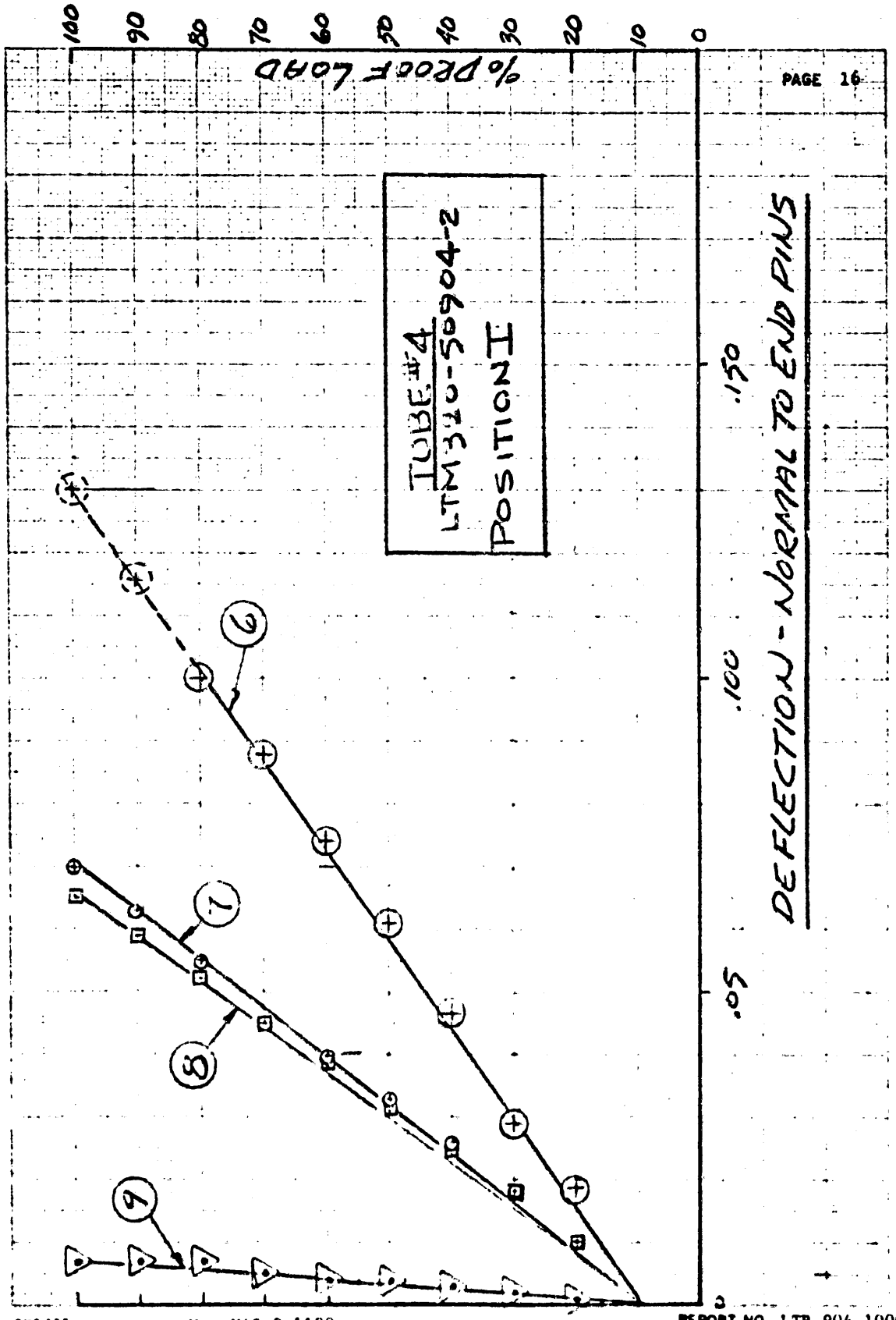

Actuator Spring
Tube #6 (with Crossover Fitting)
LEM320 50902
Crossover Fitting
LEM320M 50903
Tube #4
LEM320 50904
Tube #4
Tube #3
Tube #3
LEM320 50903
Tube #1
LEM320 50901
Secondary Struts
Primary Strut
SIMILAR PHOTOGRAPH WILL BE SUBSTITUTED
FOR THIS PAGE

STRAIN GAGE RESULTS

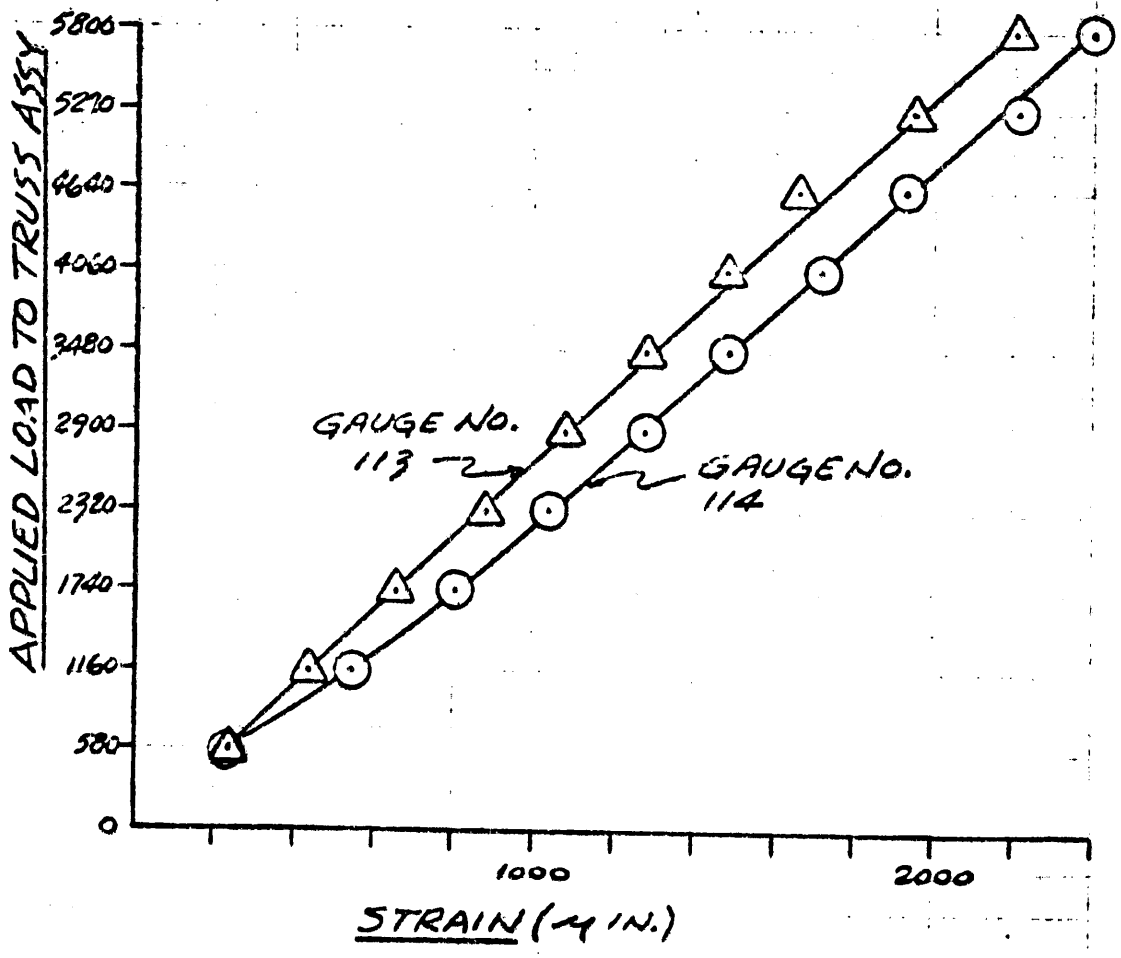
Test Item 160 DEPLOYMENT TRUSS Condition POSITION I Test Date 8-31-65
Ult. Test Press. _____ Axial Stress= E x Strain; Shear Stress= E x Strain/2.66
A1, A2: Axial Gage; S1, S2: Shear Gage E = 10.4 x 10^6

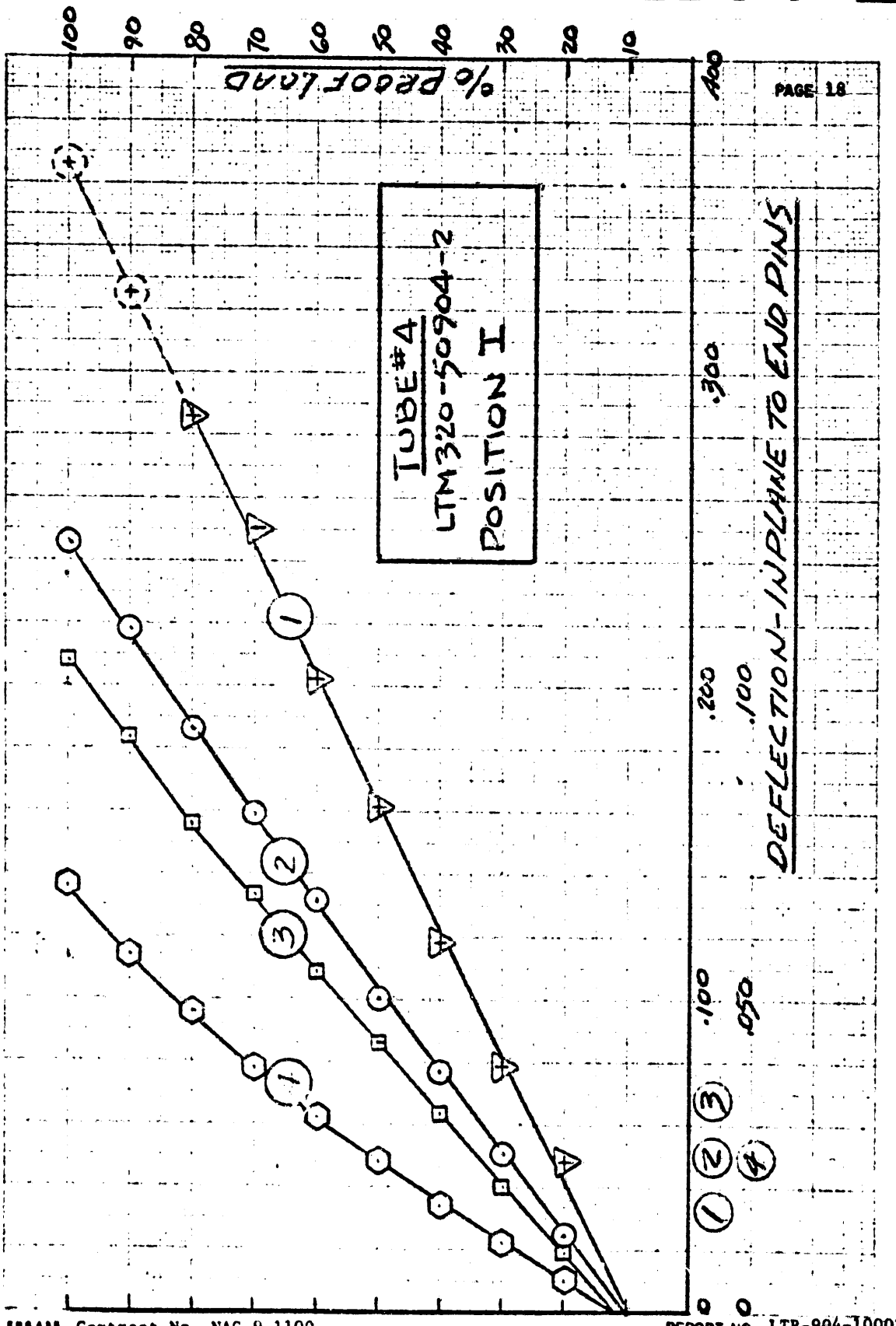
Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	P# .Strain μin/in	P# .Stress PSI
Recorder No. 1							
1	101	LTM 320-50901	A1		10.3	+2975	30900
2	102					3250	33800
3	103					1270	13200
4	104					1290	13400
5	105	MID-SPAN				1290	13400
6	106	MID-SPAN				1300	13500
7	107					1380	14350
8	108					1360	14150
9	109					2925	30400
10	110	LTM 320-50901				+3100	32200
11	111	LTM 320-50904				-1870	19500
12	112					2000	20800
13	113	MID-SPAN				2100	21800
14	114	MID-SPAN				2250	23400
15	115					2050	21300
16	116	LTM 320-50904	A1		10.3	-2050	21300
Recorder No. 2							
17	117	LTM 320-50903	A1		10.3	-680	7070
18	118					500	5200
19	119	MID-SPAN				920	9560
20	120	MID-SPAN				700	7300
21	121					430	4470
22	122	LTM 320-50903	A1		10.3	-430	4470
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
Recorder No.							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							
47							
48							


PROOF LOAD
DEFLECTION
TUBE #4
POSITION I
IN-PLANE
NORMAL
400
300
200
100
.021
.026
.011
.004
25.55
1
6
4
9


% PROOF LOAD
100
90
80
70
60
50
40
30
20
10
0
.05
.100
.150
DEFLECTION - NORMAL TO END PINS
TUBE #4
LTM1310-50904-2
POSITION I
6
7
8
9

APPLIED LOAD VS STRAIN FOR TUBE #4 - CRITICAL IN COMPRESSION




% PROOF LOAD
100
90
80
70
60
50
40
30
20
10
TUBE #4
LTM320-50904-2
POSITION I
DEFLECTION-INPLANE TO END PINS
0
.100
.200
.300
.400
0
.050
.100
1
2
3
4

DATE: 9-2-65

H
200°F

0		
10	580	82
20	1160	164
30	1740	246
40	2320	328
50	2900	410
60	3480	492
70	4060	574
80	4640	656
90	5220	738
100	5800	820

203	200	200	206	206	203
200	203	203	200	202	200
SIDE		DN.LOCK		CROSS	
MEMBER					

DEPLOYMENT TRUSS
SUMMARY SHEET

POSITION I

TUBE NO. 1 ASSY. NO. LTM 320-50901 MID.-SPAN	
STRAIN (ε)	STRESS (σ)
+1290 M.IN.	+13400 PSI
+1350	+14000
TUBE NO. 3 ASSY. NO. LTM320-50903 MID-SPAN	
-920 M.IN.	-9560 PSI
-700	-7300
TUBE NO. 4 ASSY. NO. LTM 320-50904	
-1870 M.IN.	-19500 PSI
2000	20800
2100	21800
2400	24900
2050	21300
-2050 M.IN.	-21300 PSI

STRAIN GAGE RESULTS

Test Item 160 DEPLOYMENT TRUSS Condition POSITION II Test Date 9-10-65

Ult. Test Press. _____ Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage E = 10.4 x 10^6 PSI

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	Pr. Strain μin/in	Pr. Stress PSI
Recorder No. _____			Recorder Identification ____				
1	101	LTM 320-50901	A1		10.3	+3045	31600
2	102					3185	33100
3	103					1270	13200
4	104					1310	13600
5	105	MID-SPAN				1180	12250
6	106	MID-SPAN				1350	14000
7	107					1280	13300
8	108					1380	14350
9	109					2815	29200
10	110	LTM 320-50902				+3500	34300
11	111	LTM 320-50904				+1105	11500
12	112					1209	13400
13	113	MID-SPAN				1320	13700
14	114	MID-SPAN				1350	14000
15	115					1430	14850
16	116	LTM 320-50904	A1		10.3	+1265	13100
Recorder No. _____			Recorder Identification ____				
1	117	LTM 320-50903	A1		10.3	-2400	24900
2	118					2530	26250
3	119					3095	32100
4	120					3175	32950
5	121					2460	25550
6	122	LTM 320-50905	A1		10.3	-2345	24400
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
Recorder No. _____			Recorder Identification ____				
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

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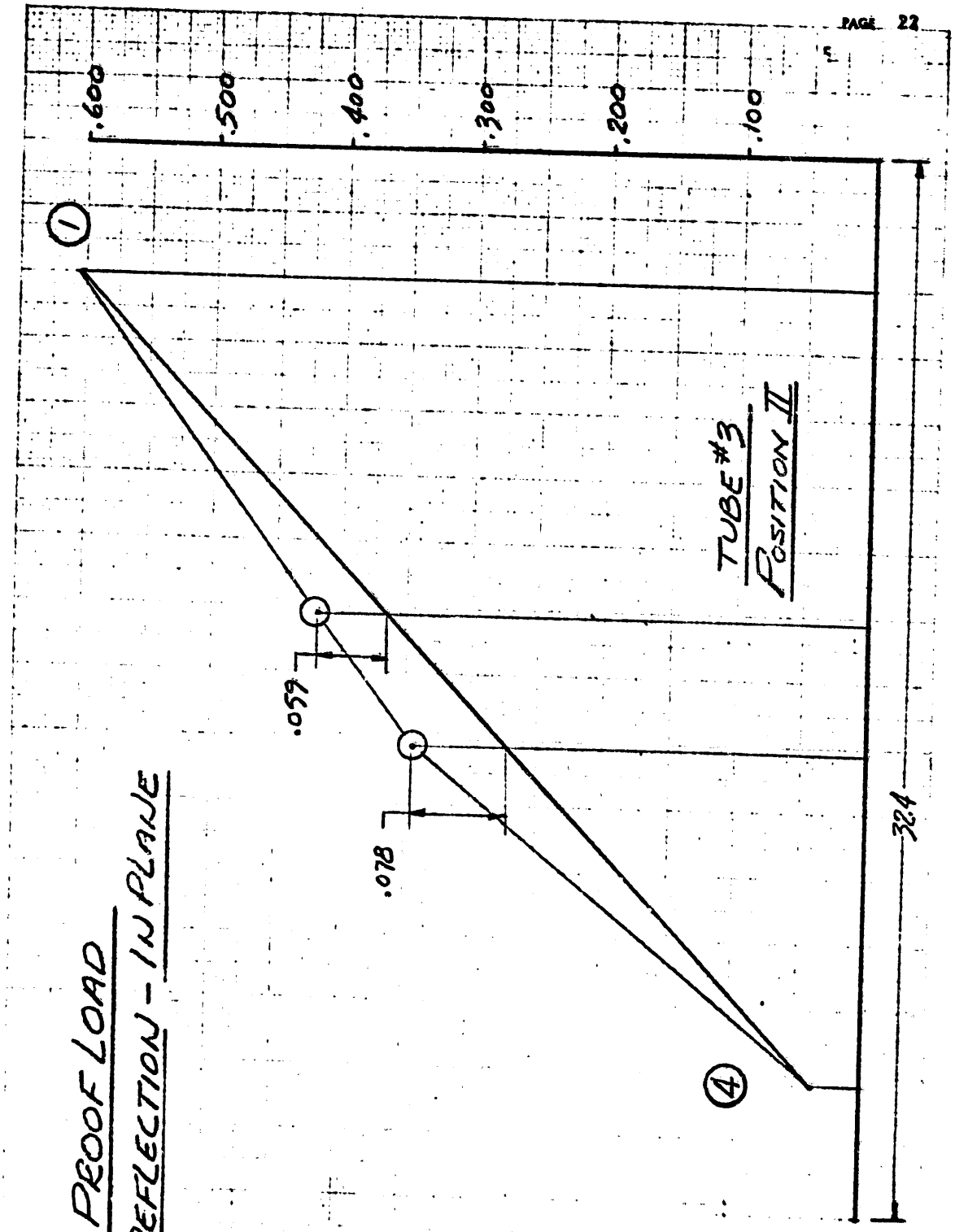
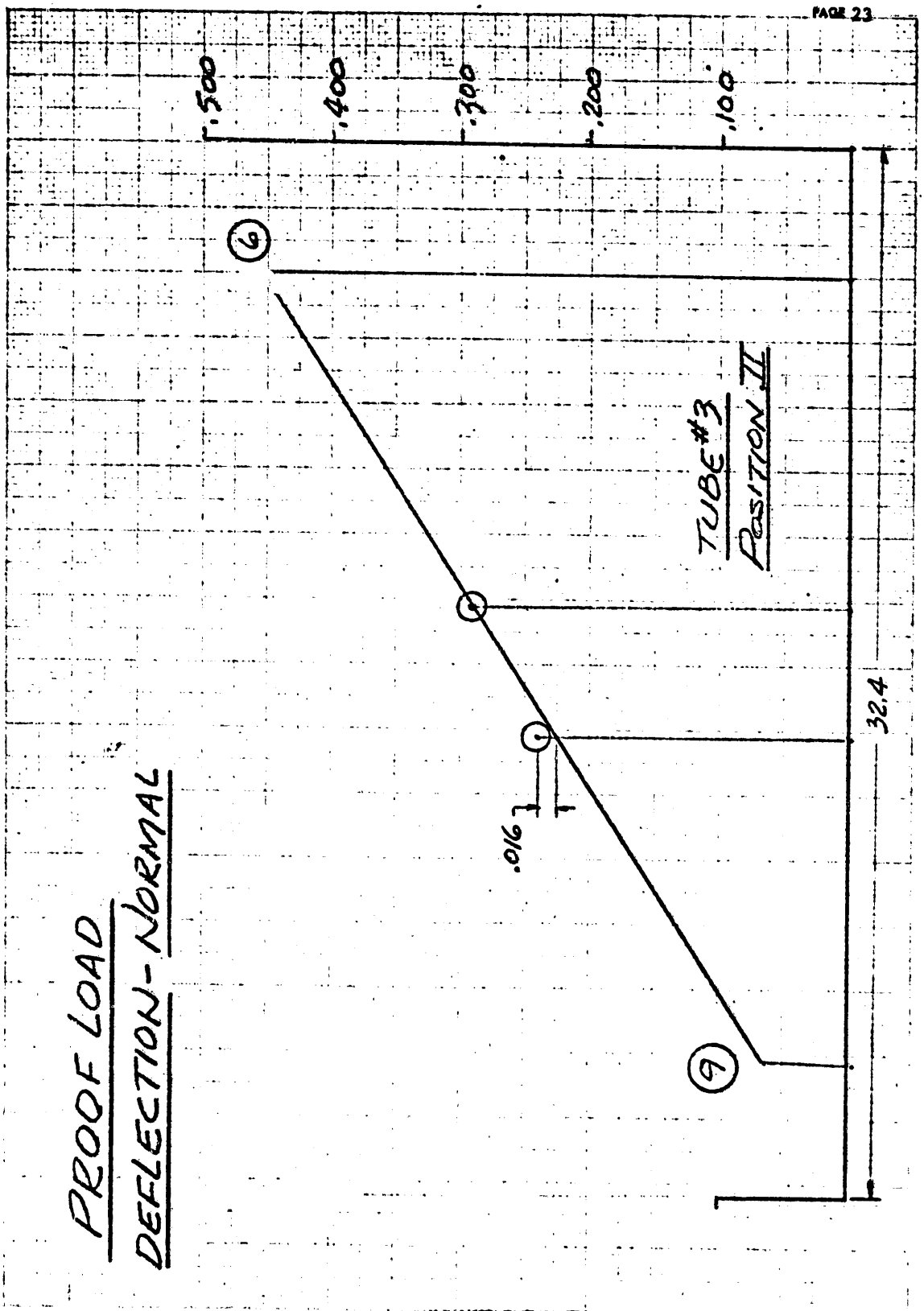


PROOF LOAD
DEFLECTION - IN PLANE


PROOF LOAD
DEFLECTION - NORMAL
TUBE #3
POSITION II
.500
.400
.300
.200
.100
6
9
.016
32.4

DATE: 9-15-65

II
200°F

0	0	0
10	580	90
20	1160	170
30	1740	260
40	2320	349
50	2900	410
60	3480	519
70	4060	600
80	4640	685
90	5220	775
100	5800	867

200	200	200	200	202	202
202	200	202	203	203	205
SIDE		DN.LOCK		CROSS	
MEMBER					

DEPLOYMENT TRUSS

POSITION II

1 LTM 320-50901	
+ 1180 μ.IN.	+ 12250 PSI
1350	14000
4 LTM 320-50904	
+ 1320 μ.IN.	+ 13700 PSI
1350	14000
3 LTM 320-50903	
- 2400 μ.IN.	- 24900 PSI
2530	26250
3050	31900
3050	31900
2460	25550
- 2345 μ.IN.	- 24400 PSI

STRAIN GAGE RESULTS

Test Item "160" DEPLOYMENT TRUSS Condition POSITION III Test Date 9-17-65

Ult. Test Press. _____ Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage E = 10.4 x 10^6

Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	Pf .Strain µin/in	Pf .Stress PSI
Recorder No. 1			Recorder Identification				
1	101	LTM 320-50901	A1		10.3	-3350	-34800
2	102					3800	39500
3	103					1450	15100
4	104					1650	17200
5	105	MID SPAN				1440	15000
6	106	MID SPAN				1750	18200
7	107					1550	16150
8	108					1750	18200
9	109					3300	34150
10	110	LTM 320-50901				-3850	-40000
11	111	LTM 320-50904				SMALL	
12	112						
13	113	MID SPAN					
14	114	MID SPAN					
15	115						
16	116	LTM 320-50904	A1		10.3	SMALL	
Recorder No. 2			Recorder Identification				
1	117	LTM 320-50903	A1		10.3	+2150	+22400
2	118					2100	21800
3	119	MID SPAN				2700	28100
4	120	MID SPAN				2750	28600
5	121					1850	19300
6	122	LTM 320-50903	A1		10.3	+2000	+20800
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
Recorder No.			Recorder Identification				
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

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STRAIN GAGE RESULTS

Test Item 160 DEPLOYMENT TRUSS Condition POSITION III Test Date 9-24-65

Ult. Test Press. _____ Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage E = 10.4 x 10^6

Ch.	Gage No.	Location	Gage Type	RC	Mat'l E10-6	Pf. Strain μin/in	Pf. Stress PSI
Recorder No. 1			Recorder Identification				
1	5	LTM 320-50902	A1	33K	10.3	+900	+9350
2	32					+18	+190
3	44					+3300	+34300
4	45					+2400	+25000
5	46					+3350	+34800
6	49					—	—
7	51		A1			-2600	-27100
8	52		DEN			-3700	-38500
9	53	LTM 320-50902	A1			+280	+2920
10			—	—	—		
11	111	LTM 320-50904	A1				
12	112						
13	113	MID SPAN					
14	114	MIDSPAN					
15	115						
16	116	LTM 320-50904	A1	33K	10.3		
Recorder No.			Recorder Identification				
1	117	LTM 320-50903	A1	33K	10.3	+1940	+20400
2	118					2150	22400
3	119	MID SPAN				3660	37400
4	120	MID SPAN				2550	26500
5	121					1820	19950
6	122	LTM 320-50903				+2000	+20800
7	60	LTM 320-50902				-3250	-33800
8	61					-4300	44800
9	62					2000	20800
10	63					1950	20300
11	64					600	6250
12	65					1560	16200
13	66					1620	16900
14	67					1820	19000
15	68					3500	36500
16	69	LTM 320-50902	A1	33K	10.3	-3700	-38600
Recorder No.			Recorder Identification				
1	70	LTM 320-50902	DEN	33K	10.3	-3800	-39500
2							
3	72	LTM 320-50902				+3500	+39500
4	73					-3550	-36900
5	71	LTM 320-50902	DEN	33K	10.3	+3800	+39500
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
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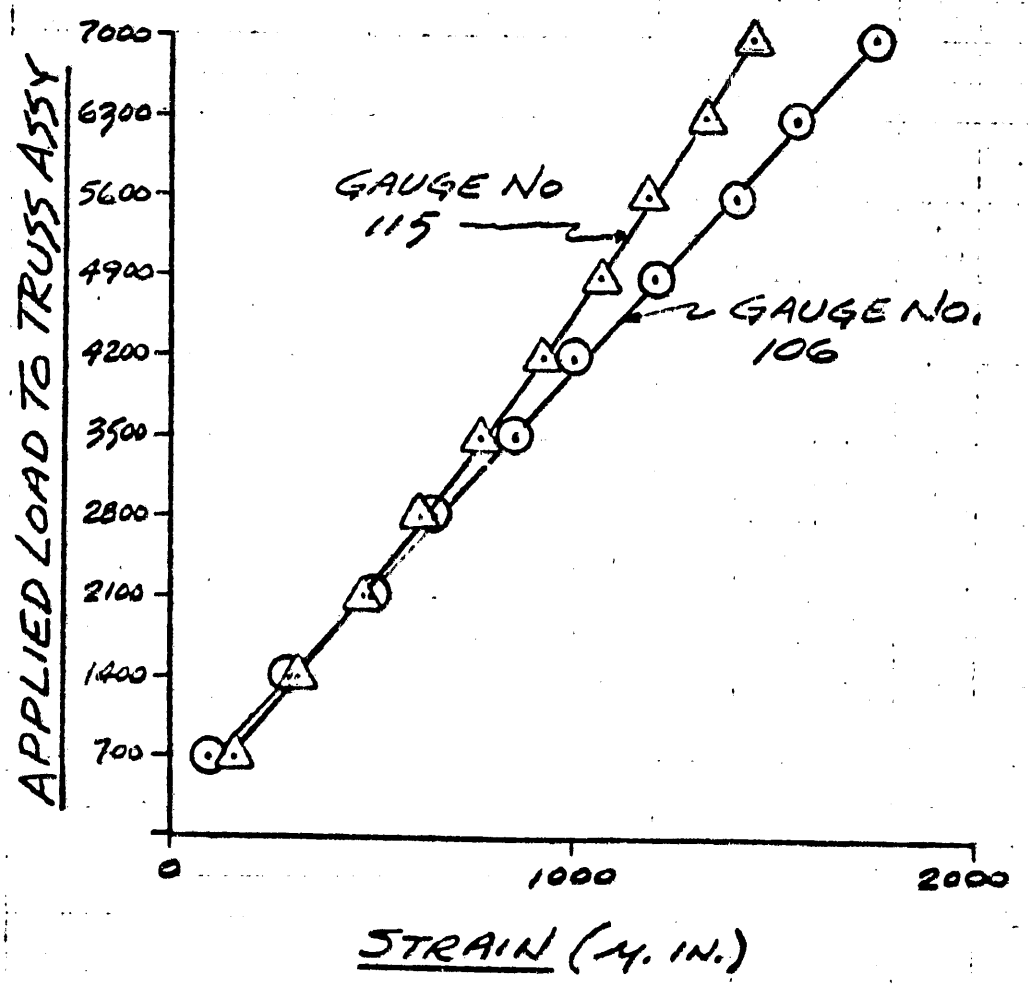
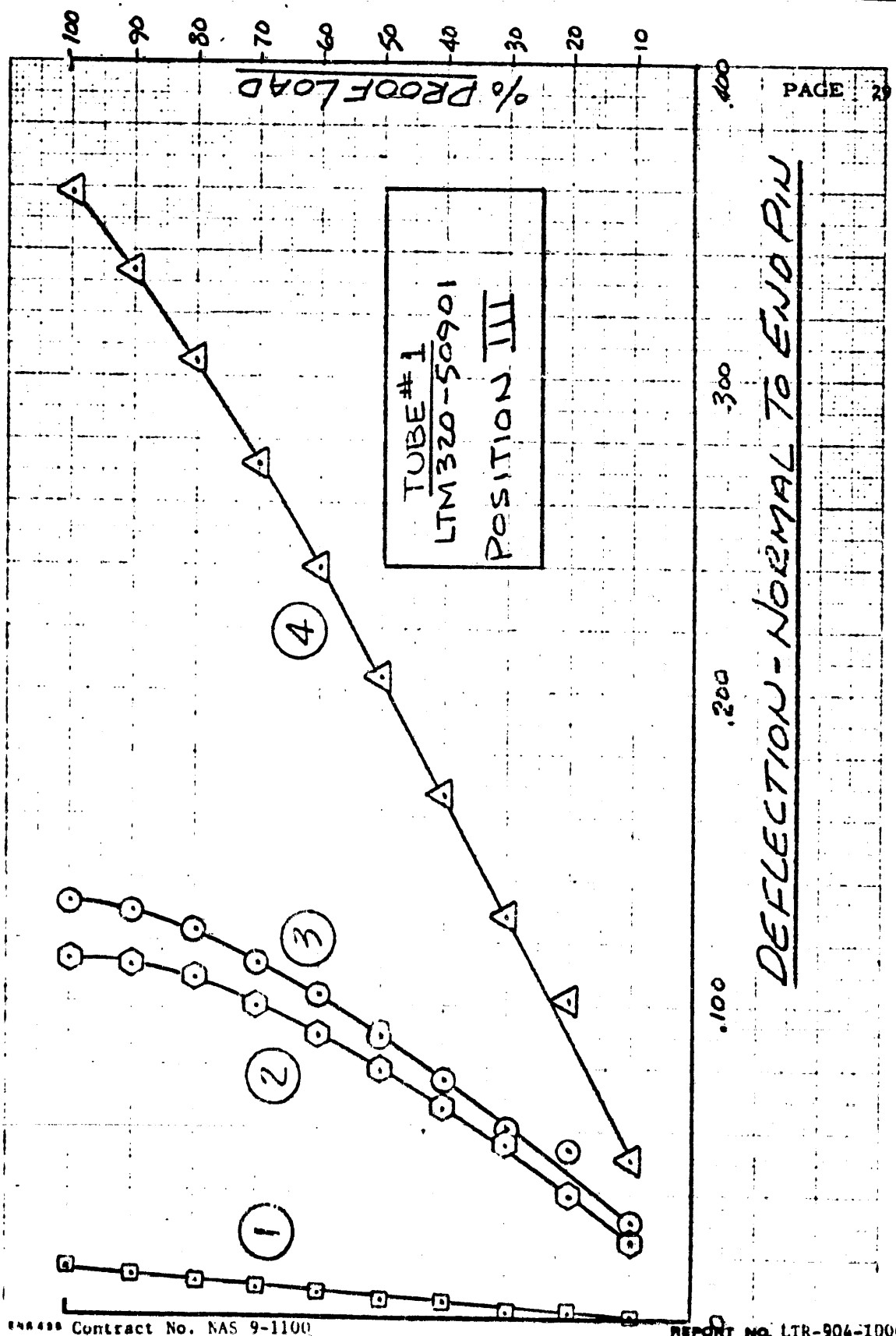
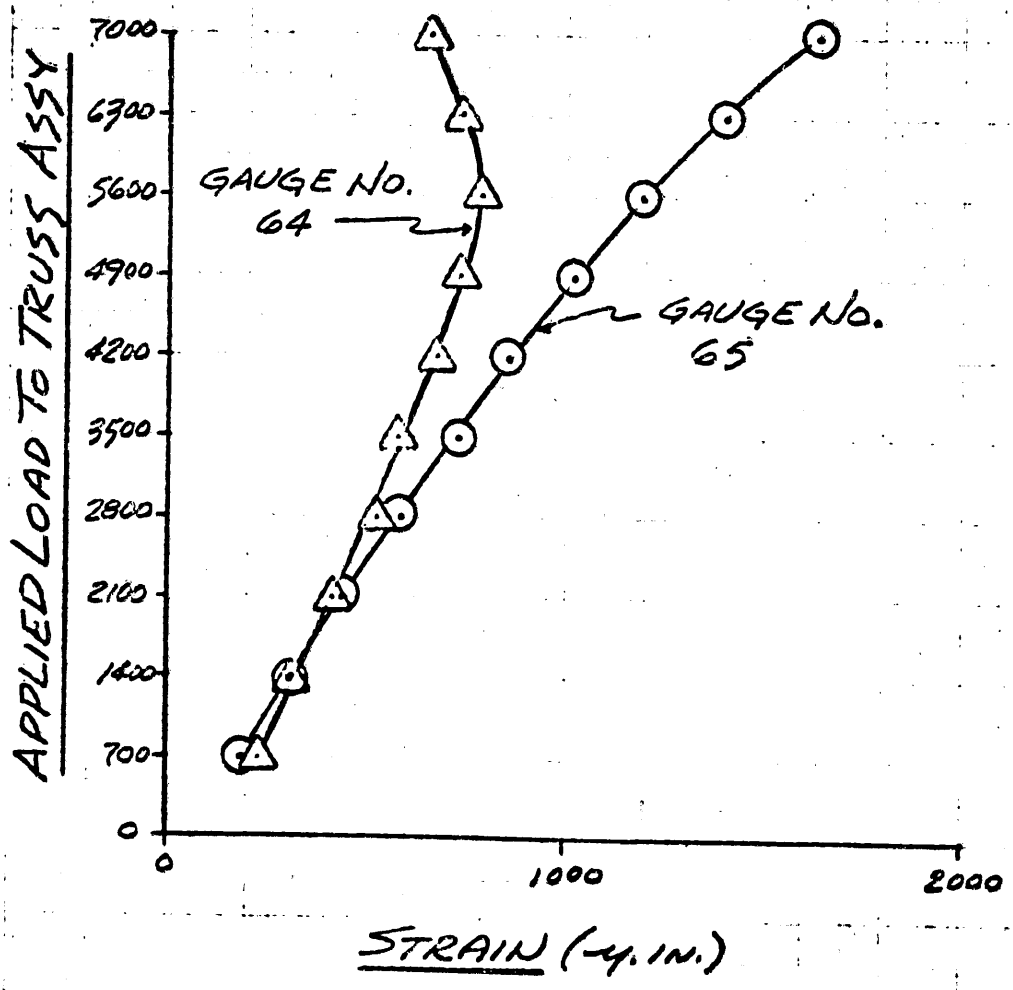
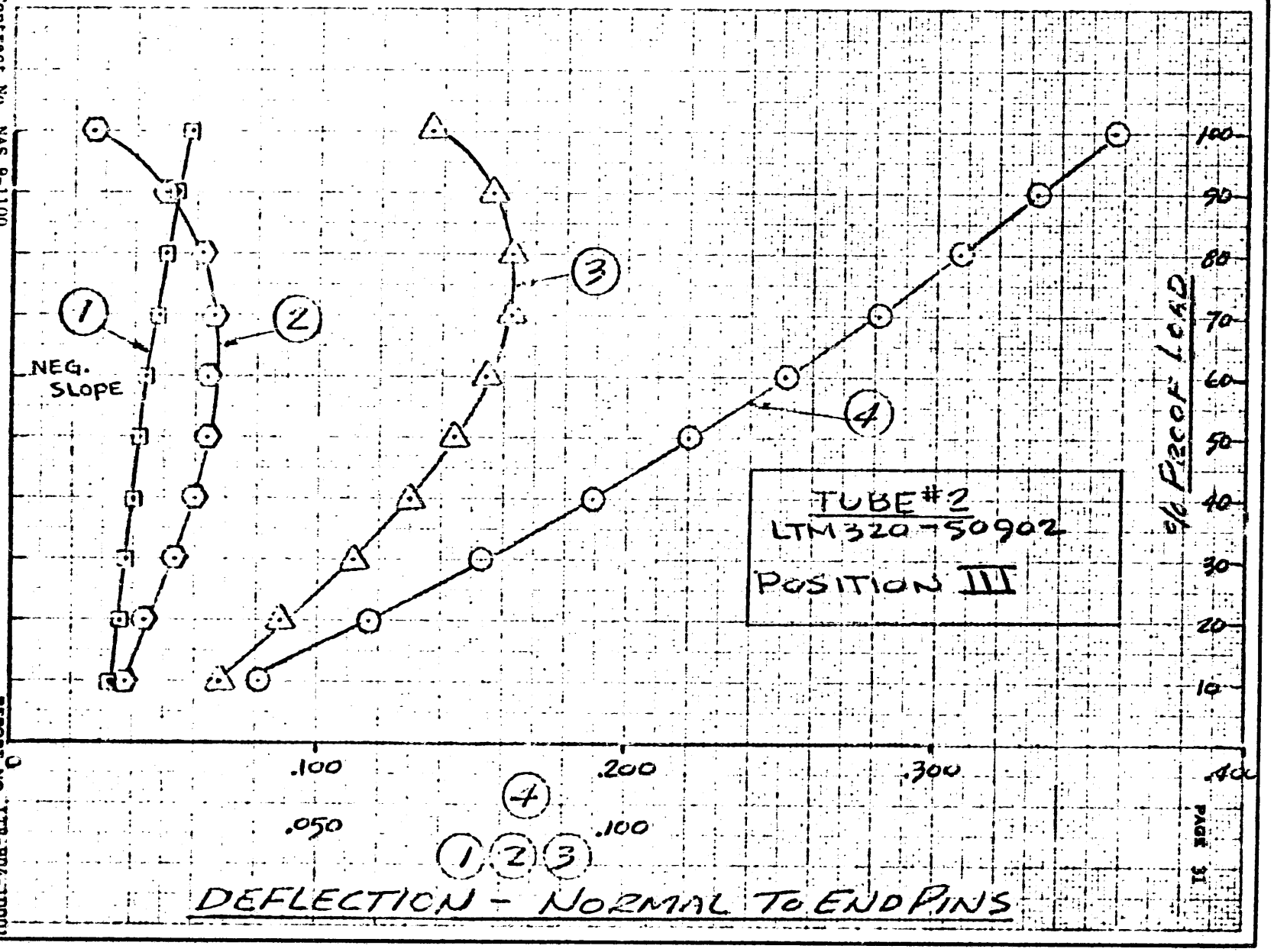
APPLIED LOAD VS STRAIN FOR TUBE #1 - CRITICAL IN COMPRESSION




DEFLECTION - NORMAL TO END PIN
.100
.200
.300
.400
% PROOF LOAD
100
90
80
70
60
50
40
30
20
10
TUBE #1
LTM320-50901
POSITION III
1
2
3
4

APPLIED LOAD VS STRAIN FOR TUBE #2 - CRITICAL IN COMPRESSION




NEG. SLOPE
1
2
3
4
TUBE #2
LTM320-50902
POSITION III
% P12 OF LOAD
100
90
80
70
60
50
40
30
20
10
0
.100
.200
.300
.400
.050
.100
DEFLECTION - NORMAL TO END PINS

E: 9-20-65

III
200°F

0	0	0
10	700	120
20	1400	235
30	2100	352
40	2800	470
50	3500	585
60	4200	700
70	4900	815
80	5600	930
90	6300	1044
100	7000	1158

200	200	197	200	200	200
200	200	200	200	200	200
SIDE		DN.LOCK		CROSS	
MEMBER					

DEPLOYMENT TRUSS
DATA SHEET

DATE: 9-24-65

TEST CONDITION: POSITION III
TEMP. 200°F

PROOF %	LOAD	JACK PRESS. (psi)	
0	0	0	BEFORE
10	700	124	AFTER
20	1400	236	
30	2100	350	
40	2800	465	
50	3500	576	
60	4200	680	
70	4900	805	
80	5600	922	
90	6300	1035	
100	7000	1150	

THERMOCOUPLE (°F)					
1	2	3	4	5	6
200	200	193	200	200	200
200	200	200	200	204	205
SIDE		DN. LOCK		CROSS	
MEMBER					

DEPLOYMENT TRUSS
SUMMARY SHEET

POSITION III

3 LTM320-50903	
+ 3660 M.IN + 2550 M.IN	+37400 PSI +26,600 PSI
4 LTM320-50904	
— —	— —
2 LTM320-50902	
-3250 M.IN. 4300 2000 1950 600 1560 1620 1820 3500	-33800 PSI 44800 20800 20300 6250 16200 16900 19000 36500
-3700	-38600
-3800	-39500
+3800	+39500
+3800	+39500
-3550	-36900
+900	+9350
+3300	+34300
+280	+2920
-2600	-27100
-3700	-38500

DEPLOYMENT TRUSS

[illegible]

POSITION III

4 LTM320-50904 [illegible]	
[illegible]	[illegible]
—	—
—	—
3 LTM320-50903 [illegible]	
+2700 M.IN.	+28100 PSI
+2750	+28600
1 LTM320-50901	
-3350 M.IN.	-34800 PSI
3800	39500
1450	15100
1650	17200
1440	15000
1750	18200
1550	16150
1750	18200
3300	34150
-3850 M.IN.	-40000 PSI

STRAIN GAGE RESULTS

Test Item 160 DEPLOYMENT TRUSS Condition POSITION IV Test Date 9-15-65

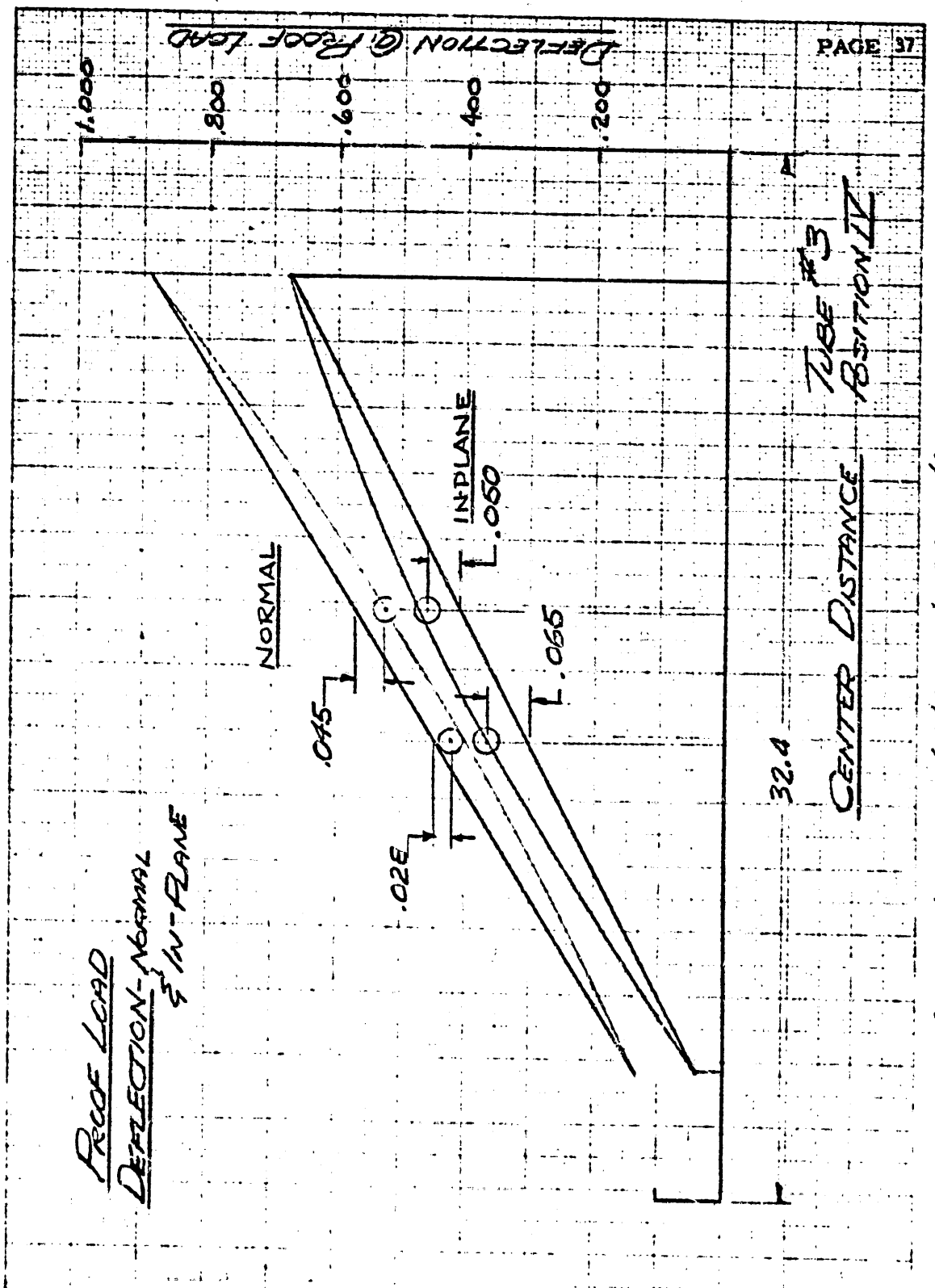
Ult. Test Press. _____ Axial Stress = E x Strain; Shear Stress = E x Strain/2.66

A1, A2: Axial Gage; S1, S2: Shear Gage

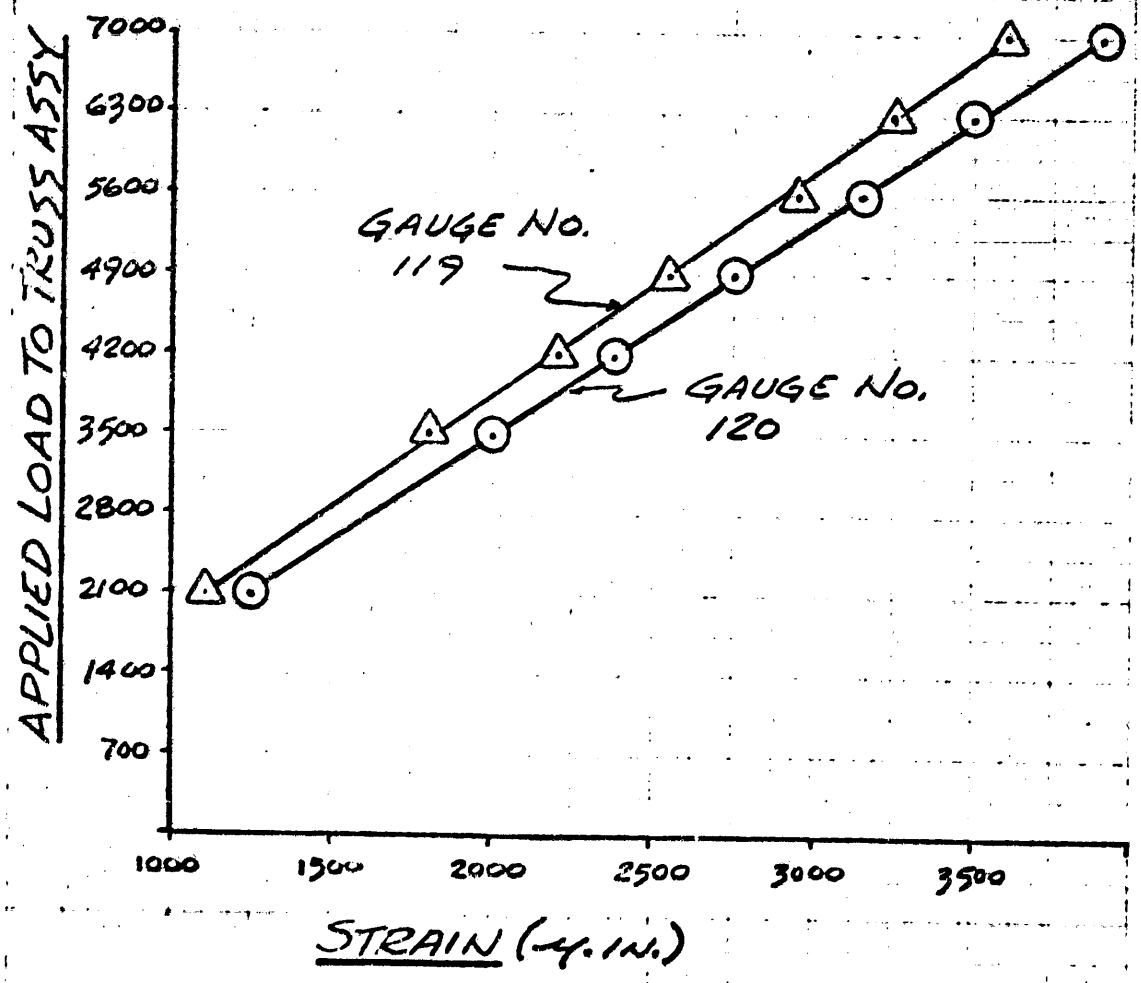
Ch.	Gage No.	Location	Gage Type	Sketch Page	Mat'l E10-6	Pf. Strain µin/in	Pf. Stress PSI
Recorder No. 1			Recorder Identification				
1	101	LTM320-50901	A1		10.3	-3000	-31300
2	102					3350	35000
3	103					1300	13550
4	104					1500	15650
5	105	MID SPAN				1340	14000
6	106	MID SPAN				1520	15850
7	107					1320	13750
8	108					1470	15400
9	109					3000	31300
10	110	LTM320-50901				-3450	-35900
11	111	LTM320-50904				-1780	-18550
12	112					900	9370
13	113	MID SPAN				1950	20300
14	114	MID SPAN				1100	11450
15	115					1500	15600
16	116	LTM320-50904	A1		10.3	-1500	-15600
Recorder No. 2			Recorder Identification				
1	117	LTM320-50903	A1		10.3	+2550	+26600
2	118					3150	32800
3	119	MID SPAN				3600	37500
4	120	MID SPAN				3900	40600
5	121					2800	29200
6	120	LTM320-50903	A1		10.3	+2550	+26700
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
Recorder No. _____			Recorder Identification				
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

GRUMMAN AIRCRAFT ENGINEERING CORPORATION
ENGINEERING DEPARTMENT

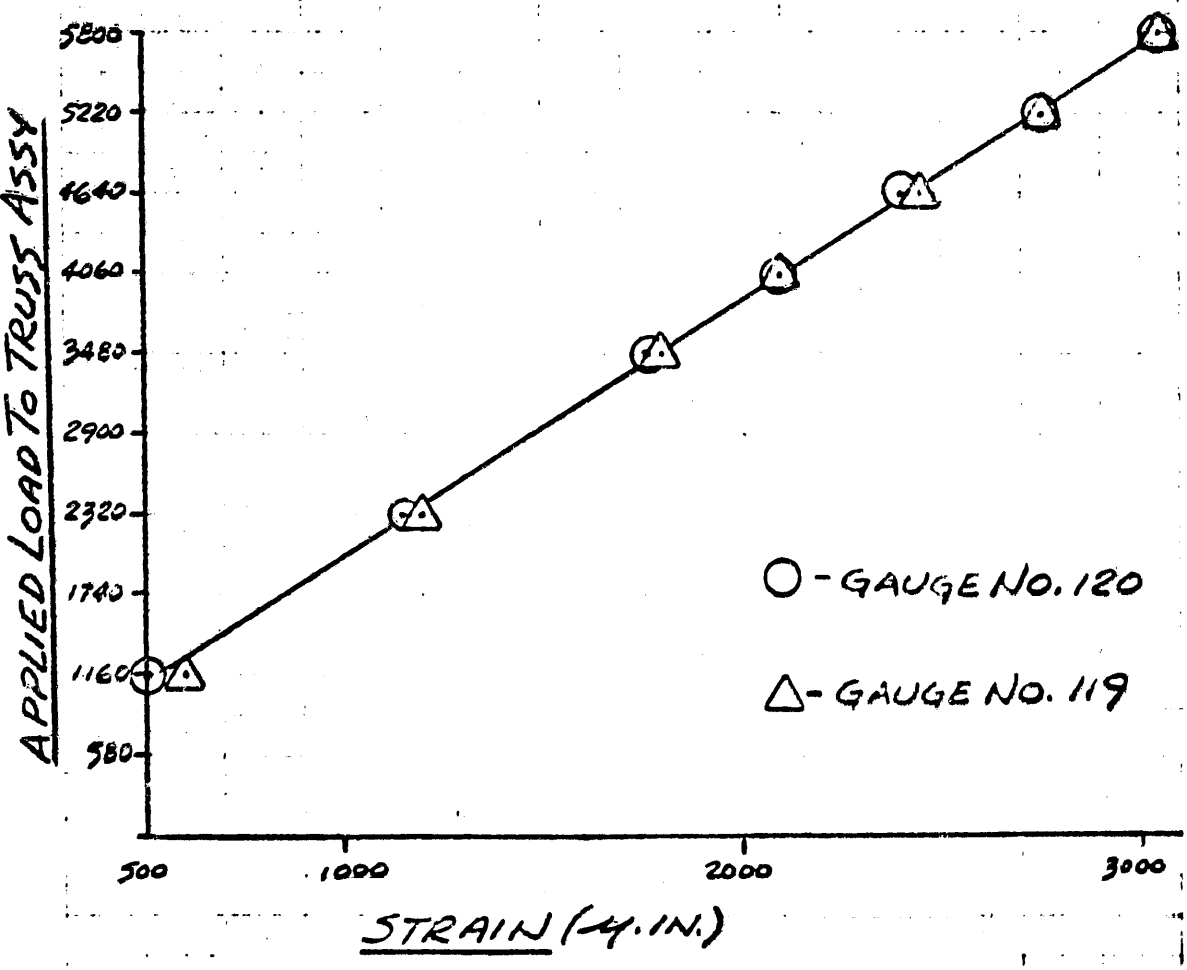
ENG 696 1-63


PROOF LOAD
DEFLECTION-NORMAL & IN-PLANE
DEFLECTION @ PROOF LOAD
1.000
.800
.600
.400
.200
NORMAL
.045
.02E
IN-PLANE
.060
.065
32.4
CENTER DISTANCE
TUBE #3
POSITION IV

APPLIED LOAD VS STRAIN FOR TUBE #3 - CRITICAL IN TENSION



APPLIED LOAD VS STRAIN FOR TUBE #3 - CRITICAL IN COMPRESSION



E 9-15-65

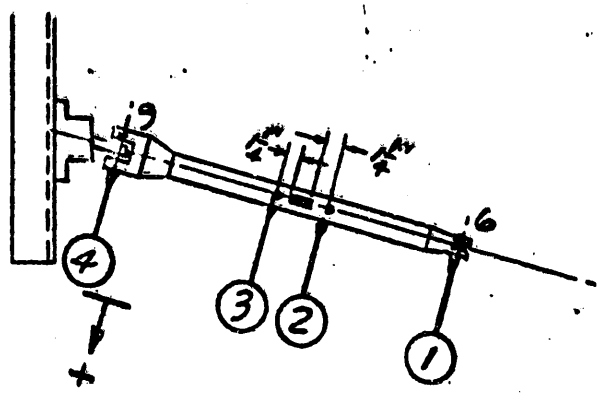
IV
200°F

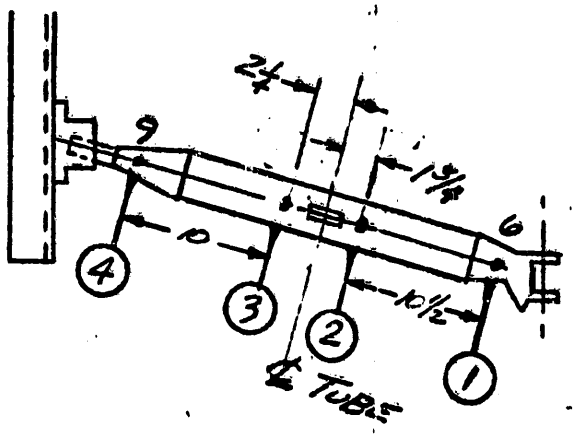
0	0	0
10	700	118
20	1400	232
30	2100	348
40	2800	464
50	3500	580
60	4200	699
70	4900	815
80	5600	928
90	6300	1044
100	7000	1160

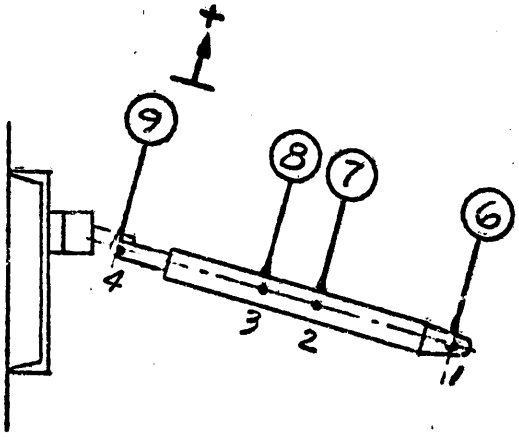
201	201	200	202	205	205
201	201	201	201	205	205
SIDE		DN.LOCK		CROSS	
MEMBER					

IV

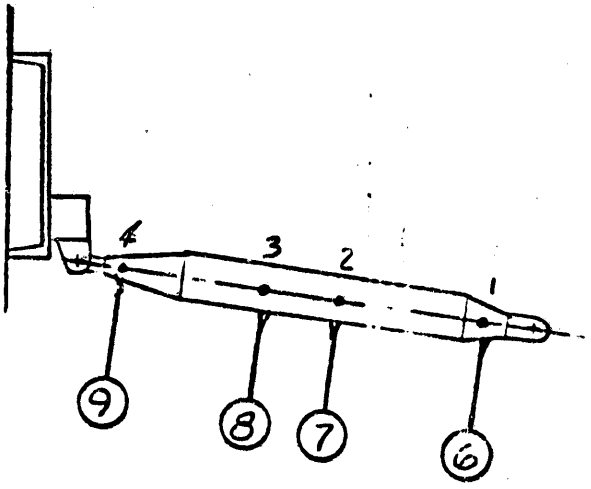
1 LTM320-50901	
-1340 M.IN.	-14000 PSI
-1520 M.IN.	-15850 PSI
4 LTM320-50904	
-1950 M.IN.	-20300 PSI
-1100 M.IN.	-11450 PSI
3 LTM320-50903	
+ 2550 M.IN.	+ 26600 PSI
3150	32800
3600	37500
3900	40600
2800	29200
+ 2850 M.IN.	+ 29700 PSI







TUBE #4



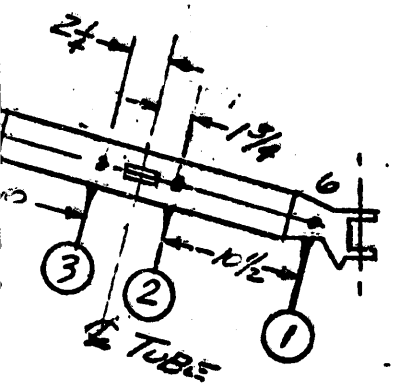
TUBE #3

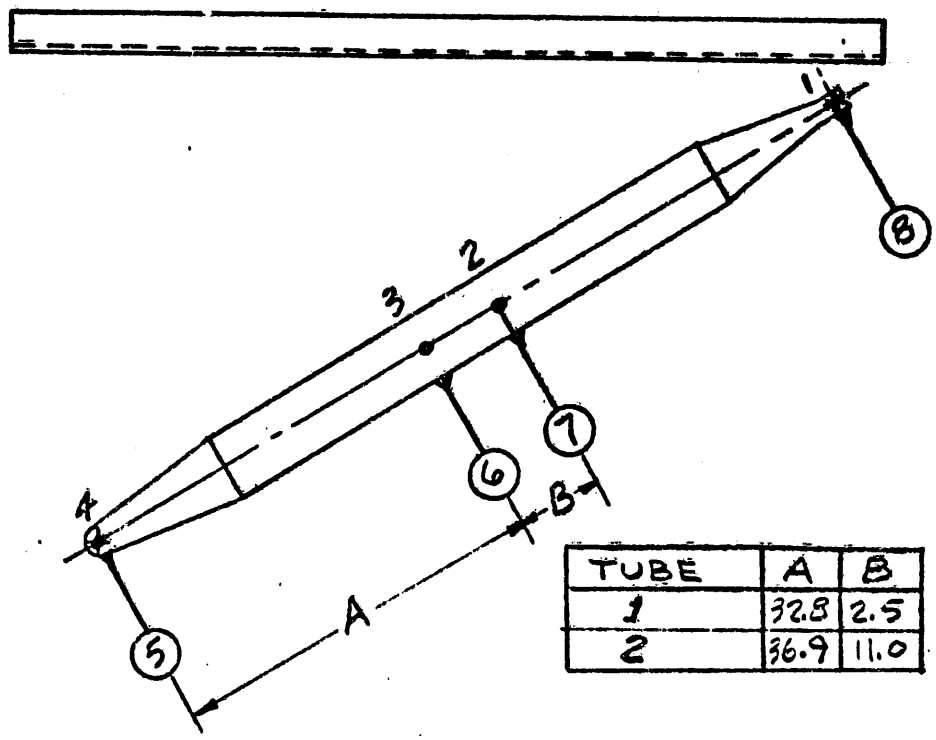
DIAL GAUGE LO

Contract No. NAS 9-1100
Primary No. 811

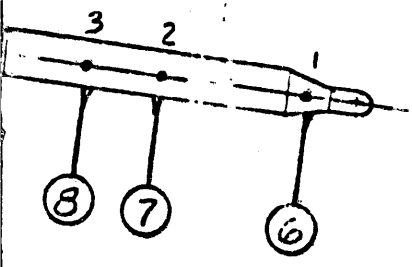
FIGURE 3

GRUMMAN AIRCRAFT

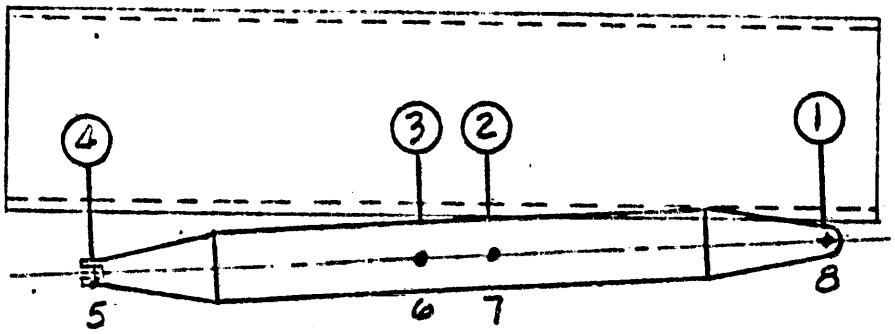




TUBE	A	B
1	32.8	2.5
2	36.9	11.0



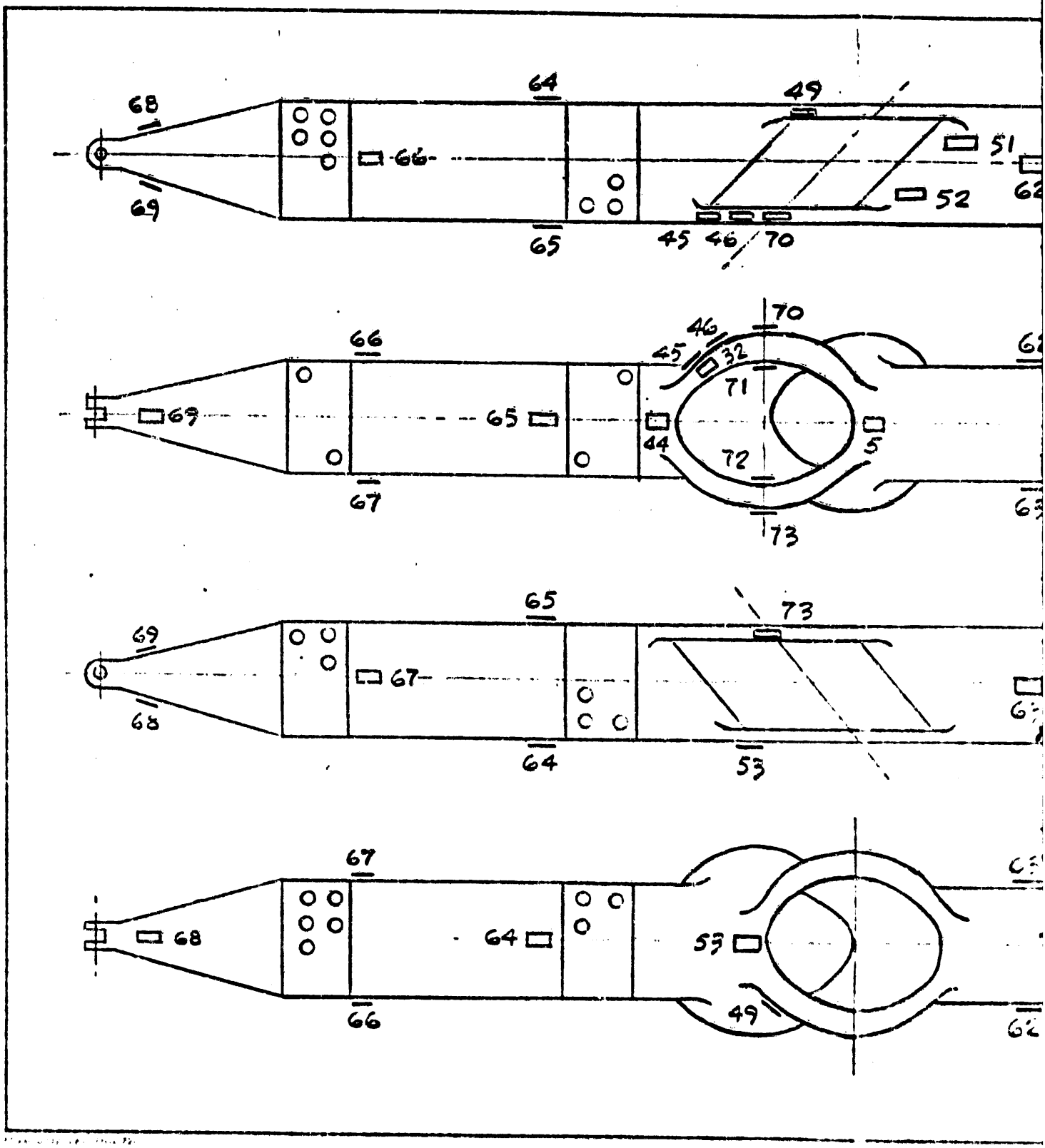
UBE #3



TUBE #1
℄
TUBE #2 (NOT SHOWN)

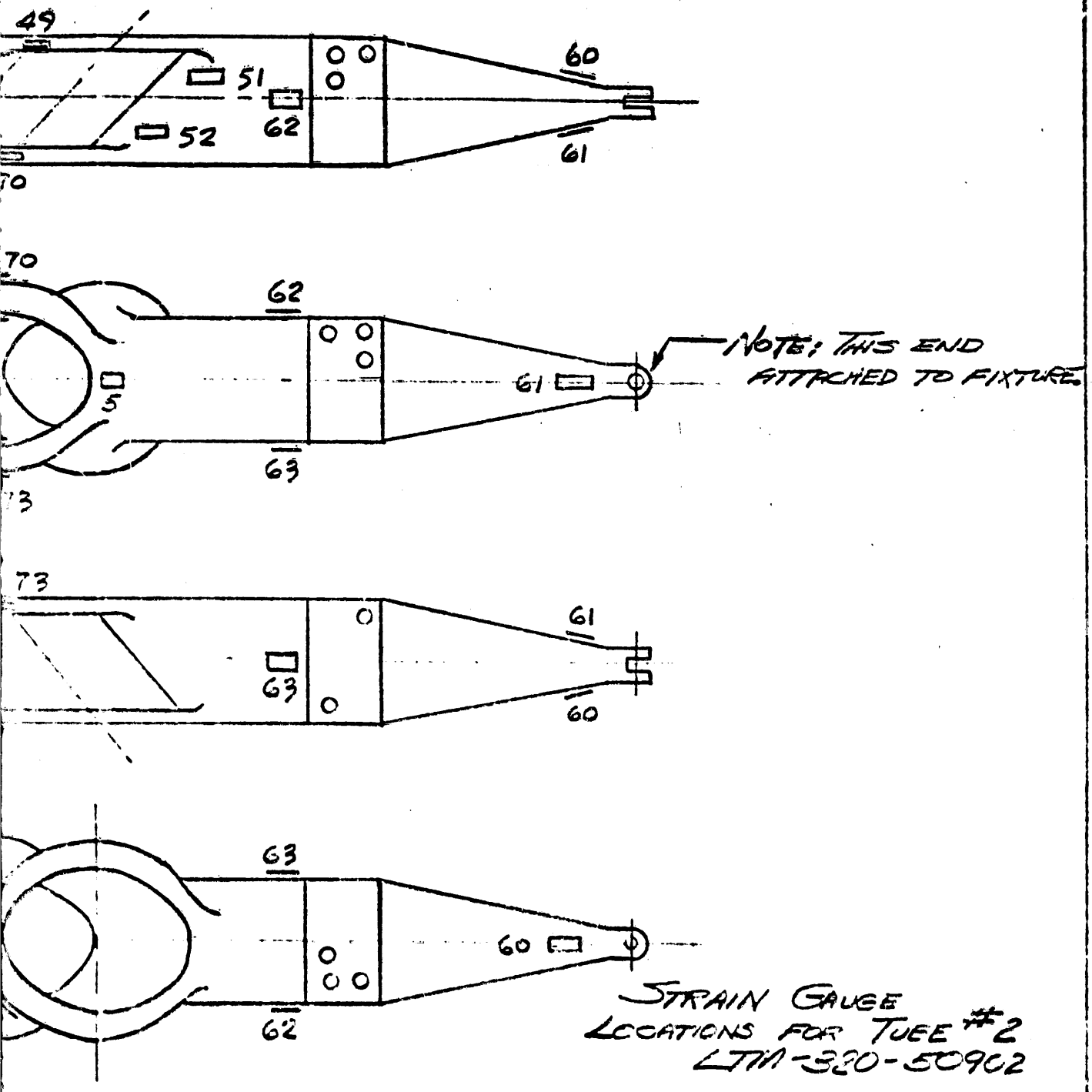
L GAUGE LOCATIONS

FIGURE 3



Contract No. NAS 9-1100
Primary No. 811

FIGURE-6



STRAIN GAUGE LOCATIONS FOR TUBE #2 LTA-320-50902

FIGURE-6

DEPLOYMENT TRUS
DATA SHEET

DATE: 8-31-65
TEST CONDITION: POSITION I
TEMP. AMBIENT

PROOF %	LOAD	JACK PRESS. (PSI)	LOAD CELL CAL.	LOAD CELL READING	DIAL 1	2	3	4
0	0	0	1.58 d/4 IN./IN.	9730	0	0	0	
10	580	82		10070	+0	+0	+0	+0
20	1160	164		10435	.048	.025	.019	.005
30	1740	248		10815	.079	.051	.040	.011
40	2320	328		11175	.119	.077	.063	.017
50	2900	410		11560	.161	.105	.083	.024
60	3480	492		11910	.201	.131	.109	.031
70	4060	574		12275	.250	.159	.133	.039
80	4640	656		12620	.236	.186	.156	.048
90	5220	738		12990	.346	.218	.186	.057
100	5800	820		13350	.395	.246	.208	.069

PLOYMENT TRUSS
DATA SHEET

DIAL READING - DEFLECTION										
2	3	4	5	6	7	8	9	10	11	12
0	0									
+0	+0	+0	+0	+0	+0	+0	+0	-0	+0	+0
.025	.019	.005	.004	.019	.008	.010	.001	.011	.004	.005
.051	.040	.011	.010	.029	.018	.017	.002	.014	.016	.012
.077	.063	.017	.016	.047	.026	.024	.003	.017	.016	.018
.105	.083	.024	.022	.061	.033	.031	.004	.022	.023	.025
.131	.109	.031	.028	.074	.040	.039	.004	.025	.029	.030
.159	.133	.039	.035	.088	.045	.045	.005	.030	.036	.036
.186	.156	.048	.042	.100	.055	.052	.007	.034	.044	.043
.218	.186	.057	.052		.063	.059	.007	.040	.053	.048
.246	.208	.069	.063		.070	.065	.007	.047	.063	.055

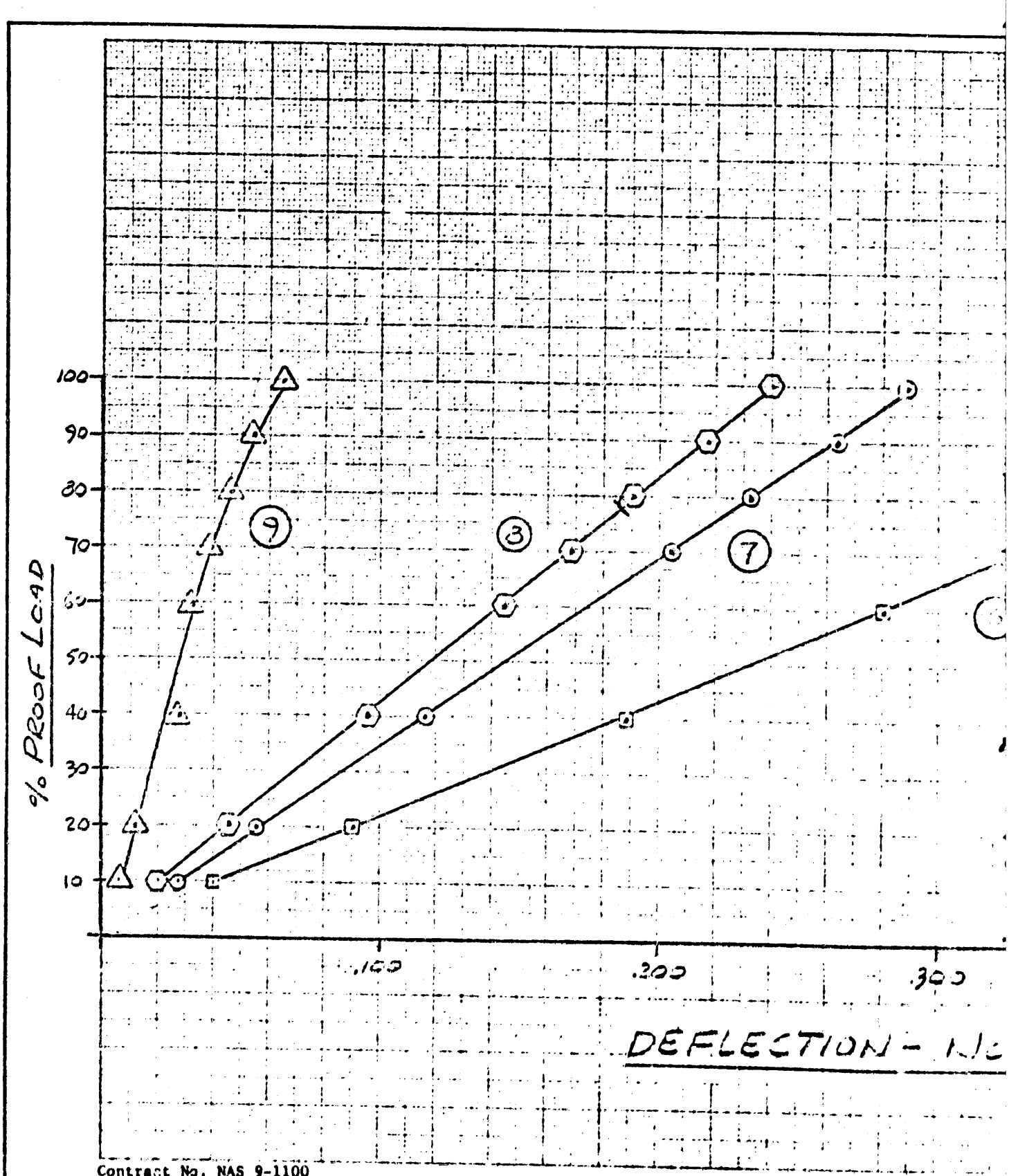
DEPLOYMENT TRUSS
DATA SHEET

DATE: 9-10-65
TEST CONDITION: POSITION II
TEMP. AMBIENT

PROOF %	PROOF LOAD	JACK PRESS. (psi)	LOAD CELL CAL.	LOAD CELL READING	DIAL RE				
					1	2	3	4	5
0	0	0	1.58#/μin/in.	965	+0	+0	+0	+0	+0
10	580	—	—	600	—	—	—	—	—
20	1160	170		235	.113	.072	.057	0	.026
30	1740	—	—	-130	—	—	—	—	—
40	2320	349		-495	.218	.142	.115	.005	.049
50	2900	—	—	-860	—	—	—	—	—
60	3480	519		-1225	.316	.214	.171	.012	.072
70	4060	600		-1590	.366	.248	.199	.014	.092
80	4640	685		-1955	.418	.284	.225	.017	.094
90	5220	775		-2320	.470	.320	.253	.020	.107
100	5800	867		-2685	.601	.420	.346	.037	.160

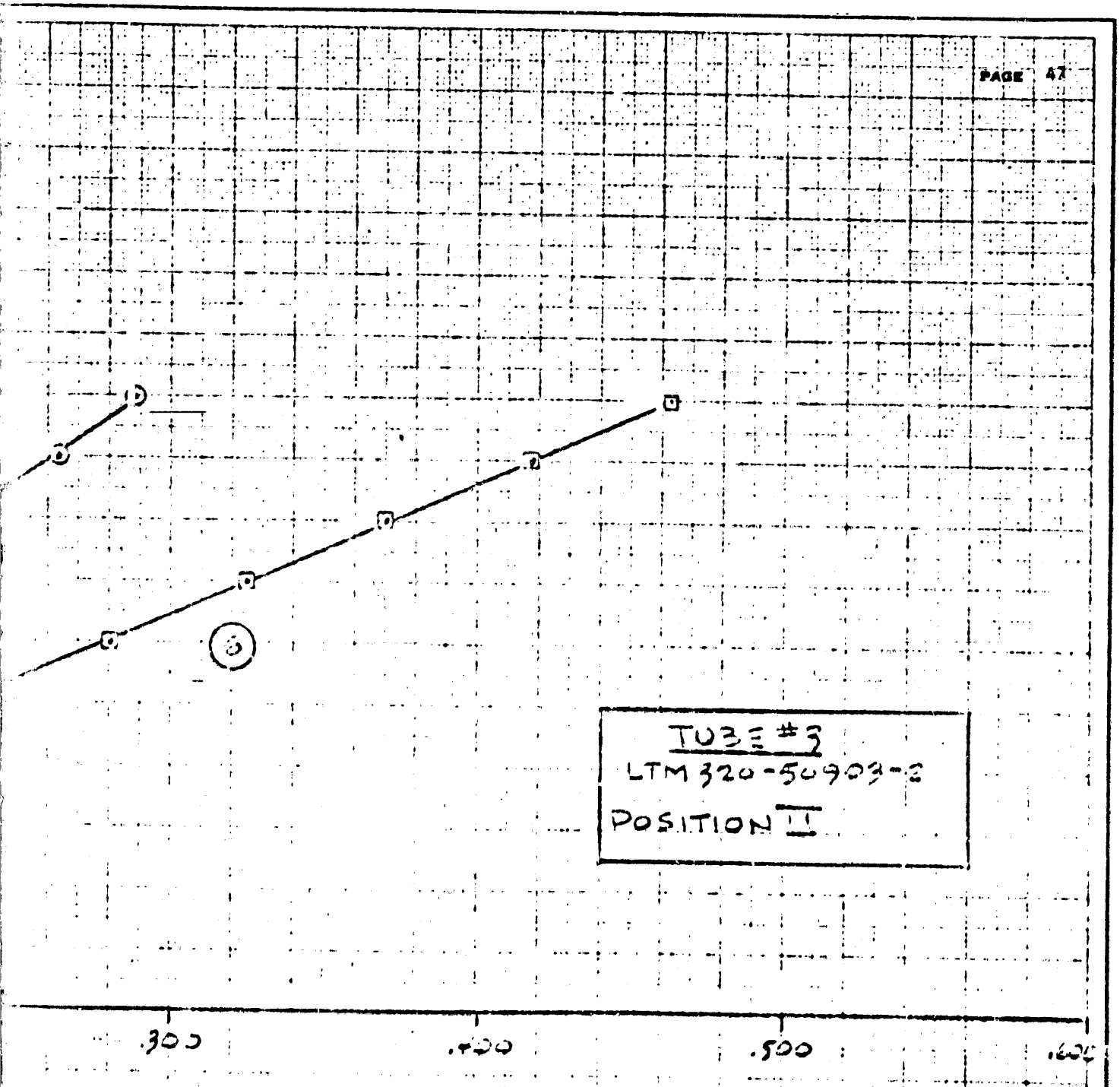
PLOYMENT TRUSS
DATA SHEET

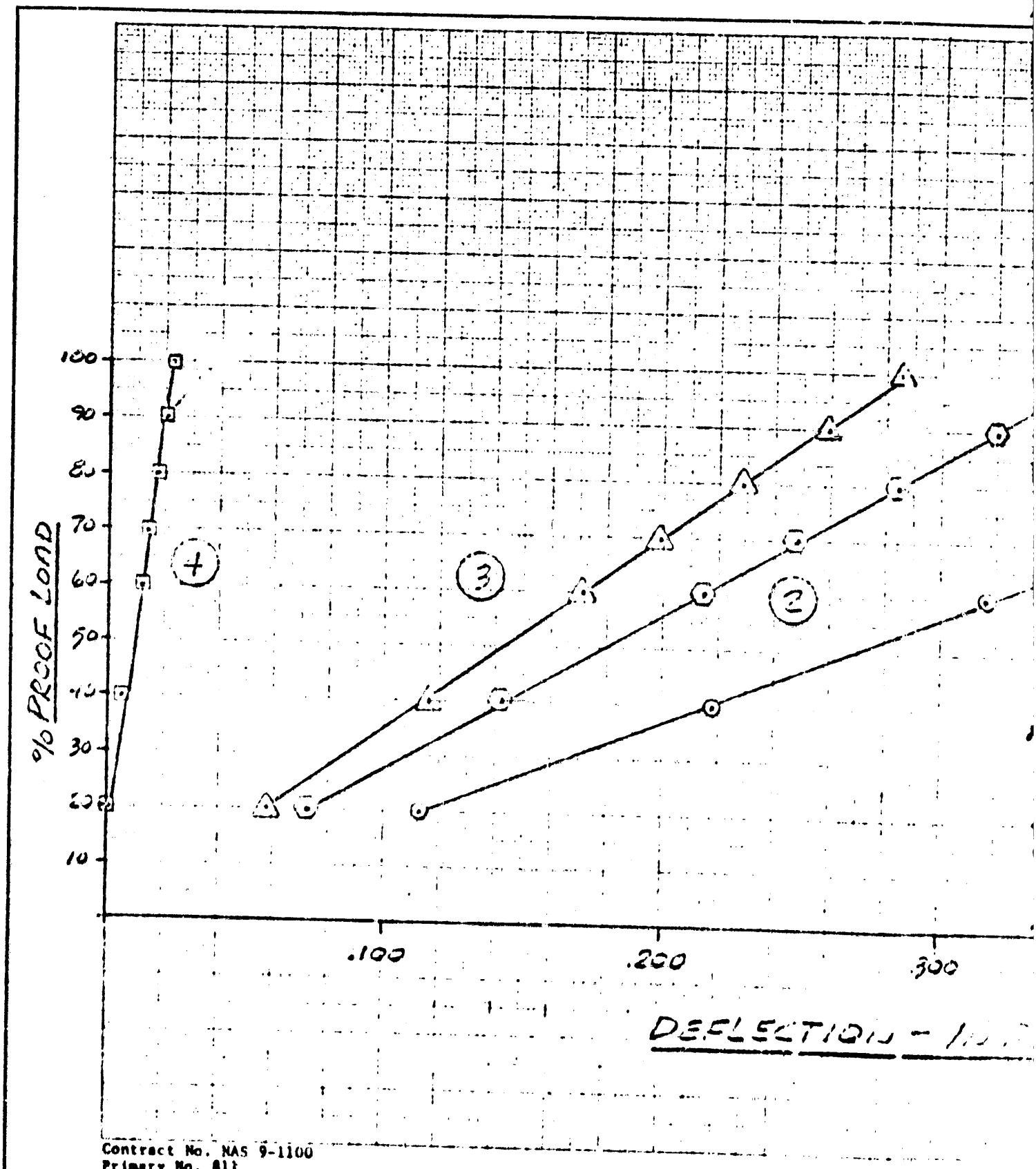
DIAL READING - DEFLECTION										
2	3	4	5	6	7	8	9	10	11	12
+0	+0	+0	+0	+0	+0	+0	+0	-0	+0	+0
—	—	—	—	—	—	—	—	—	—	—
.072	.057	0	.026	.090	.054	.045	.012	.004	.007	.010
—	—	—	—	—	—	—	—	—	—	—
.142	.115	.005	.049	.189	.116	.096	.023	.009	.015	.021
—	—	—	—	—	—	—	—	—	—	—
.214	.171	.012	.072	.230	.176	.145	.032	.013	.022	.031
.248	.191	.014	.082	.324	.204	.168	.039	.016	.026	.036
.284	.225	.017	.094	.370	.233	.191	.046	.019	.030	.041
.320	.253	.020	.107	.417	.264	.217	.054	.024	.035	.047
.420	.346	.037	.160	.452	.255	.240	.065	.030	.146	.070



Contract No. NAS 9-1100
Primary No. 811

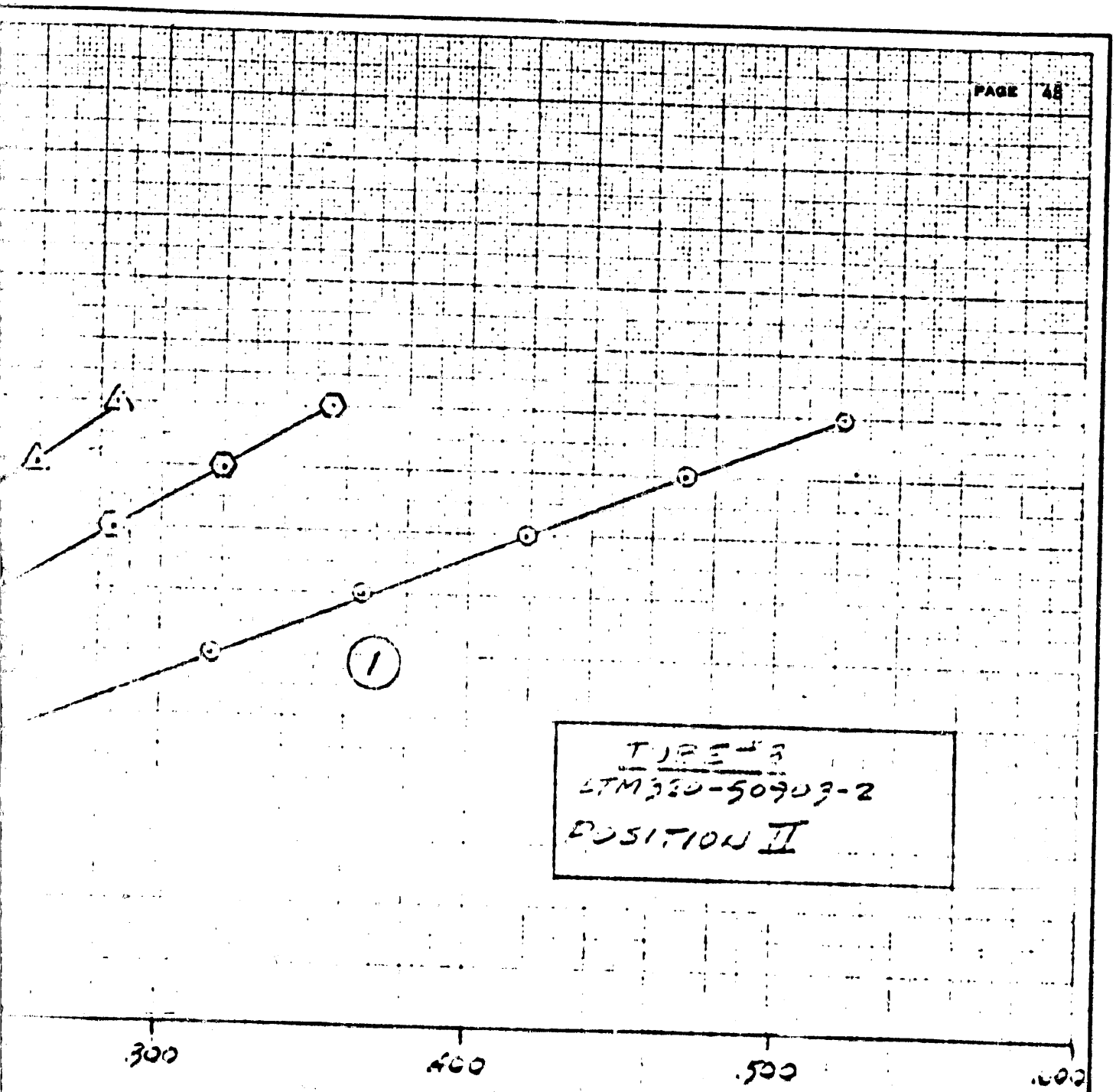
GRUMMAN AIRCRAFT ENGINEERING


TUBE #3
LTM 320-50903-2
POSITION II
.300
.400
.500
.600
TION - NORMAL TO END PINS



Contract No. NAS 9-1100
Primary No. 811

GRUMMAN AIRCRAFT ENGINEERING CO


1
TYPE-3
LTM330-50903-2
POSITION II
.300
.400
.500
.600

DEPLOYMENT TRUSS
DATA SHEET

DATE: 9-17-65
TEST CONDITION: CONFIGURATION III
AMBIENT

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
					1	2	3		
0	0	0	1.58#/4.in/in	10120	-0	+0	+0	+0	+0
10	700	115		9677	.001	.025	.031	.051	.04
20	1400	237		9234	.002	.039	.054	.102	.11
30	2100	352		8791	.003	.055	.061	.129	.16
40	2800	470		8348	.005	.067	.076	.168	.22
50	3500	585		7905	.006	.079	.090	.205	.29
60	4200	700		7462	.008	.090	.103	.240	.35
70	4900	815		7019	.009	.099	.113	.273	.41
80	5600	930		6576	.011	.108	.123	.305	.46
90	6300	1043		6133	.013	.112	.129	.334	.52
100	7000	1158		5690	.015	.114	.132	.354	.57

EPLOYMENT TRUSS

[illegible]

	2	3	[illegible]	5	6	7	[illegible]	[illegible]	11	10	12
0	+0	+0	+0	+0	+0	+0	+0	+0	+0	-0	+0
01	.025	.031	.051	.043	.014	.016	.005	.027	.006	—	.005
02	.039	.054	.102	.116	.058	.045	.010	.030	.015	.015	.012
03	.055	.061	.129	.168	.081	.075	.013	.040	.021	.022	.017
05	.067	.076	.168	.229	.115	.105	.018	.054	.029	.030	.024
06	.079	.090	.205	.291	.149	.135	.022	.068	.037	.037	.033
8	.090	.103	.240	.351	.180	.163	.025	.081	.045	.045	.039
7	.099	.113	.273	.410	.214	.192	.031	.095	.052	.053	.046
1	.108	.123	.305	.466	.244	.218	.034	.108	.060	.060	.053
3	.112	.129	.334	.524	.277	.245	.039	.123	.068	.067	.060
5	.114	.132	.359	.577	.304	.272	.043	.137	.078	.076	.067

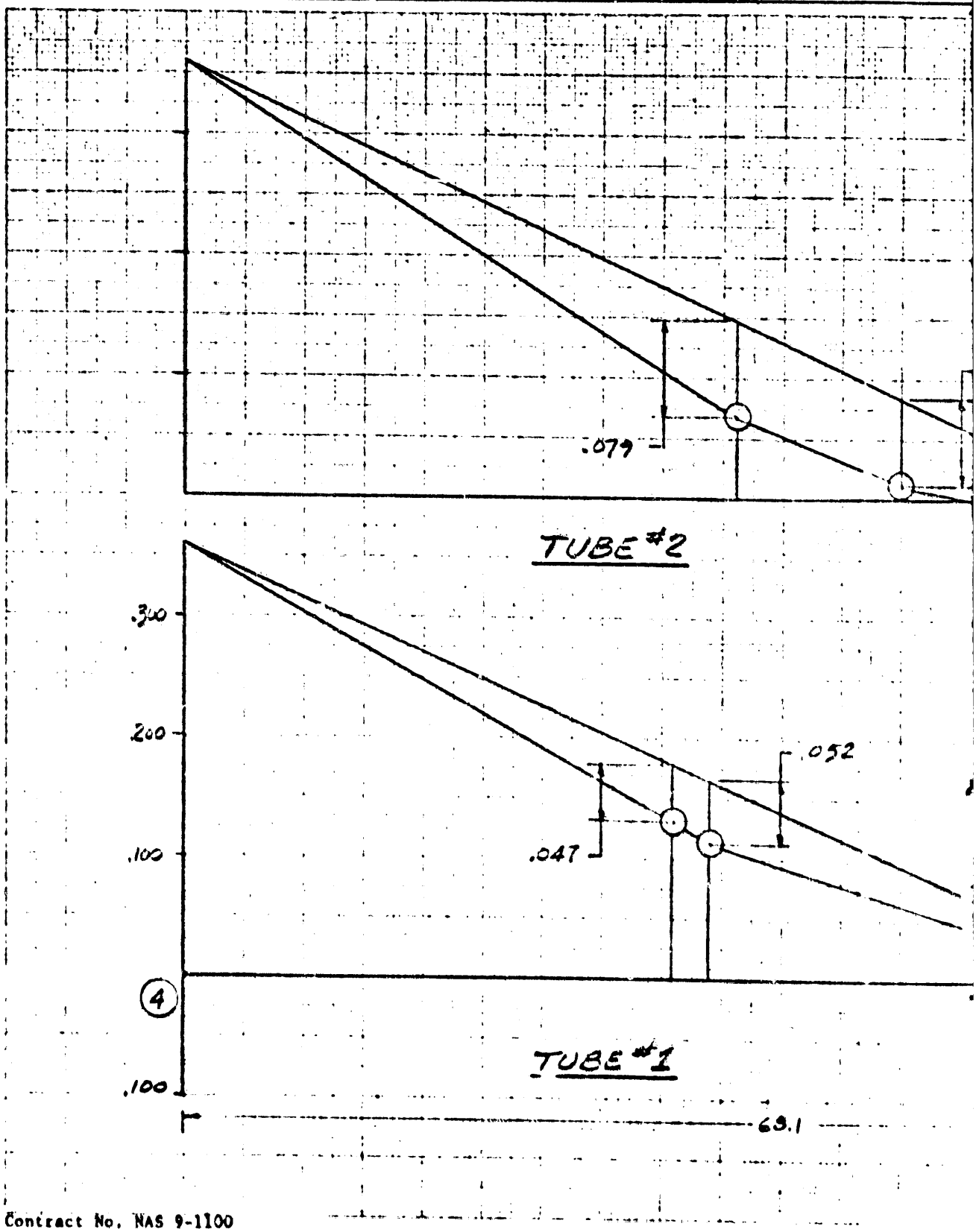
DEPLOYMENT TRUSS
DATA SHEET

DATE 9-24-65
TEST CONDITIONS POSITION III
AMBIENT

[illegible]	[illegible]	[illegible]	[illegible]	LOAD CELL READING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	0	0	1.58#/4.4M/IN.	10360	-0	+0	+0	+0	+0
10	700	124		9917	.017	.019	.034	.081	.08
20	1400	236		9474	.018	.022	.044	.117	.14
30	2100	350		9031	.019	.027	.056	.153	.20
40	2800	405		8588	.020	.030	.065	.189	.26
50	3500	576		8145	.021	.032	.072	.220	.31
60	4200	680		7702	.022	.032	.077	.251	.37
70	4900	805		7259	.024	.033	.081	.281	.43
80	5600	922		6816	.025	.031	.081	.307	.43
90	6300	1035		6373	.027	.025	.075	.332	.54
100	7000	1150		5930	.029	.013	.068	.357	.6

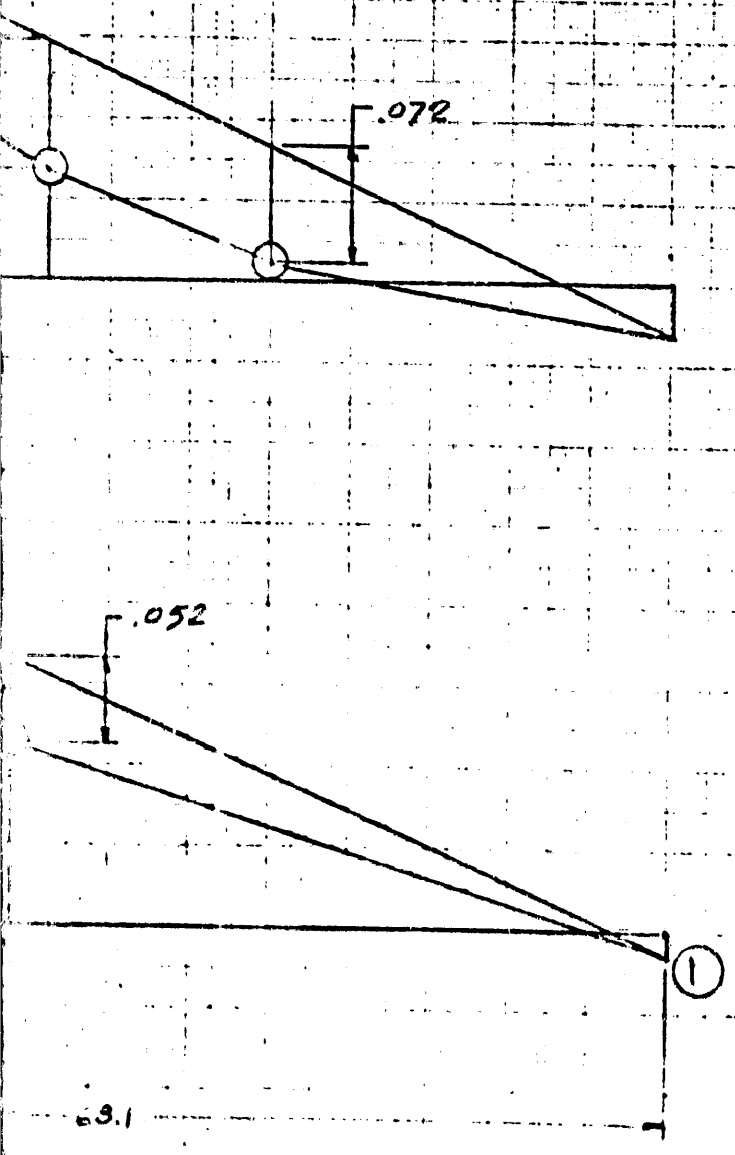
DYMENT TRUSS
ATA SHEET

+0	+0	+0	+0	+0	+0	+0	+0	+0	+0	—
.019	.034	.081	.086	.044	.044	.003	.113	.010	.004	—
.022	.044	.117	.144	.087	.067	.003	.124	.016	.008	—
.027	.056	.153	.206	.124	.101	.004	.134	.024	.013	—
.030	.065	.189	.260	.165	.135	.008	.145	.031	.018	—
.032	.072	.220	.316	.209	.170	.012	.156	.037	.024	—
.032	.077	.251	.373	.258	.207	.017	.169	.048	.029	—
.033	.081	.281	.431	.314	.256	.022	.180	.055	.035	—
.031	.081	.307	.488	.376	.307	.028	.191	.064	.042	—
.025	.075	.332	.544	.452	.371	.034	.202	.071	.048	—
.013	.062	.357	.606	.562	.461	.043	.214	.078	.054	—

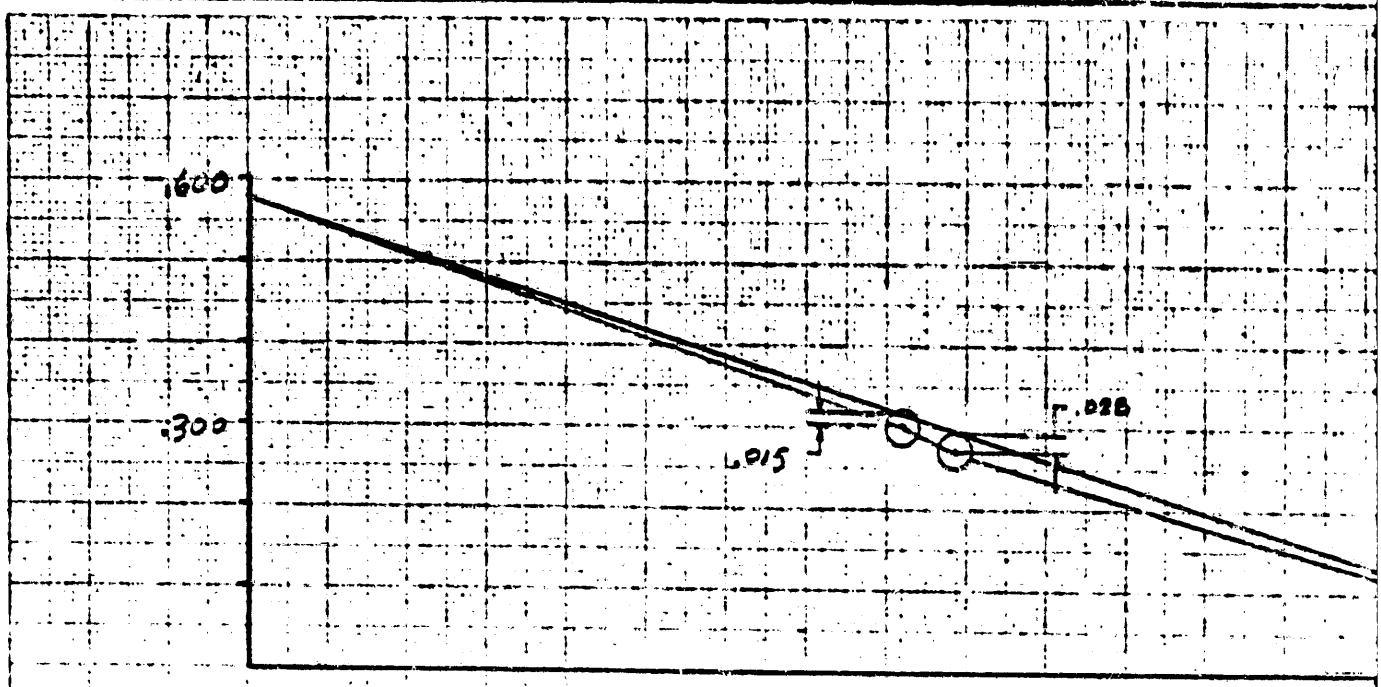


Contract No. NAS 9-1100
Primary No. 811

GRUMMAN AIRCRAFT ENGINEERING



PROOF LOAD
DEFLECTION - NORMAL
TO END PINS



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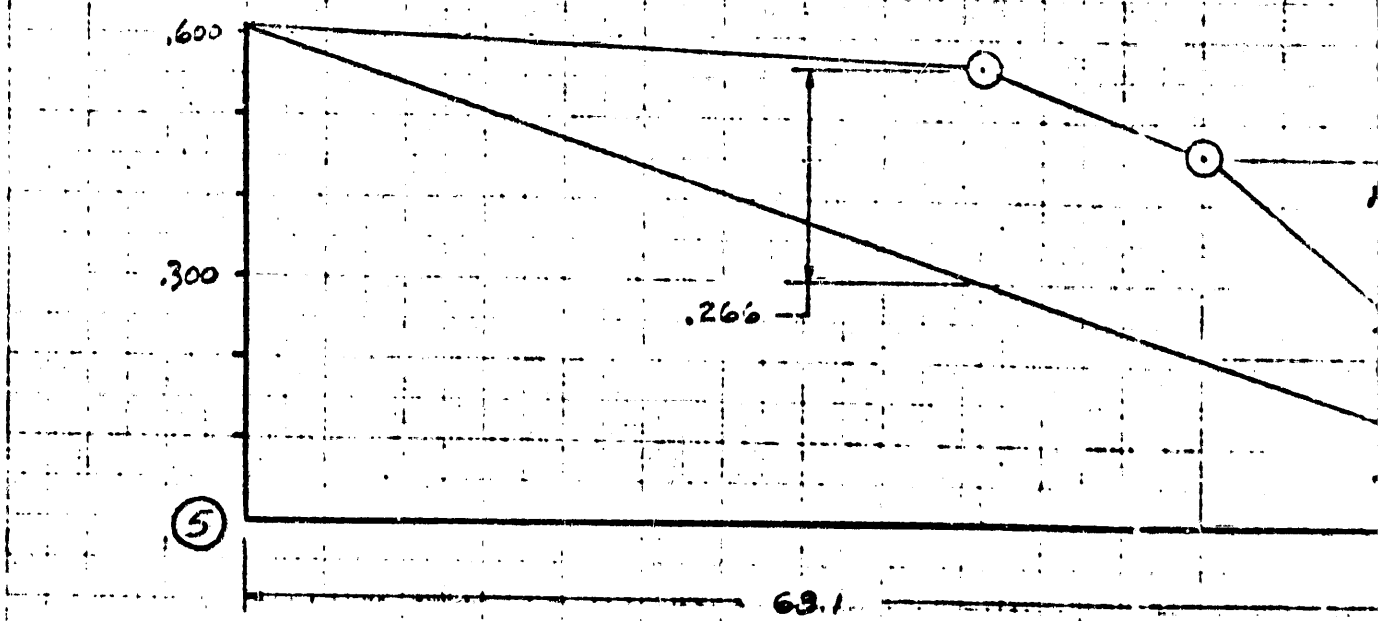
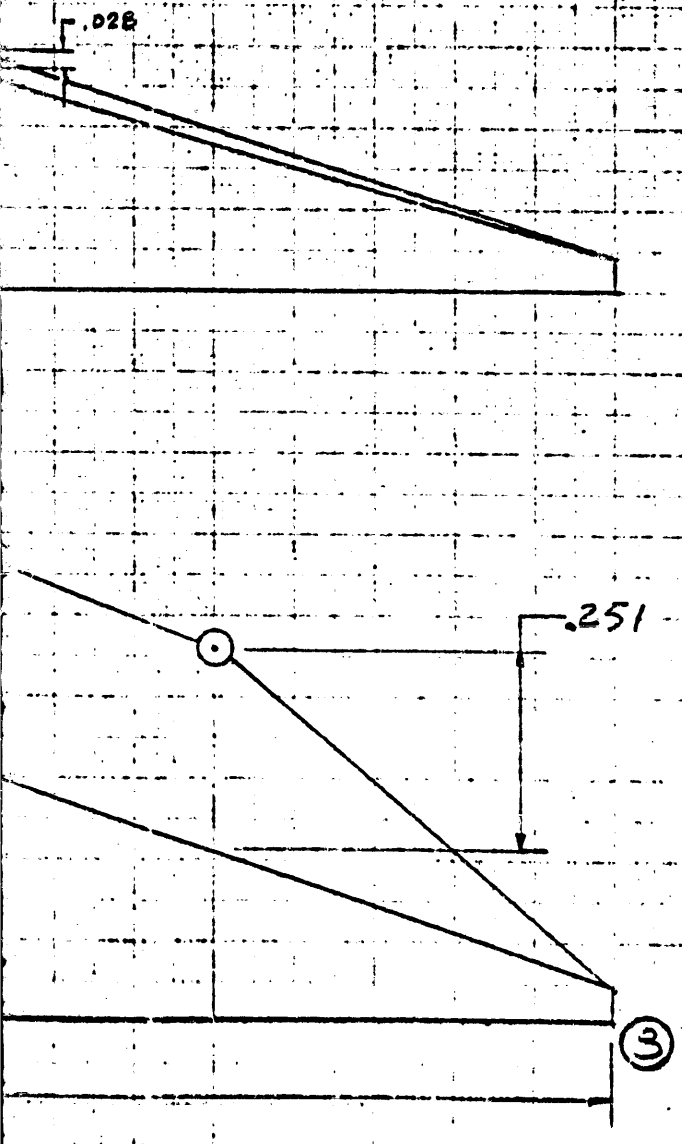


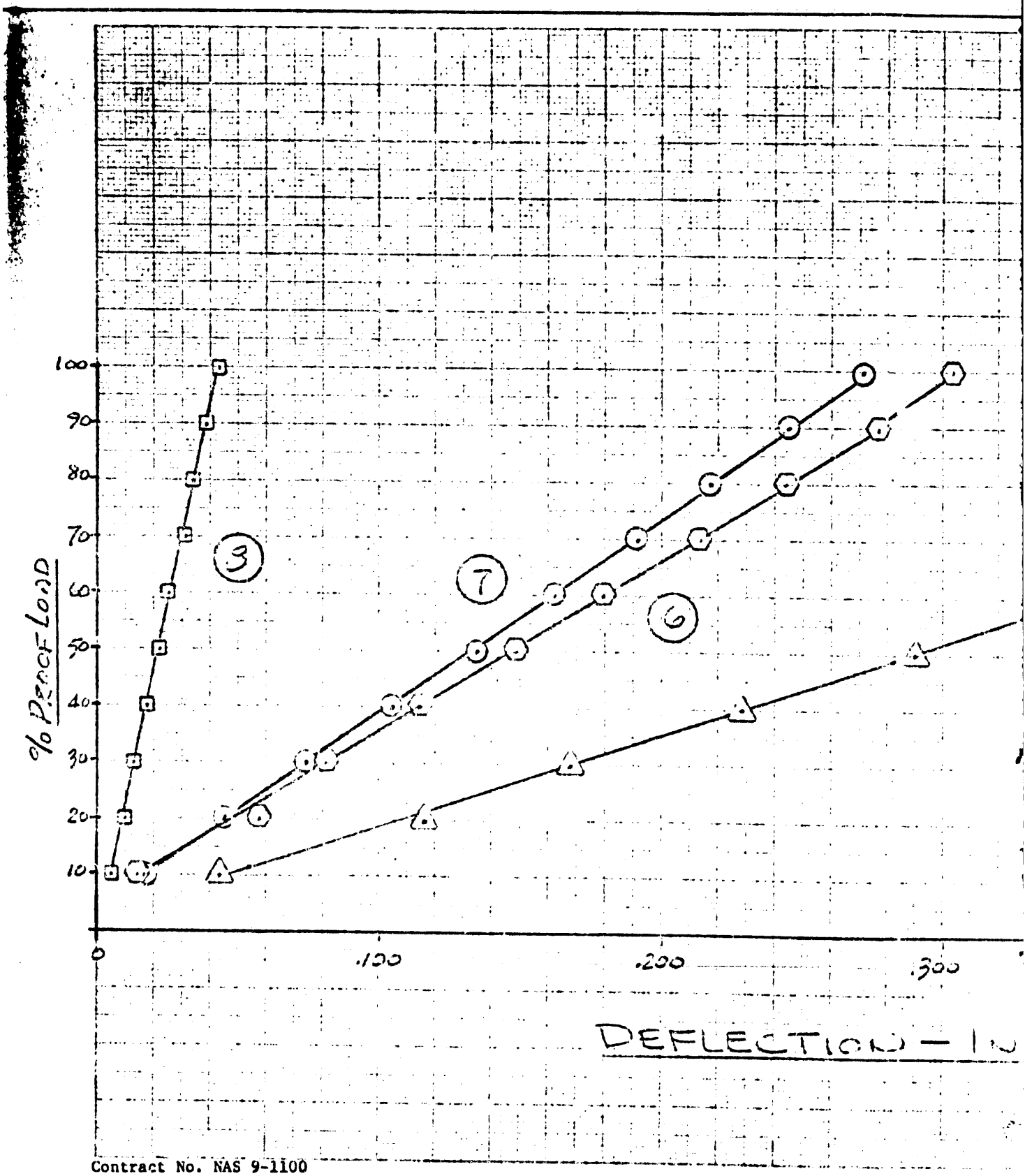
TUBE #2

Contract No. NAS 9-1100
Primary No. 611

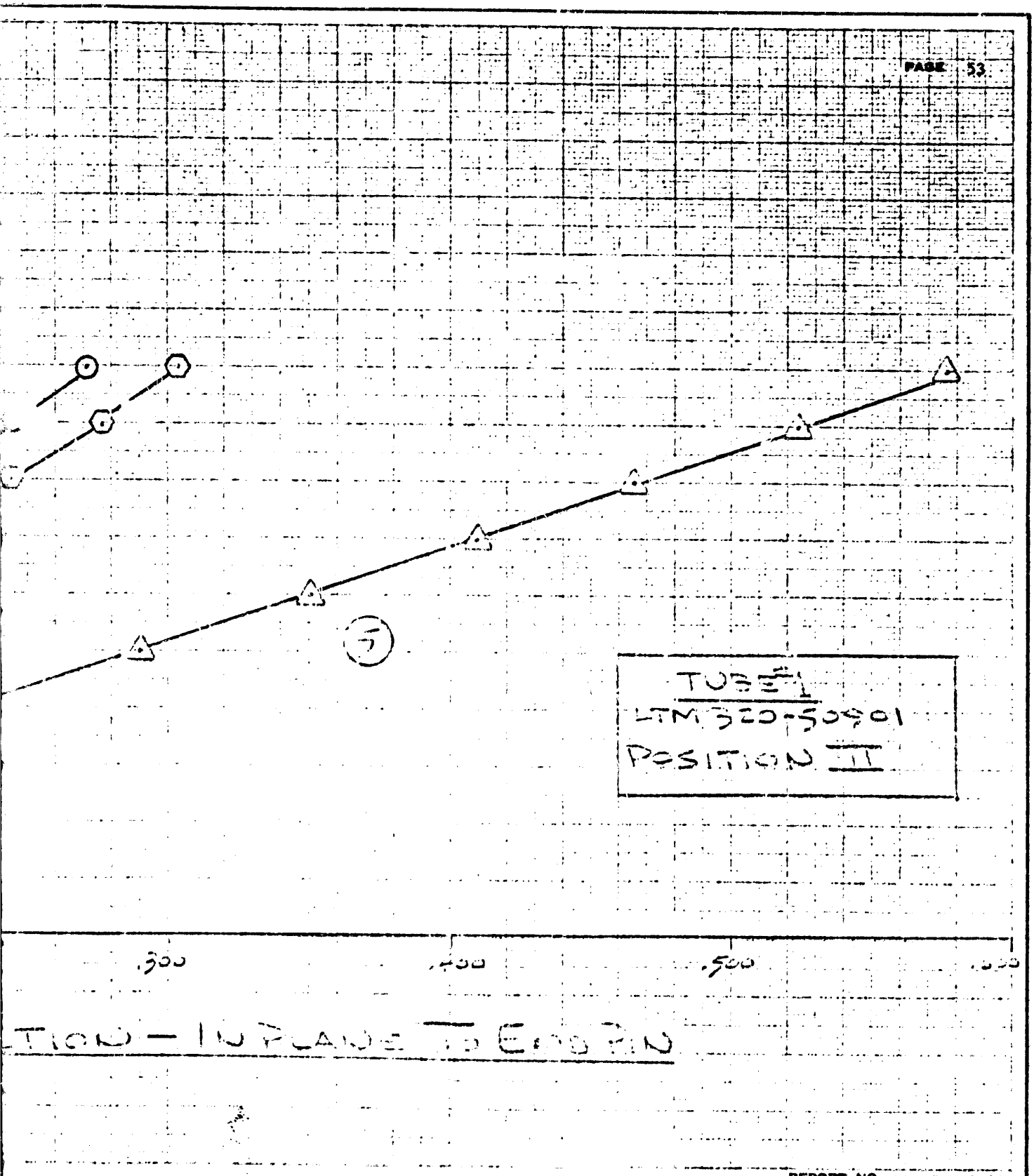


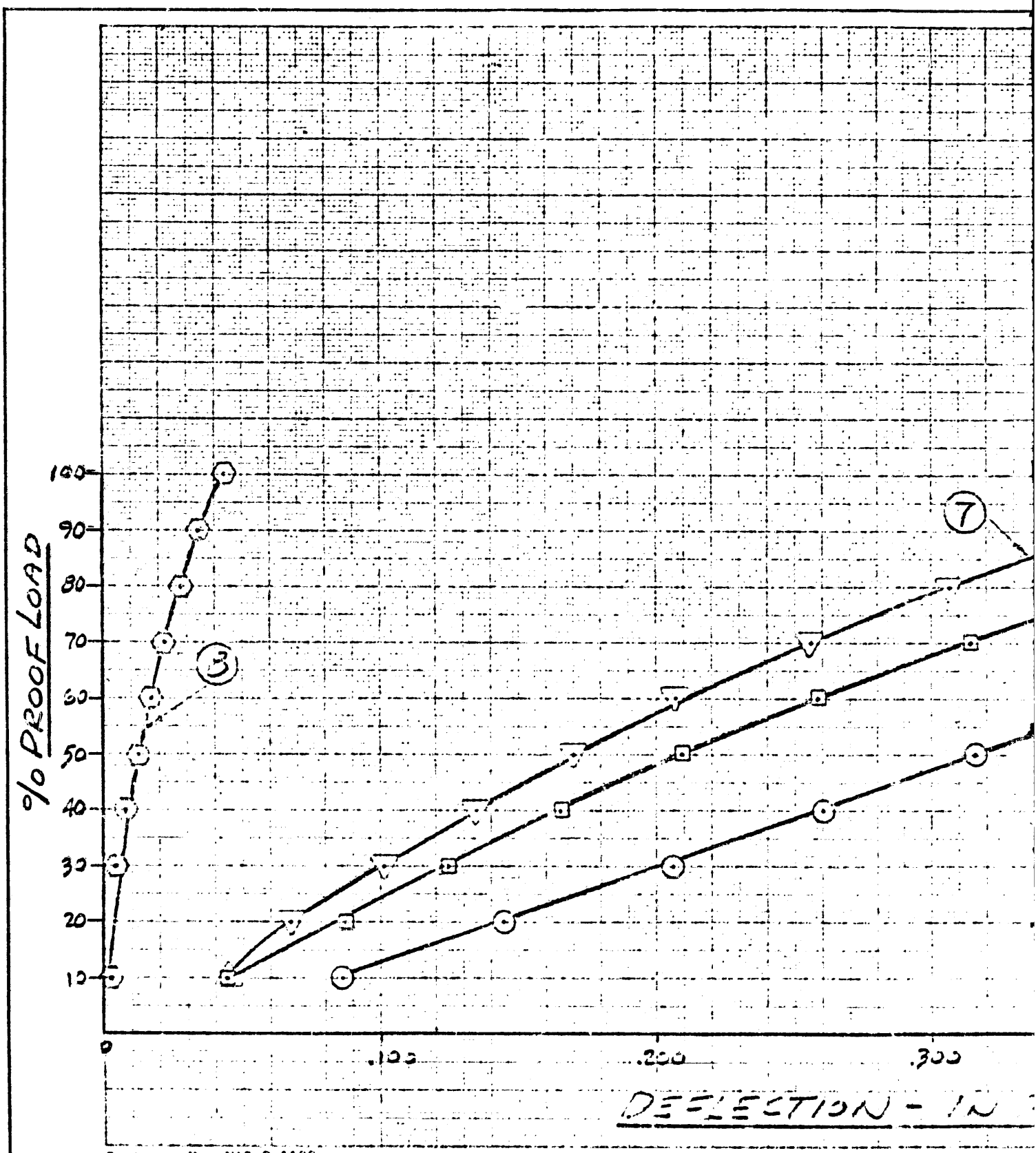
PROOF LOAD
DEFLECTION - IN PLANE

V1



Contract No. NAS 9-1100
Primary No. 811


5
TUBE 1
LTM 320-50901
POSITION II
.300
.400
.500
TION — IN PLANE TO END PIN



Contract No. NAS 9-1100
Primary No. 811

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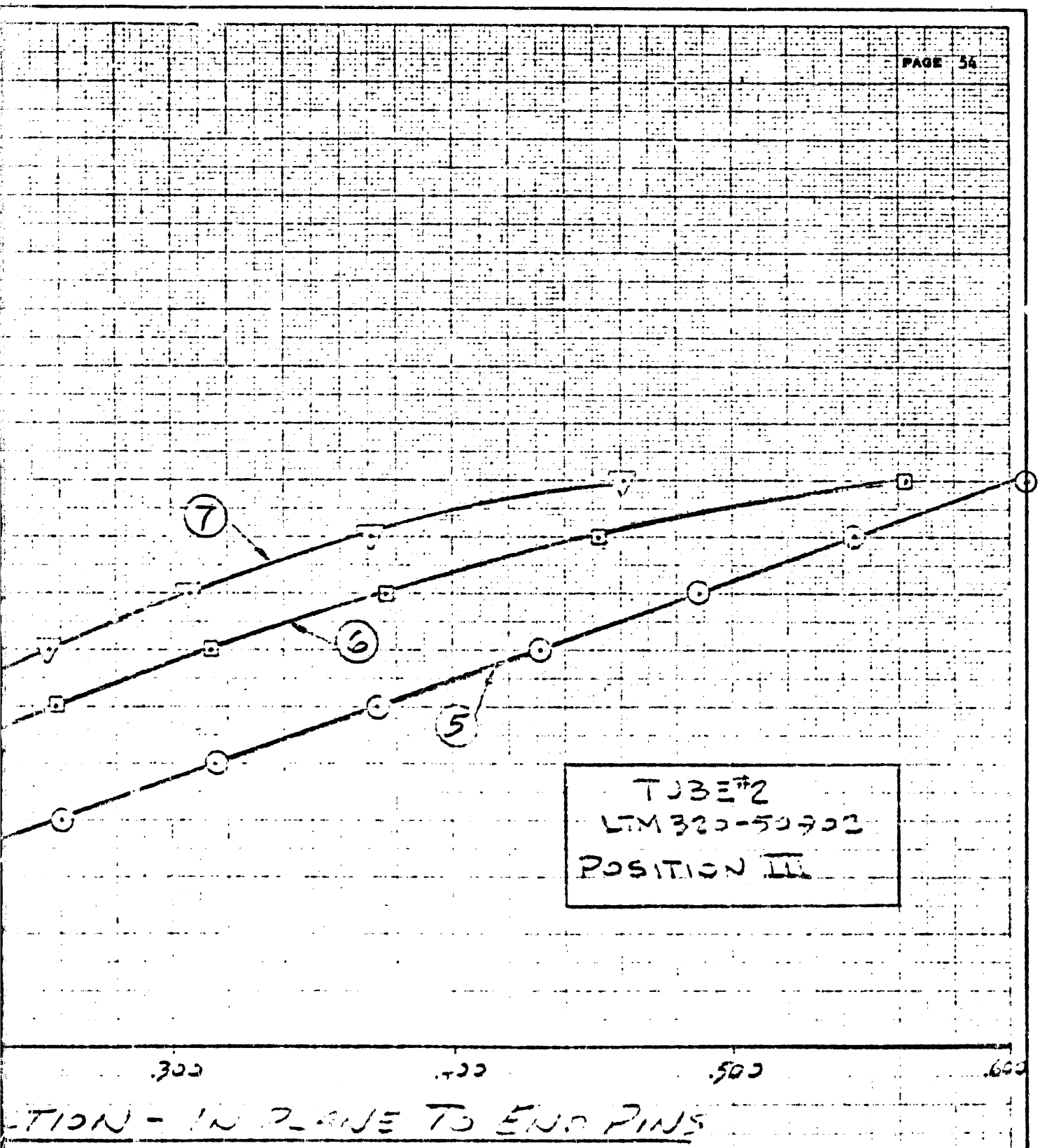
K+E ALBANENE 1967


7
6
5
TUBE #2
LTM 320-50902
POSITION III
.300
.400
.500
.600
TION - IN PLANE TO END PINS

DEPLOYMENT TRUSS

9-13-65

IV

200°F

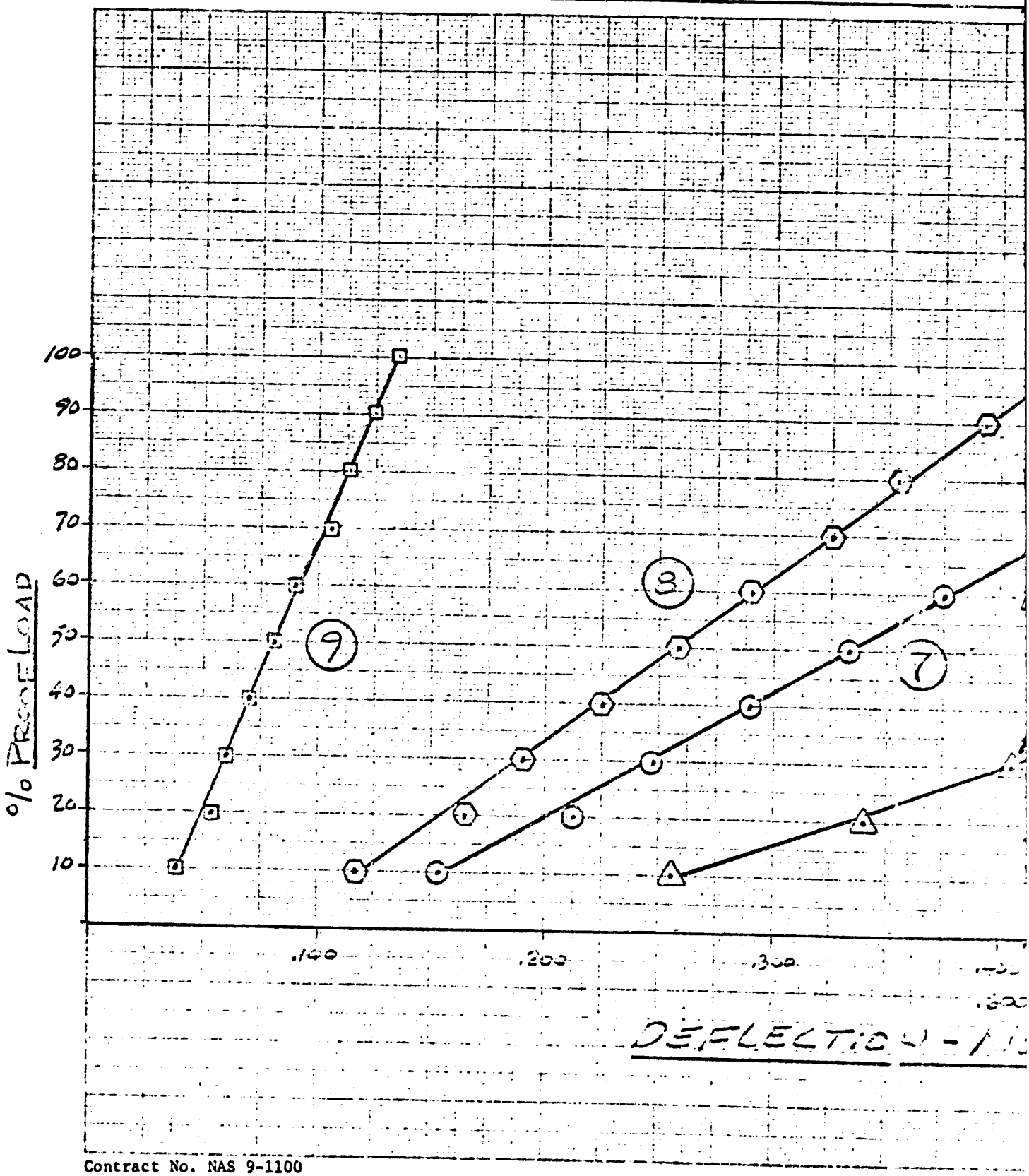
					*				
							3	4	
0	0	0	1.53#/4IN./IN.	10200	-0	-0	-0	-0	-0
10	700	116		—	.130	.077	.056	.001	.001
20	1400	232		—	.199	.127	.099	.003	.015
30	2100	348		8371	.254	.163	.127	.008	.031
40	2800	464		—	.316	.205	.161	.012	.047
50	3500	580		7935	.378	.247	.195	.016	.063
60	4200	699		7542	.439	.289	.229	.020	.074
70	4900	812		7099	.500	.330	.264	.025	.095
80	5600	928		6656	.566	.374	.301	.030	.112
90	6300	1039		6213	—	—	.509	.072	.150
100	7000	1158		5770	—	—	—	.037	

* COMBINING

MENT TRUSS

* DIAL READING - DEFLECTION										
	3	4	5	6	7	8	9	10	11	12
0	-0	-0	-0	-0	-0	-0	-0	+0	-0	-0
77	.056	.001	.001	.256	.153	.117	.033	0	.004	.006
27	.099	.003	.015	.340	.212	.165	.054	.003	.009	.011
63	.127	.008	.031	.407	.247	.191	.059	.008	.014	.018
05	.161	.012	.047	.474	.239	.225	.070	.013	.019	.024
47	.195	.016	.063	.546	.332	.259	.081	.017	.024	.029
33	.229	.020	.079	.614	.375	.292	.092	.020	.029	.034
30	.264	.025	.095	.684	.418	.325	.106	.023	.034	.041
74	.301	.030	.112	.760	.465	.356	.165	.026	.040	.047
—	.509	.072	.153	.891	.570	.452	.209	—	.066	.108
—	—	.037		.999	.644	.513	—	—	—	.122

* COMBINING RUN 1 & 2



Contract No. NAS 9-1100
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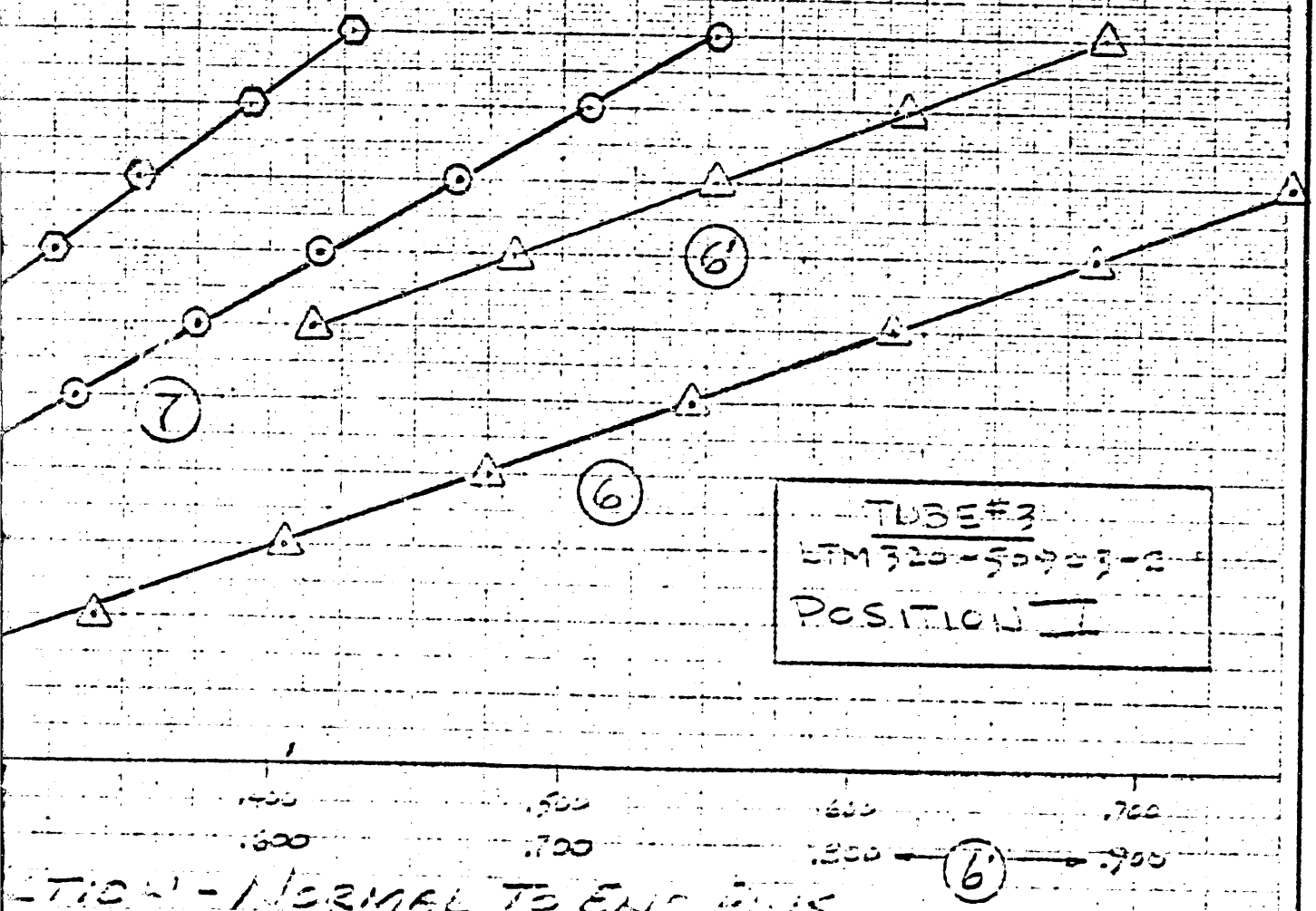
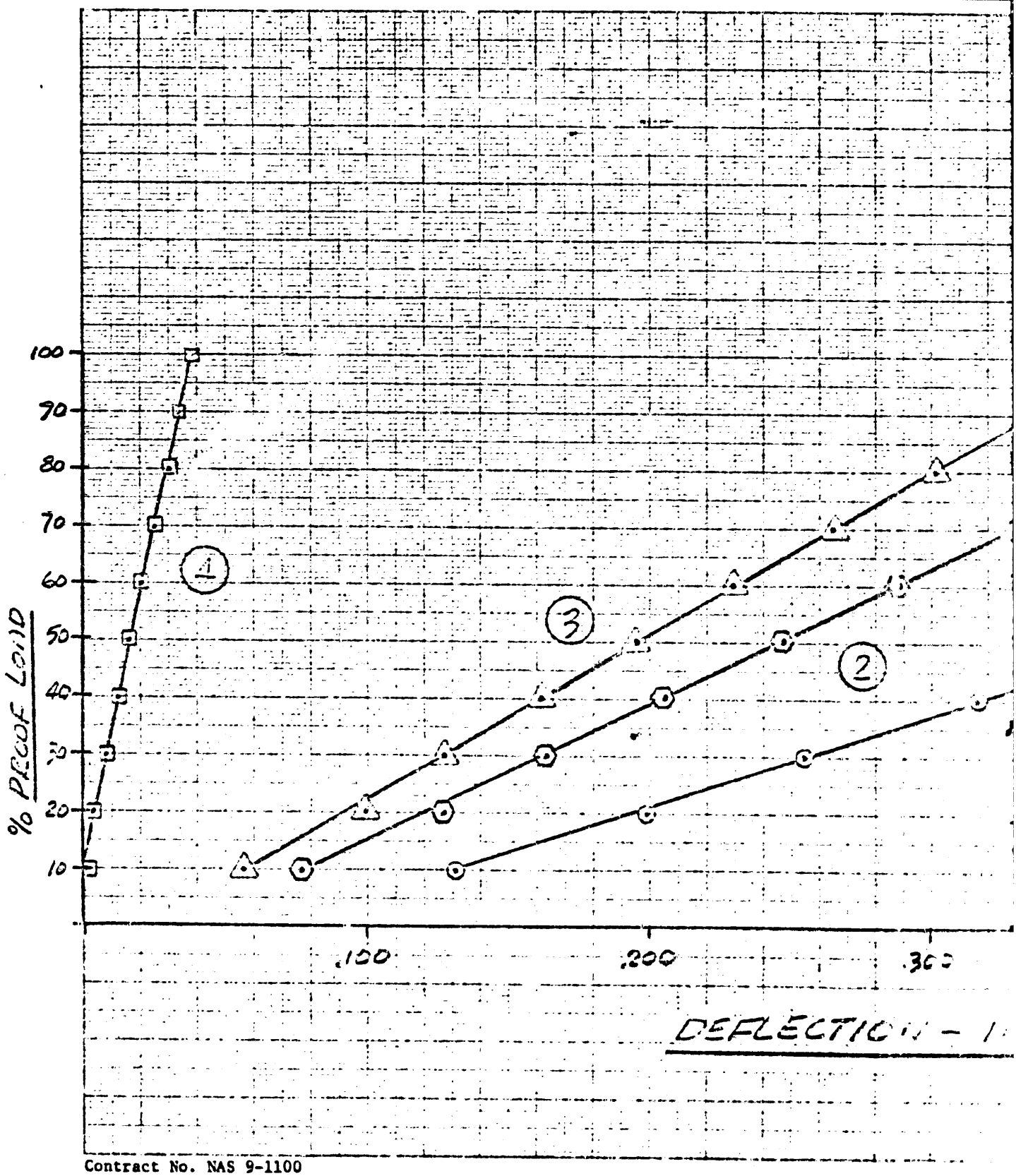


LTION - NORMAL TO END PLATE



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Primary No. 811

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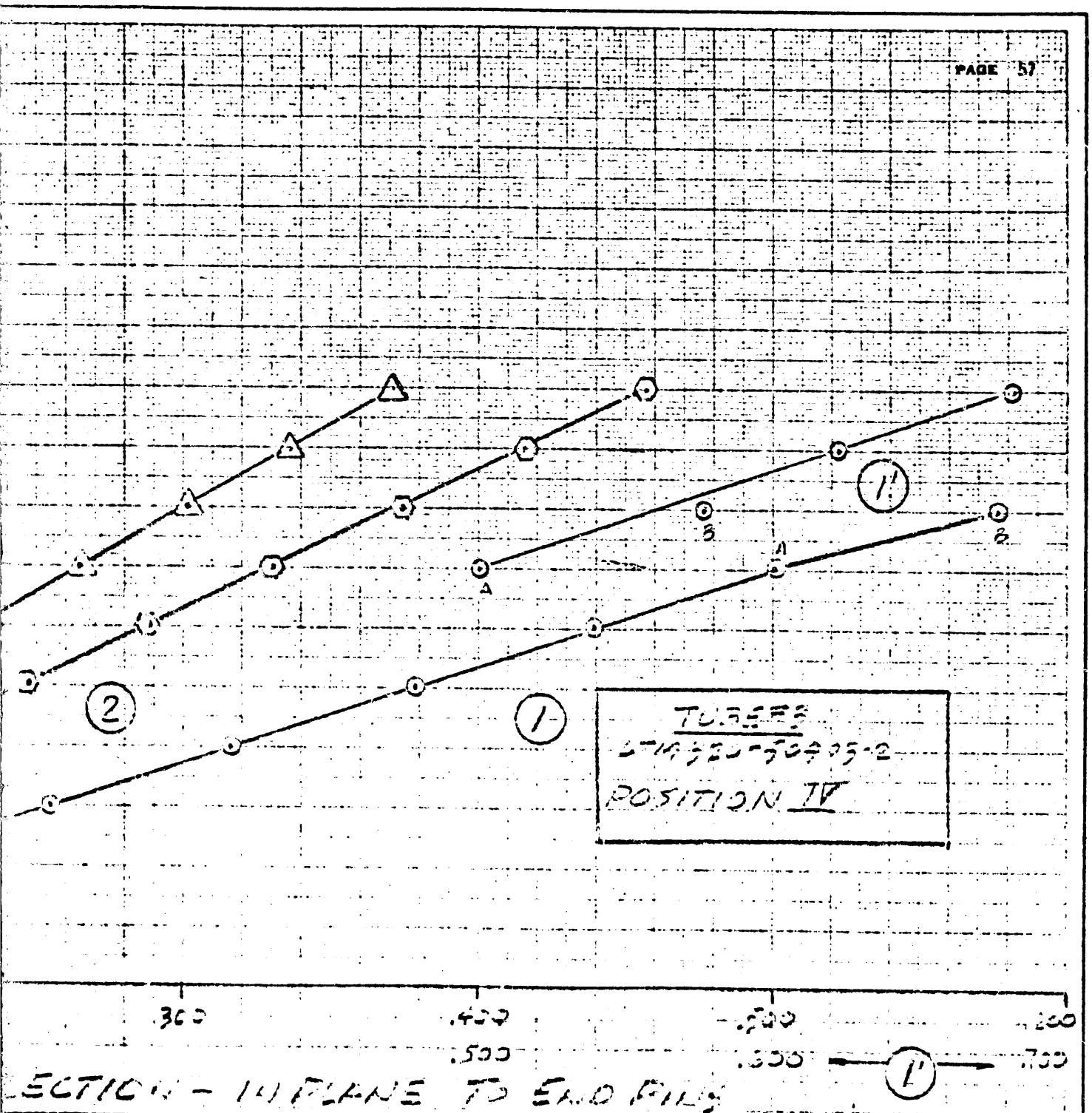


ECTION - IN PLANE TO END PILE

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION M - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-[illegible]707

PREPARED BY:
R. Gartenschlaeger

CHECKED BY:
R. L. Makemson

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION M - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10707

INTRODUCTION

This section of the report contains the results of all tests conducted on the LEM Landing Gear Footpad LSK-320-10707. It was concluded that the addition of the circumferential strap resulted in no significant improvement in the energy absorption characteristics of the footpad.

This was a continuation of the footpad development program. The results of previous tests were presented in Section D and Section J of this report.

Refer to LTP 904-10001, Section M - Plan for the Static Test of the LEM Landing Gear Footpad LSK 320-10707.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION M - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10707

1.0 PURPOSE OF TEST

1.1 The purpose of this test was to investigate the effects on the load-stroke characteristics of the Landing Gear Footpad when modified by the addition of a circumferential strap.

2.0 DESCRIPTION OF TEST SPECIMEN

2.1 Two footpads were supplied conforming to the assembly shown on Dwg. LSK 320-10707. The footpad basic structure was identical to that of the LSK 320-10704 pad described in Section J of this report. However, these pads were modified by the addition of a stainless steel (301-1/4 hard) circumferential strap (13/16 inch wide and 0.015 inch thick). Of the two footpads supplied for this test, only one was used, for the reason stated in Paragraph 5.1 of this report.

3.0 TEST CONDITIONS

3.1 All tests were performed under ambient environmental conditions In all tests, the pad was installed in a horizontal attitude. During these tests, no attempt was made to attain a specific rate of loading but rather a uniform rate of loading. The pads were crushed into hard fixed bearing surfaces, mounted on the apex of an outside 90° wedge, having the configurations of a 2 inch diameter steel dowl and a 3 inch wide steel flat surface. Refer to test plan for detailed sketch of obstacle configurations.

4.0 TEST SET-UP AND PROCEDURE

4.1 The test set-up and procedure was essentially as described in Test Plan LTP 904-10001, Section M. Prior to the tests, the jig was system calibrated to determine the friction forces inherent in the jig. This calibration resulted in an Applied Load vs. Corrected Load curve which is shown on Figure 1, Page M-5 . A platform was set up tangent to the lowest point of the outer skin to maintain proper orientation of the pad during the test. See photo sequences on Figures 5, 6 and 7. The pad was crushed into obstacle configurations described in Paragraph 3.1 of this report at a slow uniform rate.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

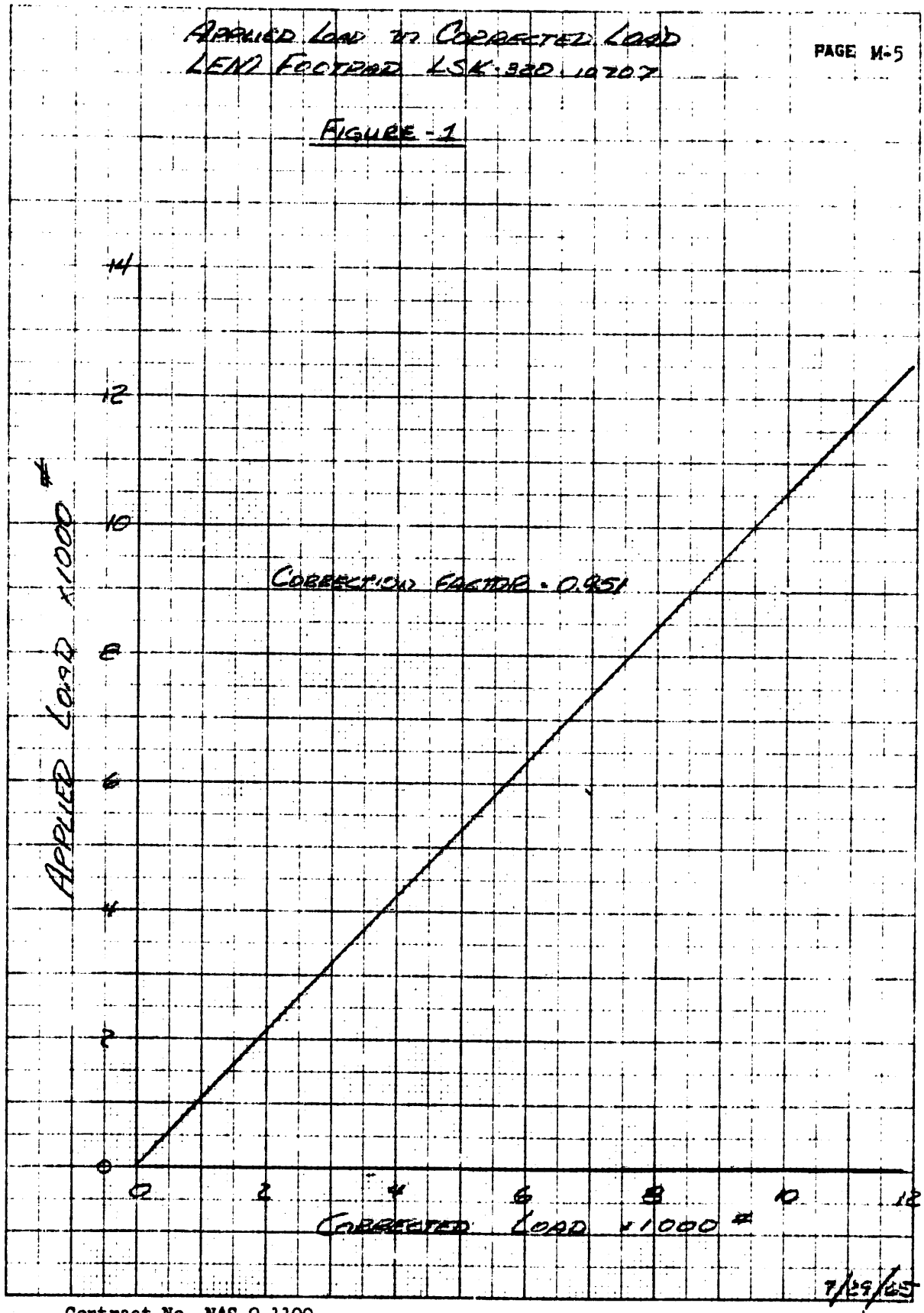
SECTION M - RESULTS OF THE STATIC TEST OF THE LEM LANDING GEAR FOOTPAD LSK-320-10707

5.0 RESULTS AND CONCLUSIONS

5.1 Load-stroke characteristics established during lateral crushing into the obstacle configurations described in Paragraph 3.1 are presented on Figures 2, 3 and 4. (These curves were not corrected because the correction factor was not of significant magnitude.) A comparison of Figures 2 and 3 showed that the addition of a circumferential strap resulted in no significant improvement in the energy absorption characteristics. The primary cause for this was attributed to the relative weakness of the surrounding honeycomb structure. Photograph LPS-560-528 (Run #1) shows that the strap ripped the pad prior to contact with the wedge. It was observed that the strap did not stretch appreciably and did not follow the sides of the wedge during the crushing cycle. For these reasons, it was considered that no significant information would result from testing the second footpad.

APPLIED LOAD VS CORRECTED LOAD
LEM FOOTPAD LSK-320-10707

FIGURE - 1

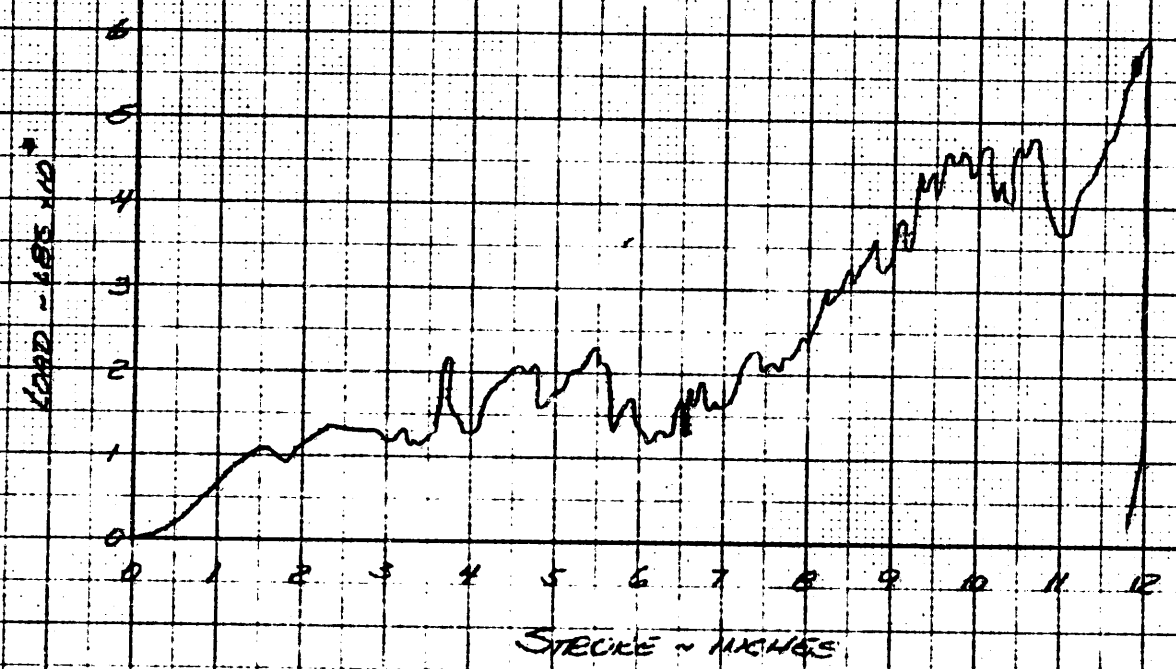


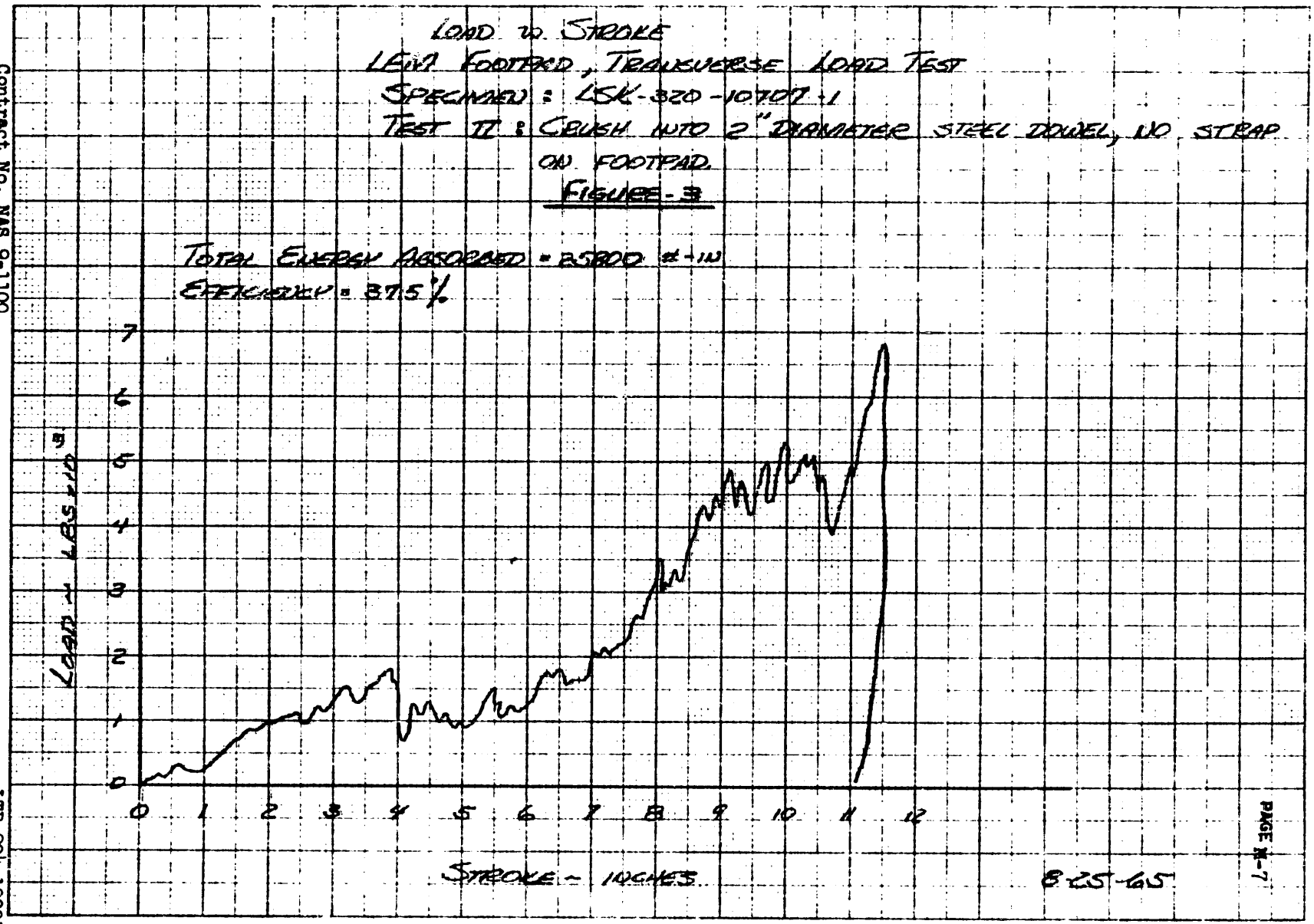
7/29/65

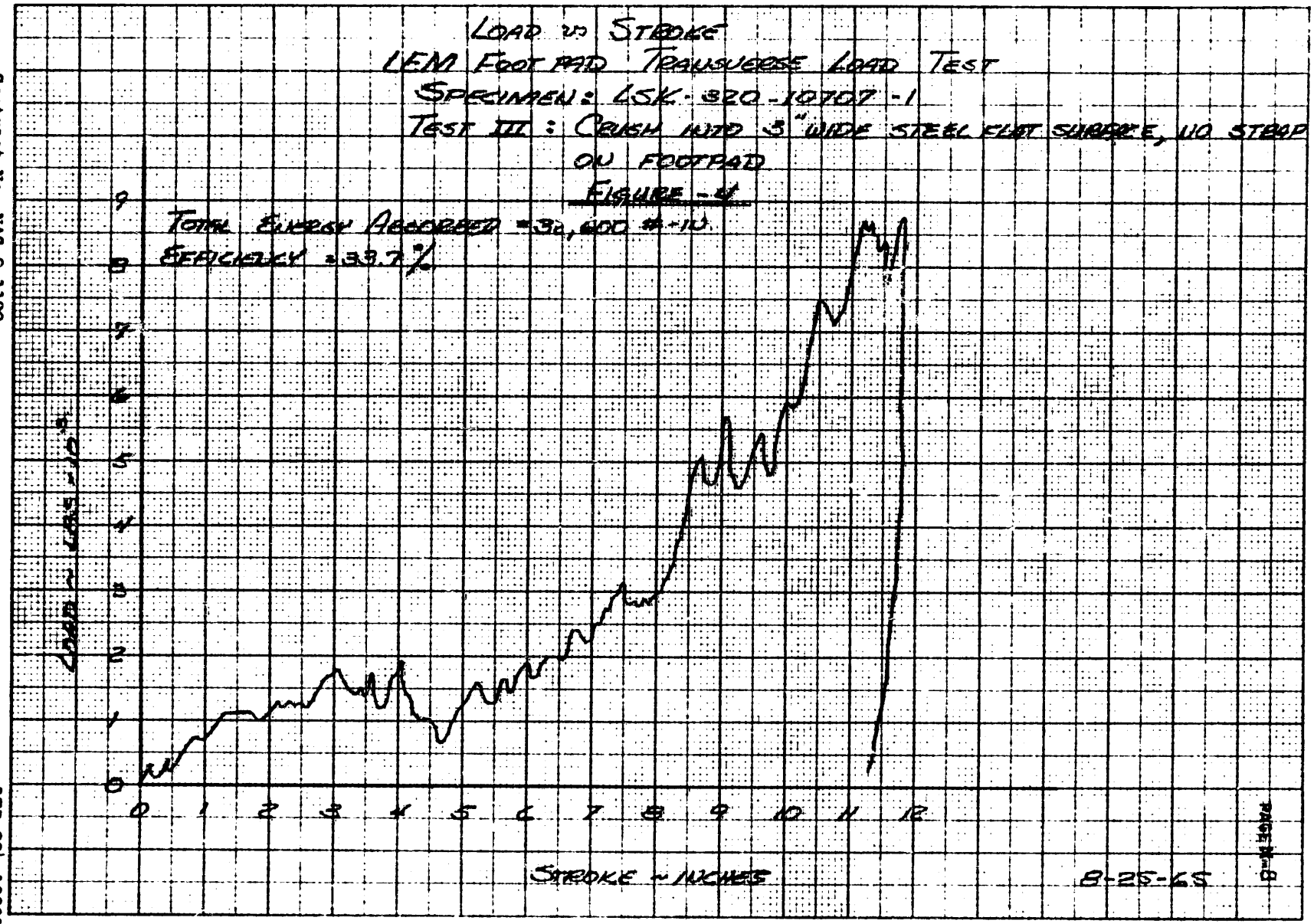
LOAD vs STROKE
LEM FOOTPAD, TRANSVERSE LOAD TESTS
SPECIMEN: LSK-320-10707-1
TEST I: CRUSH INTO 2" DIAMETER STEEL DOWEL, STRAP ON FOOTPAD

FIGURE - 2

TOTAL ENERGY ABSORBED = 29,200 #-IN
EFFICIENCY = 42.6%




LOAD vs. STROKE
LEM FOOTPAD, TRANSVERSE LOAD TEST
SPECIMEN: LSK-320-10707-1
TEST II: CRUSH INTO 2" DIAMETER STEEL DOWEL, NO STRAP ON FOOTPAD.
FIGURE-3
TOTAL ENERGY ABSORBED = 25800 #-IN
EFFICIENCY = 37.5%
LOAD ~ LBS x 10^3
0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
7
8
9
10
11
12
STROKE ~ INCHES
8-25-65



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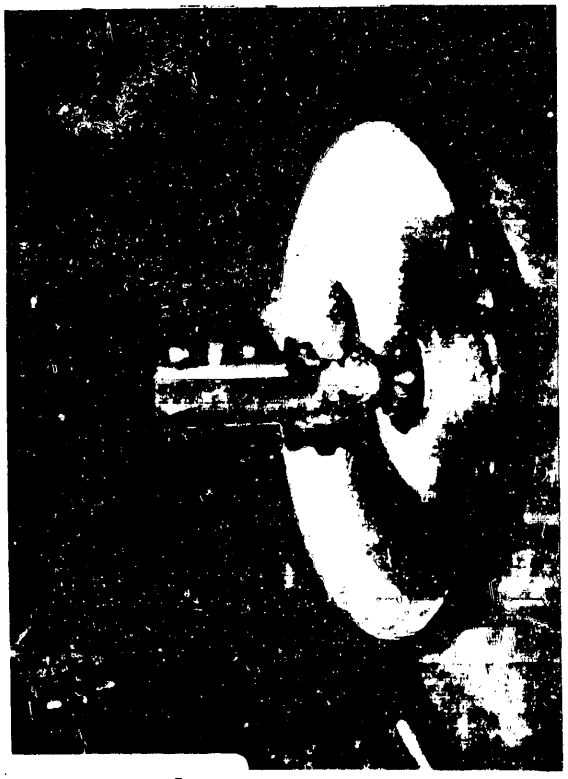
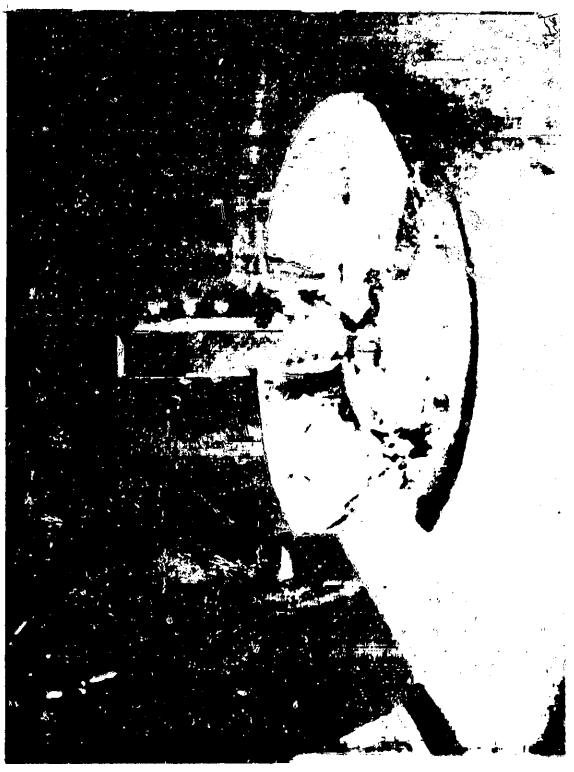
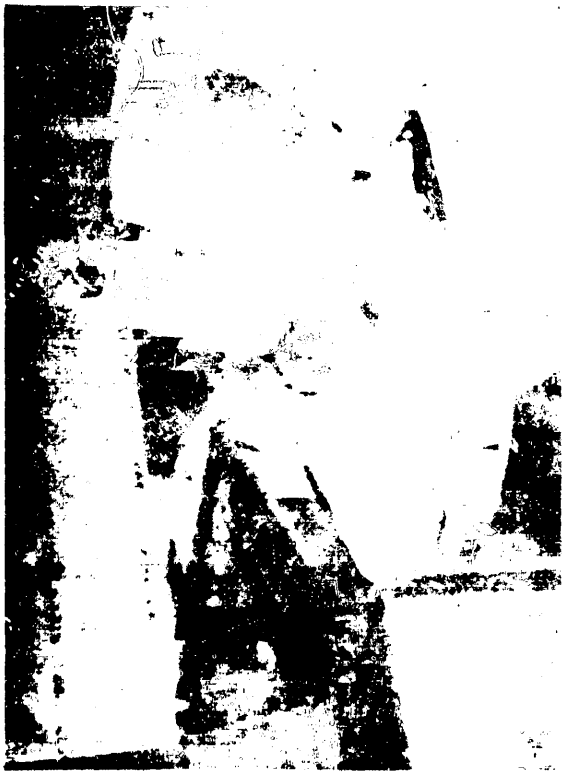
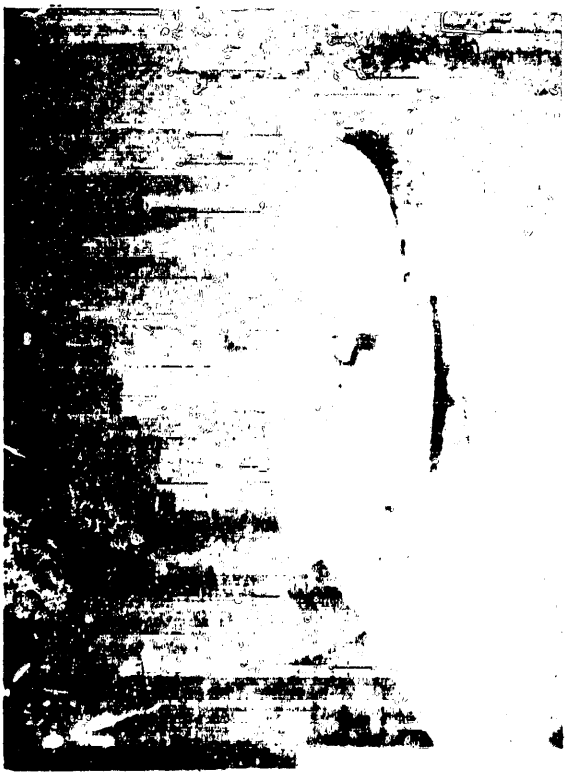
Prim. No. 8
BRUNMAN AIRCRAFT ENGINEERING CORPORATION
REPORT NO. LTR 904-10001
12 Feb. 1966









RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

Prepared by:
M. Bonner

Checked by;
R. L. Makemson

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND OLD 167" LANDING GEAR ASSEMBLIES

INTRODUCTION

The tests and results described herein are a continuation of the development test program on energy-absorbing cartridges as outlined in Section B. The initial phase of the program was concerned with the selection of materials and cartridge configurations; this latest phase was an investigation of the characteristics of prototype designs. The time period involved was from November 1965 until July 1966, and coincided with the drop tests on the early 160" gear and the re-designed 167" gear.

Since this program exists as a parallel effort in support of the landing gear testing, it was required that cartridges be approved for use in the drop tests as well as developed for the final landing gear. During the course of testing another re-design was effected resulting in modifications of the cartridges. It is anticipated that this will be the final modification and the next part of the cartridge testing will finalize the design.

This new design will be identified as the 167" (10-7-4) gear or "new" 167 gear. Throught this report the designation 167" will refer to the earlier or "old" 167" gear.

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART I - 160" HONEYCOMB CARTRIDGES

1.0 PURPOSE

The purpose of these tests was to evaluate the structural and energy-absorption properties of the 160" Landing Gear Primary and Secondary Strut Cartridges. Prior to the start of testing, the landing gear underwent a design modification affecting the cartridges. It is for this reason that most of the test effort was directed toward supplying information to support the 160" landing gear drop test program.

2.0 DESCRIPTION OF TEST ARTICLE

The test specimens consisted of the primary cartridge assembly, and the secondary tension and compression cartridges. These cartridges are described fully in paragraph 2.0 of the test plan with the one correction being that the primary was tested only as an assembly and not in individual stages. The actual number of cartridges tested and the conditions imposed are shown in Table I on page 6 of this report.

3.0 TEST CONDITIONS

The mission phase to be simulated and the general test conditions are described in paragraph 3.2.1 of the test plan. Briefly, the cartridges were tested statically under ambient conditions to establish a crush load reference point. Dynamic tests were then conducted over an impact velocity range of 4 to 25 feet per second. With the remaining cartridges, dynamic temperature tests were run over a range of +200°F to -200°F. The temperature tests were the only additions to the original schedule as outlined in the test plan.

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART I - 160" HONEYCOMB CARTRIDGES - continued

4.0 TEST SETUP AND PROCEDURE
(See Paragraphs 3.2 and 3.3 of Test Plan)

4.1 Static Test

At the start of testing, a Baldwin Testing Machine was used to apply the static loads to the chamber shaft. Subsequently it was replaced with self-contained loading fixture (LSK915-526). This rig was checked satisfactorily against the earlier results and used for all testing thereafter. The only other difference from the test plan was the replacement of the linear Bourns potentiometer with a rack and pinion driven rotary helipot to measure stroke.

4.2 Dynamic Test

The dynamic tests were performed as described in the test plan. This consisted of dropping a weighted carriage at a specified impact velocity to generate the required energy to crush the cartridge. The load and stroke were measured and recorded on a direct readout oscillograph. At the conclusion of the tests the cartridges were examined for any variations from the normal crush pattern.

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART I - 160" HONEYCOMB CARTRIDGES - continued

5.0 SUMMARY OF TEST RESULTS

The results presented here are based on the curves included at the end of this report. All the individual test points are recorded on the graphs; however, some points of questionable validity are not considered in drawing the curves.

I - 160" Cartridges

Primary Assemblies

1. The static crush loads generally fell within ± 2% of the desired nominal values. There was a slight drop in crush level toward the end of stroke in all three assemblies tested.

2. At impact velocities of from 4 ft/sec to 12 ft/sec, there was an increase or magnification in crush level of about 10%. At higher impact velocities (12 to 25 ft/sec) an additional increase in crush level was noted but was not as repeatable in the limited number of specimens tested.

3. Dynamic tests were also conducted over a temperature range of +200°F and -200°F for a total of five test points. Using the room temperature crush level as a reference point the crush load varied from 80% at +200°F to 140% at -200°F.

4. In all cases the cartridges crushed in a uniform manner and were able to absorb the applied impact loads. There was no evidence of distortion of the honeycomb core or excessive mis-alignment of the assembly after the test.

Secondary Cartridges

1. The secondary cartridges exhibited a more erratic crush pattern. The static crush loads varied by ± 4% from the average value.

160" LANDING GEAR HONEYCOMB CARTRIDGES

TEST SCHEDULE

Cartridge	Type	Part Number	Quantity	Static Ambient Temp.	Dynamic: Velocity (FPS) 4	8	12	18	25	Temp. V = 12 FPS + 200	+ 135	- 70	- 200 °F
Primary													
6000#	3/16-3003-1.5P	LTM-320H 50501	-	-	-	-	-	-	-				
12000#	1/8-3003-2P	50502	-	-									
Assy.	6000/12000	50500	27	3	4	4	4	3	4	1	1	2	1
Secondary													
Tens 1500#	Tubecore												
Tens 6000#	Tubecore												
Tens Assy.	1500/6000	50550-1	23	3	8	7	6	-	-				
Comp-5000#	Tubecore	50550-9	28	3	9	9	7	-	-				

TABLE I

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART I - 160" HONEYCOMB CARTRIDGES - continued

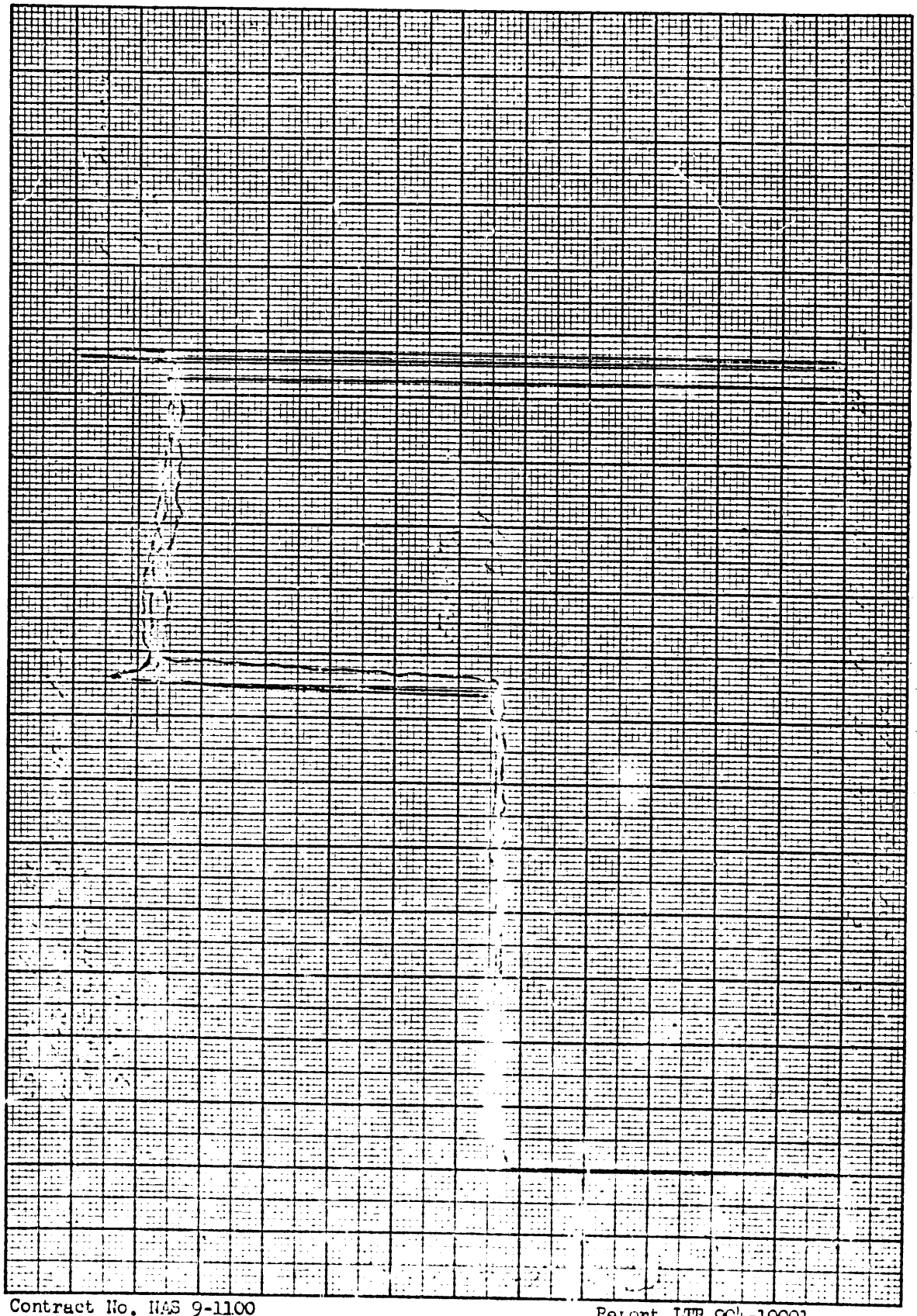
5.0 SUMMARY OF TEST RESULTS - continued

2. The dynamic characteristics of both the tension and compression cartridges did not show any degree of repeatability and for this reason no characteristic curve was drawn. The crush loads varied by ± 10% over the velocity range of 4 to 12 ft/sec.

3. Various methods of taping the cartridges were used but most proved to be inadequate in that they could not compensate for the honeycomb core being structurally unsound.

6.0 The following curves and data are included as part of the detailed test results on the 160" cartridges:

1. Tracing of Typical Load-Stroke Curve-Static Test of Primary Cartridge
2. Load-Stroke Curve-Static Test Secondary Tension Cartridge
3. Load-Stroke Curve-Static Test Secondary Compression Cartridge
4. Dynamic Crush Load vs Impact Velocity-Primary Cartridge 1st Stage
5. Dynamic Crush Load vs Impact Velocity-Primary Cartridge 2nd Stage
6. Dynamic Crush Load-Temperature-Primary Cartridge Assembly
7. Actual Crush Load vs Temperature-Primary Cartridge Assembly
8. Dynamic Crush Load vs Velocity-Secondary Compression Cartridge
9. Dynamic Crush Load vs Velocity-Secondary Tension Cartridge 1st Stage
10. Dynamic Crush Load vs Velocity-Secondary Tension Cartridge 2nd Stage



Contract No. NAS 9-1100
Primary No. 811

Report LTR 904-10001
Date 5 April 1967

K+E 10 X 10 TO THE ½ INCH 359T-11
KEUFFEL & ESSER CO. MADE IN U.S.A.
ALBANENE 5

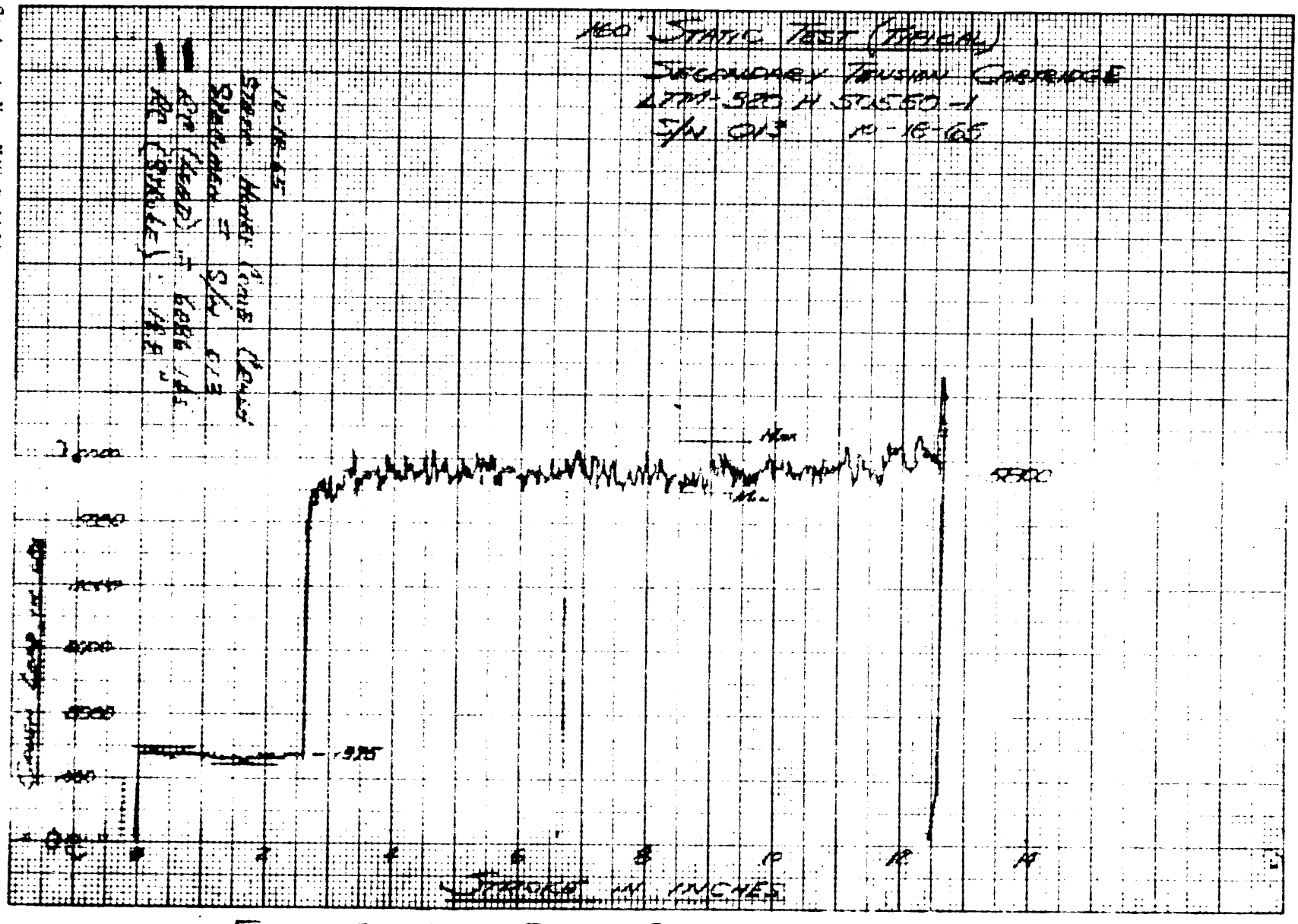


FIGURE 2- LOAD-STROKE CURVE NO SEC. TENSION CARRIAGE

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Primary No. 811

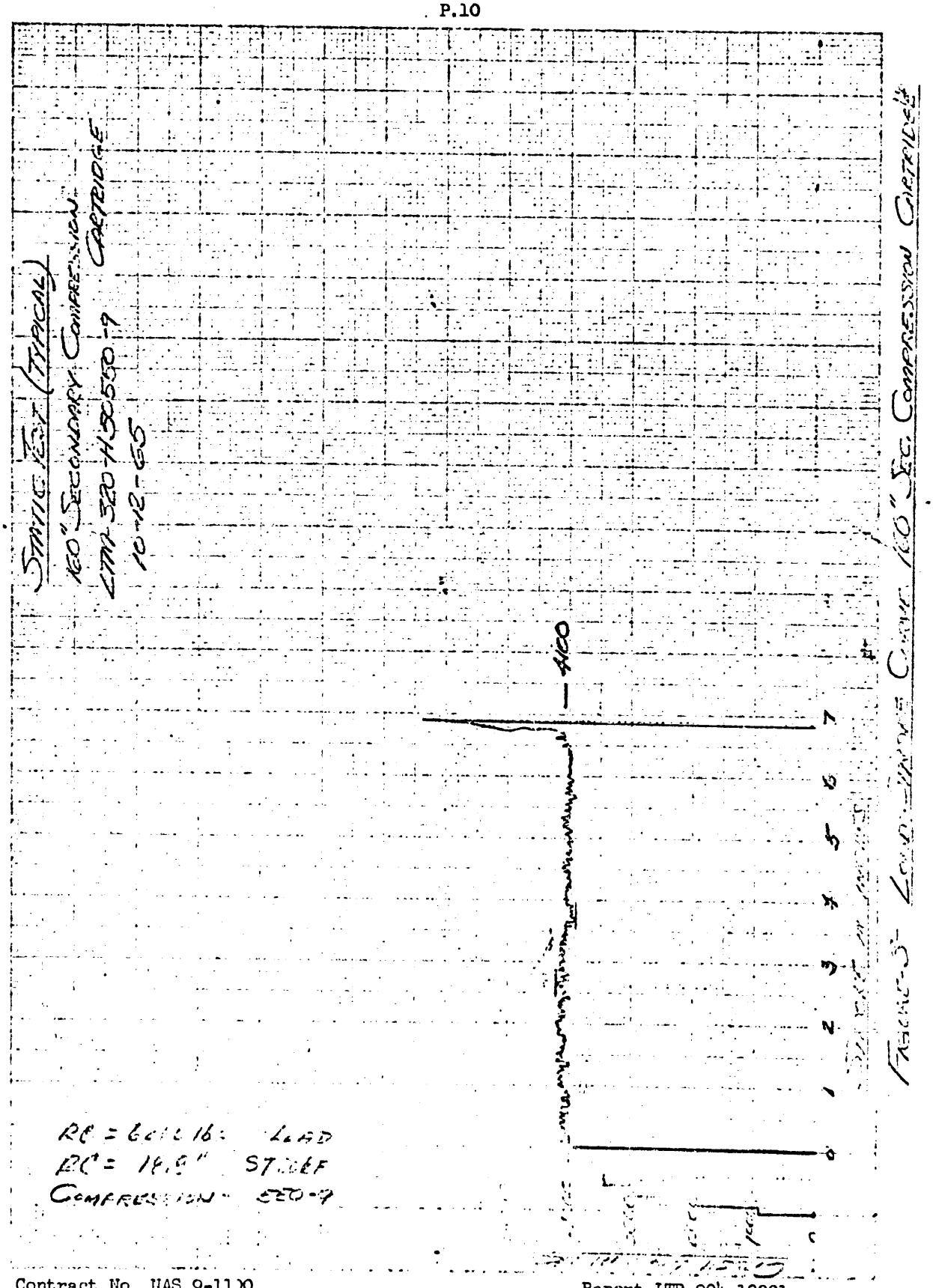
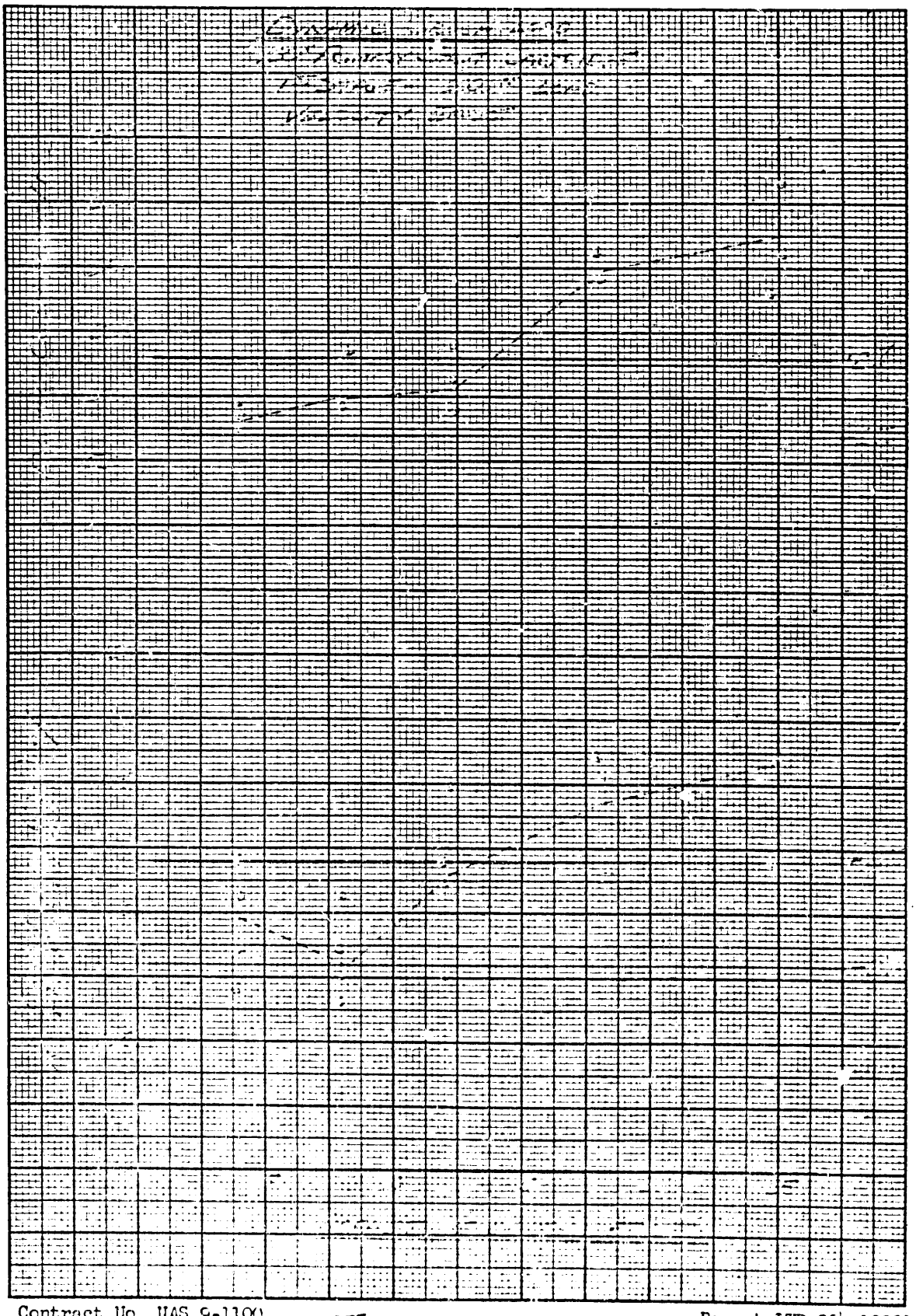


FIGURE 3 - LOAD-STROKE CURVE 160" SEC. COMPRESSION CARTRIDGE



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7 X 10 IN. • ALBANENE® MADE IN U.S.A.
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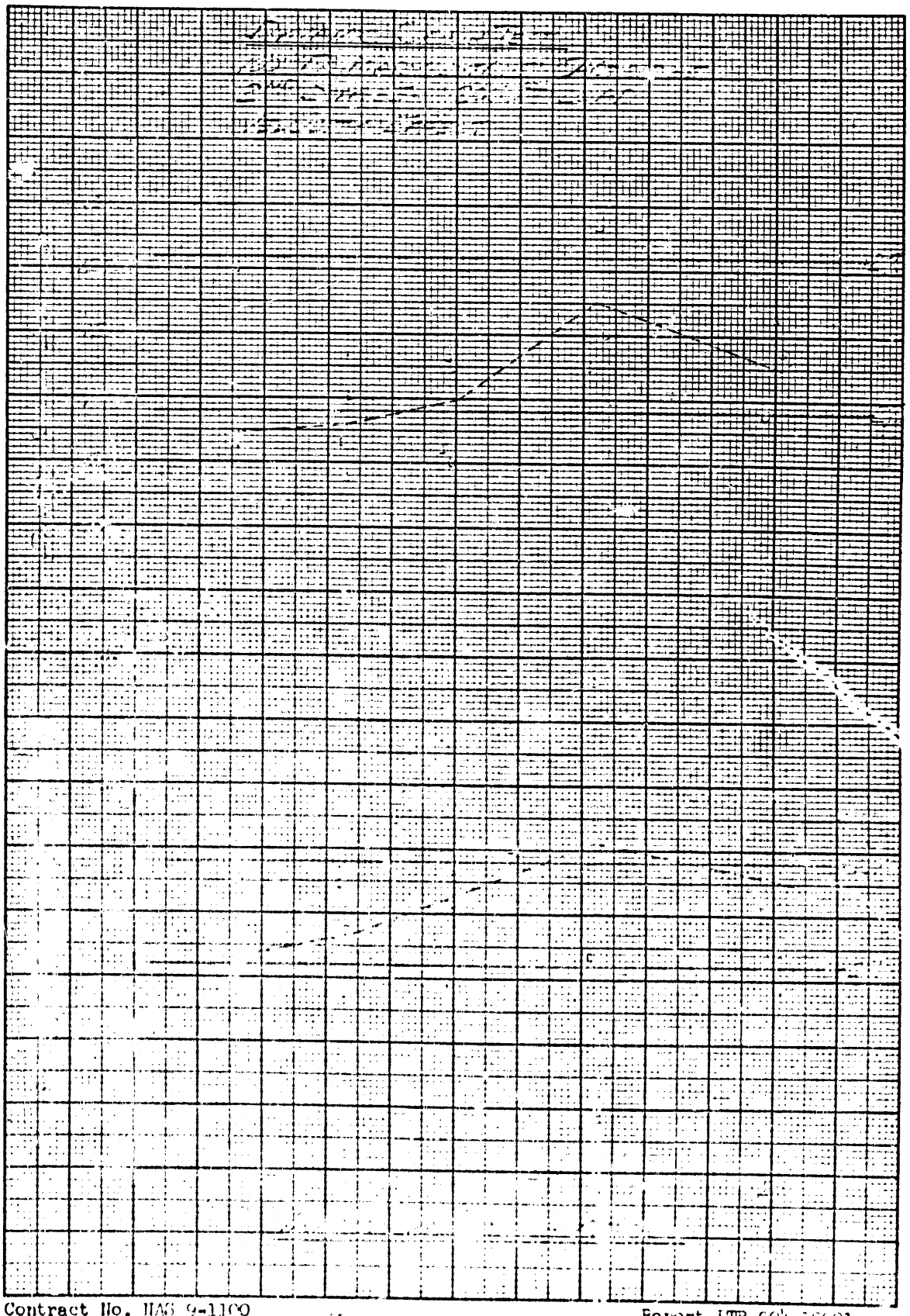

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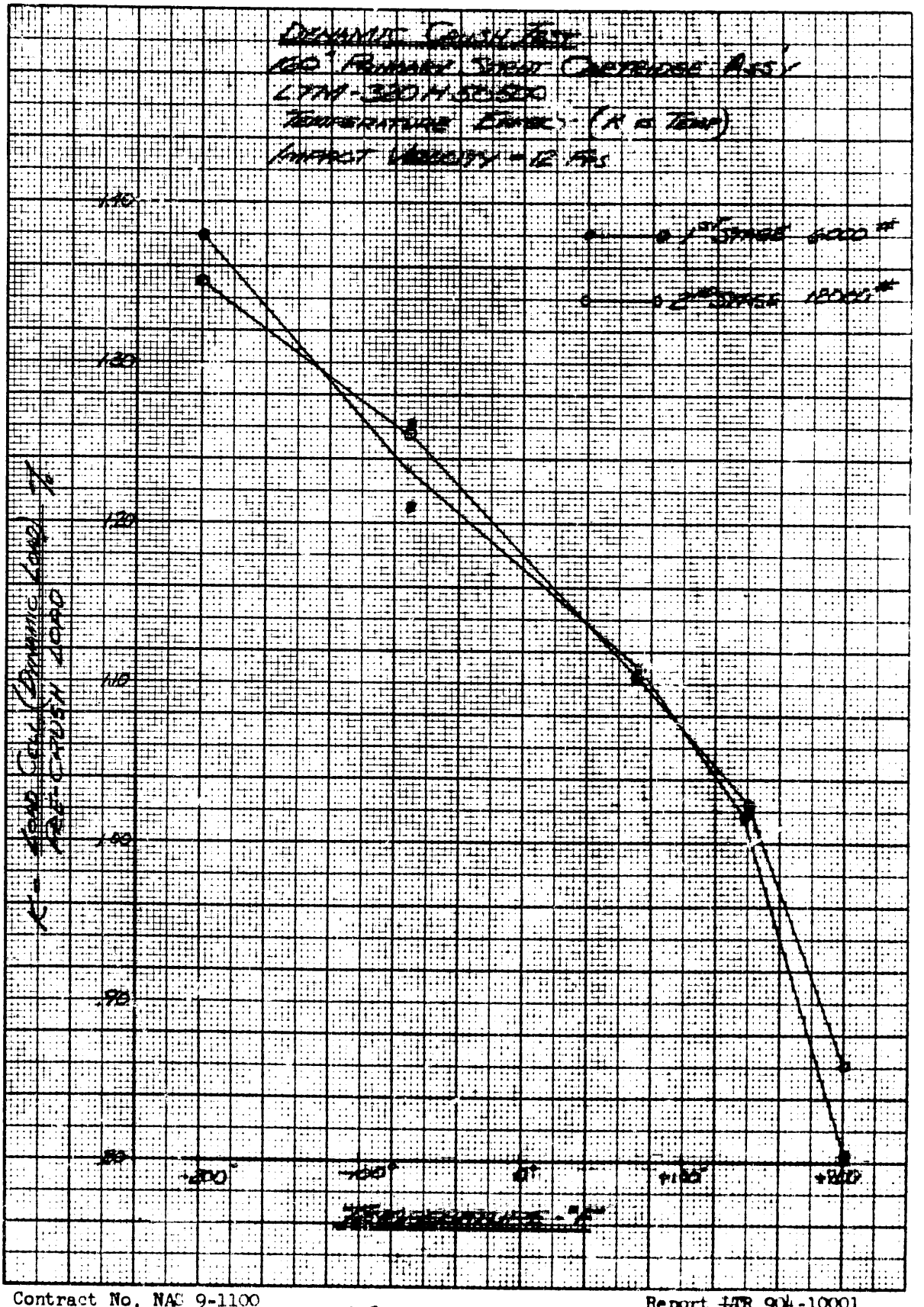

K+E 10 X 10 TO ½ INCH 46 1327
7 X 10 IN. • ALBANENE
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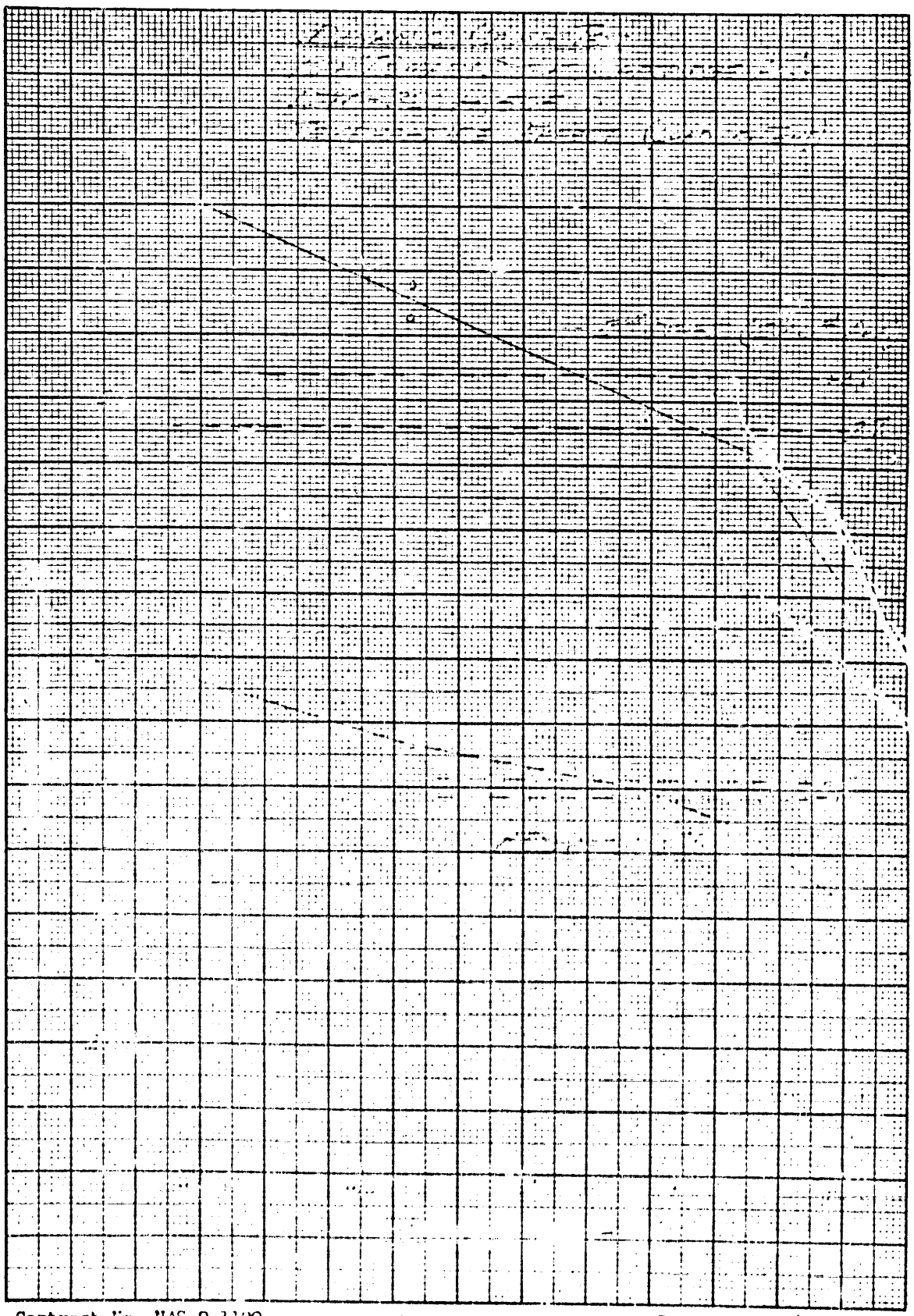
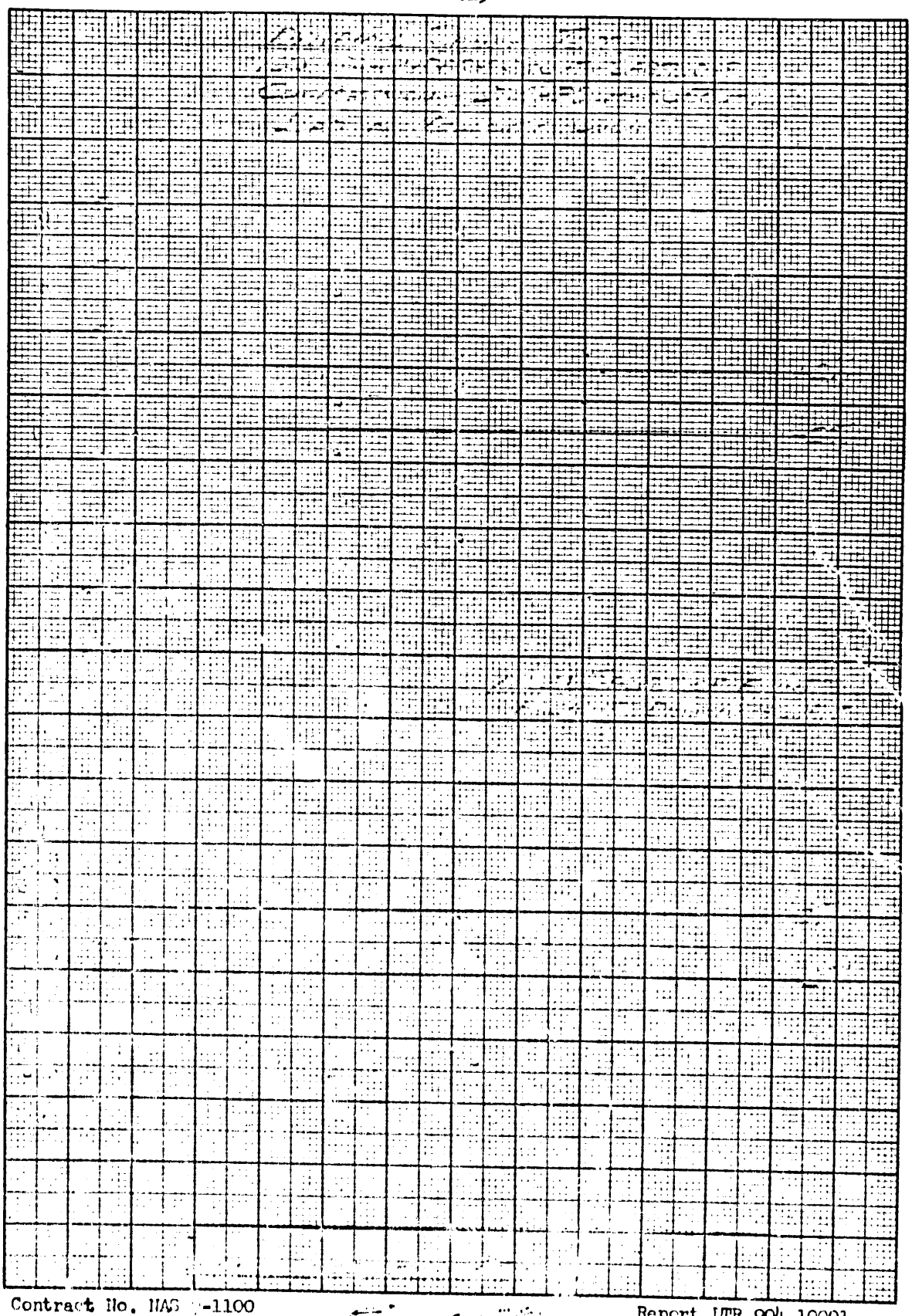


K+E 10 X 10 TO ½ INCH 7 X 10 IN. • ALBANY N.Y. 46 1327 KEUFFEL & ESSER CO.



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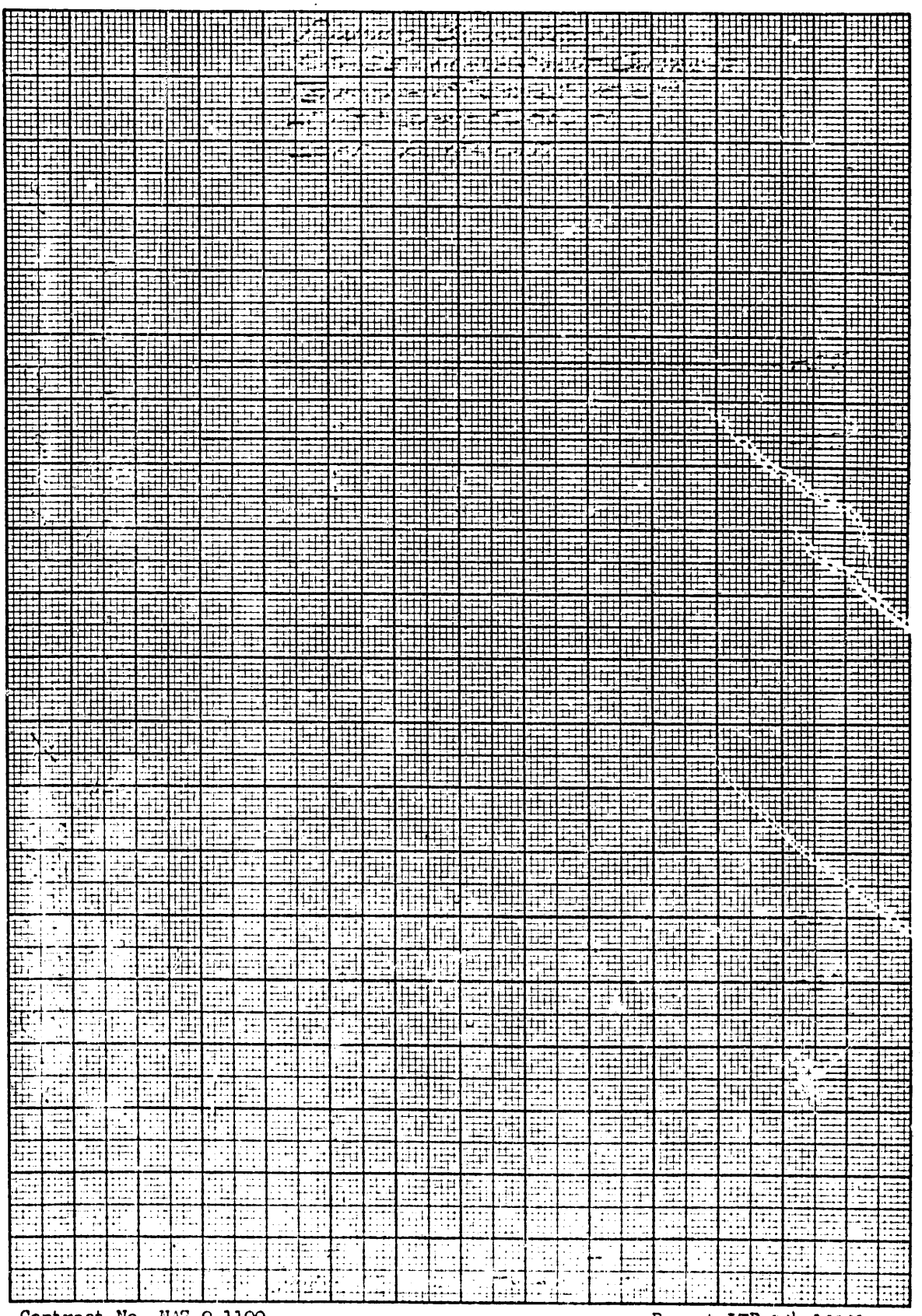

K+E 10 X 10 TO ½ INCH 46 1327
7 X 10 IN. • ALBANENE® MADE IN U.S.A.
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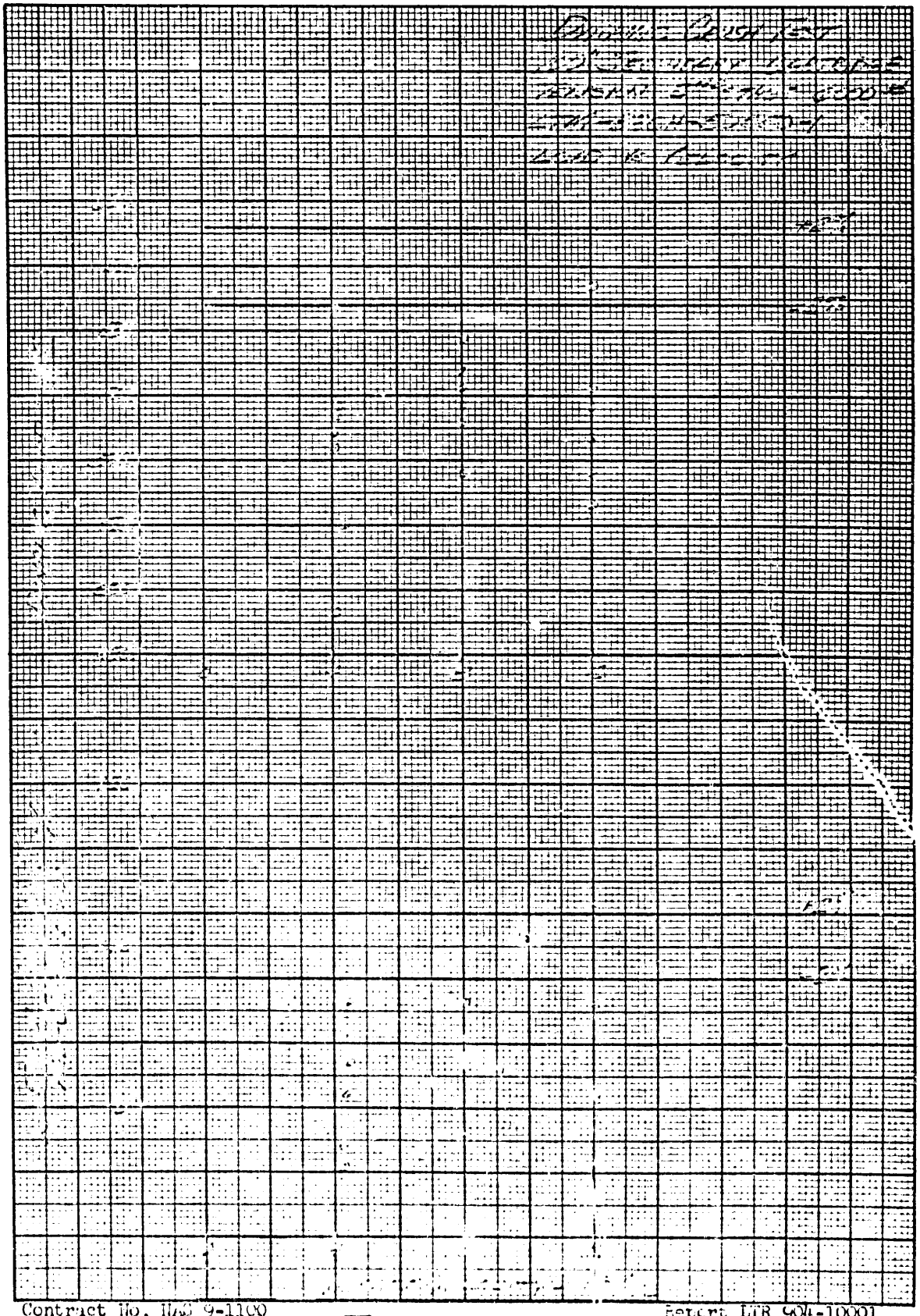

K+E 10 X 10 TO ½ INCH 46 1327
7 X 10 IN • ALBANENE® MADE IN U.S.A.
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FIGURE 10

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMB CARTRIDGES

1.0 PURPOSE

The purpose of these tests was to evaluate and compare the two types of aluminum honeycomb that appeared most promising when incorporated in the prototype designs for the 167" landing gear strut cartridges. Whereas the 160" cartridges were tested mostly under ambient conditions, the 167" cartridges were subjected to a variety of environmental conditions. The structural properties and energy absorption were still the main areas of investigation.

2.0 DESCRIPTION OF THE TEST ARTICLES

These cartridges were similar to the 160" cartridges in configuration but differed in physical dimensions, cell size, and type of aluminum core. Both the primary and secondary cartridges were made of expanded cellular honeycomb. The primary cartridge was assembled into the strut by using end caps attached to the cartridge by studs. Most of the tests were conducted using special steel caps which were then compared to tests using the actual prototype caps. The test articles consisted of the following aluminum honeycomb cartridges:

Primary Strut -

Component Cartridges

LTM-320H-50505-1	1/8 - AL 3003 - 6000#
LTM-320H-50506-1	1/8 - AL 3003 - 12,000#
LTM-320H-50508-1	3/16 - AL 5052 - 12,000#
LTM-320H-50509-1	3/16 - AL 5052 - 6000#

Assembly

LTM-320H-50504-11	
composed of 50509-1	6000#
50508-1	12,000#

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMB CARTRIDGES - continued

2.0 DESCRIPTION OF THE TEST ARTICLES - continued

Secondary Strut -

Compression - LTM-320H-50560

-7 made from 562-13	1/8 - AL 3003 Round - 6000#
-9 made from 563-13	1/8 - AL 5052 Round - 6000#
-11 made from 564-13	1/8 - AL 5052 Hex. - 6000#

Tension -

LTM-320H-50560-3	
composed of 50563-15	1/8 - AL 5052 Round - 1500#
50563-11	1/8 - AL 5052 Round - 6000#
LTM-320H-50560-1	
composed of 50562-15	1/8 - AL 3003 Round - 1500#
50562-11	1/8 - AL 3003 Round - 6000#
LTM-320H-50560-5	
composed of 50564-15	1/8 - AL 5052 Hex. - 1500#
50564-11	1/8 - AL 5052 Hex. - 6000#

The additional cartridges tested using the prototype studs and caps were identified by serial number LTM-320H-50504-9. The actual number of cartridges tested and the conditions imposed are shown in Table II on page 23 of this report.

3.0 TEST CONDITIONS

The test conditions are described in paragraph 3.1 of Part II of the test plan. The actual test schedule used is shown in Table II on page 23 of this report. The changes from the original schedule were dictated by the need for information pertinent to a re-design of the gear which was initiated after the start of the program.

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMB CARTRIDGES - continued

3.0 TEST CONDITIONS - continued

The main difference from the 160" testing was that the 167" cartridges underwent a full environmental sequence including temperature and vacuum tests. The temperature range was reduced to between +135° and -70°F and the impact velocity limited to 12 ft/sec. The vacuum tests were conducted at pressures of 100μ of Hg of less. The "outgassing" tests were deleted entirely and scheduled for a later phase of the testing.

4.0 TEST SETUP AND PROCEDURE

The test setup and procedures are described in paragraphs 3.2 and 3.3 (Part II) of the test plan. The basic facilities are identical to those used in previous tests. The chambers were designed to conform to the internal dimensions of the primary strut. The test instrumentation was completely re-calibrated and adapted to the 167" design changes.

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMBE CARTRIDGES - continued

5.0 SUMMARY OF TEST RESULTS

Of the two base types of aluminum honeycombe core used, the AL5052 proved to be superior to the AL3003 in terms of performance repeatability and structural integrity. This fact was apparent early in the program through testing of the component stages. Consequently, the assembly tests on the AL3003 honeycombe were deleted from the test schedule and the AL5052 core was used in the cartridges for the landing gear tests. A tabulation of the test results for the AL5052 cartridges is included on page 25 of this report. Information for the remaining cartridges can be abstracted from the curves or the test data. No attempt is made to evaluate the cartridges in terms of honeycomb purchase or fabrication specifications. The complete qualitative evaluation will depend on these results in conjunction with the results of the other tests such as the gear drop test and the component strut tests. It is expected that the subsystems group (Mechanical Design) will issue further reports concerning the details of cartridge construction, fabrication and the evolution of the design through the development stages to the design through the development stages to the final vehicle product.

6.0 TEST CURVES

The following is a list of the curves included as part of the detailed test results on the 167" Landing Gear Cartridges:

1. Tracing of Typical Load-Stroke Curve-Static Test of Primary Cartridge
2. Load-Stroke Curve-Static Test of Secondary Tension Cartridge
3. Load-Stroke Curve-Static Test of Secondary Compression Cartridge

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMB CARTRIDGES - continued

6.0 TEST CURVES - continued

4. Static Test - Primary Cartridges (6000#) - Test Load Ratio vs Temperature

5. Static Test - Primary Cartridges (12000#) - Test Load Ratio vs Temperature

6. Static Test - Secondary Cartridges (Tension) - Test Load Ratio vs Temperature

7. Static Test - Secondary Cartridges Compression - Test Load Ratio vs Temperature

8. Primary Cartridge - Static and Dynamic Test Load Ratio vs Temperature - LTM-320H-50505

9. Primary Cartridge - Static and Dynamic Ratio vs Temperature - LTM-320H-50509

10. Primary Cartridge - Static and Dynamic vs Temperature - LTM-320H-50506

11. Primary Cartridge - Static and Dynamic vs Temperature - LTM-320H-50508

12. Primary Cartridge Assembly - Static and Dynamic Crush Load

13. Primary Cartridge - 6000# Stage - Ratio vs Velocity - Types 50505 and 50509 Compared

14. Primary Cartridge - 12000# Stage - Load vs Velocity - Types 50506 and 50508 Compared

15. Secondary Cartridge - Tension - Load vs Velocity - Three Types, Both Stages Compared

RESULTS FOR LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION P - CRUSHABLE HONEYCOMB CARTRIDGES FOR THE 160" AND 167" LANDING GEAR ASSEMBLIES

PART II - 167" HONEYCOMB CARTRIDGES - continued

6.0 TEST CURVES - continued

16. Secondary Cartridge - Compression - Load vs Velocity - Three Types Compared

17. Primary Assembly - LTM-320H-50504 - Load vs Velocity - Assembly Cartridge

18. Secondary Cartridges - Tension - LTM-320H-50560-3 - Compression - LTM-320H-50560-9 - Temperature Sensitivity

167" HONEYCOMB CARTRIDGES

ACTUAL TEST SCHEDULE

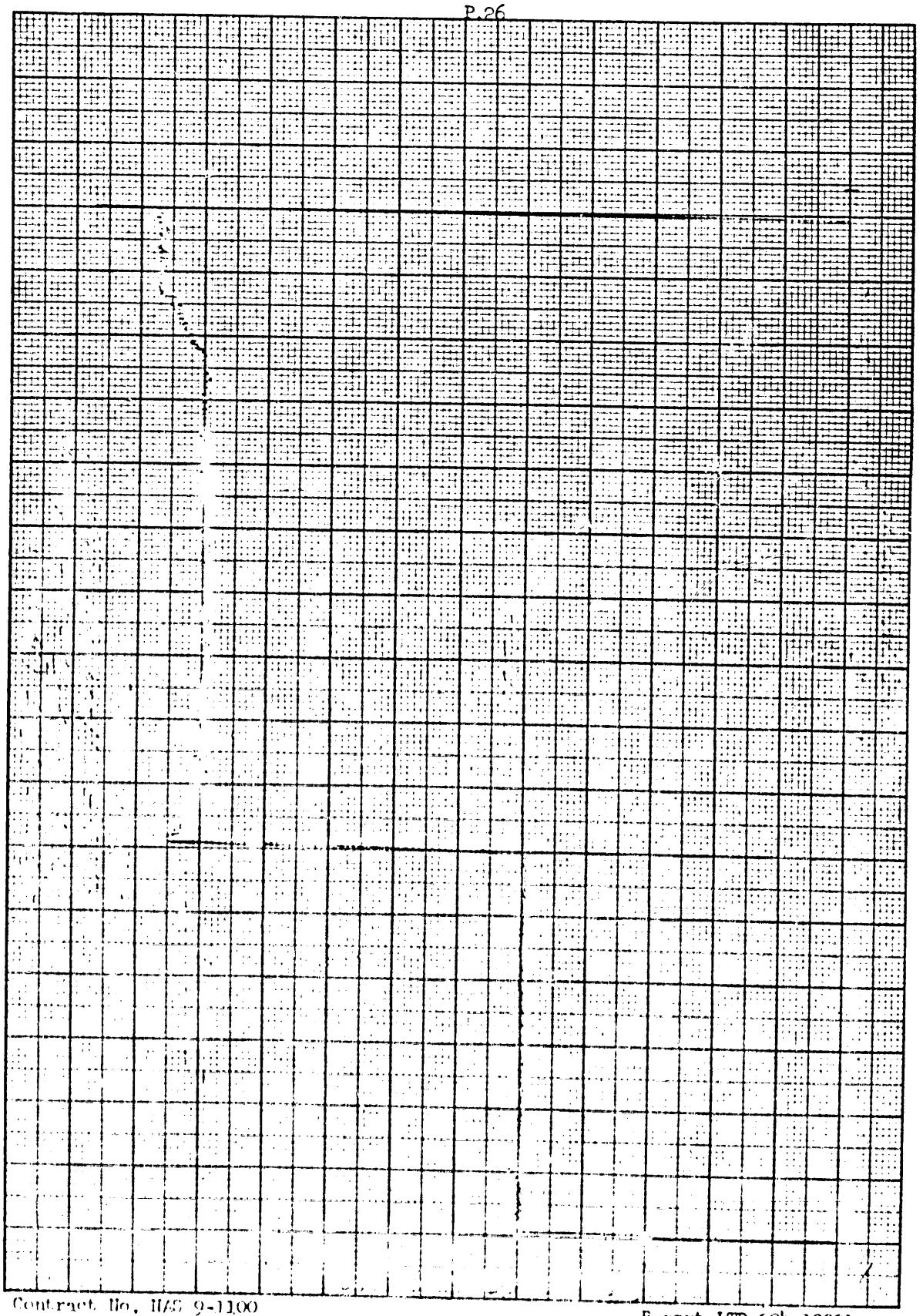
Cartridge	Quant.	Static						Dynamic															
		Temperature						Velocity (FPS) T = Amb.					Temperature Vel. = 12 FPS				Vacuum Temp.					Vacuum Velocity		
		+ AMB	+ 135	+ 100	- 30	- 20	- 70	4	6	8	10	12	+ 135	+ 30	- 20	- 70	AMB	+ 135	+ 30	- 20	- 70	4	8	10
Z Primary																								
LTM-320H-																								
6000# 50505	26	1	1	1	1	2	1	1	1	2	2	2	2	1	1	1	2	1		1				1
6000# 50509	29	1	1	1	1	1	2	1	1	2	3	3	3	1	1	2	1	1		1				2
12000# 50506	29	2	2	1	2	1	2	2	2	1	2	2	1	2	2	2	2							1
12000# 50508	46	2	2	2	2	3	3	2	2	2	6	11	2	1	1	2	1							2
Assembly 50504	22	1	1		1		1	1	1	1	1	5	2	1	1	2	1	1		1				
Secondary																								
LTM-320H-																								
Compression																								
50560-7	14	1	1	1	1	1	1	1		1	1	1	1		1	1	1	-						
50560-9	9	1	1				1	1		1		1	1			1	1	-						
50560-11	9	1	1				1	1		1		1	1			1	1	-						
Tension																								
50560-1	14	1	1	1	1	1	1	1		2		1	1	1		1	1	-						
50560-3	10	1	1				1	1		1		1	2			1	1	-						
50560-5	9	1	1				1	1		1		1	1			1	1	-						

TABLE 2

SUMMARY OF TEST RESULTS - 167" CARTRIDGES

TEST PARAMETER	LTM-320H-50504 PRIMARY ASSEMBLY 1ST STAGE 6000# LOAD	LTM-320H-50504 PRIMARY ASSEMBLY 2ND STAGE 12000# LOAD	LTM-320H-50560-3,-9 SECONDARY CARTRIDGES TENSION 1500# LOAD	LTM-320H-50560-3,-9 SECONDARY CARTRIDGES TENSION 6000# LOAD	LTM-320H-50560-3,-9 SECONDARY CARTRIDGES COMPR. 6000# LOAD
STATIC TESTS					
DEVIATION FROM NOMINAL LOAD OVER FULL STROKE	-3%	-3%	-10%	±1%	-2%
TEMPERATURE SENSITIVITY RANGE -70°F TO +135°F	10% TOTAL	10% TOTAL	26% TOTAL	20% TOTAL	15% TOTAL
DYNAMIC TESTS					
DYNAMIC MAGNIFICATION FACTOR $K = \frac{\text{DYN. LOAD}}{\text{STAT. LOAD}}$ @ 12 FPS & AMB. TEMP.	10%	7%	4%	11%	5%
DYN. MAG. FACTOR VARIATION OVER VELOCITY RANGE (4-12 FPS)	3%	9%	2%	3%	5%
TEMPERATURE SENSITIVITY RANGE -70°F TO +135°F	20% TOTAL	13% TOTAL	30% TOTAL	21% TOTAL	21% TOTAL
VACUUM EFFECT (100μ) V = 12 FPS	-3%	-5%	-4%	-9%	-10%

GRUMMAN AIRCRAFT ENGINEERING CORPORATION TABULATION FORM



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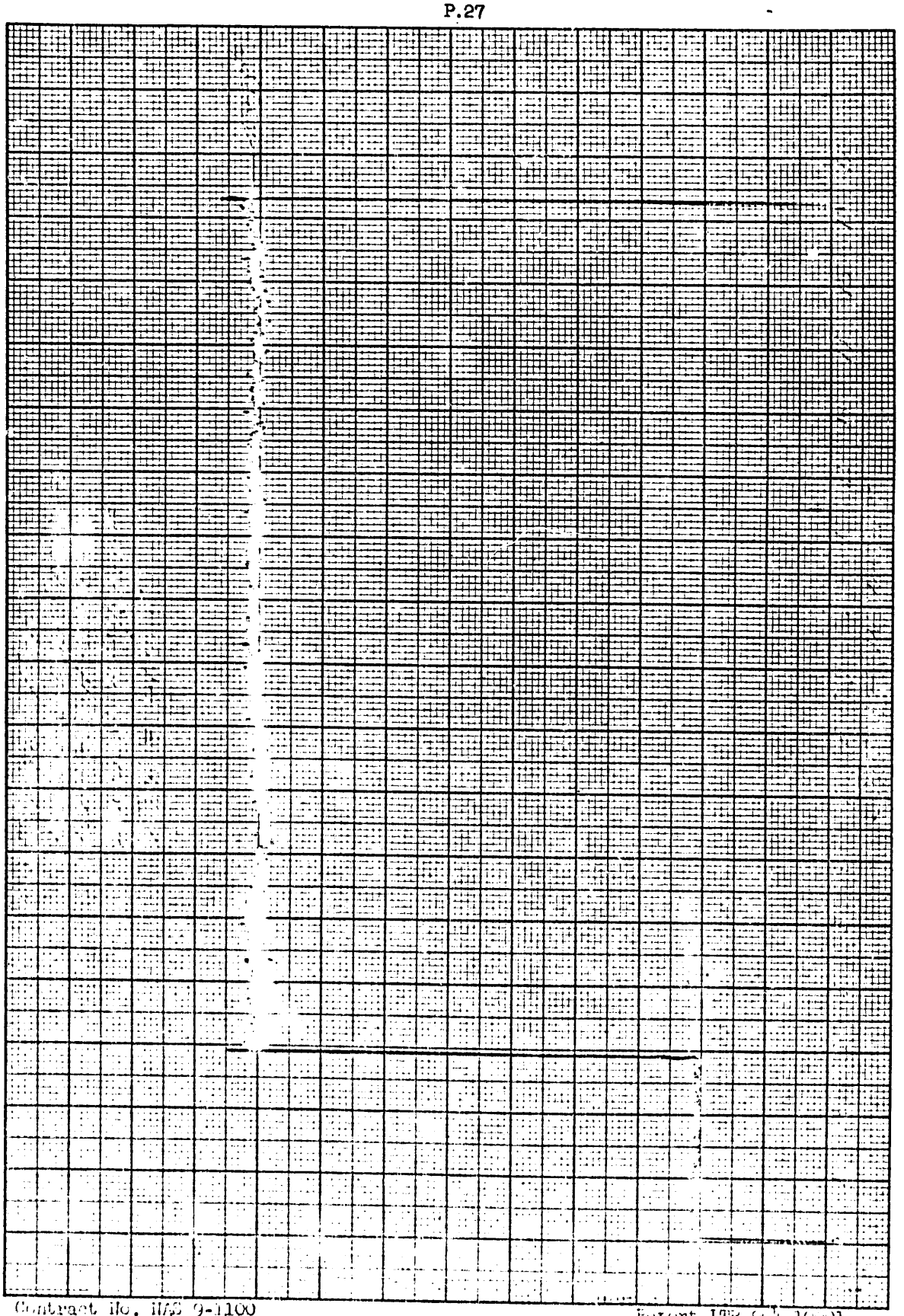

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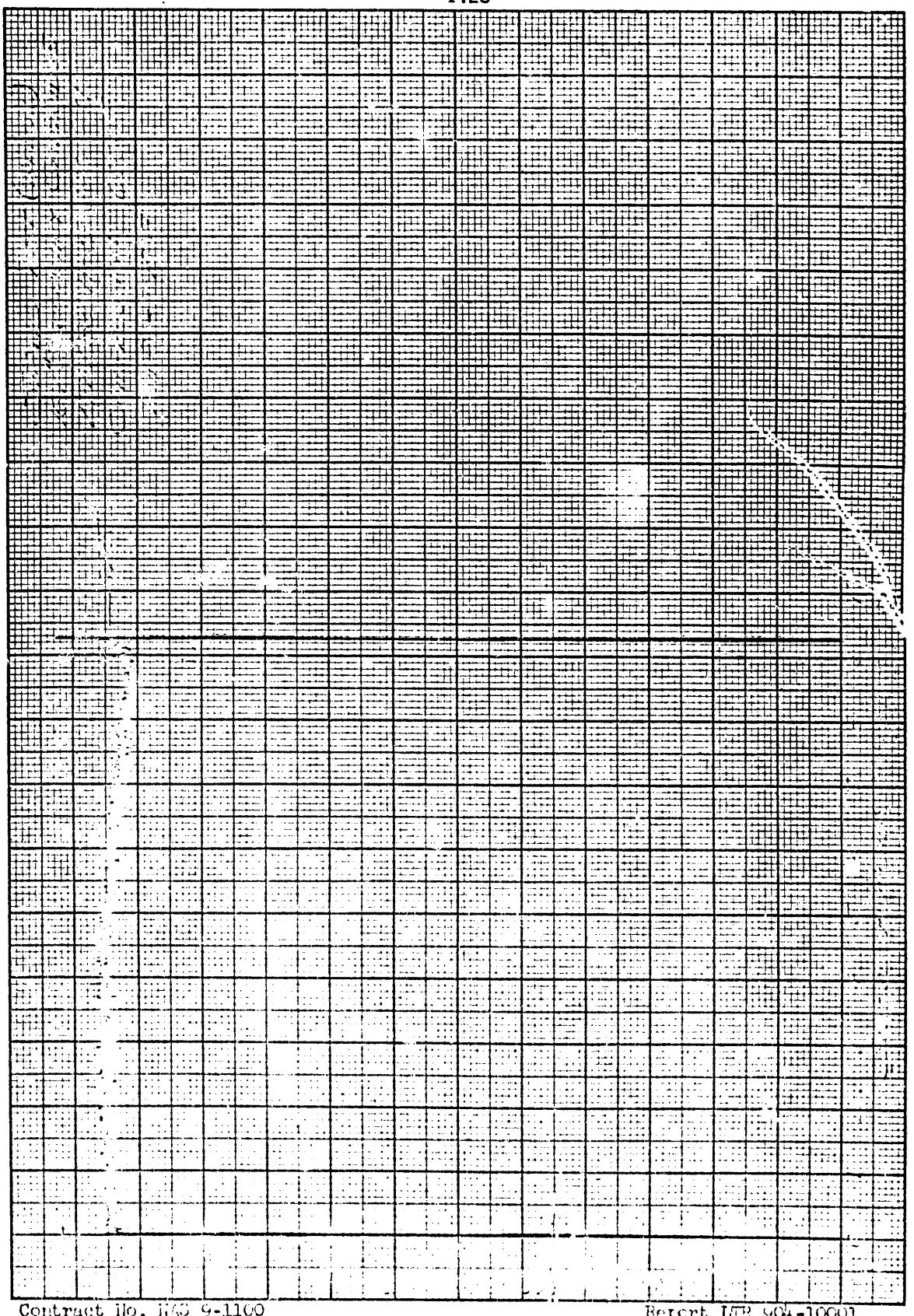

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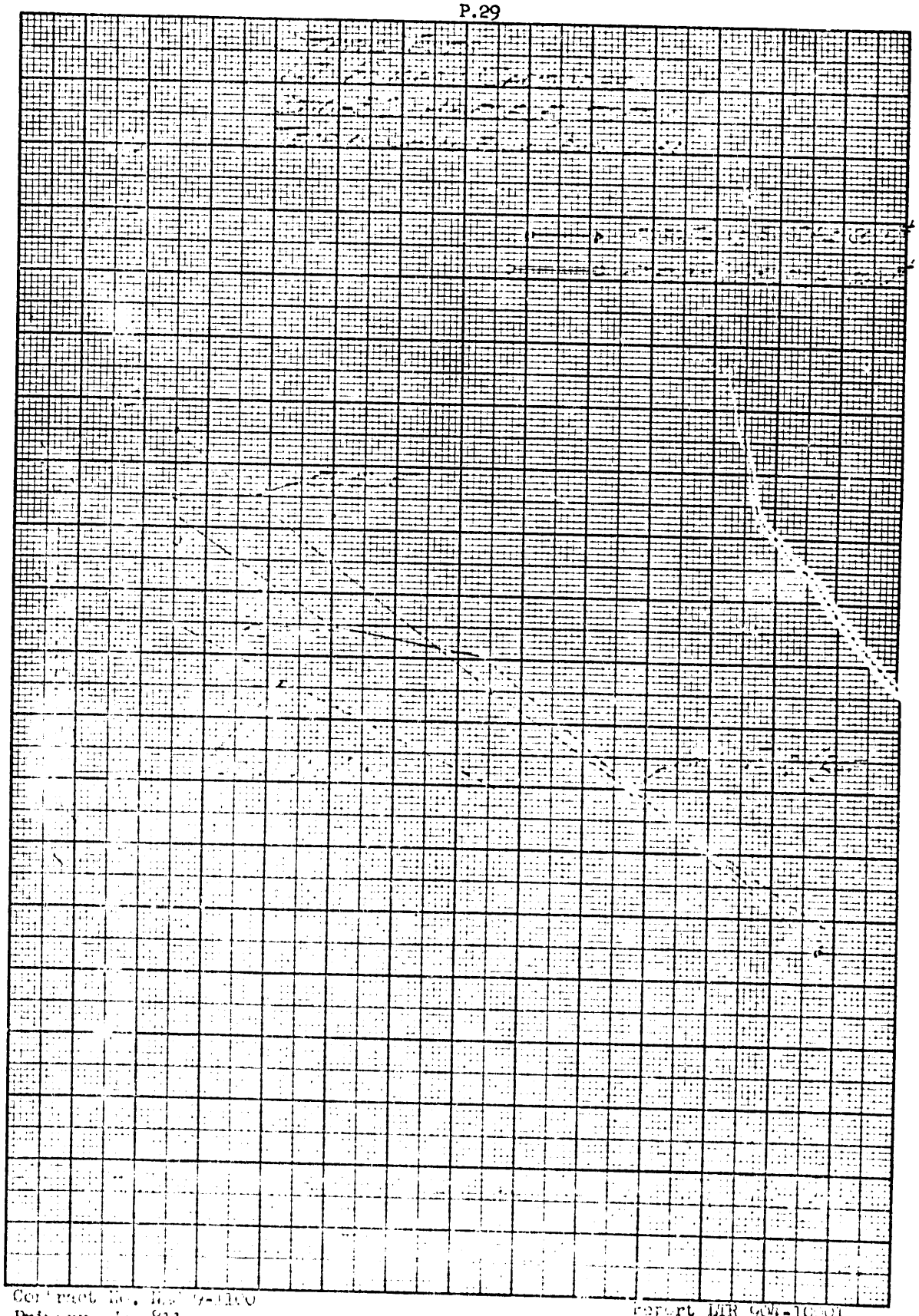

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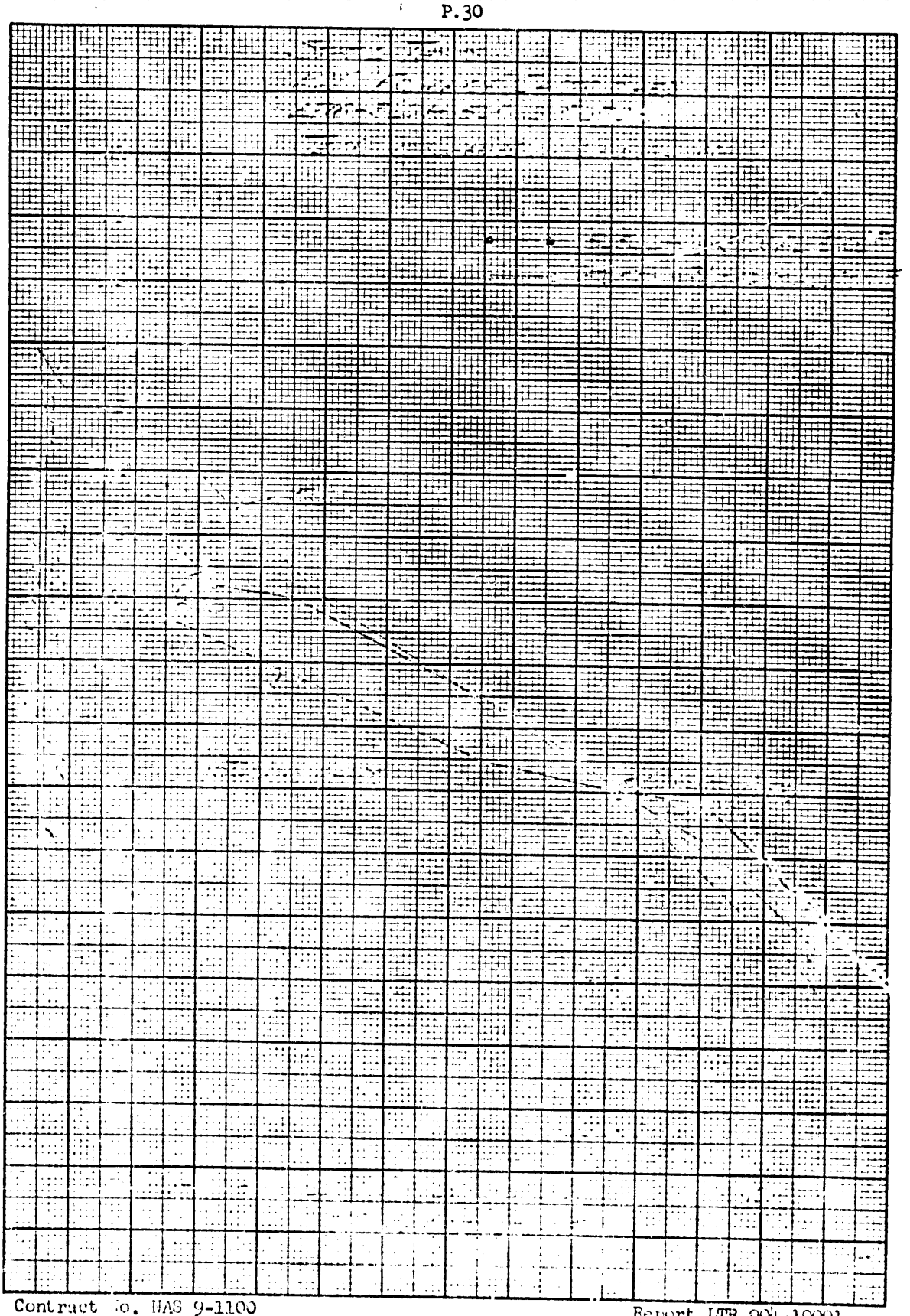

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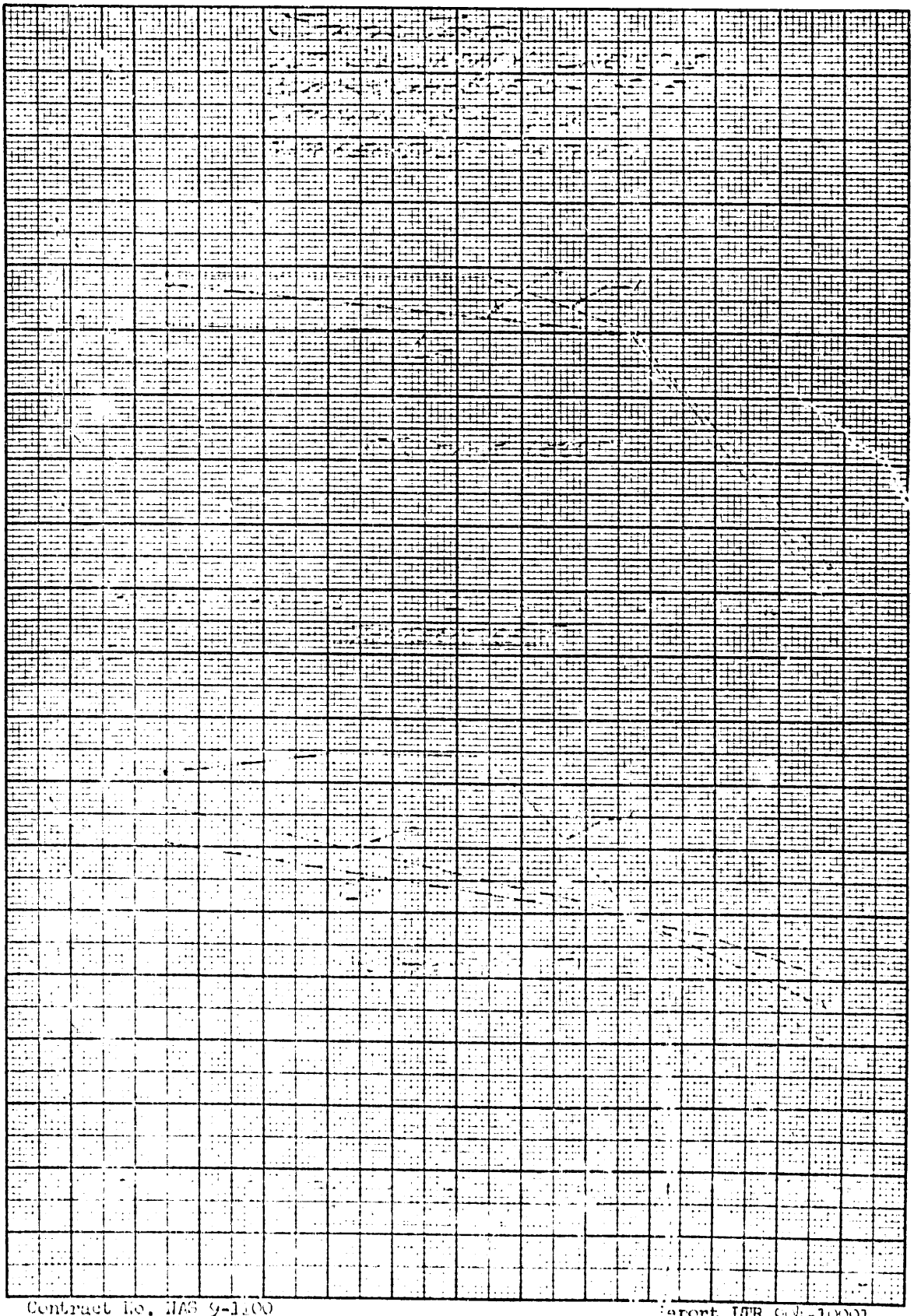

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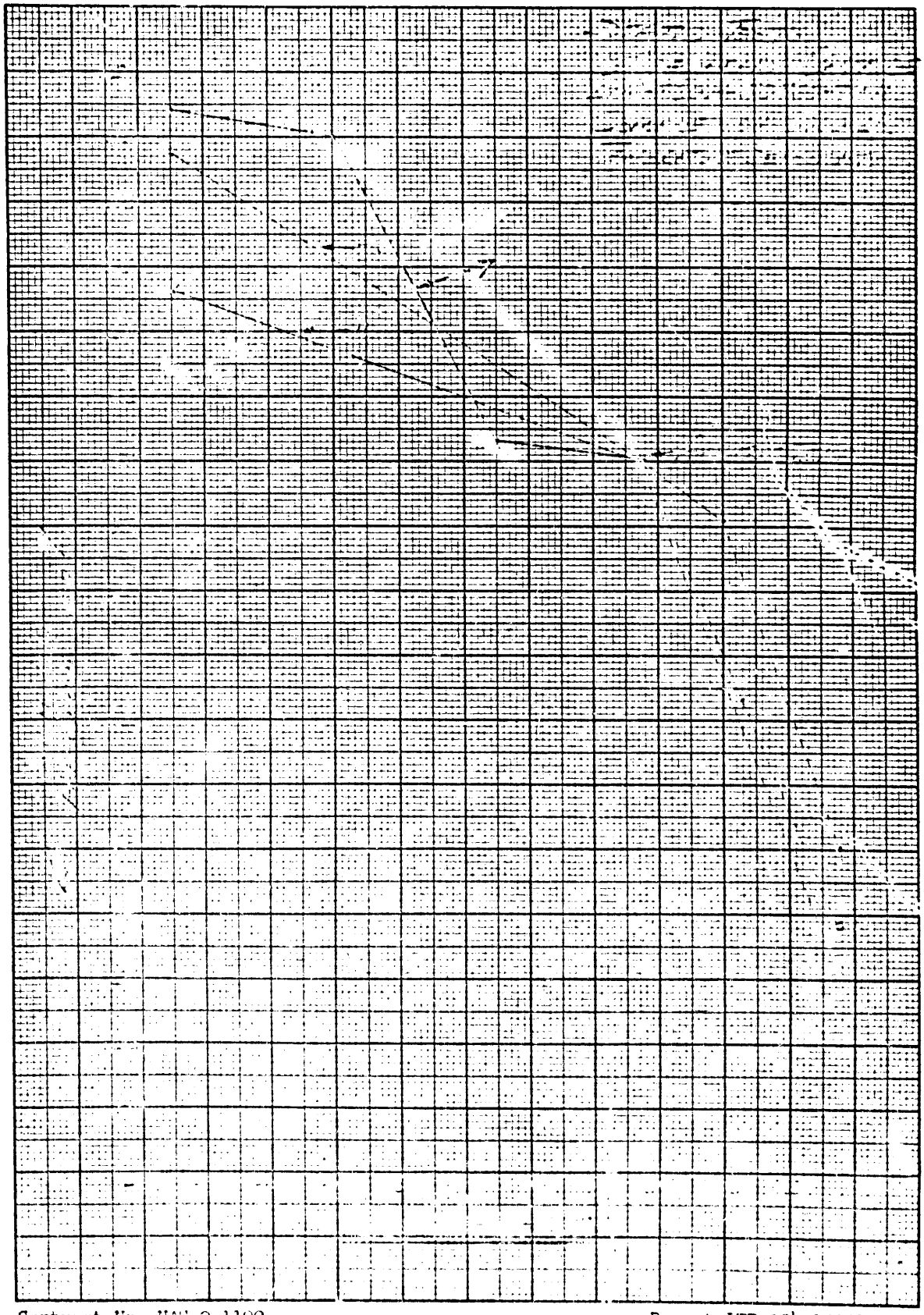

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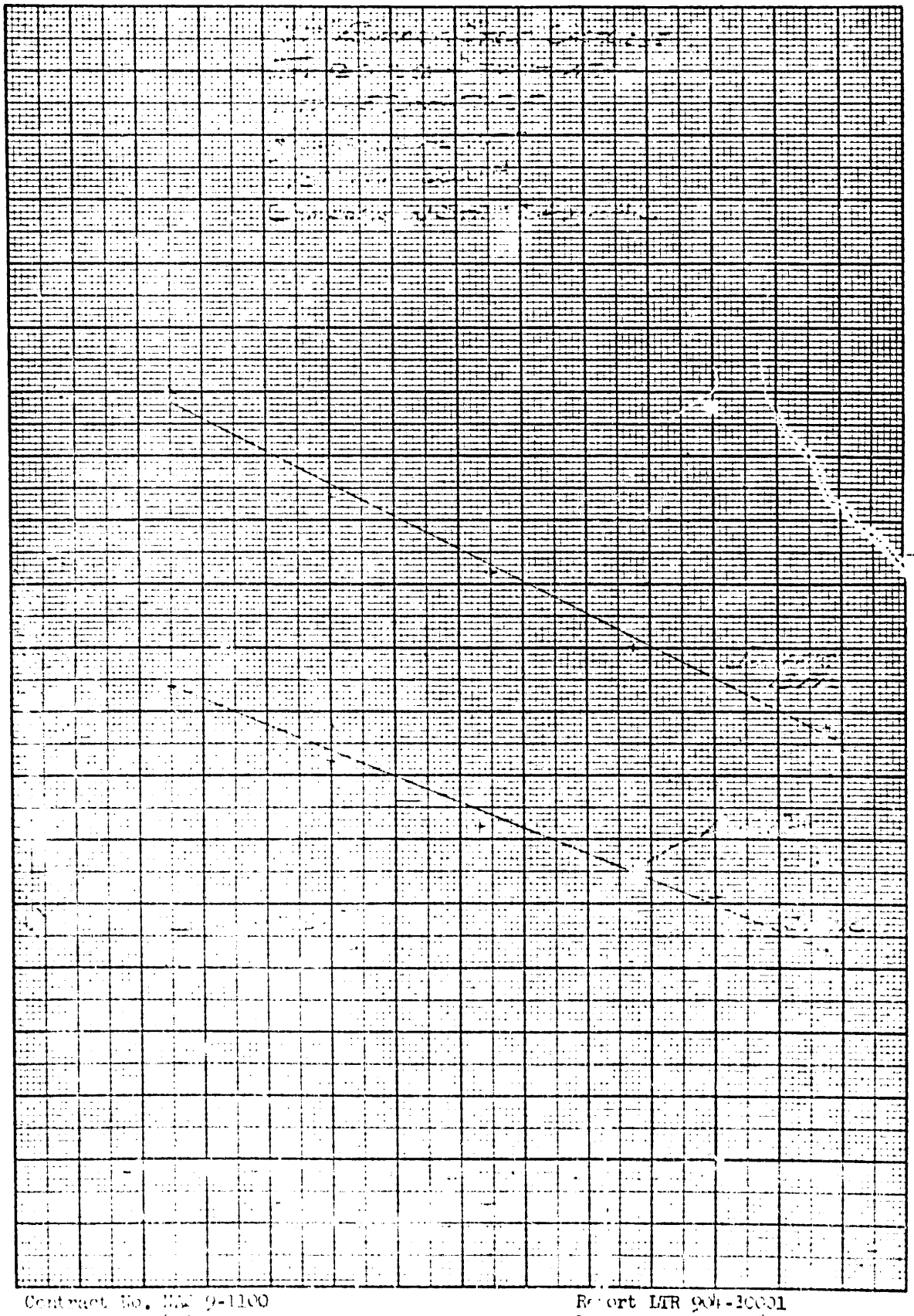

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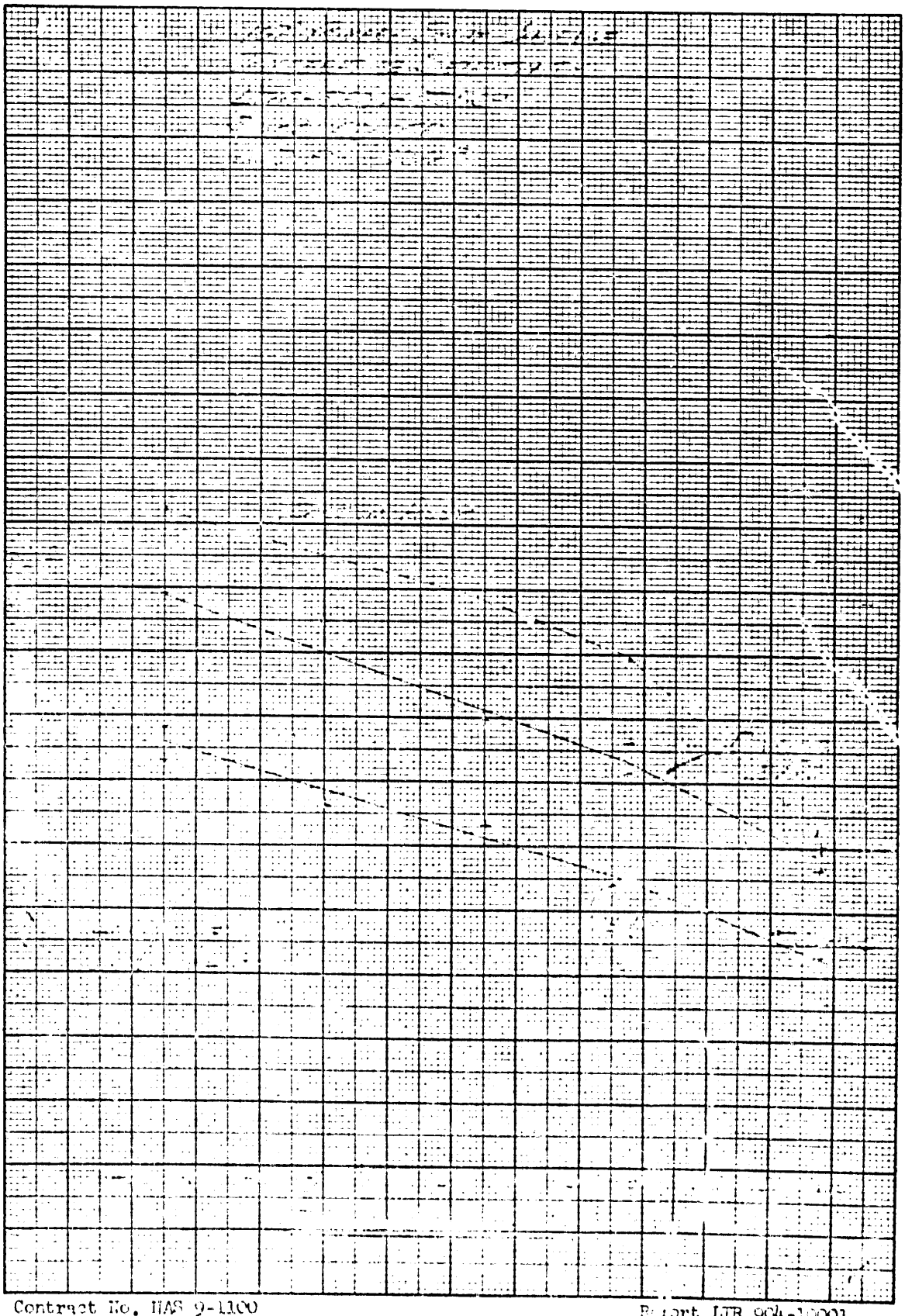

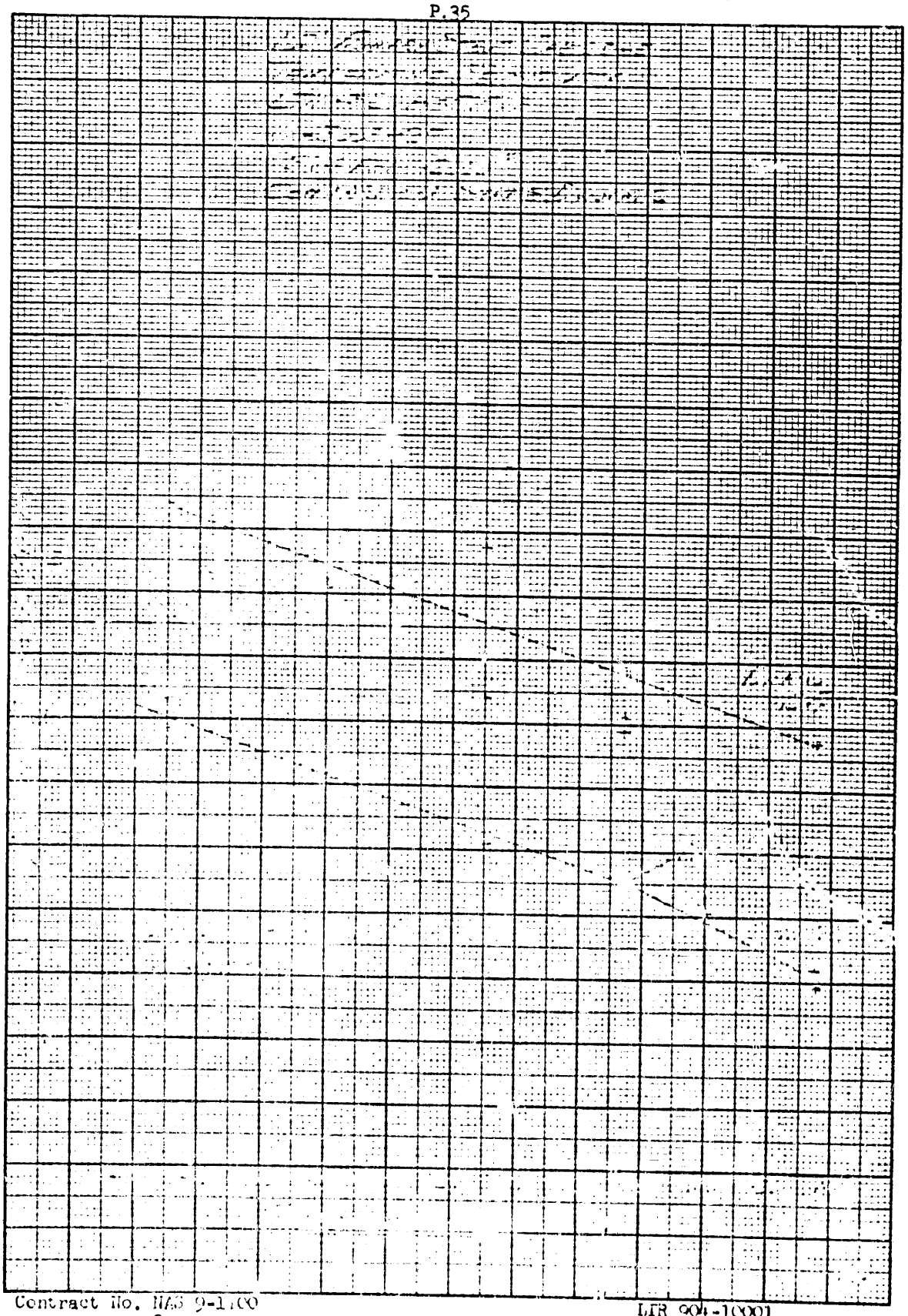

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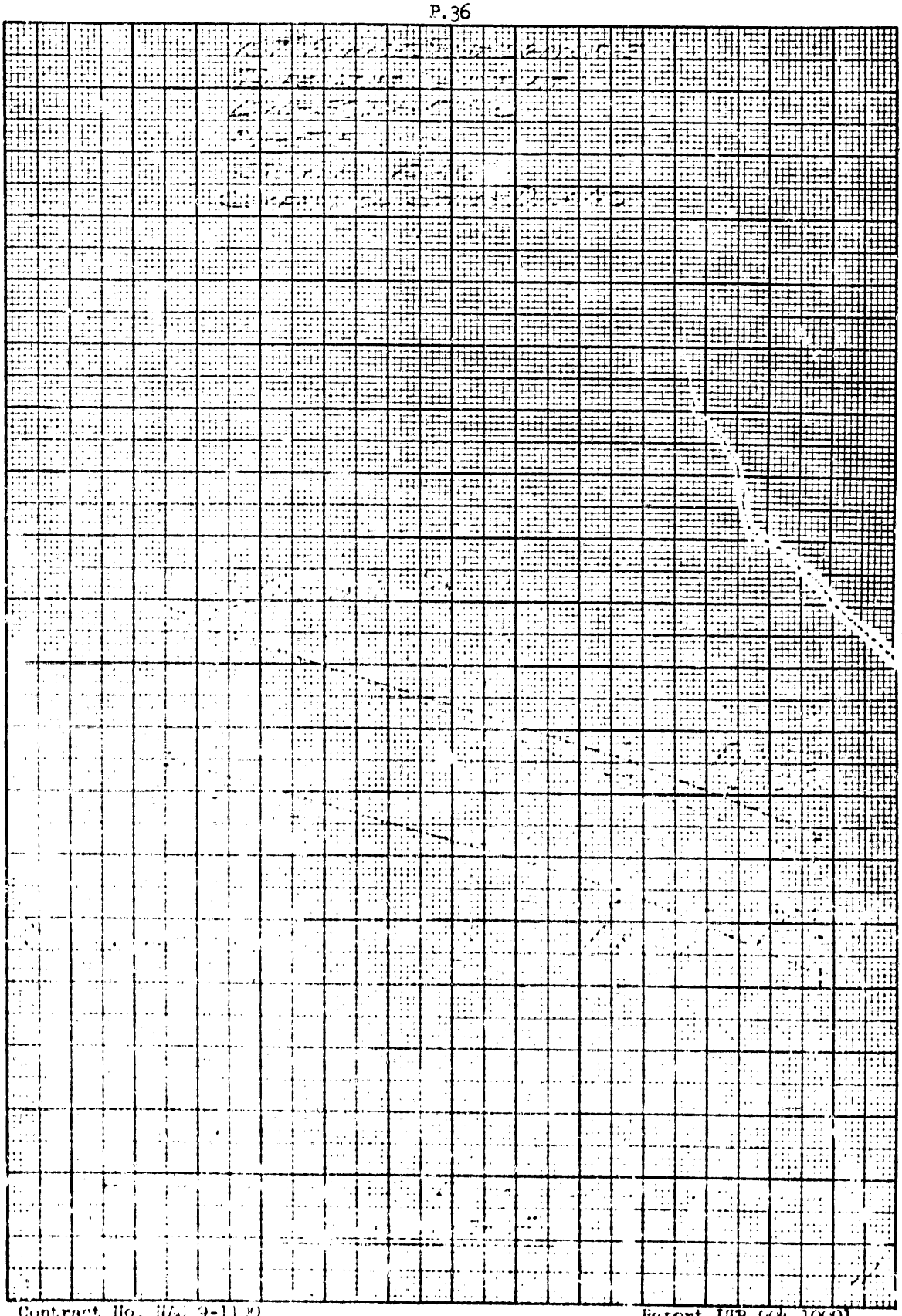

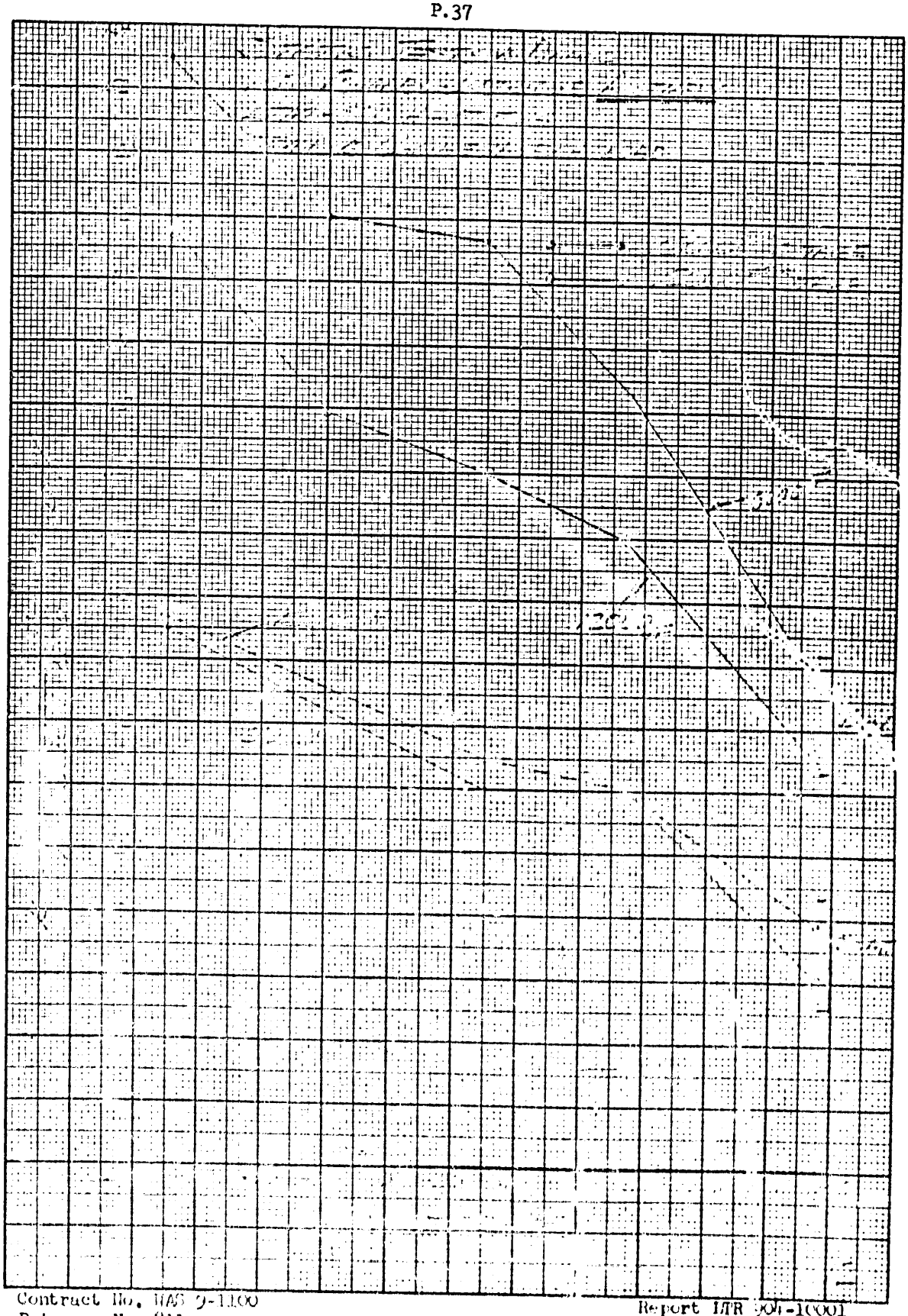

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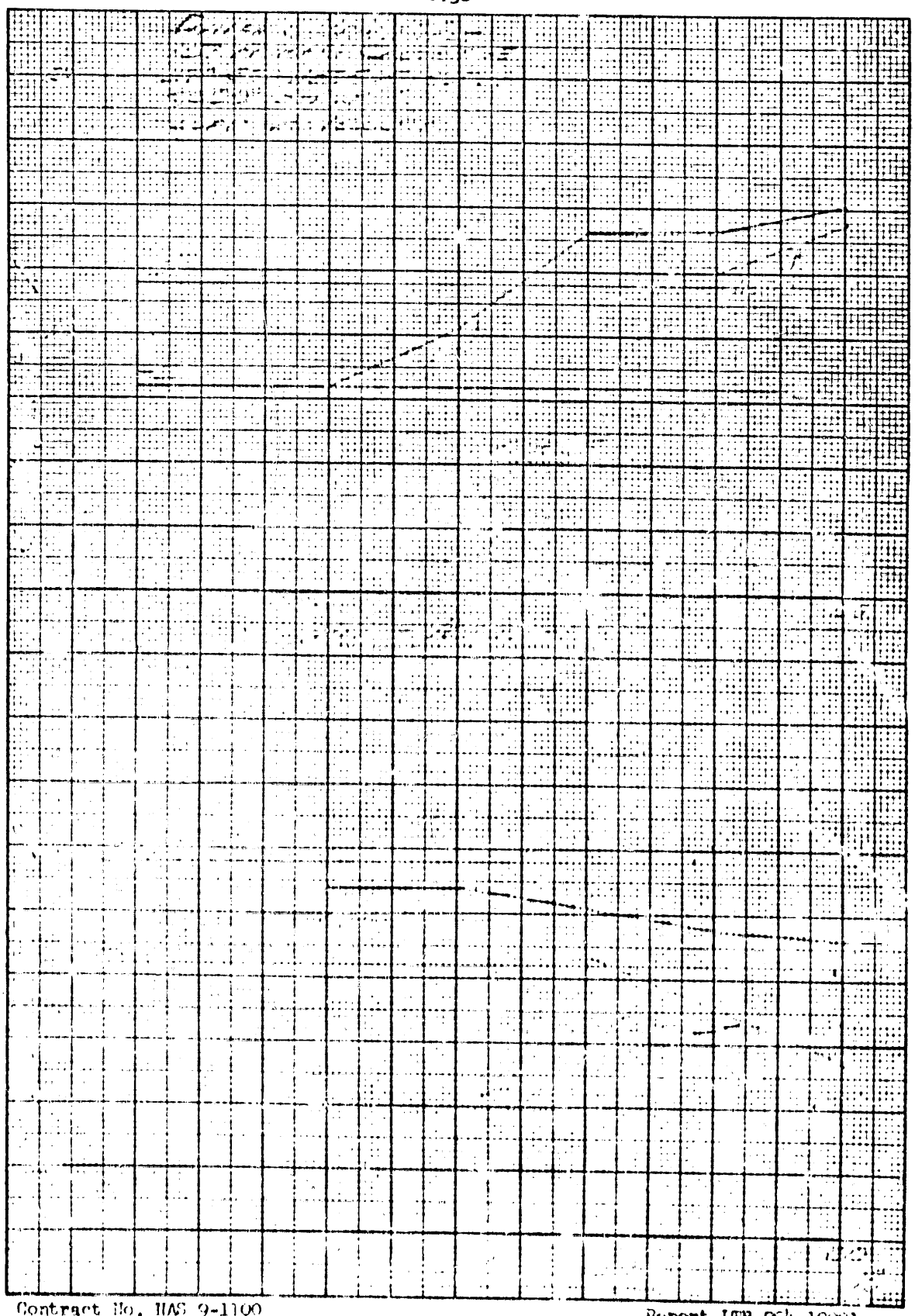

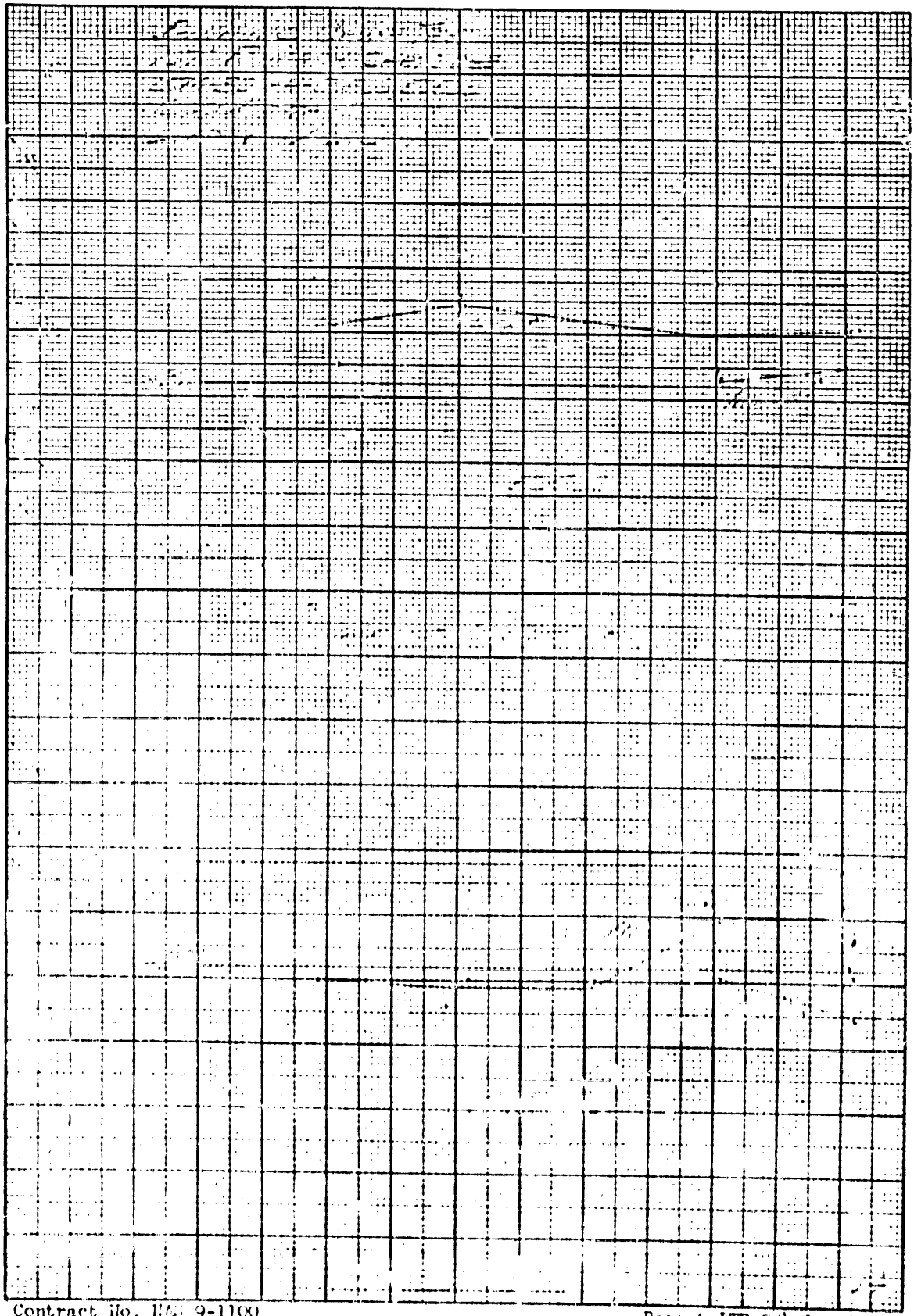

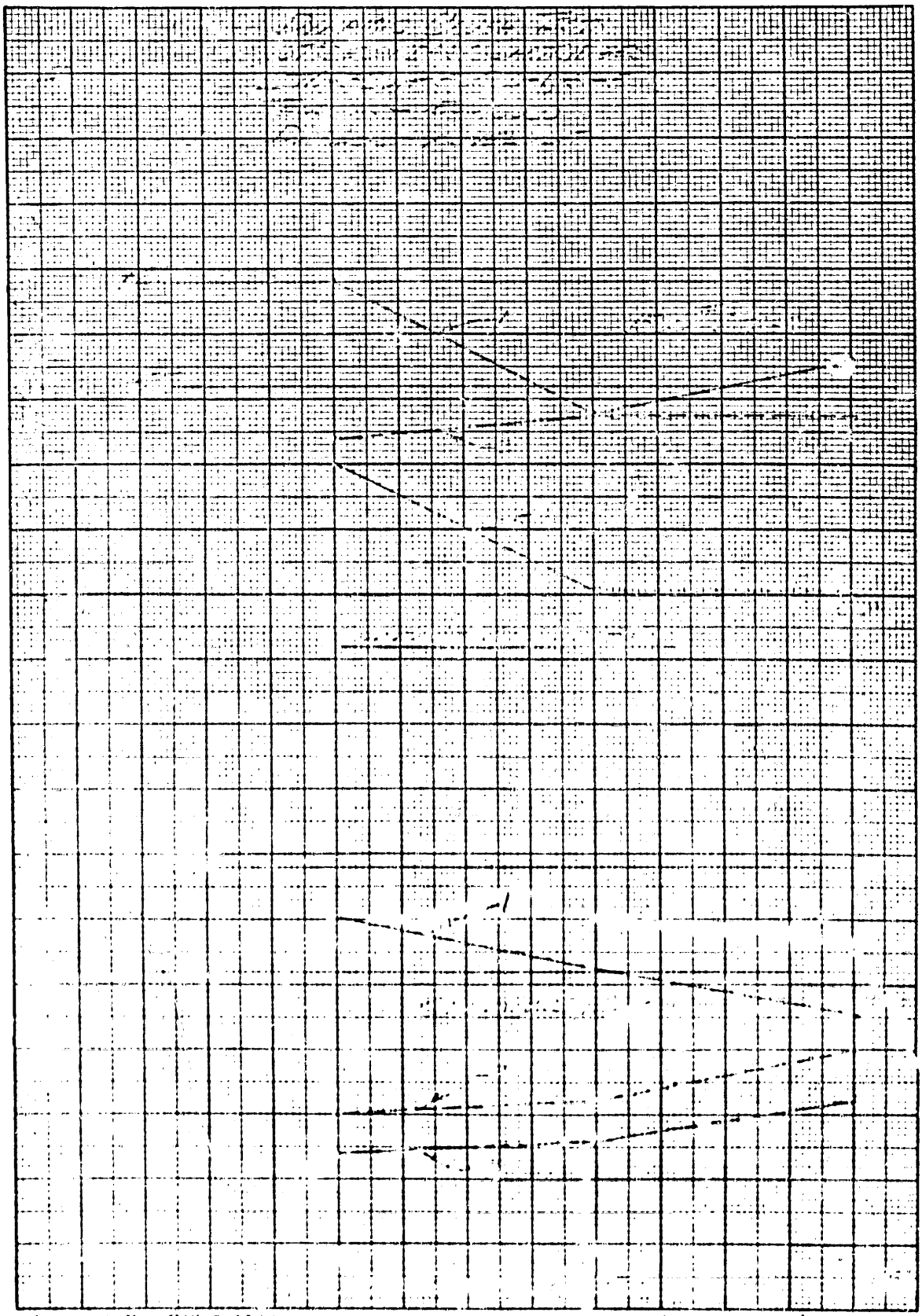

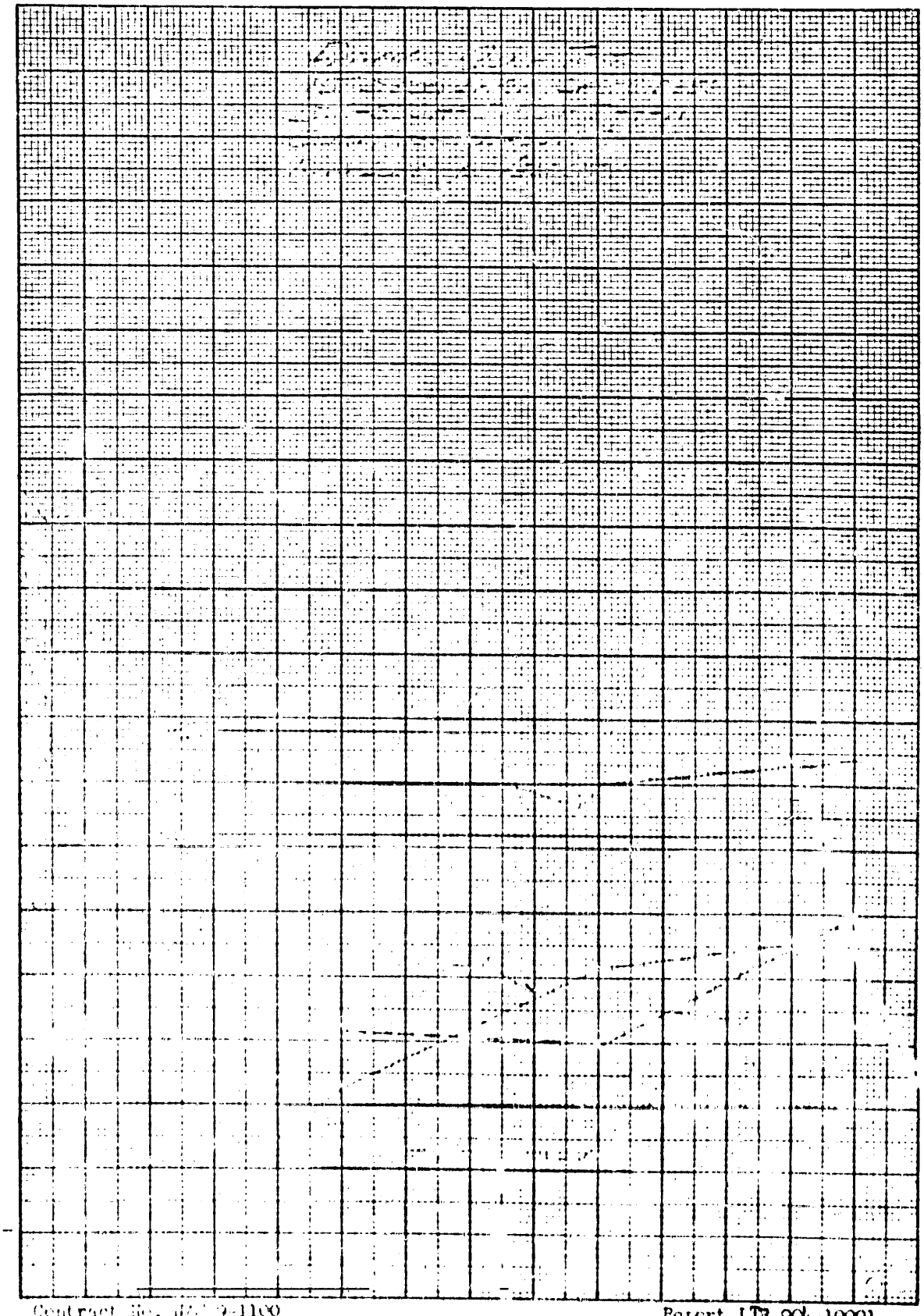

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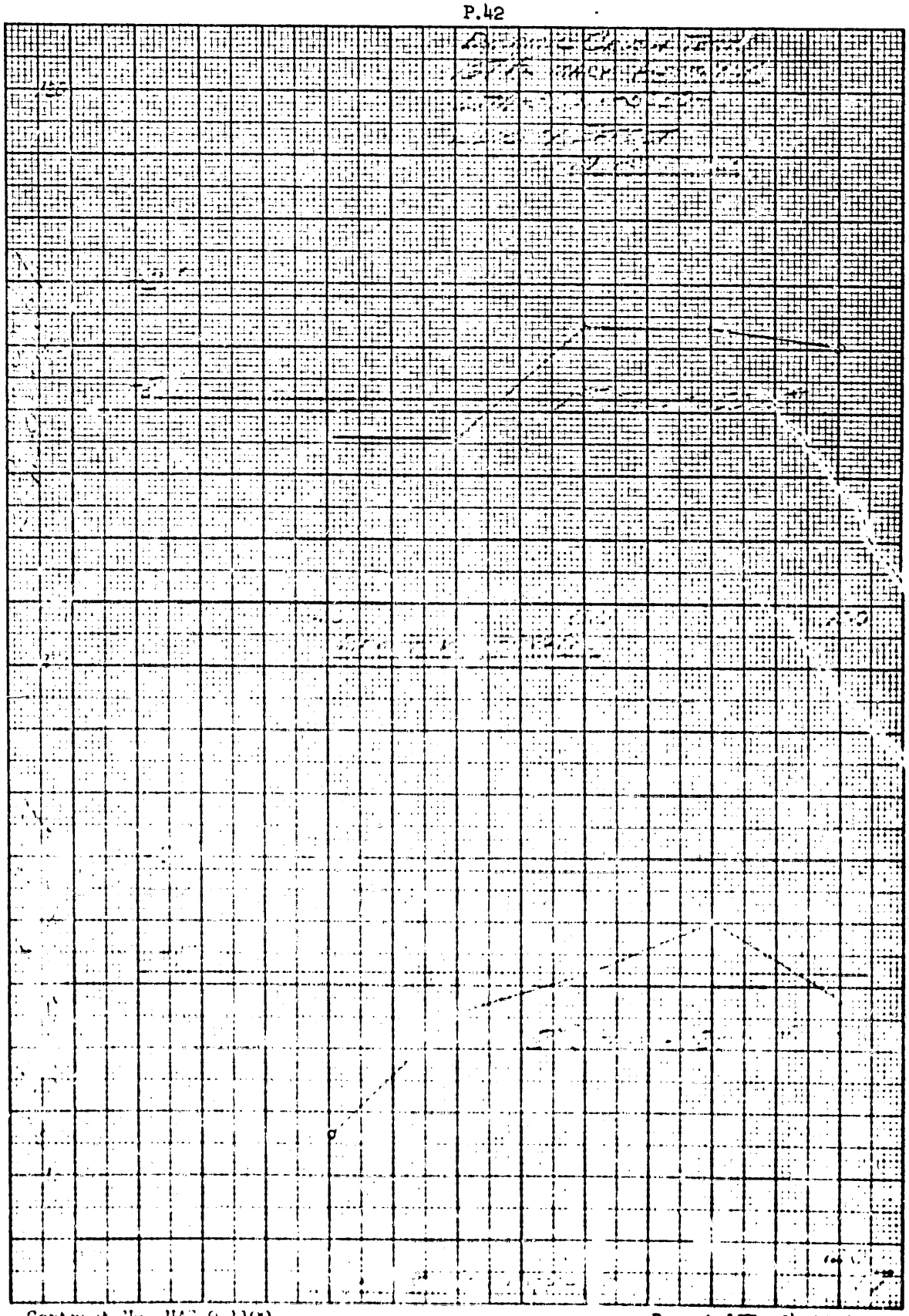

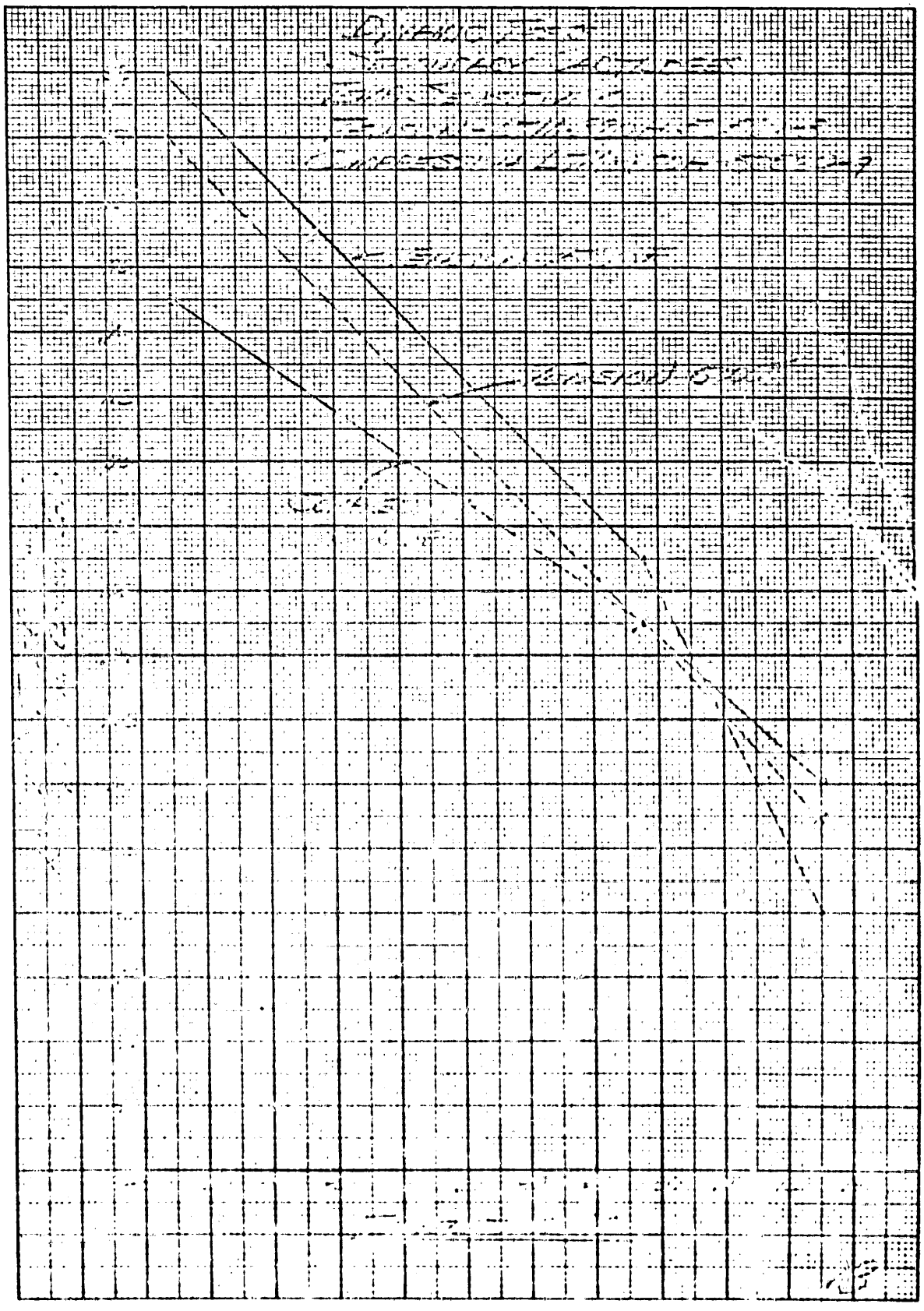

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS
160" CARTRIDGES

TEST No.	CARTRIDGE SER. No		NOMINAL CRUSH	PRECRUSH LOAD	ACTUAL LOAD	% DIFF FROM NOM	MAX. VARIATION	MAX. VAR %	STROKE INCHES
PRIMARY - LTM-320 H50500 ASSEMBLY									
1	4	3	5450	5400	5300	-3.0	100	2.0	15
		4	10900	10800	10700	-2.0	400	4.0	10
2	3	2	5450	5250	5300	-3.0	100	2.0	15
		23	10900	10800	10500	-3.6	200	4.0	10
3	7	31	5450	5550	5400	-1.8	100	2.0	15
		8	[illegible]	[illegible]	[illegible]	-2.3	400	4.0	10
SECONDARY - COMPRESSION - LTM-320 H [illegible] -9									
4	012		4550	4450	4500	-1.1	400	9.0	6.55
5	[illegible]		[illegible]	[illegible]	[illegible]	-3.8	[illegible]	18.0	6.55
6	[illegible]		4550	4470	[illegible]	-9.9	300	7.0	6.55
SECONDARY TENSION LTM-320 H [illegible]									
7	012		[illegible]	[illegible]	[illegible]	+1.1	[illegible]	18.0	2.5
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.0	[illegible]
[illegible]	014		1350	1400	[illegible]	+2.9	150	11.0	2.5
			[illegible]	[illegible]	[illegible]	-2.7	[illegible]	15.0	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	2.5
			[illegible]	[illegible]	[illegible]	+1.0	[illegible]	16.0	[illegible]

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
PRIMARY 160
LTM-320-H50500
TEMP. TESTS

Run No.	Cartridge Ser. No.		Velocity Fps	Temp. °F	Pre-Crush	Dynamic Crush	Stroke In.	Dyn. Effect %		Remarks
161	0027		12.45	−199	5550	7660	15.0	1.380		
					11[illegible]	5[illegible]	5.2	1.351		
162	0028		12.40	−201	5550	4290	15.0	.803		
					10800	9230	7.2	.853		
167	0005		4.15	+200	5325	—	—	—	RE-TEST	
					10590	10300	2.06	.957		
168	0011		4.4	+201	5500	—	—	—	RE-TEST	
					10650	14450	2.73	.911		
169	0011		4.15	−198	5500	—	—	—		
					10650	14450	1.73	1.355		
175	0034		12.5	+138	5200	5300	15.0	1.018		
					10500	11100	9.4	1.027		
176	0035		12.35	−70	5500	6650	15.0	1.209		
					11000	13780	8.1	1.253		
178	0040		12.32	−70	5325	6720	15.0	1.261		
					10550	13200	9.2	1.255		
	Repeated		Tests							
1[illegible]	0002		4.[illegible]	Amb	5325	—	—	—		
					[illegible]	11950	3.17	1.091		
1[illegible]	0002		4.[illegible]	Amb	5325	—	—	—		
					[illegible]	12[illegible]	3.[illegible]	1.09[illegible]		
1[illegible]	[illegible]		4.32	Amb	[illegible]	—	—	—		
					[illegible]	[illegible]	3.[illegible]	1.100		

Form B 53A 8-63

TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
PRIMARY 160"
LTM-320H 50500
1ST STAGE

Dyn. No.	Cartridge Ser. No	Velocity FPS	Pre-Crush	Dynamic Crush	Stroke in	Dyn. Effect %		Remarks
138	0005	4.10	5325	5890	15.0	1.106		
139	0002	4.12	5325	5970	15.0	1.121		
140	0011	4.15	5500	5970	15.0	1.086		
141	0038	4.10	5550	5940	15.0	1.070		
141	0010	8.15	5550	5970	15.0	1.074		
142	0012	8.07	5500	5970	15.0	1.086		
143	0013	8.35	5600	5970	15.0	1.064		
143	0016	8.26	5550	6140	15.0	1.106		
144	0014	12.35	5350	5930	15.0	1.112		
149	0015	12.35	5400	6050	15.0	1.120		
[illegible]	0001	12.40	5350	6150	15.0	1.148		
152	[illegible]	12.10	[illegible]	5970	15.0	1.075		
155	0021	17.9	[illegible]	6150	15.0	1.161		
156	[illegible]	17.7	5700	6350	15.0	1.113		
157	0023	18.1	[illegible]	6350	15.0	1.154		
158	[illegible]	[illegible]	[illegible]	6340	15.0	1.120		
159	0025	[illegible]	[illegible]	[illegible]	15.0	1.195		
160	[illegible]	[illegible]	5550	6440	15.0	1.160		
Special Cartridges - LTM-320 - #134								
166	0001	15.5	—	[illegible]	22.4	—	Re-dimed	
170	0002	18.15	—	[illegible]	21.0	—	To check	
179	0003	25.6	—	[illegible]	24.4	—	[illegible]	

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
PRIMARY 160"
LTM 320-H50500
2ND STAGE

Run No	Cartridge Ser No	Velocity FPS	Pre-Crush	Dynamic Crush	Stroke In.	Dyn Effect %	Remarks
138	0005	4.10	10590	11650	1.6	1.06[illegible]	
139	0002	4.12	10[illegible]	12[illegible]	1.3	1.113	
140	0011	4.15	10650	11500	1.7	1.078	
194	0038	4.10	10500	11400	1.1	1.070	
141	0010	8.18	10500	11650	8.6	1.111	
142	0012	8.07	10800	11750	8.9	1.0[illegible]	
143	0013	8.35	10[illegible]	11550	8.7	1.0[illegible]	
193	0018	8.26	10800	11500	7.7	1.092	
144	00[illegible]	12.35	10800	11600	7.2	1.07[illegible]	
[illegible]	0015	12.35	10800	11950	9.5	1.103	
[illegible]	0001	12.40	10650	11900	9.2	1.117	
192	0029	12.10	10350	11650	9.1		
155	00[illegible]	17.9	10400	[illegible]	9.5	1.1[illegible]	
156	0022	17.7	11[illegible]	11900	10.0	1.0[illegible]	
157	00[illegible]	18.1	10[illegible]	12000	10.3	1.1[illegible]	
158	0024	24.6	10[illegible]	11750	9.5	1.107	
159	00[illegible]	25.0	105[illegible]	12[illegible]	9.6	1.147	
160	0026	25.2	110[illegible]	11[illegible]	9.6	1.05[illegible]	
	SPECIAL CARTRIDGE [illegible]						
166	0001	12.3	—	11[illegible]	[illegible]	—	RE-[illegible]
170	00[illegible]	13.[illegible]	—	1[illegible]	6.6	—	TO CHECK
1[illegible]	00[illegible]	25.6	—	12[illegible]	[illegible]	—	[illegible]

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
SECONDARY 160"
LTM-320H-50550-1
TENSION 1ST STAGE

Test No	Cartridge Ser. No.		Velocity Fps		Pre-Crush	Dynamic Crush	Dynamic Effect %	Stroke in.		Remarks
145	0002		4.24		1350	1405	1.040	2.50		
146	0003		4.25		1400	1460	1.043	2.50		
147	0004		4.28		1350	1460	1.081	2.50		
179	0025		4.24		1411	1320	.935	2.50		
197	0026		4.21		1410	1405	.997	2.50		
198	0036		4.28		1360	1350	.993	2.50		
200	0027		4.26		1329	1370	1.032	2.50		
149	0005		8.00		1400	1460	1.043	2.50		
150	0006		8.20		1300	1375	1.057	2.50		
151	0007		9.12		1400	1375	.982	2.50		
178	0024		7.90		1323	1500	1.133	2.50		
[illegible]	0028		8.06		1325	1340	1.012	2.50		
202	0037		8.05		1325	1340	1.013	2.50		
203	0038		8.02		1350	1370	1.015	2.50		
152	0008		12.20		1375	1495	1.088	2.50		
153	0009		12.20		1350	1490	1.103	2.50		
176	0023		12.03		1341	1550	1.161	2.50		
177	0010		12.20		1364	1500	1.100	2.50		
204	0031		12.15		1325	1340	1.012	2.50		
205	0039		12.10		1400	1350	.977	2.50		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
SECONDARY 160"
LTM-320 H-50550-1
TENSION 2ND STAGE

[illegible] No.	CARTRIDGE SER. No.		VELOCITY FPS		FRE CRUSH	DYNAMIC CRUSH	DYNAMIC EFFECT %	STROKE IN.		REMARKS
145	0002		4.24		5600	5430	.969	3.40		
146	0003		4.25		5500	5890	1.071	3.28		
147	0004		4.28		5300	5500	1.037	3.34		
179	0025		4.24		5297	5550	1.047	3.16		
197	0026		4.21		5457	5525	1.013	2.90		
198	0036		4.28		5482	5200	1.054	3.45		
200	0027		4.26		5262	5060	.962	2.22		
148	0005		8.00		5400	5760	1.067	5.96		
150	0006		8.20		5500	5680	1.033	6.65		
151	0007		9.12		5400	5530	1.024	7.07		
178	0024		7.90		5380	5620	1.043	7.36		
[illegible]	0028		8.06		5433	5590	1.028	5.34		
202	0037		8.05		5461	5360	.982	6.45		
203	0038		8.02		5377	5520	1.025	6.05		
152	0008		12.20		5450	5470	1.003	7.90		
153	0009		12.00		5250	5940	1.132	7.35		
176	0023		12.03		5503	5570	1.012	7.15		
177	0010		12.20		5289	5620	1.063	7.05		
204	0031		12.15		5336	5360	1.006	6.97		
205	0029		12.10		5431	5260	.969	6.75		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
SECONDARY 160"
LTM-320H50550-9
COMPRESSION

Run No	Specimen Ser. No		Velocity Fps		Pre-Crush	Dynamic Crush	Stroke In	Dynamic Effect %		Remarks
130	0002		4.51		4500	4240	6.91	.945		
131	0009		4.14		4500	4500	4.15	1.000		
132	0011		4.24		4500	4720	3.81	1.049		
133	0015		4.27		4560	5330	3.26	1.169		
137	0005		4.18		4440	4900	3.90	1.105		
171	0013		4.28		4700	4700	4.00	1.000		
189	0022		4.30		4500	4840	3.42	1.075		
196	0032		4.27		4652	4990	3.42	1.077		
157	0034		4.25		4754	4840	3.02	1.017		
134	0004		8.20		4600	5060	5.50	1.099		
135	0012		8.14		4600	5440	5.06	1.181		
136	0014		8.00		4600	5140	5.43	1.116		
151	0024		8.04		4400	4570	6.25	1.038		
154	0031		8.08		4431	4725	5.74	1.070		
165	0035		8.17		4571	5510	4.71	1.205		
170	0036		8.00		4444	4940	5.40	1.112		
191	0037		8.00		4614	5040	5.06	1.072		
206	0053		8.80		4441	4625	5.15	1.037		
172	0012		12.15		4450	4400	6.72	.940		
173	0020		12.25		4550	4700	6.20	1.032		
174	0021		12.00		4600	4905	5.40	1.064		
175	0023		12.10		4550	4610	5.59	1.023		
192	0025		12.15		4500	5140	5.59	1.141		
193	0030		12.50		4454	5100	5.74	1.150		
198	0035		12.10		4652	4990	5.60	1.072		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS 167
Primary
LTM320H50504 Ass'y

Run No	Cartridge Ser No		Temp °F		Pre Crush	Amb Crush	Static Crush		Static / Pre Crush	
43	0010		-70			5225	5600		1.055	
							11200		1.056	
45	0014		+30				5200		1.00	
							10375		1.01	
41	0001		Amb				5,000		1.000	
							10000		1.000	
						5425	5225		.958	
42	0009		+135			10500	9700		.940	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS 167
Primary
LTM320H50505
& LTM320H50509

Form No.	Cartridge Ser. No	Temp °F	Pre-Crush	Ambient Crush	Static Crush	Static/Pre-Crush %
50505			LTM-320-H-50505			
11	0005	-70	5200	5300	5900	1.11
12	0005	-20	5200	5300	5475	1.07
25	0013	-20	5300	5350	5800	1.085
13	0004	+30	5100	5300	5450	1.03
3	0001	Amb	5300	5300	5300	1.00
5	0003	+100	5175	5350	5250	.982
4	0002	+135	5175	5420	5150	.950
			LTM-320H-50509			
50509						
22	0005	-70	5225	5400	5800	1.075
[illegible]	0008	-70	5300	5260	5750	1.09
18	0004	-20	5375	5300	5550	1.05
29	0017	+30	5300	5350	5550	1.04
17	0005	Amb	5225	5275	5275	1.00
25	0019	+100		5250	5150	.98
27	0014	+135		5400	5150	.95

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS 167
Primary 167
LTM320H50506

RUN No.	Surface Gage No.		Temp °F		Pre-Crack	Amb Crack	Static Crack		[illegible]	
31	0012		-70		10800	11125	12325		1.11	
30	0017		-70		10550	10620	11650		1.095	
16	0007		-20		10750	10750	11400		1.06	
15	0007		+30		10750	10750	[illegible]		1.025	
32	0012		+30		10800	11125	11500		1.03	
14	0006		Amb		10650	10600	10600		1.00	
33	0012		Amb		10900	11125	11125		1.00	
39	0016		+100		10250	10280	11[illegible]0		.887	
28	0011		+135			10300	9800		.95	
34	0011		+135		10200	10700	10100		.945	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS
Primary 167"
LTM320H50508

Gun No	Cartridge Ser No		Temp °F		Pre-Crush	Amb. Crush	Static Crush		Static / Pre-Crush	
19	0016		-70		10800	10700	11600		1.08	
37	0018		-70		10350	10350	11200		1.08	
8	0007		-55		10800	10725	11350		1.065	
9	0007		-30		10800	10650	11300		1.06	
21	0016		-20		10800	10700	11400		1.065	
38	0018		-20		10350	10350	10900		1.05	
36	0019		+30		10350	10350	10650		1.03	
10	0007		+40		10800	10650	11000		1.025	
1	0001		Amb			10650	10650		1.00	
2	0002		Amb			10500	10500		1.00	
44	0026		Amb			..	7900	DIA. REDUCED		
7	0009		+100		10800	10700	10575		.987	
27	0009		+100		10800	10700	10475		.970	
6	0006		+135		10800	10500	10500		.965	
23	0007		+135		10800	10700	10150		.95	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS
Secondary :167
LTM 320H50560-1

RUN No	Cartridge Ser No		Temp °F	Pre Crush	Time Crush	Static Crush		Static / Pre Crush		
67	0003		-70	1250		1300		1.040		
				5225		5725		1.110		
70	0007		-20	1280		1325		1.035		
				5175		5800		1.125		
69	0006		+30	1295		1300		1.035		
				5100		5375		1.121		
48	0005		Amb	1300		1200		100		
				5075		5050		100		
58	0001		+100	1260		1150		.912		
				5400		5300		.985		
51	0002		+135	1275		1025		.804		
				5250		5125		.953		

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

STATIC TESTS
Secondary 167"
LTM320H50560-3
& LTM320H50560-5

	RUN No	Cartridge Ser. No		Temp °F		Pre Crush	Amb Crush	Static Crush		Static / Pre Crush	
				LTM-320H-50560-3							
-3	66	0003		-70		1290		1325		1.035	
						4800		5225		1.023	
	49	0005		Amb		1285		1150		.90	
						5300		5375		1.00	
	50	0006		+135		1250		1050		.821	
						5025		4550		.900	
				LTM-320H-50560-5							
-5	68	0004		-70		1050		1300		1.024	
						4800		5725		1.056	
	59	0009		Amb		1045		[illegible]		1.00	
						4750		4750		1.00	
	58	0010		+135		1125		875		.801	
						5100		4700		.932	

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Static Tests
Secondary 167
LTM320H50560-7
-9
-11

	Cartridge Ser No		Temp °F		Pre Crush	Aux Crush	Static Crush		S.T./Pre Crush	
			LTM-320H-505			0-7				
-7 63	0014		-70		5300		5775		1.109	
65	0005		-20		5000		5475		1.10	
64	0027		-20		5525		5560		1.006	
46	0006		Amb		5650		55[illegible]		1.02	
55	0024		+100		5250		5150		.981	
47	0013		-135		5200	5075	4475		.88	
			LTM-320H-505			0-9				
-9 61	0005		-70		5250		5725		1.095	
54	0002		Amb		5275		[illegible]		[illegible]	
53	0006		+135		5250		4400		.857	
			LTM-320H-505			0-11				
-11 62	0005		-70		5250		5500		1.052	
56	0004		Amb		5250		[illegible]		[illegible]	
57	0010		+135		5225		[illegible]		.942	

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM320-50504 Ass'y
Pg 1 of 2

Run No.	Cartridge Serial		Velocity FPS	Temp °F	Pre-crush	Dynamic Crush	Stroke in	Dyn Effect	Pressure		
290	0007		4.0	Amb	5300	5640	17.3	1.065	Atm		
					10800	10950		1.015			
291	0007		6.0		5400	5740	21.2	1.065	Atm		
					10450	11100		1.065			
292	0003		8.0		5400	6050	25.8	1.12	Atm		
					10600	11480		1.08			
294	0010		10.0		5160	5790	25.7	1.12	Atm		
					10525	11600		1.10			
2[illegible]	0011		12.0		5340	6020	29.6	1.13	Atm		
					10350	11450		1.11			
304	0011 With Studs		12.0		5500	6130	30.5	1.12	Atm		
					10625	11300		1.06			
305	0009 With Studs		12.0		5225	5700	30	1.09	Atm		
					10600	[illegible]		1.05			
311	0008 Studs		12.0		5400	5760	29.6	1.07	Atm		
					10550	11240		1.07			
[illegible]	0013 Studs		12.0		5250	[illegible]	31	[illegible]	Vac		
					[illegible]	[illegible]		1.05			
316	0014 Studs		12.0	Amb	5175	5740	29.2	1.11	Atm		
					[illegible]	11300		1.075			

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM 326-50504 Ass'y
Pg 2 of 2

N No.	Cartridge Ser. No.		Velocity FPS	Temp °F	Pre-Crush	Dynamic Crush	Stroke IN	Dyn. Effect	Pressure	
298	0006		12	-70°	5300	6540	28.9	1.23	Atm	
					10550	12400		1.17		
299	0005		12	-70°	5225	6375	32.4	1.22	Vac	
					10450	12400		1.19		
315	0003		12	-70°	5410	6610	26.2	1.222	Atm	
					10550	12560		1.190		
303	0015		12	-20°	5325	6290	28.1	1.18	Atm	
					10650	11910		1.12		
296	0013		12	+30°	5250	6200	28.2	1.18	Atm	
					10650	11700		1.10		
297	0017		12	+135°	5300	5470	31.6	1.031	Atm	
					10650	10730		1.01		
300	0004		12	+135°	5275	5150	32.5	.976	Vac	
					10500	10600		1.01		
314	0001 STUD		12	+135°	5500	5400	31.2	.982	ATM	
					10600	10490		.980		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM 320 H 50505

Run No	Cartridge Ser. No		Velocity FPS	Temp °F	Pre-Crush	Dynamic Crush	Stroke in.	Dyn. Effect	Pressure	Remarks
211	0006		4.14	Amb	5275	5820	10.15	1.103	Atm	
253	0018		6.00		5250	5800	11.2	1.105	Atm	
212	0007		7.2		5300	6325	10.4	1.13	Atm	
213	0008.		7.97		5250	6250	10.77	1.14	Atm	
214	0009		9.96		5150	5900	11.8	1.14	Atm	
277	0021		10.0		5400	5830	3.66	1.08	Vac	
278	0021		10.0		5400	5840	3.62	1.08	Atm	
215	0016		10.08		5250	5900	11.95	1.125	20 microns	
279	0023		12.00		5200	5920	5.17	1.14	Vac	
280	0023		12.00		5200	6000	4.97	1.155	Atm	
216	0011		12.18		5125	5910	11.3	1.145	Atm	
217	0012		12.2	Amb	5325	5900	11.45	1.11	3.25 microns	
284	0017		10.0	-70	5350	6675	3.21	1.25	Atm	
285	0017		10.0	-70	5350	6300	3.24	1.18	Vac	
246	0015		11.9	-70	5200	6760	9.4	1.30	Atm	
247	0019		12.20	-20	5300	6500	9.1	1.23	Atm	
248	0016		12.00	+30	5300	6300	10.10	1.19	Atm	
282	0024		10.0	+135	5350	5800	3.65	1.085	Atm	
286	0024		10.0	+135	5350	5530	3.92	1.04	Vac	
239	0014		11.9	+135	5350	5750	11.5	1.07	Atm	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM 320 H50506

Run No	Cartridge Ser No		Velocity Fps	Temp °F	Pres Crush	Dynamic Crush	Stroke in	Dyn Eff-1	Pressure		
224	0002		3.75	Amb	10300	11600	4.92	1.125	Atm		
221	0001		4.14	↑	10250	11200	6.18	1.09	Atm		
223	0002		6.04		10200	11,400	9.26	1.115	Atm		
222	0001		6.08		10250	11400	9.36	1.11	Atm		
225	0003		7.85		10300	11975	17.3	1.105	Atm		
226	0004		10.01		10950	12250	17.25	1.12	Atm		
274	0019		10.10		10200	11050	7.46	1.083	Vac		
275	0019		10.05		10200	11050	7.46	1.083	Atm		
272	0015		12.0		10500	11410	9.85	1.087	Vac		
273	0015		12.0		10500	11600	9.65	1.105	Atm		
283	0004		12.0	↓	10250	11250	2.4	1.10	Atm		
227	0005		12.40	Amb	10800	12450	17.00	1.105	Atm		
⋮											
[illegible]9	0022		12.0	-70	10500	13100	15.4	1.25	Atm		
251	0013		12.2	-70	10200	12,600	14.9	1.235	Atm		
288	0021		12.0	-20	10650	12650	11.8	1.19	Atm		
250	0010		12.2	-20	10800	12500	14.9	1.105	Atm		
287	0020		12.0	+30	10600	11850	17.25	1.118	Atm		
249	0009		12.1	+30	[illegible]	12600	15.2	1.12	Atm		
229	0008		12.40	+135	10650	11725	18.8	1.065	Atm		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM 320 H 50508
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N No.	Cartridge Ser No		Velocity FPS	Temp °F	Pre-Crush	Dynamic Crush	Stroke IN	Dyn. Effect	Pressure	
210	0003		3.72	Amb	10500	11250	4.22	1.07	Atm	
207	0004		4.25		10500	11220	4.25	1.07	Atm	
254	0021		5.8		10600	11200	8.5	1.06	Atm	
208	0004		6.05		10500	11220	8.438	1.07	Atm	
218	0005		7.08		10650	11300	11.20	1.06	Atm	
209	0003		8.11		10500	11200	14.75	1.07	Atm	
266	0024		9.9		10300	11400	6.8	1.105	Atm	
238	0017		10.0		10700	11600	6.3	1.085	Atm	
255	0021		10.0		10600	11650	9.8	1.10	Atm	
276	0022		10.0		10650	11600	4.54	1.10	Atm	
219	0008		10.10		10800	11750	18.80	1.08	Atm	
258	0022		10.1		10650	11500	6.5	1.08	Vac	
[illegible]35	0024		10.1		10300	11400	7.3	1.105	Vac	
259	0022		10.2		10650	11225	6.78	1.055	Atm	
293	0025		12		10800	11920	2.75	1.105	Atm	
301	0025		12		10800	10610	3.2	—	Atm	
[illegible]02	0026		12		10300	[illegible]	2.47	1.081	Atm	
308	0025		12		—	9680	2.75	—	Atm	
309	0026		12		—	[illegible]	2.75	—	Atm	
310	0028		12		10700	[illegible]	7.2	1.064	Atm	
313	0026		12		—	[illegible]	3.1	—	Atm	
317	0026		12		—	[illegible]	3.52	—	Atm	
[illegible]37	0017		12.2		10700	11700	9.2	1.09	Atm	
[illegible]56	0020		12.2		10650	11200	9.8	1.055	Vac.	
257	0020		12.2		10650	11400	9.43	1.07	Atm	
[illegible]20	0010		12.35	Amb	10950	12250	18.90	1.12	Atm	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM 320H50508
Pg 2 of 2

No.	Cartridge Ser No		Velocity FPS	Temp °F	Pre-crush	Dynamic Crush	Stroke In	Dyn. Eff	Pressure	
233	0015		12.0	-70	10800	12550	15.15	1.16	Atm	
231	0013		12.25	-70	10650	12700	15.7	1.19	Atm	
232	0014		12.25	-20	10700	12150	16.25	1.135	Atm	
230	0012		12.25	+30	10850	12350		1.14	Atm	
267	0023		12.0	+135	10850	11200	15.75	1.03	Atm	
228	0011		12.40	+135	10700	11325	19.20	1.07	Atm	

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Dynamic Tests
Primary 167"
LTM320 H 50509

Run No.	Cartridge Ser. No.		Velocity FPS	Temp °F	Pre-Crush	Dynamic Crush	Stroke IN	Dyn Effect	Pressure	
234	0001		4.08	Amb.	5375	5950	8.77	1.11	Atm	
235	0002		6.11		5450	6025	11.2	1.11	Atm	
236	0003		7.98		5250	5950	11.2	1.13	Atm	
307	0023		8.0		5300	5720	6.65	1.08	Atm	
260	0021		8.5		5300	5775	2.9	1.09	Vac	
262	0021		9.8		5300	5925	3.56	1.12	Atm	
261	0021		9.9		5300	5650	3.58	1.035	Vac	
252	0010		10.0		5500	6050	11.32	1.10	Atm	
306	0007		10.0		5300	5790	10.94	1.09	Atm	
264	0022		11.8		5400	5840	5.4	1.08	Atm	
263	0022		11.9		5400	5650	5.57	1.045	Vac	
242	0012		12.00		5400	5740	11.4	1.06	Atm	
281	0011		12.0	Amb.	5300	5980	11.1	1.13	Atm	
270	0020		9.75	-70	5200	5950	3.53	1.145	Atm	
271	0020		9.9	-70	5200	5950	9.9	1.145	Vac	
243	0013		12.0	-70	5600	5890	11.5	1.18	Atm	
244	0015		12.0	-20	5250	6100	11.02	1.16	Atm	
245	0018		12.0	+30.	5550	6100	10.4	1.10	Atm	
269	0016		9.9	+135	5375	5280	4.3	—	Vac	
241	0009		12.0	+135	5250	5490	11.2	1.05	Atm	
268	0016		9.9	+135	5375	5360	3.91	1.03	Atm	
240	0006		12.15	+135	5550	5660	11.5	1.02	Atm	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
SECONDARY 167"
LTM320H50560-1

Ring No	Cartridge Ser No		VELOCITY F.P.S	Temp °F	Pre-CRUSH	Dynamic CRUSH	Stroke IN	Dyn. EFFECT	PRESSURE	
333	0023		4	Amb	1265	1435	16.45	1.13	Atm	
					5000	5490		1.10		
335	0024		8		1300	[illegible]	10.15	1.06	Atm	
					5175	5500		1.06		
345	0020		8		1295	1390	8.43	1.07	Atm	
					5240	5750		1.10		
344	0022		12		1275	1390	13.1	1.09	Atm	
					5275	5630		1.07		
35[illegible]	0012		12	Amb	1320	1475	13.32	1.12	Vac	
					5250	5590		1.045		
351	0013		12	-70	1320	[illegible]	11.30	1.27	Atm	
					5100	6372		1.25		
352	0002		12	+30	1255	1630	11.6	1.27	Atm	
					5275	[illegible]		1.17		
341	0021		12	-135	[illegible]	[illegible]	11.45	1.02	Atm	
					[illegible]	[illegible]		1.05		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
Secondary 167"
LTM 320 H 50560-3

RUN NO.	CARTRIDGE SER. NO.		Velocity FPS	Temp °F	Pre-crush	Dynamic Crush	Stroke In	Dyn. Eff.	Pressure	
331	0001		4	Amb	1260	1335	16.4	1.06	Atm	
					4975	5100		1.025		
334	0002		8		1300	1390	15.0	1.07	Atm	
					4900	5050		1.03		
342	0004		12		1295	1390	15.1	1.07	Atm	
					5100	5340		1.05		
355	0010		12	Amb	1275	1260	16.5	.99	Vac	
					4950	5050		1.02		
34[illegible]	0008		12	-70	1255	1535	13.12	1.22	Atm	
					5000	6000		1.20		
346	0009		12	+135	1280	1320	15.5	1.01	Atm	
					5175	5150		1.00		
347	0003		12	+135	1125	1035		.921	Atm	
					4925	4760		.987		

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TABULATION FORM

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
Secondary 167"
LTM 320H50560-5

RUN No.	Cartridge Ser No		Velocity FPS	Temp °F	Pre-Crush	Dynam. Crush	Stroke In	Dyn. Effect	Pressure	
332	0006		4	Amb	1050	1100	16.5	1.047	Atm	
					4900	4875		1.01		
336	0007		8		1120	1125	14.5	1.00	Atm	
					4925	5000		1.015		
343	0008		12		1100	1100	15.1	1.00	Atm	
					4830	5000		1.03		
355	0001		12	Amb	1115	1100	15.4	1.00	Vac	
					4875	5110		1.05		
356	0002		12	-70	1075	1400	13.32	1.31	Atm	
					4775	5500		1.15		
347	0003		12	-125	1125	1030	13.52	.915	Atm	
					4925	4750		.987		

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
Secondary 167"
LTM320H50560-7

RUN No	Cartridge Ser No		Velocity FPS	Temp °F	Pre-crush	Dynamic Crush	Stroke In	Dyn Effect	Pressure	
318	0017		4	Amb	5775	6360	9.75	1.10	Atm	
319	0021		8	↑	5325	5860	8.88	1.10	Atm	
360	0007		10		5675	5930	3.00	1.045	Vac	
361	0007		10		5675	6060	3.00	1.07	Atm	
320	0018		12	↓	5430	6050	8.45	1.11	Atm	
357	0039		12	Amb	5350	5430	8.95	1.01	Vac	
321	0025		12	-70	5250	6330	7.8	1.205	Atm	
324	0045		12	-20	5275	6200	8.44	1.175	Atm	
325	0016		12	+135	5475	5600	9.32	1.02	Atm	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC TESTS
Secondary 167"
LTM326H50560-9

RUN No	Cartridge Ser No		Velocity FPS	Temp. °F	Pre-Crush	Dynamic Crush	Stroke In	Dyn. Eff	Press.	
329	0001		4	Amb	5250	5280	9.35	1.005	Atm	
338	0010		8	↑	5200	5210	9.05	1.00	Atm	
322	0008		12	↓	5275	5540	9.76	1.05	Atm	
358	0004.		12	Amb.	5475	5220	9.75	.954	Vac	
340	0003		12	-70	5225	6000	8.83	1.15	Atm	
326			12	+135	5250	5250	9.77	1.00	Atm	

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

DYNAMIC ANALYSIS
Secondary 167"
LTM 320 H50560-11

RUN No	Cartridge Ser. No		Velocity FPS	Temp °F	Pre-Crush	Dynamic Crush	Stroke In	Dyn. Effect	Press.	
330	0002		4	Amb	4900	4750	9.5	.97	Atm	
339	0006		8	↑	5175	5340	9.05	1.03	Atm	
327	0004		12	↓	5250	5450	9.45	1.04	Atm	
359	0003		12	Amb	5150	5110	9.75	.99	Vac	
341	0007		12	-70	5000	5610	8.8	1.12	Atm	
338	0001		12	+135	5225	4570	9.95	.875	Atm	

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

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RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

LIST OF DRAWINGS

LTM-320-H-10701	Landing Panel Assembly

LIST OF REFERENCES

LTP-904-10001; Section Q

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

INTRODUCTION

This section of the report contains the results of the test conducted on the LEM Landing Gear Footpad LTM-320-H-10701. With one minor exception, the footpad satisfactorily withstood the Design Normal Load of 12 psi at both ambient and 215°F temperature.

This is a continuation of the Footpad Development Program. The results of previous tests were presented in Section D & J of this report.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

1.0 PURPOSE OF TEST

1.1 The purpose of the test was to verify the structural integrity of the footpad when subjected to a uniformly distributed load at ambient and 215 ± 10°F temperature conditions. A test failure at 215 ± 10°F temperature was conducted to establish the design reserve margins.

1.2 Strain gages were located on the footpad as shown on Figure 1 to verify the stress analysis.

2.0 DESCRIPTION OF TEST SPECIMEN

2.1 The test article consisted of a panel assembly as per dwg. No. LTM-320-H-10701.

2.2 The test specimen was 37 inches in diameter and of bonded aluminum honeycomb sandwich construction. The core is a composite of 5052 Aluminum Foil (0.0010 inch thick and 3/16 inch cell size) and of 2024-T81 Aluminum Foil (0.0015 inch thick and 3/16 inch cell size) assembled as shown on dwg. No. LTM-320-H-10701. The skins are 7075-T6 aluminum tapered to the outer edge.

2.3 One pad conforming to dwg. LTM-320-H-10701 was used for this test.

3.0 TEST CONDITIONS

3.1 The test simulated that part of the Lunar Landing which would subject the pad to a uniformly distributed pressure loading.

3.2.1 Test 1 : Proof Test (Design Normal Load - 12 psi) was conducted at ambient environmental conditions.

3.2.2 Test 2 : Proof Test and Failure Test were conducted at 215 ± 10°F temperature.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

3.0 TEST CONDITIONS - continued

3.2.3 Design limit and ultimate normal pressures are coincident at 12 psi since the pad is designed to a ultimate factor of safety of 1.

3.2.4 During both tests the pad remained in a horizontal attitude. The method of load application was essentially static in that no attempt was made to achieve a specific rate of pressure loading.

4.0 TEST SET-UP AND PROCEDURE

4.1.1 The test article was set up and installed as previously described in Section J of this report. (see photo LPS-560-848)

4.1.2 Pressure was measured using a pressure transducer at the inlet port of the rubber bladder. The normal pressure load was reacted by a rigid compression member incorporating a strain gage load cell. Strain gages were installed on the footpad as shown in Figure 1.

4.2 The pad was first subjected to the design normal load of 12 psi at room temperature. Upon completion of the above, the pad was heated to 215°F and subjected to an increasing pressure load until failure ocurred.

5.0 RESULTS AND CONCLUSIONS

5.1 Examination of the results as indicated on Strain Gages #5,7,8, 18,10,20 indicates a possible local bond failure on the compression skin (inner skin) at 11.2 psi during the proof test. At the completion of the proof test, visual inspection of the footpad showed no external structural damage. However, this apparent failure was not critical enough to effect the continuity of the pad since total failure did not occur until 13.8 psi during the elevated temperature test.

RESULTS OF THE LEM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION Q. - RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LTM-320-H-10701

5.0 RESULTS AND CONCLUSIONS - continued

5.2 Further examination of the strain data and resulting stress distribution curves indicated that the stress analysis was conservative. The magnitude of the stresses derived from the test data were lower than those derived from the original stress analysis. Closer correlation of test data to analysis is obtained if maximum skin thicknesses are used instead of the minimum skin thickness.

5.3 The failure mode of the pad may be seen in photographs LPS-560-861, 862, 928.

5.4 A comparison of the data presented on Table I (Results of Ambient Temperature Test) and Table II (Results of Elevated Temperature Test - 215°F) shows good correlation of the strains in both tests.

TABLE I

RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LSK-320-H-10701

PROOF TEST - AMBIENT TEMPERATURE

Pressure (psi)	1.16	1.98	3.28	4.23	4.95	5.38	6.02	6.42	6.65
Axial Load	450#	2050#	3440#	4450#	5300#	5750	6450#	6850#	7100#
Strain # / Direct. of Msm't.									
1/Comp	0	31	66	100	130	100	160	160	190
2/Ten	30	192	267	355	474	505	565	625	710
3/Comp	0	28	56	69	83	97	100	110	130
4/Comp	63	153	229	306	376	415	470	521	565
5/Comp	55	136	219	313	384	410	480	520	575
6/Ten	64	190	300	405	460	538	602	650	730
7/Comp	45	134	179	207	267	275	305	327	343
8/Comp	27	134	240	294	375	428	482	545	590
9/Ten	29	145	263	365	467	496	555	613	670
10/Comp	28	198	312	412	510	540	595	654	680
11/Comp	10	12	17	20	24	27	30	34	38
12/Ten	34	152	270	340	422	456	510	590	640
13/Comp	0	0	0	35	70	44	70	88	88
14/Comp	68	186	270	354	423	475	575	610	625
15/Comp	58	181	298	365	470	520	560	630	690
16/Ten	44	191	312	384	490	520	570	630	700
17/Comp	32	63	110	140	158	175	190	204	215
18/Comp	68	132	203	304	355	430	470	540	600
19/Ten	50	200	303	370	475	505	575	615	675
20/Comp	65	225	325	390	425	475	490	530	560

All Strain Values Shown on Tables I & II Have Units of -in/in

TABLE I - continued

RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LSK-320-H-10701
PROOF TEST - AMBIENT TEMPERATURE

Pressure	7.65	8.15	9.25	9.55	10.3	10.7	11.2	11.4	11.6
Axial Load	8200**	8700**	9850	10200**	11000**	11400**	11900**	12150**	12300**
Strain # / Direct. of Msm't.									**
1/Comp	210	210	240	270	300	330	360	365	380
2/Ten	770	860	965	1010	1040	1155	1190	1220	1260
3/Comp	138	151	165	179	192	206	221	214	211
4/Comp	643	705	782	829	860	935	1010	995	1030
5/Comp	629	667	795	820	875	902	985*	890	902
6/Ten	792	855	980	1010	1090	1140	1200	1225	1270
7/Comp	387	417	446	476	505	537	568	655*	685
8/Comp	682	750	800	830	895	945	990*	1390*	1900*
9/Ten	760	819	905	934	1020	1090	1165	1220	1255
10/Comp	755	810	880	910	965	1020	1080	1020	990
11/Comp	44	56	61	61	61	68	68	85	85
12/Ten	728	780	880	930	980	1030	1090	1105	1175
13/Comp	105	122	122	175	140	149	176	158	186
14/Comp	695	740	830	865	910	980	1050	1075	1100
15/Comp	760	830	920	960	990	1050	1070	1115	1145
16/Ten	765	870	905	975	1010	1090	1120	1160	1185
17/Comp	223	223	238	255	270	285	294	335	319
18/Comp	660	710	825	840	910	980	1010	990*	990
19/Ten	780	810	900	940	1010	1040	1120	1125	1180
20/Comp	620	650	720	750	780	820	835	935*	945

*Indication of Internal Failure **Average Strain Over 15 Sec. Time Period

TABLE II

RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LSK-320-H-10701

215° 10°F

Pressure TPI	2.58	3.12	3.55	4.09	4.74	4.95	5.80	6.65	7.20	8.00	8.92	9.25	9.50
Axial Load	2750#	3330#	3780#	4360#	5050#	5290	6200#	7100#	7700	8530#	9500#	9850#	10100#
Strain # / Direct of Msm't.													
1/Comp	28	55	69	83	110	117	138	179	206	247	262	272	300
2/Ten	268	327	387	438	507	536	579	685	745	833	910	955	1030
3/Comp	30	41	48	55	76	90	110	138	162	172	200	221	235
4/Comp	152	213	243	304	335	395	455	548	593	670	745	815	890
5/Comp	0	545	109	136	190	245	322	365	438	520	585	655	710
6/Ten	375	390	440	490	550	605	650	710	765	840	910	950	980
7/Comp	150	209	245	270	315	360	405	435	470	570	600	630	675
8/Comp	96	136	218	288	383	465	585	740	850	985	1120	1210	1340
9/Ten	375	430	475	530	590	630	690	745	800	890	960	1020	1070
10/Comp	375	430	515	575	645	690	745	820	890	945	1020	1060	1100
11/Ten	51	68	85	68	68	---	---	---	---	---	---	---	---
12/Ten	272	340	374	409	460	495	545	585	630	745	815	885	920
13/Comp	71	71	71	71	71	71	71	71	89	124	142	160	168
14/Comp	187	221	272	340	374	442	510	580	645	780	845	885	920
15/Comp	99	165	214	280	314	396	465	560	645	775	860	910	960
16/Ten	360	411	445	495	580	615	685	750	785	835	925	990	960
17/Comp	128	144	160	225	240	272	289	336	385	418	418	418	418
18/Comp	51	60	67	102	136	187	238	323	409	510	575	650	680
19/Ten	334	402	435	502	550	600	645	735	780	820	905	990	1035
20/Comp	376	480	562	580	682	715	765	820	890	955	990	1020	1060

TABLE II - continued

RESULTS OF THE NORMAL LOAD TEST OF FOOTPAD LSK-320-H-10701

215° 10°F

Pressure PT	10.55	11.0	11.6	11.7	12.45	12.6	13.1	13.25	13.35	13.45	13.50	13.65	13.80
Load	11200	11650	12350	12450	13300	13400	13950	14100	14200	14300	14400	14500	14600
Strain # / Direct. of Msm't.													
1/Comp	317	331	352	359	395	400	415	427	450	455	460	470	496
2/Ten	1085	1150	1220	1210	1340	1340	1385	1400	1410	1420	1450	1470	1520
3/Comp	249	262	276	276	316	316	322	322	360	359	360	375	388
4/Comp	955	1015	1080	1090	1180	1190	1210	1220	1250	1260	1270	1280	1310
5/Comp	765	900	950	960	970	975	990	980	1010	1010	1040	1000	985
6/Ten	1035	1110	1140	1180	1240	1250	1280	1300	1325	1300	1340	1350	1370
7/Comp	705	745	795	780	840	865	885	900	915	945	960	1020	1085
8/Comp	1450	1610	1770	1880*	2100	2760*	2860	3000*	3070	3140*	3310*	3530*	3750*
9/Ten	1120	1170	1260	1260	1350	1360	1370	1400	1400	1430	1460	1490	1520
10/Comp	1140	1200	1260	1290	1520	1550	1590	1430*	1460*	1370*	1370	1190	1200
11/Ten	---	---	-68	-68	-68	-85	-102	-102	-102	-102	-102	-102	-102
12/Ten	960	1035	1085	1085	1190	1200	1220	1220	1240	1240	1240	1260	1260
13/Comp	178	195	213	213	231	231	248	248	248	265	265	265	285
14/Comp	1000	1050	1140		1240		1260				1320		1360
15/Comp	1055	1140	1220		1320		1350				1450		1440
16/Ten	1090	1160	1210		1310		1400				1400		1440
17/Comp	435	450	465		465		465				515		515
18/Comp	785	815	920		1000		1020				1160		1100
19/Ten	1070	1135	1200		1300		1360				1380		1420
20/Comp	1120	1160	1230		1300		1300				1360		1370

* Indication of Internal Failure

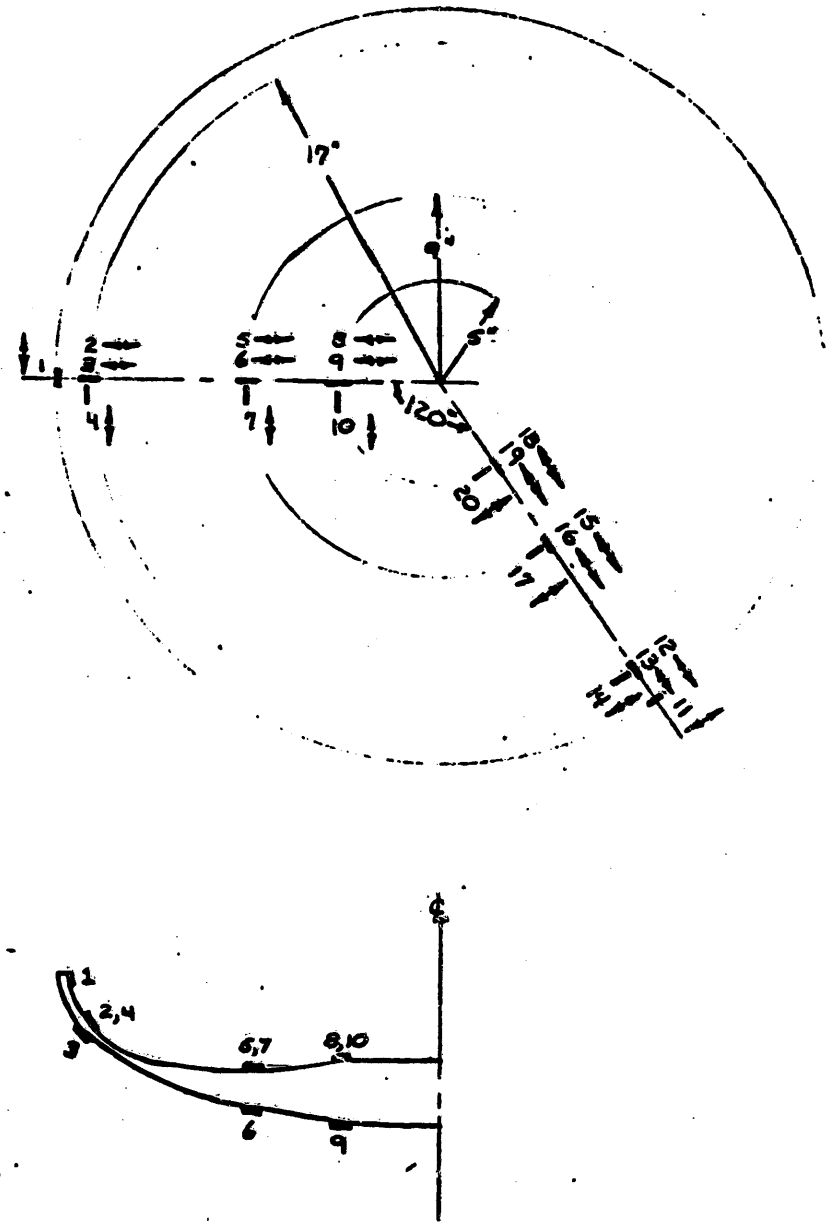
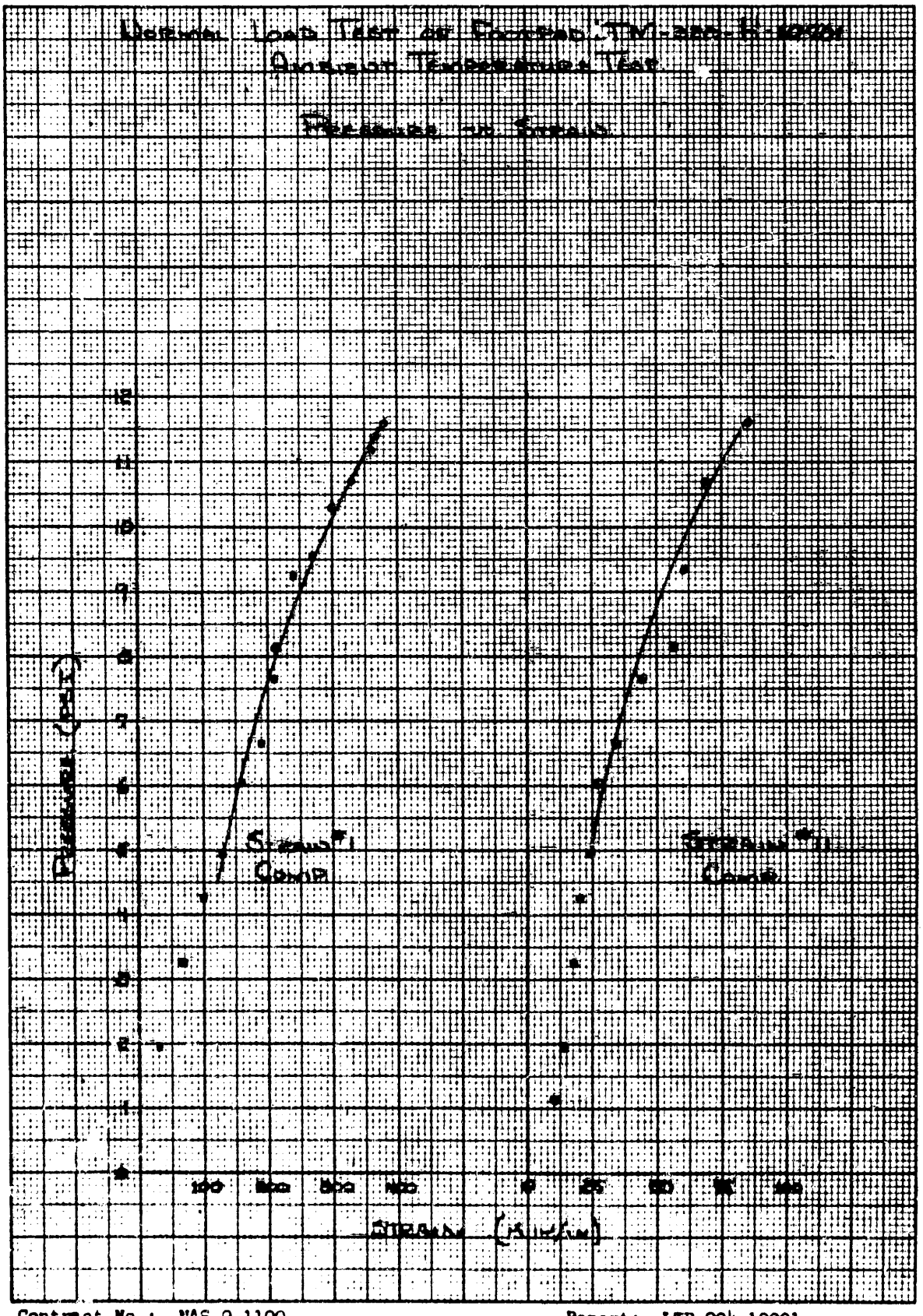


FIGURE 1

STRAIN GAGE INSTALLATION



Contract No.: NAS 9-1100
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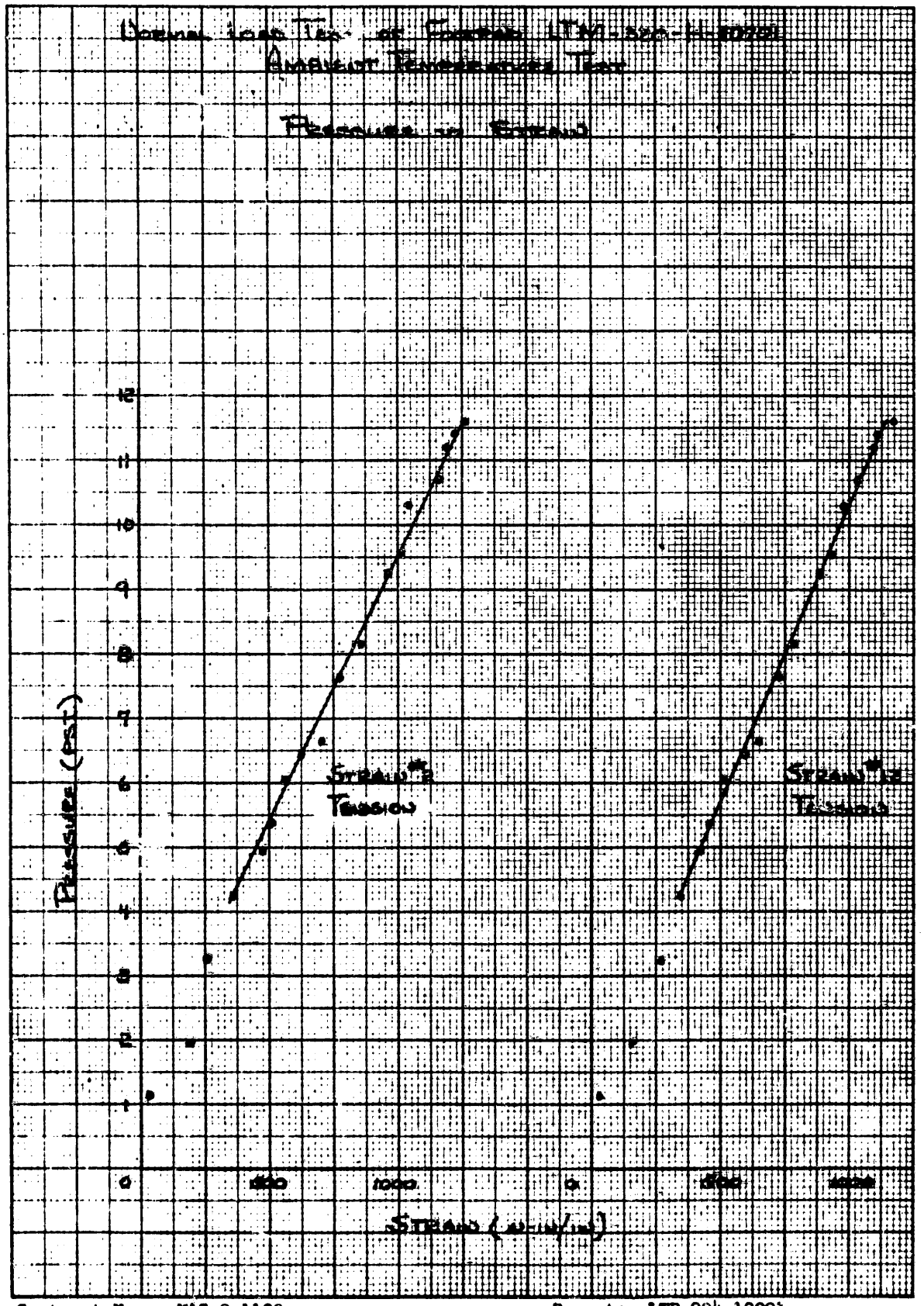
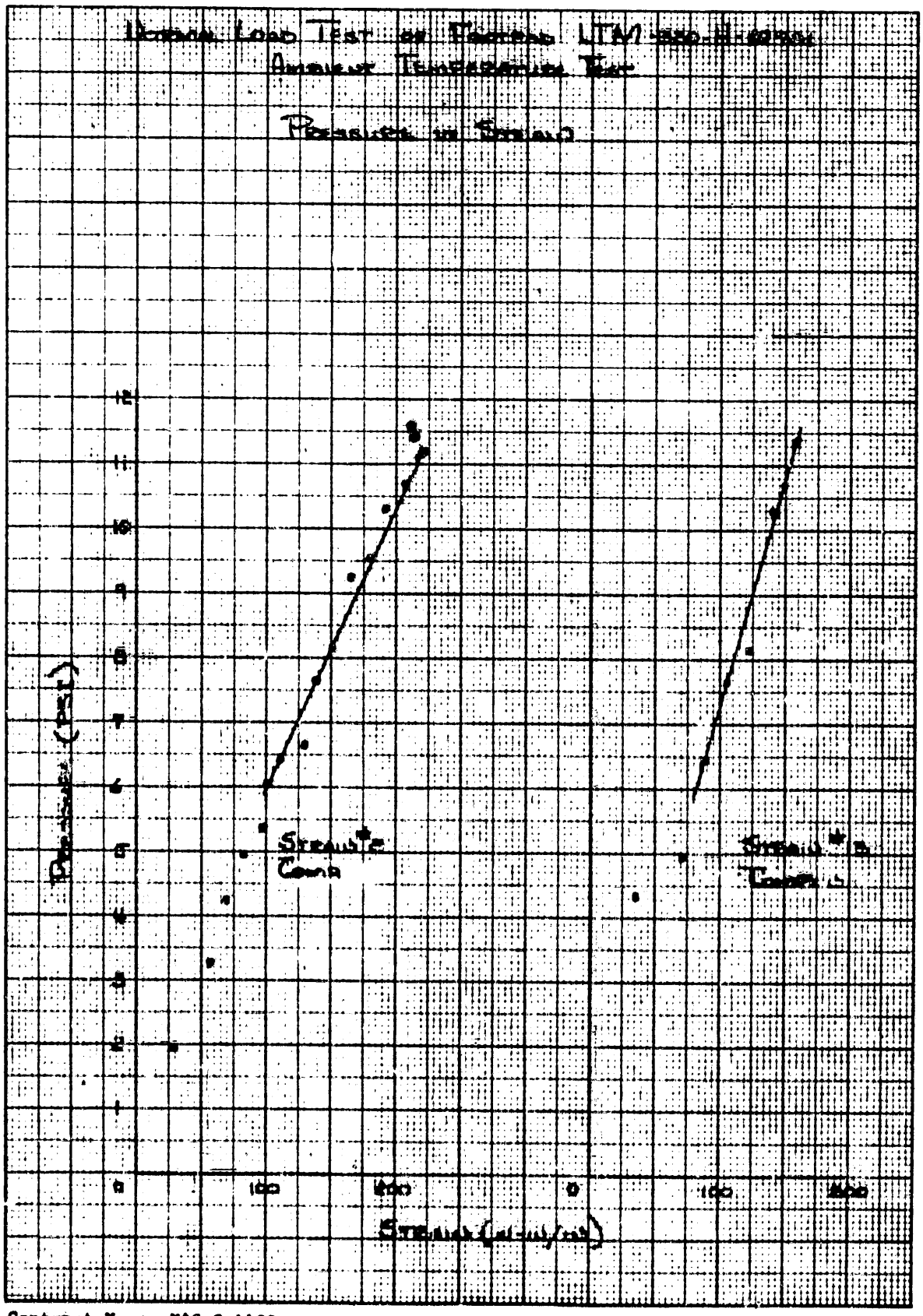

Normal Load Test of Forward LTM-320-H-10701
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
Strain #2
Tension
Strain #12
Tension
Strain (in-in/in)
0
1000
1000
1000
1
2
3
4
5
6
7
8
9
10
11
12



Contract No.: NAS 9-1100
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Report: LTR 904-10001
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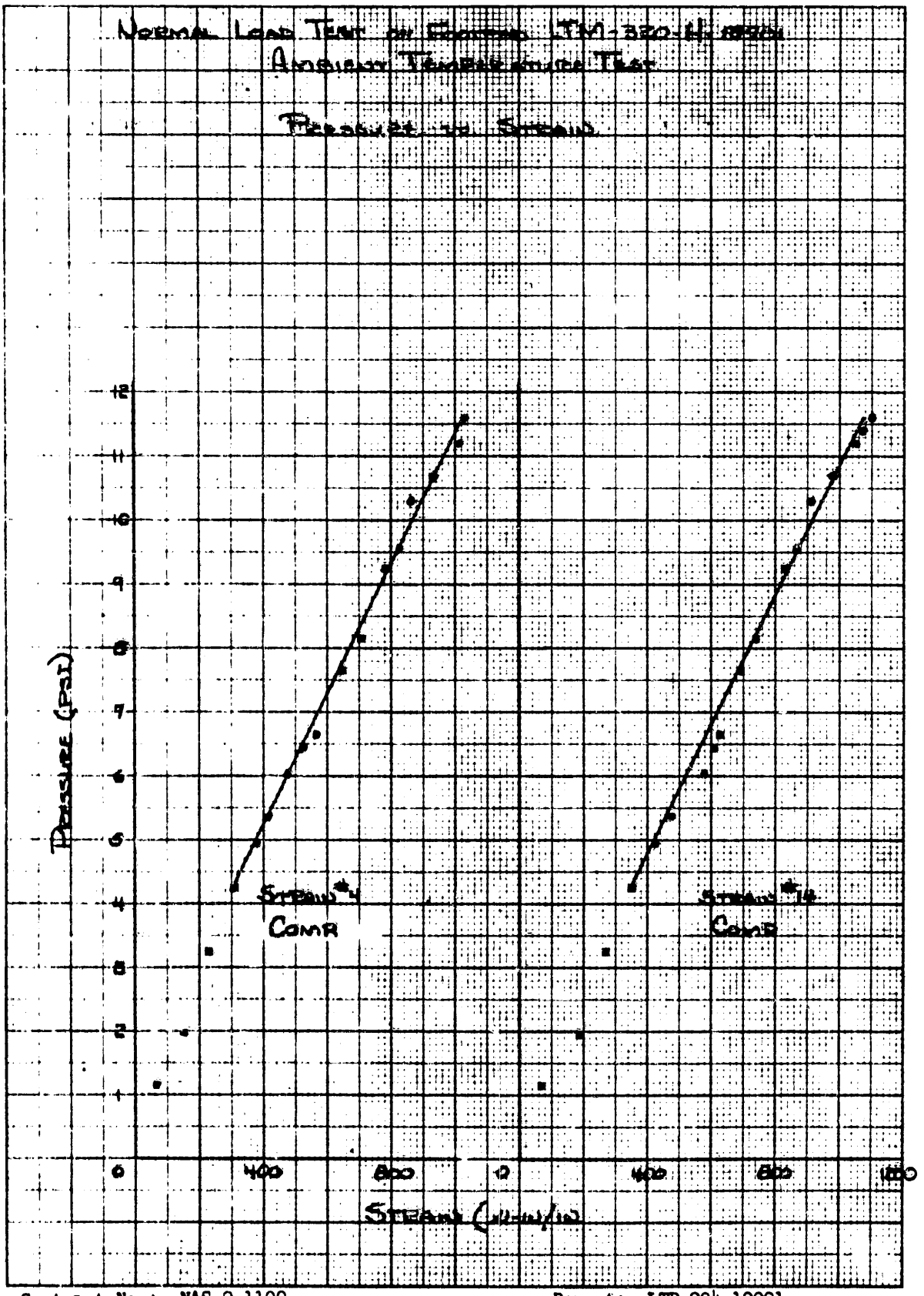
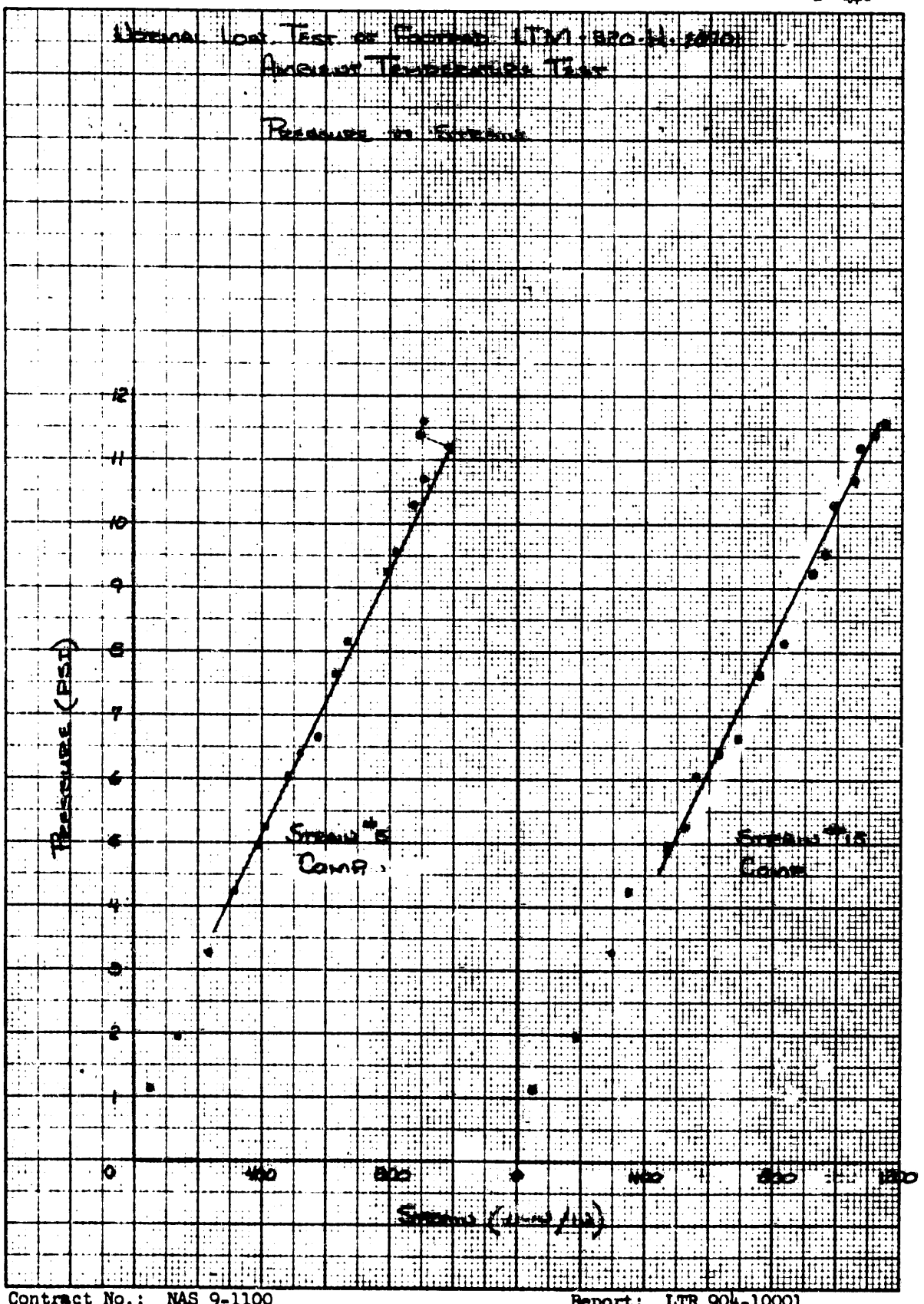
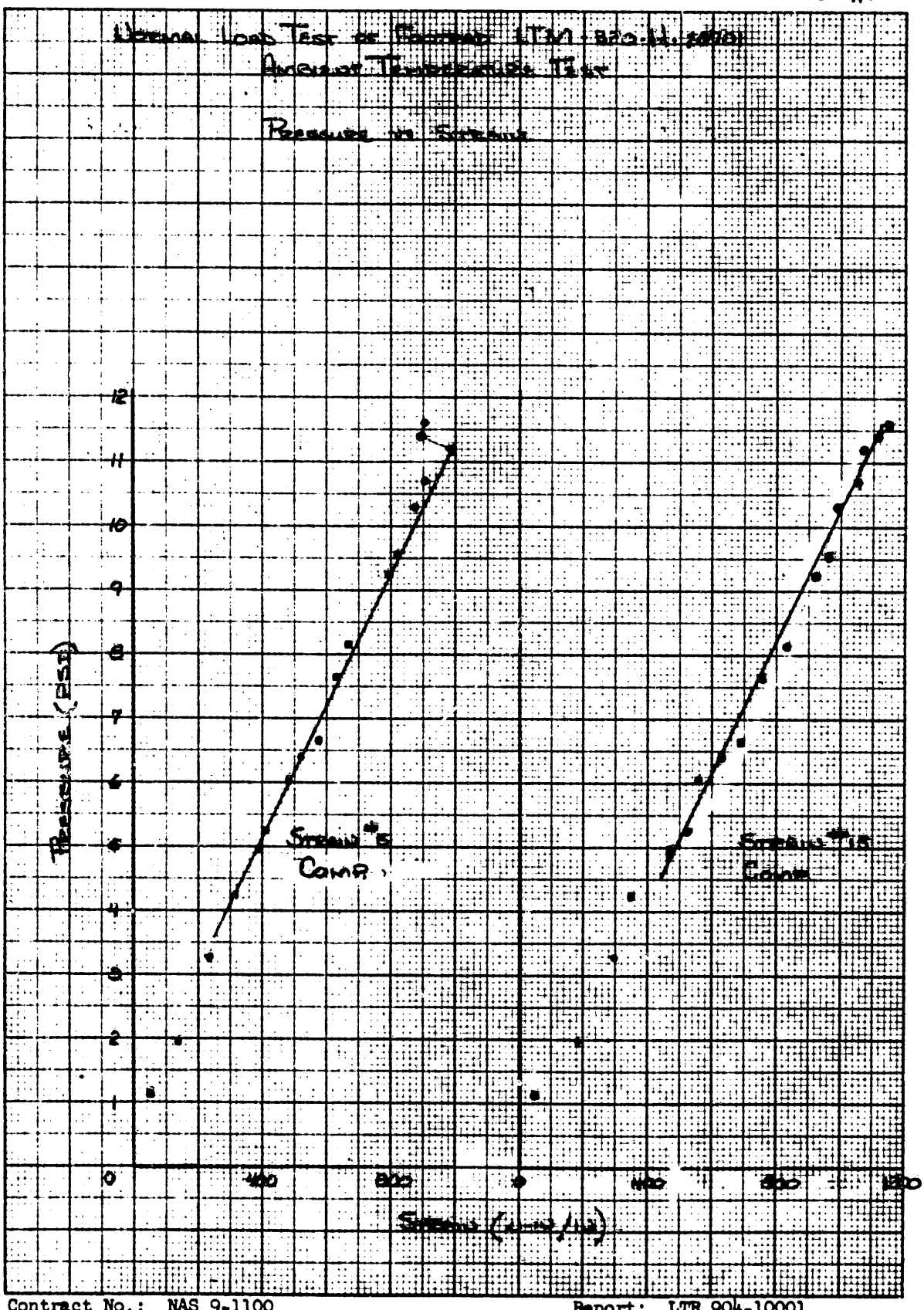
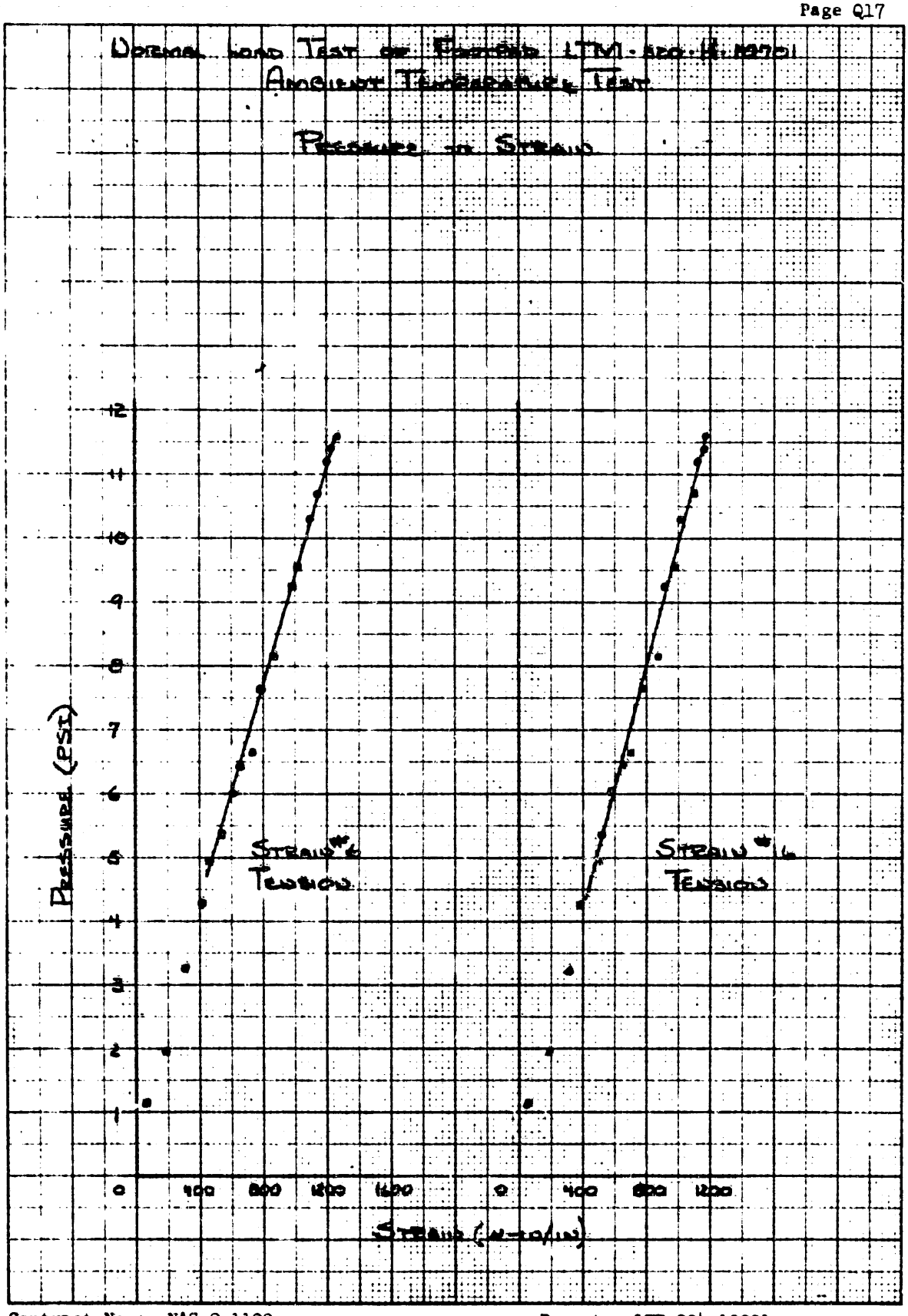
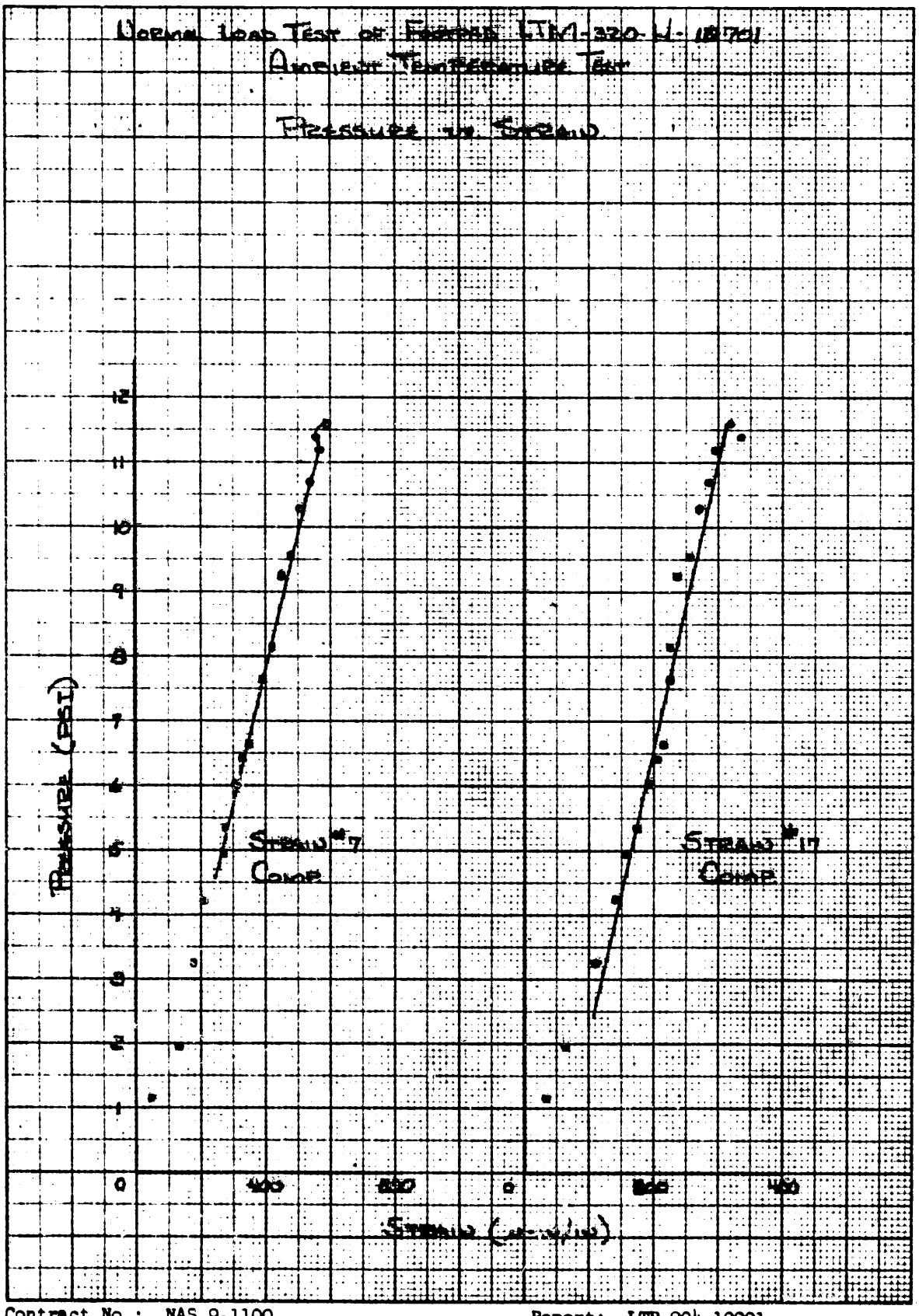

Normal Load Test
Ambient Temperature Test
Pressure vs. Strain
Pressure (psi)
Strain #4
Comp
Strain #14
Comp
Strain (μ-in/in)
0
1
2
3
4
5
6
7
8
9
10
11
12
400
800
0
400
800
1000


Normal Load Test of Footpad LTM-320-H-10001
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
Strain #5
Comp.
Strain #15
Comp.
Strain (μ-in/in)
0
400
800
1200
1
2
3
4
5
6
7
8
9
10
11
12


Pressure (PSI)
0
1
2
3
4
5
6
7
8
9
10
11
12
Strain #5
Comp.
Strain #15
Comp.


Normal Load Test of Footpad LTM-320-H-19701
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
12
11
10
9
8
7
6
5
4
3
2
1
0
400
800
1200
1600
0
400
800
1200
Strain #6 Tension
Strain #16 Tension
Strain (μ-in/in)



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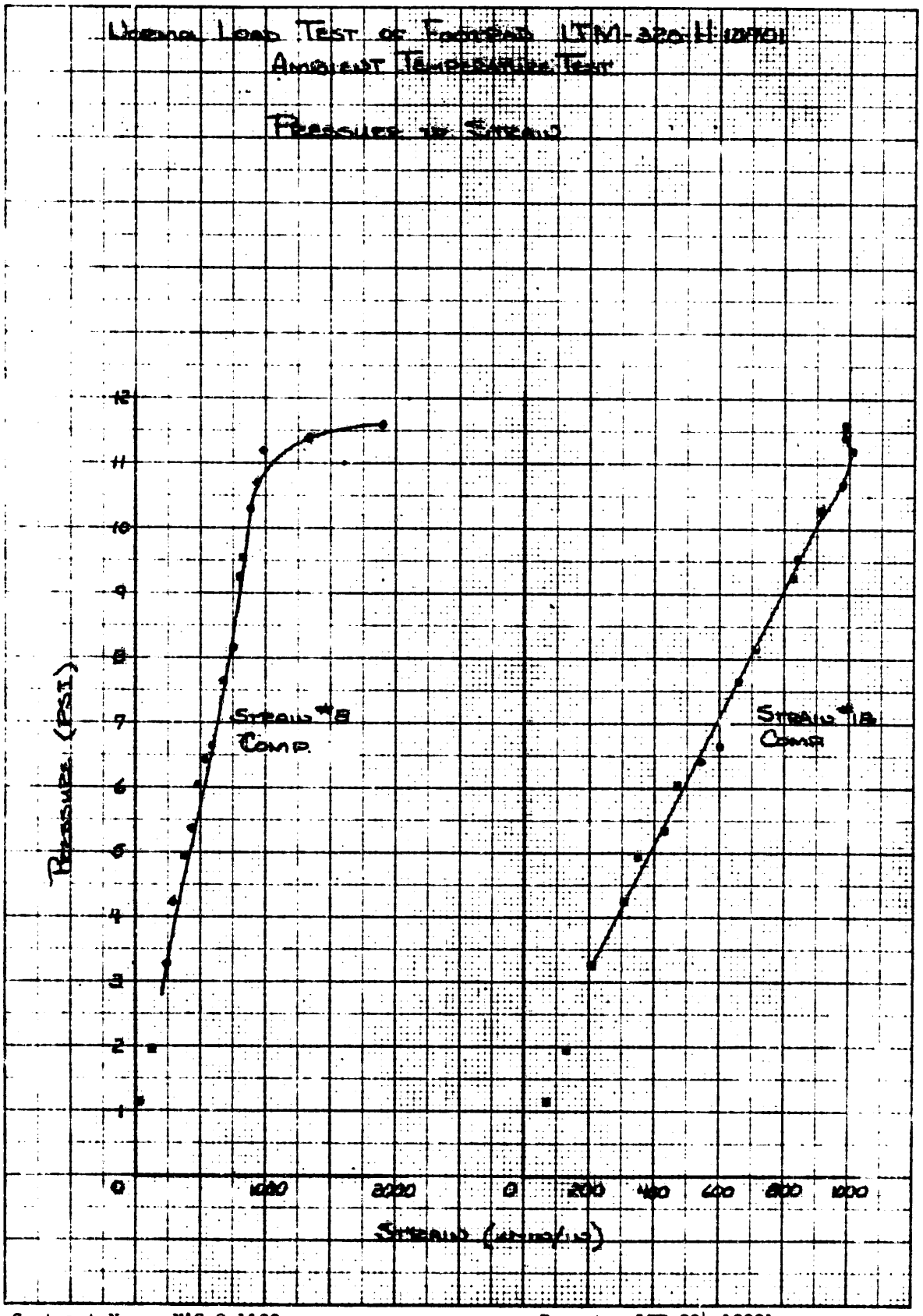
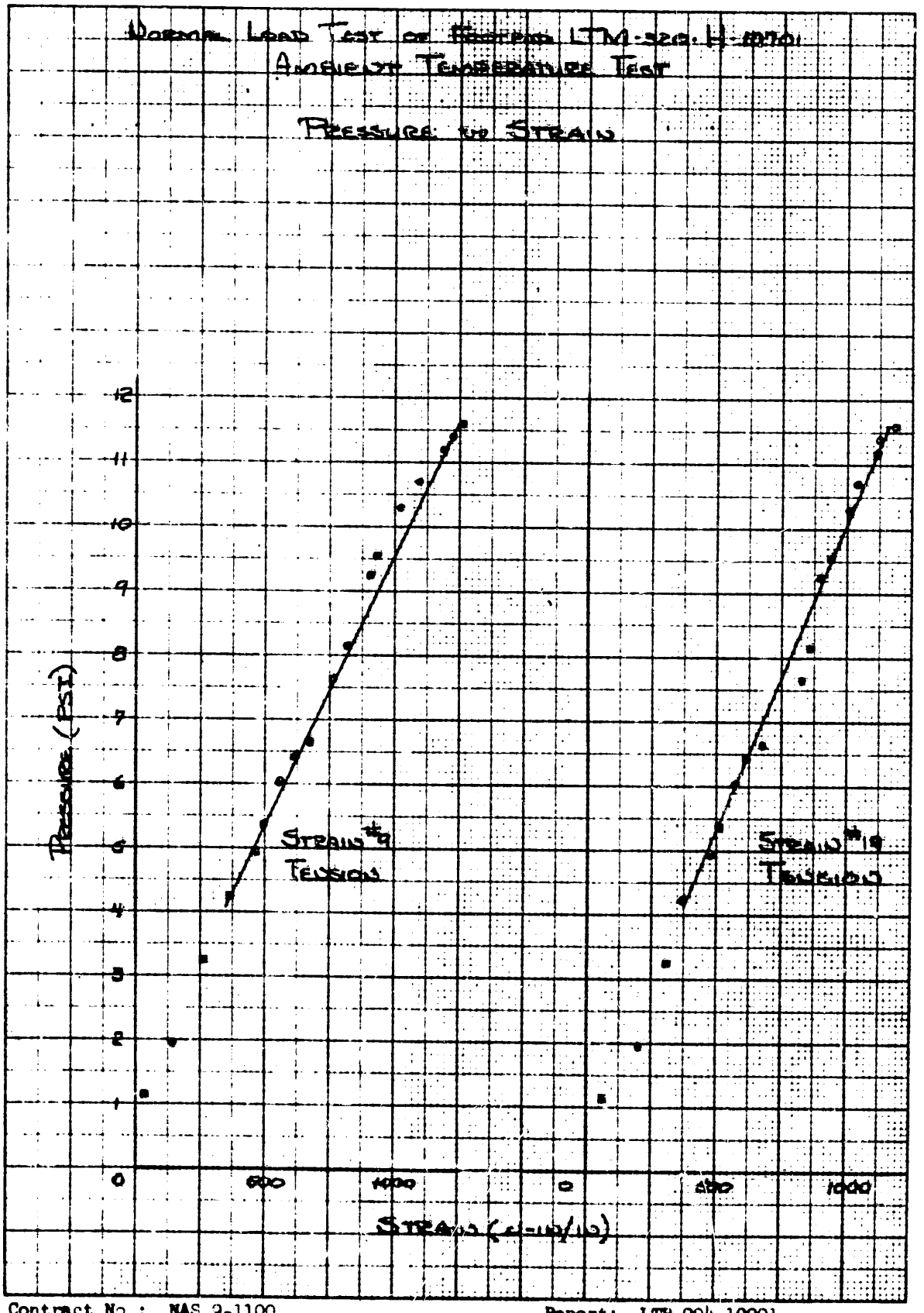
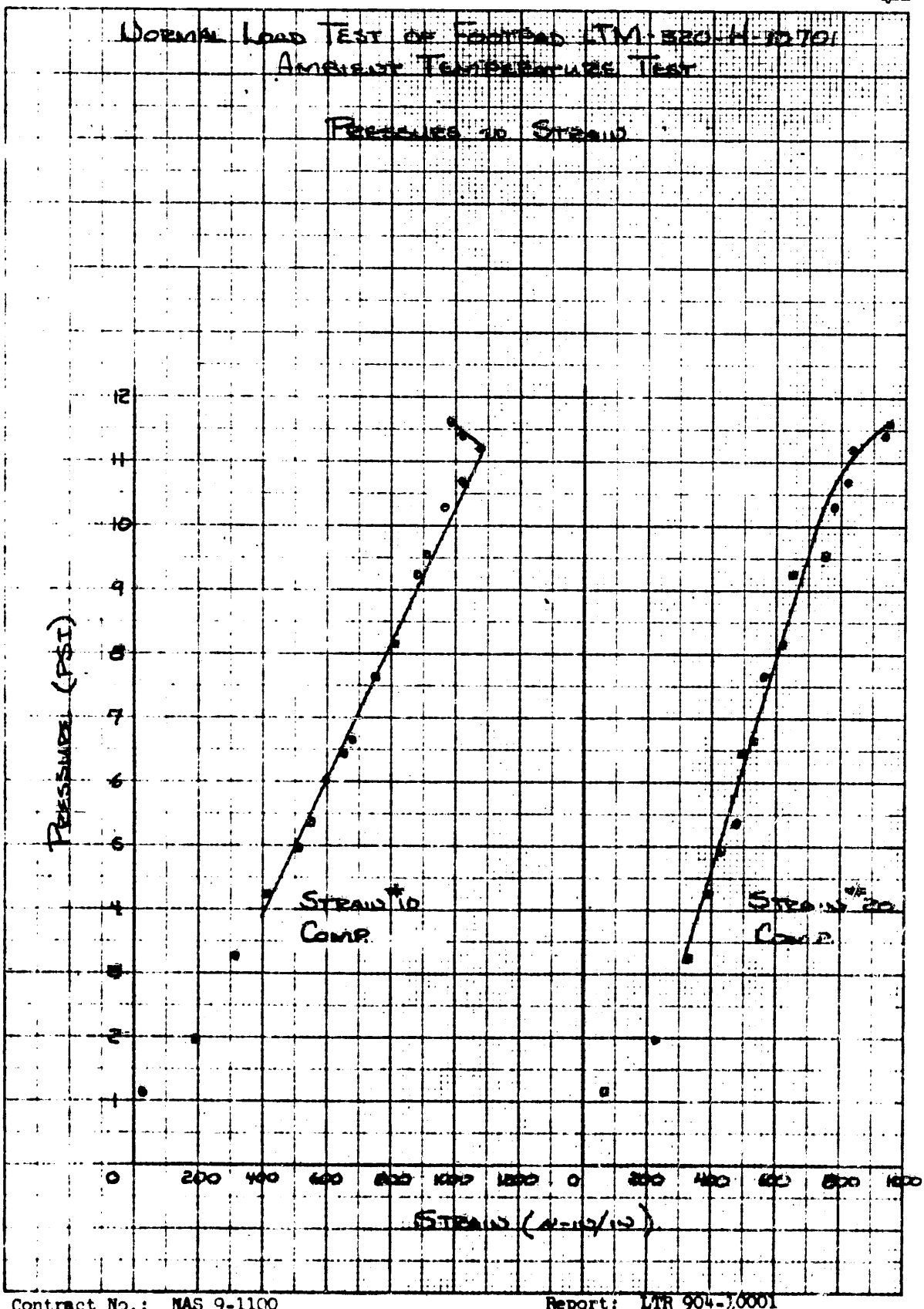
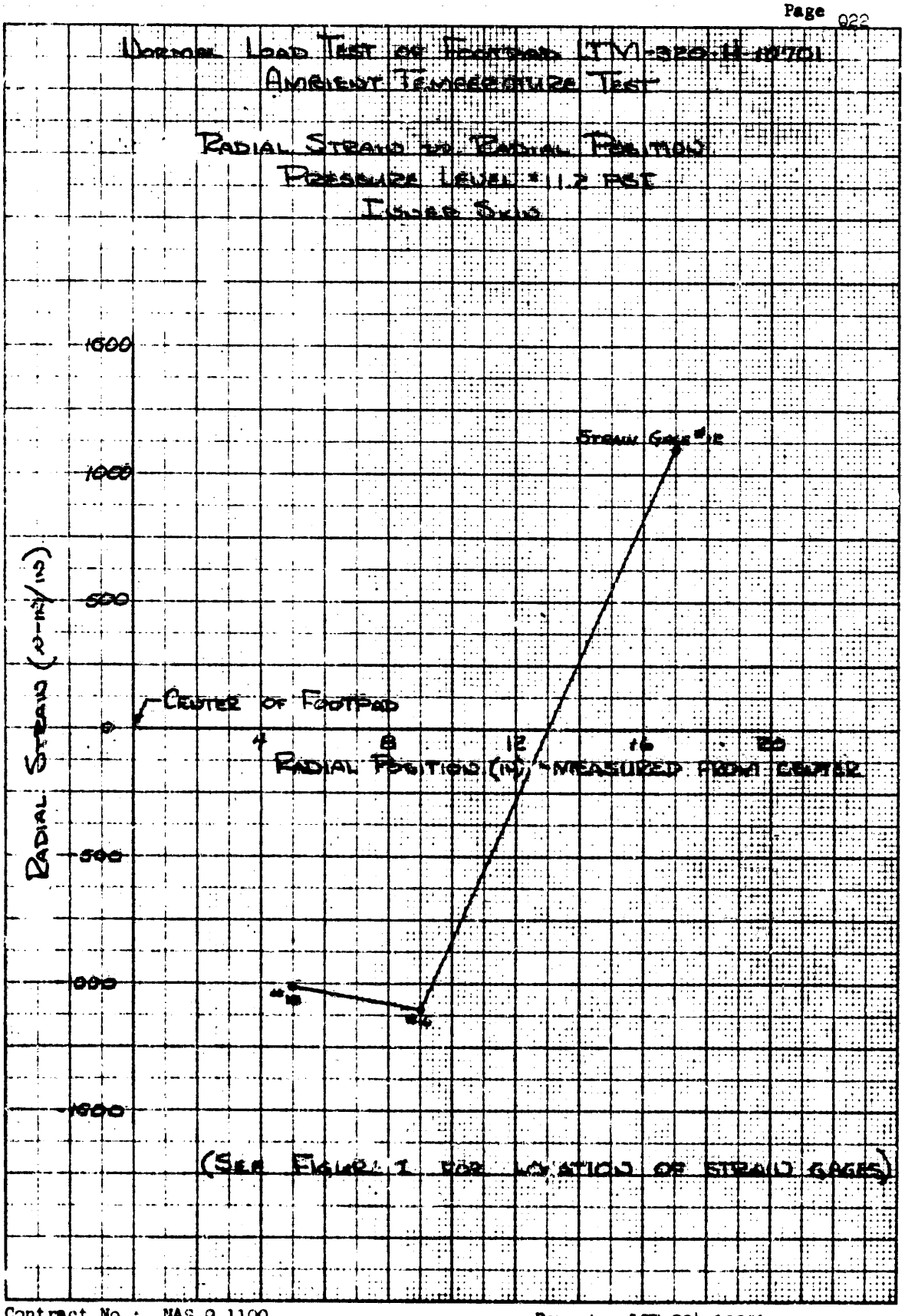
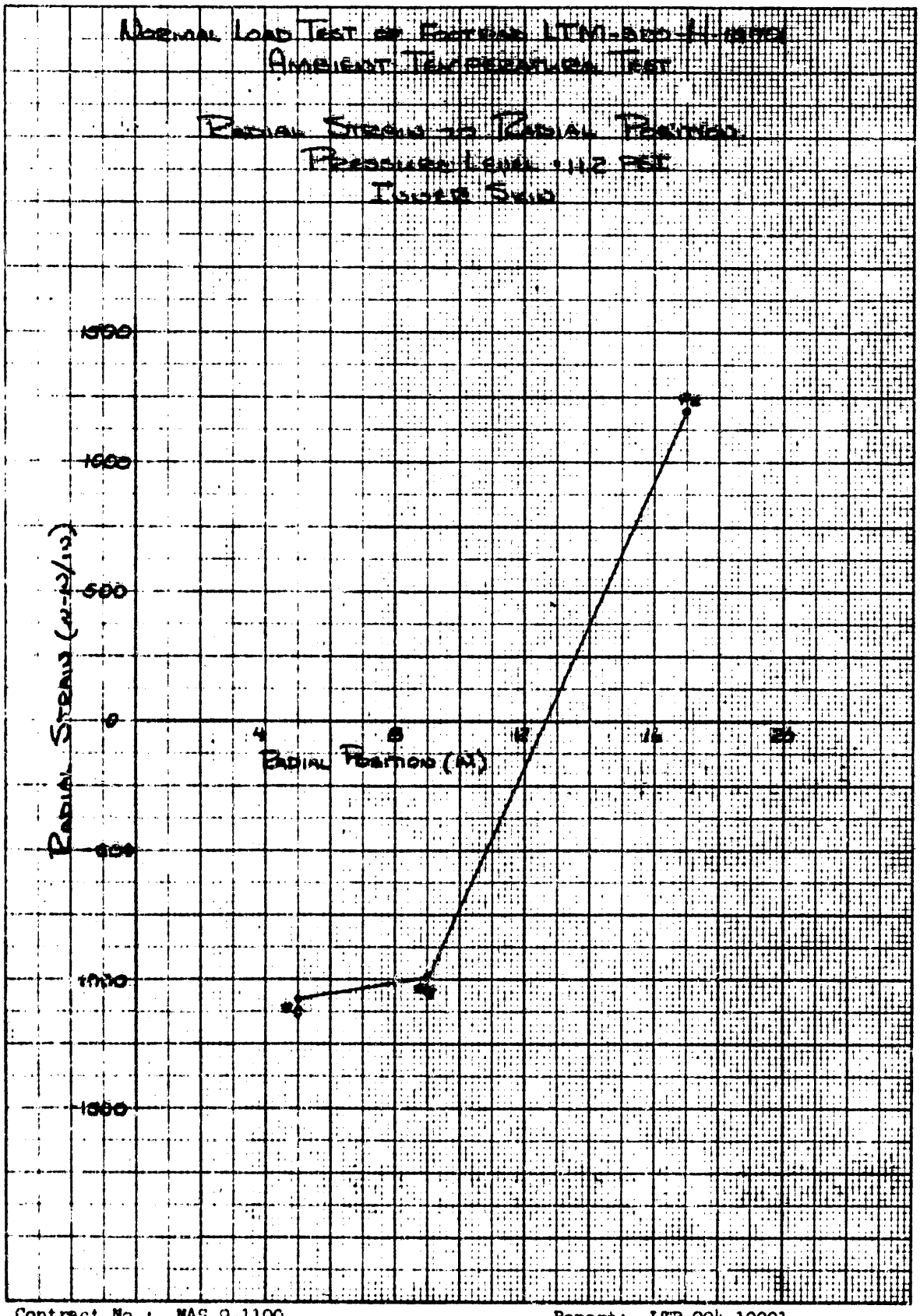

Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
Strain #8
Comp.
Strain #18
Comp.
Strain (μmin/in)
0
1000
2000
0
200
400
600
800
1000
1
2
3
4
5
6
7
8
9
10
11
12


Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
Strain #9
Tension
Strain #19
Tension
Strain (μ-in/in)
0
500
1000
0
500
1000
1
2
3
4
5
6
7
8
9
10
11
12


Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Pressure vs Strain
Pressure (PSI)
12
11
10
9
8
7
6
5
4
3
2
1
0
200
400
600
800
1000
1200
0
200
400
600
800
1000
Strain #10
Comp.
Strain #20
Comp.
Strain (μ-in/in)


Vertical Load Test of Footpad LTV-320-H-10701
Ambient Temperature Test
Radial Strain vs. Radial Position
Pressure Level = 1.2 PSI
Lower Skin
1500
1000
500
0
500
1000
1500
Radial Strain (μ-in/in)
Center of Footpad
4
8
12
16
20
Radial Position (in) - Measured from Center
Strain Gage #12
#16
#14
(See Figure 1 for Location of Strain Gages)



Contract No.: NAS 9-1100
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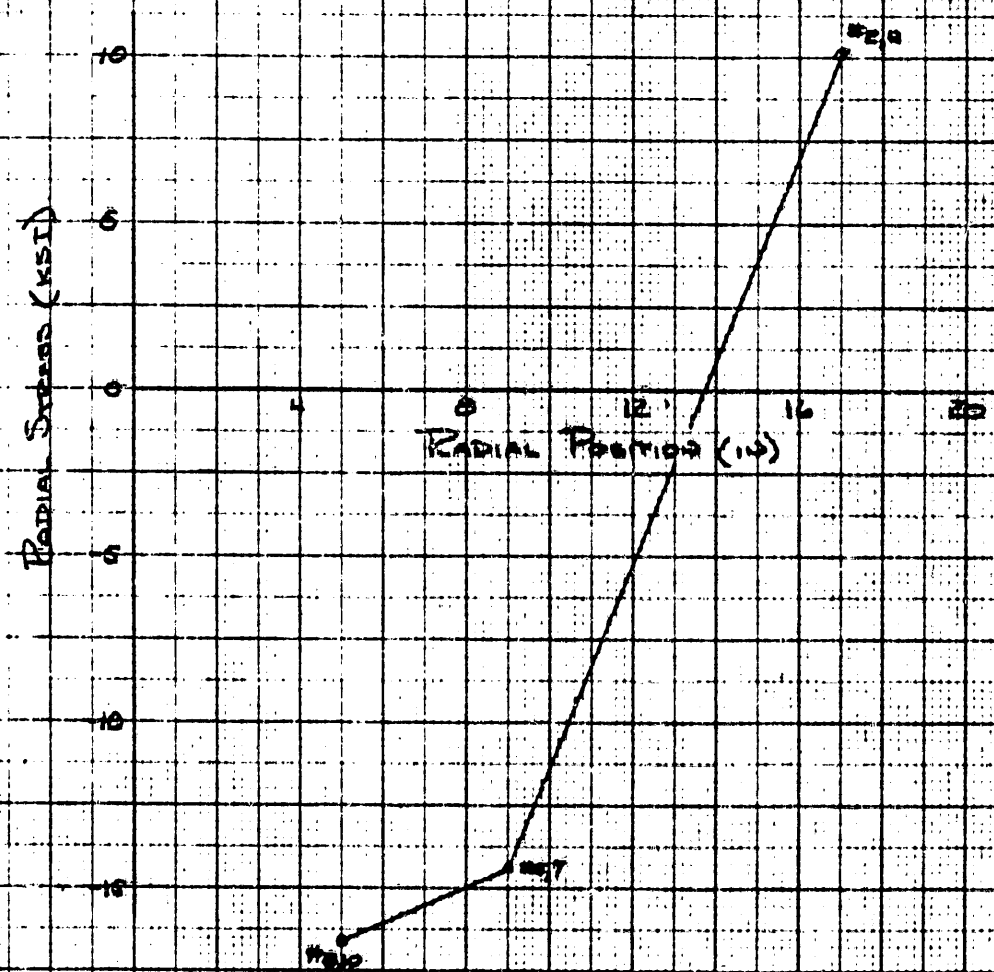
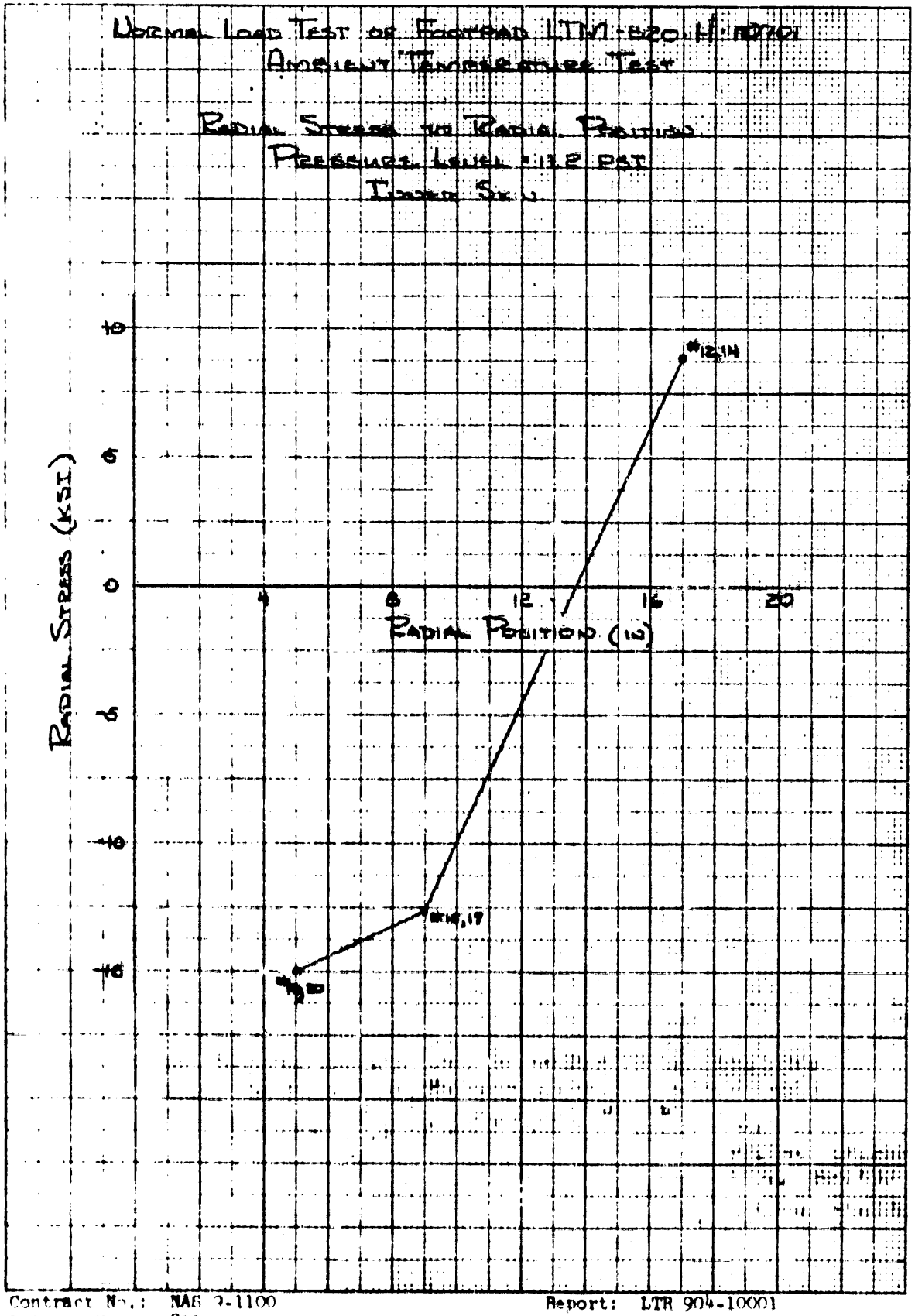
Normal Load Test of Footprint LTM-320-L-[illegible]
Ambient Temperature Test

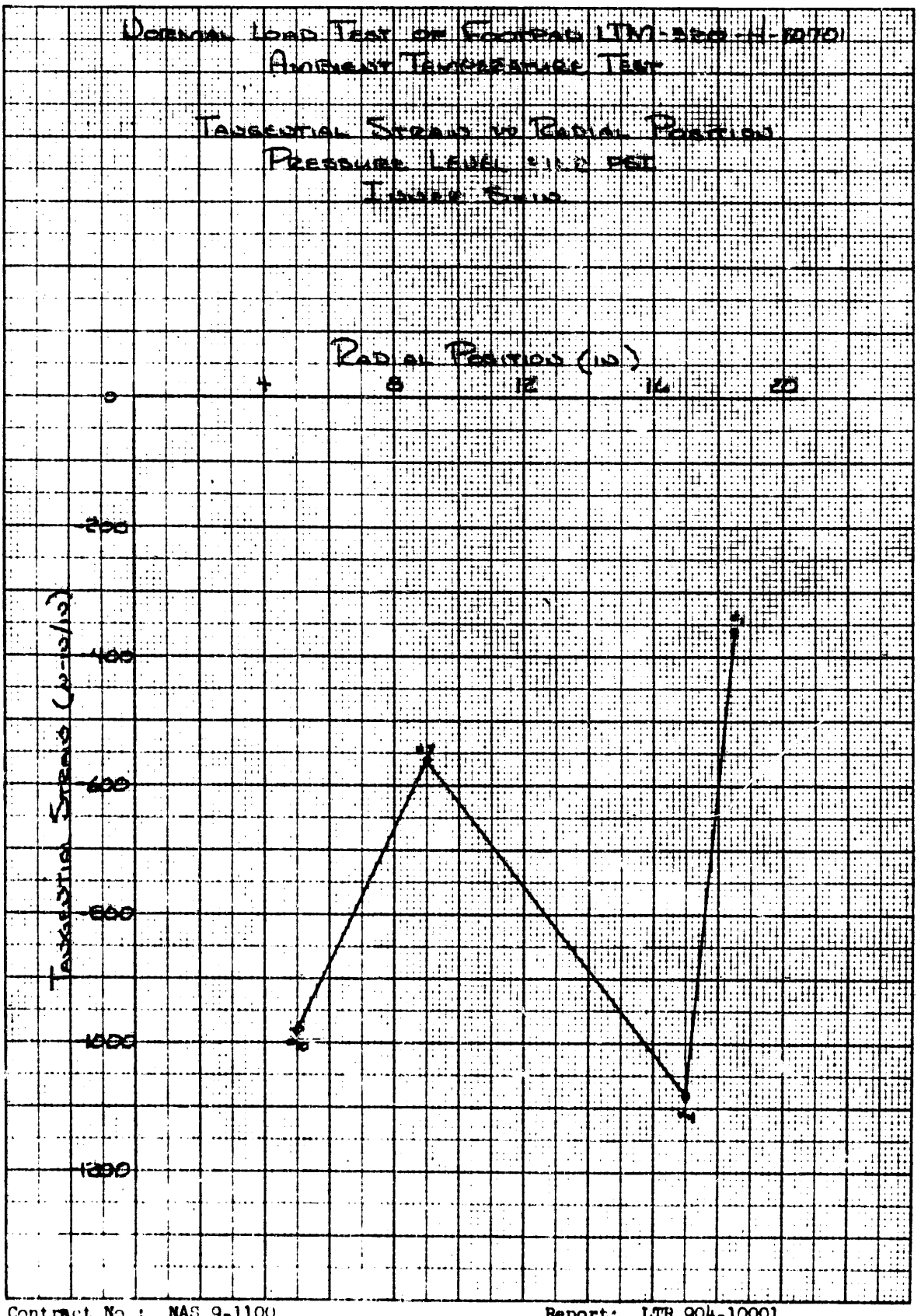
Radial Stress to Radial Position
Pressure Level = 11.2 PSI
Inner Skin



The stress levels shown above are computed allowing for the Poisson effect in the biaxial field. $\sigma_R = \frac{E}{1-\nu^2}(\epsilon_R + \nu\epsilon_T)$ where:

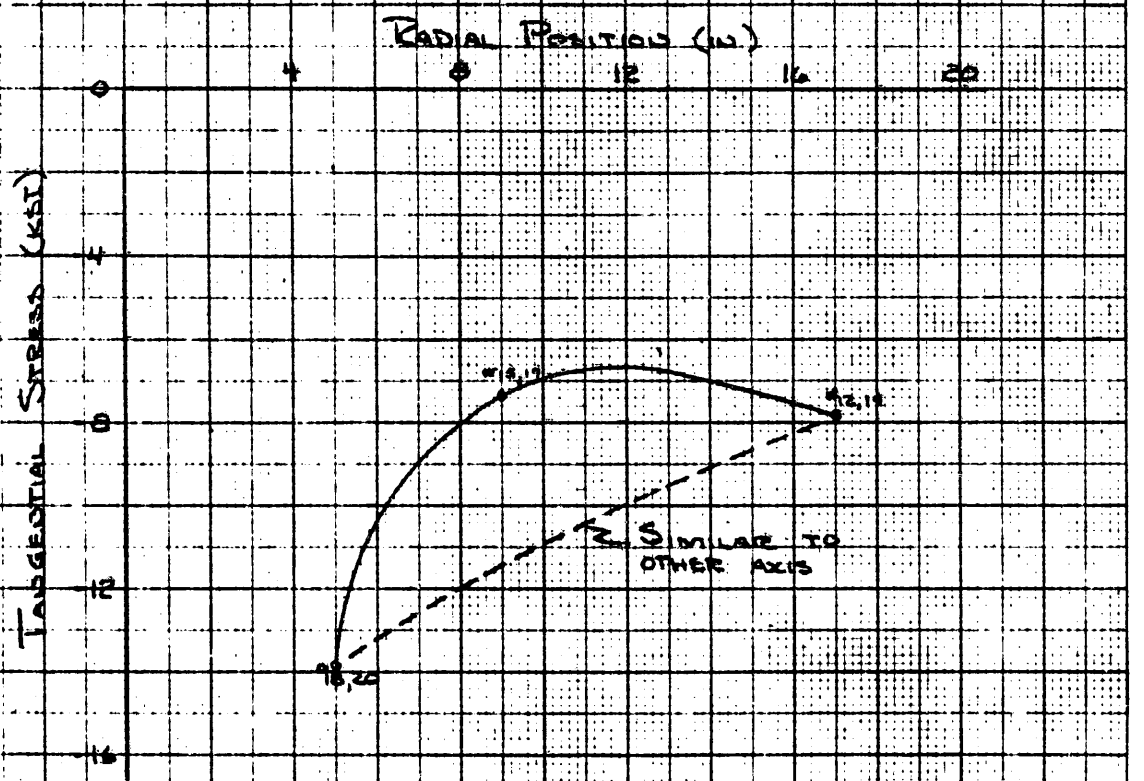
ν = .33
ϵ_R = Radial strain
ϵ_T = Tang. strain
σ_R = Radial stress


Normal Load Test of Footpad LTM-620-H-00701
Ambient Temperature Test
Radial Stress vs Radial Position
Pressure Level = 13.2 psi
Lower Skin
Radial Stress (ksi)
Radial Position (in)
10
5
0
-5
-10
-15
4
8
12
16
20
#12,14
#14,17
#20


Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Tangential Strain vs Radial Position
Pressure Level
Inner Skin
Radial Position (in)
4
8
12
16
20
0
-200
-400
-600
-800
-1000
-1200
Tangential Strain (in-in/in)

NORMAL LOAD TEST OF FOOTPAD LTM-320-H-[illegible]
AMBIENT TEMPERATURE TEST

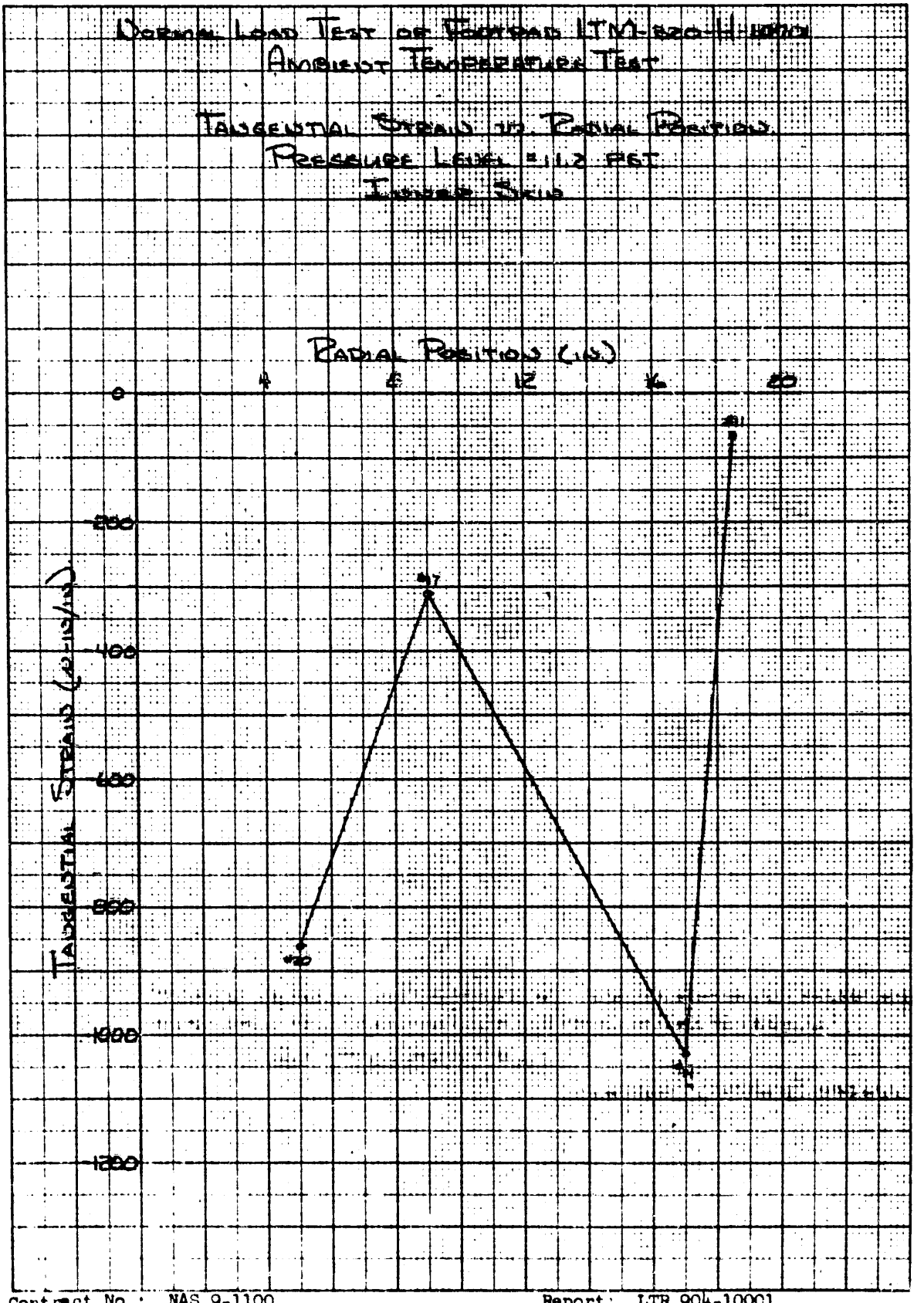
TANGENTIAL STRESS VS RADIAL POSITION
PRESSURE LEVEL = 11.2 PSI
INNER SKIN

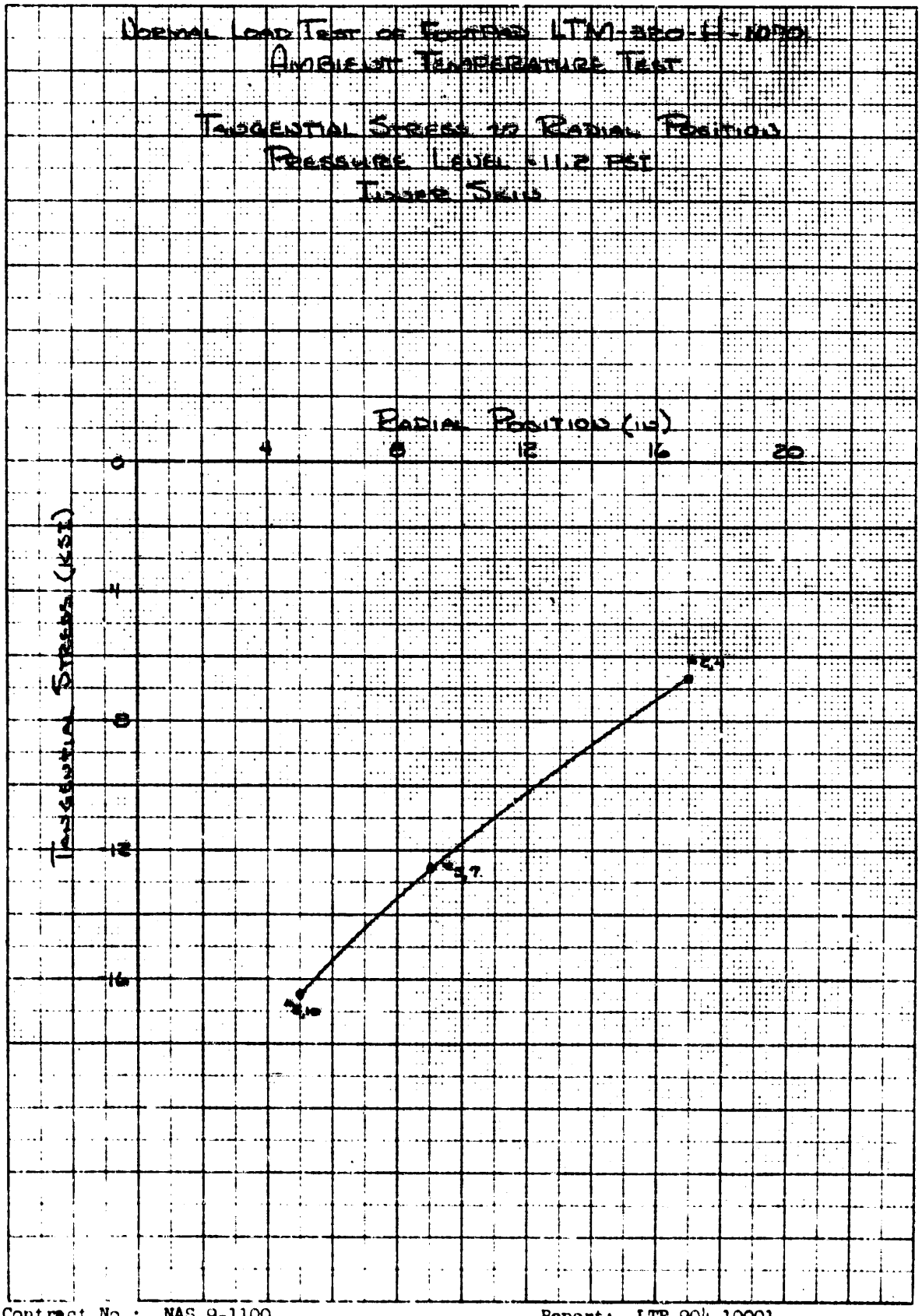


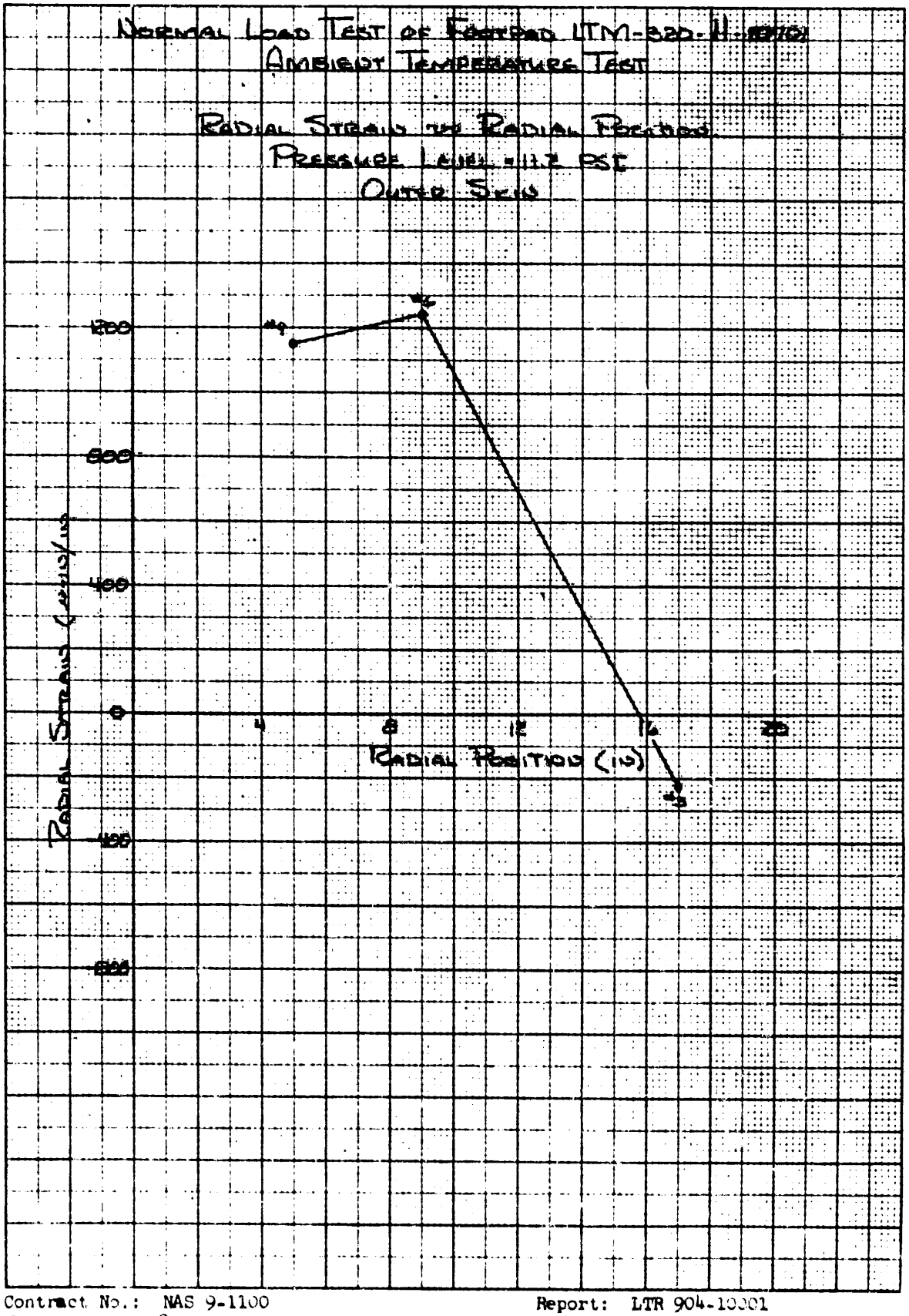
STRESS LEVELS SHOWN ABOVE ARE COMPUTED ALLOWING FOR THE POISSON EFFECT IN THE BIAXIAL FIELD.

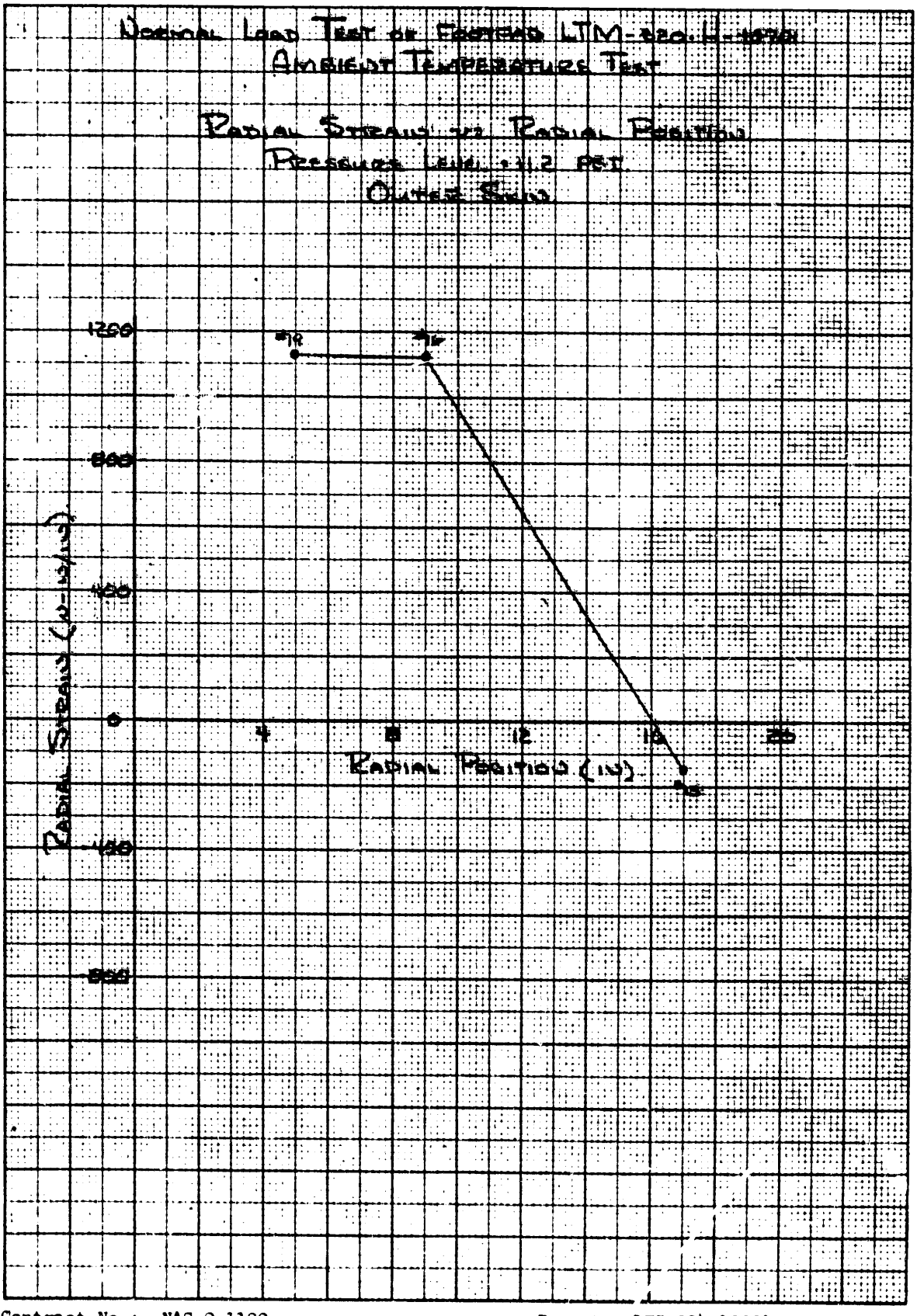
$$\delta_T = \frac{E}{1-\nu^2}\left(\epsilon_T + \nu\epsilon_R\right)$$

WHERE: δ_T = TANG. STRESS.

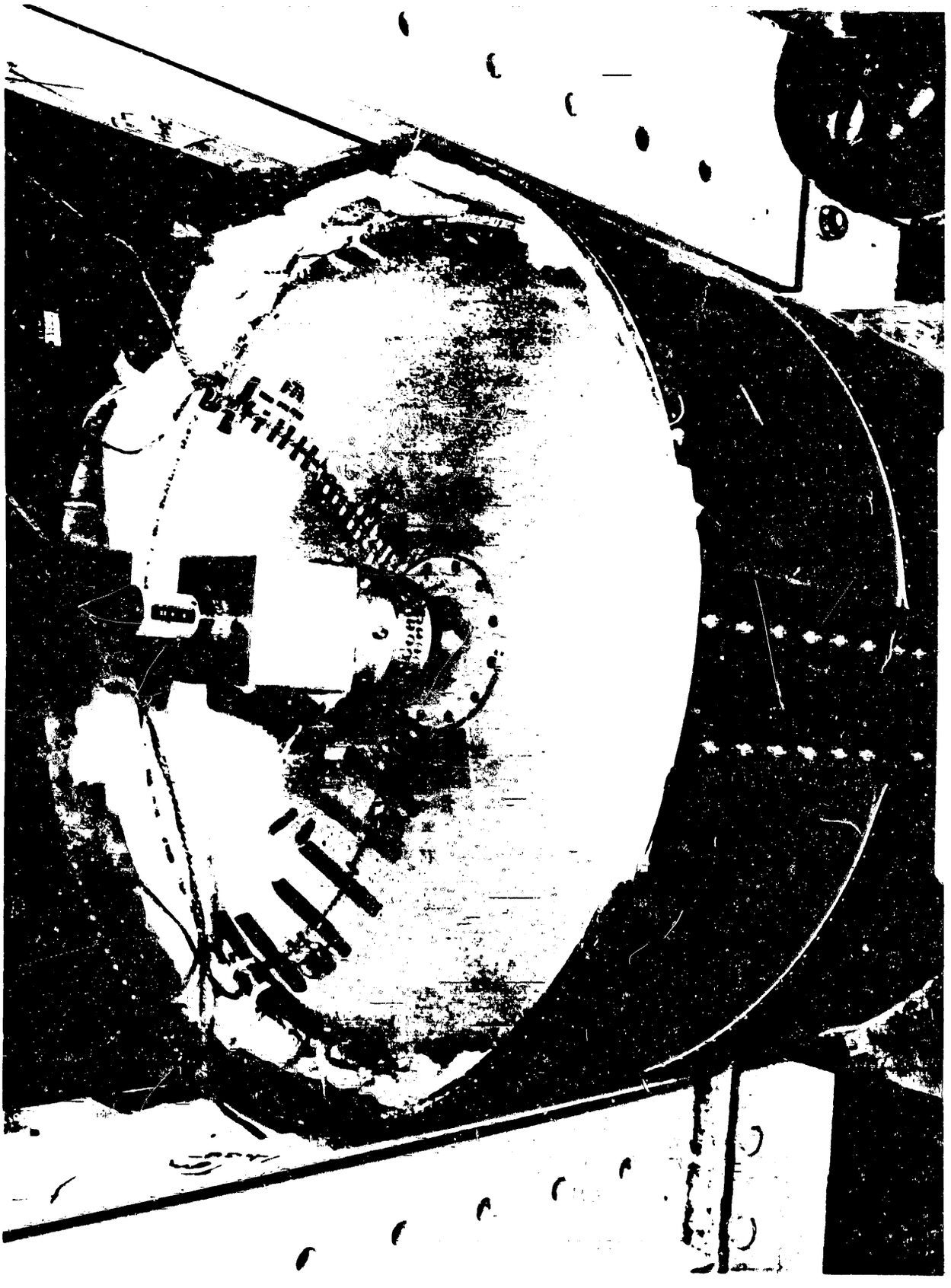

Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Tangential Strain vs. Radial Position
Pressure Level = 11.2 PSI
Inner Skin
Radial Position (in)
0
4
8
12
16
20
Tangential Strain (μ-in/in)
-200
-400
-600
-800
-1000
-1200
#20
#17
#11


Normal Load Test of Footpad LTM-320-H-10701
Ambient Temperature Test
Tangential Stress vs Radial Position
Pressure Level = 11.2 PSI
Inner Skin
Radial Position (in)
4
8
12
16
20
Tangential Stress (KSI)
0
4
8
12
16
2.4
3.7
3.10


NORMAL LOAD TEST OF FOOTPAD LTM-320-11-
AMBIENT TEMPERATURE TEST
RADIAL STRAIN vs RADIAL POSITION
PRESSURE LEVEL = 11.2 PSI
OUTER SKIN
1200
800
400
0
-400
-800
4
8
12
16
20
RADIAL POSITION (IN)
RADIAL STRAIN (μin/in)

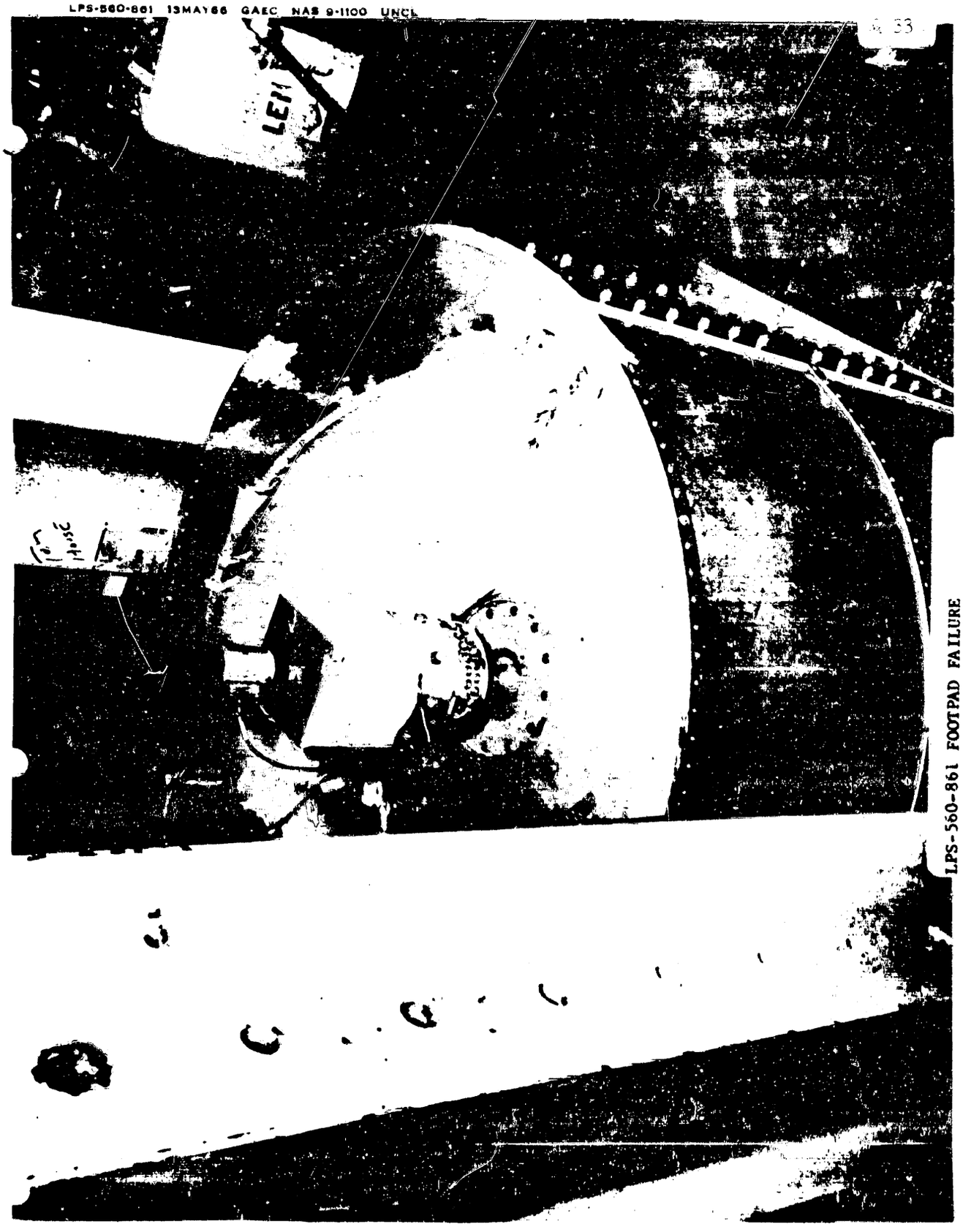

Normal Load Test of Footpad LTM-320-H-
Ambient Temperature Test
Radial Strain vs Radial Position
Pressure Level +11.2 PSI
Outer Skin
1200
800
400
0
-400
-800
4
8
12
16
20
Radial Position (in)
Radial Strain (in-in/in)

LPS-560-848 12MAY66 GAEC NAS 9-1100 UNCL



LPS-560-848 TEST SET UP

LPS-560-861 13MAY66 GAEC NAS 9-1100 UNCL



LPS-560-861 FOOTPAD FAILURE

LPS-560-862 13MAY66 GAEC NAS 9-1100 UNCL

LPS-560-862 FAILURE MODE-VIEW LOOKING DOWN

LPS-560-928 INTERNAL FAILURE MODE

RESULTS OF THE LM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION S - DEPLOYMENT TRUSS (10-7-4) GEAR OVER-CENTER STRAP TEST

PREPARED BY:
E. C. Montanez

CHECKED BY:
R. L. Makemson

SECTION S - DEPLOYMENT TRUSS 167 (10-7-4) GEAR-OVERCENTER STRAP TEST

LIST OF REFERENCES

Grumman Drawings

LSK 915-1150	Overcenter Strap Test Assembly
LDW 320-23905	Strap Assembly
LDW 320-10900	Strap - Titanium
LSK 320-10550	Strap - Stainless Steel

Grumman Documents

LTQ 320-53	Systems Test Request
LTR 904-10001(Section S)	Plan for Tension Yield Tests of the 167 (10-7-4) Landing Gear Deployment Truss Overcenter Strap

RESULTS OF THE LM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION S - DEPLOYMENT TRUSS 167 (10-7-4) GEAR-OVERCENTER STRAP TEST

INTRODUCTION

This section of the report contains the results of the tension yield tests conducted on one titanium and three different combinations of Stainless Steel Overcenter Straps for proposed use on the LM Landing Gear Deployment Truss.

These tests were conducted in accordance with Test Plan No. LTP 904-10001, Section S, Plan for Tension Yield Tests of the 167 (10-7-4) Landing Gear Deployment Truss Overcenter Strap.

RESULTS OF THE LM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION S - DEPLOYMENT TRUSS (10-7-4) GEAR OVER-CENTER STRAP TESTS

1.0 PURPOSE OF TEST

The purpose of this test was to define the yielding characteristics of various overcenter straps and to obtain engineering data for the final strap design.

2.0 DESCRIPTION OF TEST ARTICLE

The overcenter strap is attached across the apex points of the deployment truss. The proposed use of the strap is to absorb the load applied to it by the primary strut, should the secondary struts of the landing gear compress more than ten (10) inches during landing impact. All straps tested were 59 3/32 inches long, one inch wide, and are described below.

TEST NO. 1

Titanium Alloy (BAL-1MO-1V) Strap (.040 inch thick) - One strap per assembly, conforming to Drawing No. LDW 320-10900-11

TEST NO. 2

1/4 Hard (301) Stainless Steel Strap No. 1 (.012 inch thick) - Three laminated straps per assembly, conforming to Drawing No. LSK 320-10550-25

TEST NO. 3

1/4 Hard (301) Stainless Steel Strap No. 2 (.018 inch thick) - Two laminated straps per assembly, conforming to Drawing No. LSK 320-10550-23.

TEST NO. 4

1/4 Hard (301) Stainless Steel Strap No. 3 (.036 inch thick) - One strap per assembly, conforming to Drawing No. LSK 320-10550-21

RESULTS OF THE LM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION S - DEPLOYMENT TRUSS (10-7-4) GEAR OVER-CENTER STRAP TEST

3.0 DESCRIPTION OF TEST

3.1 Test Conditions

The tests were conducted under ambient environmental conditions. In all tests, the straps were axially preloaded to 100 lbs. Transvers load was applied at an approximate uniform rate.

4.0 TEST SET UP AND PROCEDURES

Each test article was installed in a test fixture, as shown in Photograph No. LPS 560-1287 and Figure 1. It consisted of a steel structure capable of supporting the test article in a horizontal attitude.

An axial preload of 100 lbs. was applied to the test article. The transverse load was applied by forcing the bumper (LDW 320M-10510), attached to a dummy primary strut, into the strap. Application of this transverse load to the dummy strut was by means of a hydraulic jack. This set-up simulated the geometry of the actual LM Landing Gear. The load was increased until a deflection of at least 14 inches was attained or until failure occurred.

5.0 INSTRUMENTATION

Instrumentation support was provided for measuring and recording the following test data:

(A) Transverse load
(B) Deflection (at midspan of overcenter strap)

The location of the load cell is shown in Figure 1. The transverse deflection was recorded using a linear potentiometer. Load versus deflection was plotted directly on an X-Y Plotter.

RESULTS OF THE LM LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION S - DEPLOYMENT TRUSS (10-7-4) GEAR OVER-CENTER STRAP TEST

6.0 PRESENTATION OF TEST DATA

The test data is presented in Figures 2 through 5. These figures show transverse load versus transverse deflection for each of the overcenter straps.

7.0 DISCUSSION OF RESULTS

The energy absorbed by each of the straps tested has been estimated by the summation of the areas under their respective load-stroke curves. Pertinent results data for each strap is summarized below.

TEST NO. 1

Titanium Strap - the strap failed at a transverse load of 4500 lbs. and a transverse deflection of 13.33 inched. Total energy absorption estimated was 27,631 lb-in just prior to failure (see Figure 2 and Photograph No. LPS 560-1288)

TEST NO. 2

Stainless Steel Strap No. 1 - the strap was deflected beyond the required 14.00 inches, as described in Para. 4.0, without failure. Total energy absorption estimated was 28,662 lb-in at a load of 3925 lbs. and a deflection of 16.00 inches (see Figure 3)

TEST NO. 3

Stainless Steel Strap No. 2 - the strap was deflected beyond the required 14.00 inches without failure. Total energy absorption estimated was 29,727 lb-in at a load of 3825 lbs. and a deflection of 17.00 inches (see Figure 4)

TEST NO. 4

Stainless Steel Strap No. 3 - the strap was deflected beyond the required 14.00 inches without failure. Total energy absorption estimated was 32,276 lb-in at a load of 4100 lbs. and a deflection of 16.50 inches (see Figure 5)

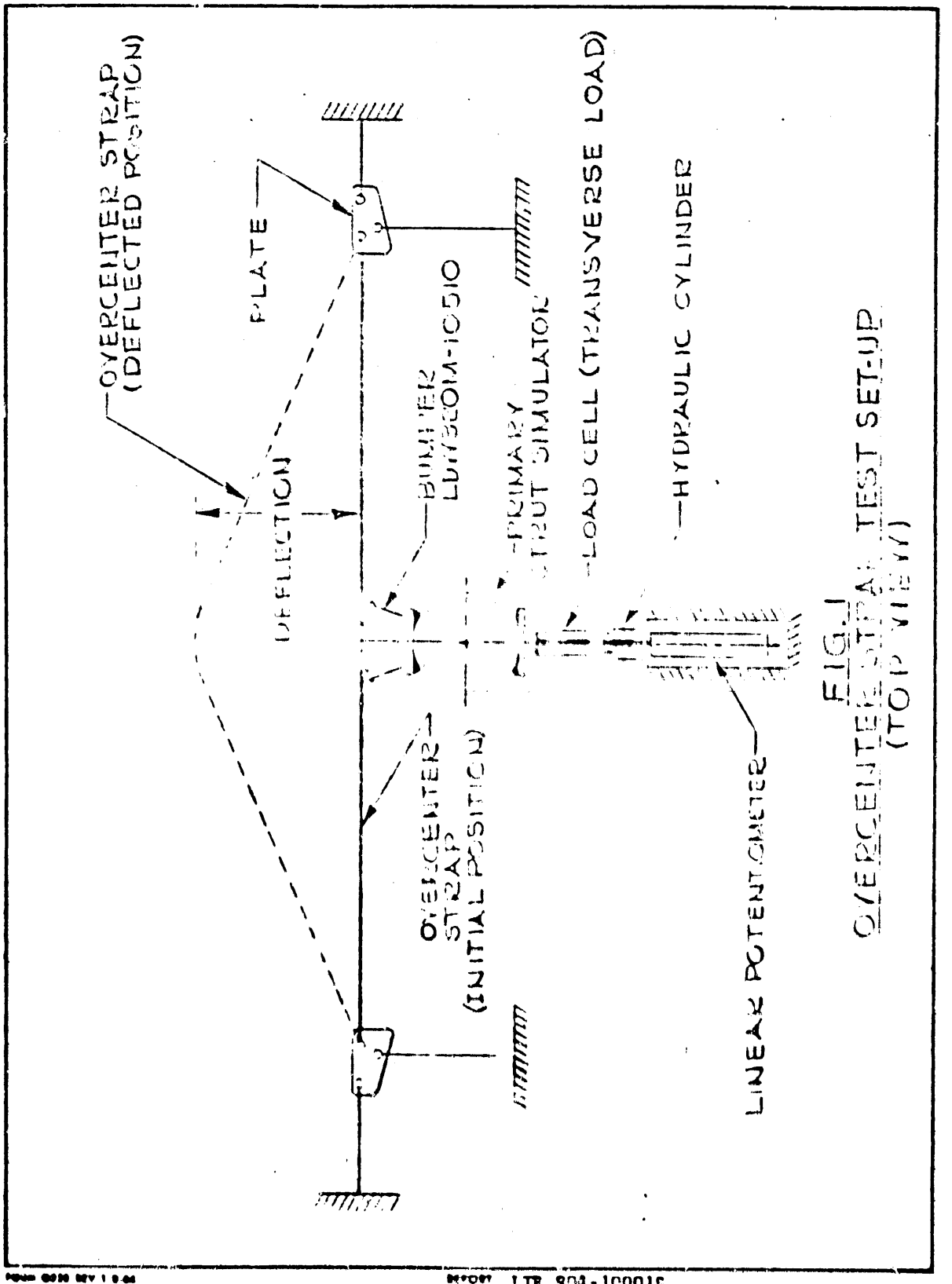


FIG. 1
OVERCENTER STRAP TEST SET-UP
(TOP VIEW)

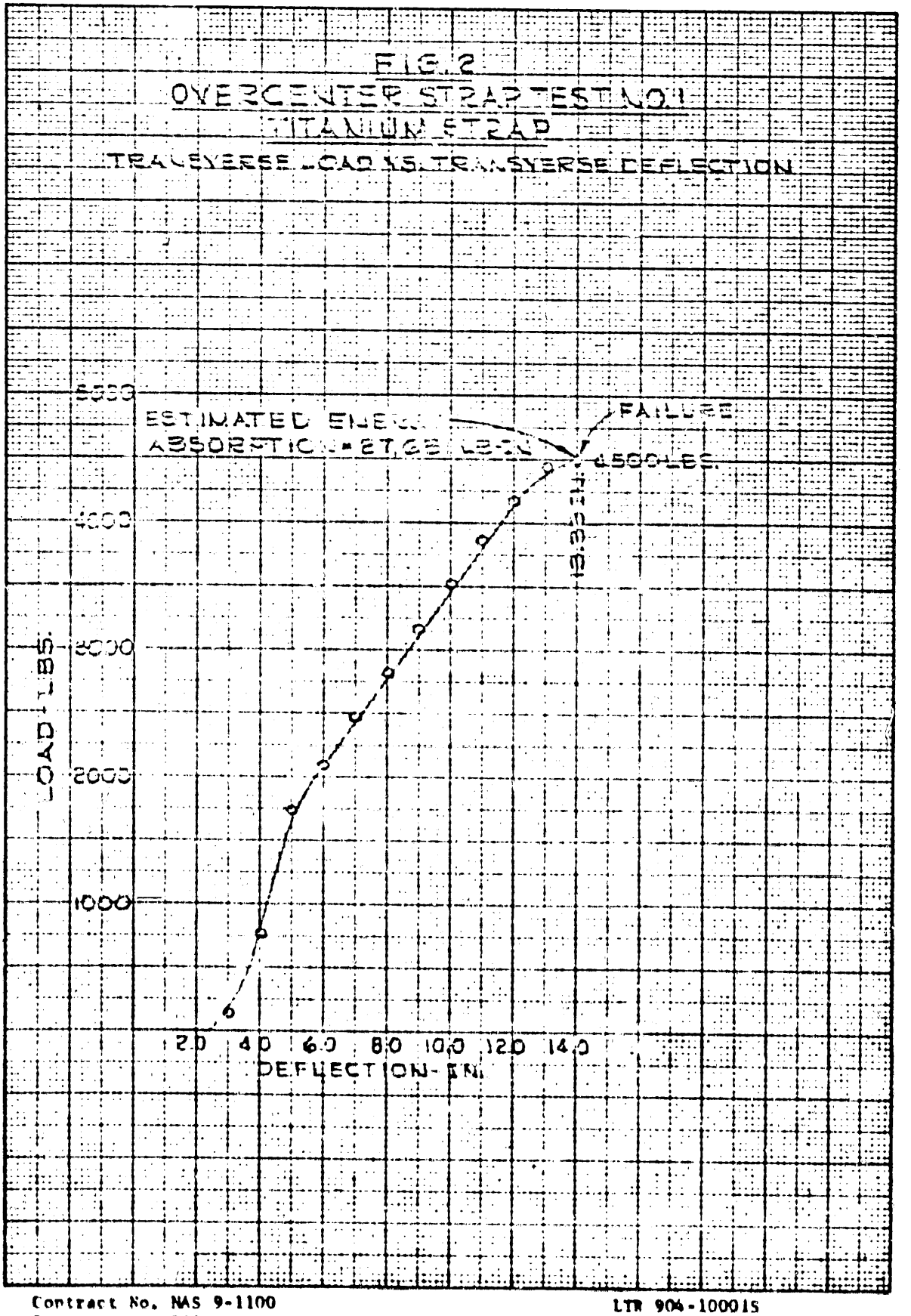


FIG. 2
OVERCENTER STRAP TEST NO. 1
TITANIUM STRAP
TRANSVERSE LOAD VS. TRANSVERSE DEFLECTION
ESTIMATED ENERGY
ABSORPTION = 27,68 LB-IN
FAILURE
4500 LBS.
13.33 IN.
5000
4000
3000
2000
1000
LOAD - LBS.
2.0
4.0
6.0
8.0
10.0
12.0
14.0
DEFLECTION - IN.

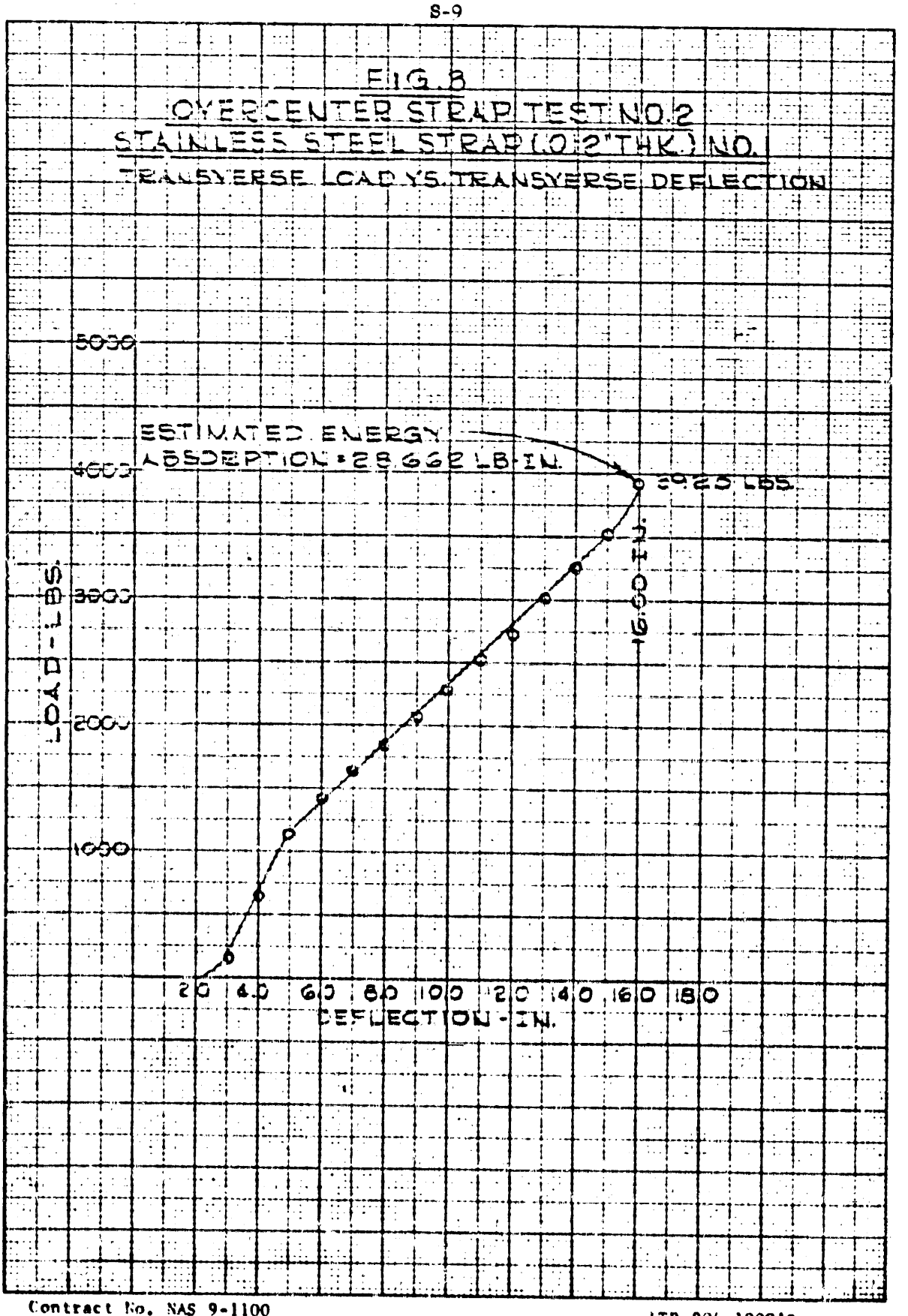


FIG. 8
OVERCENTER STRAP TEST NO. 2
STAINLESS STEEL STRAP (0.2" THK.) NO.
TRANSVERSE LOAD VS. TRANSVERSE DEFLECTION
ESTIMATED ENERGY ABSORPTION = 28,662 LB-IN.
2925 LBS.
16.00 IN.
LOAD - LBS.
5000
4000
3000
2000
1000
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
DEFLECTION - IN.

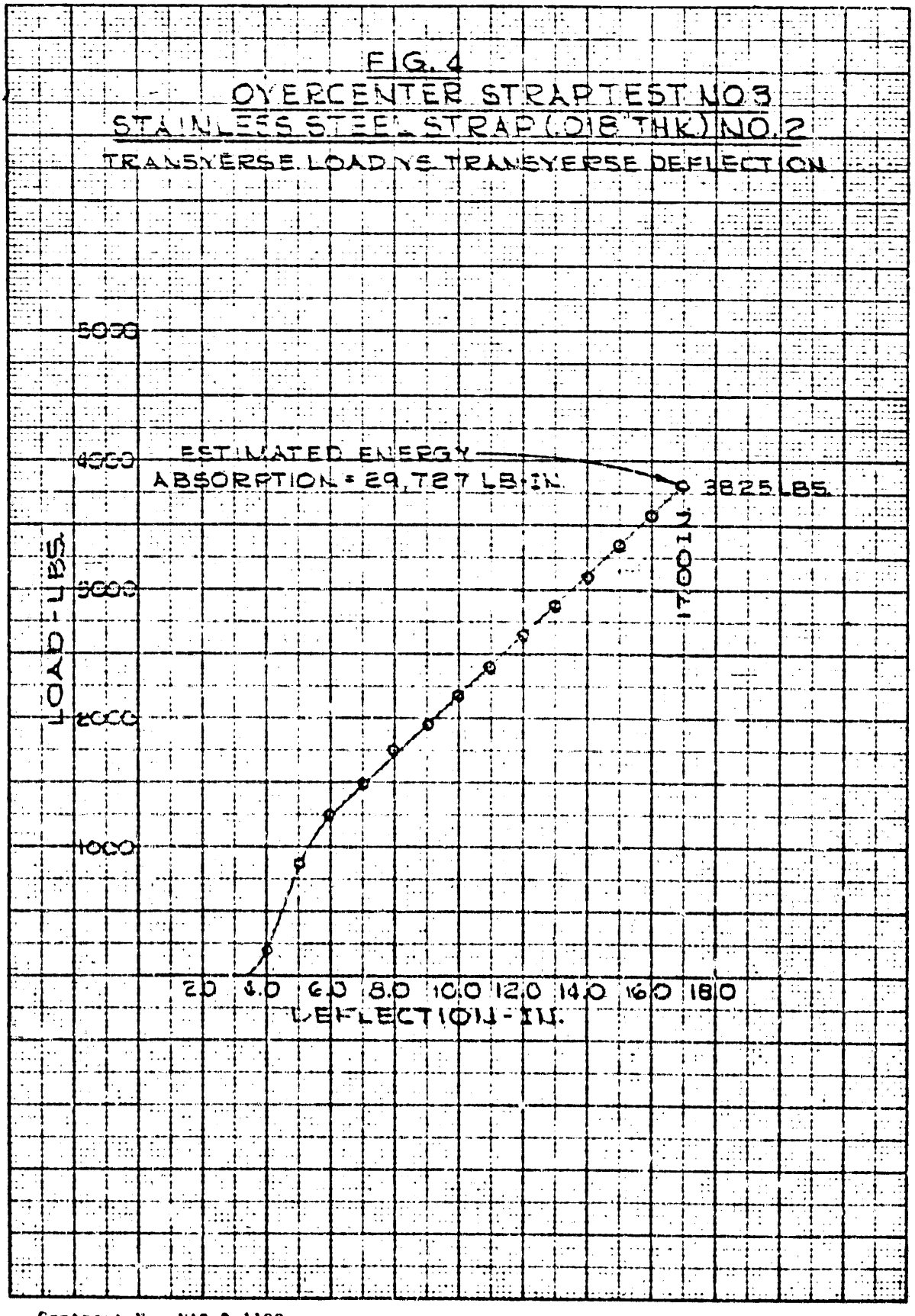


FIG. 4
OVERCENTER STRAP TEST NO 3
STAINLESS STEEL STRAP (.018 THK) NO. 2
TRANSVERSE LOAD VS TRANSVERSE DEFLECTION
ESTIMATED ENERGY
ABSORPTION = 29,727 LB-IN.
3825 LBS.
17.00 IN.
LOAD - LBS.
5000
4000
3000
2000
1000
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
DEFLECTION - IN.

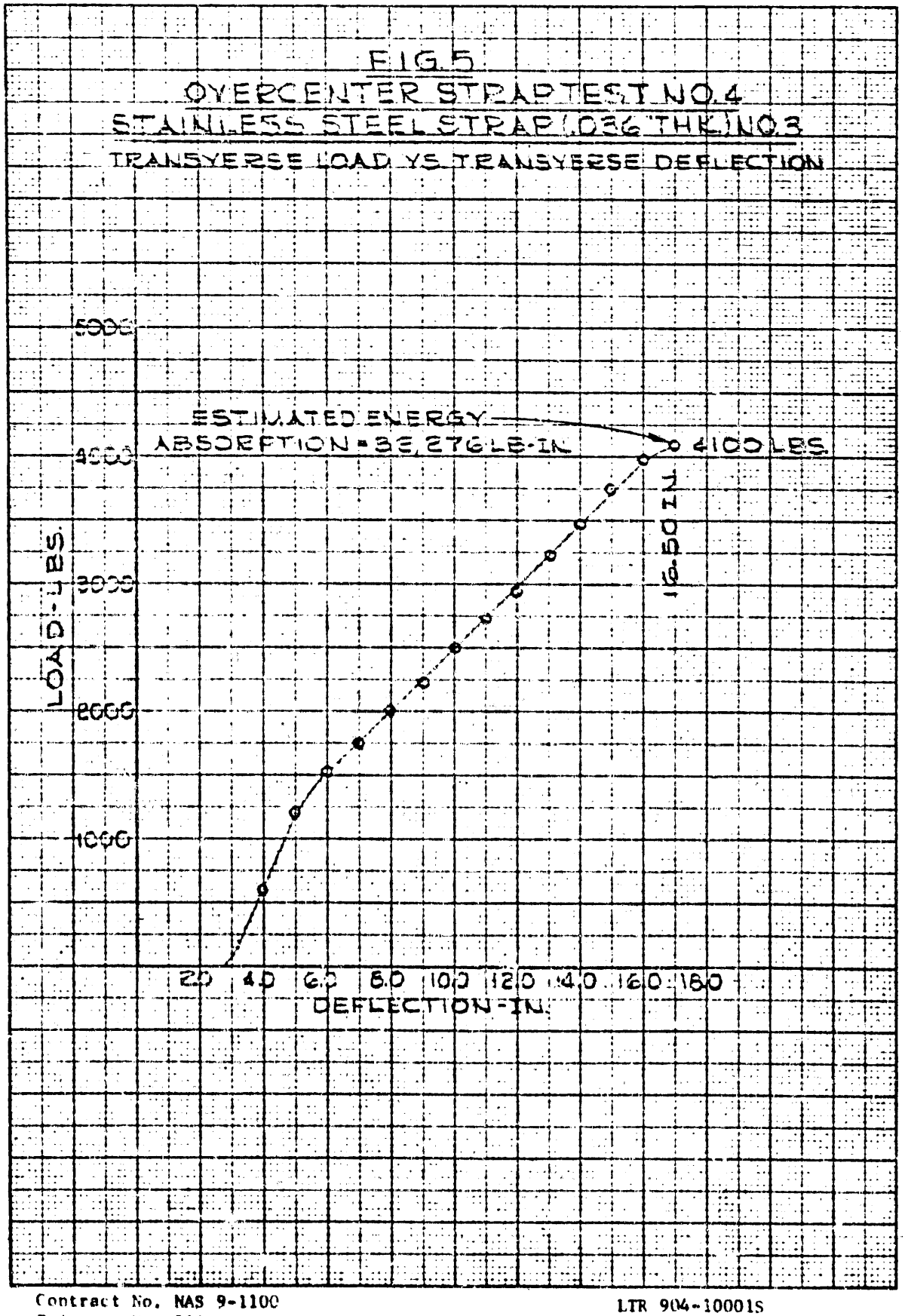
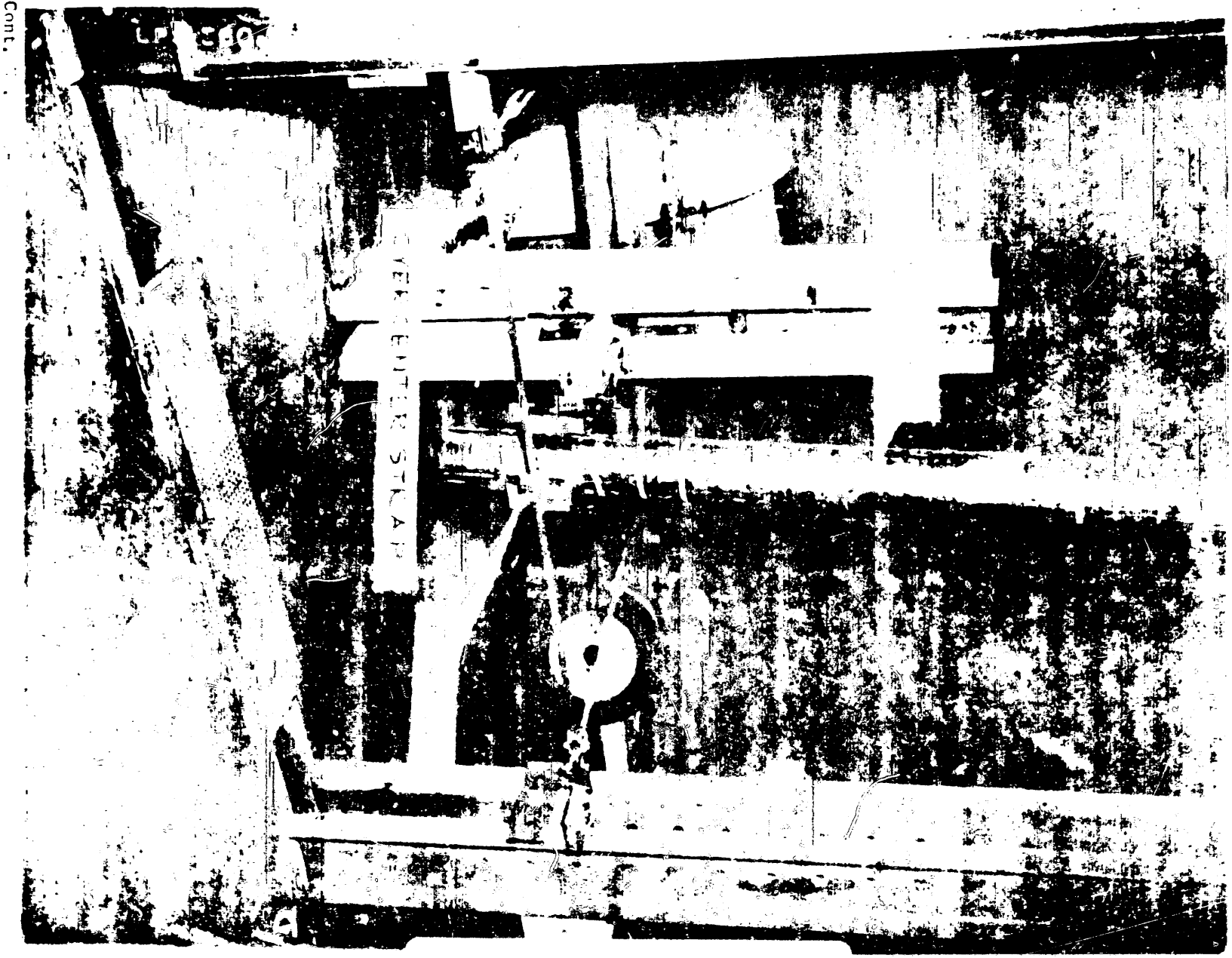


FIG. 5
OVERCENTER STRAP TEST NO. 4
STAINLESS STEEL STRAP (.036 THK) NO. 3
TRANSVERSE LOAD VS TRANSVERSE DEFLECTION
ESTIMATED ENERGY ABSORPTION = 36,276 LB-IN
4100 LBS.
16.50 IN.
LOAD - LBS.
5000
4000
3000
2000
1000
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
DEFLECTION - IN.



Overcenter Strap Test Set-Up

Cont.
Primary

Titanium Strap Failure

Cont.
Primary

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

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CHECKED BY:
R. L. Makemson

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

LIST OF REFERENCES

GRUMMAN DRAWINGS

LTM 320-51902	Tube Assembly, 167" Landing Gear Deployment Truss Cross-member
LSK 915-[illegible]92	Fixture Fitting, 167" Landing Gear Deployment Truss Cross-member

GRUMMAN DOCUMENTS

LTQ 320-36	Systems Test Request

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

INTRODUCTION

This section of the report contains the results of the structural tests conducted on the cross-member with the crossover fitting of the LEM Landing Gear Deployment Truss.

These tests were conducted in accordance with Test Plan No. LTP 904-10001, Section T - Plan for the Structural Test of 167" Landing Gear Deployment Truss Crossmember with Crossover Fitting. The tests were also conducted in partial fulfillment of the requirements of Paragraph 5.2, Exhibit E, Contract No. NAS 9-1100.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

1.0 PURPOSE OF TESTS

The primary purpose of the tests was to demonstrate the structural integrity of the test article under ultimate load conditions.

The secondary purpose of the tests was to determine the actual safety margins and modes of failure during the overstress test. In addition, strain measurements were to be recorded for the purpose of verifying stress analysis.

2.0 DESCRIPTION OF TEST ARTICLE

The test article is identified as the Crossmember (with crossover fitting) conforming to Drawing No. LTM 320-51902. This member is part of the LEM Landing Gear Truss Assembly which transmits the loads from the secondary struts of the gear to the LEM Descent Stage. By incorporating a cross-over fitting in the crossmember, the truss assembly is preserved as a simple determinant structure. Figure 1 showns the truss assembly and the crossmember.

3.0 DESCRIPTION OF TESTS

3.1 Test Conditions

For these tests, the axial compressive loads were as follows:

a. Design Limit Load: 8570 lbs.
b. Design Ultimate Load: 11,600 lbs.

The test article was subjected to ultimate load and overstress tests. For each of these conditions, a 104 lb. transverse load was applied to the test article with 36 lbs. of this load being concentrated at the center of the crossover fitting. The remaining 68 lbs. load was, approximately, distributed over the strut length. This load, maintained for the duration of the test, simulated the 20g transverse inertia load. The ultimate load test was conducted at ambient temperature and the overstress test at 285°F.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

3.0 DESCRIPTION OF TESTS - continued

3.2 Test Set-Up

3.2.1 The test article was installed in a test fixture, as shown in Photograph No. LPS 560-1159 and Figure 2. It consisted of a steel structure capable of supporting the test article in a horizontal position. The axial load was applied by means of a hydraulic jack.

3.2.2 The 68 lb. distributed transverse load was applied by means of four aluminum straps folded around the test article and applied by weights acting through a cable and pulley system, as shown in Figure 3.

A 36 lb. concentrated transverse load was applied on the crossover fitting by means of an aluminum plate, as shown in Photograph No. LPS 560-1161. This transverse load was applied using a cable and pulley system attached to a hydraulic jack.

3.2.3 A thermal chamber was used for the overstress test. Heat was supplied by means of a Wyle servo-temperature conditioning unit.

3.3 Test Procedure

3.3.1 The test article was instrumentated as indicated in Paragraph 4.0 and installed in the test fixture as described in Paragraph 3.2.1 through 3.2.3. The ultimate strength test was conducted first and was followed by the overstress test.

3.3.2 The ultimate strength test was conducted as follows:

a. The transverse load was applied to the test article. Deflections were read and strains, due to the transverse load, were recorded. The transverse load was maintained constant for the duration of the tests.

b. The axial compressive load was applied in 10% increments (of ultimate load) to limit and then in 5% increments to ultimate. Load levels were monitored by a pressure gage and were simultaneously recorded by a load cell in line with the jack. Deflections and strains were recorded after each increment.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

3.0 DESCRIPTION OF TESTS - continued

3.3 Test Procedure - continued

3.3.2 c. After reaching ultimate load (11,600 lbs.) the axial compressive load was gradually reduced to zero and the transverse load was removed. Deflections were read and recorded.

3.3.3 The overstress test was conducted as follows:

a. The test article was heated to a temperature of +285°F and stabilized.

b. The transverse load was applied to the test article and the deflections and strains were recorded. The transverse load was maintained constant for the duration of the test.

c. Ultimate load was applied. The method of load application and load increments were as described in Paragraph 3.3.2(b).

d. The design ultimate load of 11,600 lbs. was reached and maintained. On attempting to increase the load to the next increment (105% of ultimate) failure occurred.

4.0 INSTRUMENTATION

Instrumentation support was provided for measuring and recording the following test data:

a. Twelve (12) strain measurements

b. Axial compressive load

c. Deflections at two (2) locations (at the midspan of the crossmember and at the center of the crossover fitting)

The locations of the strain gages are shown in Figure 3. The location of the load link is shown in Photograph No. LPS 560-1160.

The deflections were read using dial gage indicators. The strains were recorded using a Brown and Fischer (B and F) recorder.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

4.0 INSTRUMENTATION - continued

In addition, thermocouples were provided during the overstress test for the purpose of monitoring the temperature of the test article.

5.0 PRESENTATION OF TEST DATA

The test data in this report is presented in Figures 4 through 15. These figures show strain versus axial compressive load at ambient and elevated temperatures for each of the twelve strain gages. In addition, Figures 16 and 17 show deflection versus axial compressive load at ambient and elevated temperatures.

6.0 DISCUSSION OF RESULTS AND CONCLUSIONS

6.1 After completion of the ultimate strength test, examination of the recorded data showed that axial loads, as recorded from the load link, were slightly lower than the applied loads as monitored throughout the test on a pressure gage. Data plotted for the ultimate strength test has been plotted against the corrected loads (as indicated by the load link) and it will be noted that loading was terminated at 11,100 lbs. During the overstress test, good correlation between the pressure gage and load link was achieved. Both instruments indicating that a load of 11,600 lbs. was reached and maintained by the test article at 285°F.

6.2 The test article withstood the axial compressive load of 11,100 lbs. without any evidence of structural damage and without any significant permanent deformation. Measured set after removal of the loads on the ultimate strength test was only .021 inch at midspan of the strut and .018 inch at the crossover fitting.

RESULTS OF LANDING GEAR COMPONENT DEVELOPMENT TESTS

SECTION T: RESULTS OF STRUCTURAL TEST OF 167" LANDING GEAR DEPLOYMENT TRUSS CROSS-MEMBER WITH CROSSOVER FITTING

6.0 DISCUSSION OF RESULTS AND CONCLUSIONS - continued

6.3 In the overstress test, the test article failed as the axial compressive load was being increased to 105% of ultimate load. Failure occurred at 11,920 lbs., which represents a margin of safety of 2.76% over the design ultimate load of 11,600 lbs.

.4 The non linearity of many of the strain gages particularly Nos. 3, 4 and 10 could be attributed to either local instability of the tubular members or slippage of the gages at high temperature. The latter explanation appears the more likely. In the case of gage No. 5 the gage was noted to be unbonded after the test. Results from this gage are however considered valid since the measured strains up to ultimate load are rational.

6.5 These tests showed the deployment truss crossmember (LTM 320-51902) to be structurally adequate for the design load criteria and to have a margin of safety 2.76% above design ultimate load at 285°F.

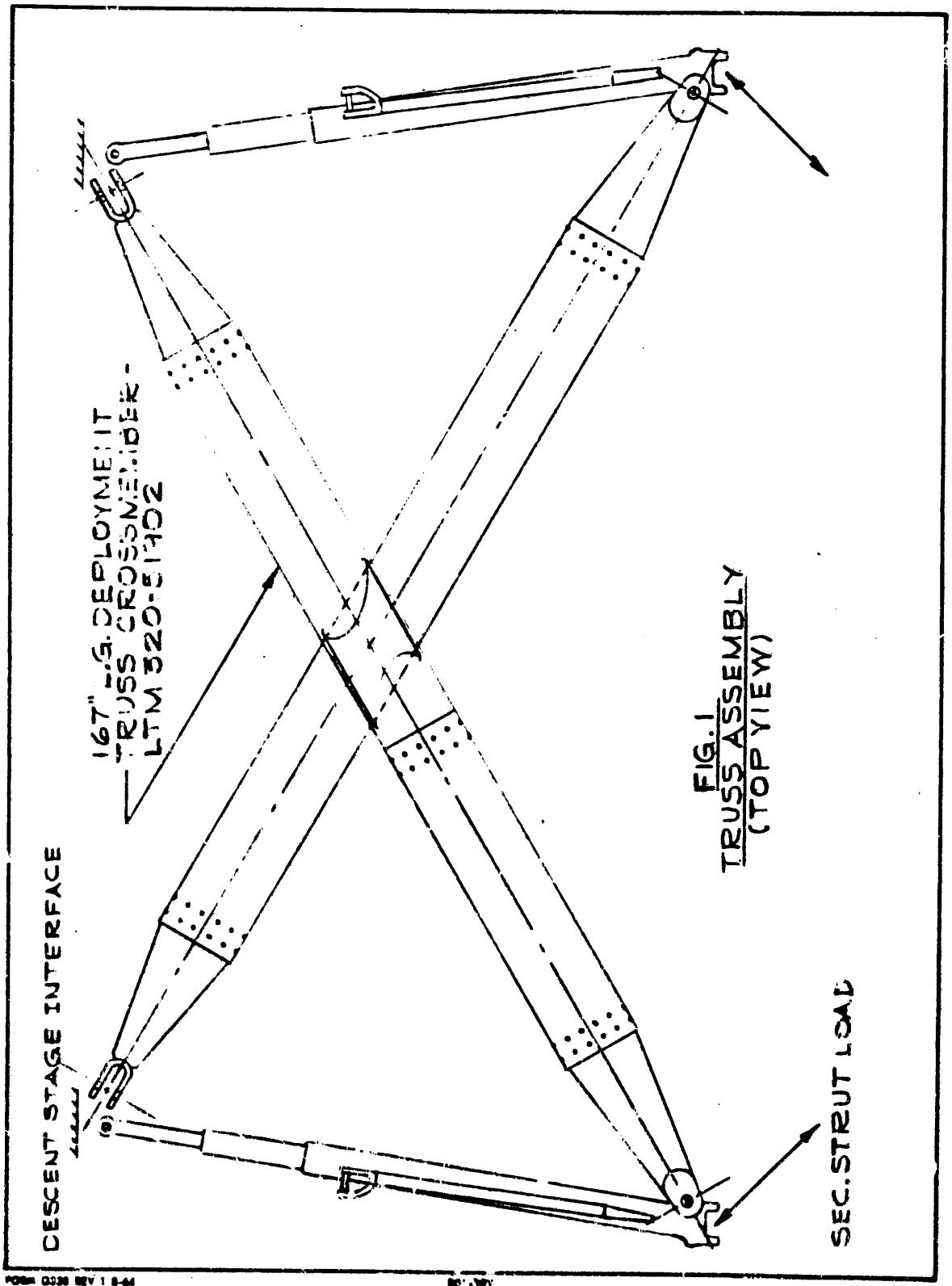


FIG. 1
TRUSS ASSEMBLY
(TOP VIEW)

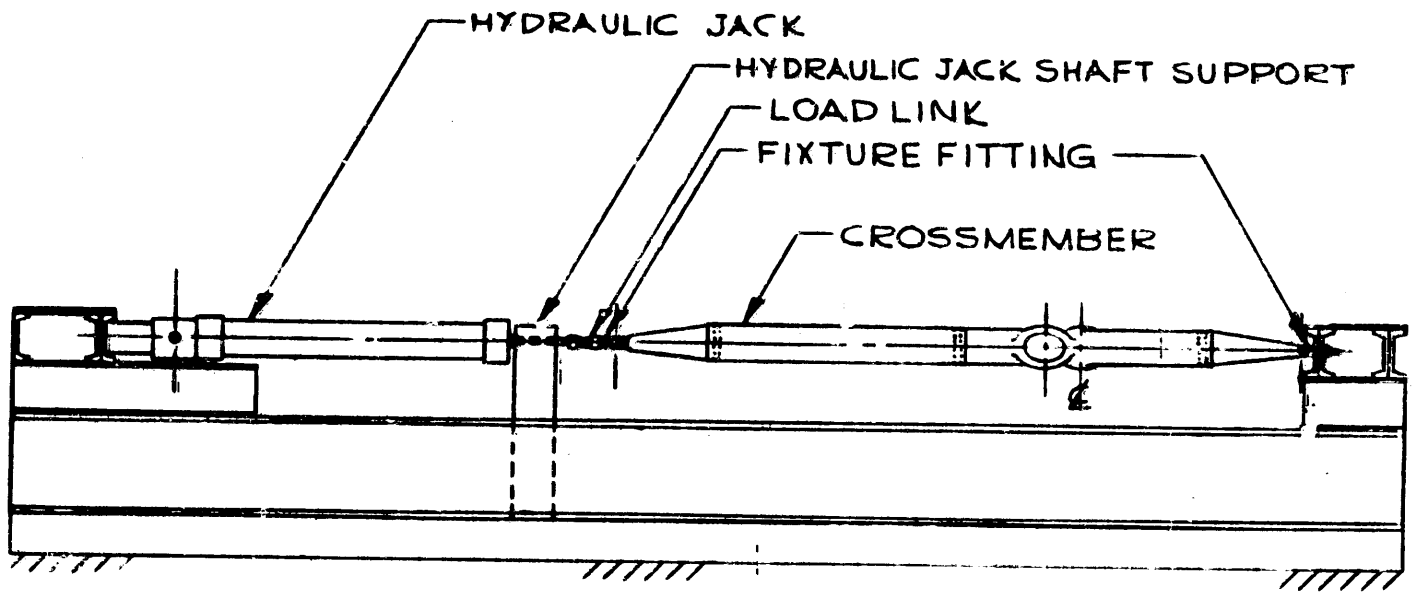


FIG. 2
167" L.G. DEPLOY TRUSS CROSSMEMBER
TEST SET-UP

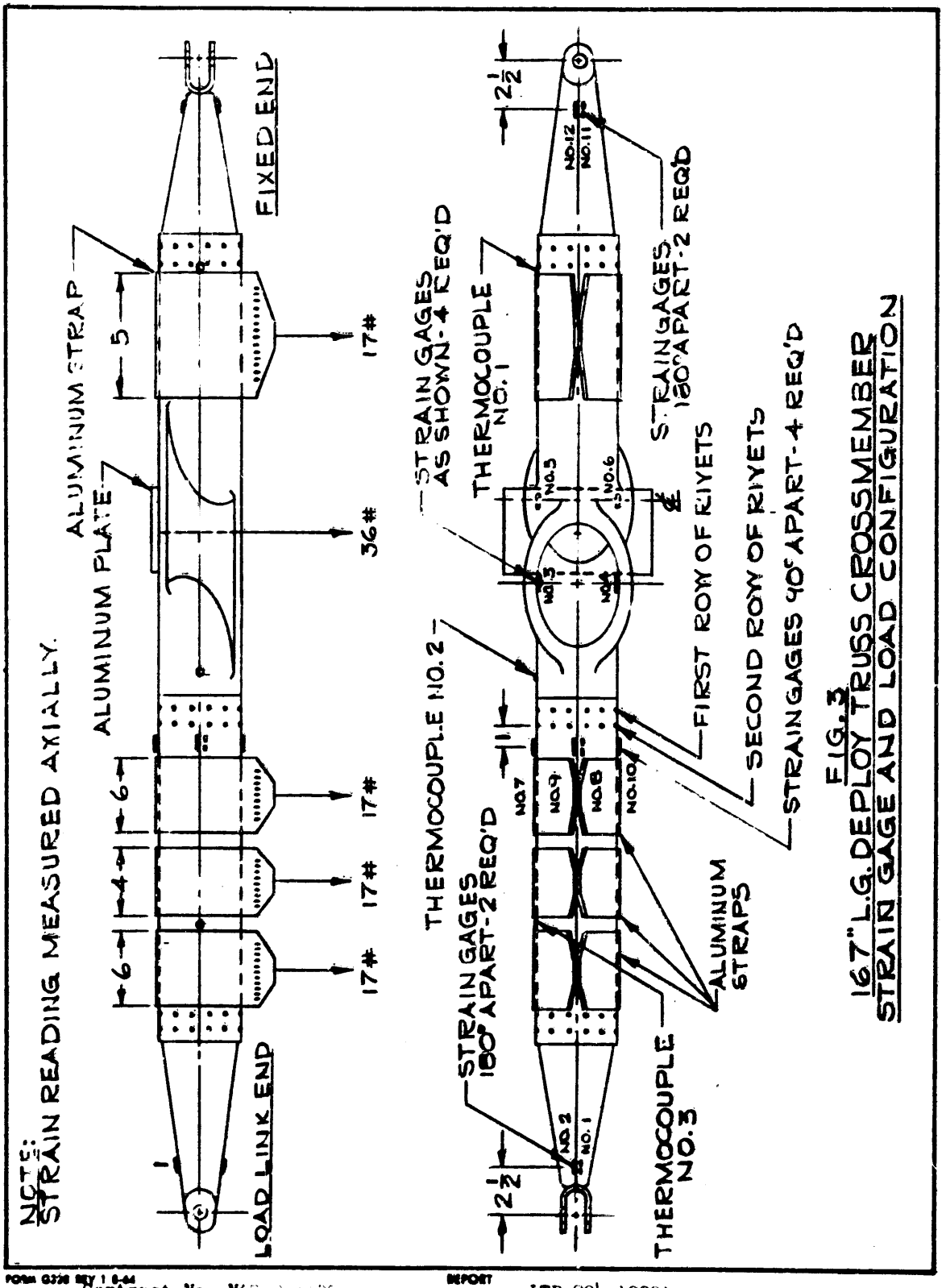
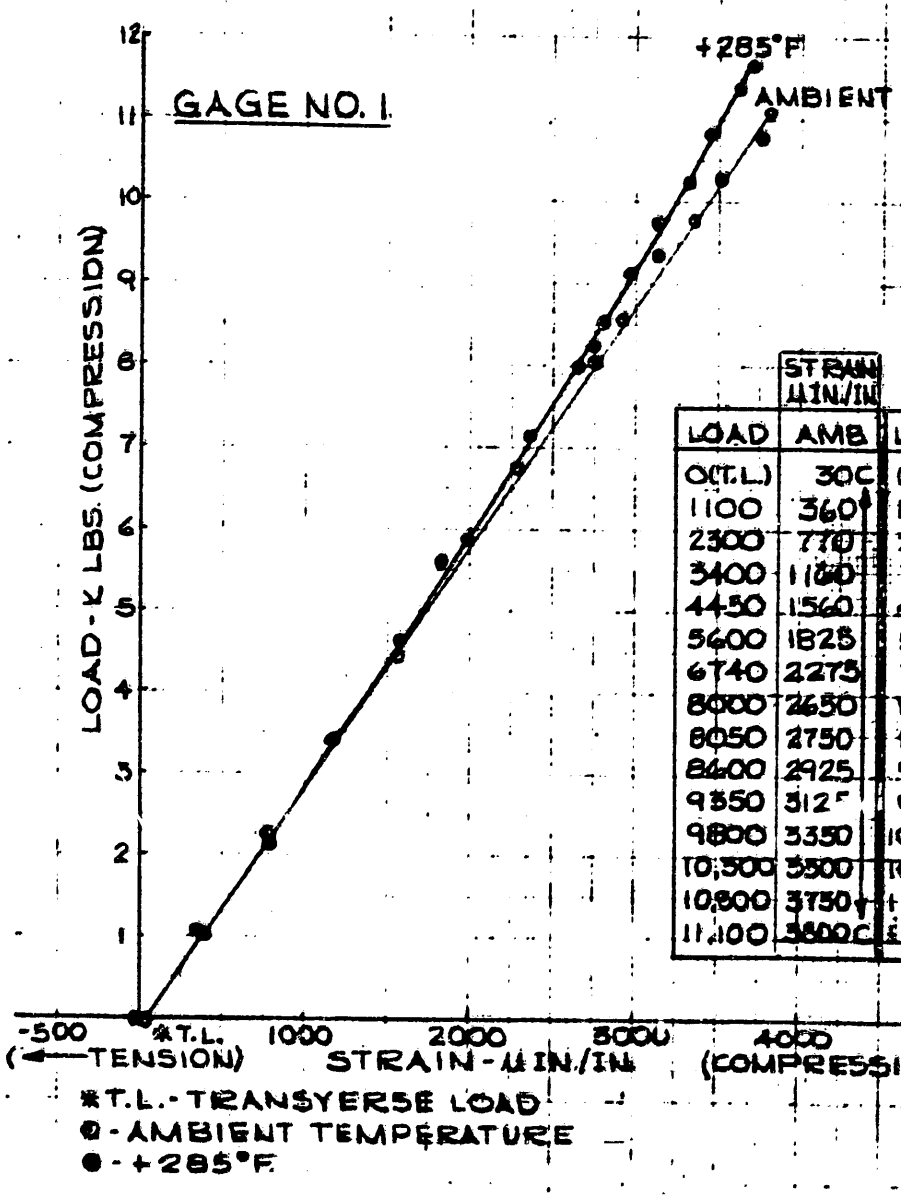


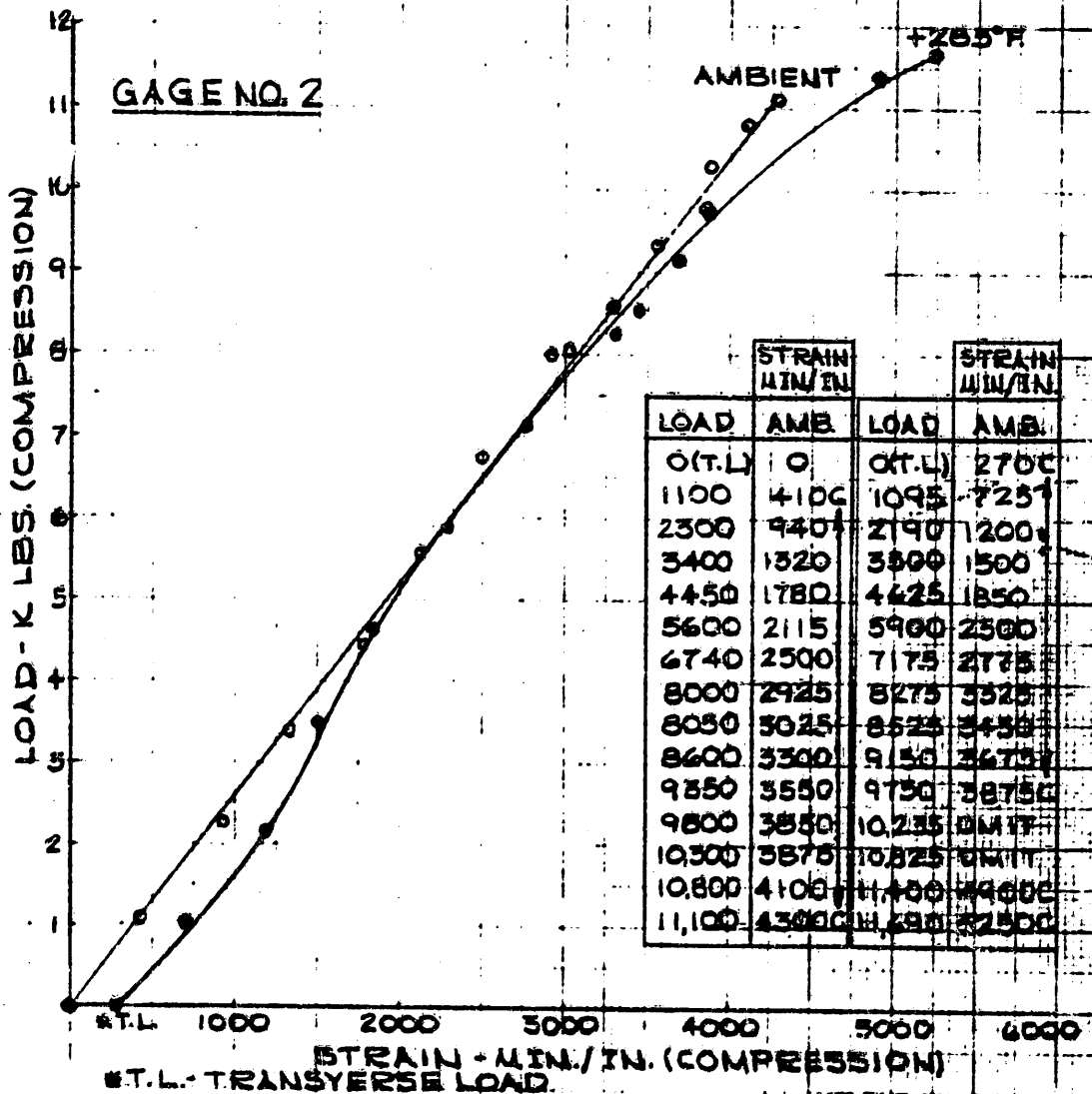
FIG. 3
167" L.G. DEPLOY TRUSS CROSSMEMBER
STRAIN GAGE AND LOAD CONFIGURATION

FIG. 4
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB	LOAD	STRAIN μIN/IN 285°F
0(T.L.)	30C	0(T.L.)	10 T
1100	360	1095	375C
2300	770	2190	775
3400	1160	3500	1150
4450	1560	4625	1575
5600	1825	5900	2000
6740	2275	7175	2350
8000	2650	8275	2750
8050	2750	8525	2800
8600	2925	9150	2975
9350	312[illegible]	9750	3125
9800	3350	10225	3325
10,300	3500	10825	3450
10,800	3750	11,400	3625
11,100	3800C	11,690	3700C

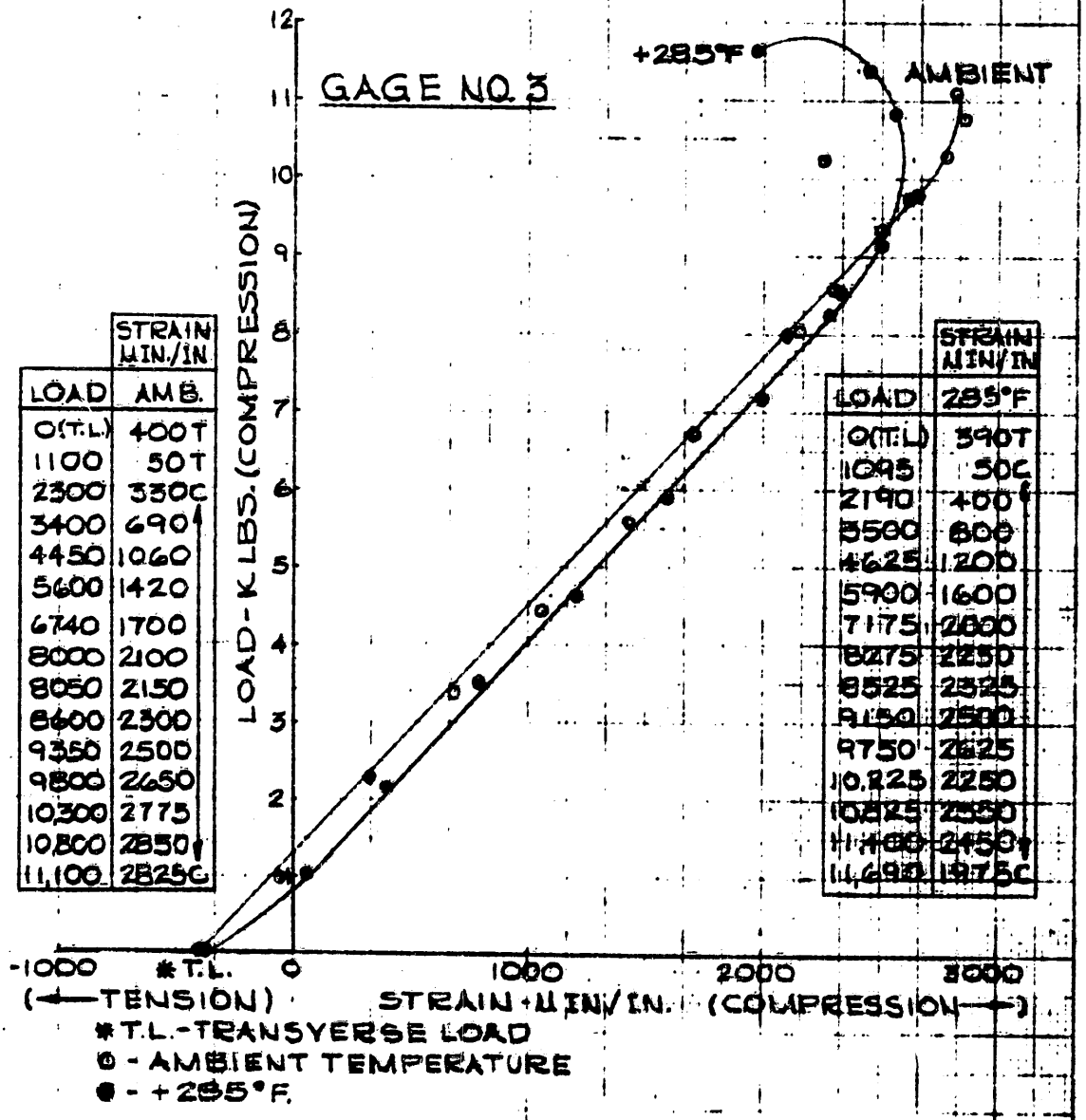
FIG. 5
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.	LOAD	STRAIN μIN/IN AMB.
0(T.L)	0	0(T.L)	270C
1100	410C	1095	725
2300	940	2190	1200
3400	1320	3500	1500
4450	1780	4425	1850
5600	2115	5900	2500
6740	2500	7175	2775
8000	2925	8275	3325
8050	3025	8525	3450
8600	3300	9150	3675
9350	3550	9750	3875C
9800	3850	10,235	OMIT
10,300	3875	10,825	OMIT
10,800	4100	11,400	4400C
11,100	4300C	11,290	4250C

*T.L. - TRANSVERSE LOAD.
⊙ - AMBIENT TEMPERATURE
● - +285°F.

FIG. 6
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.
0(T.L.)	400T
1100	50T
2300	330C
3400	690
4450	1060
5600	1420
6740	1700
8000	2100
8050	2150
8600	2300
9350	2500
9800	2650
10,300	2775
10,800	2850
11,100	2825C

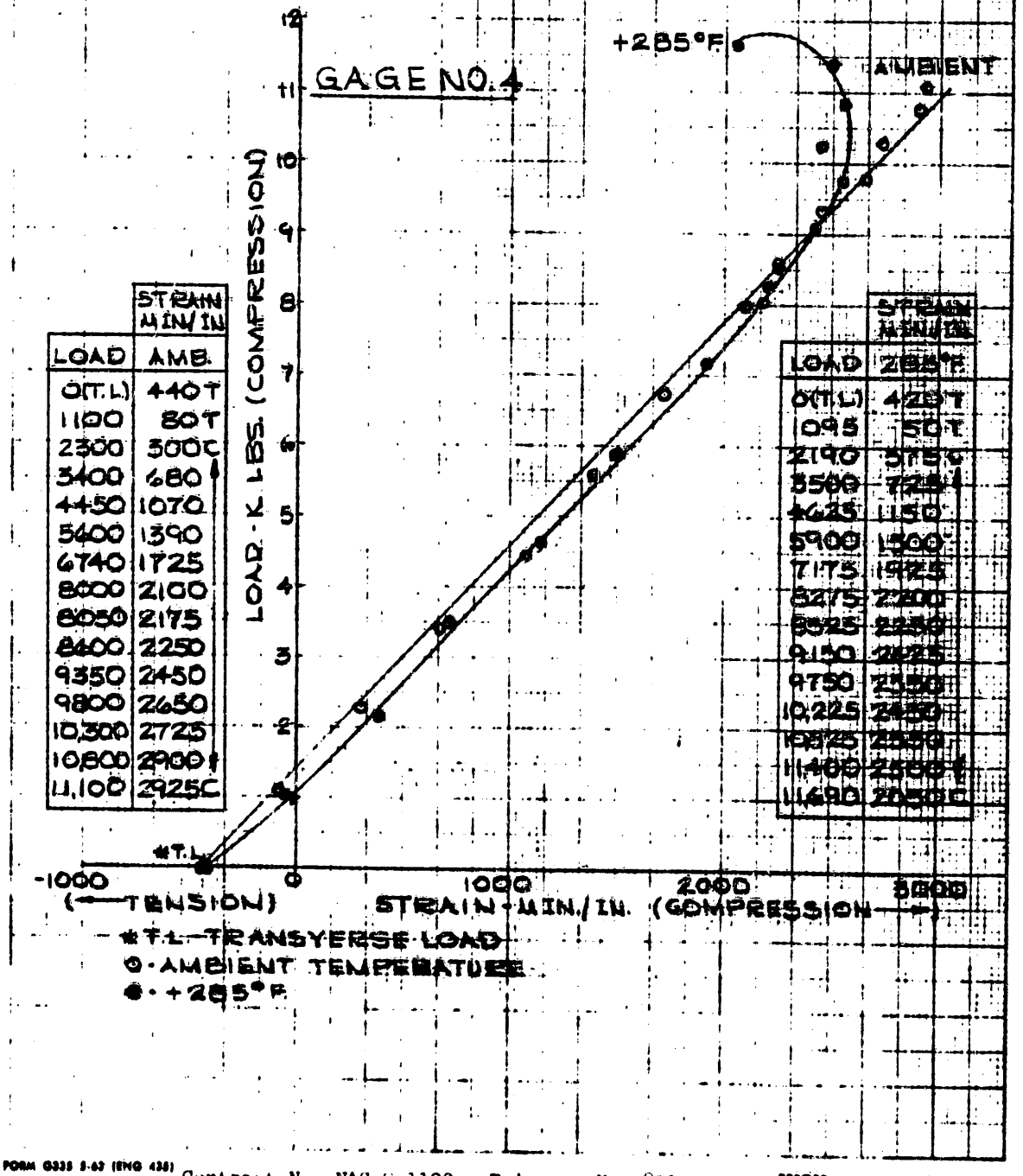
LOAD	STRAIN μIN/IN 285°F
0(T.L.)	390T
1095	50C
2190	400
3500	800
4625	1200
5900	1600
7175	2000
8275	2250
8525	2325
9150	2500
9750	2625
10,225	2250
10,825	2350
11,400	2450
11,690	1975C

FIG. 7

167" L.G. CROSSMEMBER TEST

LOAD VS. STRAIN

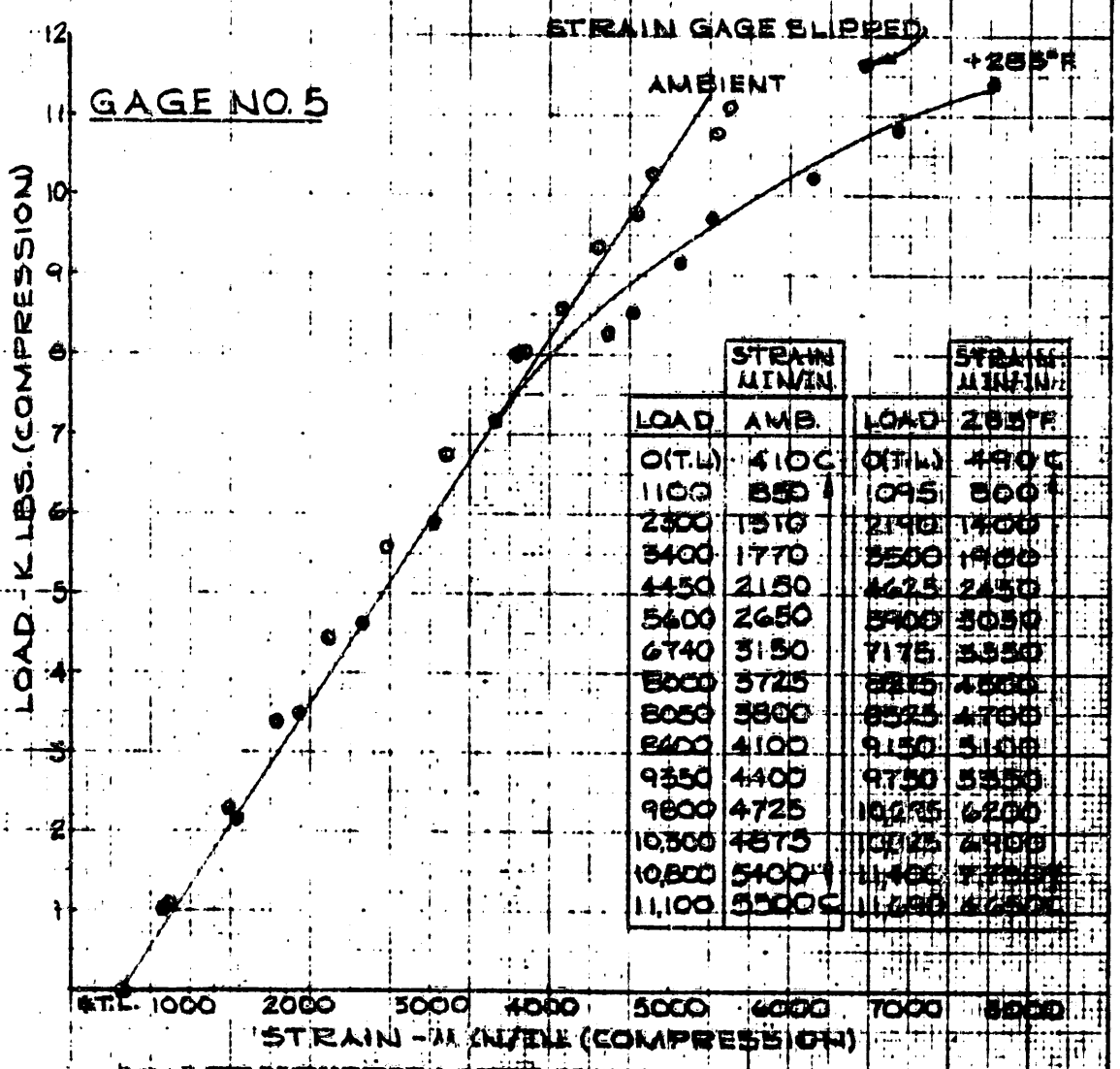
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.
0(T.L.)	440T
1100	80T
2300	500C
3400	680
4450	1070
5400	1390
6740	1725
8000	2100
8050	2175
8400	2250
9350	2450
9800	2650
10,300	2725
10,800	2900
11,100	2925C

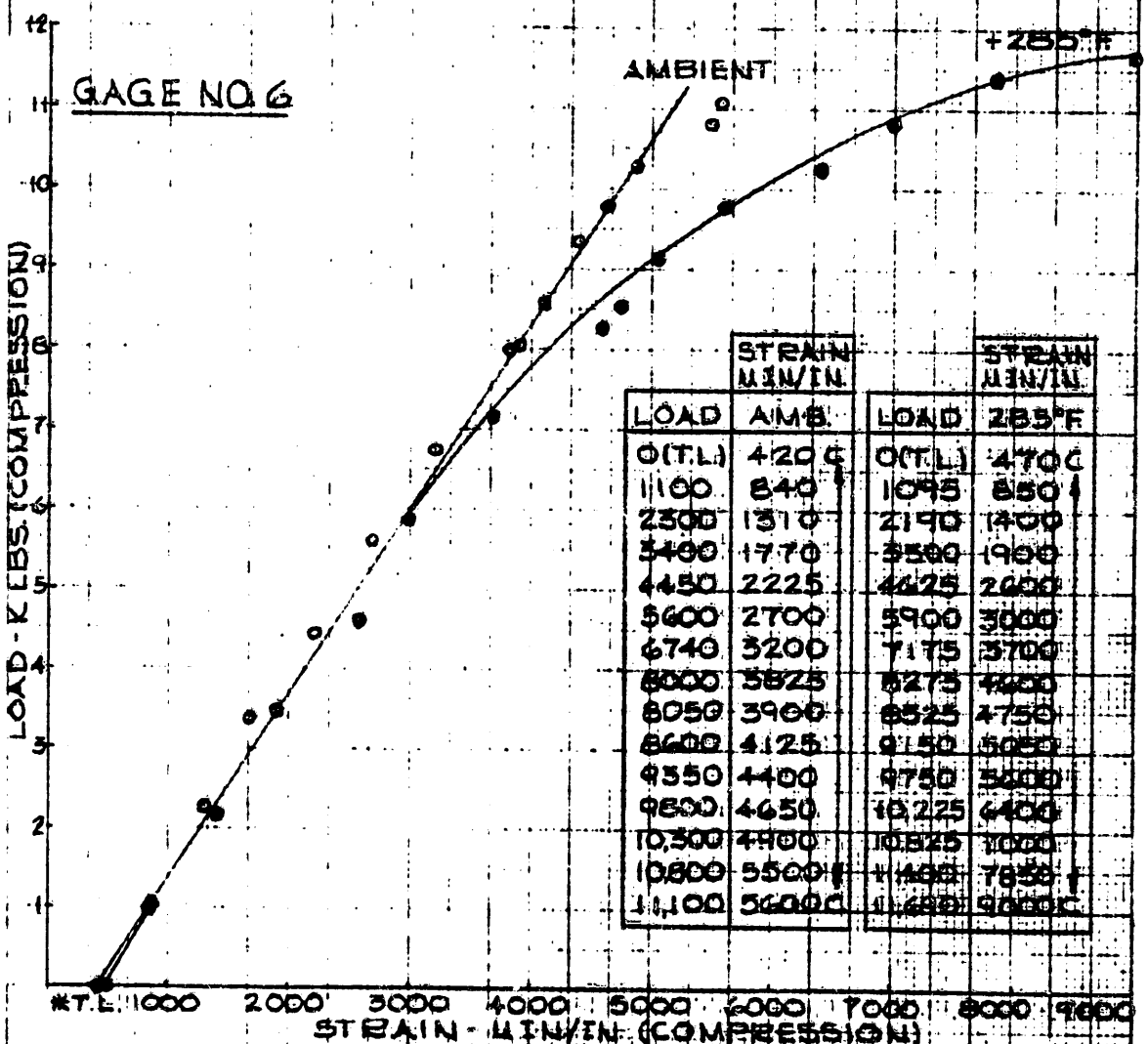
LOAD	STRAIN μIN/IN 285°F
0(T.L.)	425T
095	50T
2190	575C
3500	725
4625	1150
5900	1500
7175	1925
8275	2200
8625	2250
9150	2325
9750	2550
10,225	2450
10,625	2550
11,400	2600
11,690	2650C

FIG. 8
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.	LOAD	STRAIN μIN/IN 285°F
0(T.L.)	410C	0(T.L.)	490C
1100	850	1095	800
2300	1510	2190	1400
3400	1770	3500	1900
4450	2150	4625	2450
5600	2650	5900	3050
6740	3150	7175	3550
8000	3725	8275	4500
8050	3800	8525	4700
8400	4100	9150	5100
9350	4400	9750	5350
9800	4725	10,275	6200
10,300	4875	10,025	6900
10,800	5400	11,400	[illegible]
11,100	5500C	11,690	6650C

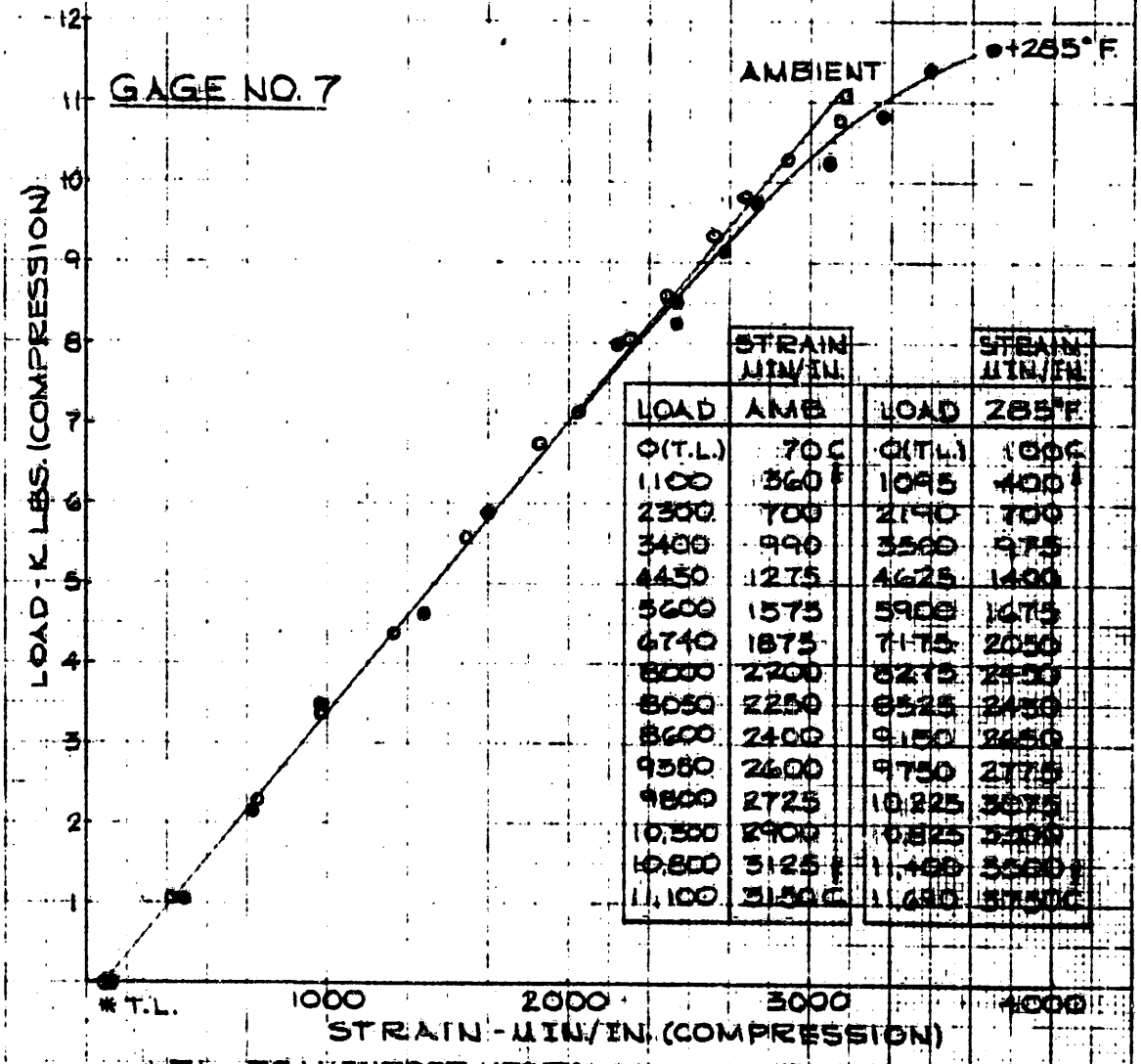
FIG. 9
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN MIN/IN. AMB.	LOAD	STRAIN MIN/IN. 285°F
0(T.L.)	420 C	0(T.L.)	470 C
1100	840 T	1095	850 T
2300	1310	2190	1400
3400	1770	3500	1900
4450	2225	4625	2600
5600	2700	5900	3000
6740	3200	7175	3700
8000	3825	8275	4400
8050	3900	8525	4750
8600	4125	9150	5050
9350	4400	9750	5400
9800	4650	10,225	6400
10,300	4900	10,825	7000
10800	5500 T	11,400	7850 T
11,100	5600 C	11,600	9000 C

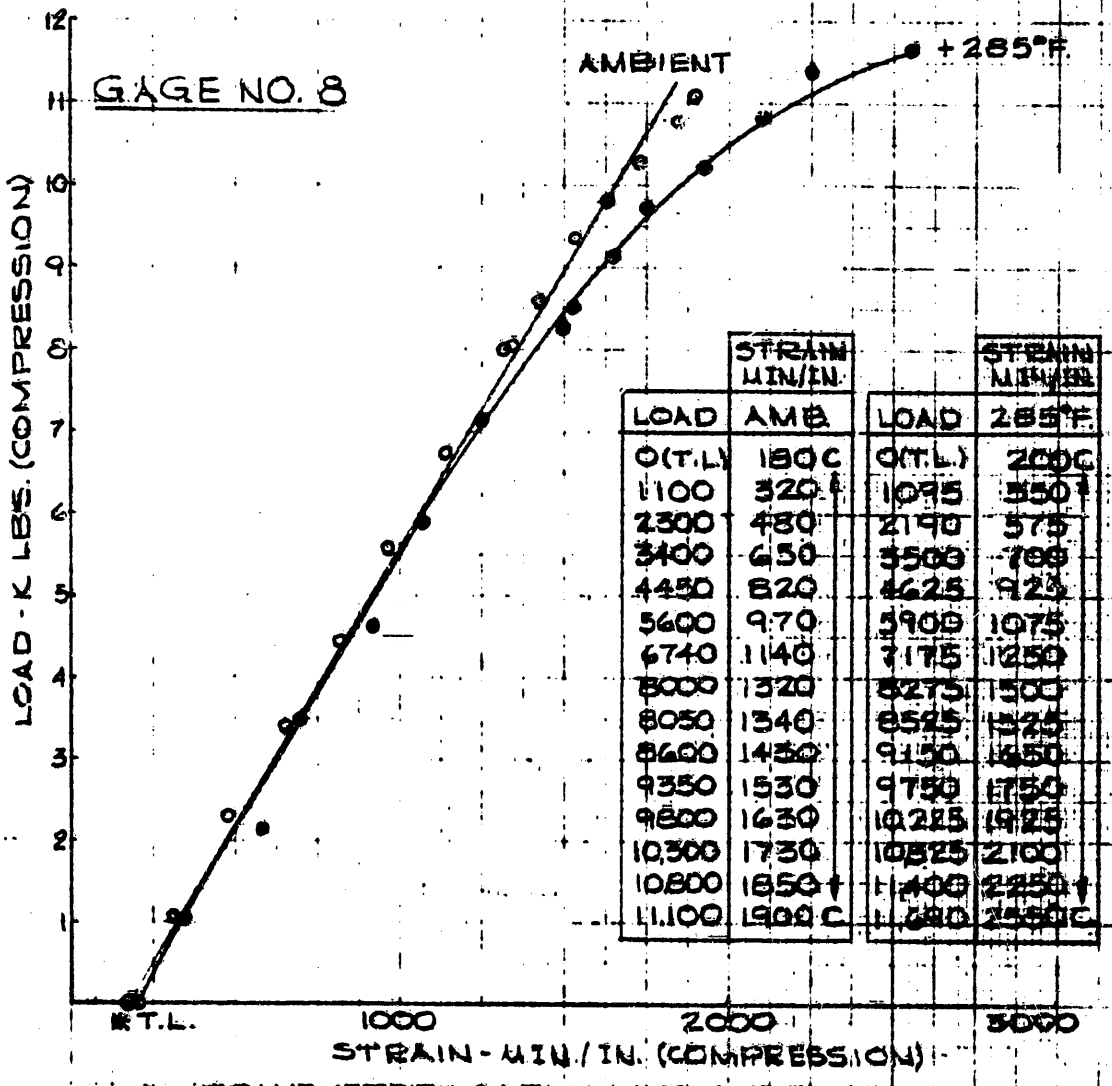
*T.L. - TRANSVERSE LOAD
○ - AMBIENT TEMPERATURE
● - +285°F

FIG. 10
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN. AMB	LOAD	STRAIN μIN/IN. 285°F
⊙(T.L.)	70 C	⊙(T.L.)	100 C
1100	360 F	1095	400 F
2300	700	2190	700
3400	990	3500	975
4450	1275	4625	1400
5600	1575	5900	1675
6740	1875	7175	2050
8000	2200	8275	2450
8050	2250	8525	2450
8600	2400	9150	2650
9380	2600	9750	2775
9800	2725	10,225	3075
10,500	2900	10,825	3300
10,800	3125 F	11,400	3500 F
11,100	3150 C	11,650	3750 C

FIG. 11
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)

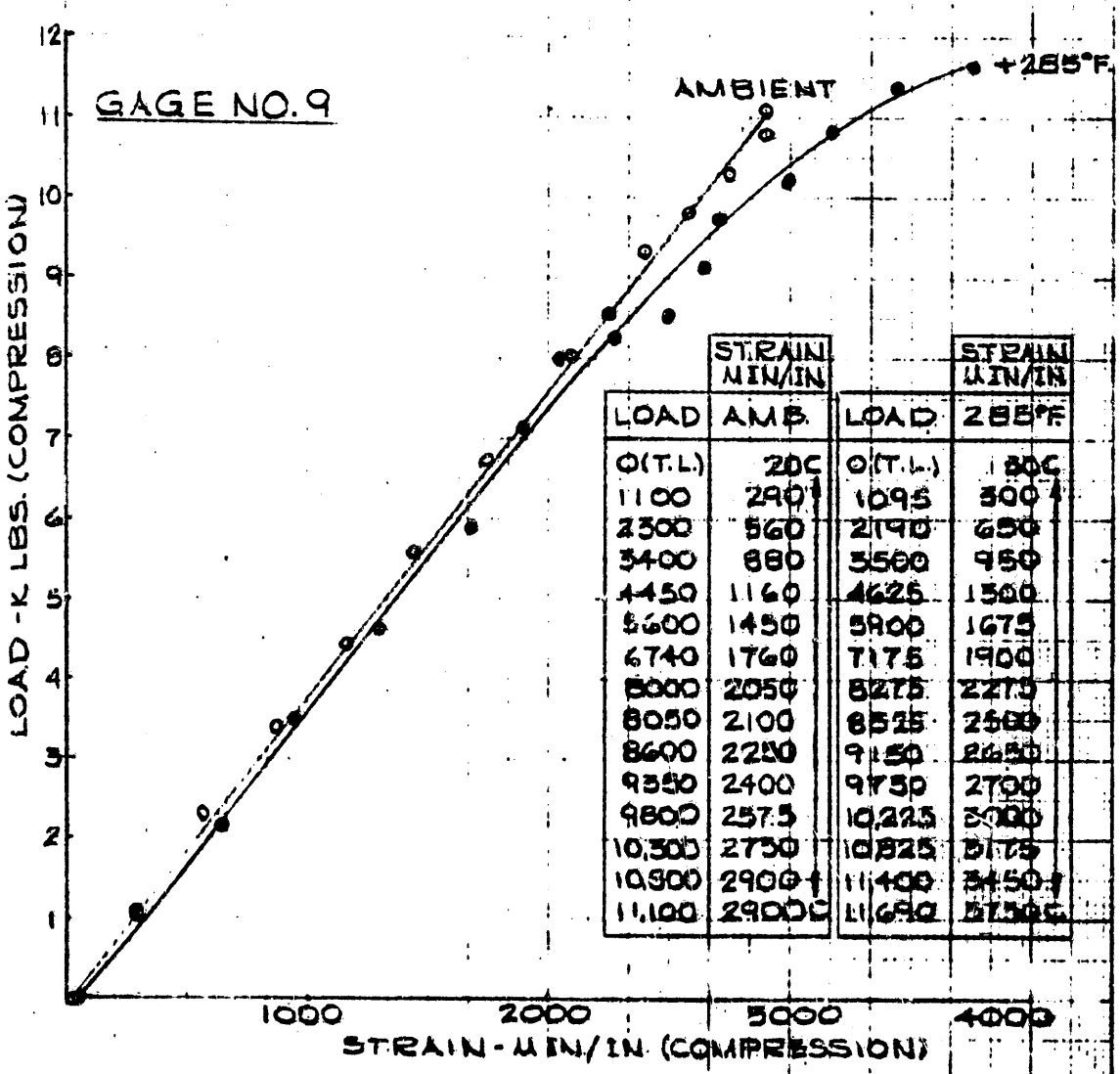


LOAD	STRAIN MIN/IN. AMB.
0(T.L.)	180 C
1100	320
2300	480
3400	650
4450	820
5600	970
6740	1140
8000	1320
8050	1340
8600	1450
9350	1530
9800	1630
10,300	1730
10,800	1850
11,100	1900 C

LOAD	STRAIN MIN/IN. 285°F.
0(T.L.)	200 C
1095	350
2190	575
3500	700
4625	925
5900	1075
7175	1250
8275	1500
8525	1525
9150	1650
9750	1750
10,225	1925
10,525	2100
11,400	2250
11,680	2500 C

*T.L.-TRANSVERSE LOAD
⊙-AMBIENT TEMPERATURE
●-+285°F.

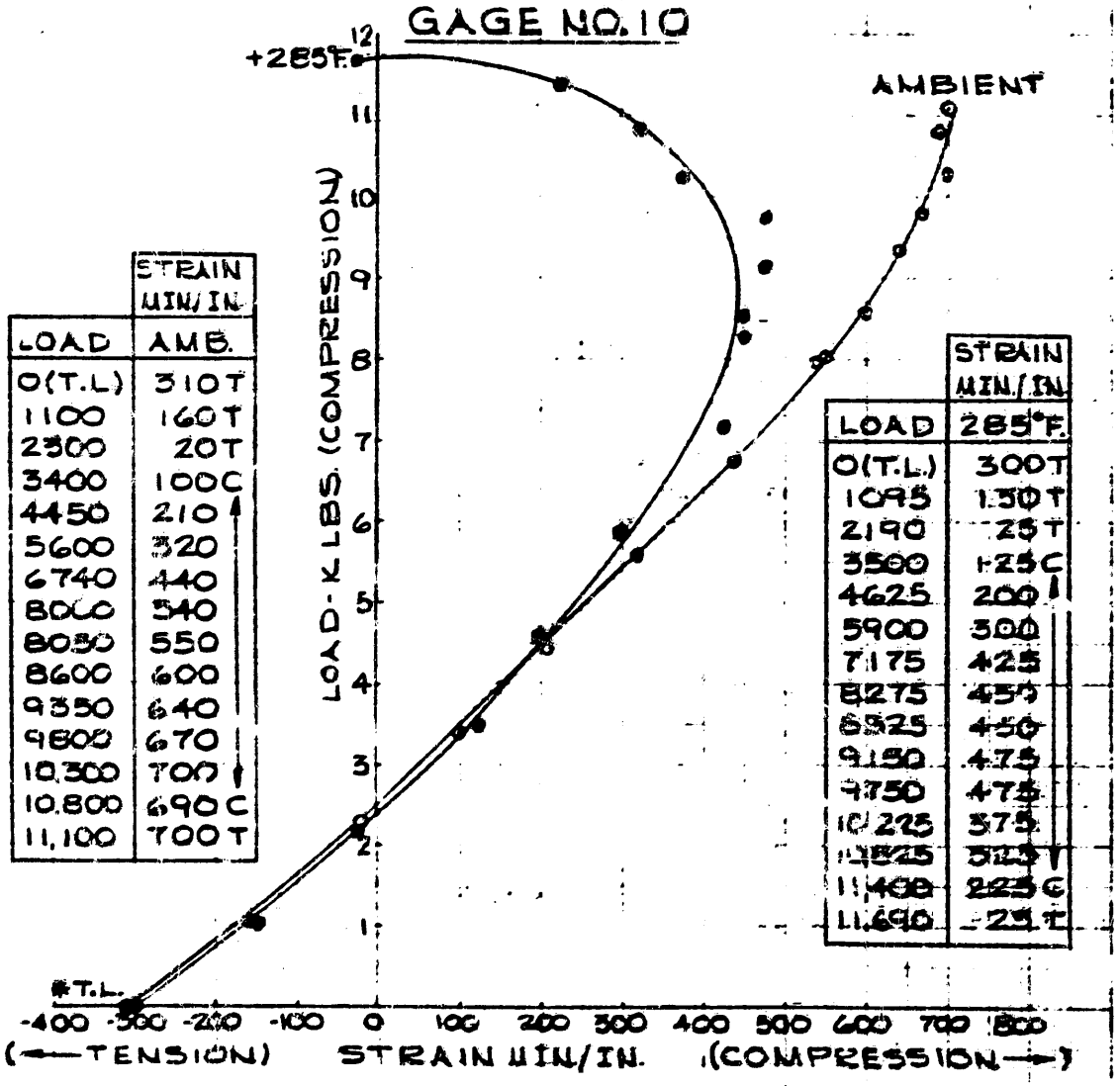
FIG. 12
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.	LOAD	STRAIN μIN/IN 285°F
0(T.L.)	200	0(T.L.)	180
1100	290	1095	300
2300	560	2190	650
3400	880	3500	950
4450	1160	4625	1500
5600	1450	5900	1675
6740	1760	7175	1900
8000	2050	8275	2275
8050	2100	8525	2500
8600	2250	9150	2650
9350	2400	9750	2700
9800	2575	10,225	3000
10,300	2750	10,825	3175
10,900	2900	11,400	3450
11,100	2900C	11,690	3750C

* T.L. - TRANSVERSE LOAD
⊙ - AMBIENT TEMPERATURE
● - +285°F

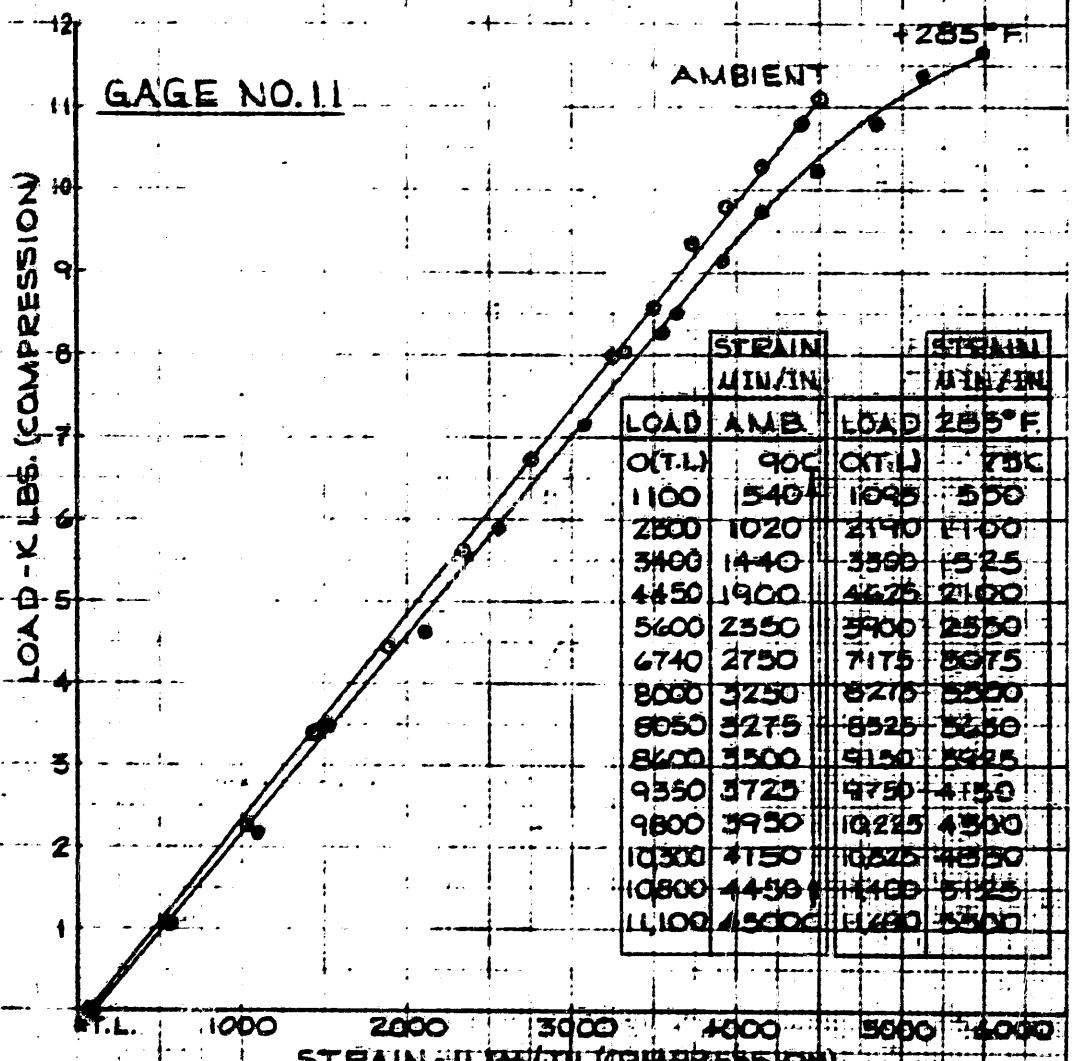
FIG. 13
67" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN MIN/IN. AMB.
0(T.L)	310T
1100	160T
2300	20T
3400	100C
4450	210
5600	320
6740	440
8000	540
8050	550
8600	600
9350	640
9800	670
10,300	700
10,800	690C
11,100	700T

LOAD	STRAIN MIN./IN. 285°F.
0(T.L.)	300T
1095	150T
2190	25T
3500	125C
4625	200
5900	300
7175	425
8275	450
8525	450
9150	475
9750	475
10,225	375
10,825	325
11,400	225C
11,690	25T

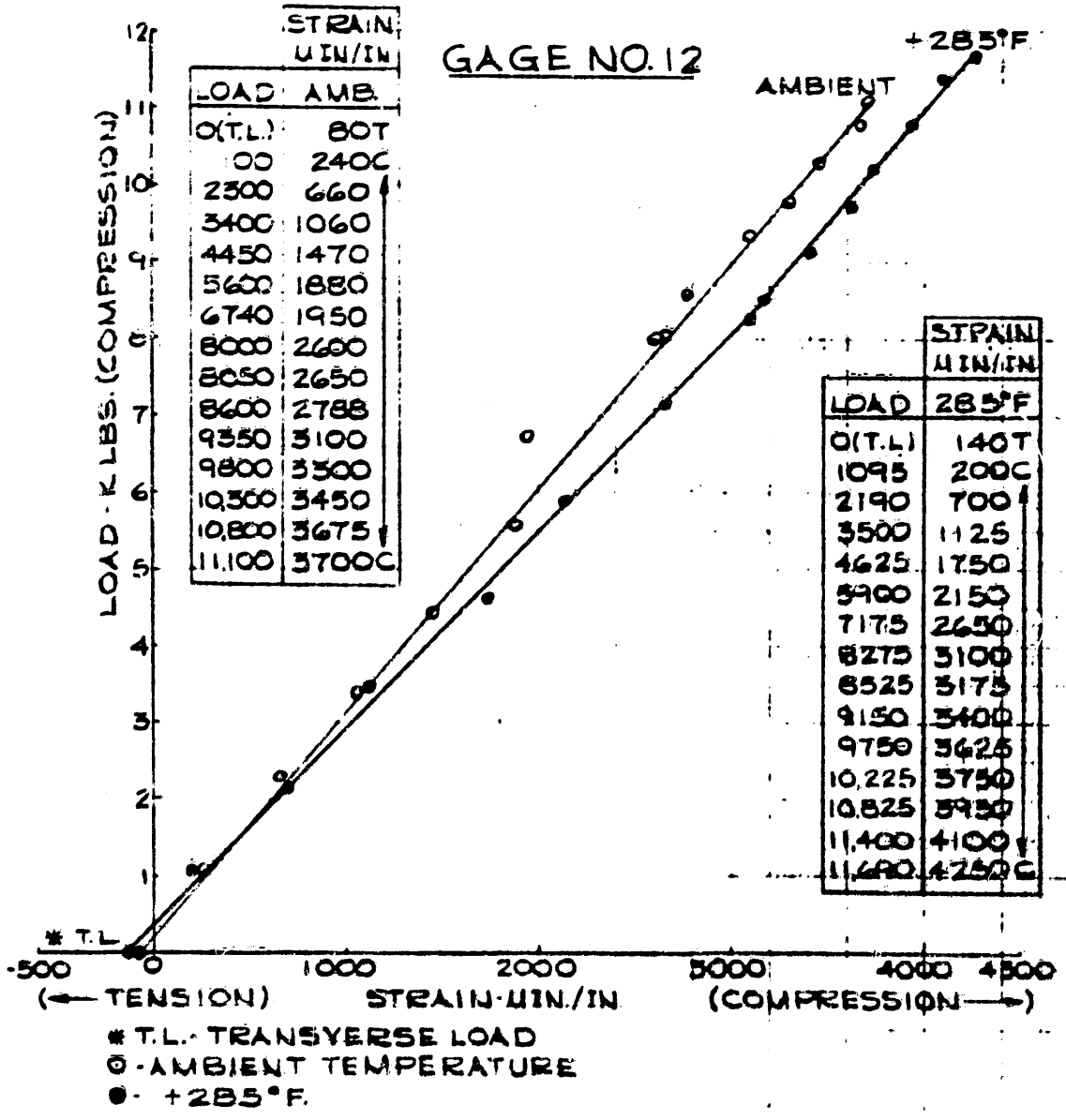
FIG. 14
167" L.G. CROSSMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.	LOAD	STRAIN μIN/IN 285°F
0(T.L.)	900	0(T.L.)	750
1100	540	1095	550
2800	1020	2190	1100
3400	1440	3590	1525
4450	1900	4625	2100
5600	2350	5900	2550
6740	2750	7175	3075
8000	3250	8275	3500
8050	3275	8525	3650
8600	3500	9150	3925
9350	3725	9750	4150
9800	3950	10225	4300
10300	4150	10625	4850
10800	4450	11400	5125
11,100	4500	11,690	5500

* T.L. - TRANSVERSE LOAD
⊙ - AMBIENT TEMPERATURE
● - +285°F.

FIG. 15
167" L.G. CROSSMEMBER TEST
LOAD VS. STRAIN
(SEE FIG. 2 FOR STRAIN GAGE LOCATION)



LOAD	STRAIN μIN/IN AMB.
0(T.L.)	80T
100	240C
2300	660
3400	1060
4450	1470
5600	1880
6740	1950
8000	2600
8050	2650
8600	2788
9350	3100
9800	3300
10,300	3450
10,800	3675
11,100	3700C

LOAD	STRAIN μIN/IN 285°F
0(T.L)	140T
1095	200C
2190	700
3500	1125
4625	1750
5900	2150
7175	2650
8275	3100
8525	3175
9150	3400
9750	3625
10,225	3750
10,825	3950
11,400	4100
11,690	4250C

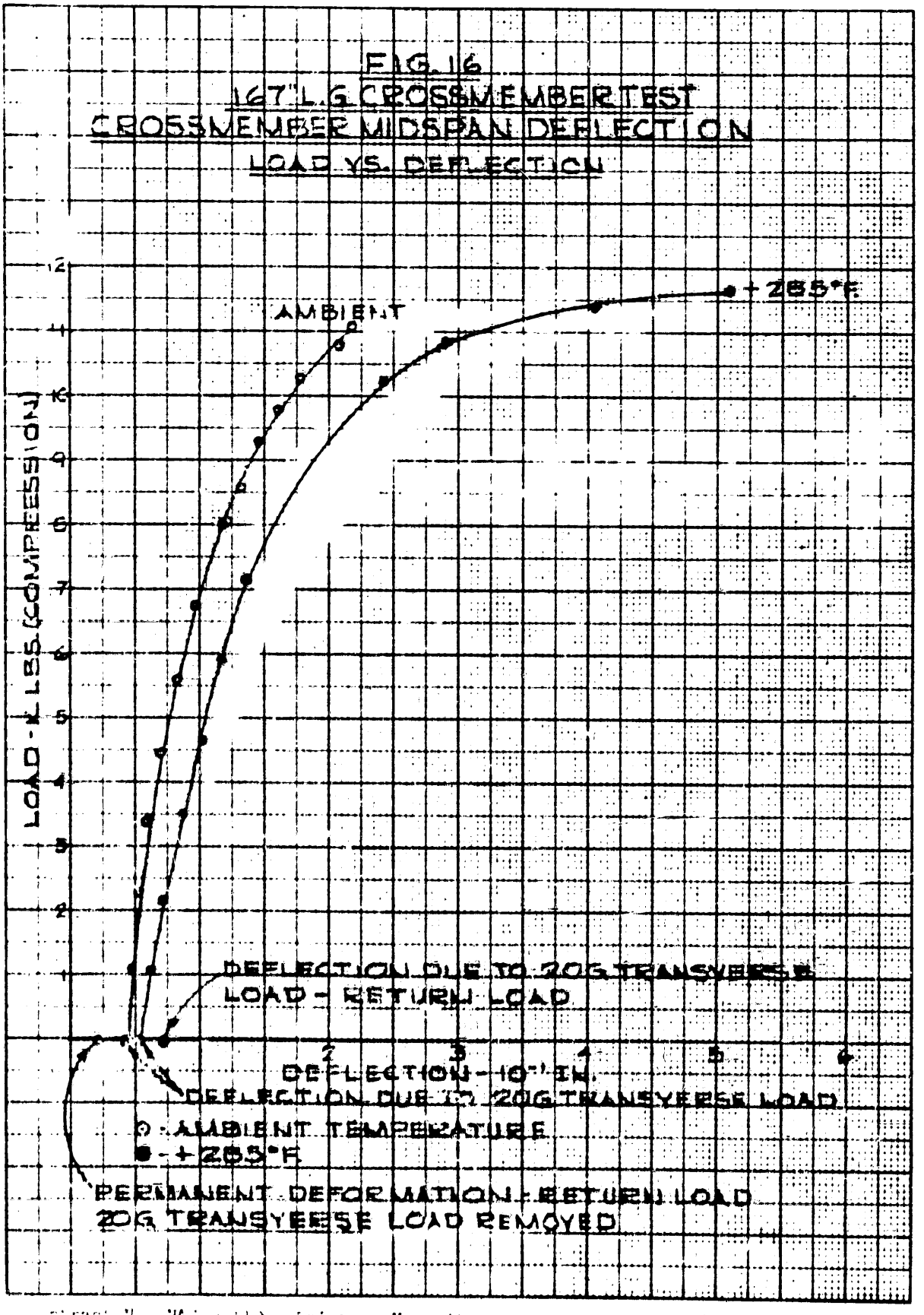


FIG. 16
167" L.G. CROSSMEMBER TEST
CROSSMEMBER MIDSPAN DEFLECTION
LOAD VS. DEFLECTION
LOAD - K LBS. (COMPRESSION)
AMBIENT
+285°F
DEFLECTION DUE TO 20G TRANSVERSE LOAD - RETURN LOAD
DEFLECTION - 10⁻¹ IN.
DEFLECTION DUE TO 20G TRANSVERSE LOAD
○ - AMBIENT TEMPERATURE
● - +285°F
PERMANENT DEFORMATION - RETURN LOAD
20G TRANSVERSE LOAD REMOVED

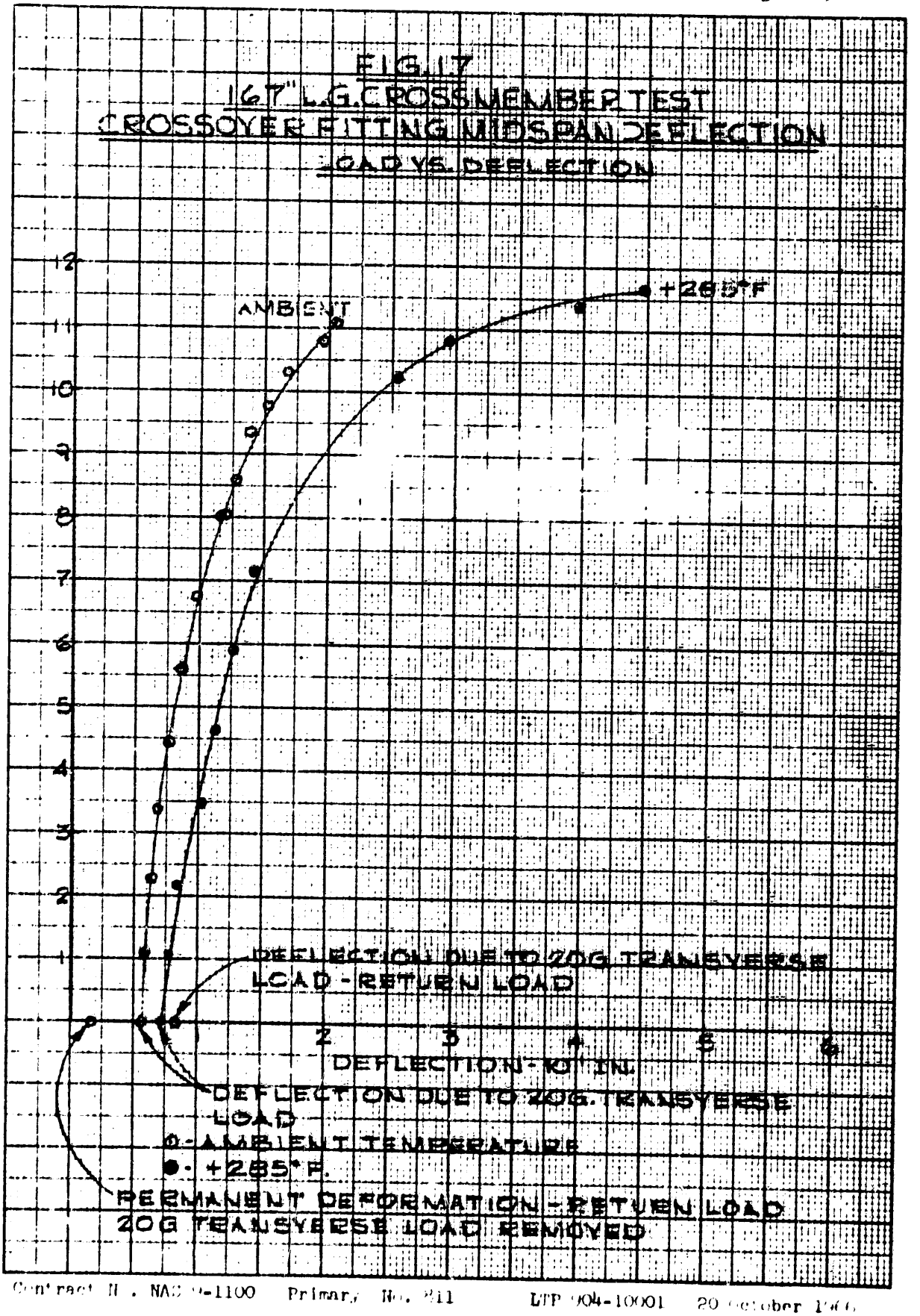
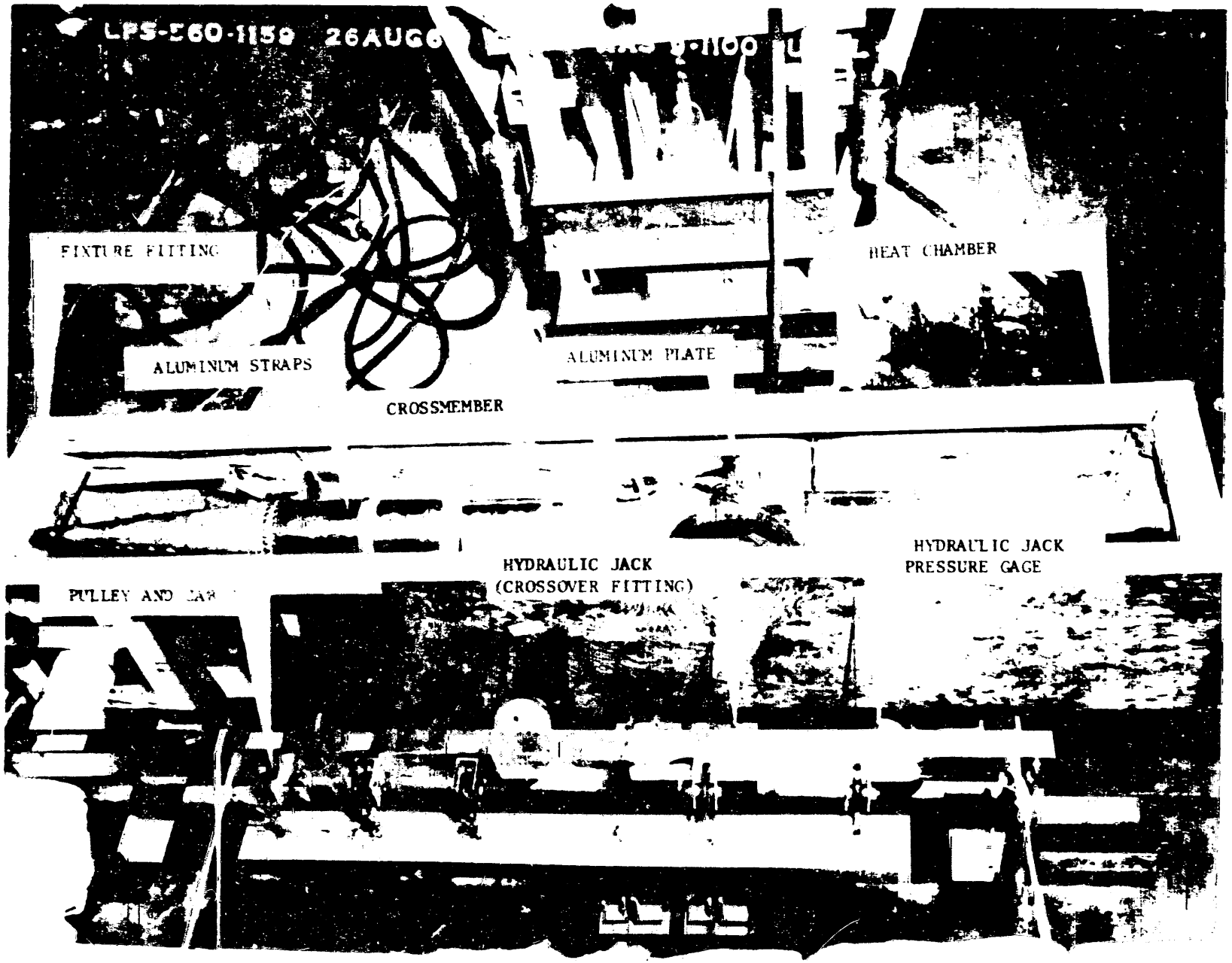
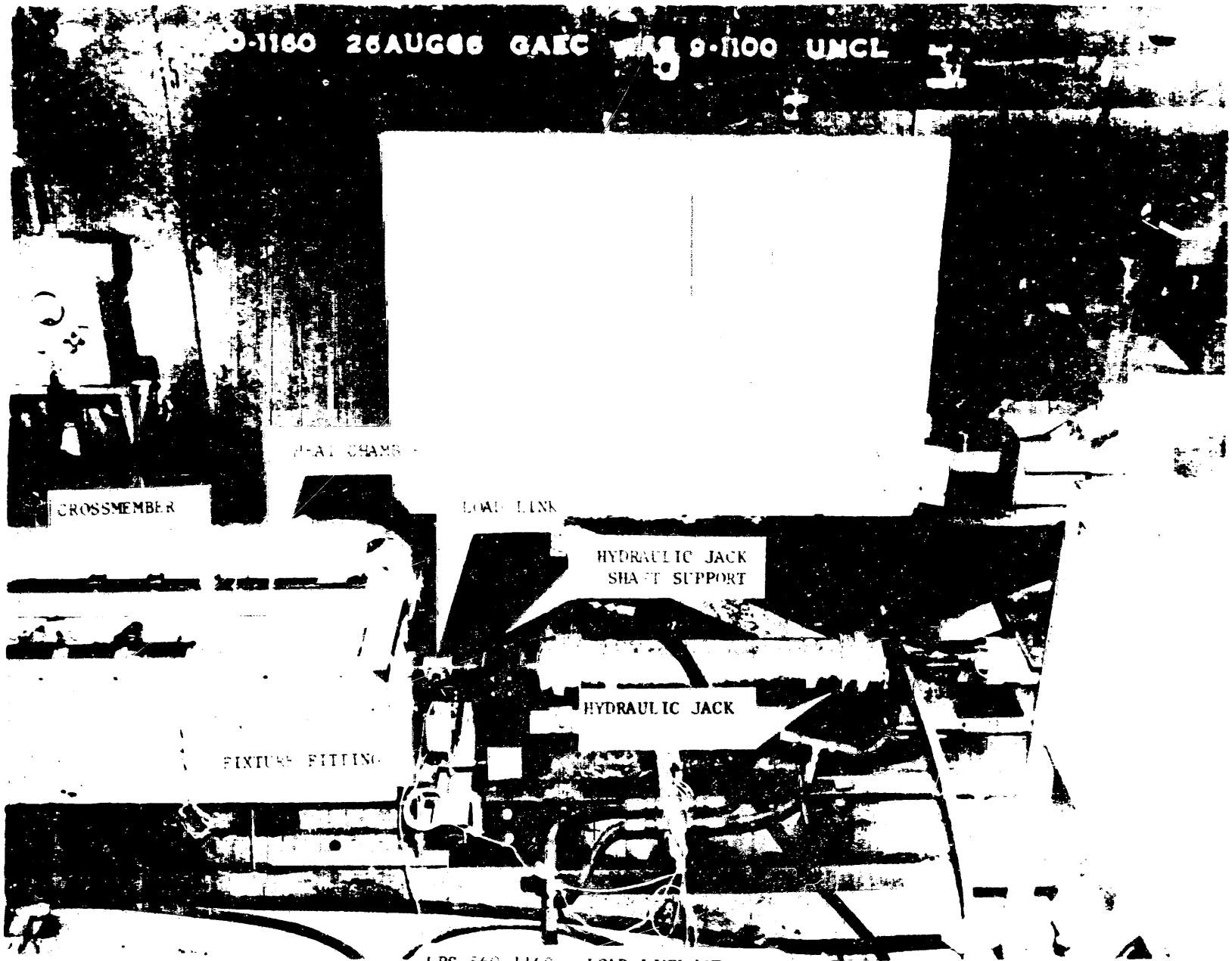


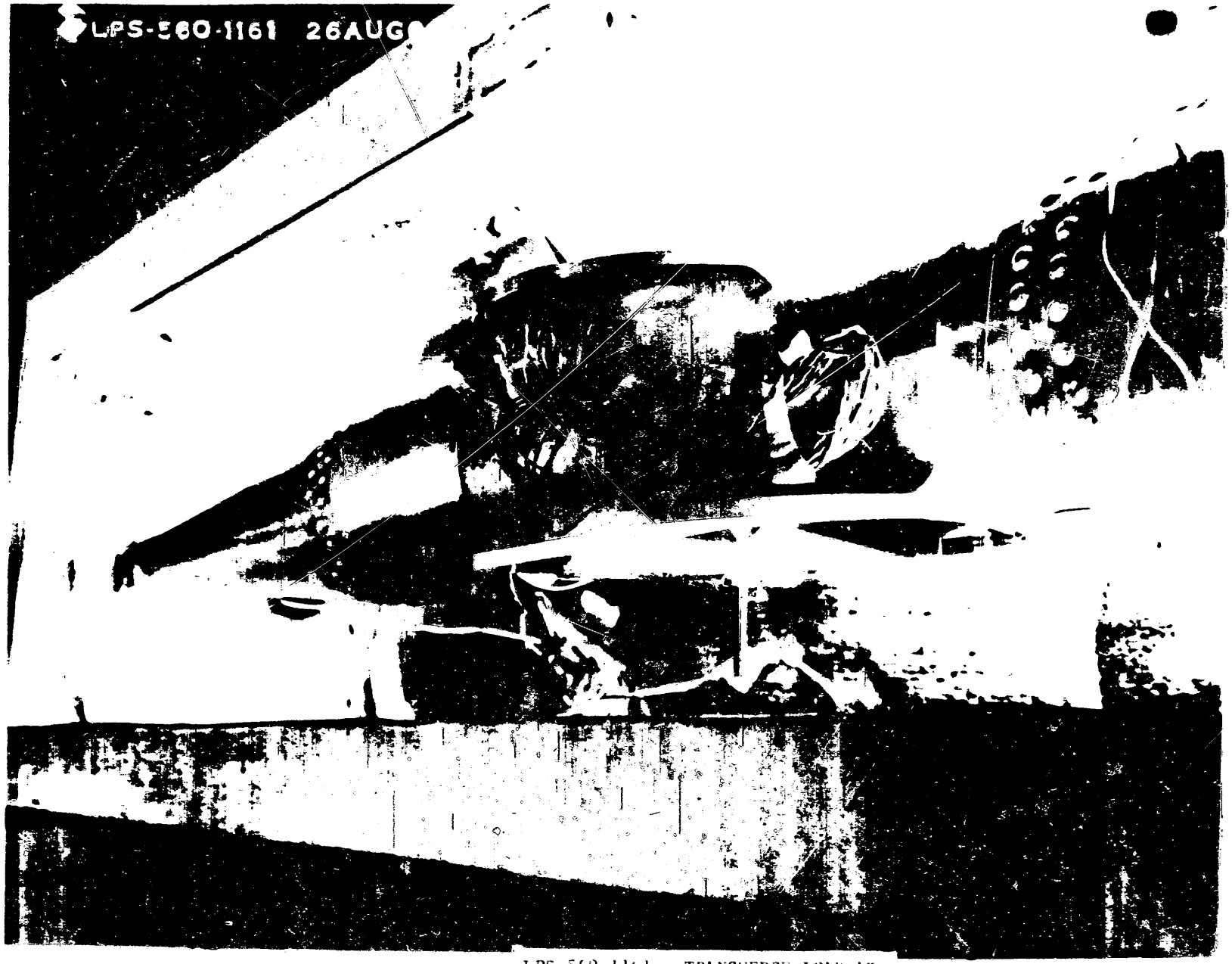
FIG. 17
167" L.G. CROSSMEMBER TEST
CROSSOVER FITTING MIDSPAN DEFLECTION
LOAD VS. DEFLECTION
AMBIENT
+285°F
DEFLECTION DUE TO 20G TRANSVERSE LOAD - RETURN LOAD
DEFLECTION - 10⁻³ IN.
DEFLECTION DUE TO 20G. TRANSVERSE LOAD
O - AMBIENT TEMPERATURE
● - +285°F.
PERMANENT DEFORMATION - RETURN LOAD 20G TRANSVERSE LOAD REMOVED



LPS 560-1159 TEST SET-UP



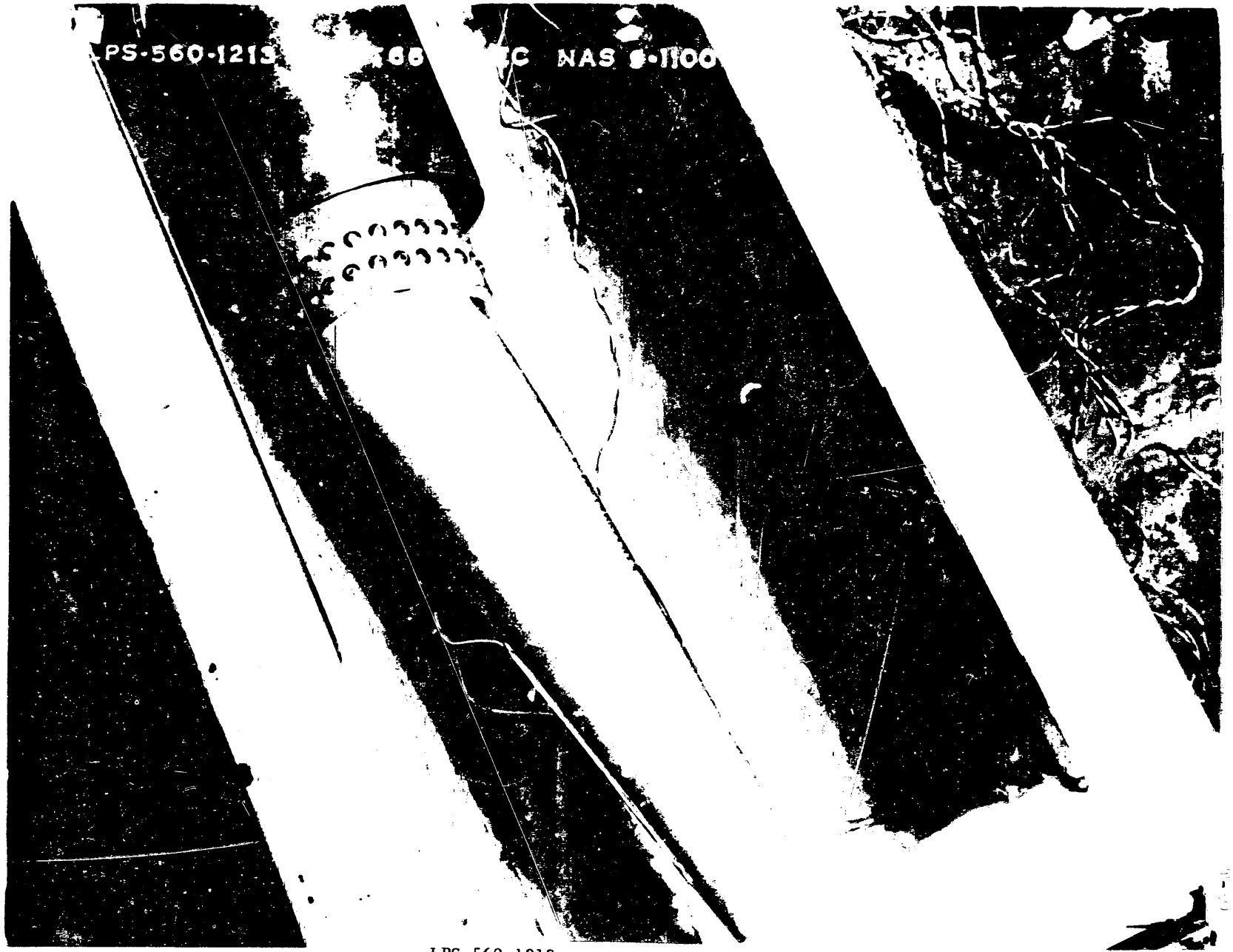
LPS 560-1160 LOAD LINK AND
HYDRAULIC JACK SET-UP



LPS 560-1161 TRANSVERSE LOAD AT
CROSSOVER FITTING SET-UP

LPS 560-1211 CROSSMEMBER FAILURE

NAS 9-11100
811



LPS 560-1213 CROSSMEMBER FAILURE
IN RELATION TO HEAT CHAMBER