

UNCLASSIFIED

AD 408 930

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

N-63-4-2

408 930

BOEING



CATALOGED BY **DDC**
AS AD No. **408930**

SEATTLE, WASHINGTON

THE **BOEING** COMPANY

NUMBER D2-80086

UNCLASSIFIED TITLE LANDING GEAR DEVELOPMENT

MODEL NO. X-20A CONTRACT NO. AF33(657)-7132

ISSUE NO. 10 ISSUED TO Armed Services

CLASSIFIED TITLE
(STATE CLASSIFICATION)

See Sub-Sections

CHARGE NUMBER

PREPARED BY

H. C. Lee
H. C. Lee

5-27-63

A. R. Swegle
A. R. Swegle

SUPERVISED BY

J. K. Hepler
J. K. Hepler

5-28-63

APPROVED BY

M. A. Nelson
M. A. Nelson

6/11/63

CLASS. & DISTR.

APPROVED BY

M. A. Nelson

6/11/63

RELIABILITY
APPROVAL

(DATE)

VOL.
SEC.

NO.
PAGE 1 OF 4

DOCUMENT DISTRIBUTION

Aeronautical Systems Division (ASZRA)
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio (3cys)

Armed Services Technical Information Agency
Arlington Hall Station
Arlington, Virginia (10cys)

AFPR (KMRSE)



CONTRACT REQUIREMENT

This document is submitted in partial fulfillment of paragraph B(1.1.1.1.9.2) of the Statement of Work, System 620A, Exhibit 620A-62-2, dated 26 January 1962, revised 1 August 1962.



SUMMARY

A screening test program was conducted on five (5) promising materials for use in the X-20 landing gear energy-absorbing system. The materials tested were Inconel, "A" Nickel, Hastelloy X, 19-9DL, and 304 ELC. A total of two hundred and two (202) two-inch gage length tensile specimens were tested under various combinations of temperatures and strain rates to obtain stress-strain curves for comparing the materials. Approximately three-fourths of the specimens tested were Inconel and "A" Nickel, the two most prospective materials based on preliminary evaluation. Inconel was concluded to be the over-all best energy strap material for the X-20 landing gear application.

The energy strap development program was continued with the testing of proposed full-scale main gear and nose gear energy strap configurations under simulated X-20 landing environments. Ten (10) main gear and twelve (12) nose gear Inconel energy strap specimens were impact tested using a drop test rig to obtain load deflection curves. Incremental lengths and diameters were measured before and after impact test to determine uniformity of strain along the length of the strap. Several strap specimens were loaded to failure following the impact tests to establish maximum energy-absorbing capacities.

TABLE OF CONTENTS

	<u>Page</u>
Summary	2
Table of Contents	3
Introduction	4
Section 1 - Landing Gear Energy System Materials Evaluation	1-1
Summary	1-2
Table of Contents	1-3
Section 2 - Main Landing Gear Energy System Development	2-1
Summary	2-2
Table of Contents	2-3
Section 3 - Nose Landing Gear Energy System Development	3-1
Summary	3-2
Table of Contents	3-3

INTRODUCTION

This report is the result of work accomplished on EWAs 5-637, 5-638, and 5-639. This work was performed in order to obtain empirical data for determining the optimum X-20 landing gear energy strap material and the energy-absorbing characteristics of the proposed full-scale main gear and nose gear energy strap configurations. Using a metal strap deforming in the plastic range as a means for absorbing landing impact energy requires a material and configuration which displays a large uniform strain and yields efficient landing gear load-stroke curves over the applicable range of X-20 landing temperatures and dynamic loading rates. Under simulated landing environments, stress-strain curves were obtained and used as a means for comparing several promising energy strap materials, and load deflection curves were obtained for the full-scale straps for determining energy-absorbing characteristics.

THE BOEING COMPANY

NUMBER D2-80086 MODEL NO. Dyna-Soar

TITLE LANDING GEAR DEVELOPMENT

2-5142

SECTION TITLE PAGE U3 428 0000 REV. 2/61

PREPARED BY

J. E. Kopperstad 4-26-63
J. E. Kopperstad

SUPERVISED BY

Roy R. Logan 5/9/63
R. A. Logan

APPROVED BY

Stan Baker 5-10-63
Stan Baker

RELIABILITY
APPROVAL

W. R. Rivington 5-14-63
(DATE)

A. K. Hefler
5-25-63

AF33(657)-7132
CONTRACT NO.

5-76200-5580-05637-1-2-5353
CHARGE NUMBER

VOL.
SEC. 1

NO. D2-80086
PAGE 1 OF 99

1.1 SUMMARY

- 1.1.1 An evaluation program was conducted to determine the energy absorbing characteristics of five (5) promising energy strap materials for use in the X-20 landing gear energy absorbing system. The materials tested were Inconel, "A" Nickel, Hastelloy X, 19-9DL and 304 ELC. Seventy-three (73) tensile specimens were tested in the preliminary phase of this program. The specimens were tested at temperatures of 70°F, 600°F and 800°F and at 0.005, 200 and 300 in./in./min. average strain rates. These temperature and strain rates simulated the landing gear operational environments.
- 1.1.2 Comparison studies of the preliminary test results indicated Inconel as being the overall best energy strap material prospect with "A" Nickel and Hastelloy X next, both having approximately equal desirable characteristics. Therefore, "A" Nickel and Hastelloy X materials were selected along with Inconel for further testing.
- 1.1.3 Seventeen (17) "A" Nickel and Hastelloy X specimens were tested at -65°F at average strain rates of .005, 200 and 300 in./in./min. to determine which of the two materials will be carried through the complete final screening phase of the program along with Inconel. The test results indicated "A" Nickel as being the more prospective of the two materials.
- 1.1.4 Final screening of Inconel and "A" Nickel included tests of sixty (60) tensile specimens of each of the two materials. These tests were conducted at average strain rates of 0.005, 50, 100, 200 and 300 in./in./min. and at temperatures of -65°F, 70°F, 250°F, 600°F and 800°F.

1.2	TABLE OF CONTENTS	PAGE
1.1	Summary	1-2
1.2	Table of Contents	1-3
1.3	References	1-4
1.4	Introduction	1-5
1.5	Test Specimen	1-6
1.6	Test Setup and Instrumentation	1-6
1.7	Test Procedure	1-7
1.8	Test Results	1-7
1.9	Test Observations	1-8
	Table 1-1, Material Information	1-9
	Table 1-2, Chemical Analysis of Materials	1-10
	Table 1-3, Test Outline, Preliminary Screening	1-11
	Table 1-4, Test Outline, Final Screening	1-12
	Figure 1-1, Tensile Specimen	1-13
	Figure 1-2, Sheet Layout and Specimen Numbering Code	1-14
	Figure 1-3, 10,000 Lb. Rapid Load Machine (Cryogenic Setup)	1-15
	Figure 1-4, 10,000 Lb. Rapid Load Machine (Elevated Temperature)	1-16
	Figure 1-5, Test Setup (Preliminary Phase)	1-17
	Figure 1-6, Cryogenic Setup	1-18
	Figure 1-7, Elevated Temperature Setup	1-19
	Tabulated Data	1-20 thru 1-29
	Stress-Strain Curves	1-30 thru 1-99

1.3 REFERENCES

- | | | |
|-------|--|--|
| 1.3.1 | Landing Gear Energy Systems
Materials Evaluation | EWA 5637  |
| 1.3.2 | Specimen Configuration | BAC 23-4164 |
| 1.3.3 | Figure 1-3, 10,000 Lb. Rapid Loading Machine
(Cryogenic Setup) | Negative No. 2A65736 |
| 1.3.4 | Figure 1-4, 10,000 Lb. Rapid Loading Machine
(Elevated Temperature) | Negative No. 2A65737 |
| 1.3.5 | Figure 1-5, Test Setup (Preliminary Phase) | Negative No. 2A63041 |
| 1.3.6 | Figure 1-6, Cryogenic Setup | Negative No. 2A65735 |
| 1.3.7 | Figure 1-7, Elevated Temperature Setup | Negative No. 2A65738 |



Refer to D2-6783-1 Structural Integrity Development and Test Program -
Detail Plan - Structures Technology

U3 4000 2000 REV. 6/82

2-5142-2

REV SYM _____

BOEING	NO. D2-80086	
	SECT. 1	PAGE 1-4

1.4

INTRODUCTION

1.4.1

This report is the result of work accomplished on EWA 5-637* Reference 1.3.1. This work was required to obtain empirical data for determining the optimum material for the X-20 landing gear energy strap absorption system. Using yielding metal as a means for absorbing landing impact energy required a material which would display uniform elongation and stress characteristics over the applicable range of landing temperatures and dynamic loading rates.

*Refer to D2-6783-1 Structural Integrity Development and Test Program - Detail Plan - Structures Technology

1.5 TEST SPECIMEN

- 1.5.1 The test specimens were fabricated per Reference 1.3.2. A sketch of the test specimen is shown as Figure 1-1.
- 1.5.2 The specimens were removed from the sheets as shown in Figure 1-2, and were machined with the grain direction parallel to the test load (longitudinal).
- 1.5.3 Material information and chemical analysis data are tabulated on Tables 1-1 and 1-2.

1.6 TEST SETUP AND INSTRUMENTATION

- 1.6.1 Tests were conducted in the Boeing designed 10,000 pound capacity rapid loading tensile machine (see Figures 1-3 and 1-4). The specimens were loaded by a hydraulic cylinder actuated by a servo-valve which responded to an electrical signal.
- 1.6.2 The proper strain rate (ram speed) was obtained by controlling the fluid flow at the hydraulic pump. The flow of oil was initiated by either a Cadillac or a Sanders servo control valve in conjunction with an electronic timer circuit. In the preliminary phase, the strain was recorded on film with a 1,000 frame/second Eastman High Speed motion picture camera (see Figure 1-5) and measured with the aid of a Vanguard, Model No. M-16, analyzer. In the final phase, the elongation was measured by a pair of Crescent variable permeance gages attached over a two inch gage length (see Figures 1-6 and 1-7).
- 1.6.3 The specimens tested at 0.005 in./in./min. were loaded in a 12,000 pound capacity Baldwin Universal test machine. The machine was equipped with a Model MA-1 autographic load strain recorder. A Baldwin strainpacer was used to insure a proper average strain rate. The strain to failure was measured using a Baldwin TSMD dual range extensometer.
- 1.6.4 Cryogenic tests were conducted in a Boeing designed cryogenic chamber, using liquid nitrogen as the coolant (see Figure 1-3 and 1-6). Elevated temperatures were obtained using an Inconel strip heater powered by a variac controlled 50 KVA Research Inc. ignitron power supply (see Figure 1-4 and 1-7). Specimen temperatures were controlled manually at elevated temperature either by positioning the heater with respect to the specimen or by adjusting the heater current. In the cryogenic tests, specimen temperatures were achieved by controlling the flow of liquid nitrogen.
- 1.6.5 Chromel-alumel thermocouples spotwelded to the specimen were used in conjunction with a Leeds and Northrup strip chart recorder to measure specimen temperatures.

1.7 TEST PROCEDURES

- 1.7.1 Ninety-five (95) tensile specimens were tested in the preliminary phase of this program. The materials tested included Inconel, "A" Nickel, Hastelloy X, 19-9DL, and 304 ELC. The specimens were loaded to failure in tension at strain rates and temperatures shown in Table 1-3. The purpose of this phase of testing was to select the two most prospective energy strap materials of those tested for final screening.
- 1.7.2 The final screening included tests of sixty (60) tensile specimens each of the selected materials (Inconel and "A" Nickel). The specimens were loaded at strain rates and temperatures shown in Table 1-3 to approximately one-third of the estimated maximum elongation at rupture and then were completely unloaded. The specimens were then reloaded at the initial strain rate and temperature to failure to determine rebound characteristics of the materials.
- 1.7.3 The following data was obtained:
- (1) stress strain diagrams
 - (2) energy absorbing capacity at rupture in inch-lbs./lb. of material
 - (3) energy absorbing capacity at ultimate load in inch-lbs./lb. of material
 - (4) percent elongation at ultimate
 - (5) percent elongation at rupture

1.8 TEST RESULTS

- 1.8.1 Energy absorbing properties and percent elongations are reported on pages 1.21 through 1.29. Stress-strain diagrams are shown on pages 1.30 through 1.99.
- 1.8.2 Calculation of energy absorbed at rupture and ultimate load was based on the following formula:

$$E = \frac{A}{D}$$

where

A = Area under stress strain curve in lbs./in.²

D = Density of material in lbs./in.³

and

E = Energy absorbed in $\frac{\text{in.-lb.}}{\text{lb.}}$

1.8.3 The percent elongation at rupture and ultimate strength was measured directly from the stress-strain curves.

1.8.4 The percent of ultimate elongation at rebound was based on the following relationship:

$$\left(\frac{\text{Strain at Rebound}}{\text{Strain at Rupture}} \right) 100$$

1.9 TEST OBSERVATIONS

The test objects were met and the test equipment operated satisfactorily.

TABLE 1-1
MATERIAL INFORMATION

MATERIAL	GAGE -INCHES	MANUFACTURER	HEAT NO.	DENSITIES LBS/IN. ³	HEAT TREAT ▶
"A" Nickel	0.109	International Nickel Company	N2546A4	0.3211	(A)
Inconel	0.127	Unknown	Unknown	0.3039	(B)
Hastelloy X	0.125	Continental Metals Inc.	X-106	0.2991	(C)
19-9DL	0.125	Continental Metals Inc.	B82200	0.2876	(D)
304 ELC	0.114	Unknown	Unknown	0.2850	(E)

▶

(A)

Solution treat 1800°F (±25°F) for 20 minutes then air quench.

(B)

Solution treat 1950°F (±25°F) for 20 minutes then water quench.

(C)

Solution treat 2150°F (±25°F) for 20 minutes then water quench.

(D)

Solution treat 1950°F (±25°F) for 20 minutes then water quench.

(E)

Solution treat 1950°F (±25°F) for 20 minutes then water quench.

TABLE 1-2
CHEMICAL ANALYSIS OF MATERIALS

ELEMENT	NICKEL "A"	INCONEL	HASTELLOY X	D-19-9DL	304 ELG
Cr	—	14.17%	21.63%	19.10%	18.79%
Ni	99.16%	76.32%	—	10.02%	10.45%
Mo	—	—	8.78%	1.60%	—
W	—	—	0.82%	1.52%	—
Cb + Ta	—	—	—	0.60%	—
Ti	—	—	—	0.28%	—
Fe	0.21%	7.03%	17.21%	—	—
Si	0.20%	0.31%	0.60%	0.67%	0.71%
Mn	0.28%	0.13%	0.02%	0.97%	1.02%
Cu	0.18%	0.22%	—	Trace	—
Co	—	0.30%	0.90%	—	—
C	0.019%	0.030%	0.11%	0.31%	0.005%
S	0.005%	—	0.006%	0.015%	0.019%
P	—	—	0.002%	0.030%	0.021%

TABLE 1-3
TEST OUTLINE
PRELIMINARY SCREENING

<u>MATERIAL</u>	<u>STRAIN RATE IN./IN./MIN.</u>	<u>TEMPERATURE °F</u>
Inconel ↑ ↓	.005	-65
	.005	72
	190	72
	180	600
	200	800
	290	72
Inconel	290	800
Hastelloy X ↑ ↓	.005	-65
	.005	72
	200	-65
	170	72
	185	600
	300	-65
Hastelloy X	295	72
Hastelloy X	285	800
Nickel "A" ↑ ↓	.005	-65
	.005	72
	200	-65
	180	72
	190	600
	300	-65
Nickel "A"	280	72
Nickel "A"	280	800
19-9DL ↑ ↓	.005	72
	180	72
	185	600
19-9DL	295	72
19-9DL	295	800
304 ELC ↑ ↓	.005	72
	200	72
	200	600
304 ELC	300	72
304 ELC	285	800

U3 4230 2000 REV. 8/52

2-5142-2

REV SYM _____

BOEING

NO. D2-80086

SECT. 1 | PAGE 1-11

TABLE 1-4
TEST OUTLINE
FINAL SCREENING

MATERIAL
Inconel

STRAIN RATE
IN./IN./MIN.
.005-.05

TEMPERATURE
°F
250

600

800

50

-65

72

250

600

800

100

-65

72

250

600

800

200

-65

250

800

300

-65

250

600

Inconel

Nickel "A"

.005-.05

250

600

800

50

-65

72

250

600

800

100

-65

72

250

600

800

200

250

800

300

250

600

Nickel "A"

US 4200 2000 REV. 6/62

2-8142-1

REV SYM _____

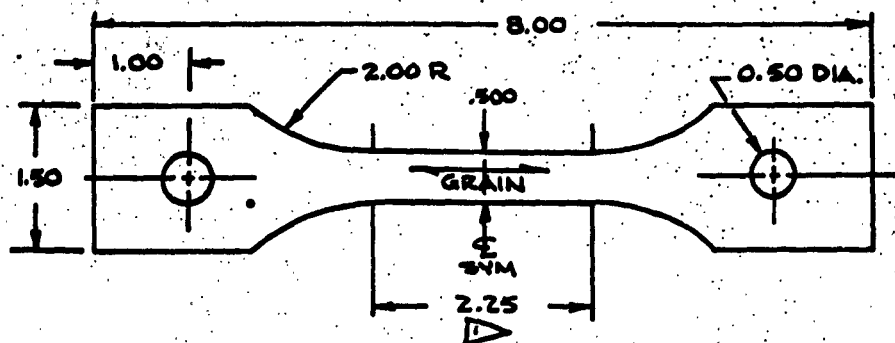
BOEING

NO. D2-80086

SECT. 1

PAGE 1-12

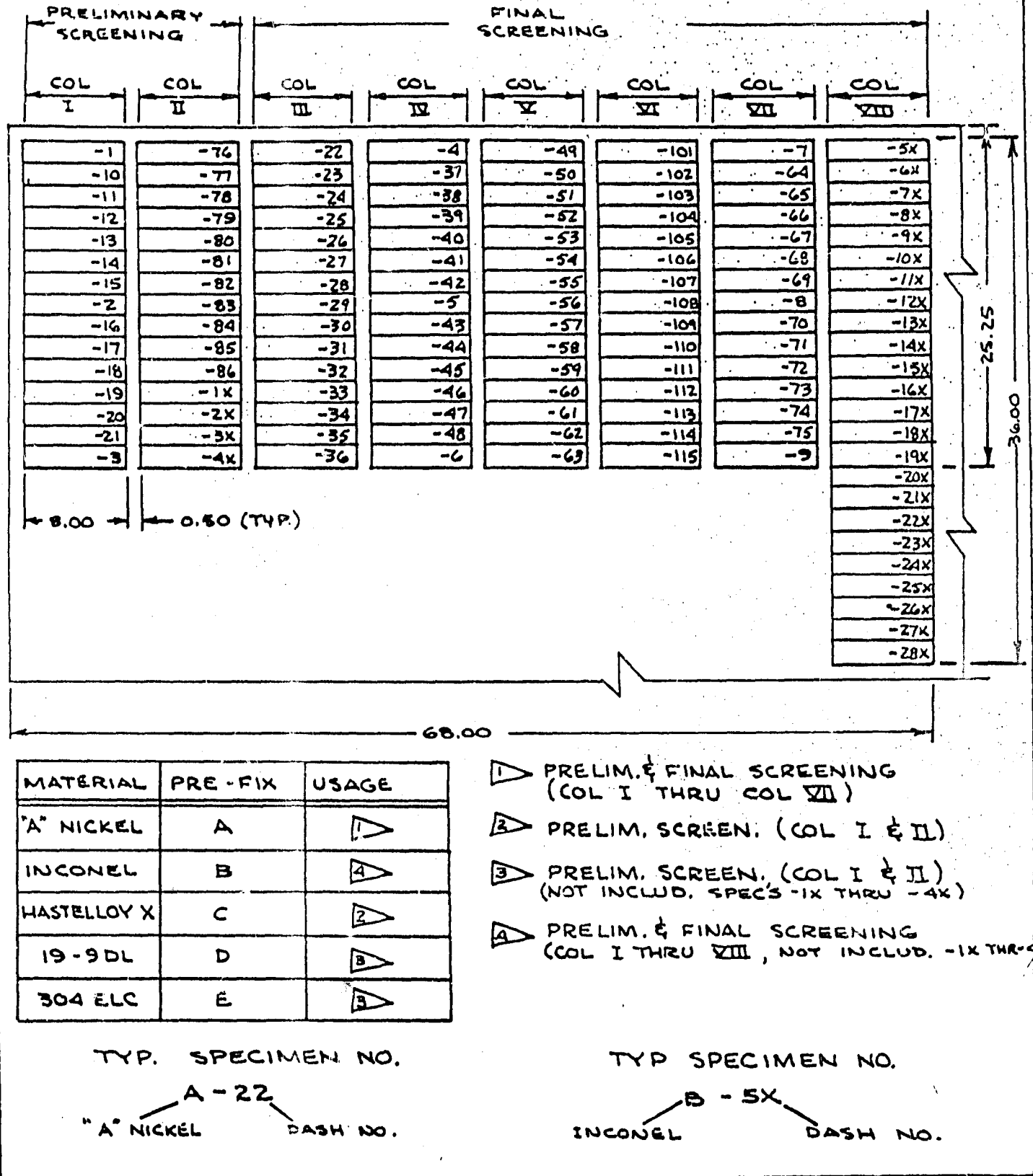
FIGURE 1-1
TENSILE SPECIMEN
(REF. BOEING DWG 23-4164)



△ STRAIN AND ELONGATION MEASURED OVER
A 2 INCH SECTION WITHIN INDICATED GAGE
SECTION.

FIGURE 1-2

SHEET LAYOUT
& SPECIMEN NUMBERING CODE



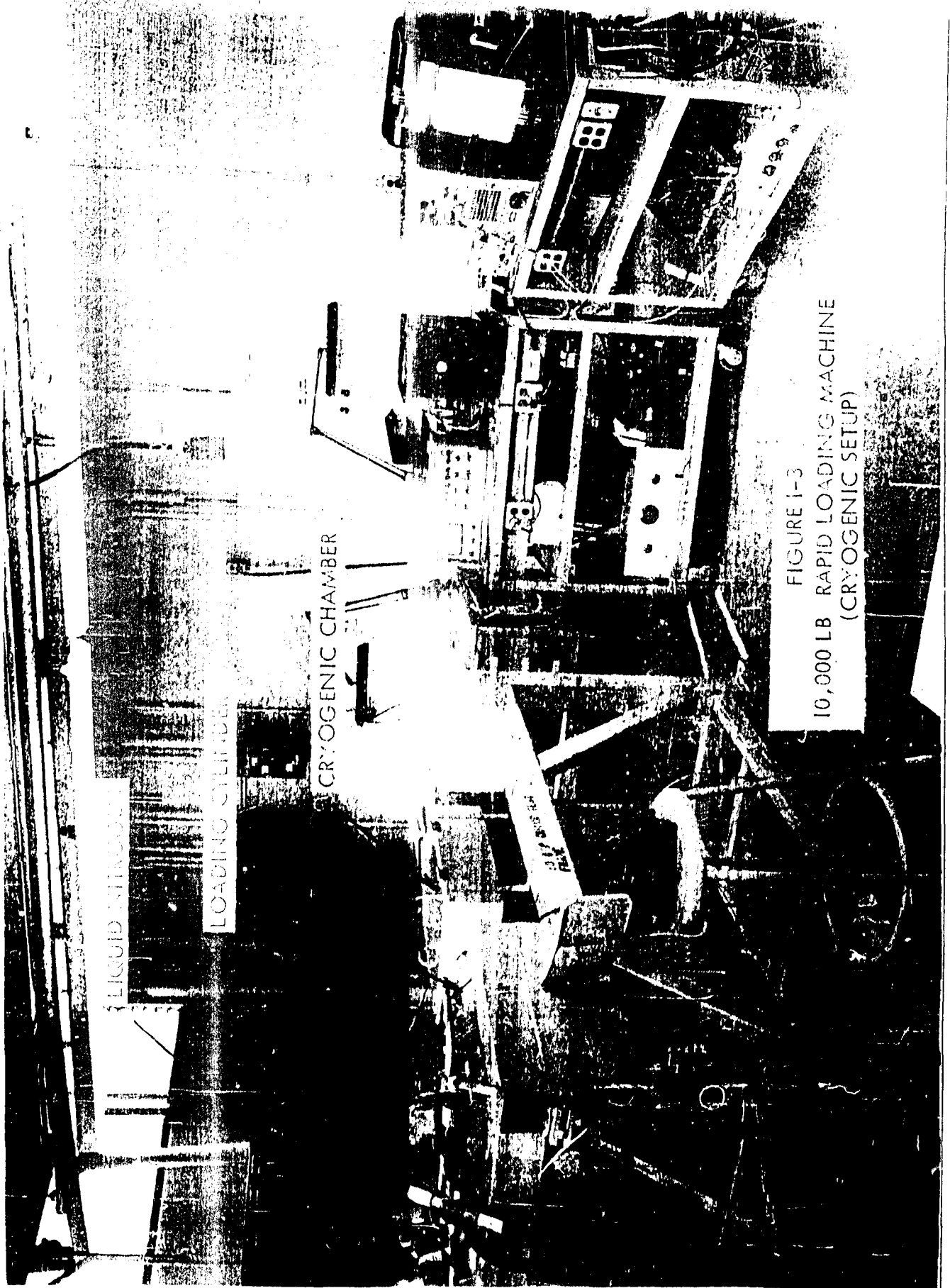


FIGURE 1-3
10,000 LB RAPID LOADING MACHINE
(CRYOGENIC SETUP)

REVISED _____

U3 4288 2000

BOEING	VER	NO D2-80086
	SEC 1	PAGE 15

2-2 JAMES EARL RAY CASE NO. 77-1000-1000 246777
 FBI (MEMPHIS, TENNESSEE) 4-25-68

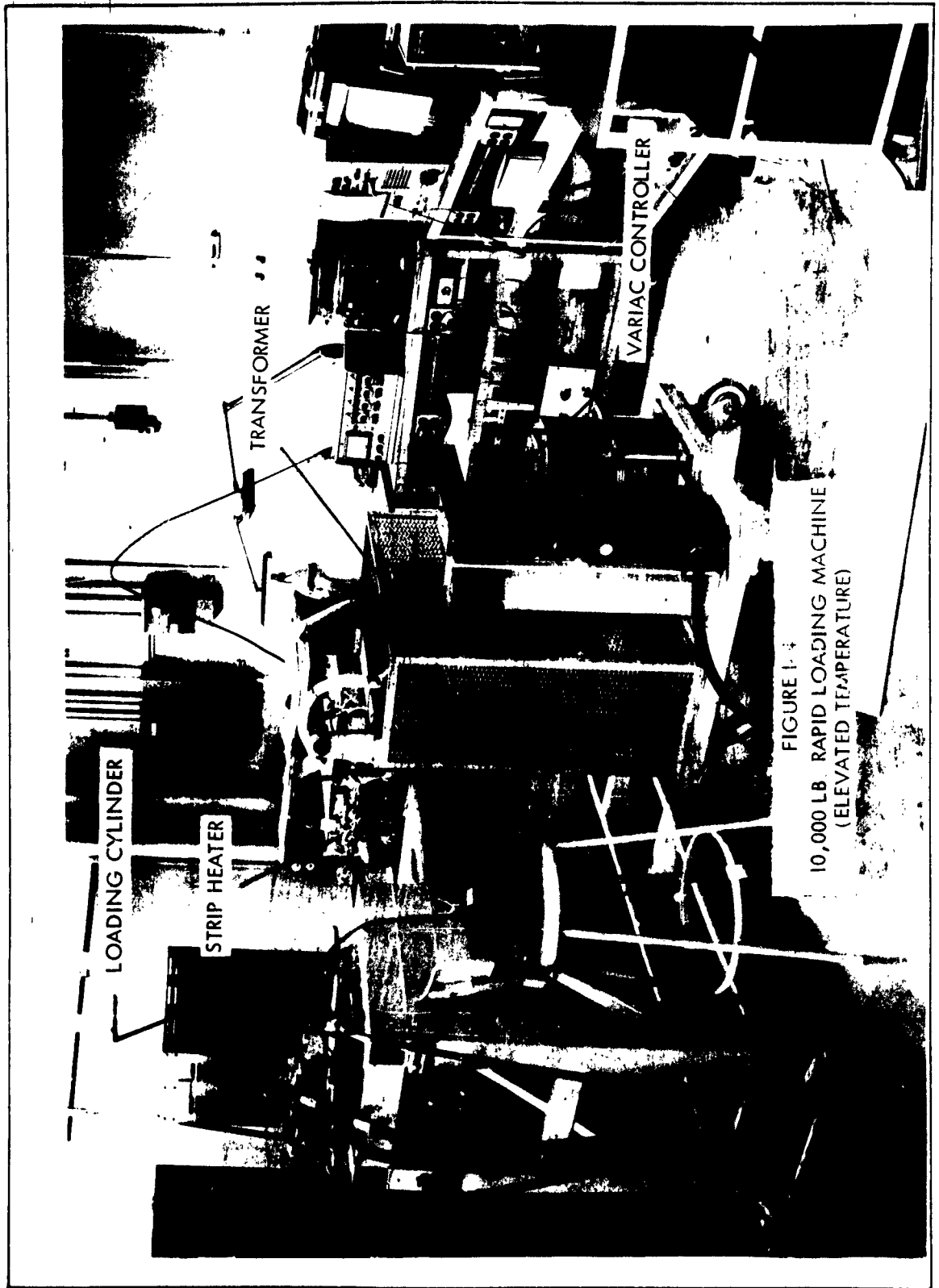
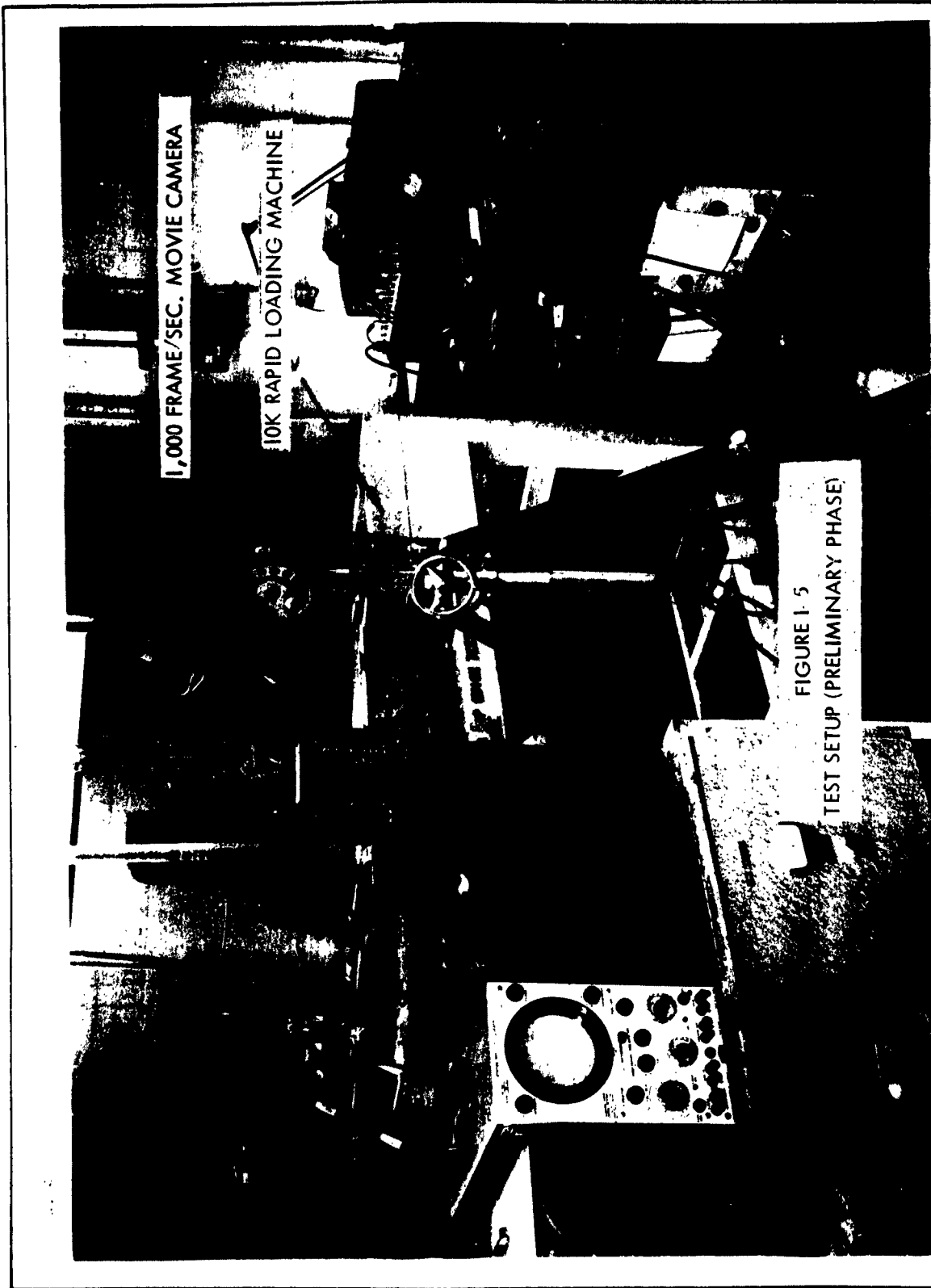
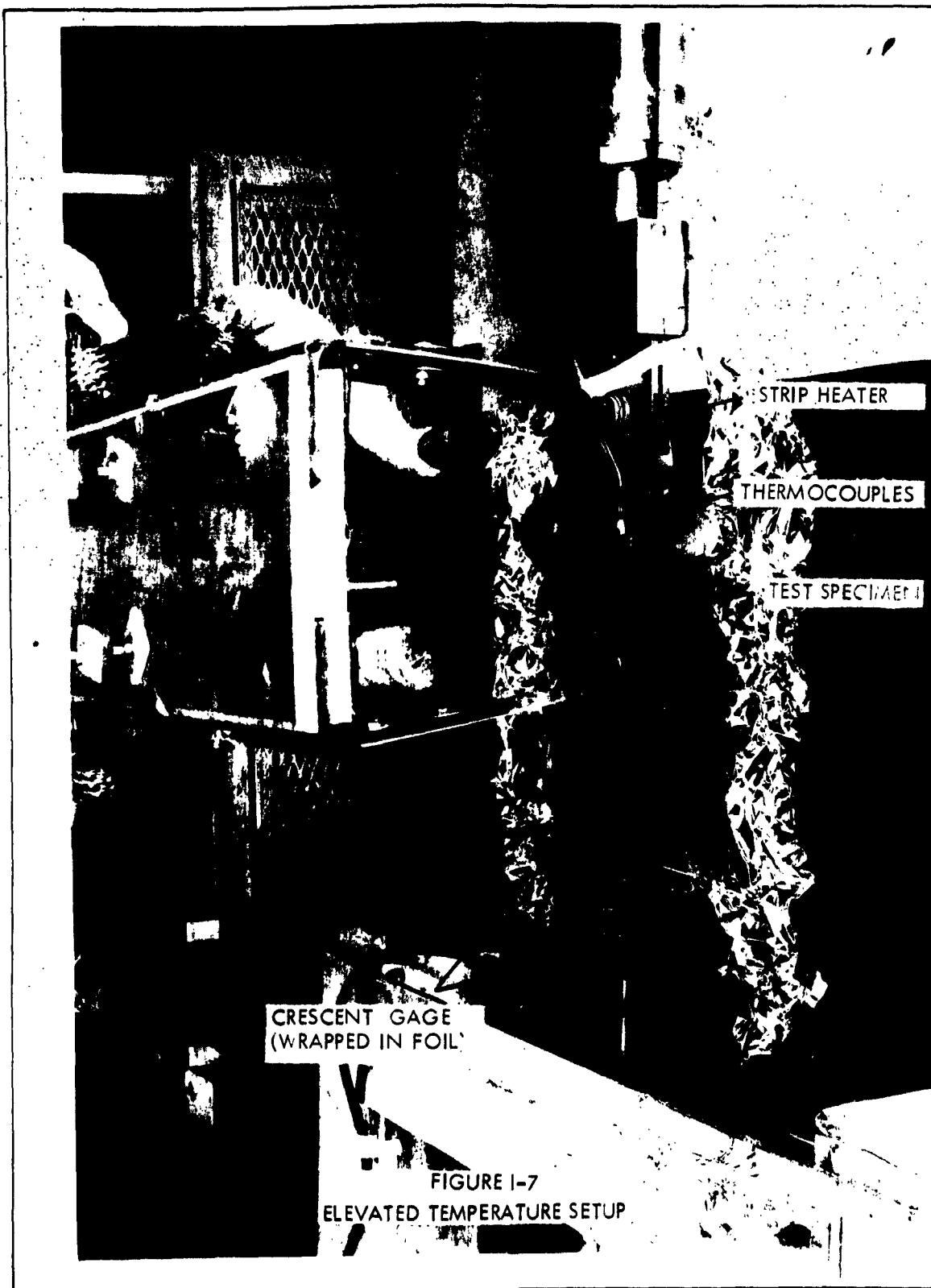


FIGURE 1-4
 10,000 LB. RAPID LOADING MACHINE
 (ELEVATED TEMPERATURE)



REVISED _____
 US 4896 2000

15-00000-1 (REVISED 10-1-66)



REVISED _____

U3 4288 2000

BOEING

VOL.

NO D2-60086

SEC.

1

PAGE 1-19

NOTES

- 1 Energy computations were based on the following densities,
Nickel "A" = 0.321 lbs./in.³
Inconel = 0.300 lbs./in.³
Hastelloy X = 0.290 lbs./in.³
304 ELG = 0.290 lbs./in.³
19-9DL = 0.287 lbs./in.³
- 2 Preliminary Screening. Specimens tested in the preliminary screening phase were loaded directly to failure.
- 3 Final Screening. Elongation was not obtained for the specimens tested in the final screening phase.
- 4 Total Measured Elongation.
- 5 % elongation on which energy to FTU (Stress, Tensile Ultimate, PSI) is based.
FTU - Ultimate Tensile Force, PSI

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~ IN ² ~	TEST TEMPERATURE ~ °F ~	STRAIN RATE ~ IN/IN/MIN ~	ULTIMATE STRENGTH ~ PSI ~	% ELONGATION TO FTU	ENERGY TO FTU ~ IN-LBS/LB △ 1	% ELONGATION TO FAILURE	ENERGY TO FAILURE ~ IN-LBS/LB △ 1	TOTAL MEASURED ELONGATION ~ % ~
A-82	△ 2	.0535	-65	.005	38,400	42.0	61,400	49.0	74,400	50.0
A-83	↑	.0535	↓	↑	60,900	46.0	70,700	51.0	81,600	52.0
A-84	↑	.0540	-65	↑	60,000	42.0	62,300	49.0	73,800	49.0
A-79	↓	.0535	72	↓	52,000	47.0	58,735	50.0	63,235	50.0
A-80	↓	.0543	↓	↓	53,500	46.0	59,681	49.0	64,125	49.0
A-81	△ 2	.0542	72	.005	53,500	46.0	60,782	48.0	65,362	46.0
A-101	38.7	.0528	250	⊕ .005 ⊕ .05	48,300	39.0	47,500	△ 3	53,250	44.0
A-103	30.0	.0529	↓	↑	49,300	39.5	50,200	↑	57,400	46.0
A-104	32.8	.0534	250	↑	48,500	39.5	49,900	↑	57,800	46.0
A-4	41.2	.0529	600	↓	43,700	35.0	38,800		44,700	40.0
A-6	41.2	.0542	↓	↓	43,500	35.0	38,900		44,200	40.0
A-105	73.2	.0533	600	↓	44,100	36.0	40,500		46,200	41.0
A-8	34.1	.0543	800	↓	35,000	40.0	38,200		44,400	47.0
A-9	33.0	.0551	↓	↓	35,500	35.0	32,600		42,200	45.5
A-106	34.4	.0539	800	⊕ .005 ⊕ .05	34,500	35.0	32,100		40,100	45.0
A-40	14.6	.0536	72	50	56,000	43.0	61,700		67,800	48.0
A-41	15.2	.0531	↓	↑	57,000	41.0	60,500		68,500	46.0
A-42	17.0	.0533	72	↑	57,000	41.0	60,000		69,000	47.0
A-36	17.4	.0541	250	↓	51,000	37.0	48,500		56,700	45.0
A-37	18.1	.0532	↓	↓	51,000	40.0	53,000		61,200	47.5
A-38	30.6	.0533	250	↓	51,900	38.0	51,200		58,500	45.0
A-51	37.5	.0532	600	↓	44,000	33.5	38,000		44,200	40.0
A-52	33.4	.0534	↓	↓	44,000	31.0	34,300		42,300	39.0
A-109	33.4	.0539	600	↓	46,000	32.0	37,100		44,700	39.0
A-64	30.4	.0527	800	↓	40,000	34.5	36,200	↓	40,400	38.0
A-65	30.6	.0527	↓	↓	41,000	35.0	38,100	↓	42,200	39.0
A-66	40.0	.0535	800	50	41,000	33.5	36,000	△ 3	39,400	37.5

~ SEE PAGE 1-20 FOR NOTES ~

CALC	STRICKLAND	4/18/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES 11 NICKEL "A" (LOW CARBON) 0.109 GAGE SHEET THE BOILING COMPANY	X-20A
CHECK	KOPPER/TAD	4/25/63				D2-80086
APR						
APR						PAGE 1-21

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~ IN ² ~	TEST TEMPERATURE	STRAIN RATE ~ IN/IN/MIN ~	ULTIMATE STRENGTH ~ PSI ~	% ELONGATION TO FTU	 ENERGY TO FTU ~ IN-LBS/LB	% ELONGATION TO FAILURE	 ENERGY TO FAILURE ~ IN-LBS/LB	TOTAL MEASURED ELONGATION ~ % ~
A-27	26.0	.0534	65	50	61,000	42.5	68,100		80,800	52.0
A-28	33.0	.0533	↑	50	62,000	41.0	66,000	↑	78,900	50.0
A-29	34.6	.0536	↑	50	63,000	45.0	73,900	↑	82,000	50.5
A-23	25.3	.0533	↓	100	64,000	43.0	72,300		86,400	51.5
A-24	30.0	.0534	↓	↑	64,000	42.5	69,000		81,400	50.0
A-25	31.8	.0534	-65	↑	65,000	44.0	73,100		85,200	52.0
A-43	33.0	.0538	72		58,000	45.5	70,300		75,400	50.0
A-44	36.0	.0539	↑		59,000	46.5	72,700		76,400	50.0
A-56	38.0	.0542	72		58,000	45.0	69,100		74,500	50.0
A-77	32.0	.0541	250		52,000	41.0	57,300		64,000	47.0
A-78	34.0	.0545	↑		52,000	41.0	56,400		63,100	47.0
A-79	38.3	.0543	250		53,000	40.0	55,000		62,400	47.0
A-53	34.2	.0532	600		46,000	37.0	43,900		47,300	41.0
A-54	28.1	.0536	↓		45,000	35.5	42,900		46,500	41.0
A-55	29.3	.0539	600		44,000	36.0	41,600		46,000	41.0
A-68	33.2	.0539	800		42,000	34.0	39,200		42,400	38.0
A-69	33.0	.0544	↑		41,000	36.0	39,800	↓	42,900	39.5
A-70	26.5	.0545	800	100	41,000	38.0	42,300		44,800	41.5
A-10		.0549	72	180	57,000	41.0	56,100	53.0	74,900	51.0
A-11	↑	.0549	↑	↑	55,700	46.0	60,500	47.0	62,100	49.0
A-12	↑	.0538	72	180	58,600	48.0	68,600	50.0	71,100	51.0
A-16		.0544	600	190	43,800	35.0	34,400	37.0	36,100	40.0
A-18		.0551	↓	↑	41,900	31.0	29,600	34.0	32,400	37.0
A-76		.0549	600	190	41,300	31.0	30,200	33.0	31,200	36.0
A-1-X	↓	.0535	-65	200	63,000	42.6	68,440	49.0	74,330	49.0
A-2-X		.0532	↑	↑	62,000	43.8	69,250	51.0	76,730	51.0
A-78	↑	.0534	-65	200	64,000	47.0	78,970	50.0	83,120	50.0

~ SEE PAGE 1-20 FOR NOTES ~

CALC	STRICKLAND	4/18/53	REVISED	DATE	ENERGY ABSORBING PROPERTIES NICKEL "A" (LOW CARBON) 0.109 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KOPPELSTADT	4/25/53				D2-80086
APR						
APR						
						MAR 1-22

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~IN ² ~	TEST TEMPERATURE ~°F~	STRAIN RATE ~IN/IN/MIN~	ULTIMATE STRENGTH ~PSI~	% ELONGATION TO FTU	△ 1 ENERGY TO FTU ~IN-LBS/LB	% ELONGATION TO FAILURE	△ 1 ENERGY TO FAILURE ~IN-LBS/LB	TOTAL MEASURED ELONGATION ~%~
A-33	33.4	.0535	250	200	53,000	42.5	59,200	△ 3	63,200	48.0
A-35	43.2	.0538	↓	↑	53,000	42.5	59,800	↑	64,200	47.5
A-67	37.0	.0538	250	↑	53,000	42.5	59,800	↑	64,200	46.0
A-71	32.2	.0547	800	↓	41,000	36.5	40,000	↓	44,250	42.0
A-74	23.8	.0548	↓	↓	41,000	36.5	39,400	↓	44,100	42.0
A-75	11.9	.0548	800	200	41,000	37.0	39,600	△ 3	44,250	42.0
A-3-X	△ 2	.0531	-65	300	64,000	44.5	73,990	51.0	81,310	51.0
A-4-X	↓	.0528	-65	↑	63,000	40.5	63,490	46.0	69,780	46.0
A-46		.0528	250		56,000	42.0	61,000	48.5	68,750	48.5
A-47		.0534	↓		56,000	45.0	64,800	49.0	69,850	49.0
A-49		.0528	250		56,000	39.5	56,900	49.0	68,250	49.0
A-60		.0542	600	↓	45,000	37.0	42,900	42.5	48,200	42.5
A-61		.0545	↓	↓	45,000	37.0	43,100	42.0	47,500	42.0
A-62		.0536	600	300	46,000	36.0	43,250	40.0	47,000	40.0
A-13		.0547	72	280	56,800	42.0	55,500	45.0	60,500	48.0
A-14		.0546	↓	↑	56,600	39.0	50,000	42.0	54,900	43.0
A-15		.0547	72		56,800	41.0	56,000	42.0	57,500	46.0
A-20	↓	.0552	800	↓	42,200	29.0	26,200	32.0	30,800	35.0
A-21	△ 2	.0552	800	280	42,200	34.0	32,600	37.0	36,800	39.0

~ SEE PAGE 1-20 FOR NOTES ~

CALC	STOCKLAND	4/19/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES NICKEL "A" (LOW CARBON) 0.109 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KAPPELSTAD	4/25/63				D2-80086
APR						
APR						PAGE 1-23

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~IN ² ~	TEST TEMPERATURE ~°F~	STRAIN RATE ~IN/IN/MIN~	ULTIMATE STRENGTH ~PSI~	% ELONGATION TO FTU	ENERGY TO FTU ~IN-LBS/LB 1	% ELONGATION TO FAILURE	ENERGY TO FAILURE ~IN-LBS/LB 1	TOTAL MEASURED ELONGATION ~%~
B-84	2	.0640	65	.005	96,900	42.0	170,000	46.0	120,000	46.0
B-85	1	.0640	65	1	94,300	45.0	106,800	52.0	127,500	52.0
B-86	1	.0640	65	1	97,200	40.0	98,400	44.0	113,700	46.0
B-1	2	.0644	72	.005	86,000	45.0	102,107	51.0	119,367	50.0
B-2	2	.0648	72	.005	87,000	45.0	99,278	51.0	115,168	49.0
B-3	2	.0645	72	.005	85,600	46.0	101,261	50.0	113,701	49.0
B-8X	35.8	.0635	250	.005	79,700	40.5	81,800	3	92,200	46.0
B-19X	44.7	.0631	250	.005	79,200	42.5	86,200	1	95,700	47.0
B-23X	34.7	.0635	250	.005	79,100	43.0	88,100	1	97,100	47.0
B-24X	28.6	.0639	600	1	79,600	54.0	110,200	1	115,200	56.0
B-25X	28.8	.0639	600	1	79,500	53.0	105,800	1	112,300	55.5
B-26X	29.4	.0633	600	1	79,900	53.6	107,700	1	115,300	56.5
B-14X	42.1	.0637	800	.005	78,200	54.0	107,100	1	114,400	57.0
B-15X	29.2	.0641	800	.005	78,300	56.0	112,700	1	120,700	59.0
B-16X	32.1	.0638	800	.005	78,000	55.0	108,700	3	115,800	58.0
B-23	2	.0634	65	50	98,000	43.0	115,500	50.0	131,800	50.0
B-25	1	.0637	65	1	98,000	40.2	104,100	47.0	116,300	47.0
B-102	1	.0631	65	1	100,000	34.5	92,000	46.0	116,000	46.0
B-42	1	.0641	R.T.	1	88,000	44.5	106,400	50.0	117,000	50.0
B-49	1	.0628	1	1	92,000	39.5	102,000	45.0	113,500	45.0
B-110	1	.0629	R.T.	1	90,000	43.0	105,000	51.0	121,500	51.0
B-111	1	.0633	250	1	84,000	39.0	89,600	42.0	95,400	42.0
B-112	1	.0637	250	1	84,000	40.0	90,300	44.0	98,700	44.0
B-113	1	.0632	250	1	92,000	38.5	98,500	43.5	109,500	43.5
B-72	1	.0638	600	1	74,000	39.0	74,900	46.0	87,000	46.0
B-63	1	.0635	600	1	78,000	39.0	80,500	46.0	91,600	46.0
B-77	3	.0640	600	50	80,000	39.5	83,000	46.5	95,000	46.5

~ SEE PAGE 1-20 FOR NOTES ~

CALC	STRICKLAND	4/19/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES INCONEL NICKEL BASE ALLOY 0.127 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KOPPERSTAD	4/15/63				D2-80086
APR						
APR						PAGE 1-24

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~ IN ²	TEST TEMPERATURE ~ °F	STRAIN RATE ~ IN/IN/MIN	ULTIMATE STRENGTH ~ PSI	% ELONGATION TO FTU	ENERGY TO FTU ~ IN-LBS/LB 1	% ELONGATION TO FAILURE	ENERGY TO FAILURE ~ IN-LBS/LB 1	TOTAL MEASURED ELONGATION ~ %
B-65	2	.0638	800	50	76,000	47.5	95,000	53.0	104,000	53.0
B-66	1	.0638	800	50	80,000	40.0	88,500	47.0	96,400	47.0
B-115	1	.0637	800	50	80,000	39.0	79,100	45.0	90,600	45.0
B-104	1	.0636	-65	100	104,000	40.0	113,900	48.0	131,600	48.0
B-28	1	.0644	-65	100	98,000	44.5	120,900	50.0	136,500	50.0
B-30	2	.0644	-65	100	98,000	44.0	116,900	51.0	130,000	51.0
B-44	41.6	.0637	72		94,000	44.0	114,800	3	123,000	48.0
B-45	41.5	.0637	72		96,000	41.0	110,000	3	123,000	47.0
B-75	35.1	.0636	72		100,000	40.0	111,800	3	124,900	47.0
B-77	23.4	.0641	250		84,000	40.0	93,100		103,000	45.0
B-59	22.8	.0637	250		84,000	42.0	97,700		107,300	46.0
B-70	25.8	.0631	250		84,000	42.5	99,700		107,500	46.5
B-73	46.0	.0632	600		84,000	37.0	89,500		96,500	43.5
B-75	39.9	.0637	600		80,000	40.0	85,600		90,400	44.0
B-78	37.2	.0640	600		78,000	40.6	82,500		88,400	43.0
B-67	27.0	.0636	800		78,000	44.5	91,600	1	100,500	50.0
B-68	30.2	.0636	800		82,000	39.0	86,800	1	94,500	43.0
B-69	26.0	.0639	800	100	78,000	46.0	95,000	3	102,500	50.0
B-16	2	.0646	600	180	75,670	40.0	74,000	44.0	85,400	43.0
B-17	1	.0643	600	180	73,960	41.0	78,600	46.0	86,700	45.0
B-10		.0646	72	190	88,500	47.0	106,700	49.0	113,200	52.0
B-11		.0641	72	190	86,100	46.0	110,000	47.0	111,600	47.0
*B-12		.0640	72	190	97,300	44.0	128,000	45.0	128,200	48.0
B-33	1	.0640	-65	200	104,000	39.5	112,700	46.0	125,500	46.0
B-107	1	.0638	-65	200	98,000	44.0	120,700	50.0	132,000	50.0
B-34	2	.0640	-65	200	100,000	44.0	120,300	51.0	136,800	51.0

~ SEE PAGE F20 FOR NOTES ~

CALC	STRICKLAND	4/22/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES INCONEL NICKEL BASE ALLOY 0.127 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KOPPERTS	4/25/63				D2-80086
APR						
APR						PAGE F25

SPECIMEN NUMBER	% OF ULT. ELONG. AT REBOUND	AREA ~ IN ²	TEST TEMPERATURE ~ °F	STRAIN RATE ~ IN/IN/MIN	ULTIMATE STRENGTH ~ PSI	% ELONGATION TO FTU	 ENERGY TO FTU ~ IN-LBS/LB	% ELONGATION TO FAILURE	 ENERGY TO FAILURE ~ IN-LBS/LB	TOTAL MEASURED ELONGATION ~ %
B-4		.0636	72	200	98,000	37.5	111,900	46.0	121,000	46.0
B-5		.0638	72	200	96,000	40.5	113,900	46.0	120,000	46.0
B-6		.0636	72	200	94,000	40.5	110,000	46.0	116,000	46.0
B-7	14.7	.0633	250		88,000	39.5	92,700		106,700	47.0
B-17X	32.3	.0622	250		88,000	43.0	104,000		116,300	48.0
B-80	39.3	.0637	250		90,000	39.0	94,600		108,200	45.0
B-18X	34.6	.0628	800		76,000	43.0	85,600		95,700	48.0
B-72	33.8	.0635	800	200	79,000	42.0	84,900		97,400	48.0
B-73	35.0	.0639	800	200	82,000	35.5	80,100		88,900	40.0
B-13		.0645	72	290	94,300	42.0	100,500	43.0	104,200	46.0
B-14		.0639	72	290	91,800	42.0	101,000	43.0	104,900	46.0
B-15		.0646	72	290	90,600	40.0	92,000	43.0	99,000	44.0
B-19		.0647	800		74,900	44.0	76,500	45.0	80,870	45.0
B-20		.0648	800		73,000	43.0	78,700	44.0	79,500	44.0
B-21		.0647	800	290	76,500	44.0	82,470	49.0	94,370	70.0
B-31		.0632	-65	300	104,000	40.5	116,700	47.0	129,400	47.0
B-38		.0637	-65	300	98,000	44.5	122,600	52.0	136,000	72.0
B-106		.0632	-65	300	98,000	42.0	113,300	51.0	128,900	51.0
B-46		.0639	250		84,000	44.0	101,500	49.0	111,700	49.0
B-47		.0642	250		88,000	41.0	96,600	44.0	102,700	44.0
B-48		.0632	250		90,000	42.0	103,000	45.5	110,500	45.5
B-60		.0635	600		84,000	35.0	79,200	49.0	86,500	49.0
B-61		.0638	600		76,000	41.0	83,200	43.5	88,900	43.5
B-62		.0631	600	300	78,000	38.0	79,600	41.0	85,500	41.0

~ SEE PAGE 120 FOR NOTES ~

CALC	STRICKLAND	4/22/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES INCONEL NICKEL BASE ALLOY 0.127 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KOPPERT	4/22/63				D2-80086
APP						
APP						PAGE 126

SPECIMEN NUMBER	AREA ~ IN ²	TEST TEMPERATURE ~ OF	STRAIN RATE ~ IN/IN/MIN.	ULTIMATE STRENGTH ~ PSI	% ELONGATION TO FTU	 ENERGY TO FTU ~ IN-LBS/LB	% ELONGATION TO FAILURE	 ENERGY TO FAILURE ~ IN-LBS/LB	TOTAL MEASURED ELONGATION ~ %
C-82	.0674	-67	.009	126,000	43.0	163,600	31.0	202,000	47.0
C-83	.0676	↓	↑	127,800	38.0	138,800	42.0	176,200	43.0
C-84	.0679	-67	↑	124,000	40.0	146,700	44.0	163,000	41.0
C-79	.0661	72	↓	110,700	42.0	141,300	46.0	151,000	43.0
C-80	.0660	↑	↓	111,200	41.0	134,768	46.0	151,268	43.0
C-81	.0658	↑	.009	111,100	41.0	134,037	47.0	147,867	43.0
C-12	.0661	↓	140	117,000	42.0	140,400	44.0	146,000	43.0
C-10	.0667	↓	170	110,400	42.0	130,900	43.0	142,400	46.0
C-11	.0660	72	170	109,100	41.0	127,300	43.0	137,000	46.0
C-16	.0671	600	185	90,450	37.0	88,000	44.0	108,700	44.0
C-17	.0674	↑	↑	93,370	38.0	99,000	42.0	111,800	42.0
C-18	.0672	600	185	89,700	34.0	81,500	36.0	88,700	41.0
C-1-X	.0674	-67	200	130,000	31.7	128,900	37.1	142,900	37.1
C-76	.0679	↓	↑	130,000	30.8	121,050	43.0	148,480	43.0
C-77	.0671	-67	200	130,000	36.8	152,690	43.2	169,240	43.2
C-19	.0676	800	285	90,000	38.0	97,000	39.0	100,200	39.0
C-20	.0676	↓	↓	92,300	40.0	97,000	41.0	101,200	41.0
C-21	.0674	800	285	90,250	41.0	98,300	44.0	105,200	43.0
C-13	.0659	72	295	117,970	43.0	142,800	43.0	150,300	46.0
C-14	.0675	↑	↑	120,610	43.0	142,500	44.0	146,200	43.0
C-15	.0676	72	295	117,350	43.0	146,600	44.0	148,500	46.0
C-2-X	.0671	-67	300	128,000	32.3	130,690	44.0	158,000	44.0
C-3-X	.0648	↓	↓	128,000	30.2	117,240	43.3	147,790	43.3
C-86	.0676	-67	300	130,000	37.8	153,520	49.0	180,760	49.0

~ SEE PAGE 120 FOR NOTES ~

CALC	STRICKLAND	4/22/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES HASTELLOY X NICKEL BASE ALLOY 0.125 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	KOPPER	4/27/63				DE-80084
APR						
APR						PAGE 1-27

SPECIMEN NUMBER	AREA ~IN ²	TEST TEMPERATURE ~°F	STRAIN RATE ~IN/IN/MIN.	ULTIMATE STRENGTH ~PSI	% ELONGATION TO FTJ	 ENERGY TO FTJ ~IN-LBS/LB	% ELONGATION TO FAILURE	 ENERGY TO FAILURE ~IN-LBS/LB	TOTAL MEASURED ELONGATION ~%
D-79	.0658	72	.005	107,900	39.0	129,071	43.0	141,421	41.0
D-80	.0648	↑	↓	108,300	38.0	123,538	42.0	137,128	40.0
D-81	.0661	↑	.005	106,800	39.0	123,826	42.0	136,336	40.0
D-10	.0661	↓	180	111,000	39.0	127,600	45.0	150,000	46.0
D-11	.0667	↓	↓	109,000	41.0	127,000	44.0	138,500	44.0
D-12	.0663	72	180	108,400	42.0	138,900	45.0	146,500	46.0
D-16	.0667	600	185	82,090	30.0	68,200	32.0	73,600	33.0
D-17	.0673	↓	↓	81,870	27.0	61,600	30.0	69,200	32.0
D-18	.0669	600	185	82,520	29.0	67,400	32.0	75,600	34.0
D-13	.0666	72	295	107,900	40.0	125,200	44.0	140,000	46.0
D-14	.0663	↓	↑	108,300	40.0	122,000	42.0	132,000	44.0
D-15	.0665	72	↑	106,400	41.0	124,000	45.0	141,000	44.0
D-19	.0665	800	↓	81,700	28.0	58,600	30.0	64,300	30.0
D-20	.0672	↑	↓	82,100	27.0	58,100	28.0	61,500	30.0
D-21	.0669	800	295	81,200	27.0	58,100	29.0	63,000	32.0

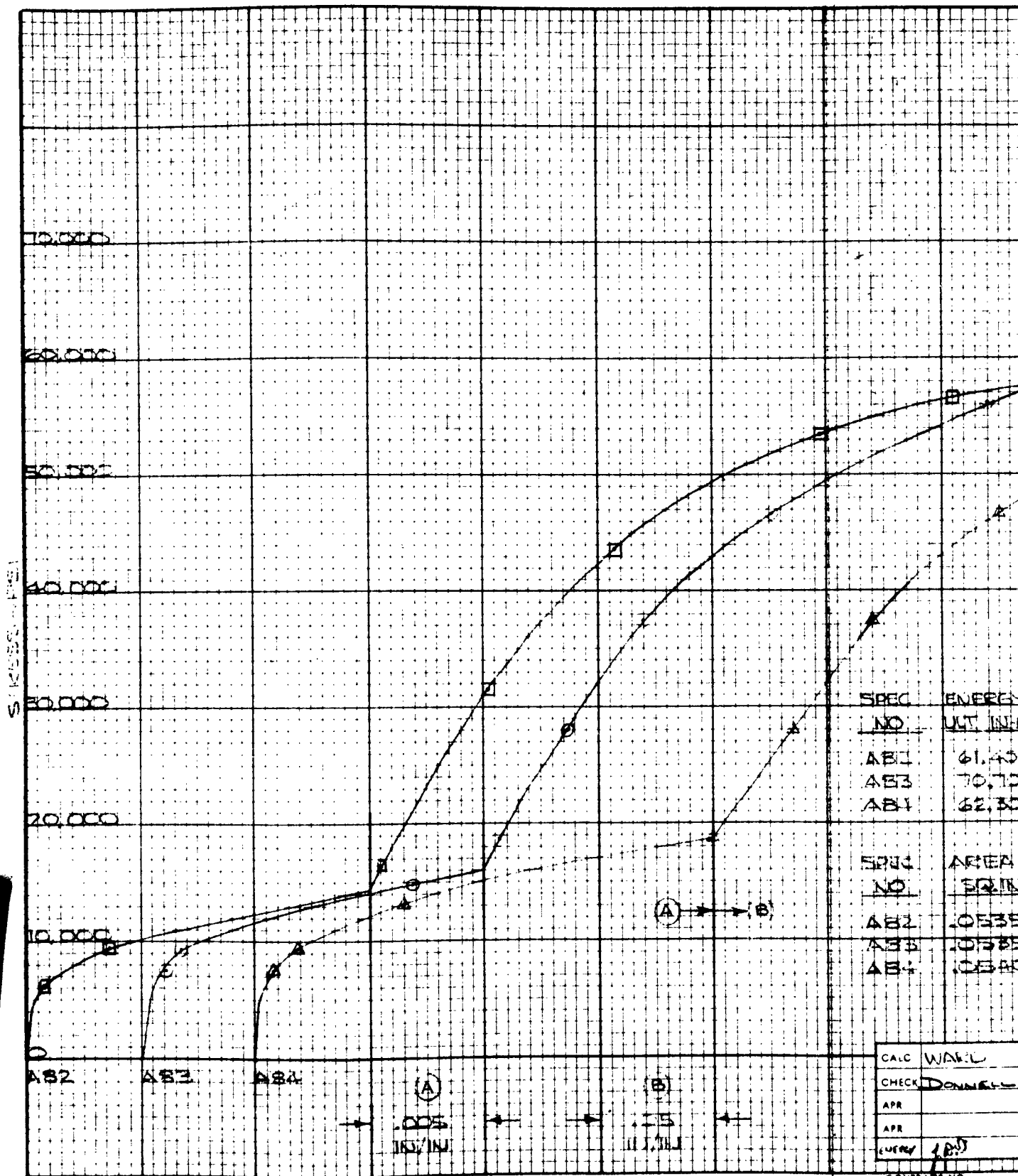
~SEE PAGE 1-20 FOR NOTES~

CALC	STRICKLAND	4/22/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES 19-9DL Q.125 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	K. J. JONES	4/25/63				DZ-80086
API						
API						PAGE 1-28

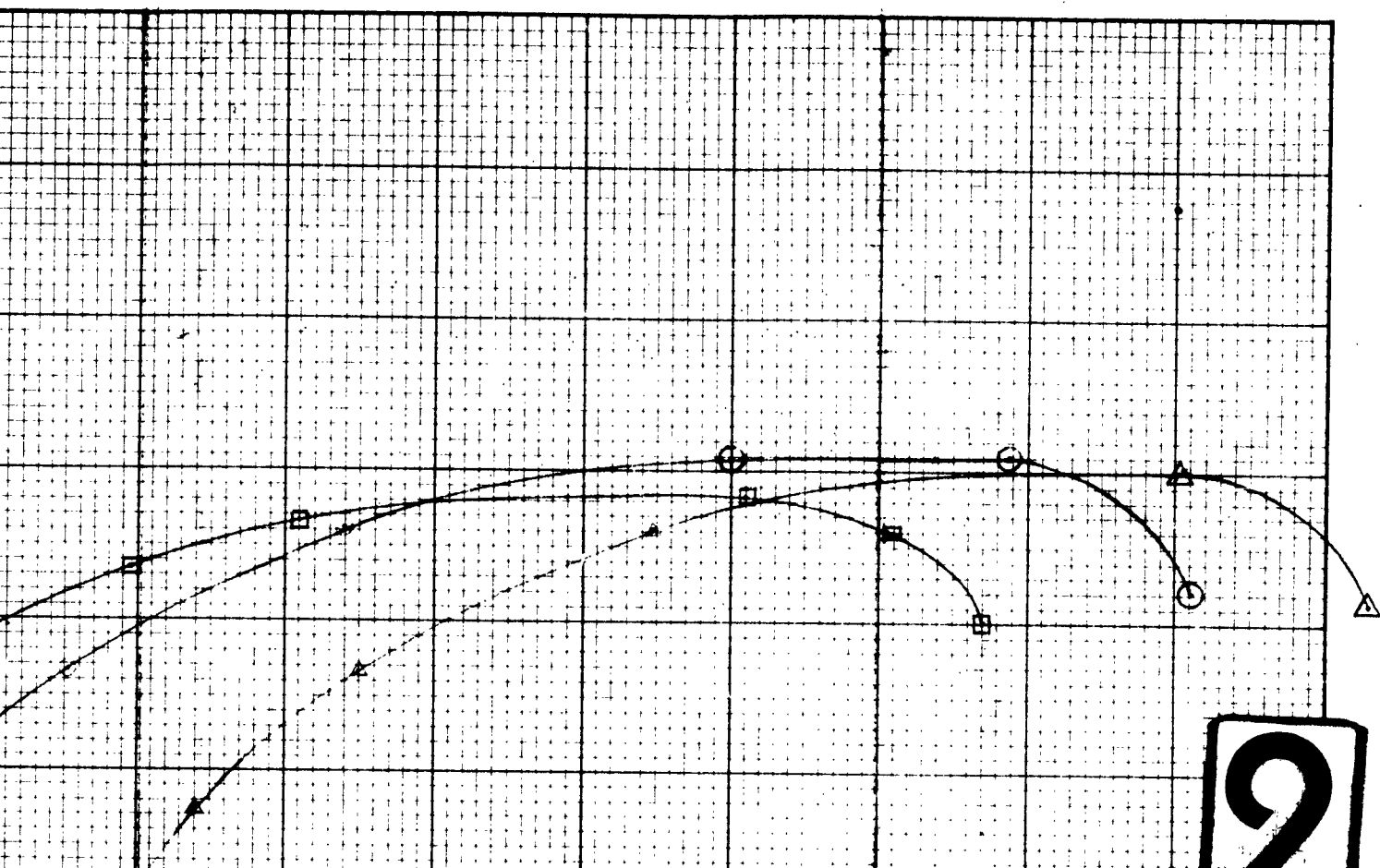
SPECIMEN NUMBER	AREA ~IN ²	TEST TEMPERATURE ~°F	STRAIN RATE ~IN/IN/MIN	ULTIMATE STRENGTH ~PSI	% ELONGATION TO FTU	 ENERGY TO FTU ~IN-IBS/IN	% ELONGATION TO FAILURE	 ENERGY TO FAILURE ~IN-IBS/IN	TOTAL MEASURED ELONGATION ~%
E-81	.0763	72	.005	77,400	61.0	138,053	65.0	149,103	65.0
E-82	.0774	72	.005	77,400	59.0	133,694	63.0	144,094	63.0
E-83	.0770	72	.005	78,000	63.0	138,329	67.0	148,529	67.0
E-11	.0767	72	200	78,000	57.0	134,500	61.0	144,000	63.0
E-18	.0766	600	200	70,500	37.0	48,500	38.0	50,600	36.0
E-78	.0575	600	200	54,000	33.0	49,100	37.0	55,800	38.0
E-79	.0760	600	200	51,300	30.0	38,900	35.0	46,400	36.0
E-19	.0577	800	285	51,200	29.0	42,300	34.0	52,600	36.0
E-20	.0569	800	285	52,700	32.0	45,900	38.0	55,200	39.0
E-21	.0571	800	285	52,500	26.0	38,800	36.0	55,400	36.0
E-14	.0558	72	300	78,100	55.0	127,900	61.0	143,300	63.0
E-15	.0557	72	300	79,950	56.0	132,900	62.0	147,000	62.0
E-80	.0565	72	300	84,900	59.0	150,000	61.0	156,000	62.0

~ SEE PAGE 1-20 FOR NOTES ~

CALC	SPICKLAND	4/24/63	REVISED	DATE	ENERGY ABSORBING PROPERTIES 304 ELC 0.114 GAGE SHEET THE BOEING COMPANY	X-20A
CHECK	W. P. BENTON	4/25/63				D2-80086
APP						
APP						MSI 1-29



2



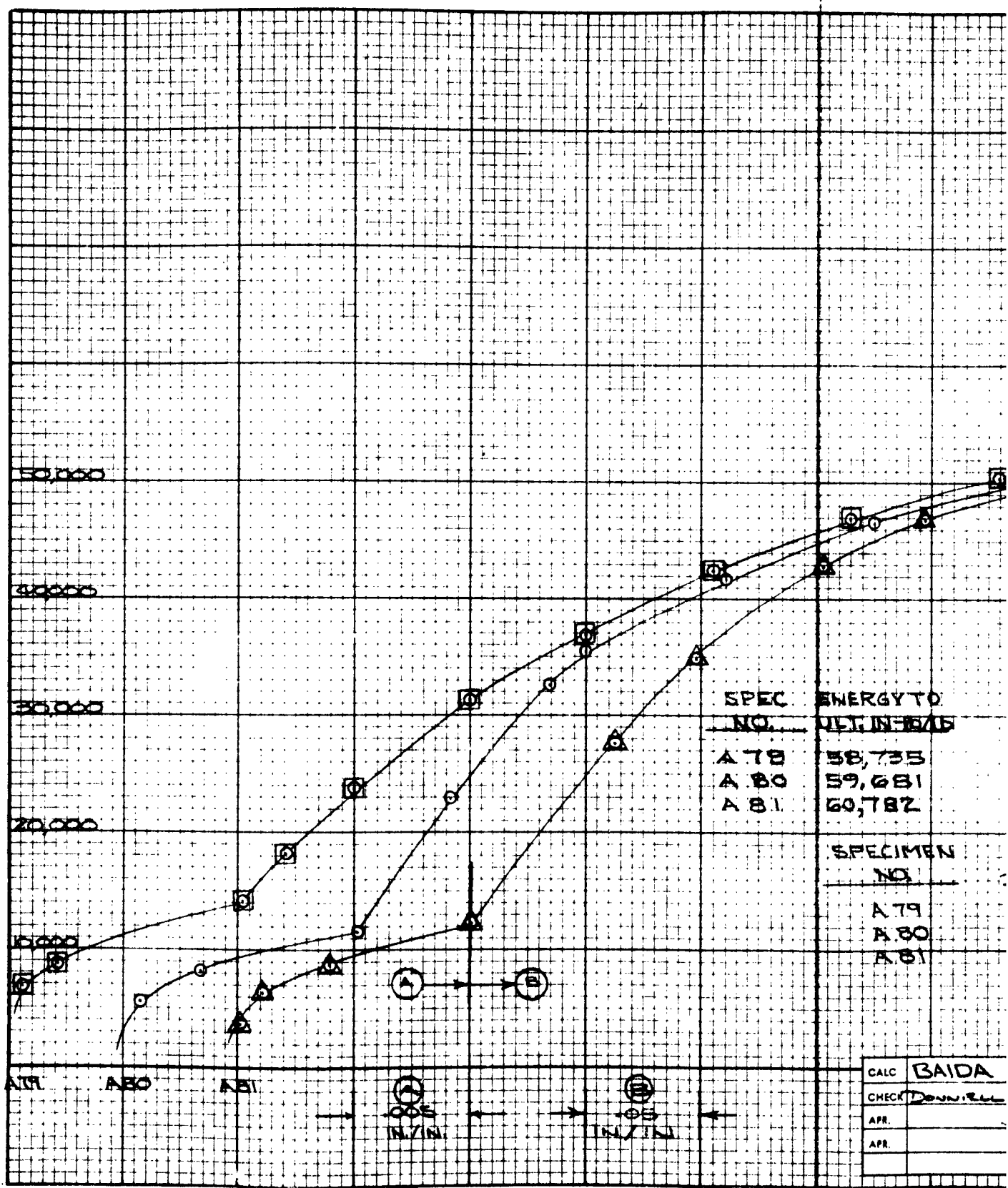
SPEC NO.	ENERGY TO ULT IN-LE/LB	ENERGY TO FAILURE IN-LB/LB	TYPICAL STRAIN IN/IN	TYPICAL STRAIN RATE IN/IN/MIN
AB1	61,400	74,400	(A) = .005	(A) = .001
AB3	70,700	81,600	(B) = .05	(B) = .10
AB4	62,300	73,800		

SPEC NO.	AREA SQ IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP, F	TEST ATMOSPHERE
AB2	.0535	58,400	LONG.	-65	NITROGEN
AB3	.0535	60,000	LONG.	-65	NITROGEN
AB4	.0530	60,000	LONG.	-65	NITROGEN

CALC	WALD	2-23-61	REVISED	DATE	STRESS-STRAIN CURVES NICKEL "A" .109 GAGE SHEET	X-20A
CHECK	Donnell	3-6-61				D2-80086
APR					BOEING AIRPLANE COMPANY	PAGE 1-30
APR						
ENERG	1.00					

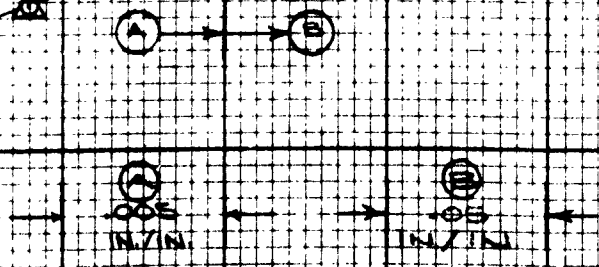
CONTRACT NO

STRESS ~ PSI



SPEC NO.	ENERGY TO ULT. IN IN/IN
A 79	58,735
A 80	59,681
A 81	60,782

SPECIMEN NO.
A 79
A 80
A 81

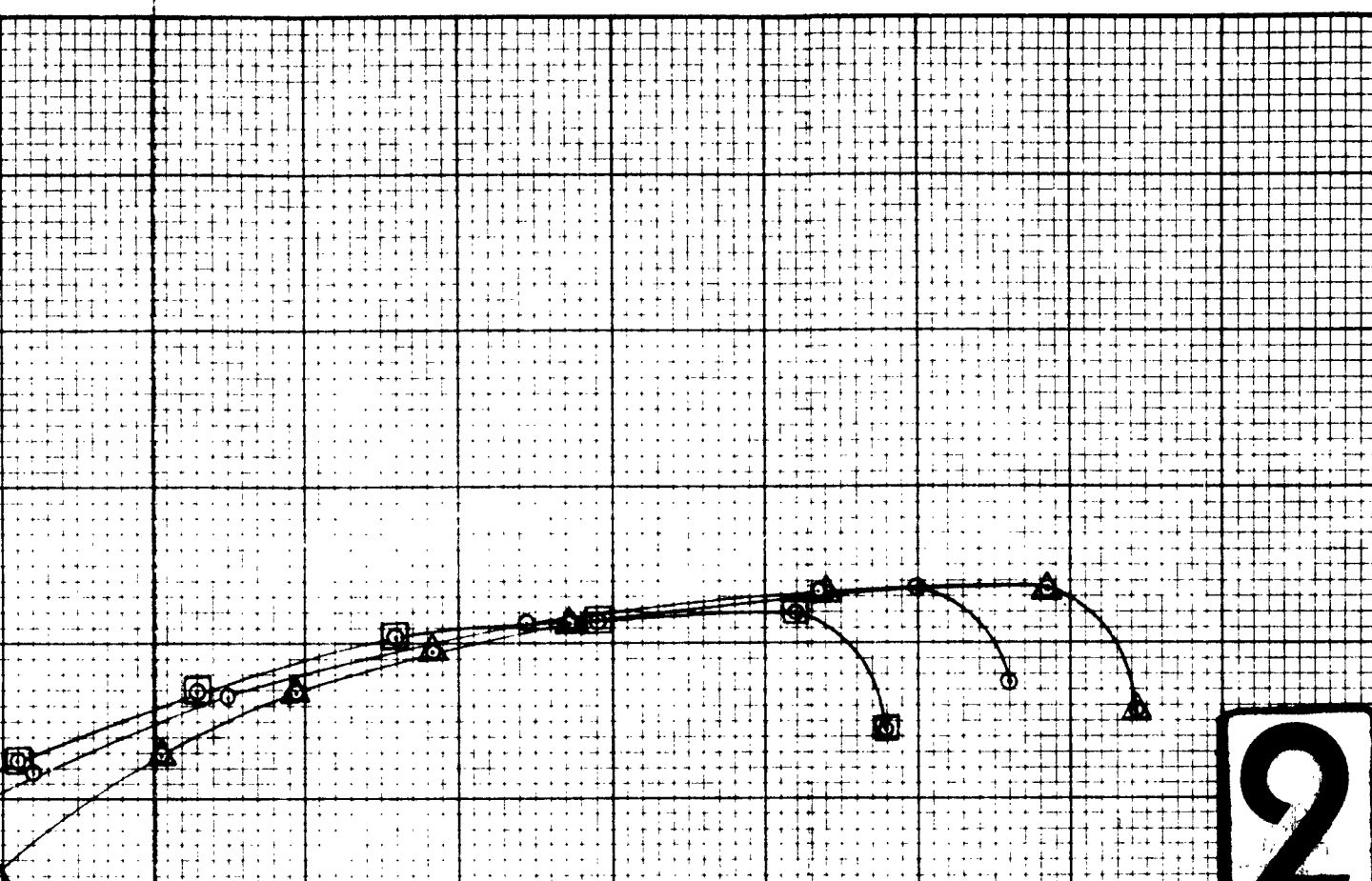


CALC	BAIDA
CHECK	DOWNELL
APR.	
APR.	

DATA SHEET

CONTRACT NO.

2

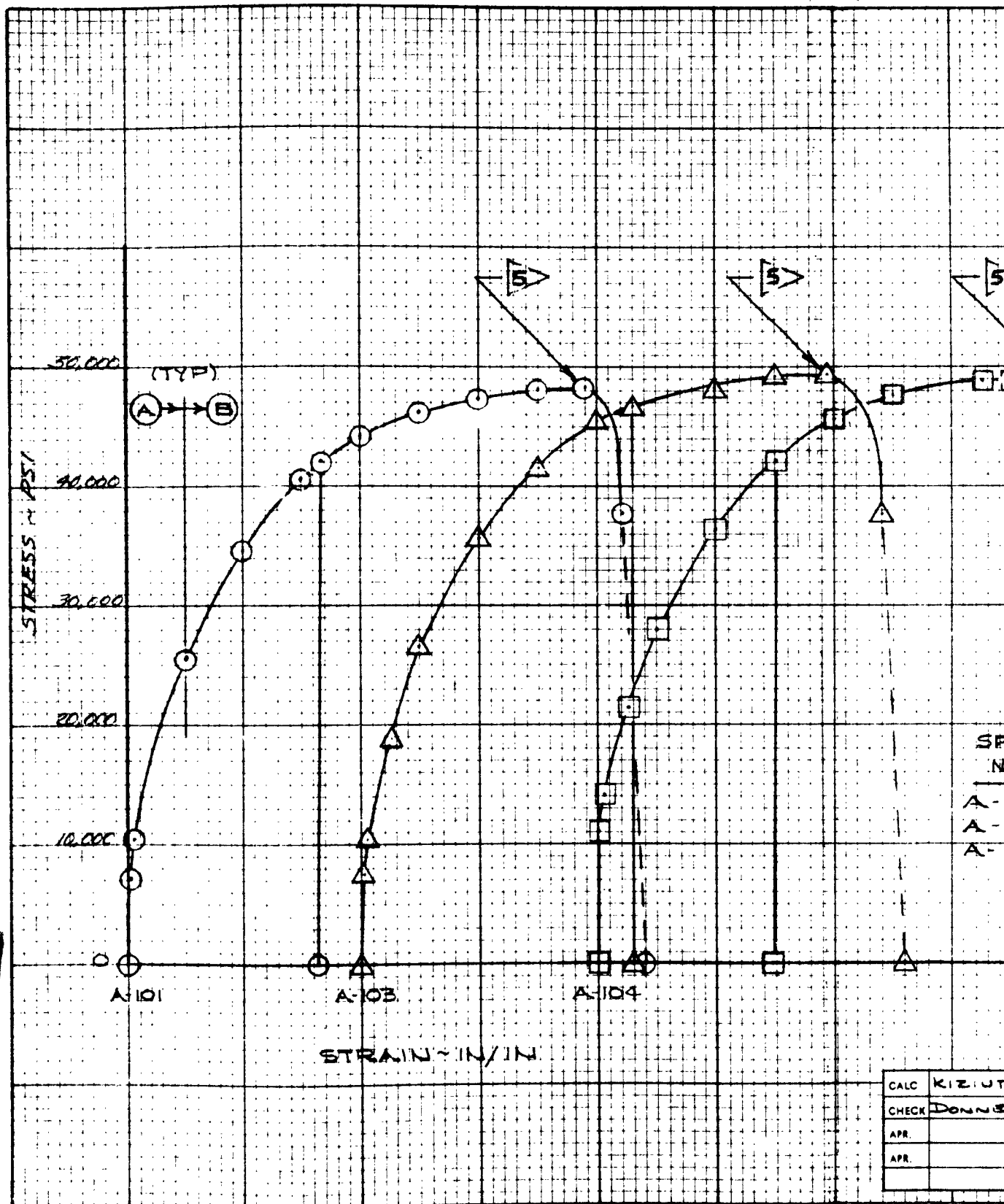


SPEC NO.	ENERGY TO ULT. IN-10/15	ENERGY TO FAIL. IN-10/15	TYR STRAIN ~ IN./IN.	TYR STRAIN. RATE ~ IN./IN./MIN.
A 79	58,735	63,235	(A) F.005	(A) F.005
A 80	59,681	64,125	(B) F.05	(B) F.10
A 81	60,782	65,362	(C) F.05	(C) F.10

SPECIMEN NO.	AREA ~ SQ. IN.	FTU ~ PSI	GRAIN DIRECT	TEST TEMP (°F)	TEST ATMOS.
A 79	.0535	52,000	LONG	72	AIR
A 80	.0543	53,500	LONG	72	AIR
A 81	.0542	53,500	LONG	72	AIR

CALC	BAIDA	14-61	REVISED	DATE	STRESS - STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE F31
CHECK	DONNELL	1-14 -1				
APR.						
APR.						

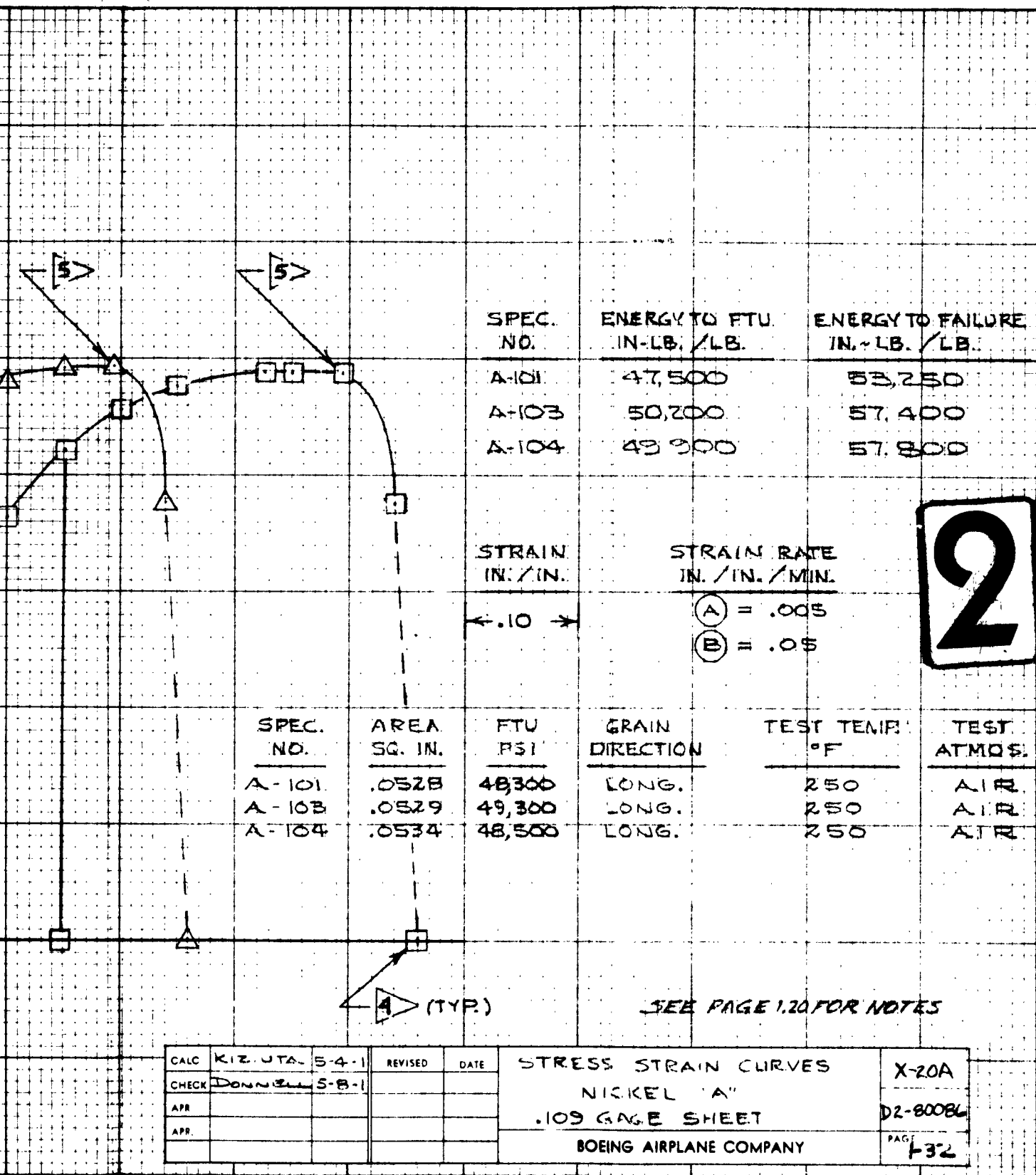
CONTRACT NO.

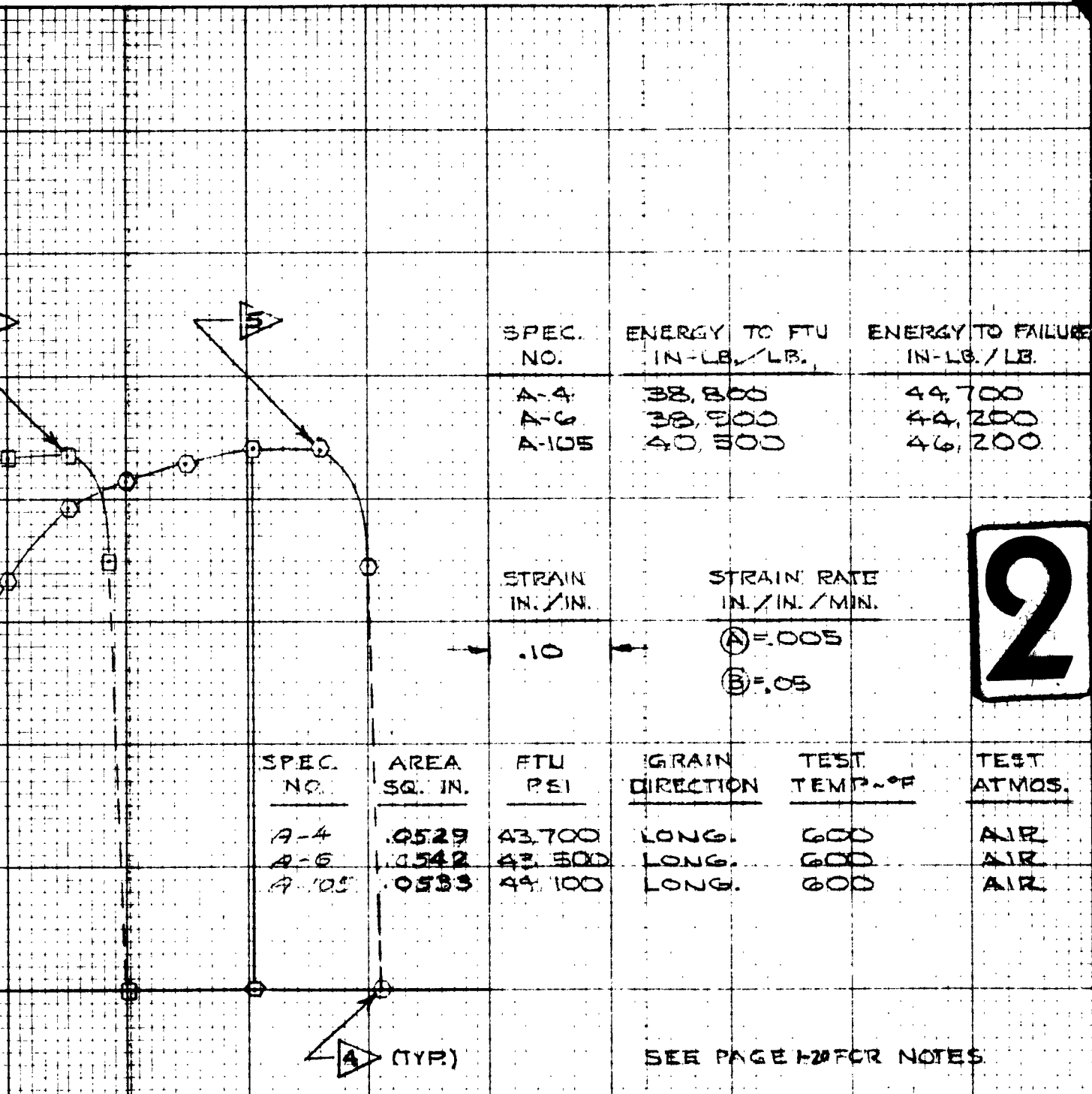


CALC	KIZIUT
CHECK	DONNS
APR.	
APR.	

CONTRACT NO.

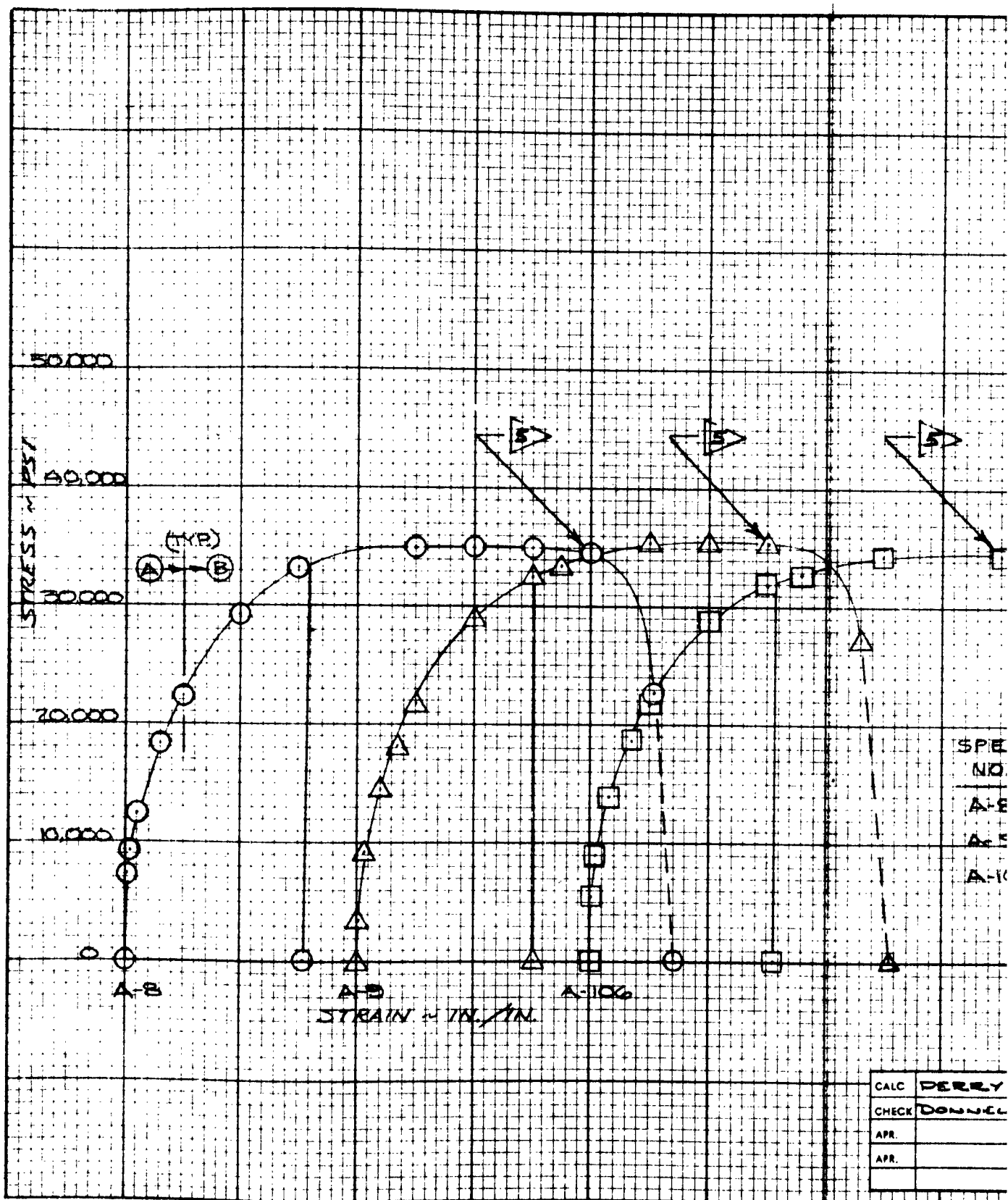
DATA SHEET





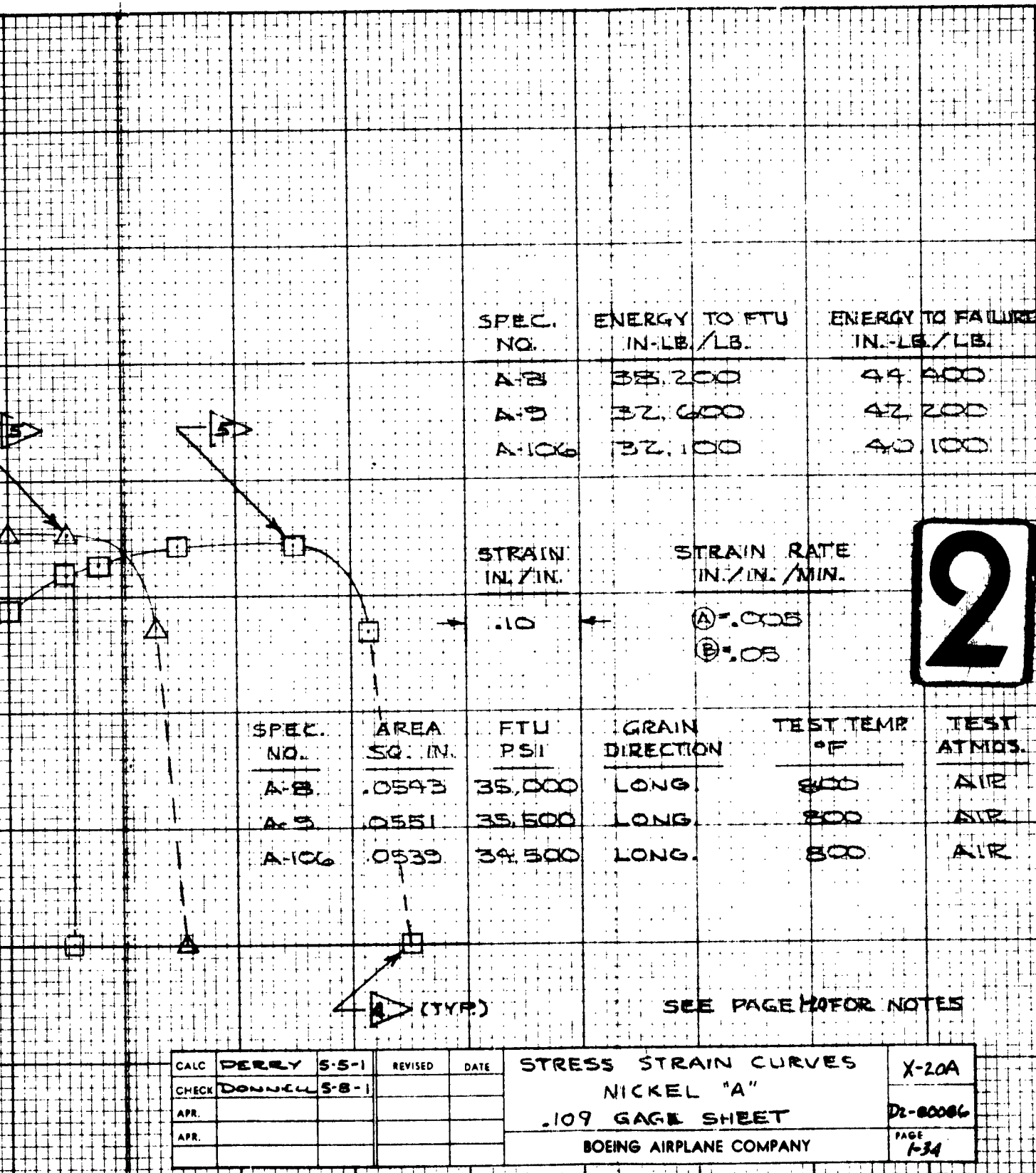
CALC	DENNEY	5-4-1	REVISED	DATE	STRESS STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	DONNELLY	5-8-1				D2-80086
APR.						PAGE 1-33
APR.						

CONTRACT NO



DATA SHEET

CONTRACT NO.



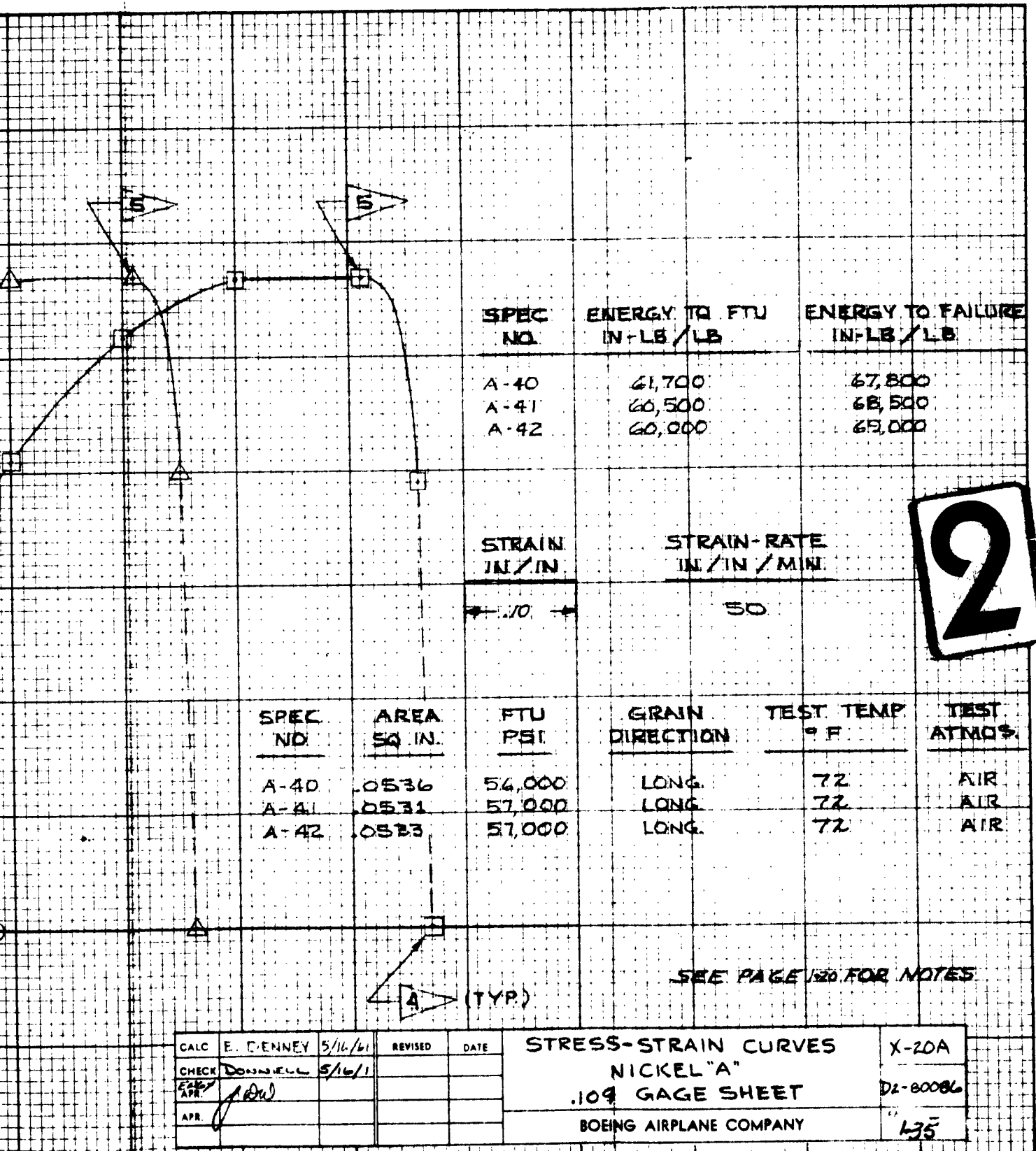


SPE
NO
A-4
A-4
A-4

CALC	E. DENNE
CHECK	DOWNELL
APR	<i>[Signature]</i>
APR	<i>[Signature]</i>

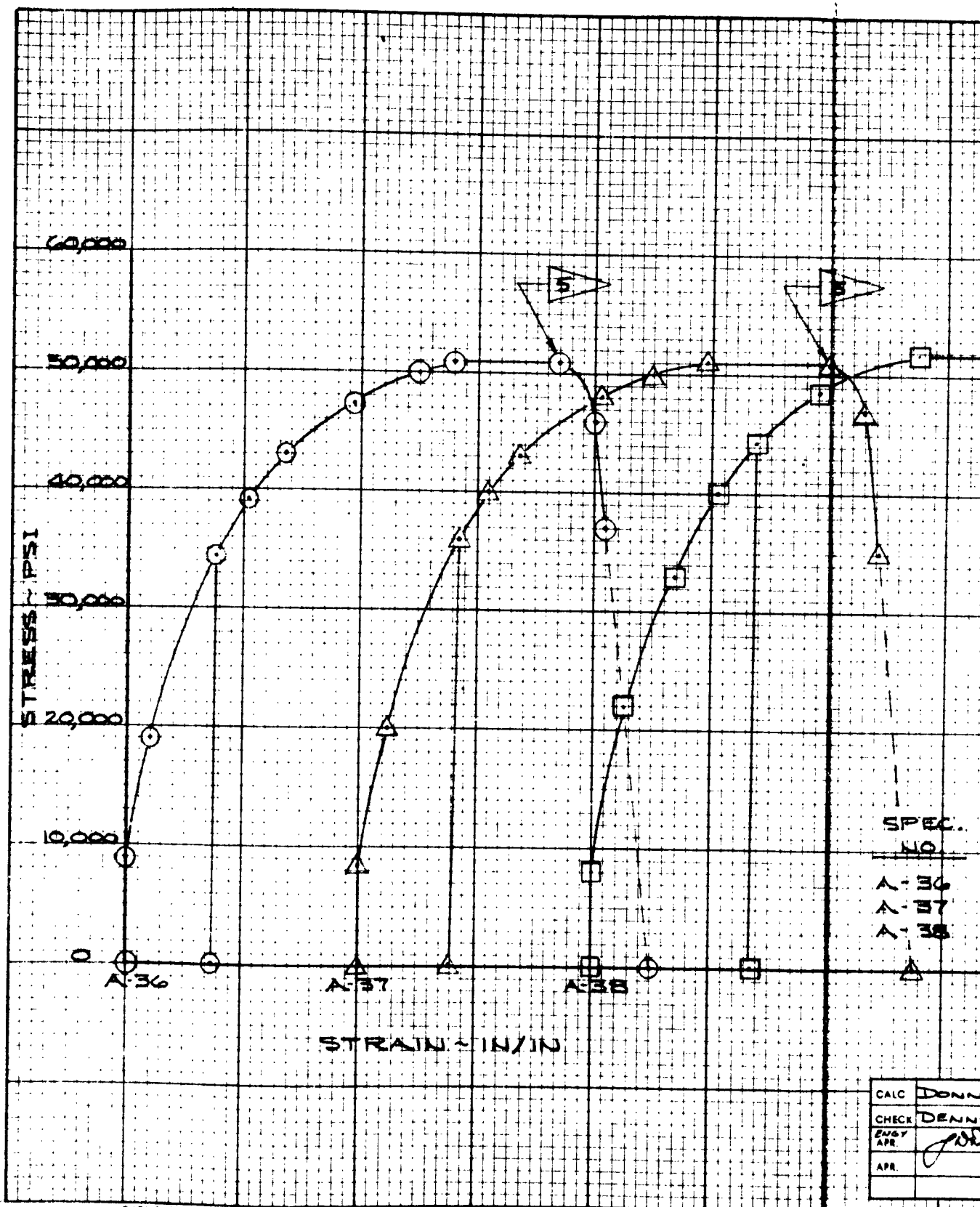
CONTRACT NO.

DATA SHEET



CALC	E. DENNEY	5/16/61	REVISED	DATE	STRESS-STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	DONNELL	5/16/61				D2-80086
APR						135
APR						

CONTRACT NO.



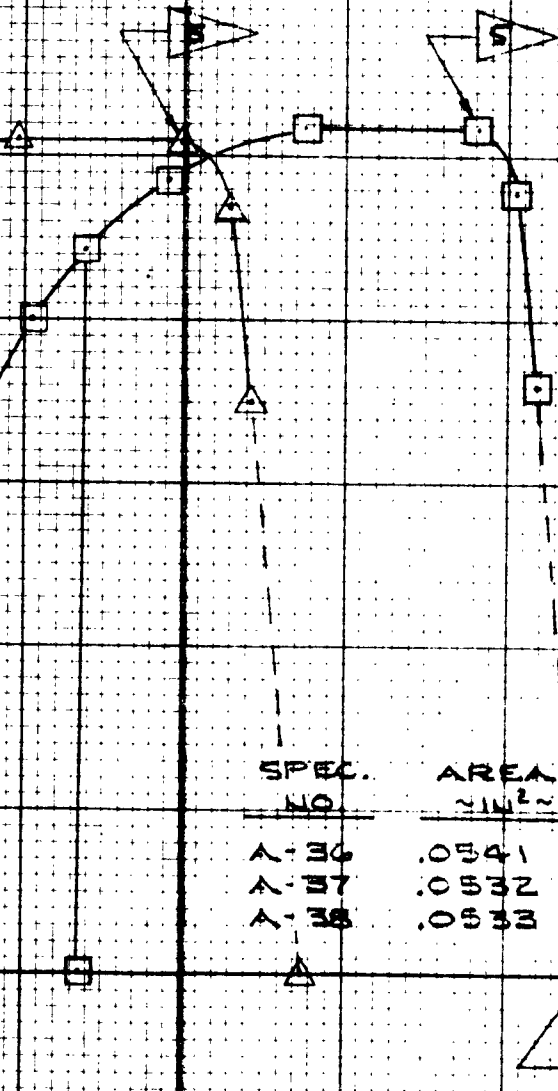
DATA SHEET

U3 4011 5000—REV 7/60 (WAS BAC 360D)

CALC	DOWN
CHECK	DENNY
ENG	APR
APR	

CONTRACT NO.

2



SPEC. NO.	ENERGY TO FTU. ~IN-LB/LB~	ENERGY TO FAILURE ~IN-LB/LB~
A-36	48,500	56,700
A-37	53,000	61,200
A-38	51,200	58,500

STRAIN ~IN/IN~	STRAIN-RATE ~IN/IN/MIN~
~.10~	50

SPEC. NO.	AREA ~IN ² ~	FTU. ~PSI~	GRAIN DIRECTION	TEST TEMP ~°F.~	TEST ~ATMOS.~
A-36	.0541	51,000	LONG.	250	AIR
A-37	.0532	51,000	LONG.	250	AIR
A-38	.0533	51,900	LONG.	250	AIR

(TYP.)

SEE PAGE 48 FOR NOTES

CALC	DONNEL	5-12-1	REVISED	DATE
CHECK	DENNEY	5-12-1		
ENG				
APR				

STRESS-STRAIN CURVES
NICKEL 'A'
.109 GAGESHEET

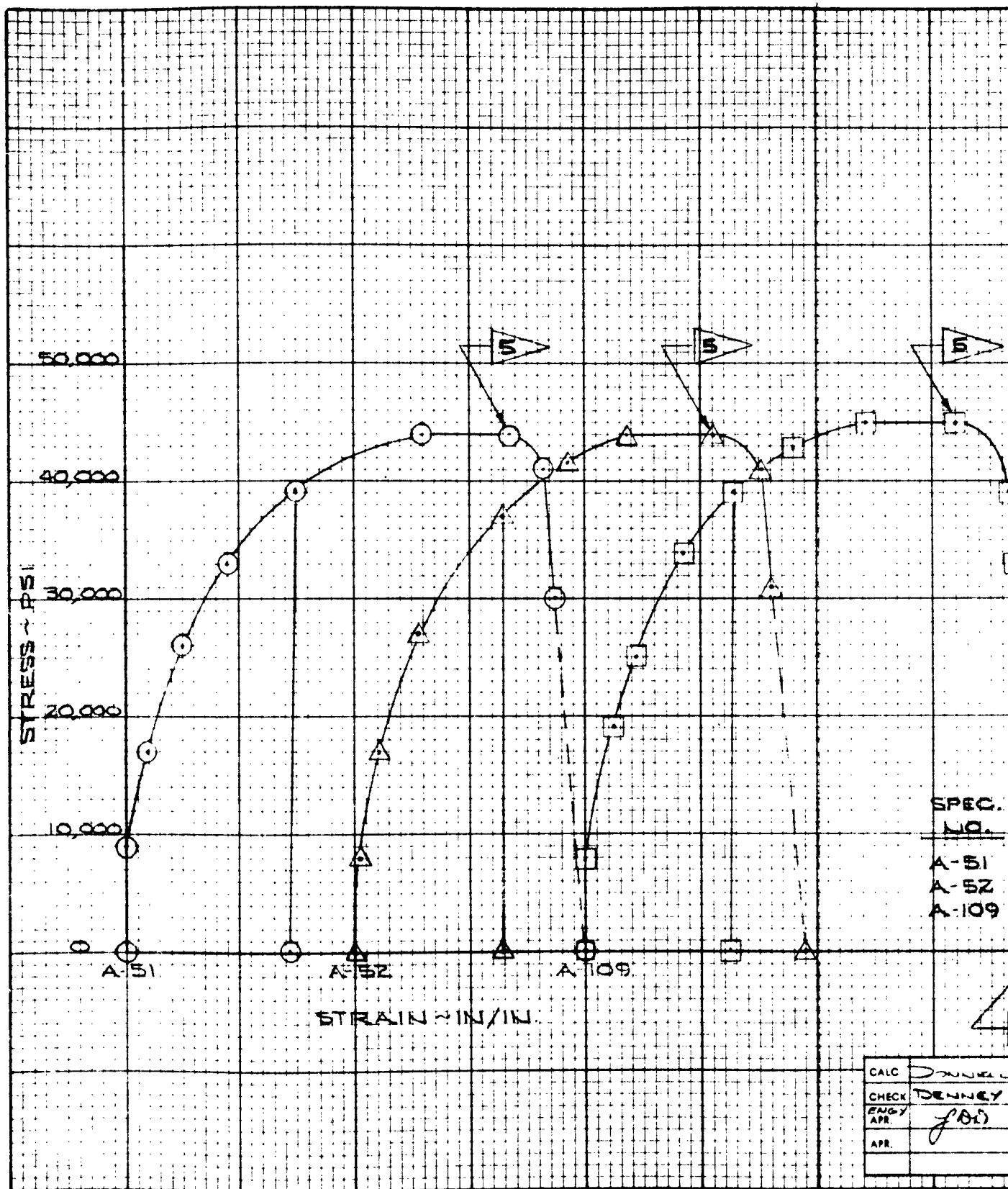
BOEING AIRPLANE COMPANY

X-20A

D2-80084

PAGE
136

CONTRACT NO.

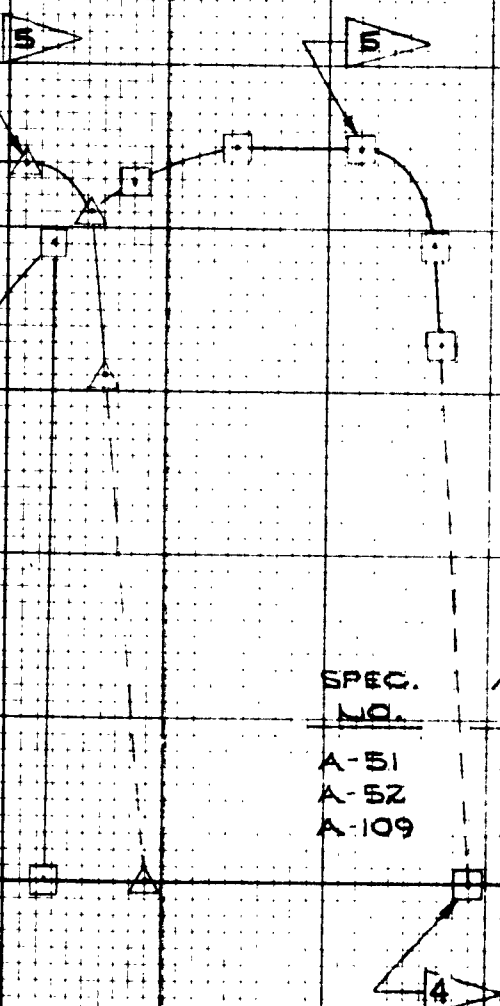


DATA SHEET

CALC	DENNEY
CHECK	DENNEY
ENG'Y	
APR.	
APR.	

CONTRACT NO.

2



SPEC. NO.	ENERGY TO FTU. ~IN-LBS/LB~	ENERGY TO FAILURE ~IN-LBS/LB~
A-51	38,000	44,200
A-52	34,300	42,300
A-109	37,100	44,700

STRAIN ~IN/IN~	STRAIN + RATE ~IN/IN/MIN.~
~.10~	50

SPEC. NO.	AREA ~IN ² ~	FTU ~PSI~	GRAIN DIRECTION	TEST TEMP ~°F~	TEST ATMOS.
A-51	.0532	44,000	LONG.	600	AIR
A-52	.0534	44,000	LONG.	600	AIR
A-109	.0539	46,000	LONG.	600	AIR

SEE PAGE 12 FOR NOTES

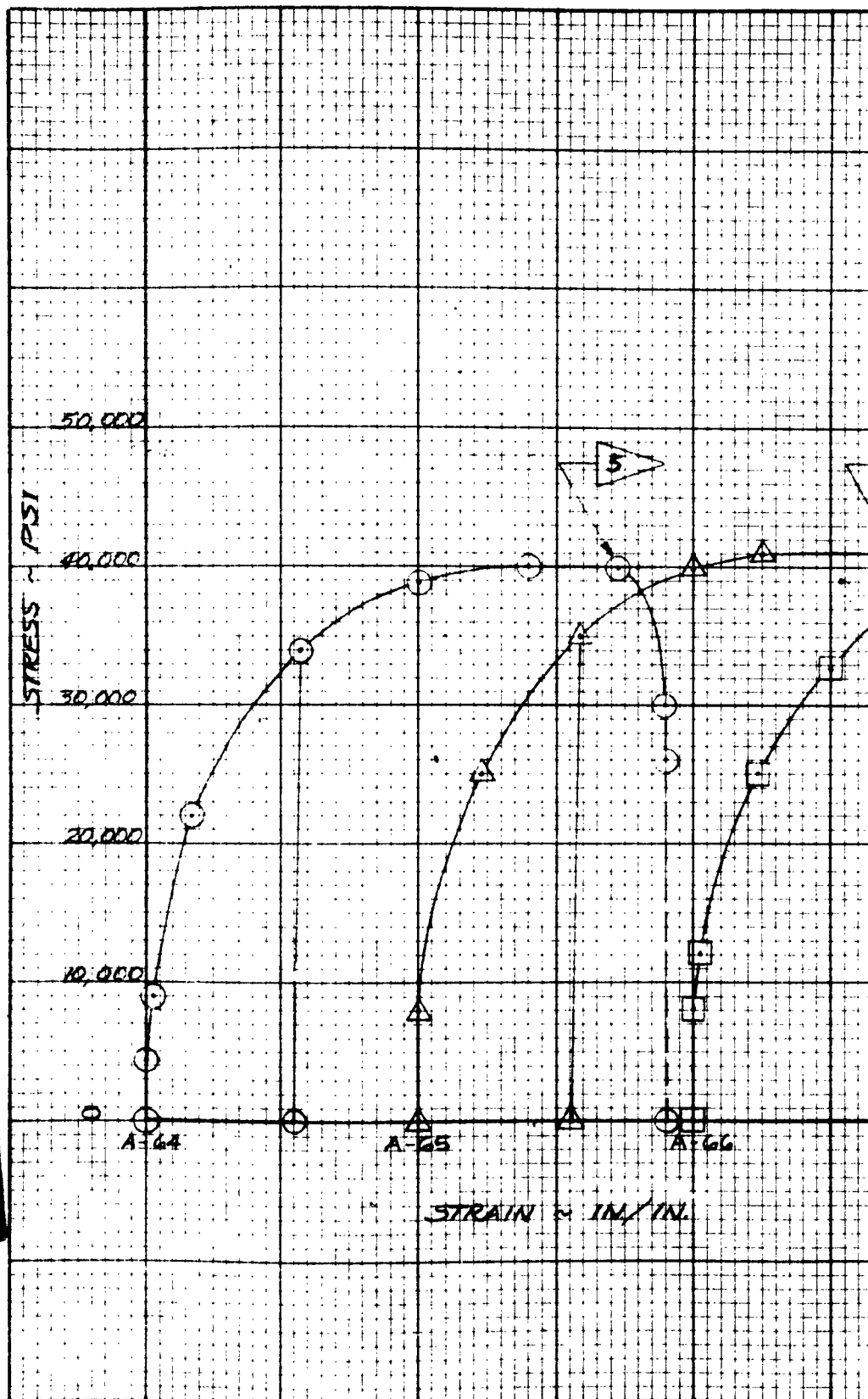
CALC	DENNEY	5-15-61	REVISED	DATE	STRESS - STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 -37
CHECK	DENNEY	5-15-61				
ENG'Y						
APR.						

CONTRACT NO.

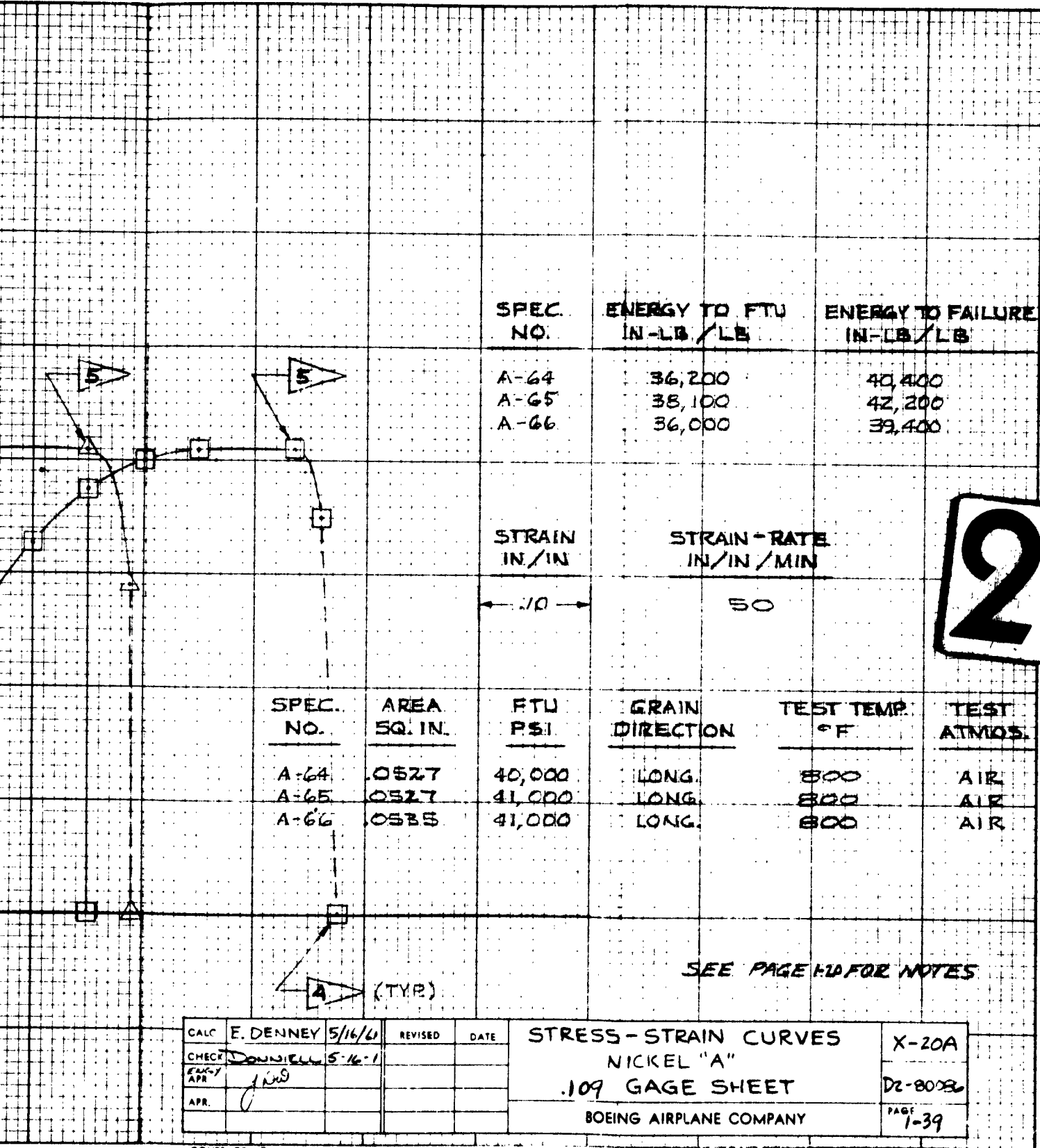
PAGE DELETED



1



DATA SHEET

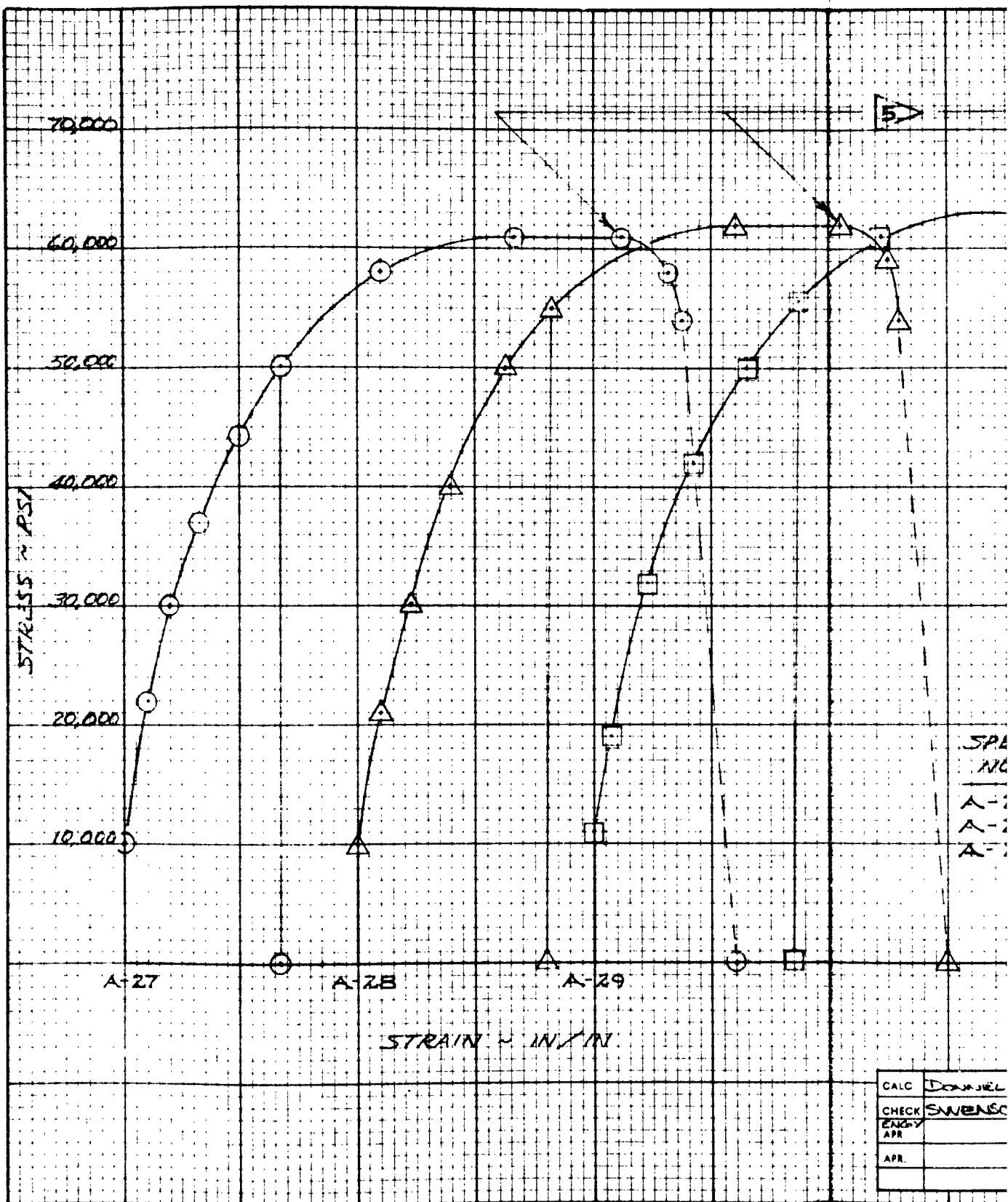


SPEC. NO.	ENERGY TO FTU IN-LB / LB	ENERGY TO FAILURE IN-LB / LB
A-64	36,200	40,400
A-65	38,100	42,200
A-66	36,000	39,400

STRAIN IN / IN	STRAIN-RATE IN / IN / MIN
10	50

SPEC. NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP. °F	TEST ATMOS.
A-64	.0527	40,000	LONG.	800	AIR
A-65	.0527	41,000	LONG.	800	AIR
A-66	.0535	41,000	LONG.	800	AIR

CALC	E. DENNEY	5/16/61	REVISED	DATE	STRESS - STRAIN CURVES	X-20A
CHECK	Donniell	5-16-1			NICKEL "A"	
APR.					.109 GAGE SHEET	D2-8008
					BOEING AIRPLANE COMPANY	PAGE 1-39



A-27

A-28

A-29

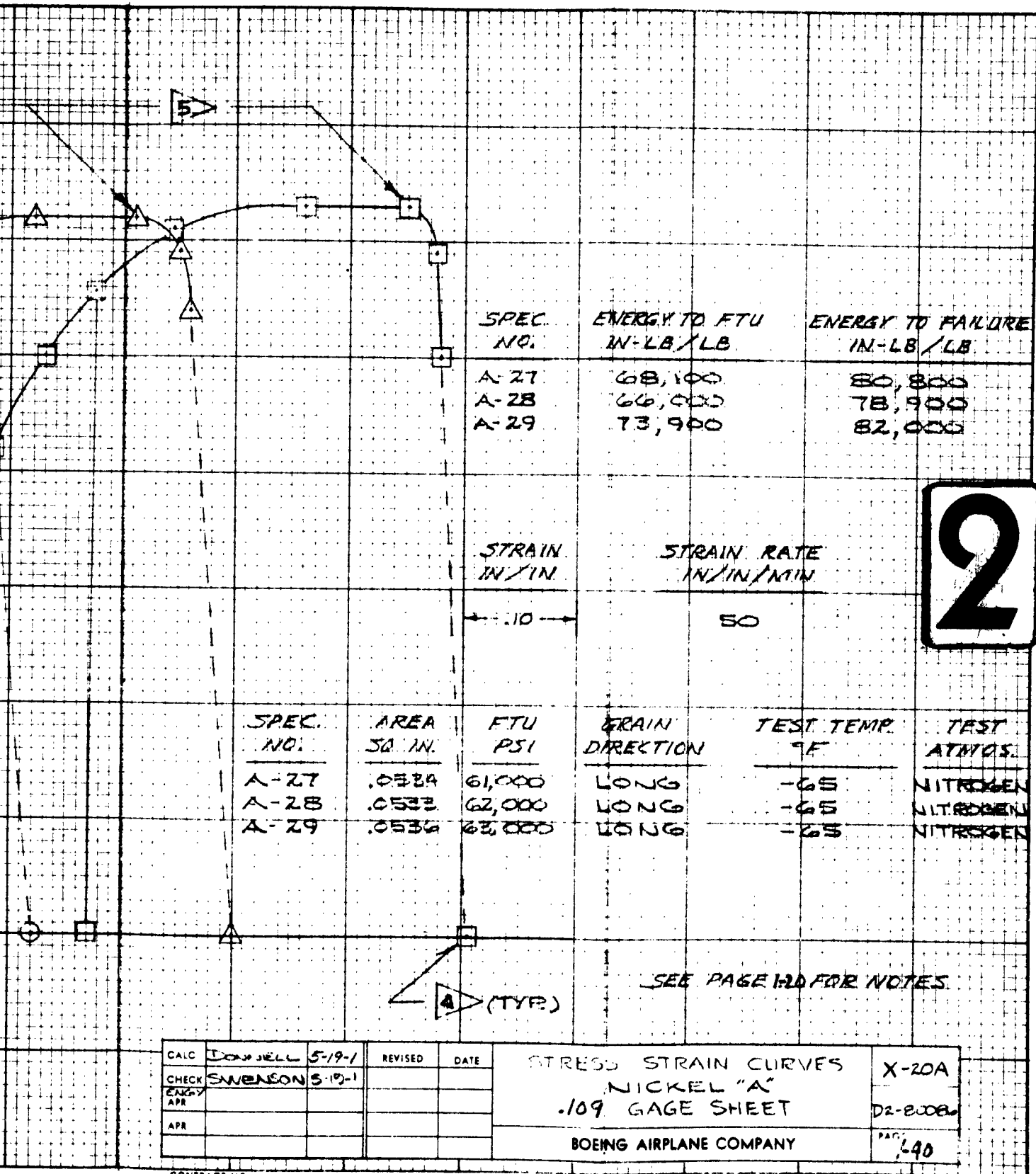
STRAIN ~ IN/IN

SPA
NO
A-27
A-28
A-29

CALC	DONNEL
CHECK	SWENSON
ENG	
APR	
APR	

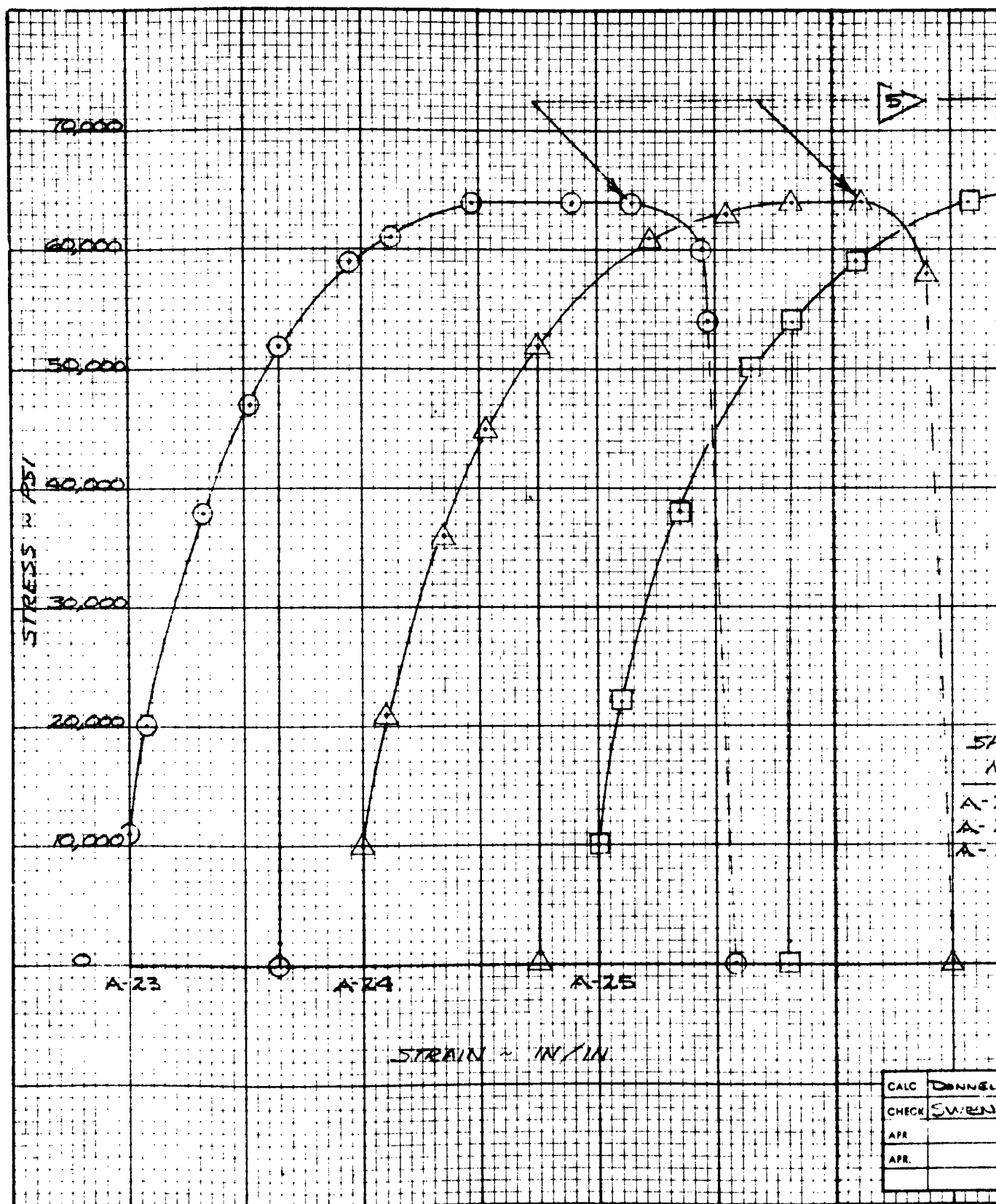
CONTRACT NO.

DATA SHEET



CONTRACT NO.

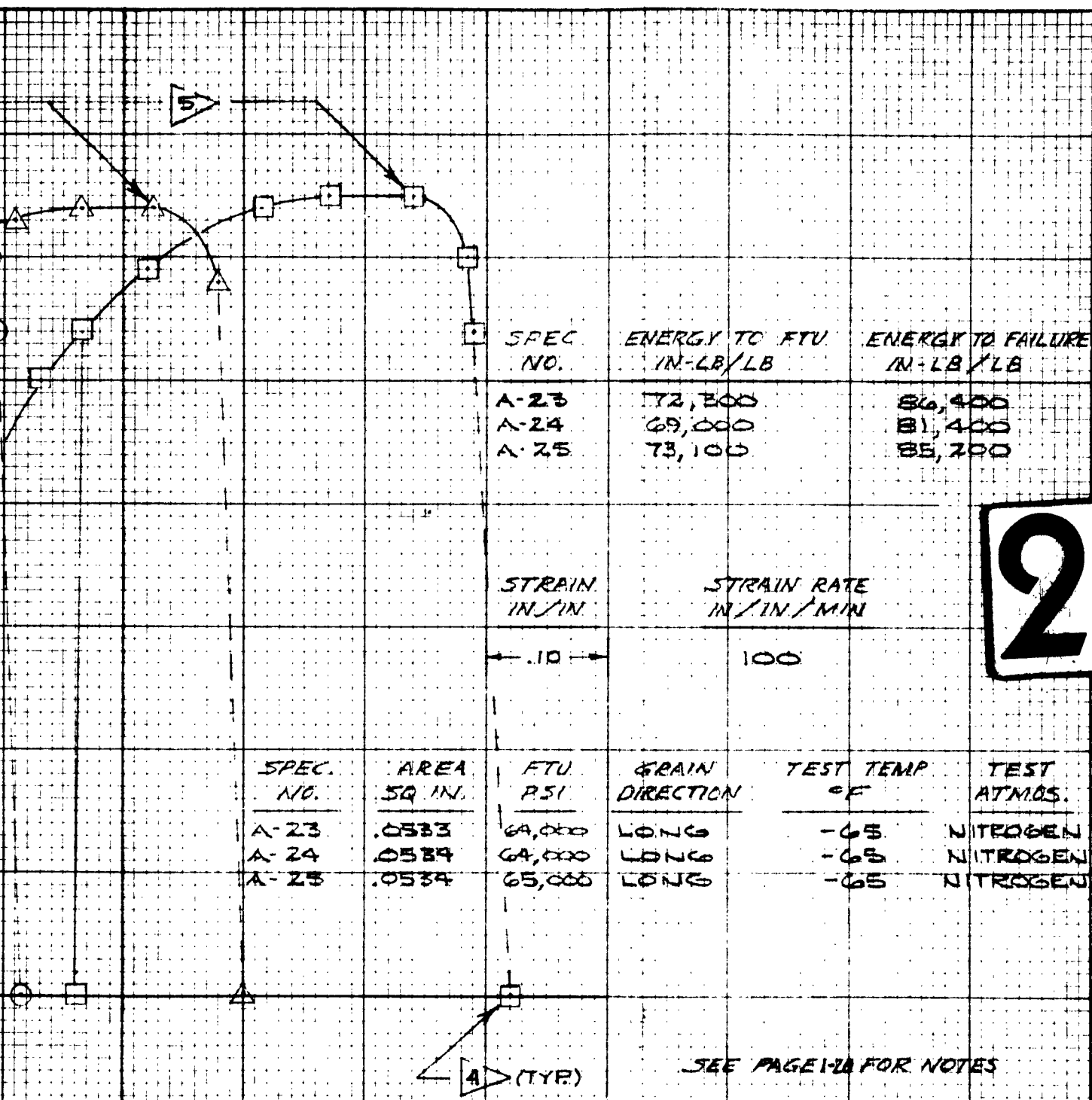
1



DATA SHEET

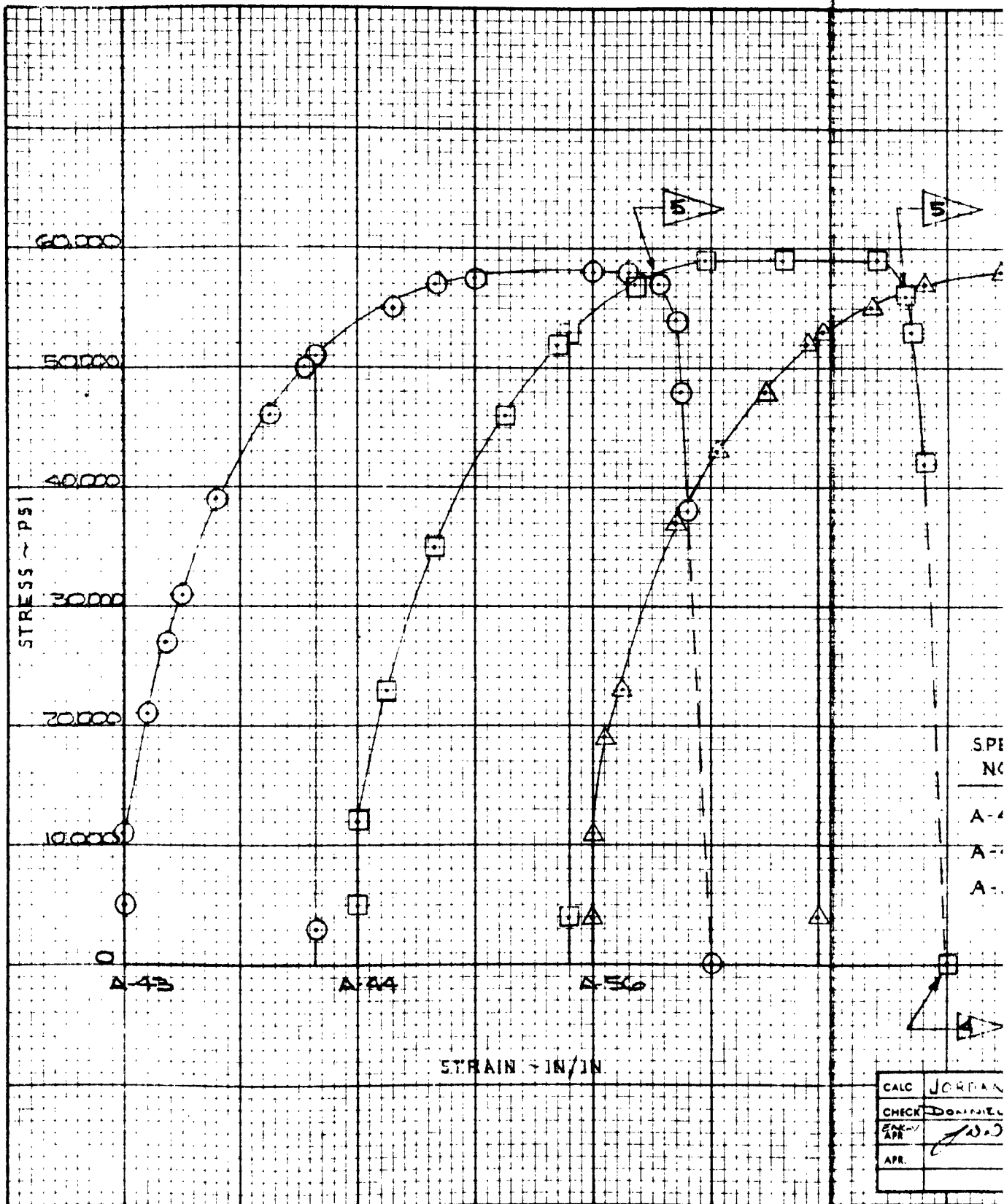
CALC	DANIEL
CHECK	SWEN
APR	
APR	

CONTRACT NO.



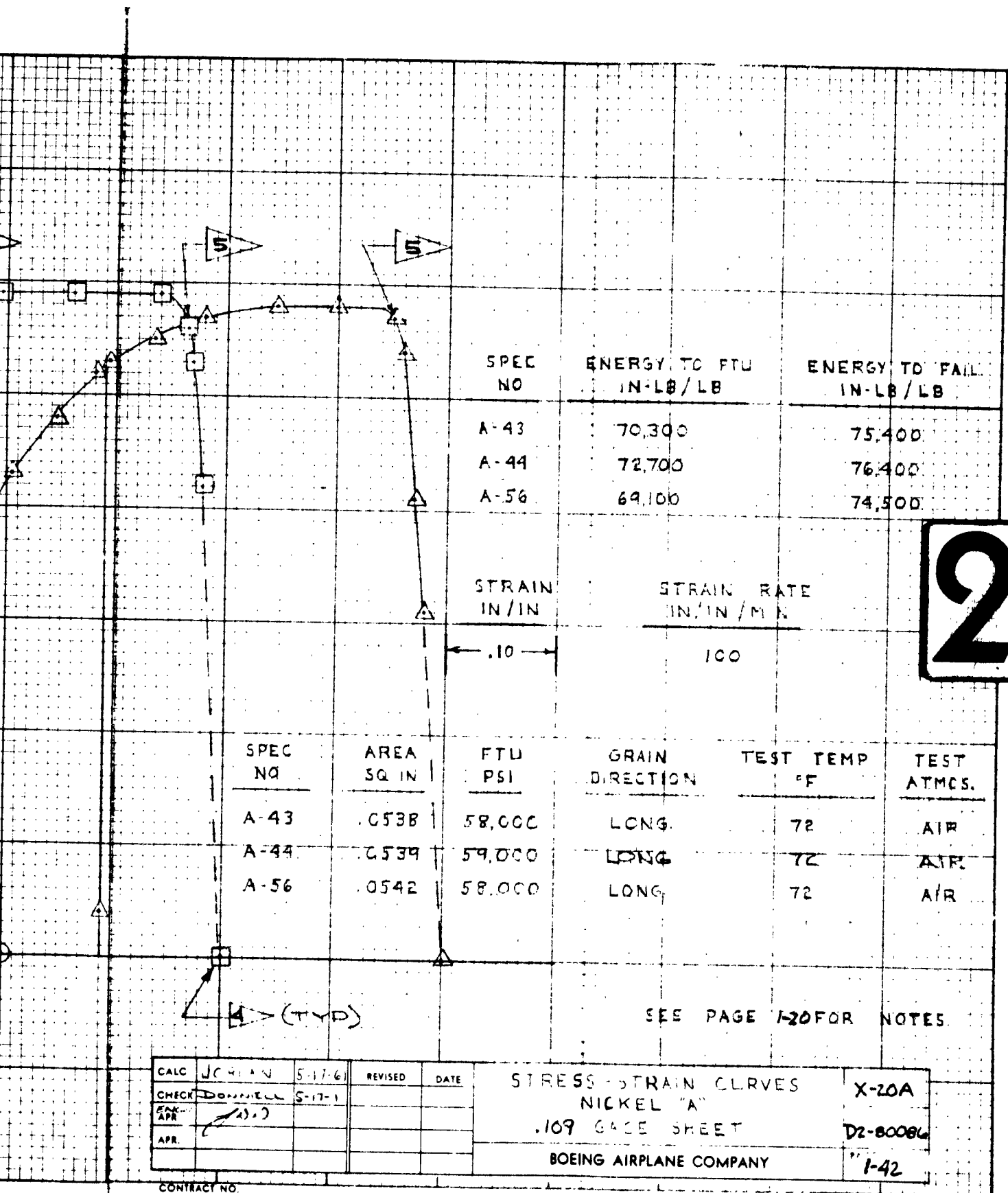
CALC	DONNELL	5-19-1	REVISED	DATE	STRESS STRAIN CURVES	X-20A
CHECK	SWENSON	5-19-1			NICKLE A	
APR					.109 GAGE SHEET	D2-80086
APR					BOEING AIRPLANE COMPANY	PAGE 1-41

CONTRACT NO.



DATA SHEET

CALC	JORDAN
CHECK	DOMINIEL
ENR-1	10.0
APR.	



SPEC
NO

ENERGY TO FTU
IN-LB/LB

ENERGY TO FAIL
IN-LB/LB

A-43

70,300

75,400

A-44

72,700

76,400

A-56

69,100

74,500

STRAIN
IN/IN

STRAIN RATE
IN/IN/MIN

.10

100

SPEC
NO

AREA
SQ IN

FTU
PSI

GRAIN
DIRECTION

TEST TEMP
°F

TEST
ATMOS.

A-43

.0538

58,000

LONG

72

AIR

A-44

.0539

59,000

LONG

72

AIR

A-56

.0542

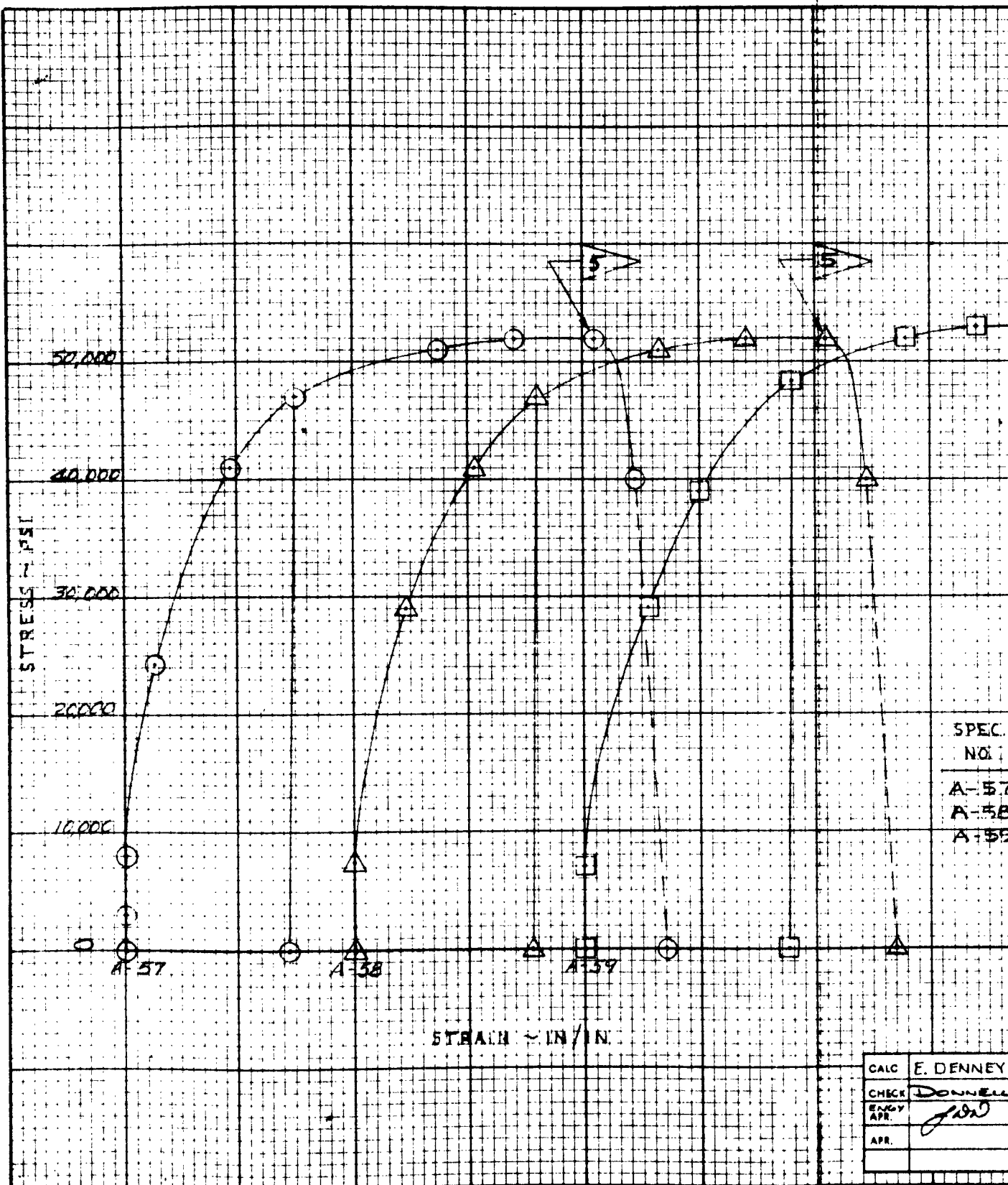
58,000

LONG

72

AIR

CALC	JOHAN	5-17-61	REVISED	DATE	STRESS-STRAIN CURVES NICKEL "A"	X-20A
CHECK	DONNELL	5-17-61			.109 GAGE SHEET	D2-80086
ENG APR	ASD				BOEING AIRPLANE COMPANY	"1-42
APR						



SPEC.
NO.

A-57

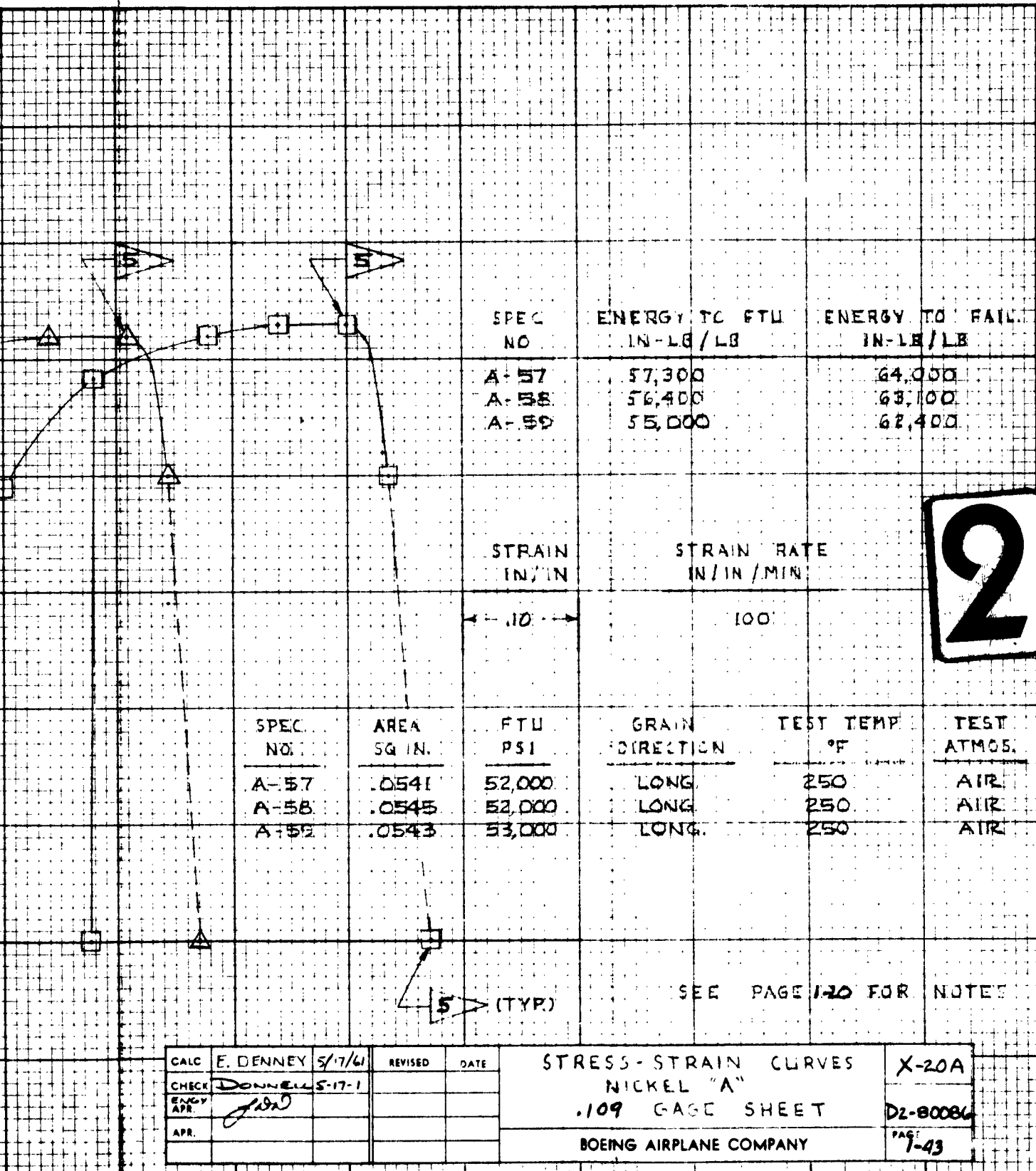
A-58

A-59

CALC	E. DENNEY
CHECK	DONNELL
ENGR	<i>[Signature]</i>
APR.	

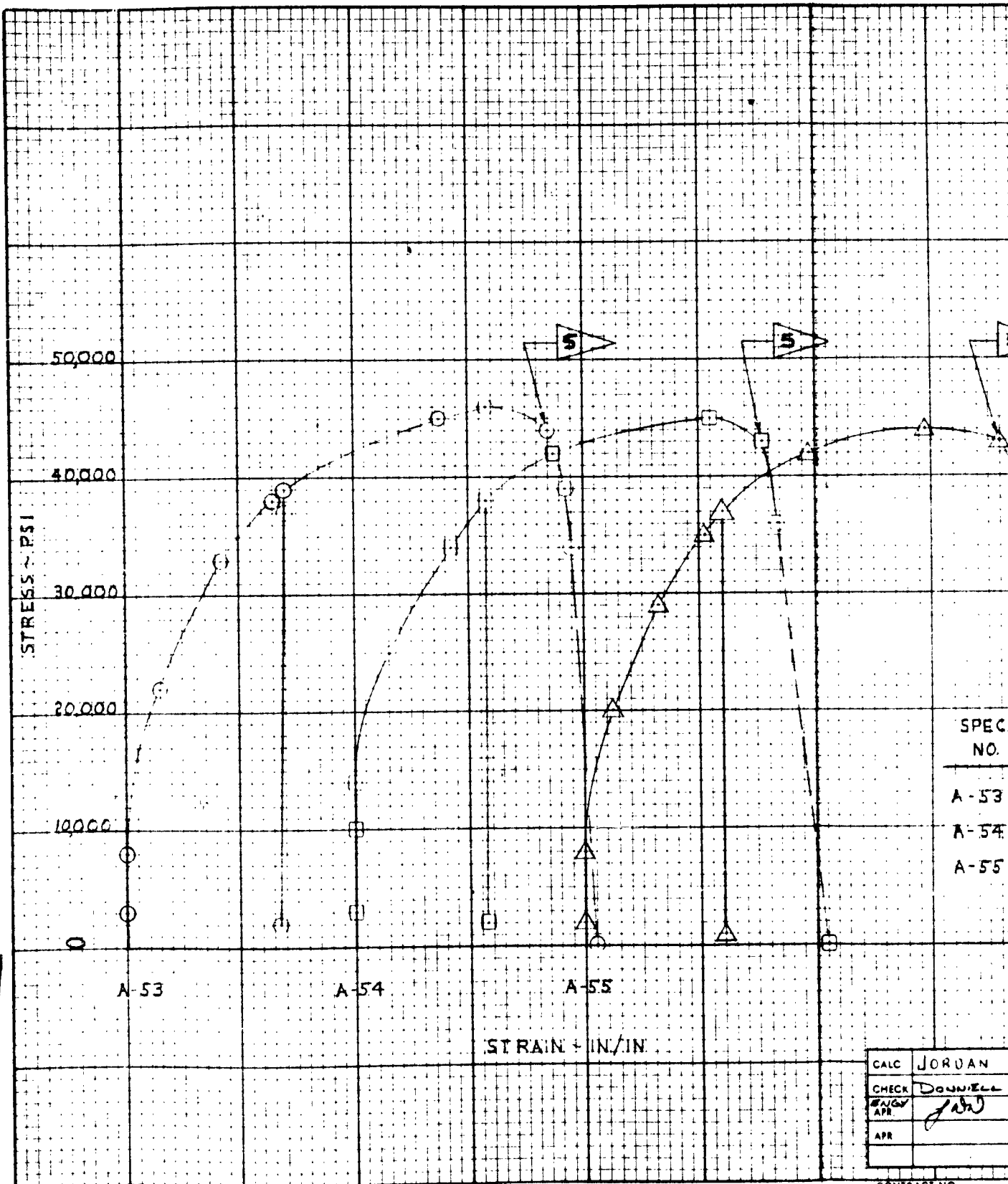
CONTRACT NO.

DATA SHEET



<table border="1"> <tr> <td>CALC</td> <td>E. DENNEY</td> <td>5/7/61</td> </tr> <tr> <td>CHECK</td> <td>DONNELLS-17-1</td> <td></td> </tr> <tr> <td>ENGR</td> <td></td> <td></td> </tr> <tr> <td>APR.</td> <td></td> <td></td> </tr> </table>	CALC	E. DENNEY	5/7/61	CHECK	DONNELLS-17-1		ENGR			APR.			<table border="1"> <tr> <td>REVISED</td> <td>DATE</td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> </table>	REVISED	DATE							STRESS-STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-43
CALC	E. DENNEY	5/7/61																					
CHECK	DONNELLS-17-1																						
ENGR																							
APR.																							
REVISED	DATE																						

CONTRACT NO.



SPEC. NO.

A-53

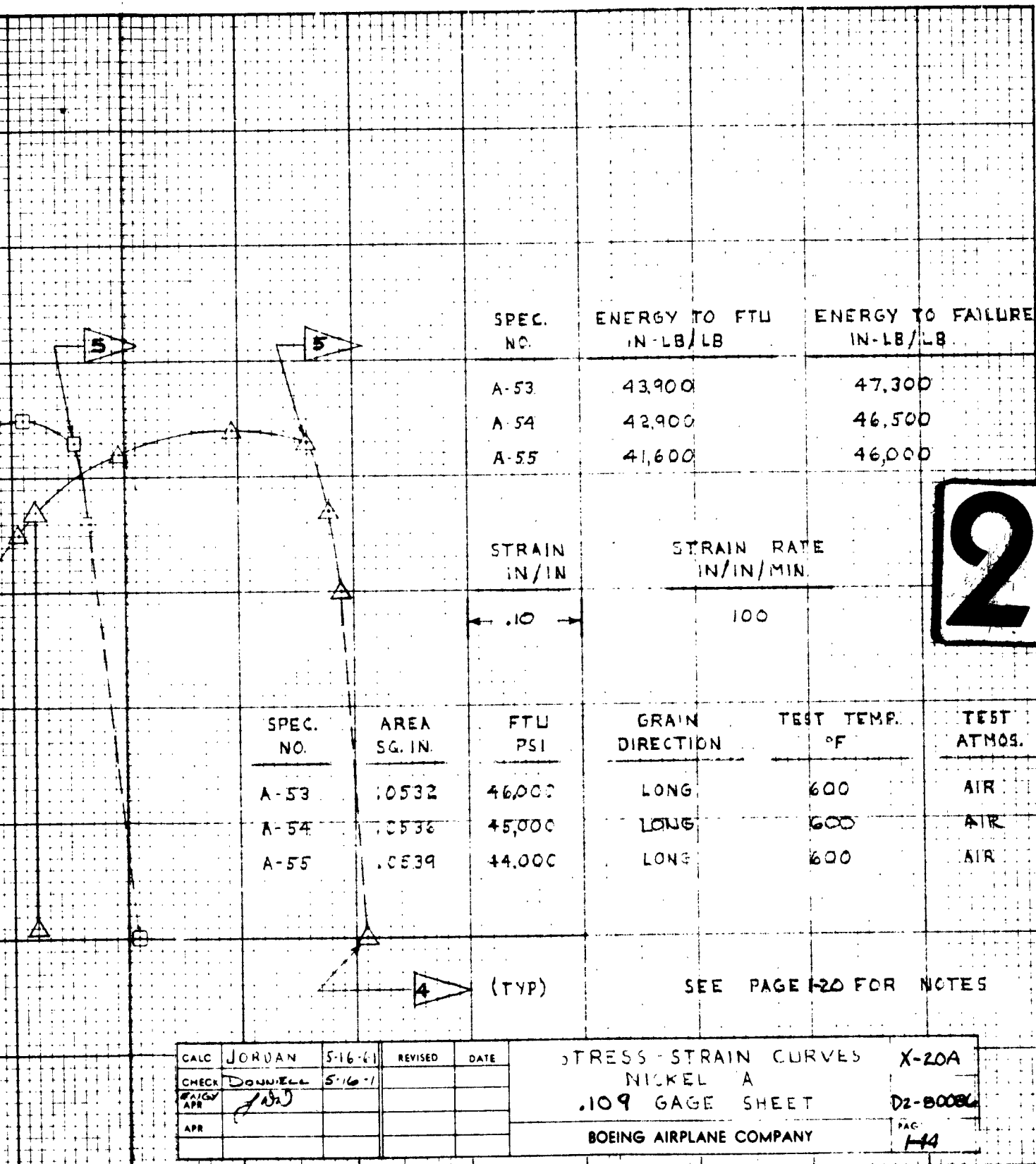
A-54

A-55

CALC	JORDAN
CHECK	DONNELL
ENG	
APR	

CONTRACT NO.

DATA SHEET



CALC	JORDAN	5-16-61	REVISED	DATE
CHECK	DONNELL	5-16-61		
APR				
APR				

STRESS-STRAIN CURVES
NICKEL A
.109 GAGE SHEET

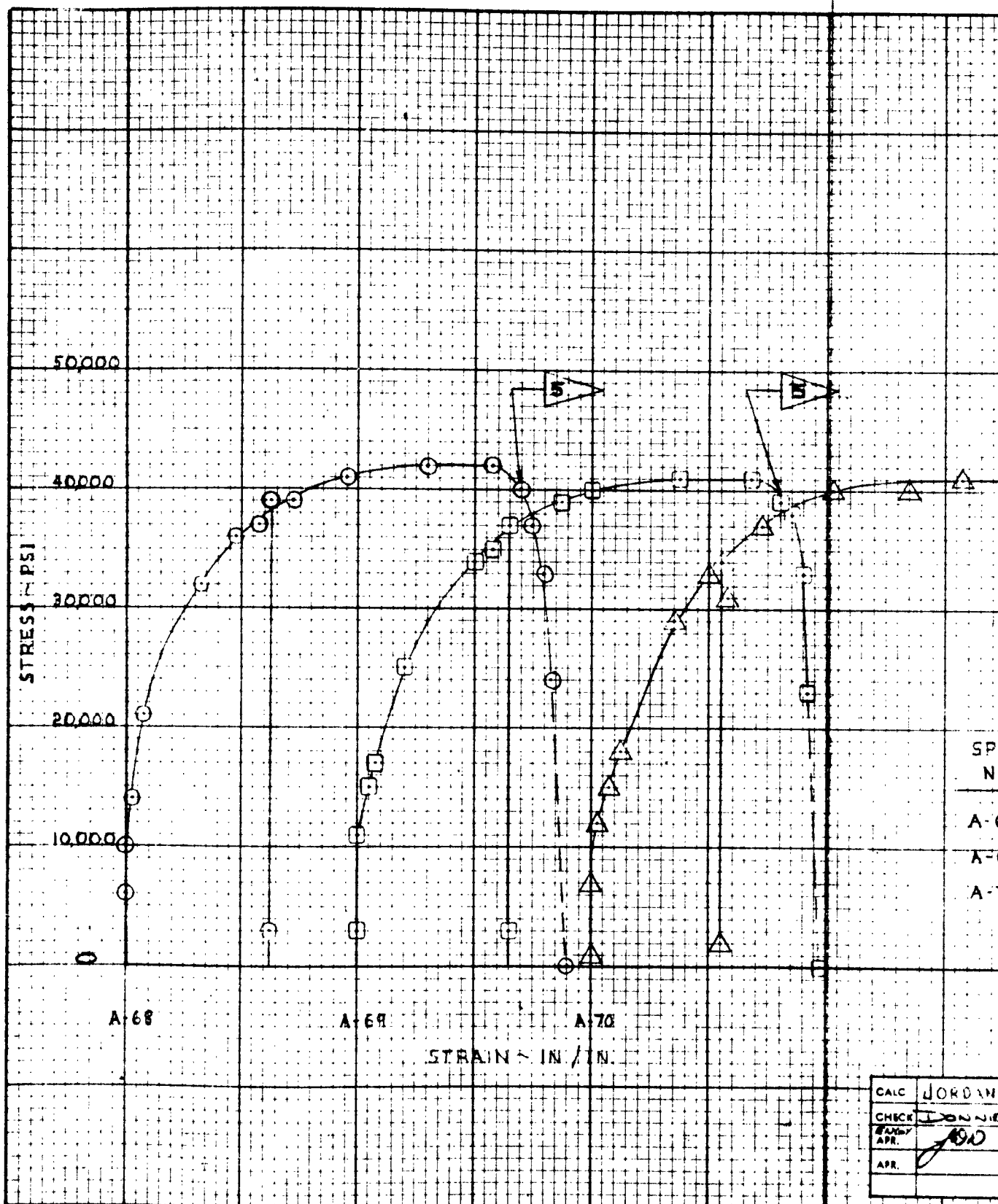
BOEING AIRPLANE COMPANY

X-20A

D2-80086

PAC
H4

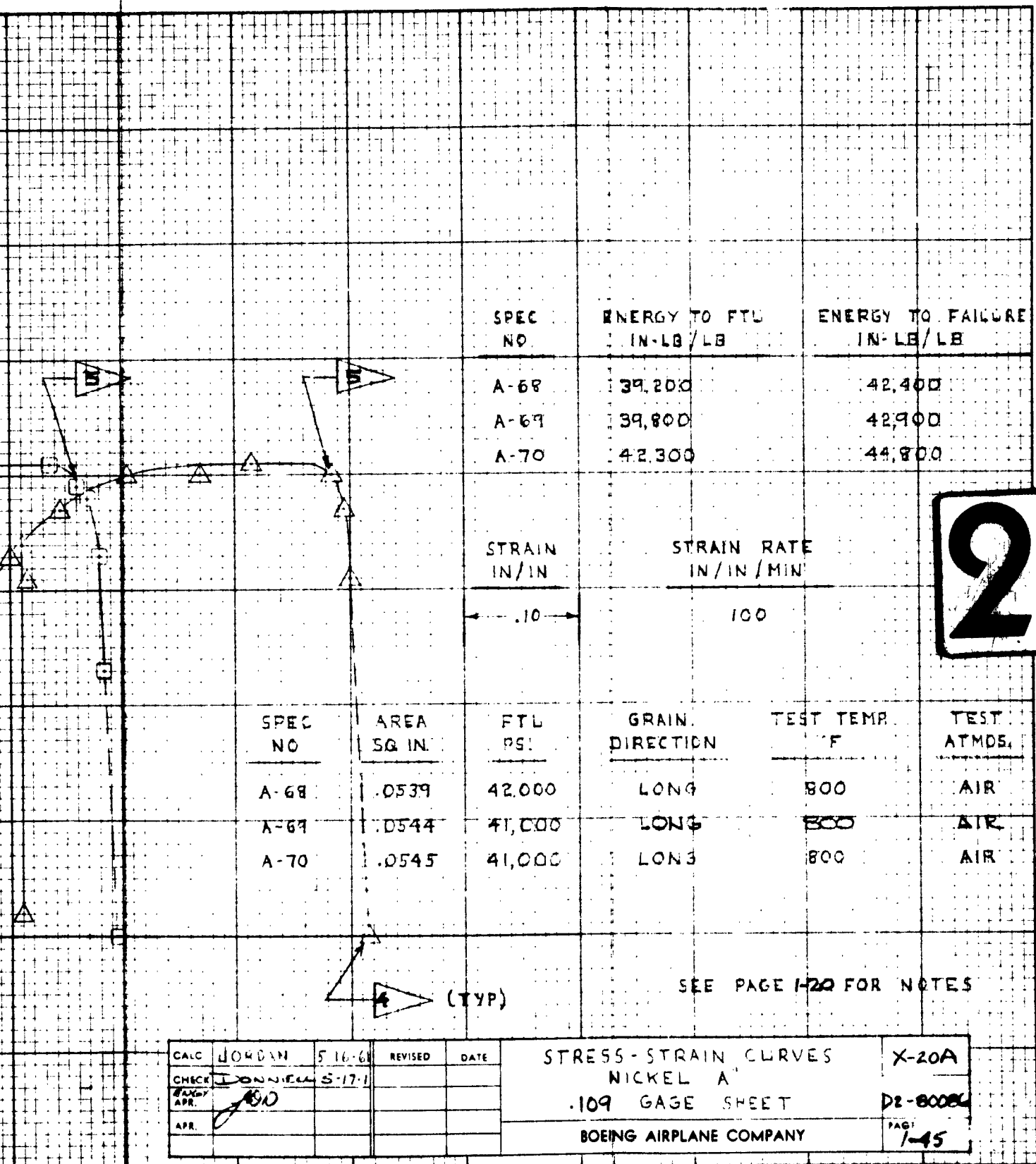
CONTRACT NO.



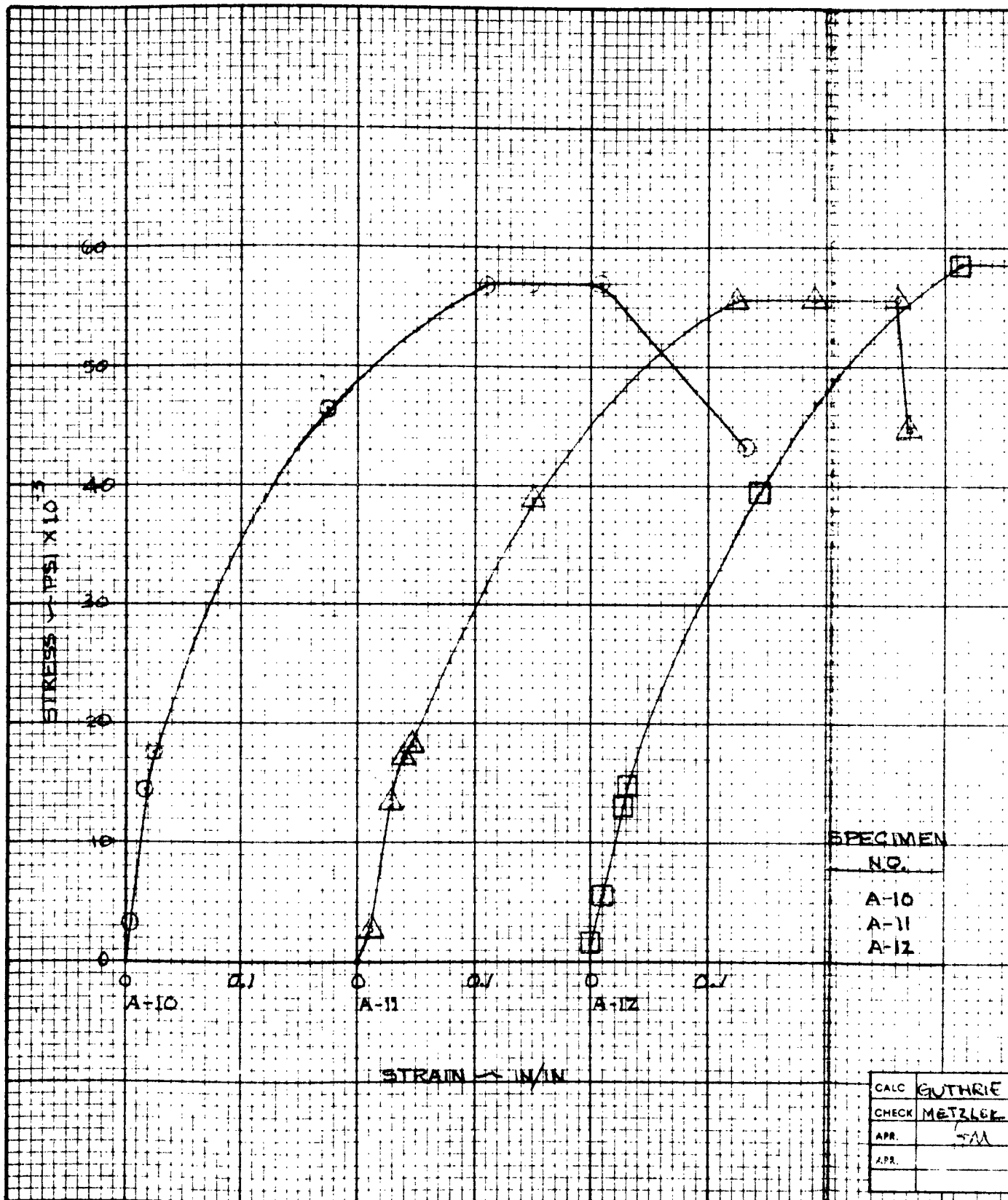
DATA SHEET

CALC	JORDAN
CHECK	JORDAN
APR.	APR.
APR.	APR.

CONTRACT NO.



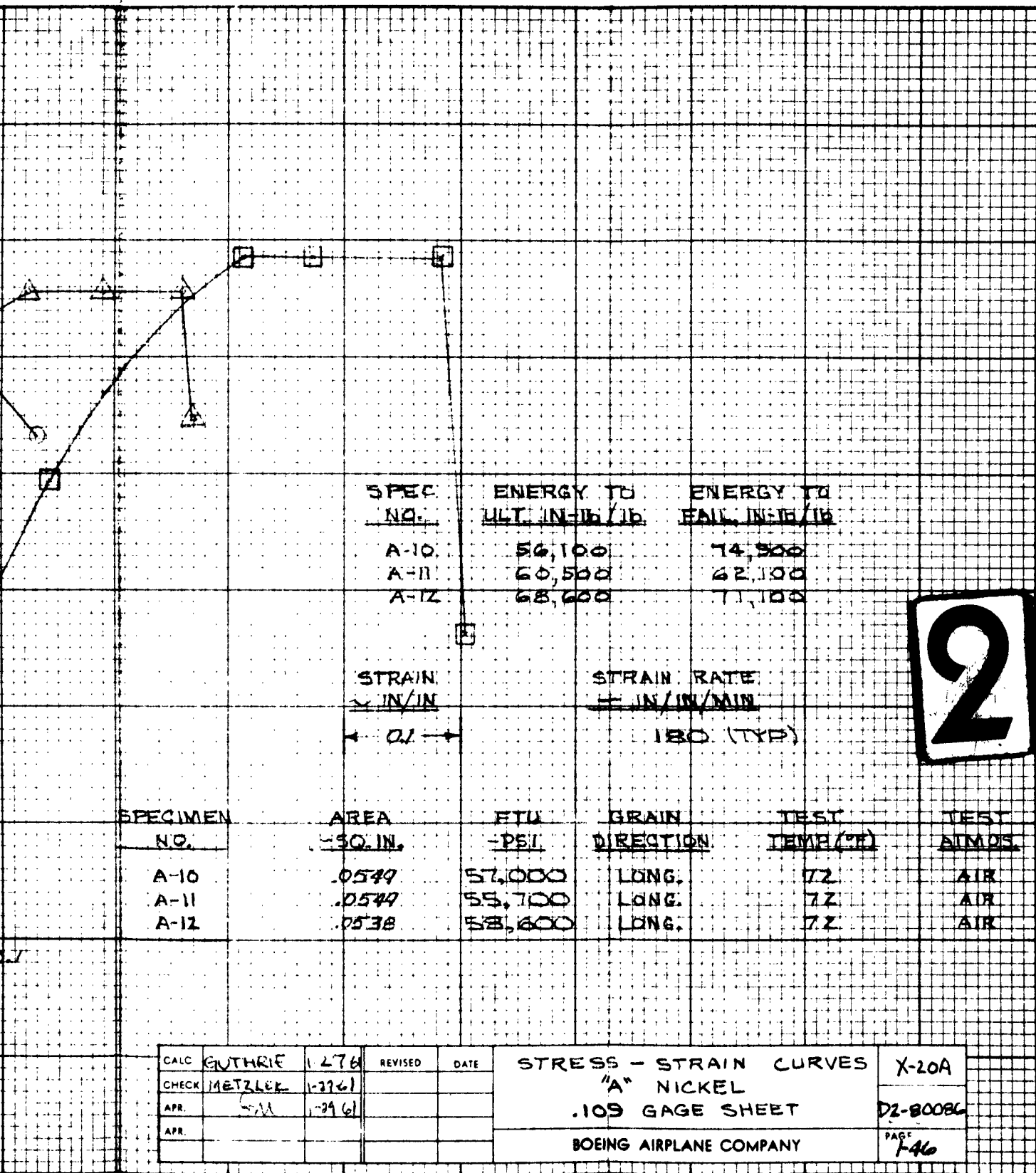
CONTRACT NO



DATA SHEET

CALC	GUTHRIE
CHECK	METZGER
APR.	5/11
APR.	

CONTRACT NO.



CALC	GUTHRIE	1-27-61	REVISED	DATE	STRESS - STRAIN CURVES "A" NICKEL .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	METZLER	1-27-61				DZ-80086
APR.	SM	1-29-61				PAGE 1-46
APR.						

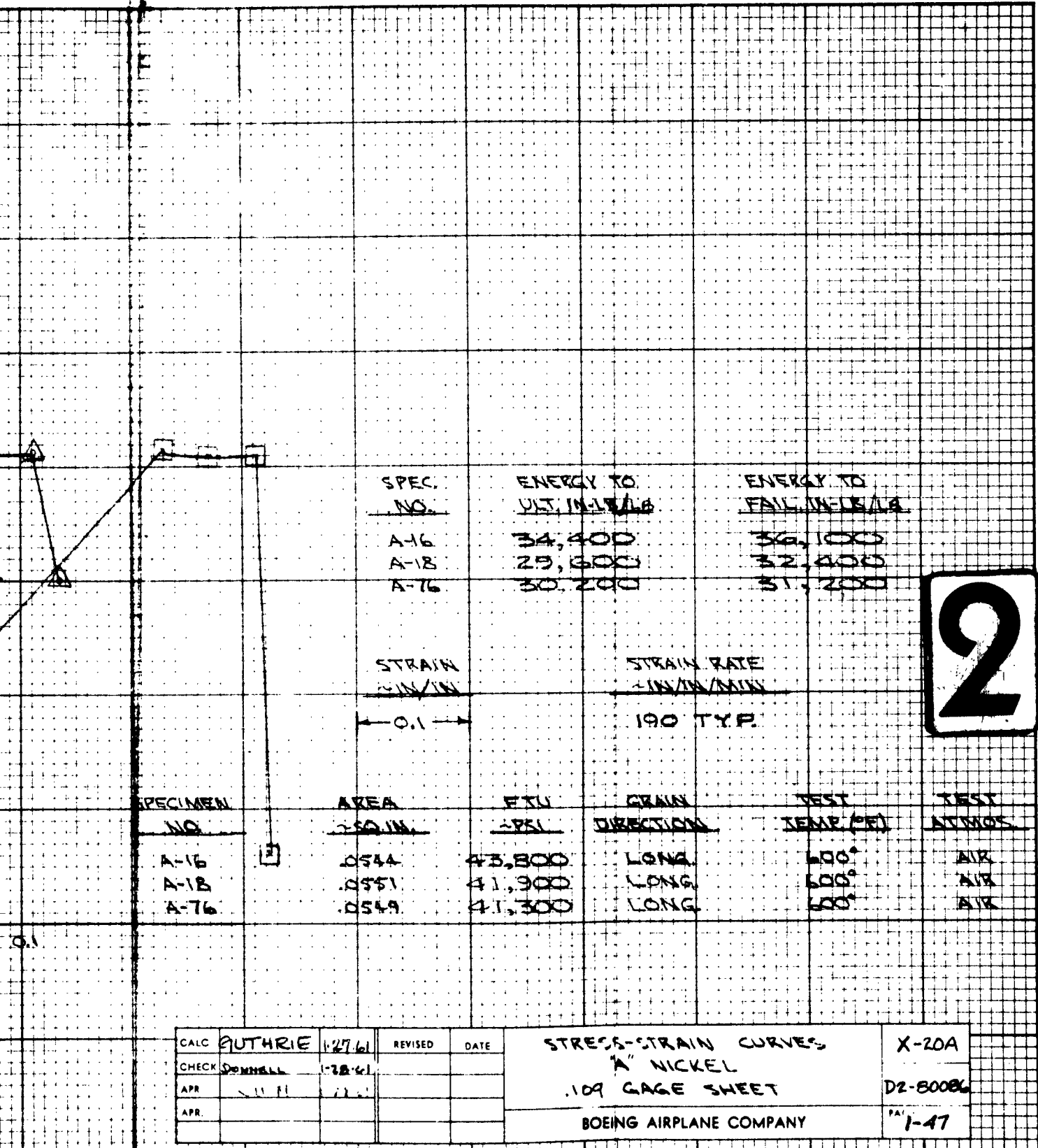
CONTRACT NO.



DATA SHEET

CALC	EUTHRIE
CHECK	DOMINELL
APR	11/11
APR	

CONTRACT NO.



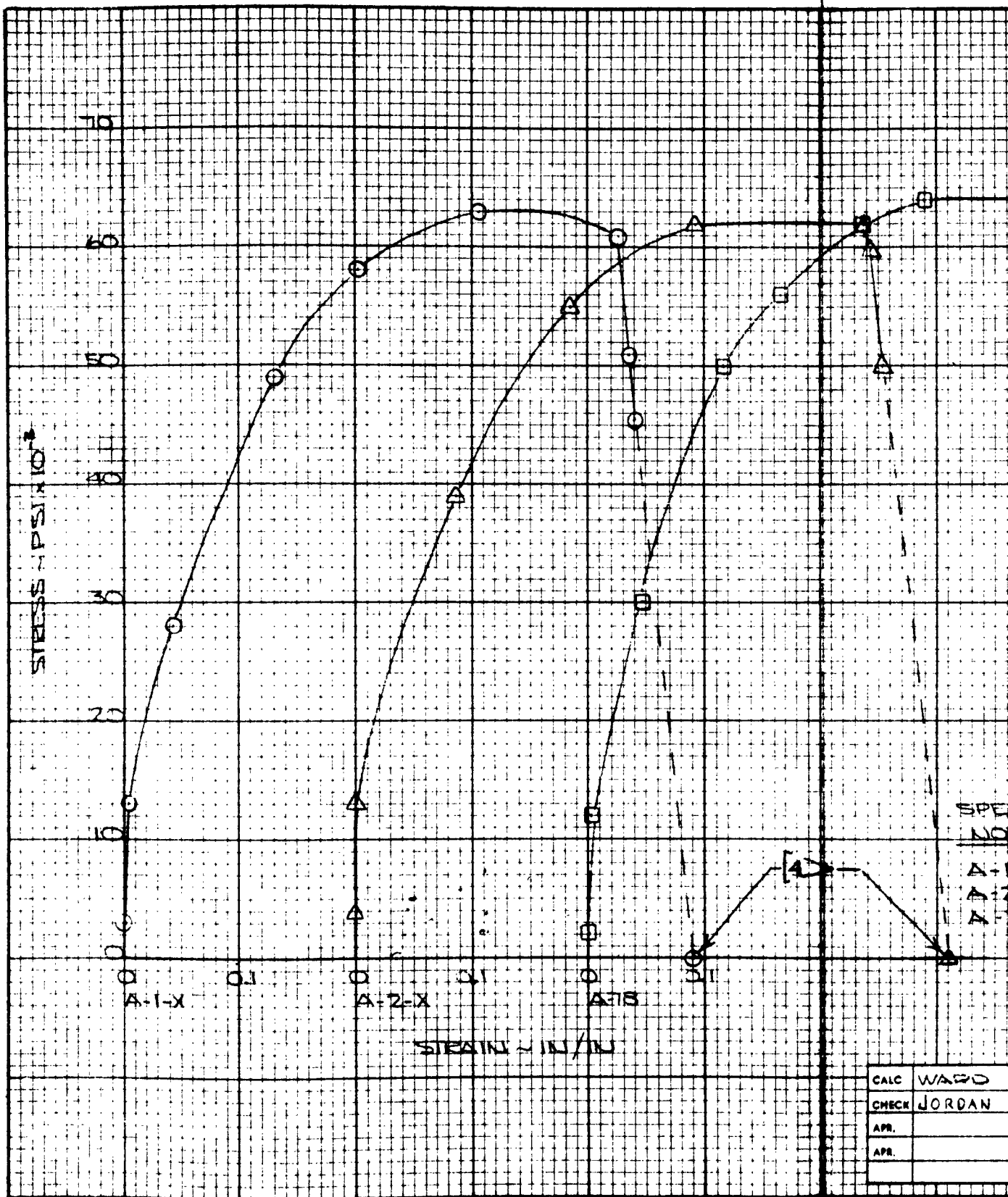
SPEC. NO.	ENERGY TO ULT. IN-IN/LB	ENERGY TO FAIL. IN-IN/LB
A-16	34,400	36,100
A-18	29,600	32,400
A-76	30,200	31,200

STRAIN IN-IN
0.1

STRAIN RATE IN-IN/MIN
190 TYP.

SPECIMEN NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP. (°F)	TEST ATMOS.
A-16	.0544	43,800	LONG.	600°	AIR
A-18	.0551	41,900	LONG.	600°	AIR
A-76	.0549	41,300	LONG.	600°	AIR

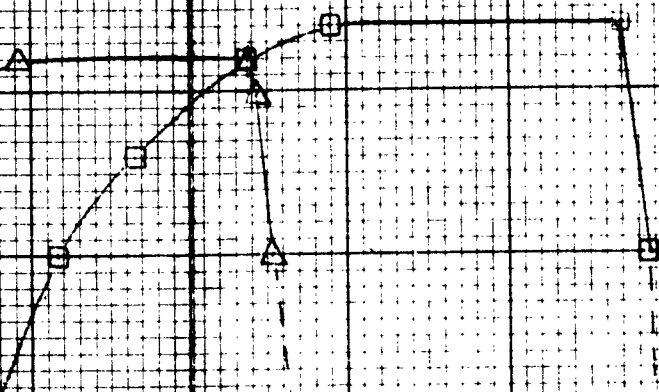
CALC	GUTHRIE	1-27-61	REVISED	DATE	STRESS-STRAIN CURVES 1/2" NICKEL .109 GAGE SHEET	X-20A
CHECK	DOMMELL	1-28-61				D2-80086
APR	11-11	12-11			BOEING AIRPLANE COMPANY	1-47
APR						



DATA SHEET

CONTRACT NO.

2



SPEC. NO.	ENERGY TO ULT. ~IN-LB/LB	ENERGY TO FAIL. ~IN-LB/LB
A-1-X	68,440	74,330
A-2-X	67,750	76,730
A-7B	78,970	83,120

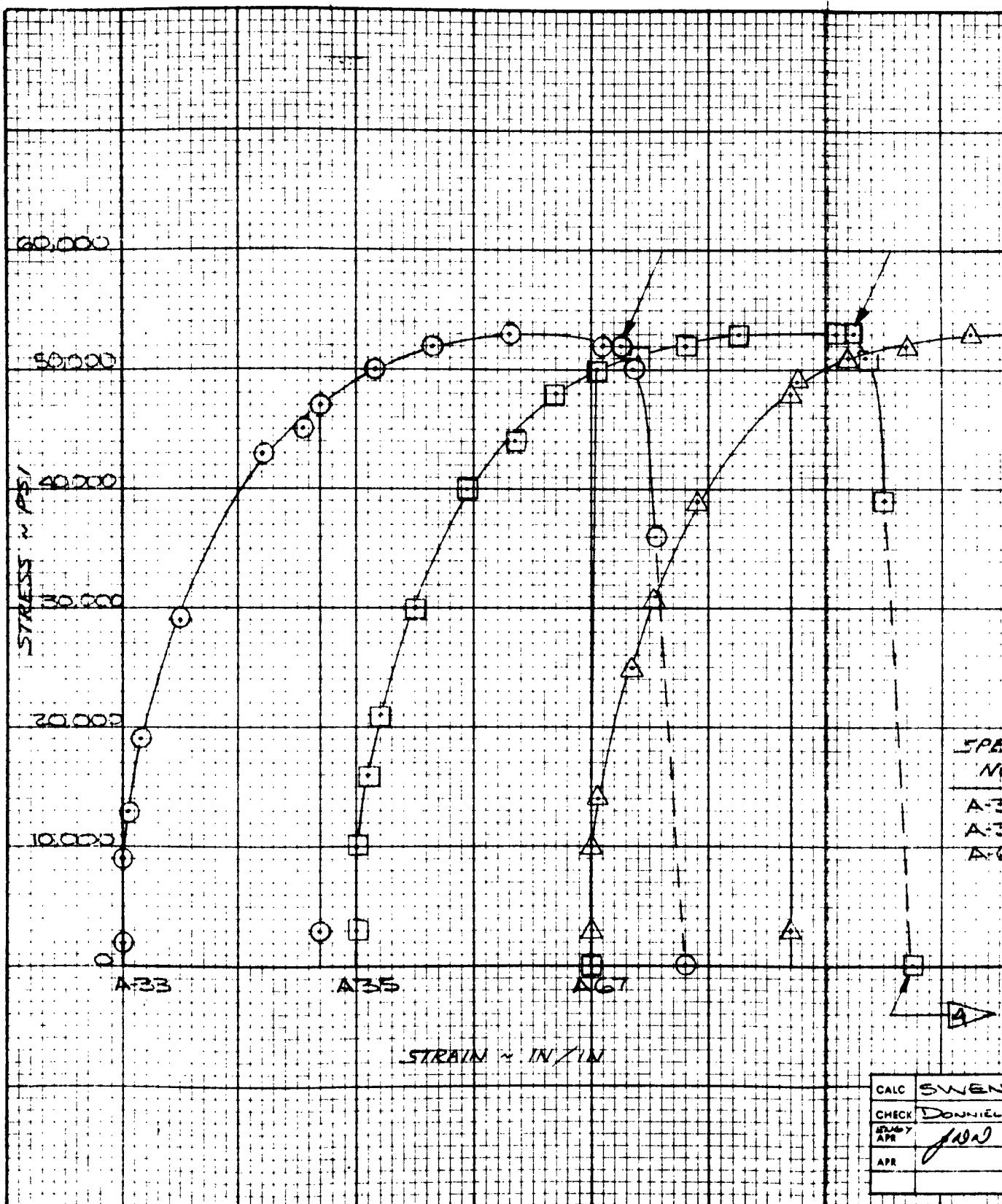
STRAIN ~IN/IN	STRAIN RATE ~IN/IN/MIN
±0.10	200

SPEC. NO.	AREA ~SQ. IN	FTU ~PSI	GRAIN DIRECTION	TEST TEMP. °F	TEST ATMOS.
A-1-X	.0533	63,000	LONG.	-65	NITROGEN
A-2-X	.0532	62,000	LONG.	-65	NITROGEN
A-7B	.0534	64,000	LONG.	-65	NITROGEN

SEE PAGE 1-20 FOR NOTES

CALC WARD 3-22-1 CHECK JORDAN 3-29-1 APR. APR.	REVISED DATE . 	STRESS-STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-48
---	----------------------------------	--	--------------------------------

CONTRACT NO.

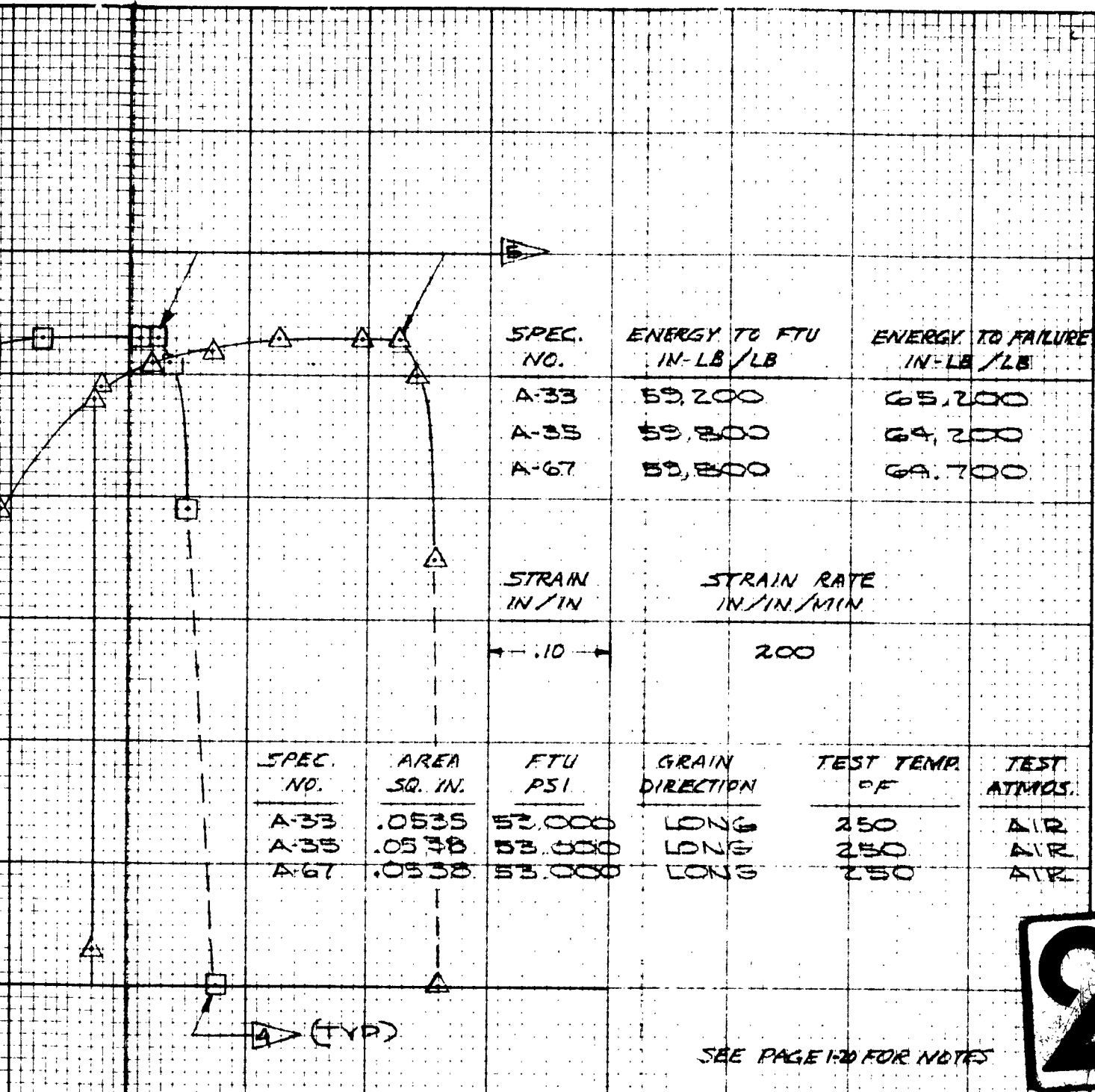


SPE
N
A-33
A-35
A-6

CALC	SWEN
CHECK	DONNIE
READY APR	1000
APR	

CONTRACT NO

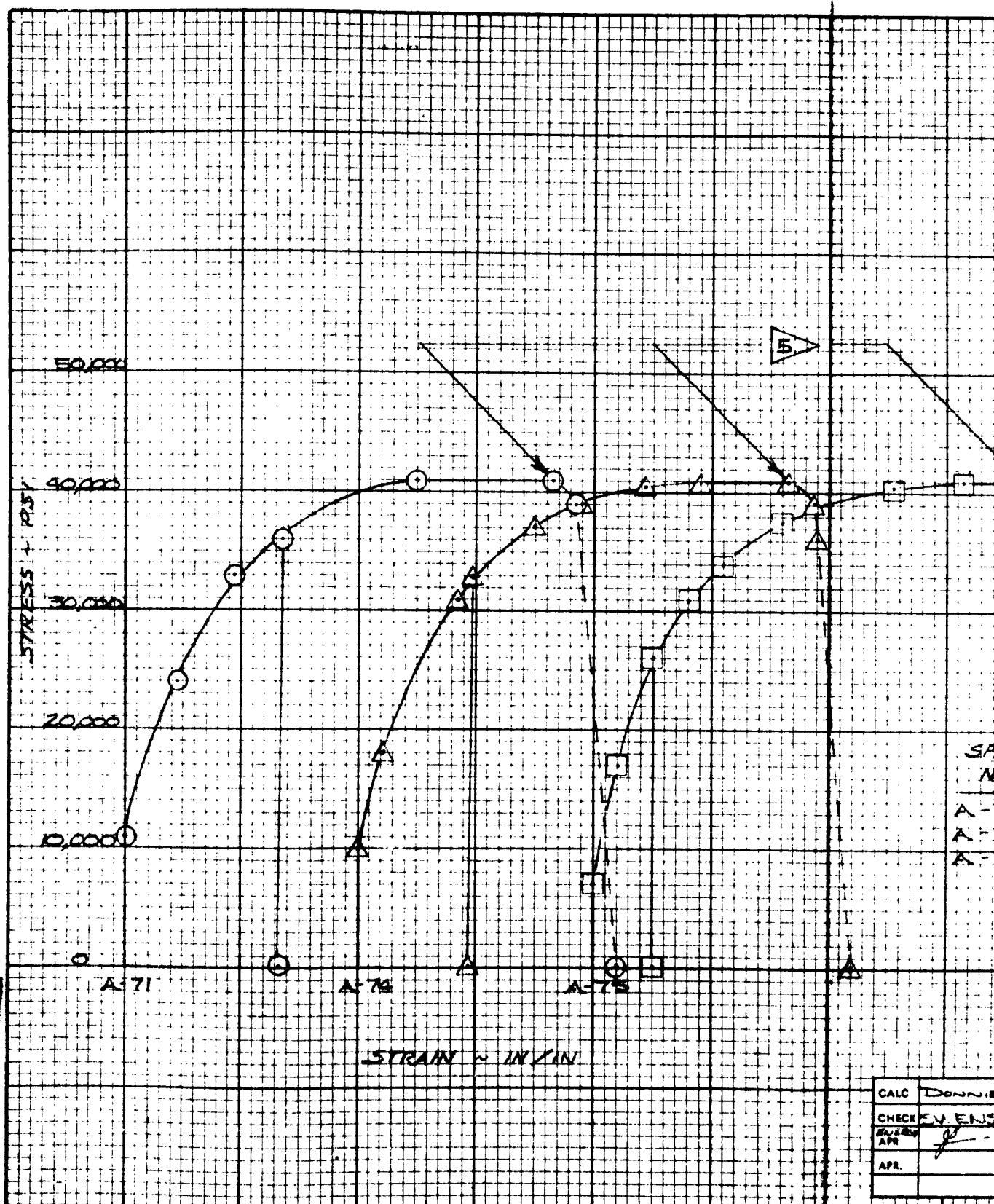
DATA SHEET



CALC	SWEN	5-51	REVISED	DATE	STRESS STRAIN CURVES	X-20A
CHECK	DONNELL	5-18-1			NICKEL A	D2-80086
APR.					.109 GAGE SHEET	PAGE 149
					BOEING AIRPLANE COMPANY	

CONTRACT NO.

1



A-71

A-72

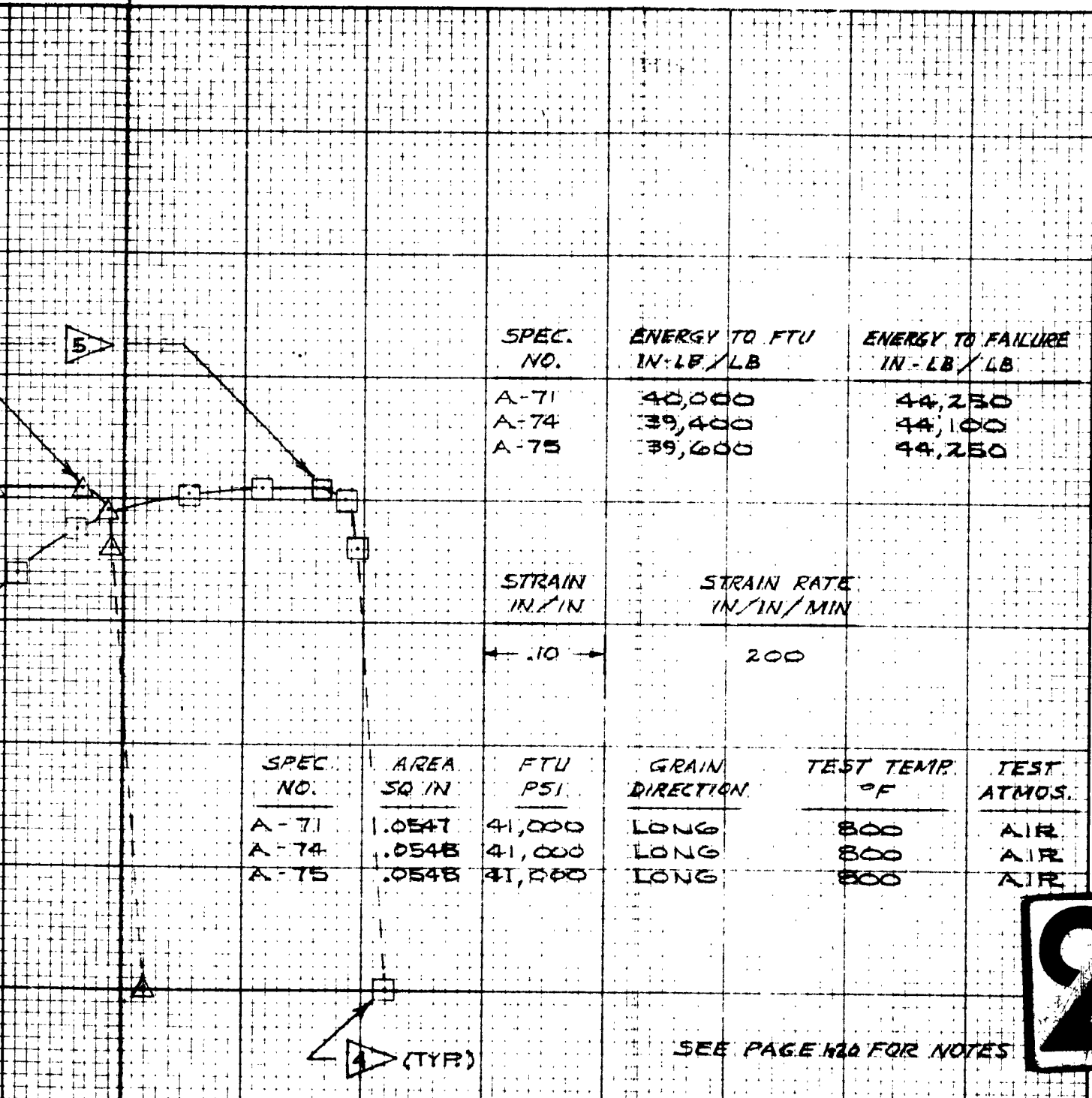
A-75

STRAIN - IN/IN

CALC	DONNIE
CHECKED	ENS
DATE	APR
APR	

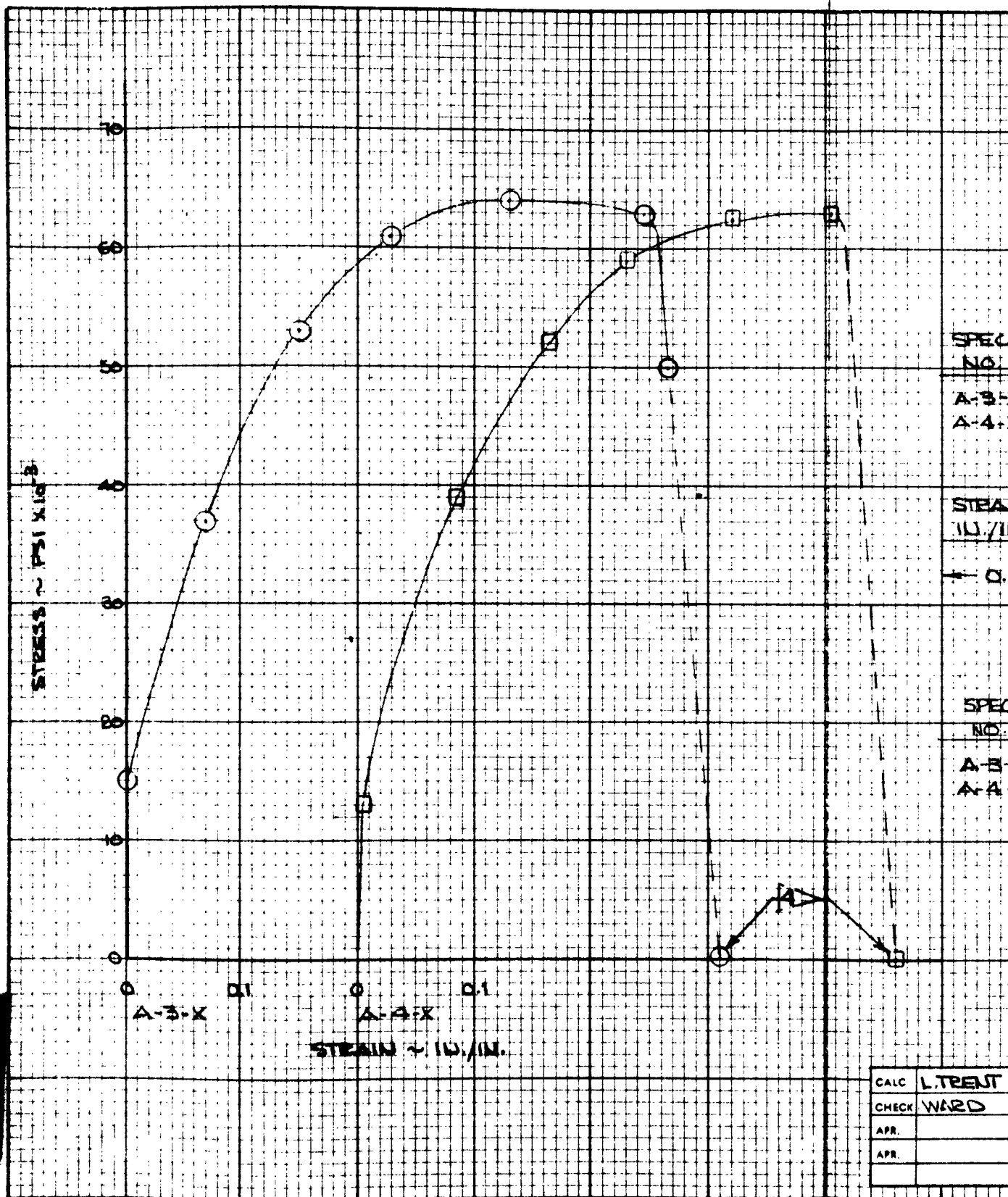
DATA SHEET

CONTRACT NO.



CALC CHECK APPROV APR.	DONNELL S-18-1 EVENSON S-18-1 	REVISED 	DATE 	STRESS STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 150
---------------------------------	--	-------------------------	----------------------	--	----------------------------------

CONTRACT NO.



SPEC NO.

A-3-

A-4-

STRA IN./IN.

0.

SPEC NO.

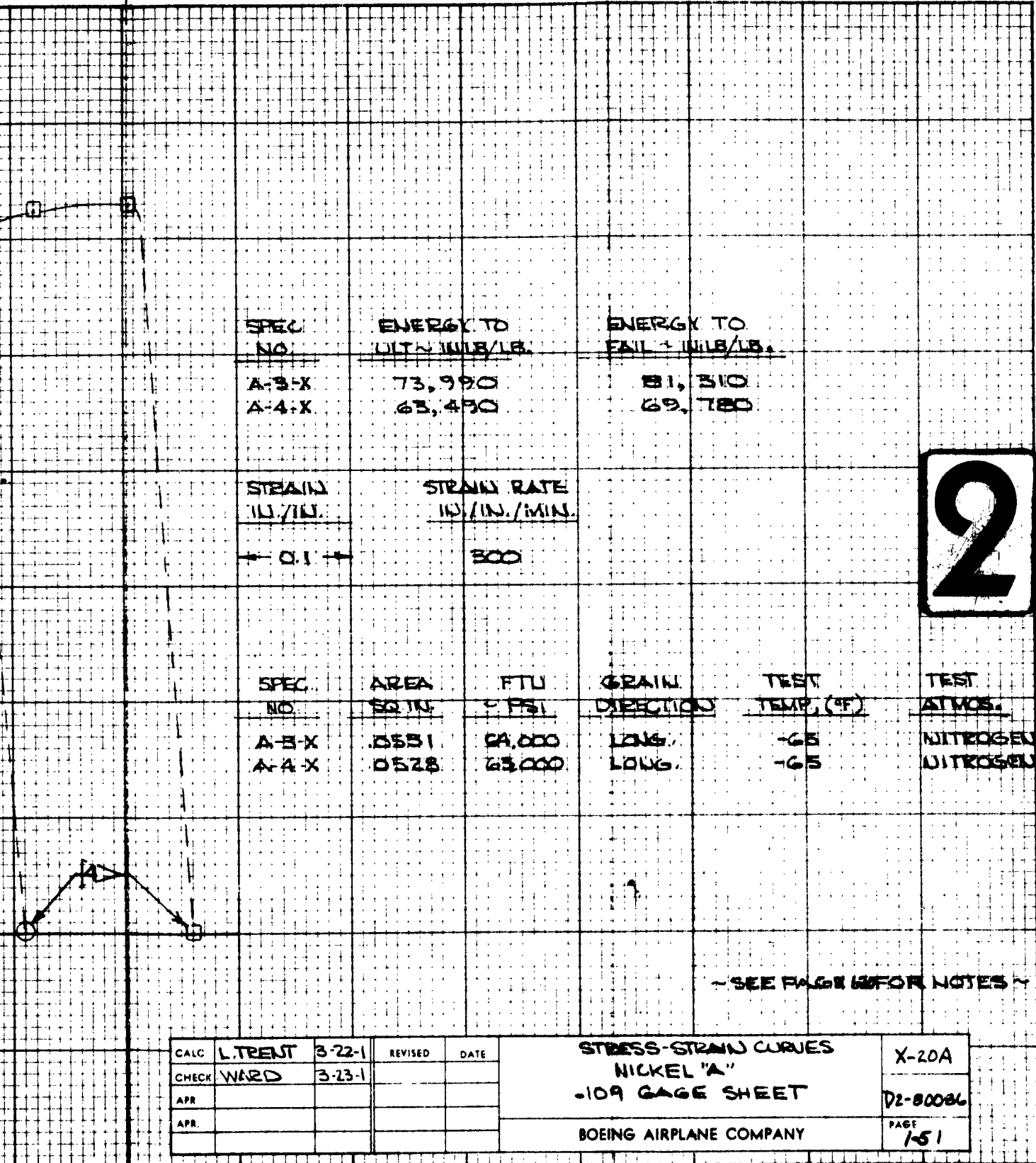
A-3-

A-4-

CALC	L.TRENT
CHECK	WARD
APR.	
APR.	

CONTRACT NO.

DATA SHEET



SPEC. NO.	ENERGY TO ULT. IN LB./IN.	ENERGY TO FAIL IN LB./IN.
A-3-X	73,990	81,310
A-4-X	63,450	69,780

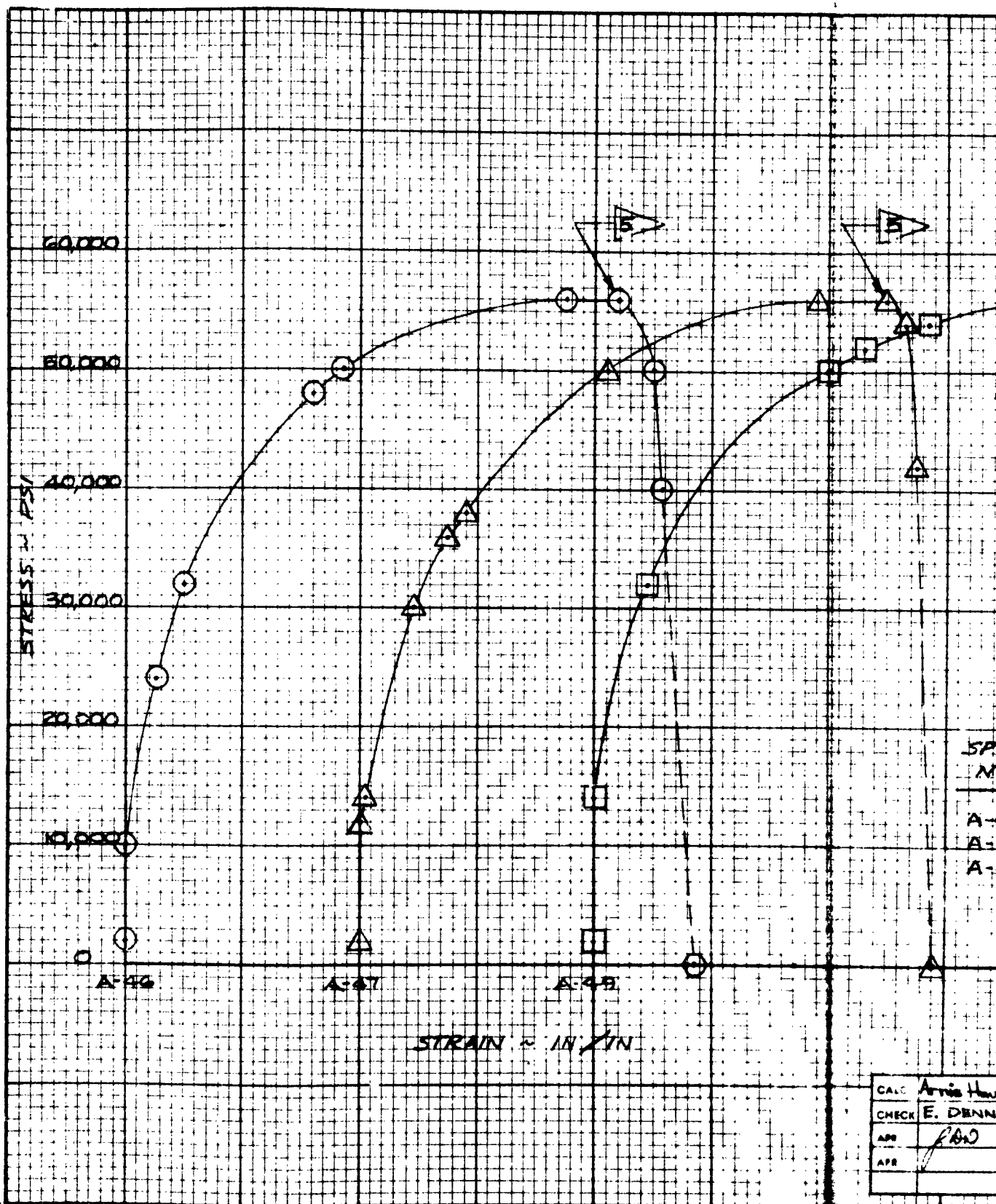
STRAIN IN./IN.	STRAIN RATE IN./IN./MIN.
0.1	300

SPEC. NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP. (°F)	TEST ATMOS.
A-3-X	.0531	64,000	LONG.	-65	NITROGEN
A-4-X	.0528	63,000	LONG.	-65	NITROGEN

~ SEE PAGE 150 FOR NOTES ~

CALC	L.TRENT	3-22-1	REVISED	DATE	STRESS-STRAIN CURVES	X-20A
CHECK	WARD	3-23-1			NICKEL "A"	
APR					-109 GAGE SHEET	D2-80086
APR					BOEING AIRPLANE COMPANY	PAGE 151

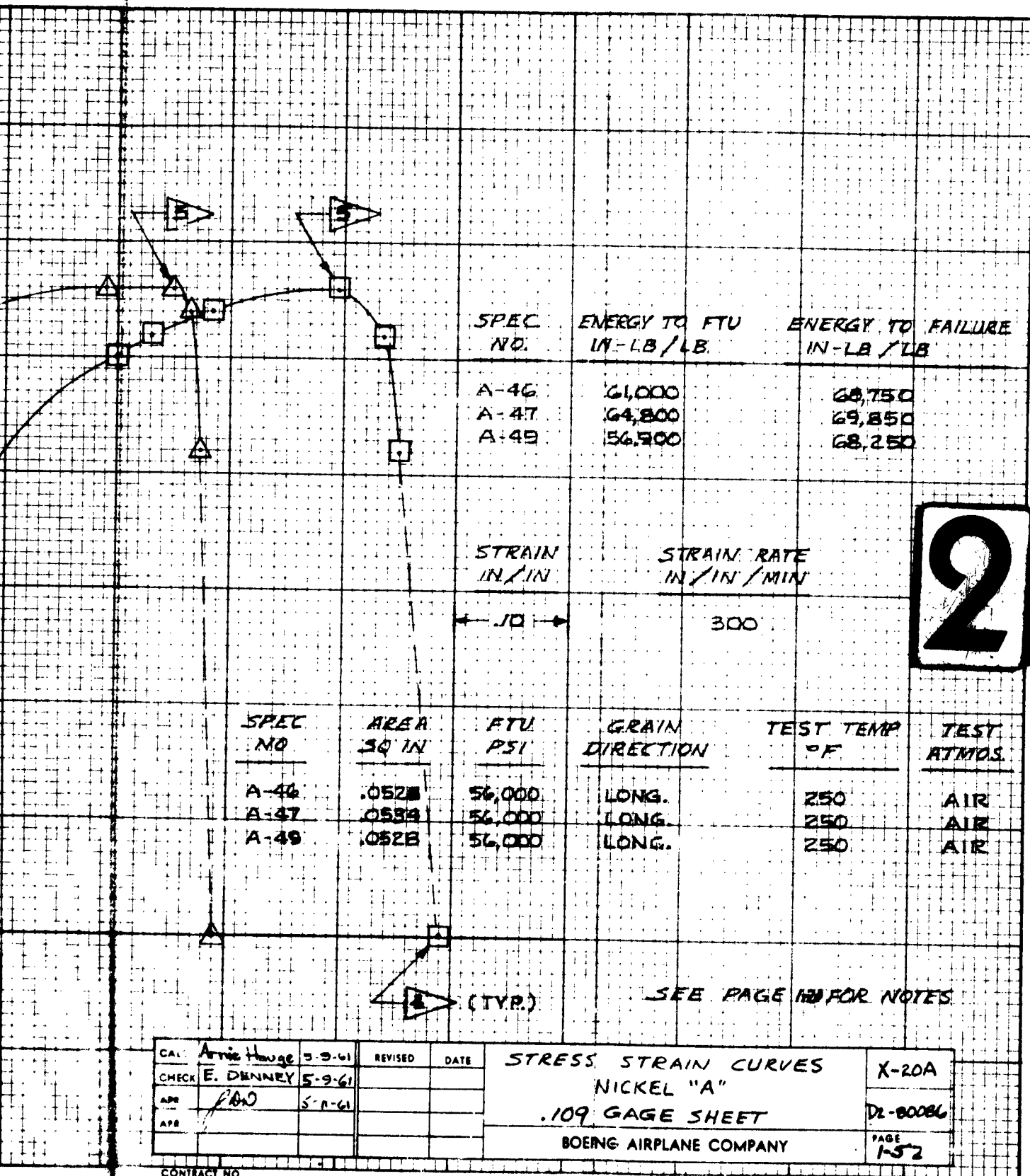
CONTRACT NO.



DATA SHEET

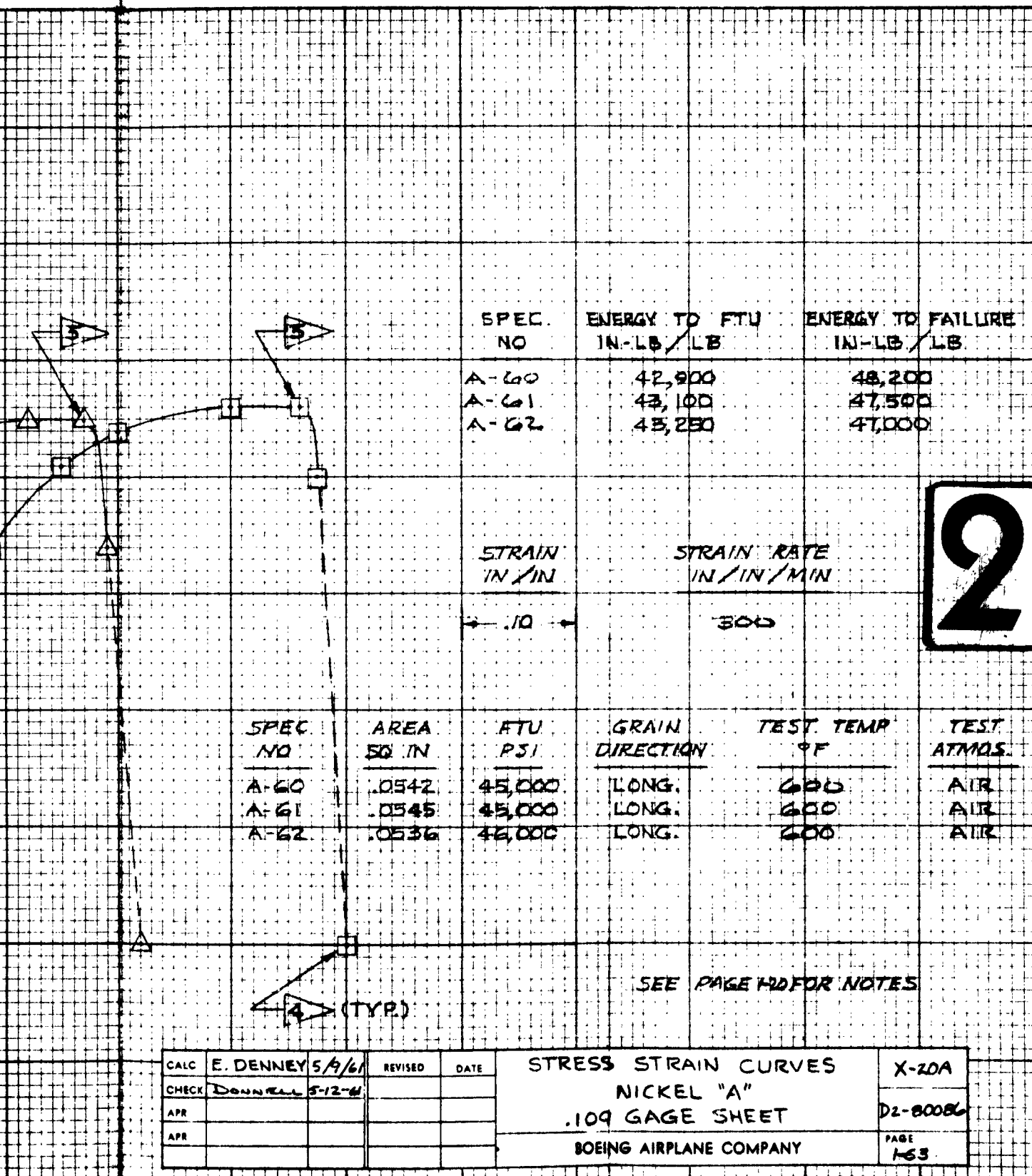
CALC	APR 1960
CHECK	E. DENN
APP	
APR	

CONTRACT NO.



CAL: <u>Arnie Hauge</u>	5-9-61	REVISED	DATE	STRESS STRAIN CURVES NICKEL "A" .109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK: <u>E. DENNEY</u>	5-9-61				D2-00086
APP: <u>FBO</u>	5-11-61				PAGE 1-52
APP:					

CONTRACT NO.



SPEC.
NO

ENERGY TO FTU
IN.-LB./LB

ENERGY TO FAILURE
IN.-LB./LB

A-60
A-61
A-62

42,900
43,100
43,250

48,200
47,500
47,000

STRAIN
IN/IN

STRAIN RATE
IN/IN/MIN

.10

300

2

SPEC
NO

AREA
SQ IN

FTU
PSI

GRAIN
DIRECTION

TEST TEMP
°F

TEST
ATMOS.

A-60
A-61
A-62

.0542
.0545
.0536

45,000
45,000
45,000

LONG.
LONG.
LONG.

600
600
600

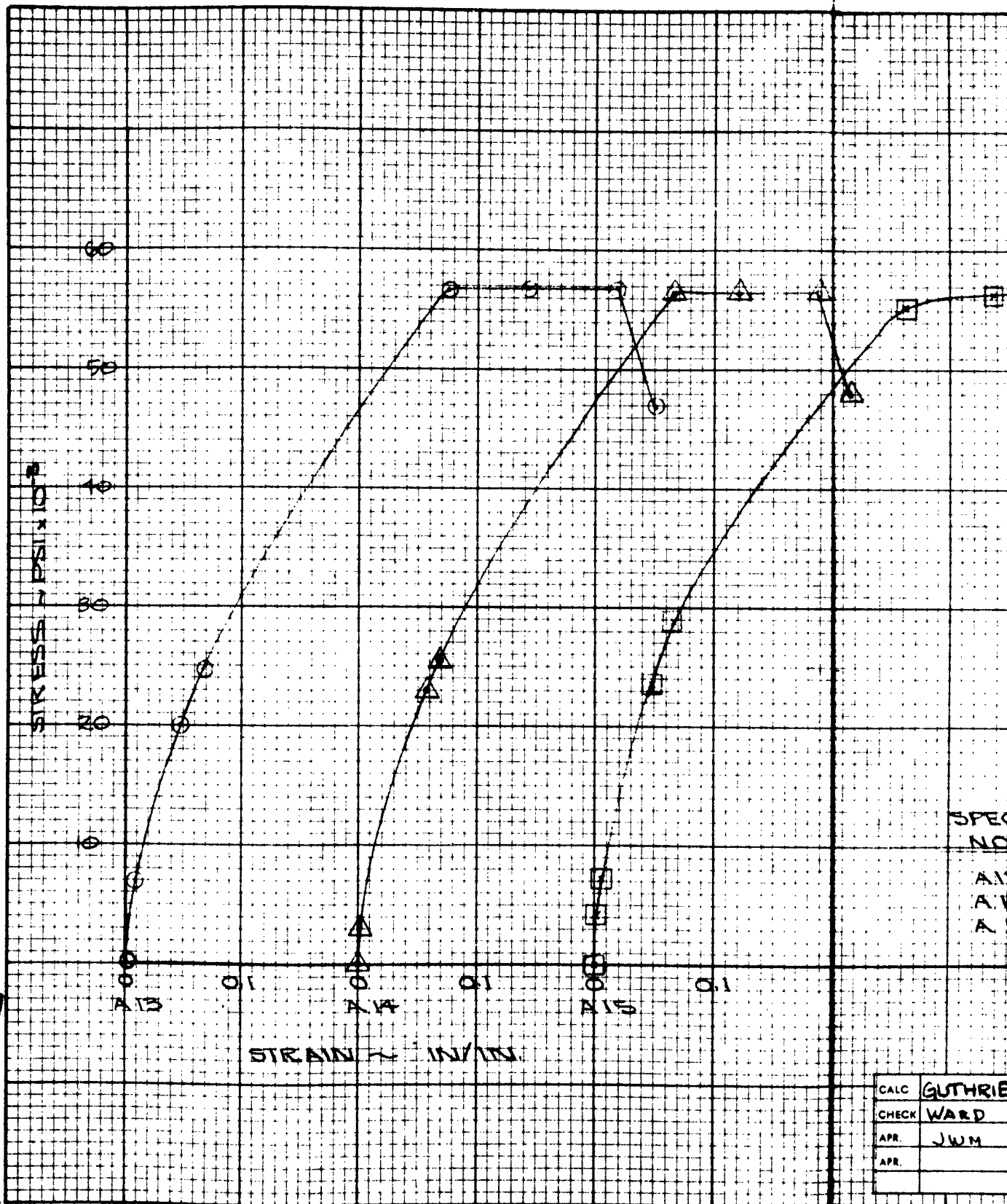
AIR
AIR
AIR

SEE PAGE TWO FOR NOTES

CALC	E. DENNEY	5/9/61	REVISED	DATE
CHECK	DONNELL	5-12-61		
APR				
APR				

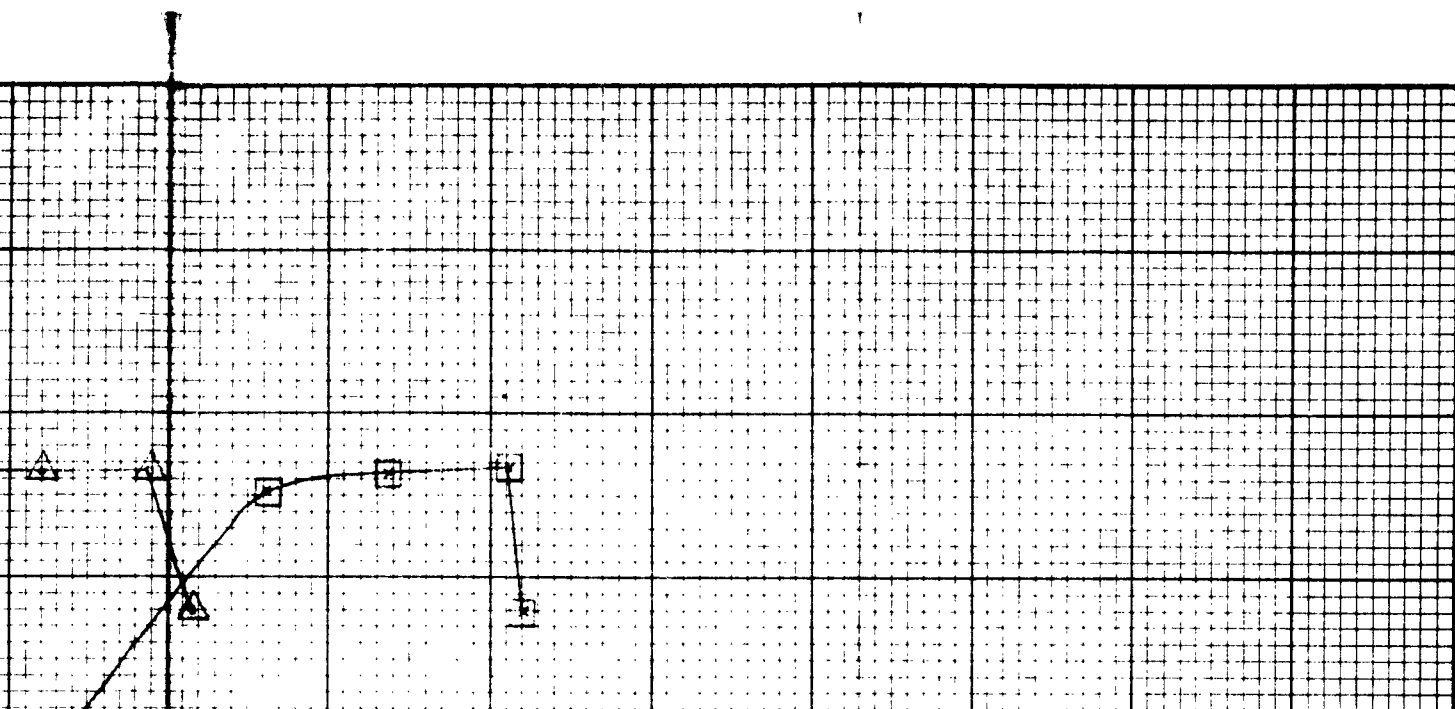
STRESS STRAIN CURVES
NICKEL "A"
.109 GAGE SHEET
BOEING AIRPLANE COMPANY

X-20A
D2-80086
PAGE
163



DATA SHEET

CONTRACT NO.



SPEC NO.	ENERGY TO ULT. IN-LB/LB	ENERGY TO FAIL IN-LB/LB
A13	55,500	60,500
A14	53,000	54,200
A15	56,000	57,500

STRAIN ~IN./IN.	STRAIN RATE ~IN./IN./MIN.
←0.1→	280 IN./IN./MIN. (TYP)

2

SPEC. NO.	AREA ~SQ. IN.	FTU ~PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOS.
A13	.0547	56,800	LONG.	72	AIR
A14	.0546	56,600	LONG.	72	AIR
A15	.0547	56,800	LONG.	72	AIR

CALC	GUTHRIE	1-27-61
CHECK	WARD	1-27-61
APR.	JWM	1-28-61
APR.		

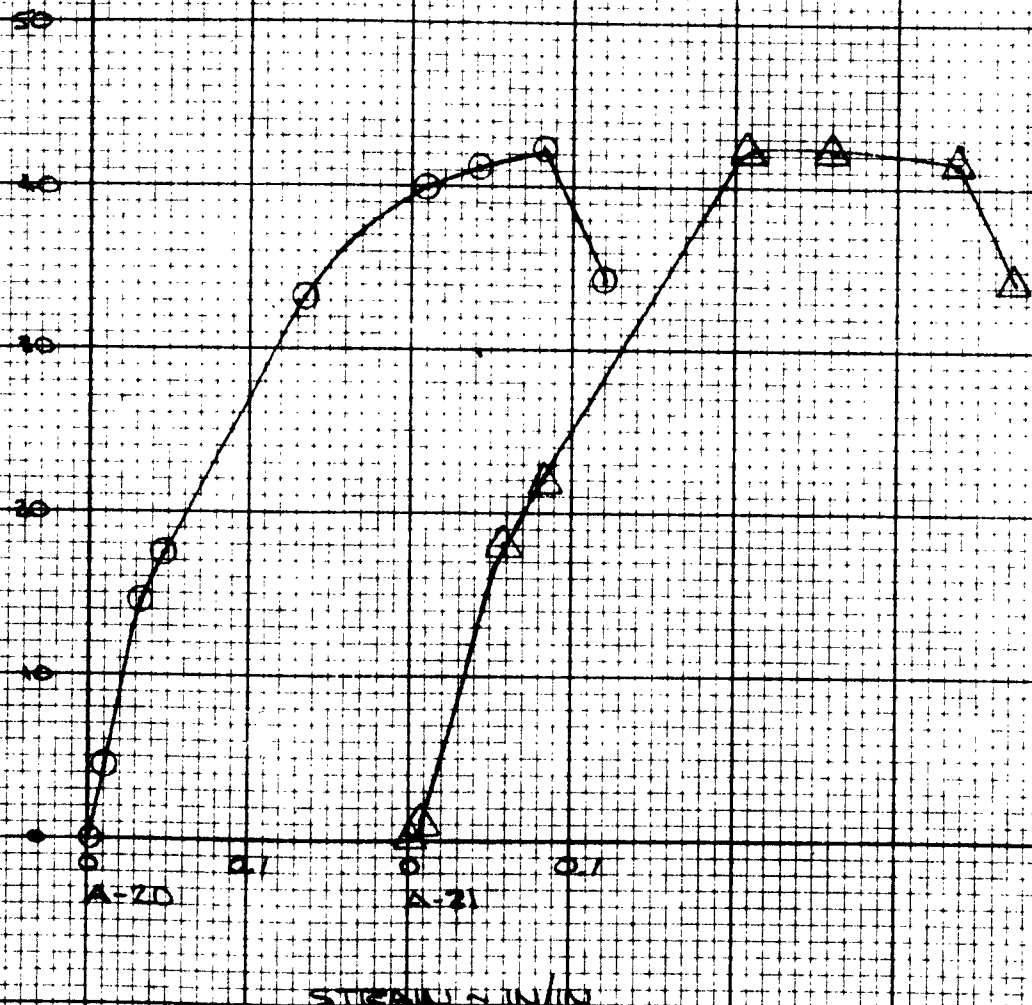
REVISED	DATE

STRESS - STRAIN CURVES
 "A" NICKEL
 .100 GAGE SHEET
 BOEING AIRPLANE COMPANY

X-20A
 D2-80086
 PAGE 1-54

CONTRACT NO.

STRESS IN PSI X 10³



A-20

A-21

STRAIN IN IN/IN

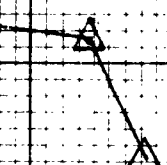
DATA SHEET

U3 4011 5000-REV. 7/60 (WAS BAC 340D)

CALC	WARD
CHECK	OLSON
APR.	JULY
APR.	

CONTRACT NO.

2



SPECIMEN NO.	ENERGY TO ULT. IN- $\frac{LB}{IN}$	ENERGY TO FAILURE IN- $\frac{LB}{IN}$
A-20	26,200	20,800
A-21	32,600	34,800

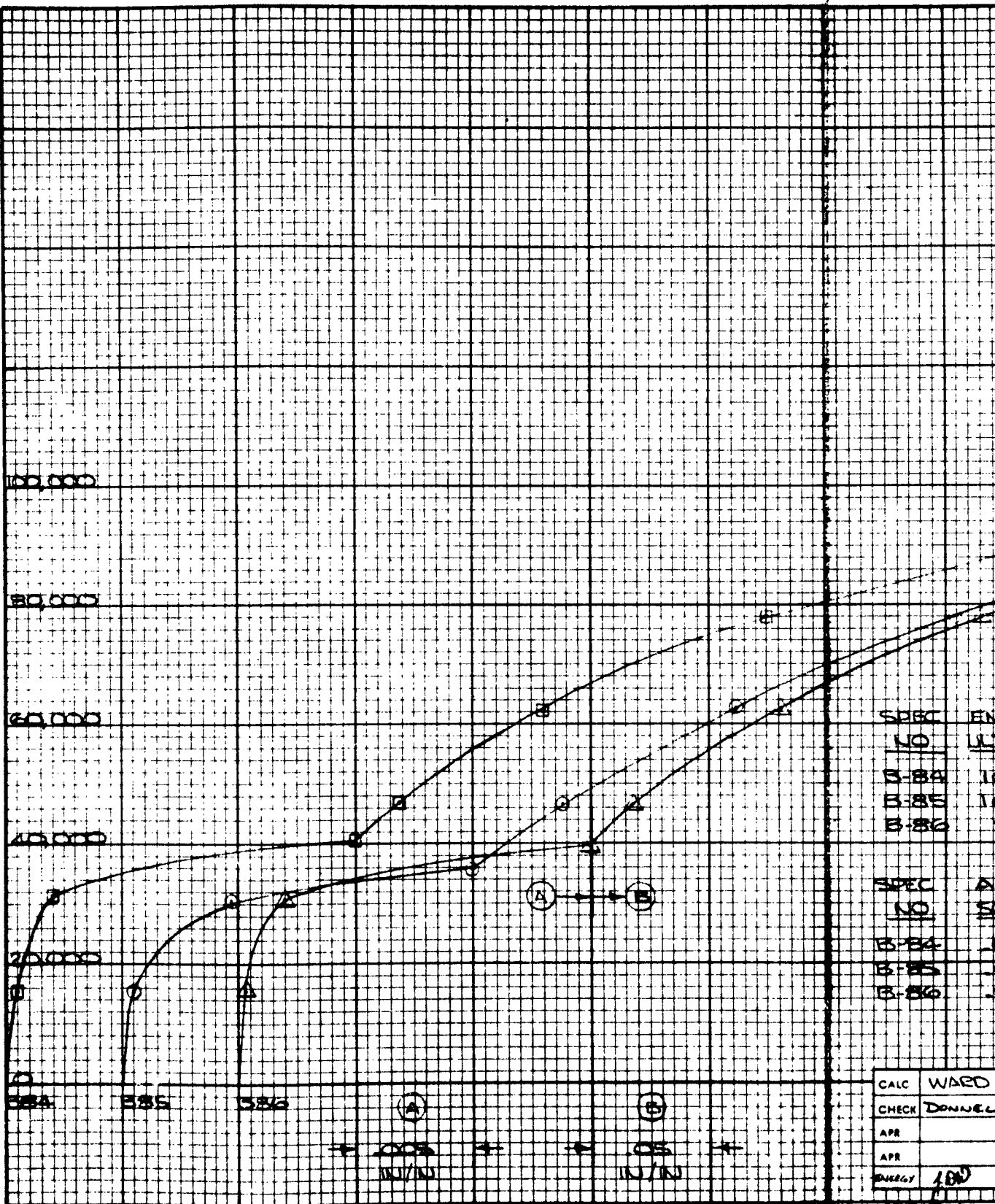
STRAIN ~IN/IN	STRAIN RATE ~IN/IN/MIN
~0.1~	280 (TYP)

SPECIMEN NO.	AREA ~SQ. IN.	ETU ~PSI	GRAIN DIRECTION	TEST TEMPERATURE	TEST ATMOS.
A-20	.0552	42,200	LONG.	800	AIR
A-21	.0552	42,200	LONG.	800	AIR

CALC	WARD	1-2-61	REVISED	DATE	STRESS-STRAIN CURVES "A" NICKEL 109 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	OLSON	1-27-61				D2-80086
APR.	JULIAN	1-28-61				PAGE 105
APR.						

CONTRACT NO

STRESS-PSI



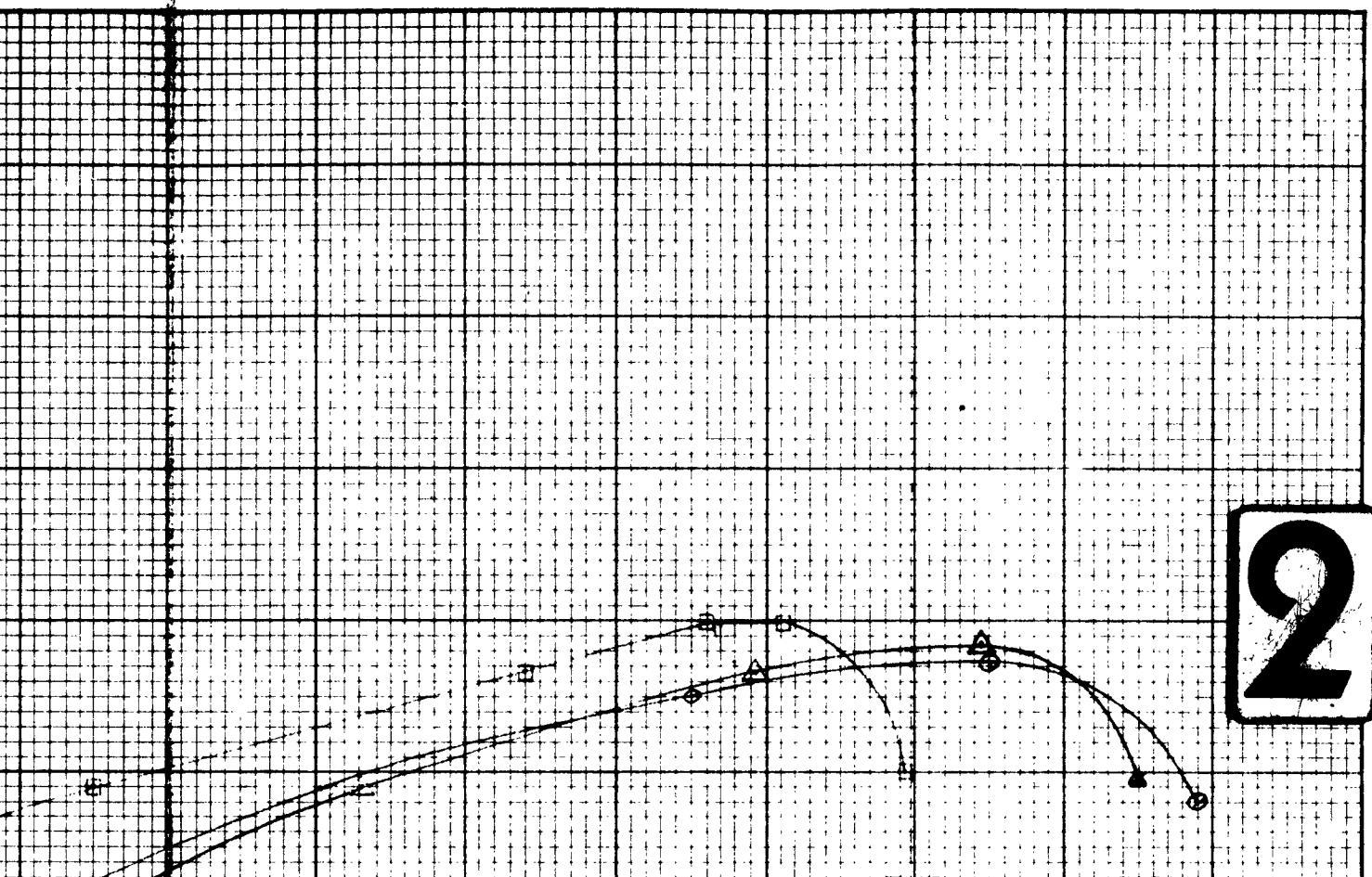
SPEC	EN
10	10
B-B4	12
B-B5	12
B-B6	12

CALC	WARD
CHECK	DONNELLY
APR	
APR	
ENERGY	1.00

CONTRACT NO.

DATA SHEET

2

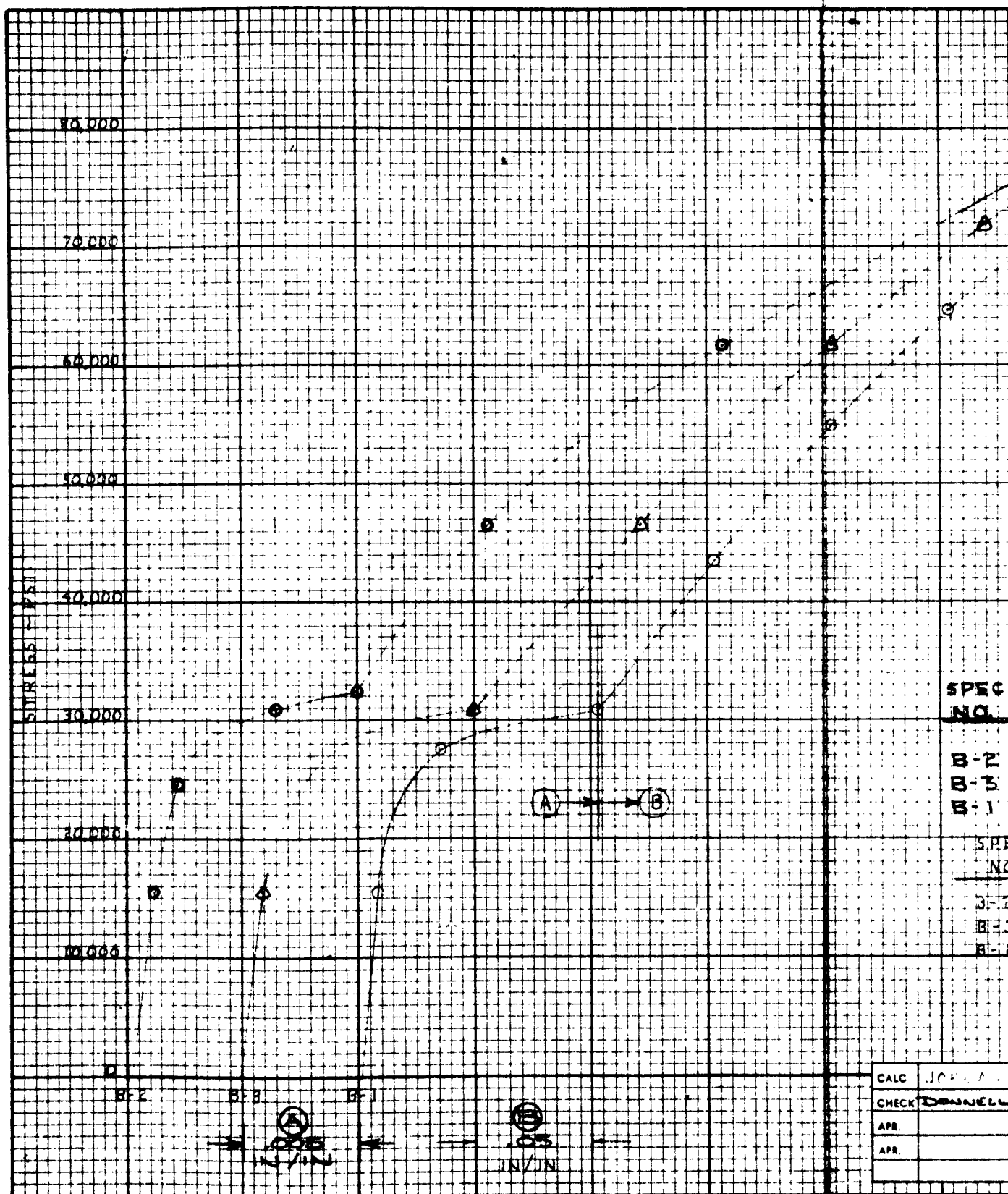


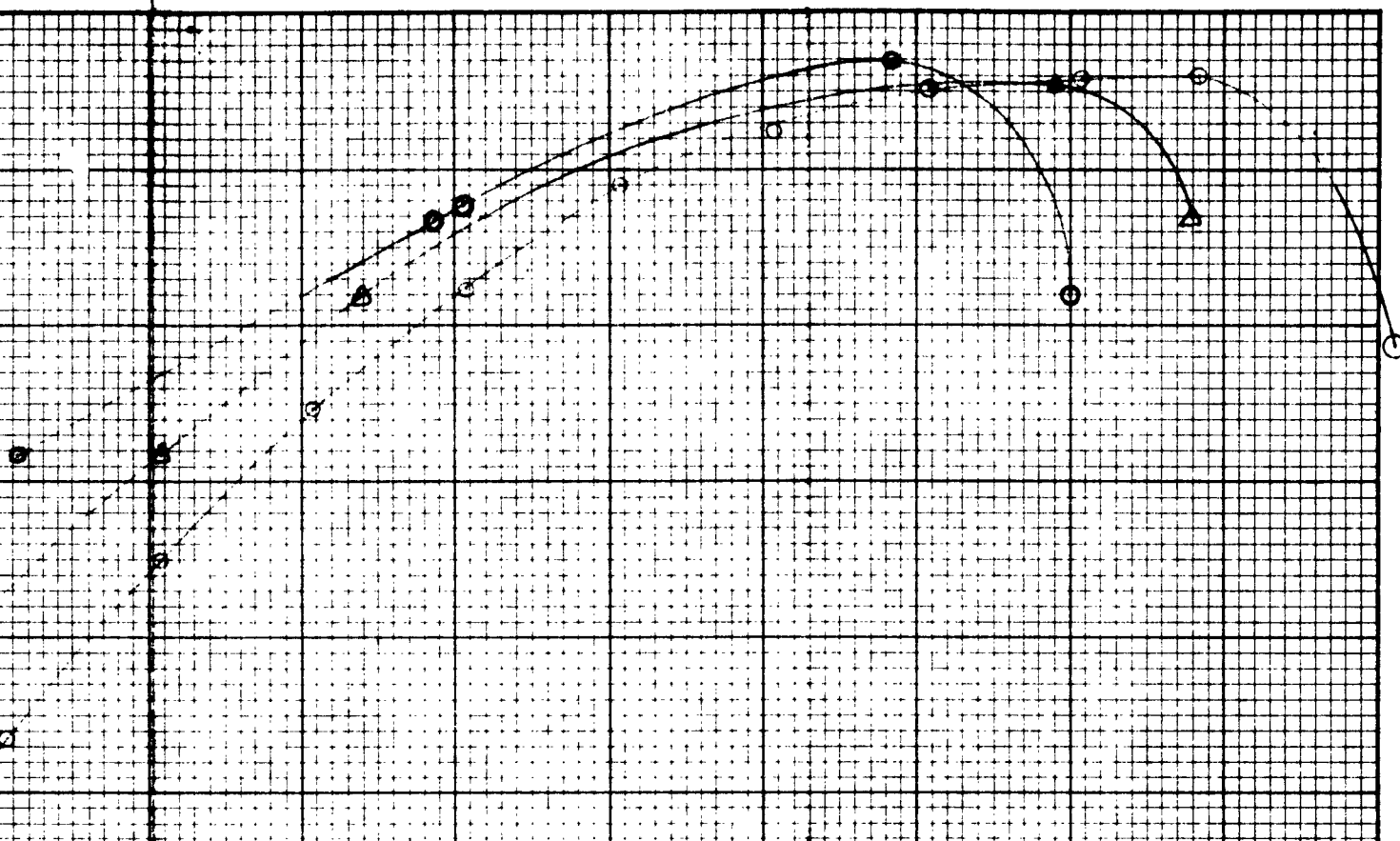
SPEC NO.	ENERGY TO ULT IN-LB/LB	ENERGY TO FAILURE IN-LB/LB	TYPICAL STRAIN IN/IN	TYPICAL STRAIN RATE IN/IN/MIN
B-84	107,000	120,000	(A) +.005	(A) = .005
B-85	106,500	127,500	(B) +.05	(B) = .10
B-86	98,400	113,700		

SPEC NO.	AREA SQ IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP °F	TEST ATMOSPHERE
B-84	.0640	96,900	LONG.	-65	NITROGEN
B-85	.0640	94,500	LONG.	-65	NITROGEN
B-86	.0640	97,200	LONG.	-65	NITROGEN

CALC WARD 2-24-61 CHECK DONNELL 3-6-61 APR APR ENERGY 100	REVISED DATE	STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-56
---	-----------------	---	--------------------------------

CONTRACT NO.





SPEC NO.	ENERGY TO ULT IN-15/16	ENERGY TO FAIL IN-15/16	TYP STRAIN IN/IN	TYP STRAIN RATE IN/IN/MIN
B-2	99,276	115,168	A = .005	A = .005
B-3	101,261	113,701	B = .05	B = .10
B-1	102,107	119,367		

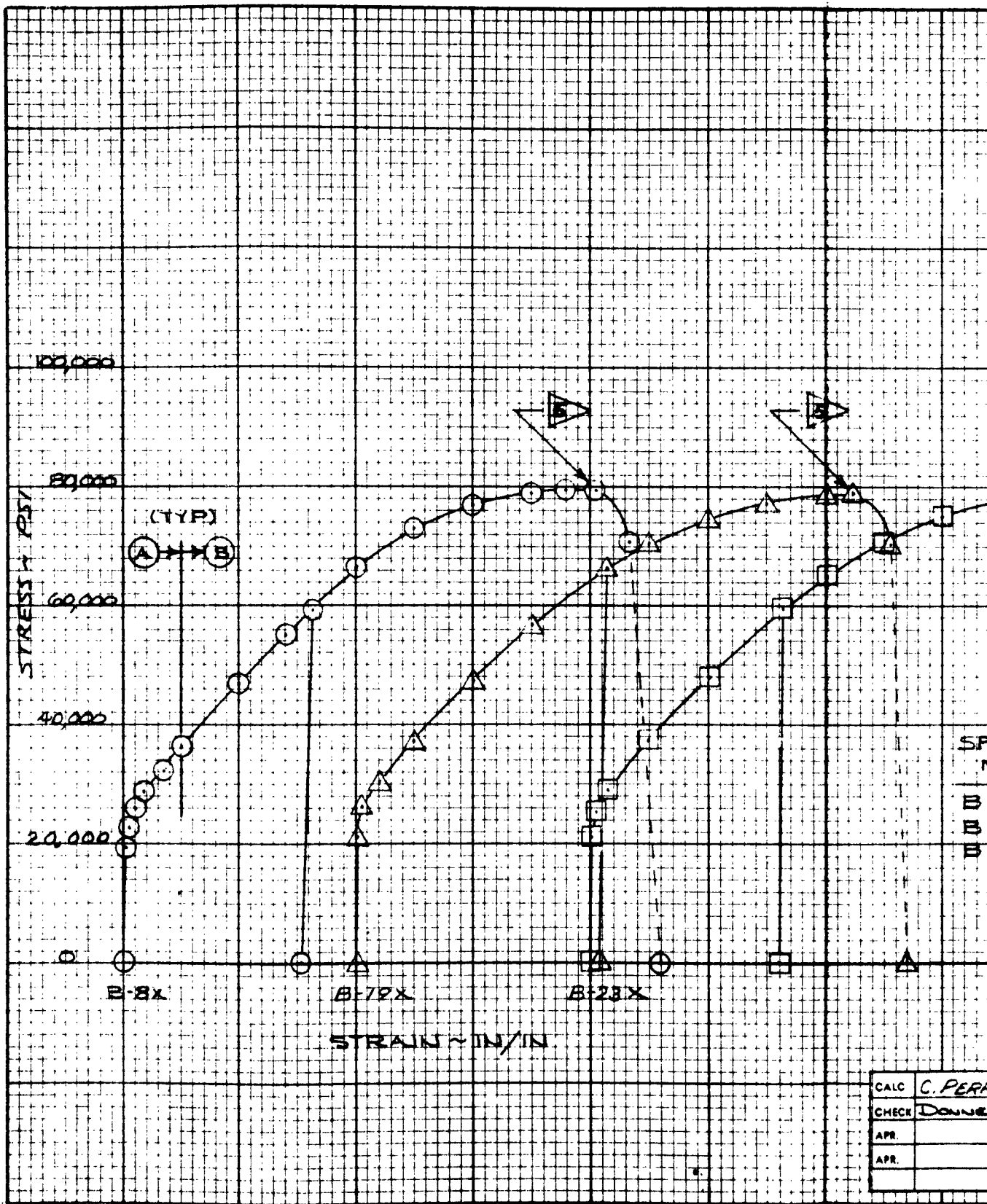
SPEC NO.	AREA SQ IN	FTO PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOSP
B-2	.0648	87,000	LONG	72	AIR
B-3	.0645	85,000	LONG	72	AIR
B-1	.0648	86,000	LONG	72	AIR

2

CALC	JONES	1-4-61	REVISED	DATE	STRESS STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	DONNELL	1-14-61				DZ-80086
APR.						PAGE
APR.						457

CONTRACT NO.

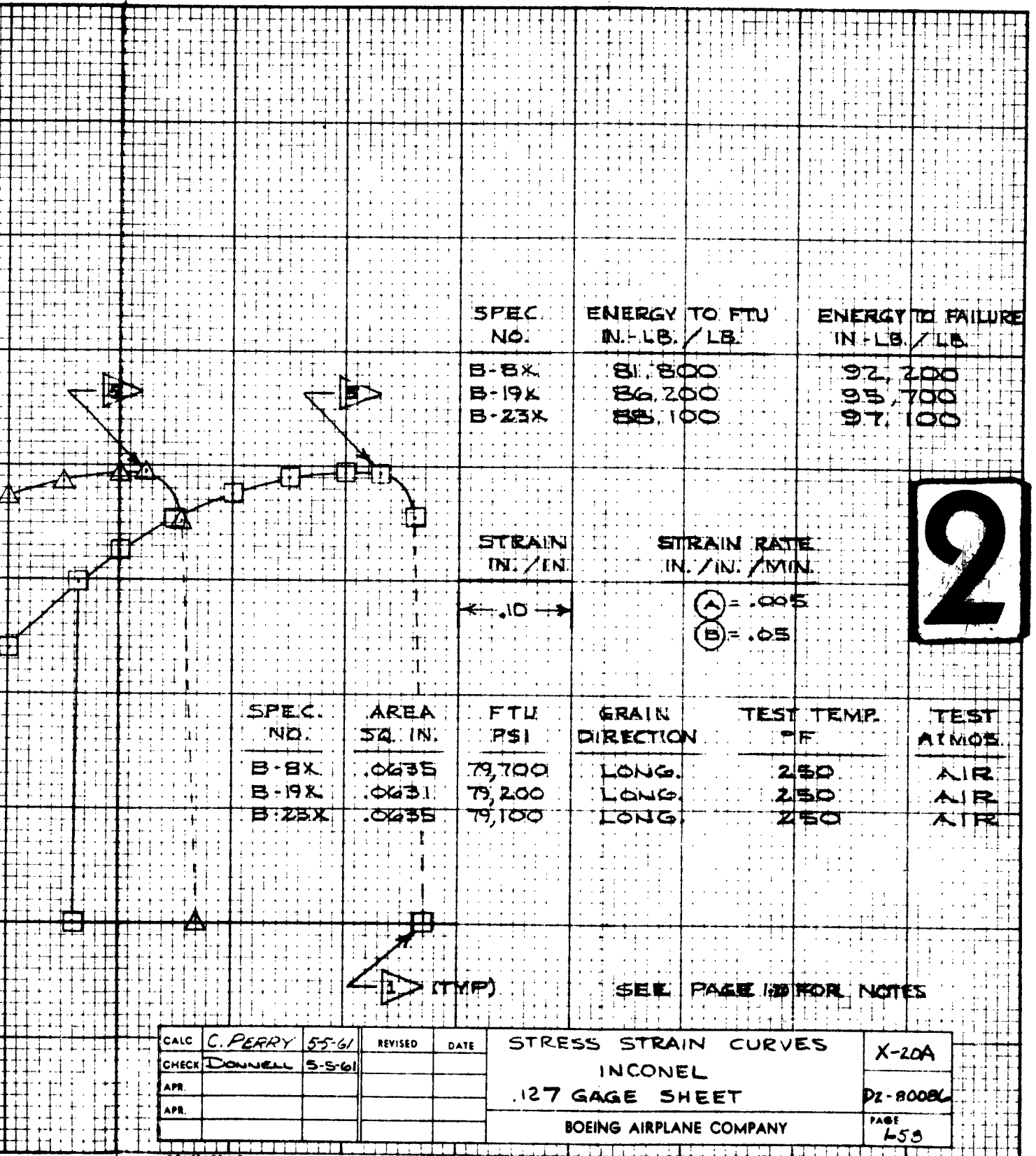
1



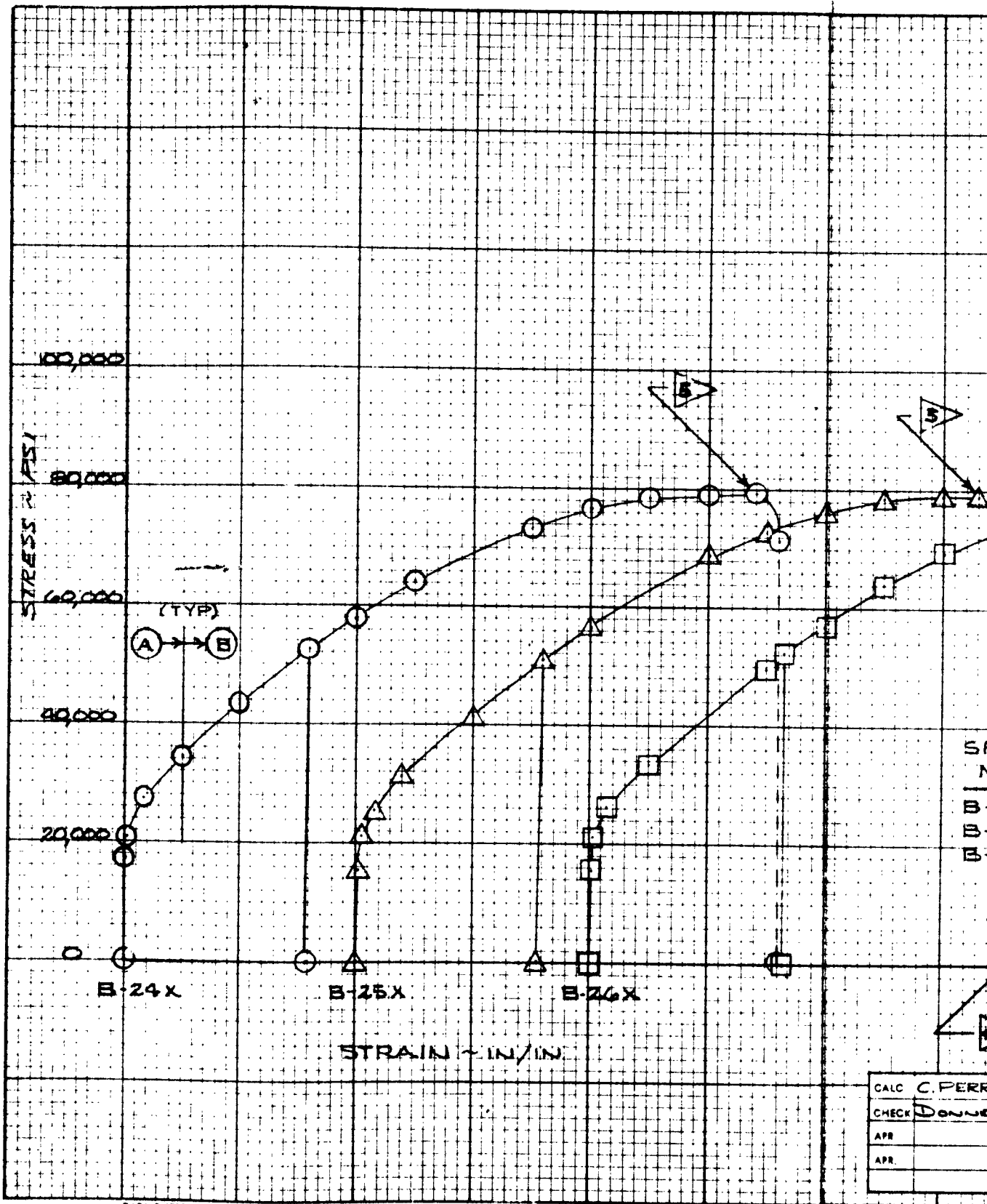
DATA SHEET

CALC	C. PERI
CHECK	Donne
APR.	
APR.	

CONTRACT NO.



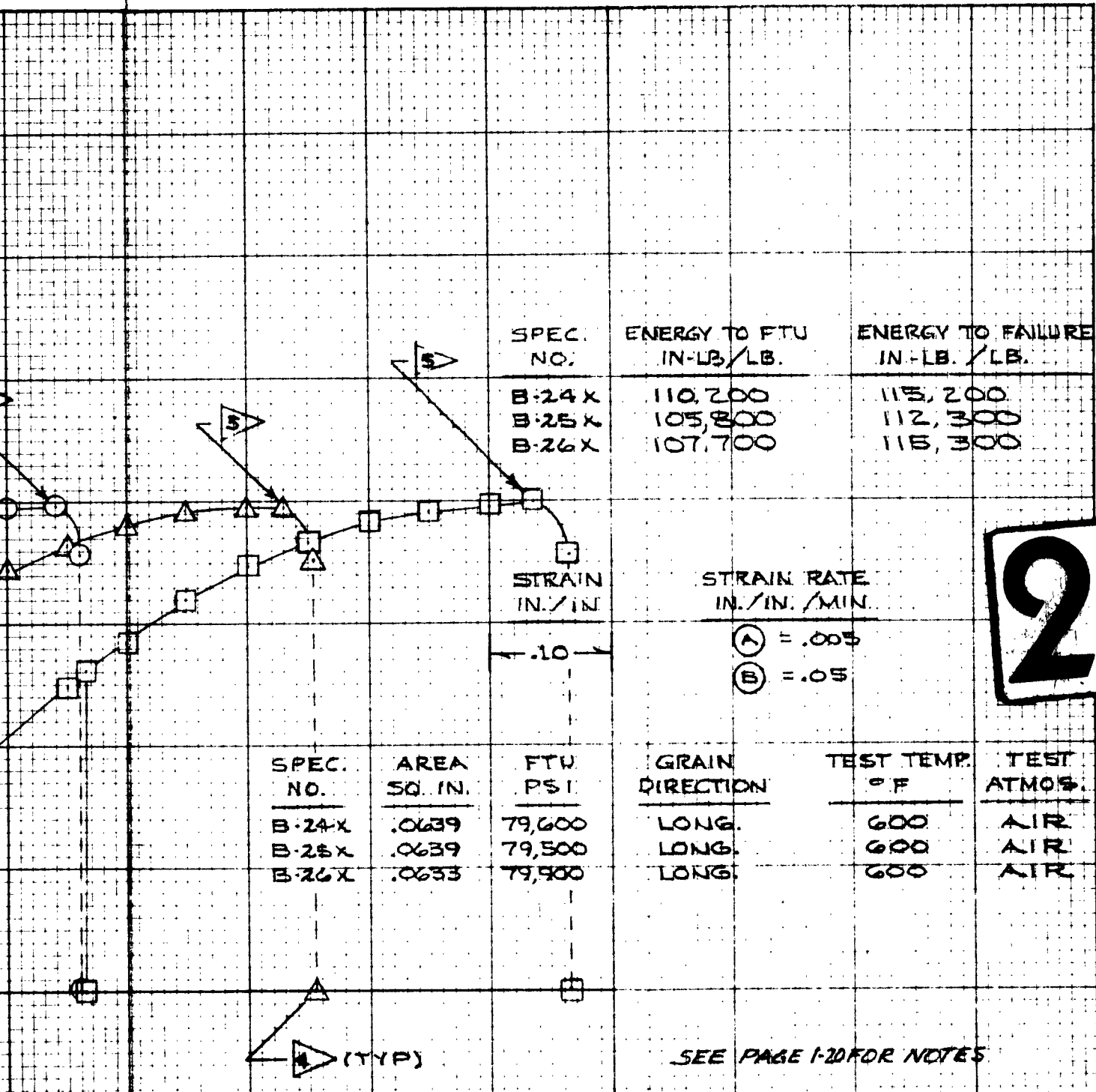
1



DATA SHEET

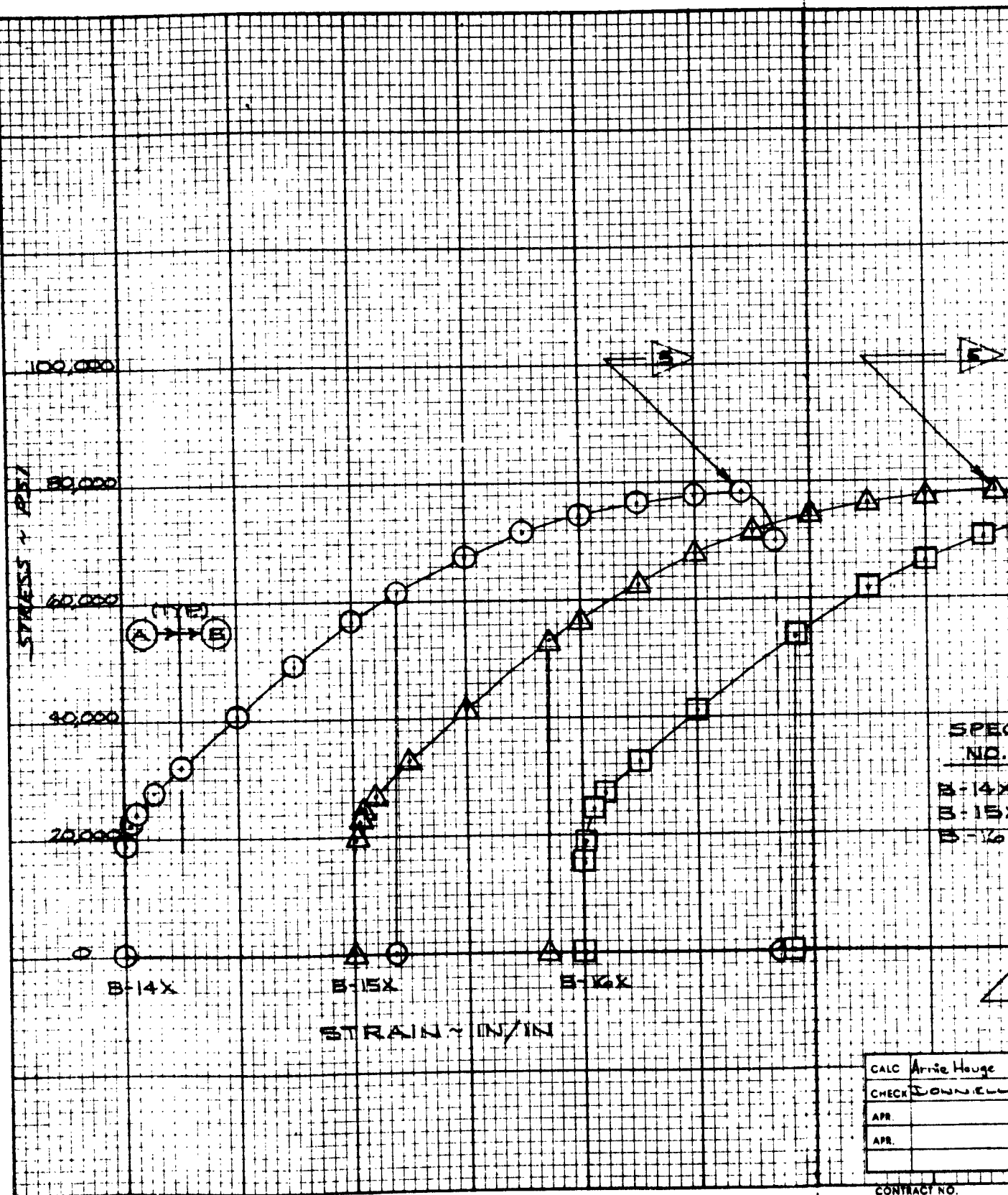
CALC	C. PERR
CHECK	Donne
APR	
APR	

CONTRACT NO.



CALC	C. PERRY S-S-1	REVISED	DATE	STRESS STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	Donnell S-B-1				D2-80086
APR					PAGE 1-59
APR					

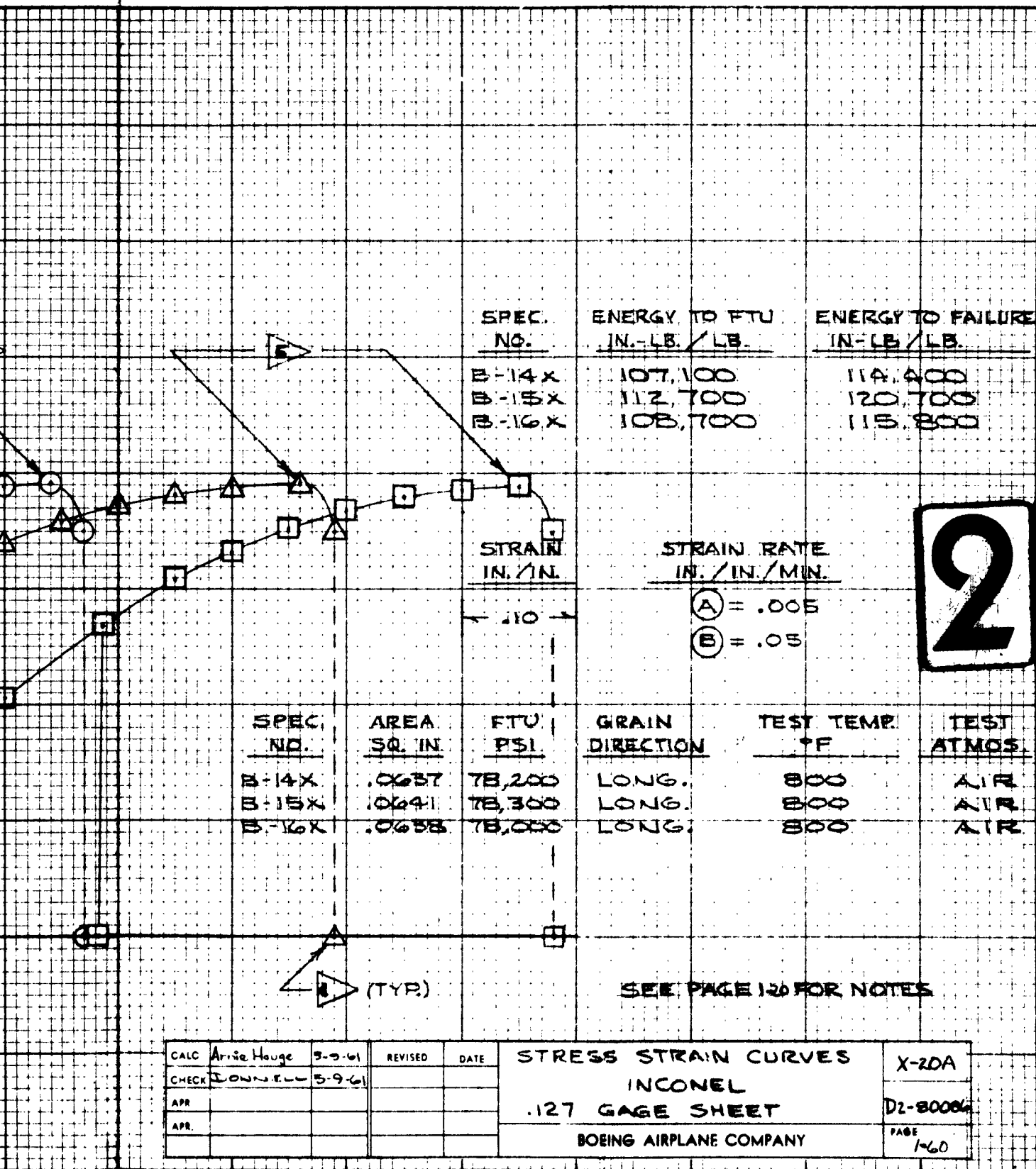
CONTRACT NO.

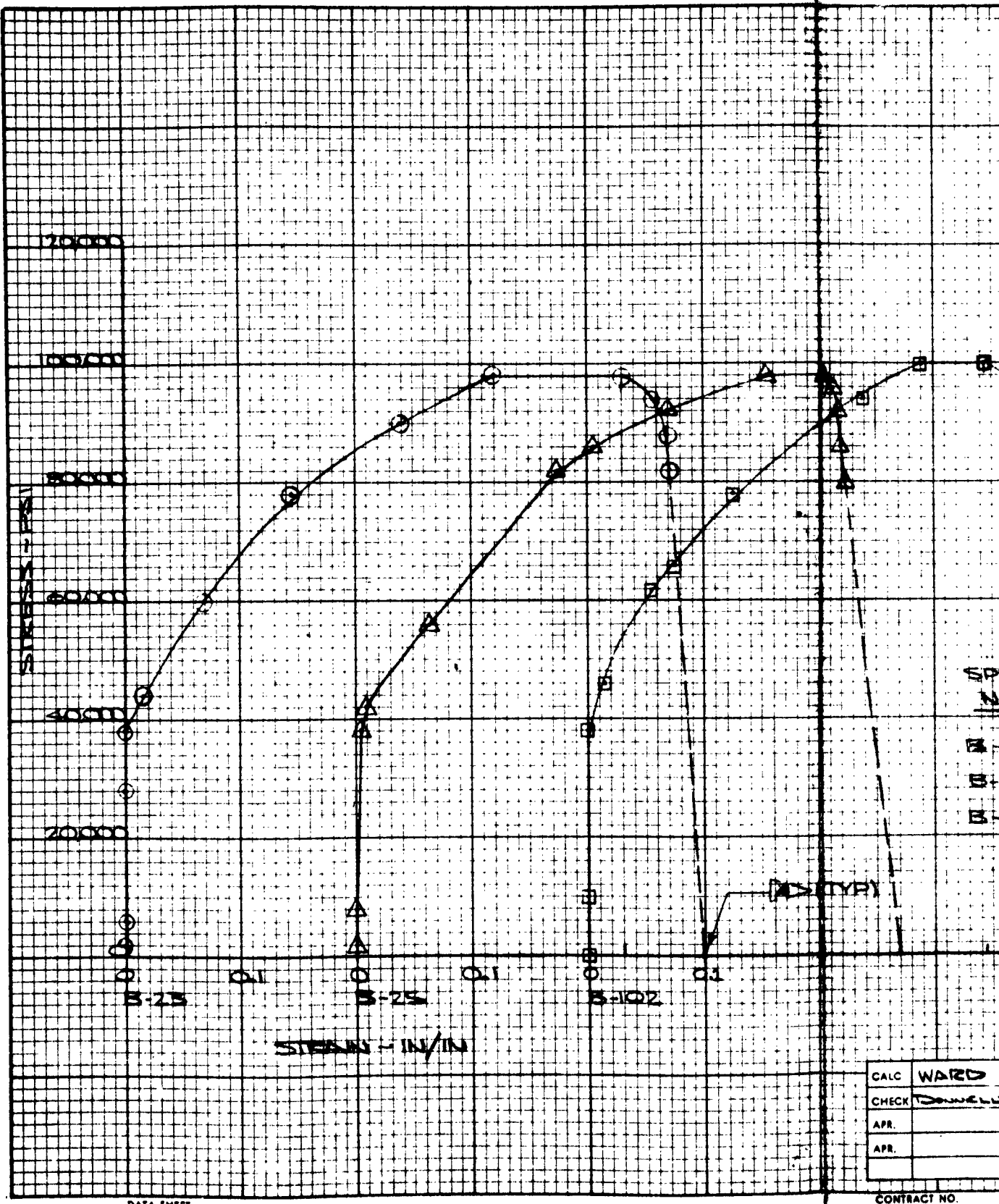


DATA SHEET

CALC	Arrie Houge
CHECK	Downell
APR.	
APR.	

CONTRACT NO.



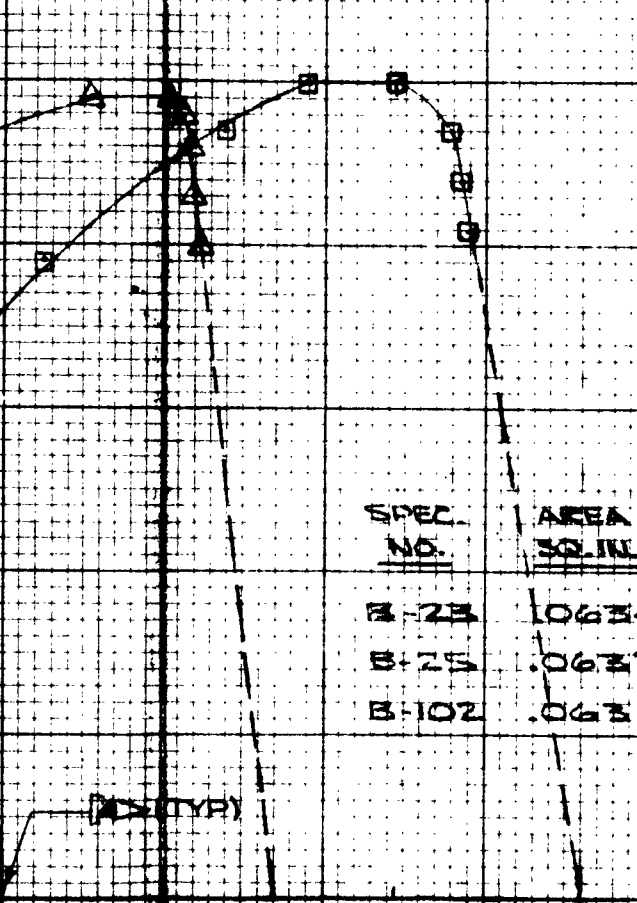


CALC	WARD
CHECK	DOWELL
APR.	
APR.	

CONTRACT NO.

DATA SHEET

2



SPEC. NO.	ENERGY TO YLT - IN-LB/LB	ENERGY TO FAILURE - IN-LB/LB
B-23	115,500	131,800
B-25	104,100	116,300
B-102	92,000	116,000

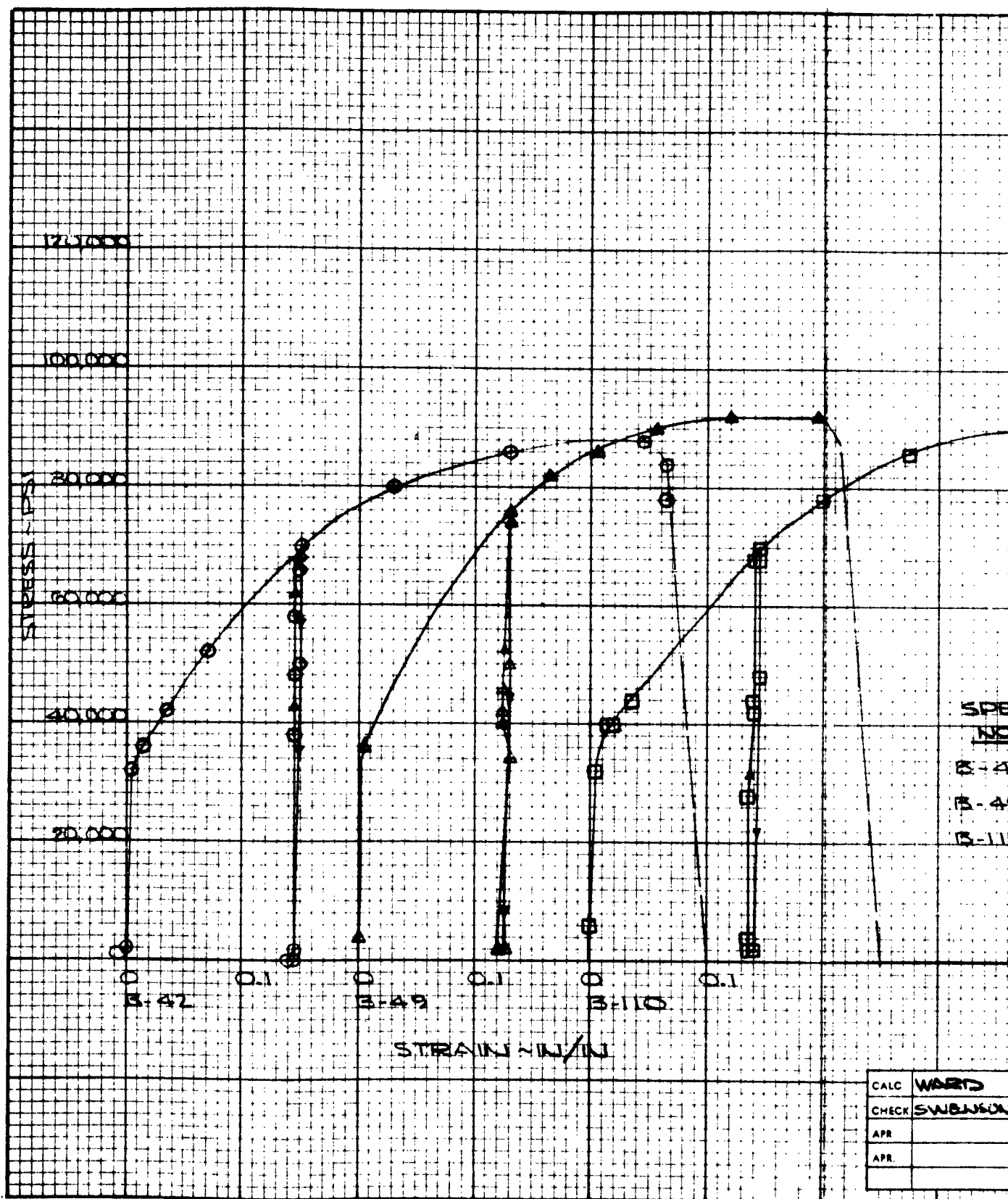
STRAIN IN/IN	STRAIN RATE IN/IN / MIN.
← 0.1 →	50

SPEC. NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP - °F	TEST ATMOS.
B-23	.0634	98,000	LONG.	-65	NITROGEN
B-25	.0637	98,000	LONG.	-65	NITROGEN
B-102	.0631	100,000	LONG.	-65	NITROGEN

~ SEE PAGE #1 FOR NOTES ~

<table border="1"> <tr> <td>CALC</td> <td>WARD</td> <td>4-10-61</td> <td>REVISED</td> <td>DATE</td> </tr> <tr> <td>CHECK</td> <td>DONNELLY</td> <td>4-12-61</td> <td></td> <td></td> </tr> <tr> <td>APR.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>APR.</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	CALC	WARD	4-10-61	REVISED	DATE	CHECK	DONNELLY	4-12-61			APR.					APR.					STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 461
CALC	WARD	4-10-61	REVISED	DATE																		
CHECK	DONNELLY	4-12-61																				
APR.																						
APR.																						

CONTRACT NO.

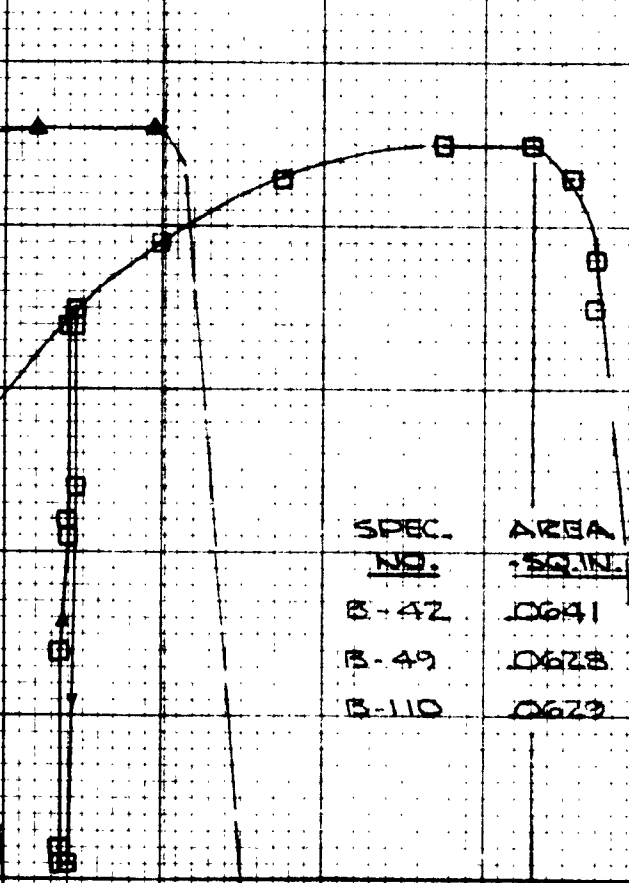


DATA SHEET

CONTRACT NO.

CALC	WARD
CHECK	SWANSON
APR	
APR	

2



SPEC. NO.	ENERGY TO FTU IN-10	ENERGY TO FAILURE IN-10
B-42	106,400	117,000
B-49	102,000	113,500
B-110	105,000	121,500

STRAIN IN/IN 0.1

STRAIN RATE IN/IN/MIN 50

SPEC. NO.	AREA - SQ. IN.	FTU - PSI	GRAN. DIRECTION	TEST TEMP. °F	TEST ATMOS.
B-42	.0641	89,000	LONG.	R.T.	AIR
B-49	.0628	92,000	↑	↑	↑
B-110	.0629	90,500	LONG.	R.T.	AIR

~ SEE PAGE 122 FOR NOTES ~

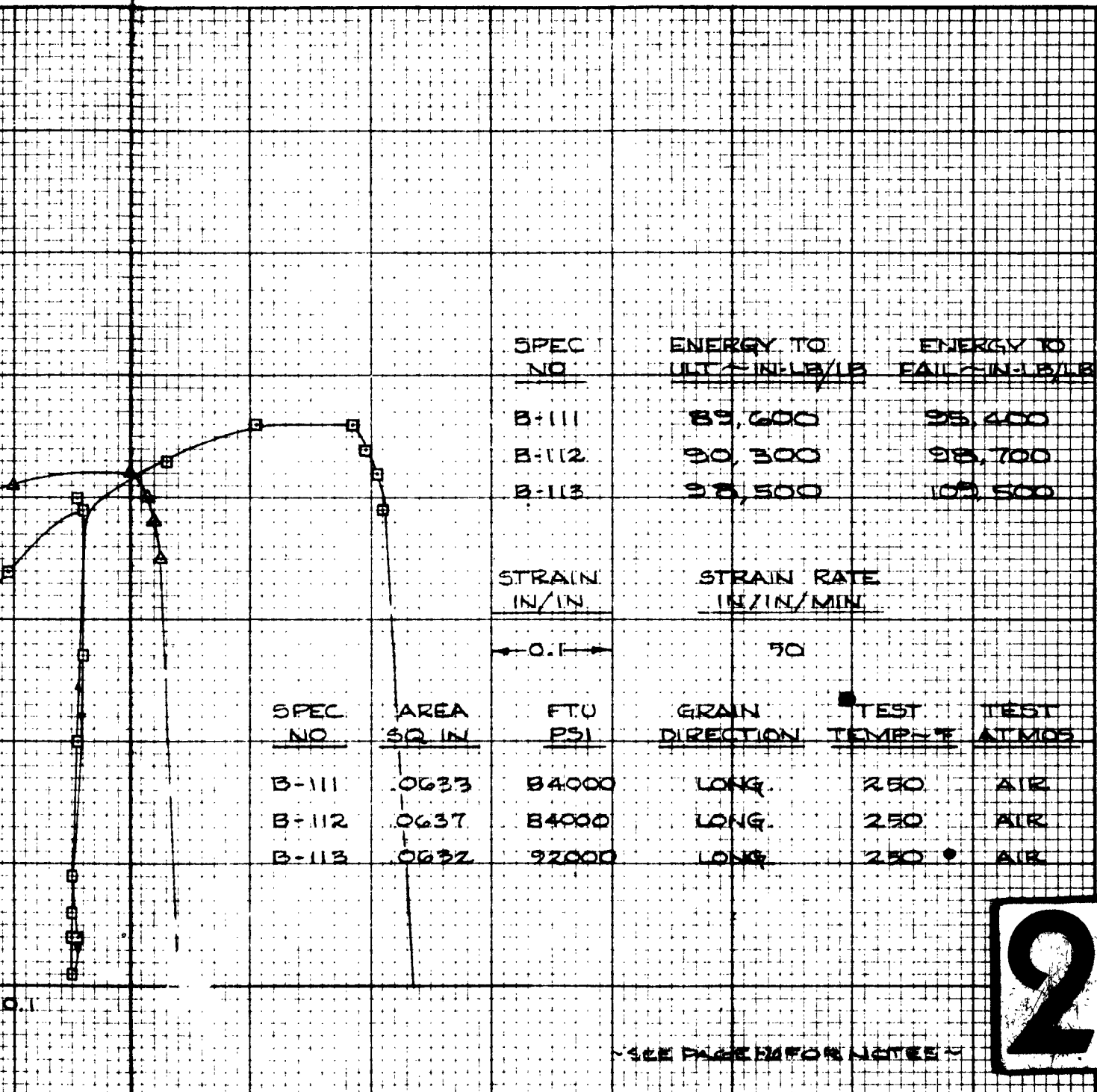
CALC	WARD	4-11-61	REVISED	DATE	STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-2
CHECK	SWANSON	4-17-61				
APR						
APR						

CONTRACT NO.



DATA SHEET

CALC	RUTHIE
CHECK	SWENSON
APR.	
APR.	
CONTRACT NO.	

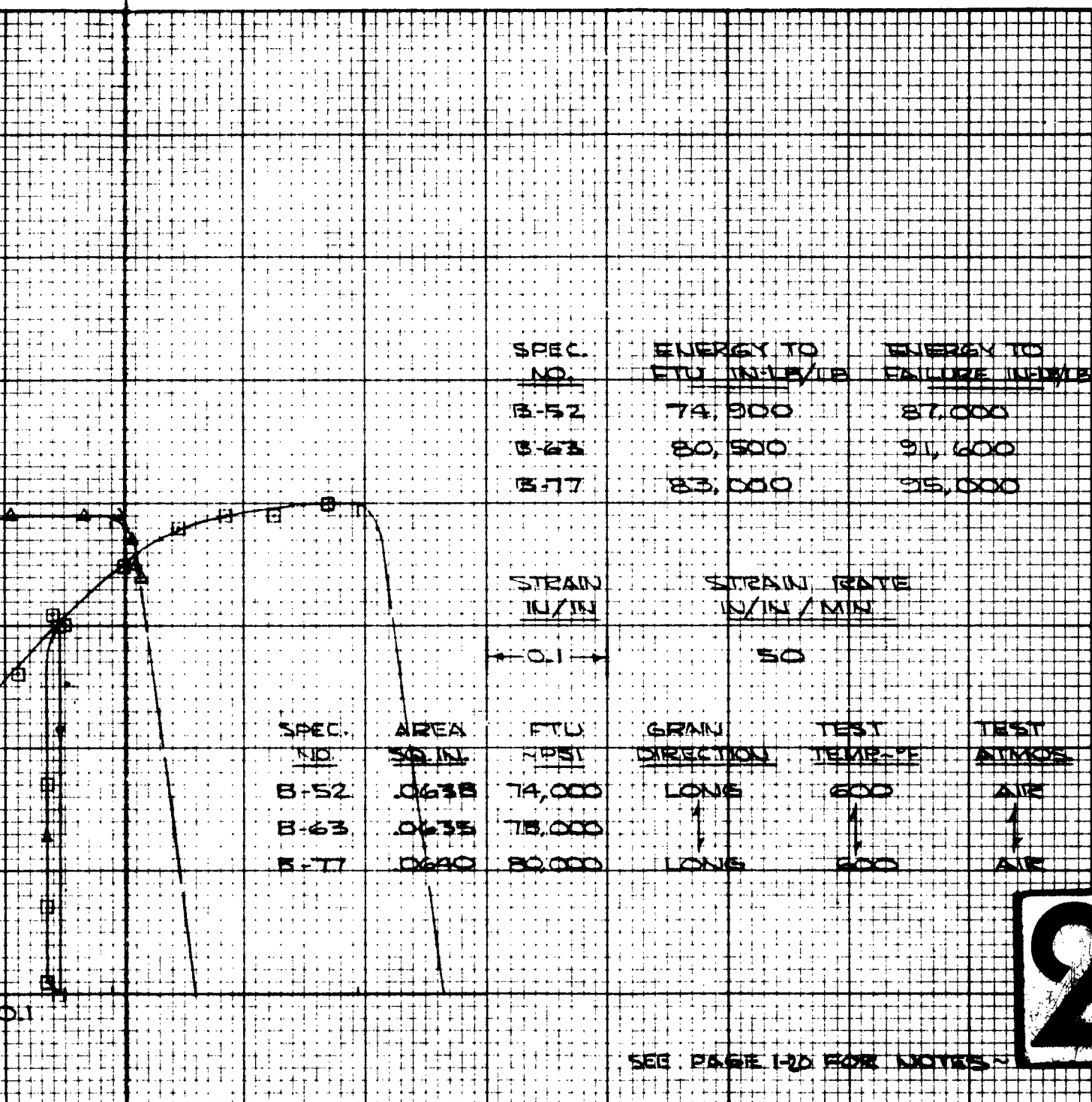


CALC	AUTHOR	4-11-61	REVISED	DATE	STRESS - STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-63
CHECK	SWENSON	4-17-61				
APP.						
APP.						

CONTRACT NO

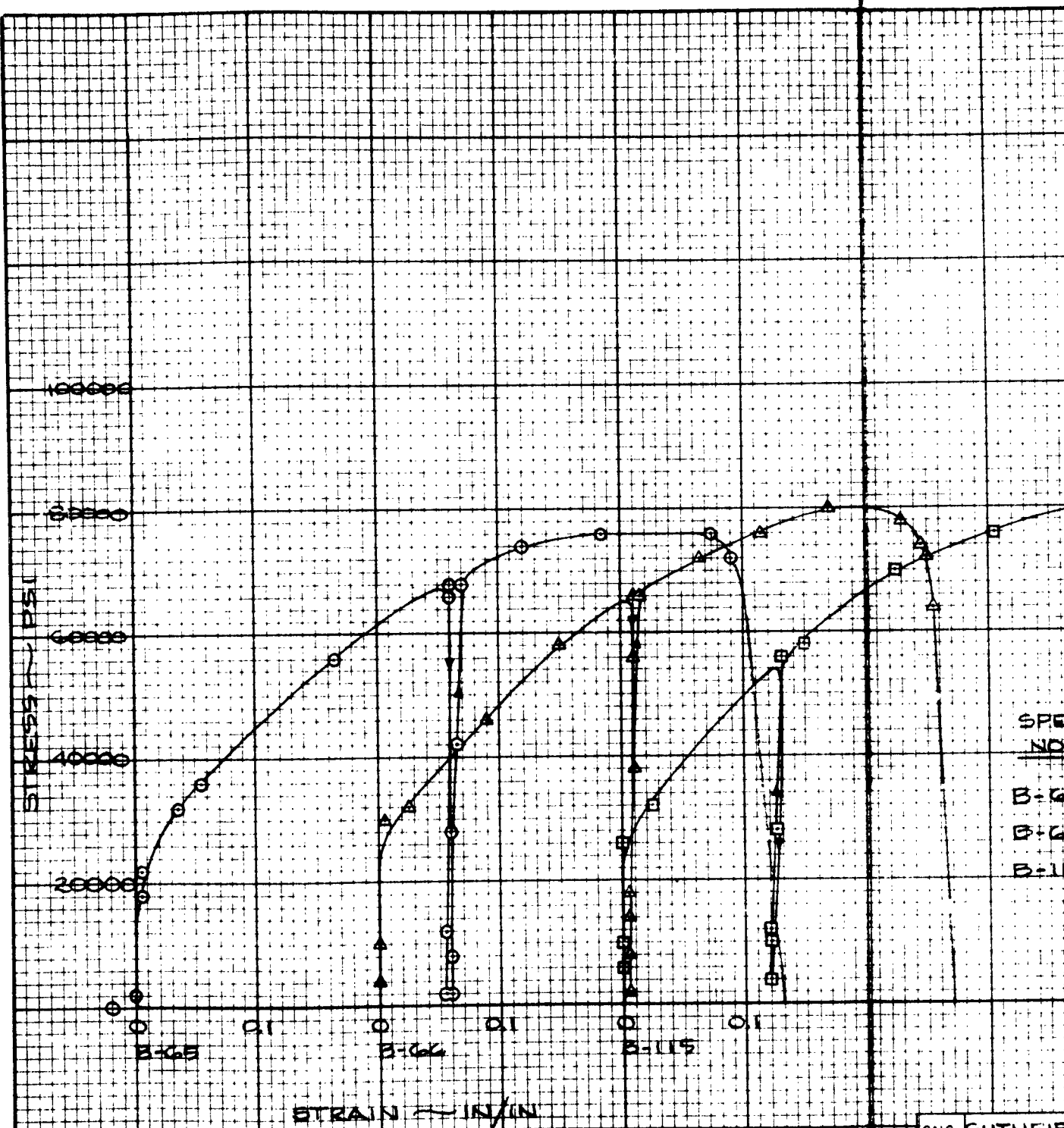


CALC	WARD
CHECK	SWENSON
APR	
APR	
CONTRACT NO.	



<table border="1"> <tr> <td>CALC</td> <td>WARD</td> <td>4-16-61</td> <td>REVISED</td> <td>DATE</td> </tr> <tr> <td>CHECK</td> <td>SWENSON</td> <td>4-17-61</td> <td></td> <td></td> </tr> <tr> <td>APR</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>APR</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	CALC	WARD	4-16-61	REVISED	DATE	CHECK	SWENSON	4-17-61			APR					APR					STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A DZ-80086 PAGE 1-64
CALC	WARD	4-16-61	REVISED	DATE																		
CHECK	SWENSON	4-17-61																				
APR																						
APR																						

CONTRACT NO.

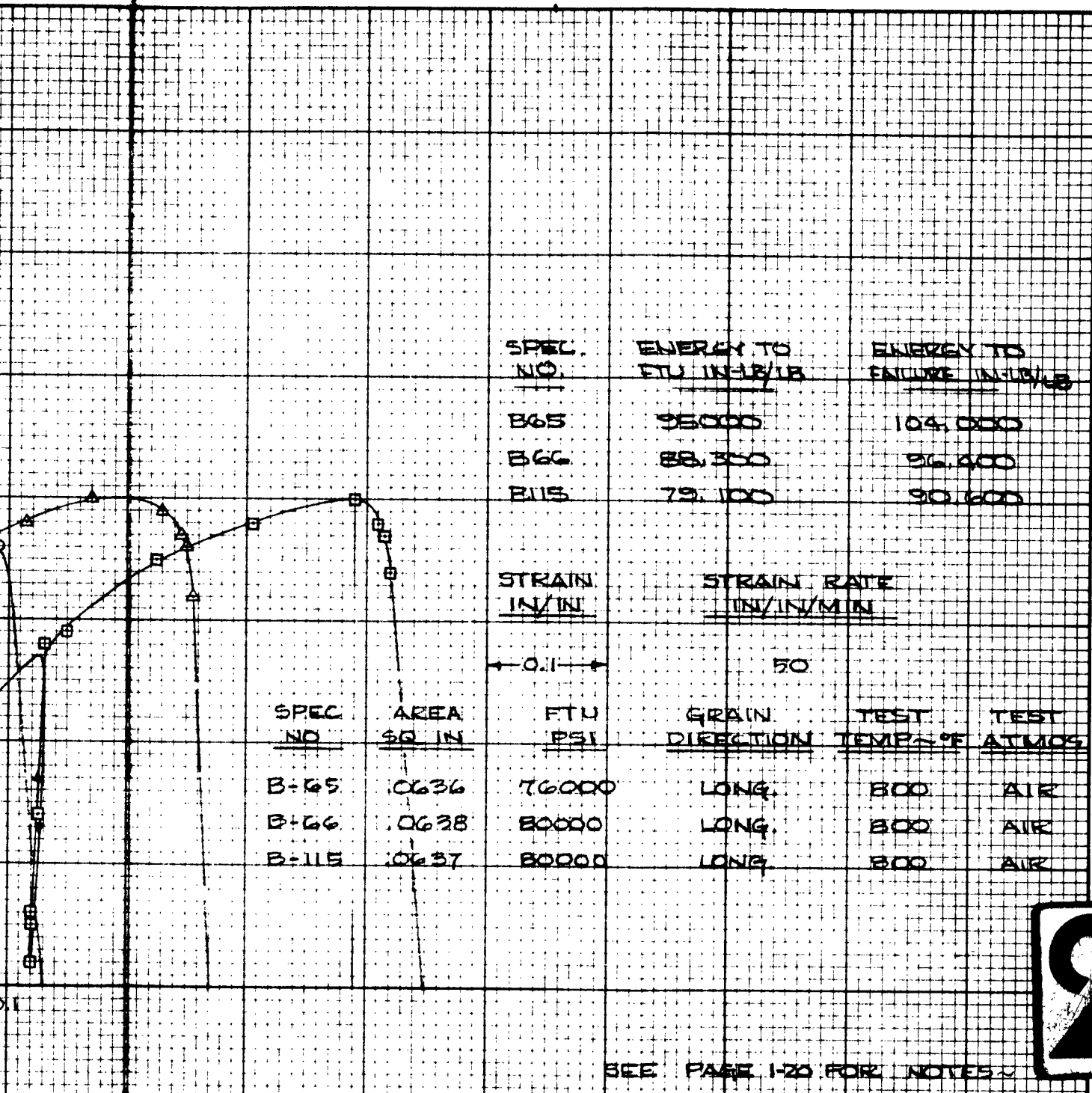


SPE
NO
B-6
B-6
B-11

CALC	GUTHRIE
CHECK	SWANSON
APR	
APR	

DATA SHEET

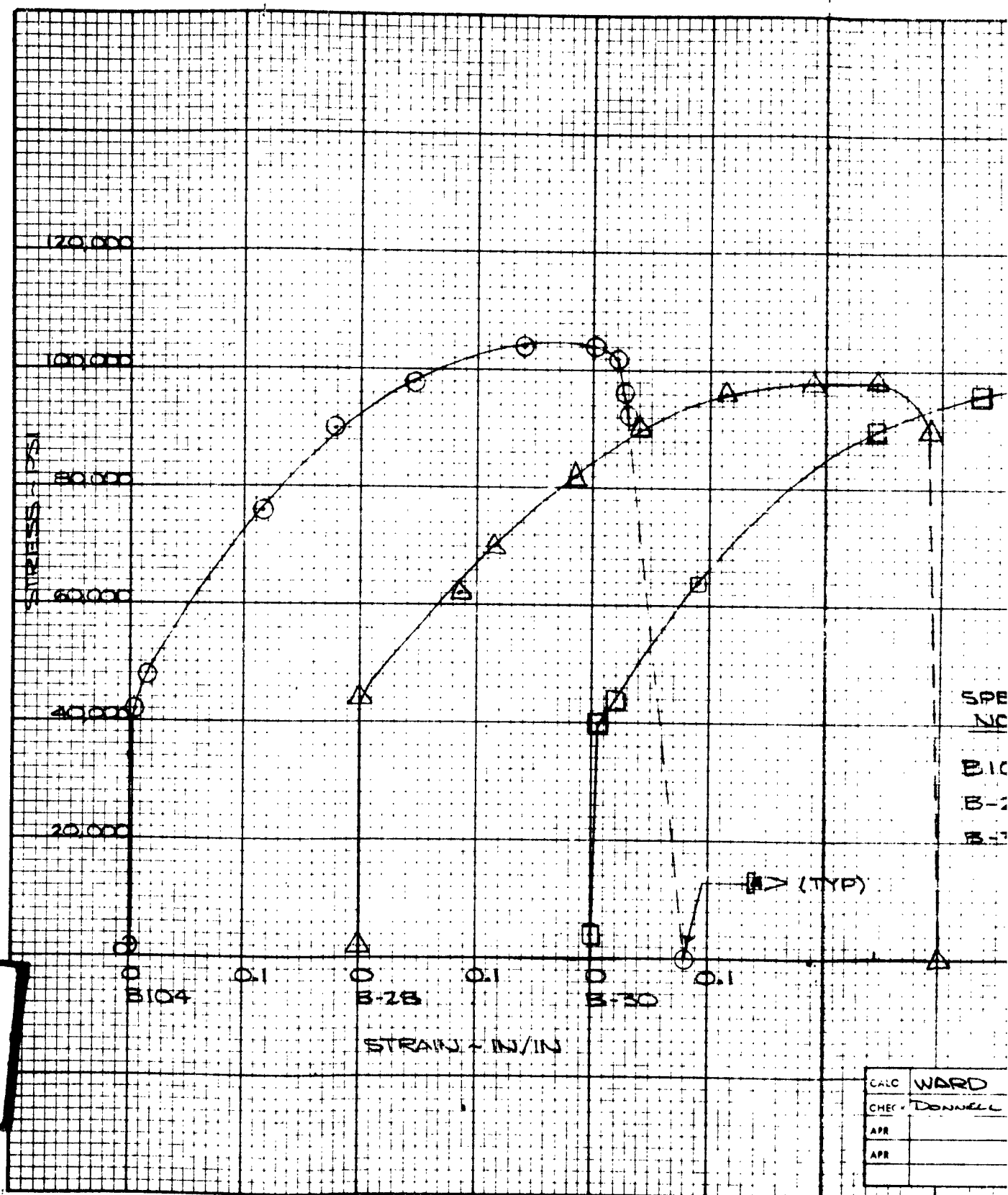
CONTRACT NO.



CALC	GUTHRIE 4.11.61	REVISED	DATE	STRESS-STRAIN CURVES INCONEL 127 GAGE SHEET	X-20A DZ-80086
CHECK	SWANSON 4-17-61				
APR				BOEING AIRPLANE COMPANY	PAGE 1-65
APR					

CONTRACT NO.

1

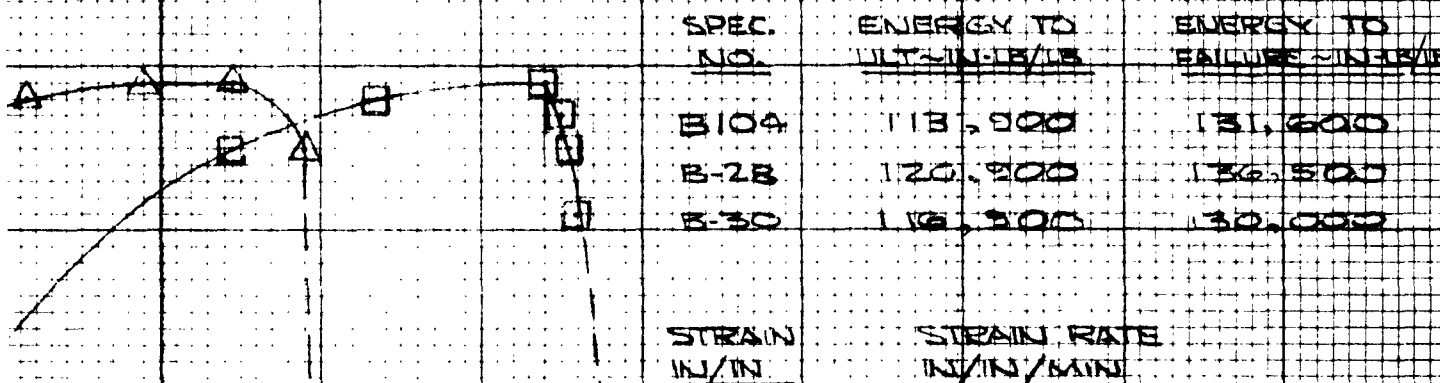


DATA SHEET

CALC	WARD
CHEC	DONNELL
APR	
APR	

CONTRACT NO.

2



STRAIN IN/IN → 0.1 → STRAIN RATE IN/IN/MIN 100

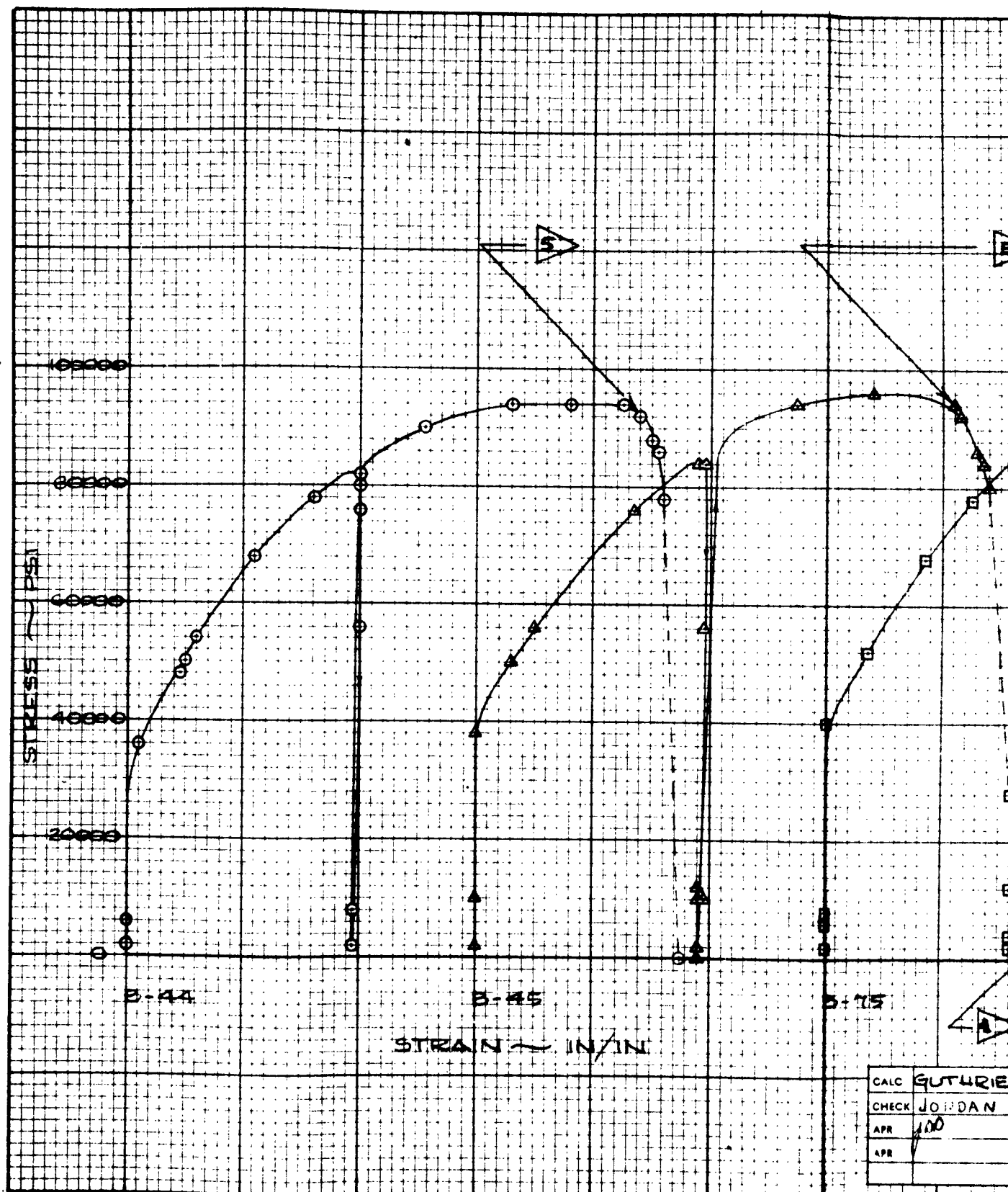
SPEC. NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP. °F	TEST ATMOS.
B104	.0636	104,000	LONG	+65	NITROGEN
B-28	.0644	98,000	LONG.	+65	NITROGEN
B-30	.0644	98,000	LONG.	+65	NITROGEN

(TYP)

SEE PAGE 1-70 FOR NOTES

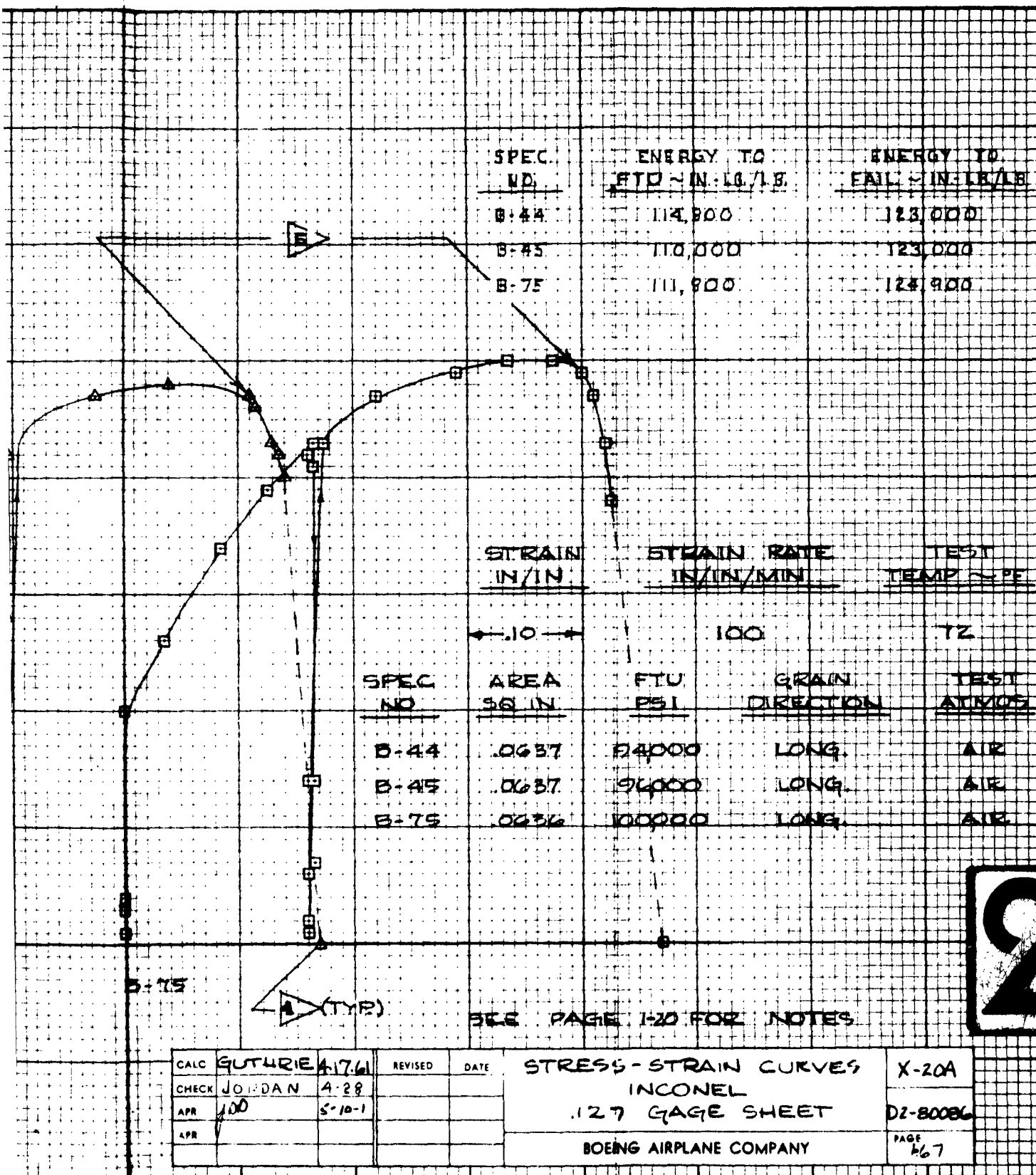
CALC	WARD	3-30-1	REVISED	DATE	STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHEK	DONNELL	4-12-61				D2-80086
APR						PAGE
APR						166

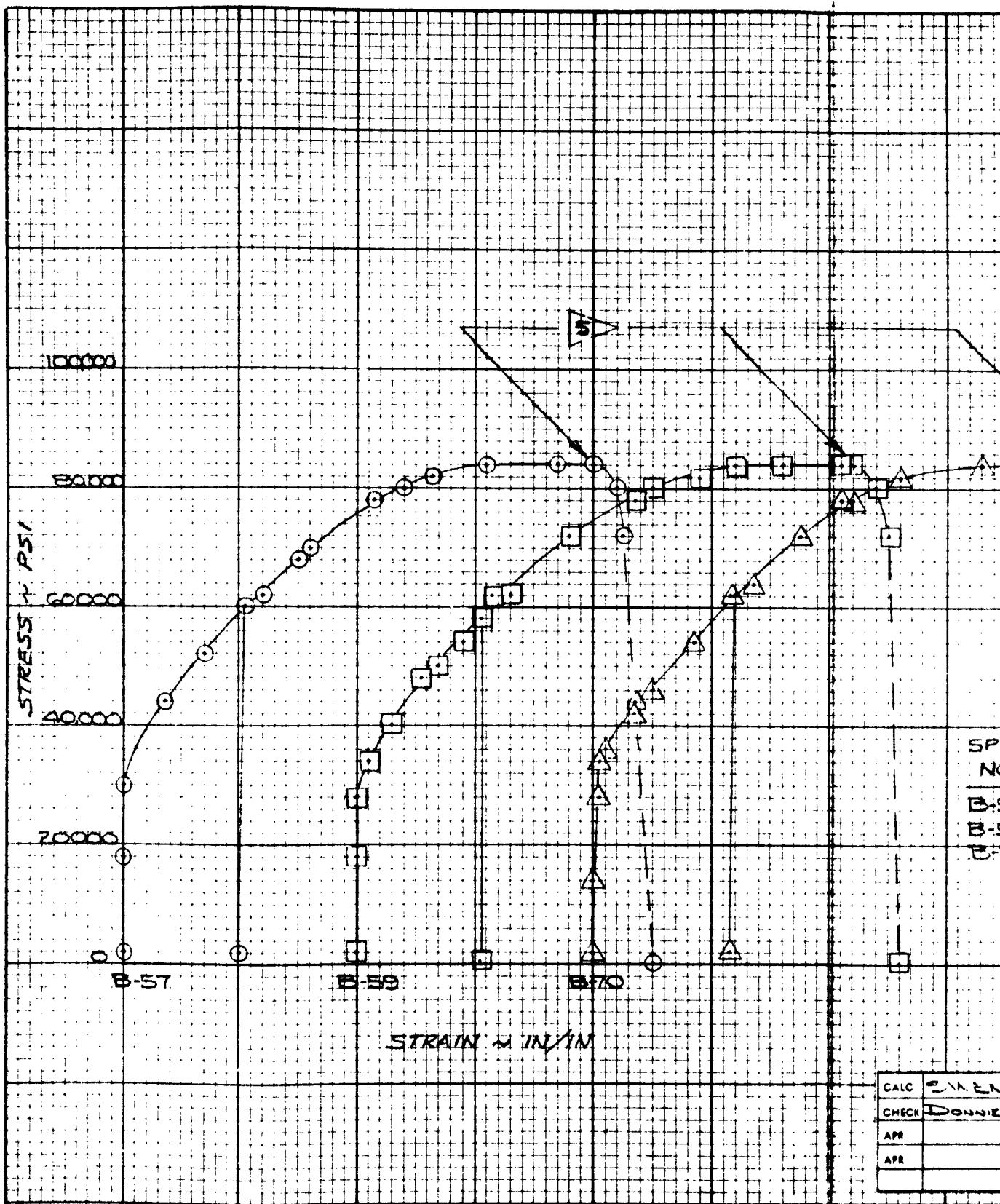
CONTRACT NO



DATA SHEET

CALC	GUTHRIE
CHECK	JORDAN
APR	100
APR	
CONTRACT NO	

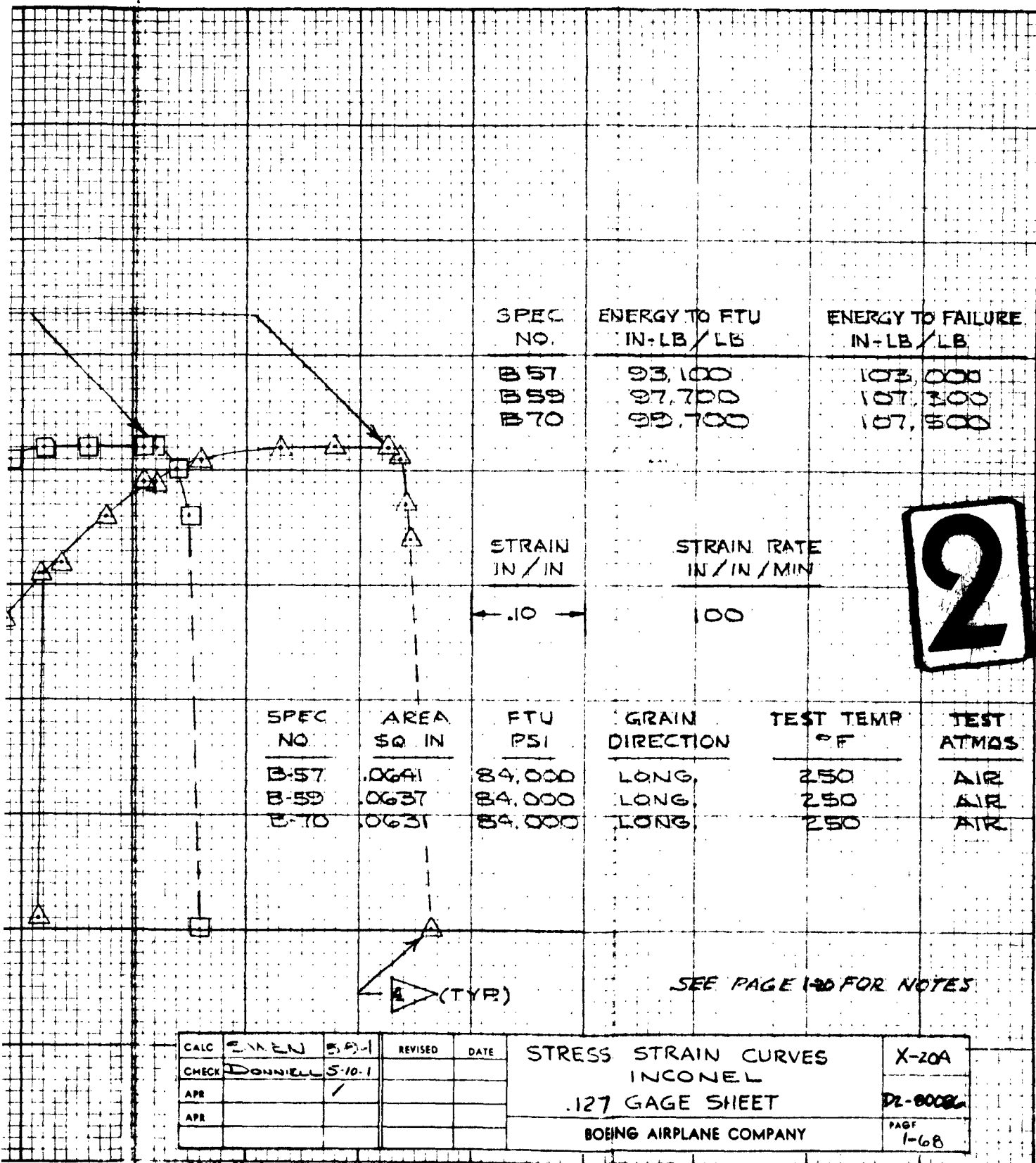




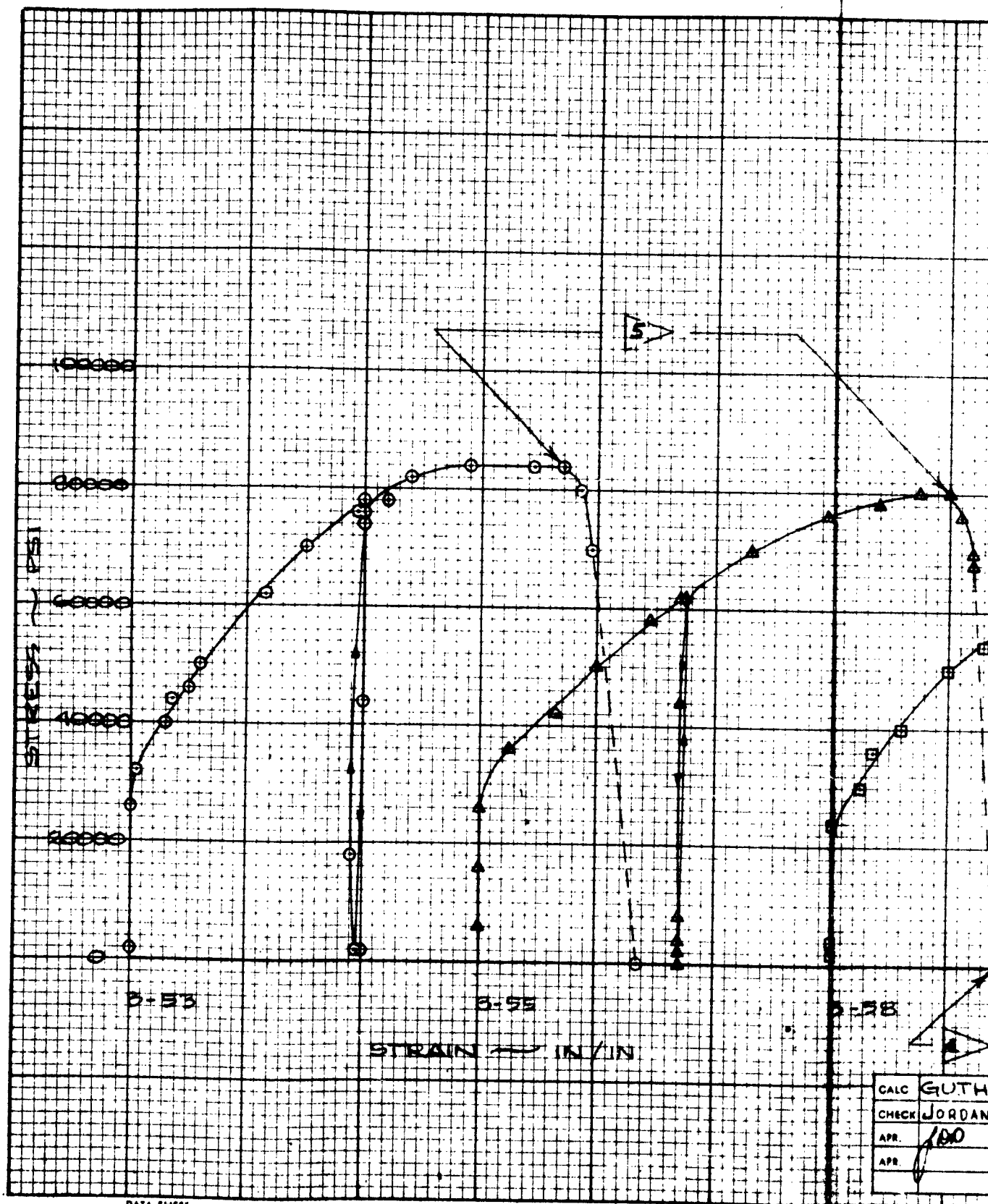
DATA SHEET

CALC	CHEN
CHECK	DONNIE
APR	
APR	

CONTRACT NO.



1

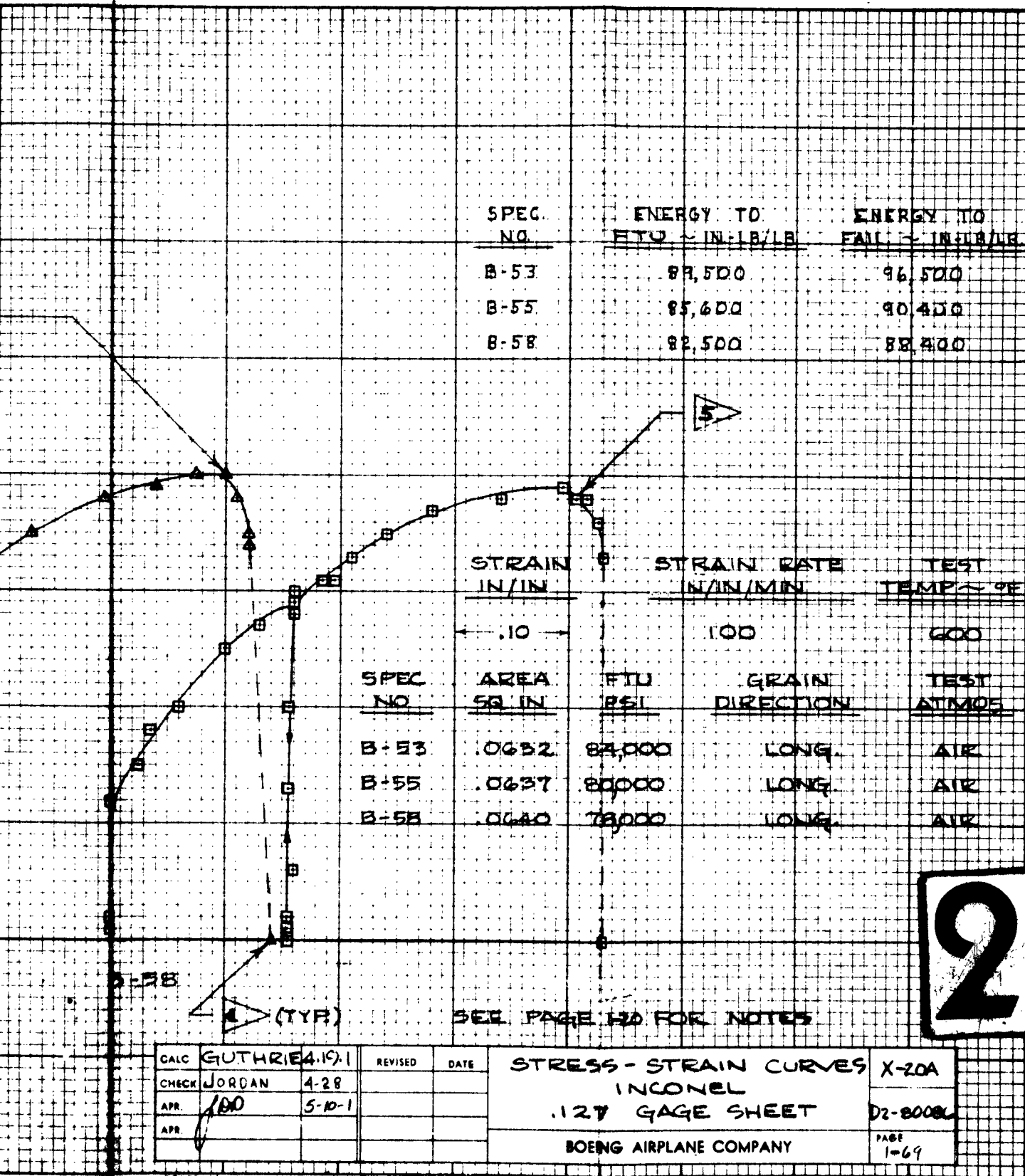


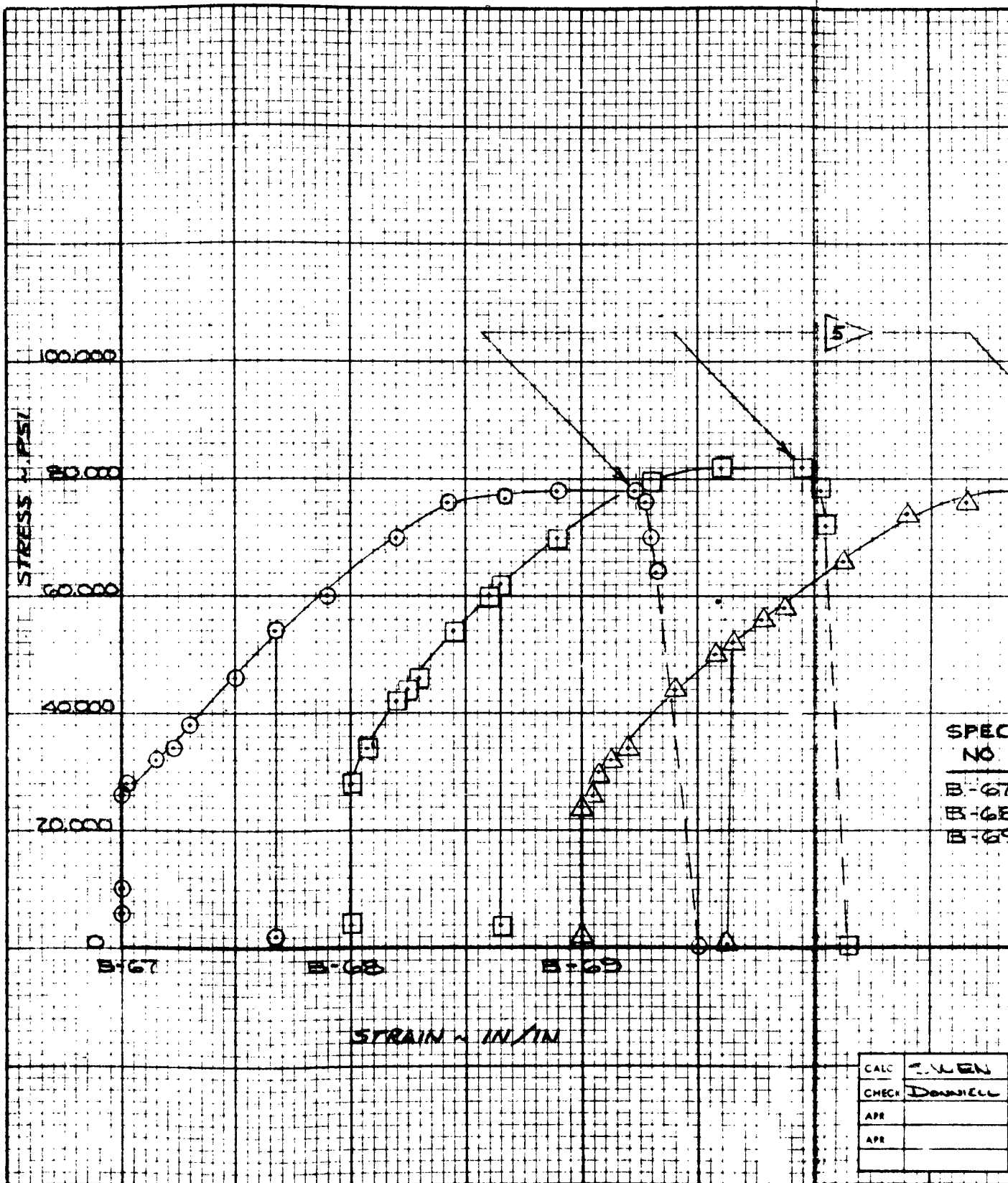
DATA SHEET

U3 4011 5000—REV. 7/60 (WAS BAC 360D)

CALC	GUTH
CHECK	JORDAN
APR.	100
APR.	

CONTRACT NO.

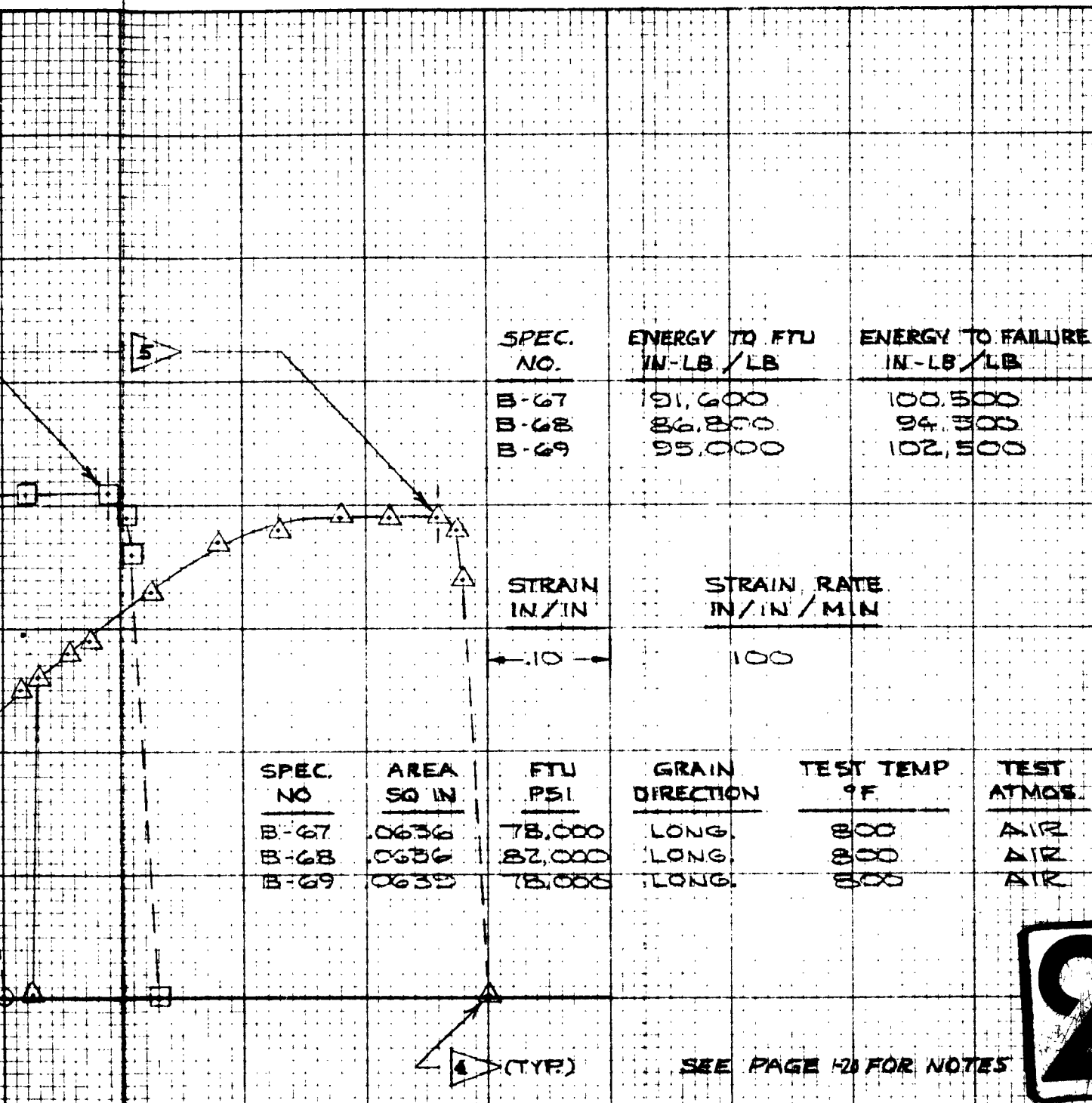




DATA SHEET

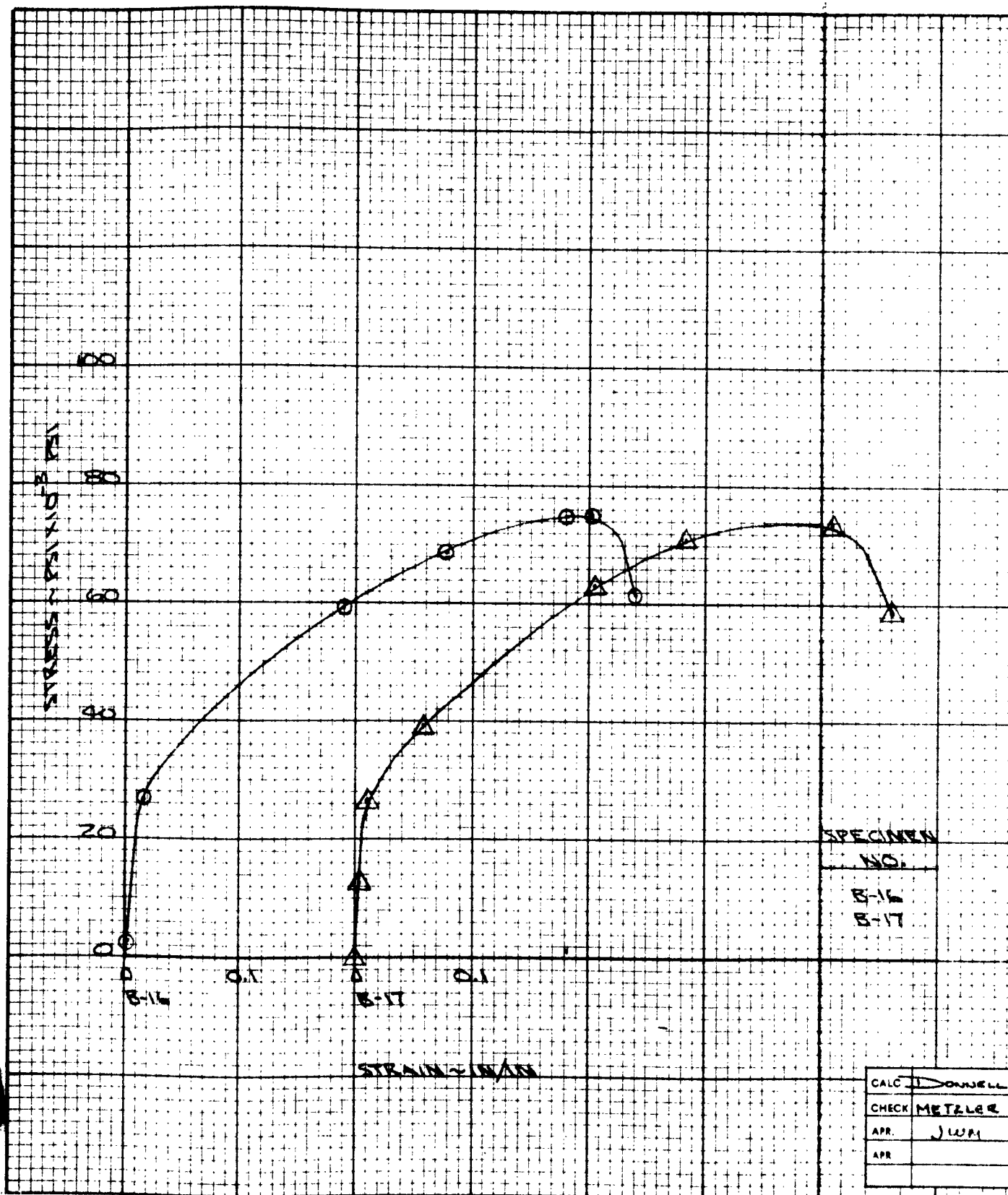
CALC	E. WEN
CHECK	Downell
APR	
APR	

CONTRACT NO.



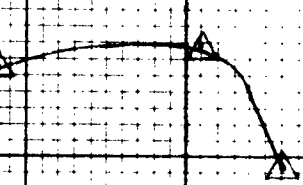
CALC	T. WEN	5-9-6	REVISED	DATE	STRESS STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	Downell	5-10-1				D2-80086
APR		✓				PAGE
APR						1-70

CONTRACT NO.



DATA SHEET

CONTRACT NO.



SPEC
NO
B-16
B-17

ENERGY TO
ULT. IN-~~LB~~ LB
74,000
78,600

ENERGY TO
FAIL IN-~~LB~~ LB
85,400
86,700

STRAIN
~IN/IN

0.1

STRAIN RATE
~IN/IN/MIN

180 TYP

2

SPECIMEN
NO.

B-16
B-17

AREA
~SQ IN

.0646
.0643

FTU
~PSI

75,670
73,960

GRAIN
DIRECTION

LONG.
LONG.

TEST
TEMP (°F)

600°
600°

TEST
ATMOS

AIR
AIR

CALC	DONWELL	1-28-1	REVISED	DATE
CHECK	METZLER	1-28-1		
APR	JUN 1	1951		
APR				

STRESS-STRAIN CURVES
INCONEL
.127 GAGE SHEET

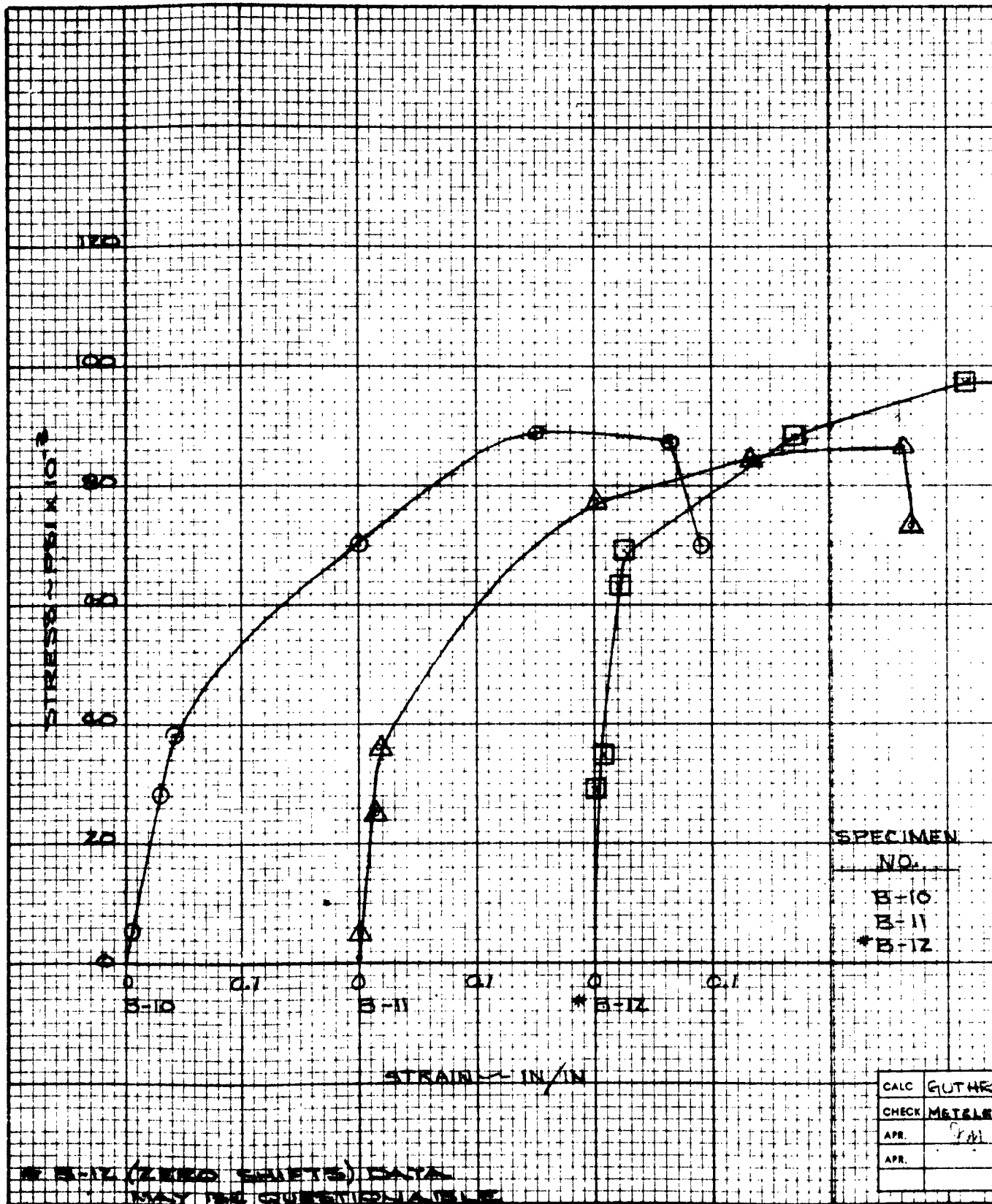
BOEING AIRPLANE COMPANY

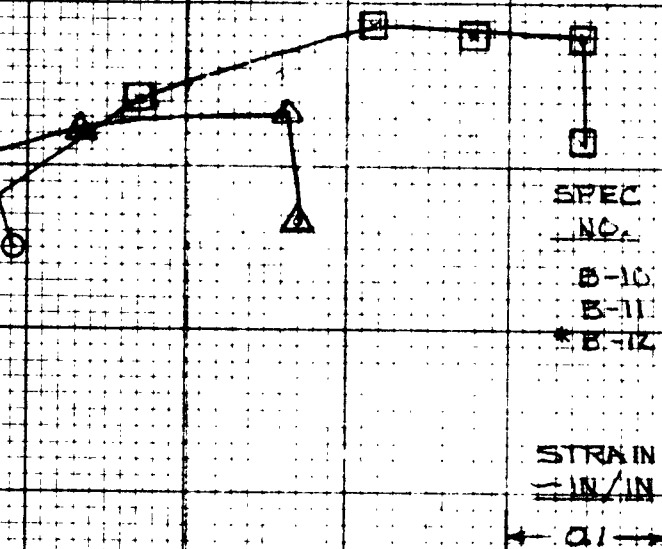
X-20A

DZ-80086

PAGE
1-71

CONTRACT NO.





SPEC NO.	ENERGY TO YLT. IN-IN/IN	ENERGY TO FAIL. IN-IN/IN
B-10	106,100	113,200
B-11	110,050	111,600
*B-12	128,050	128,200

STRAIN
- IN/IN

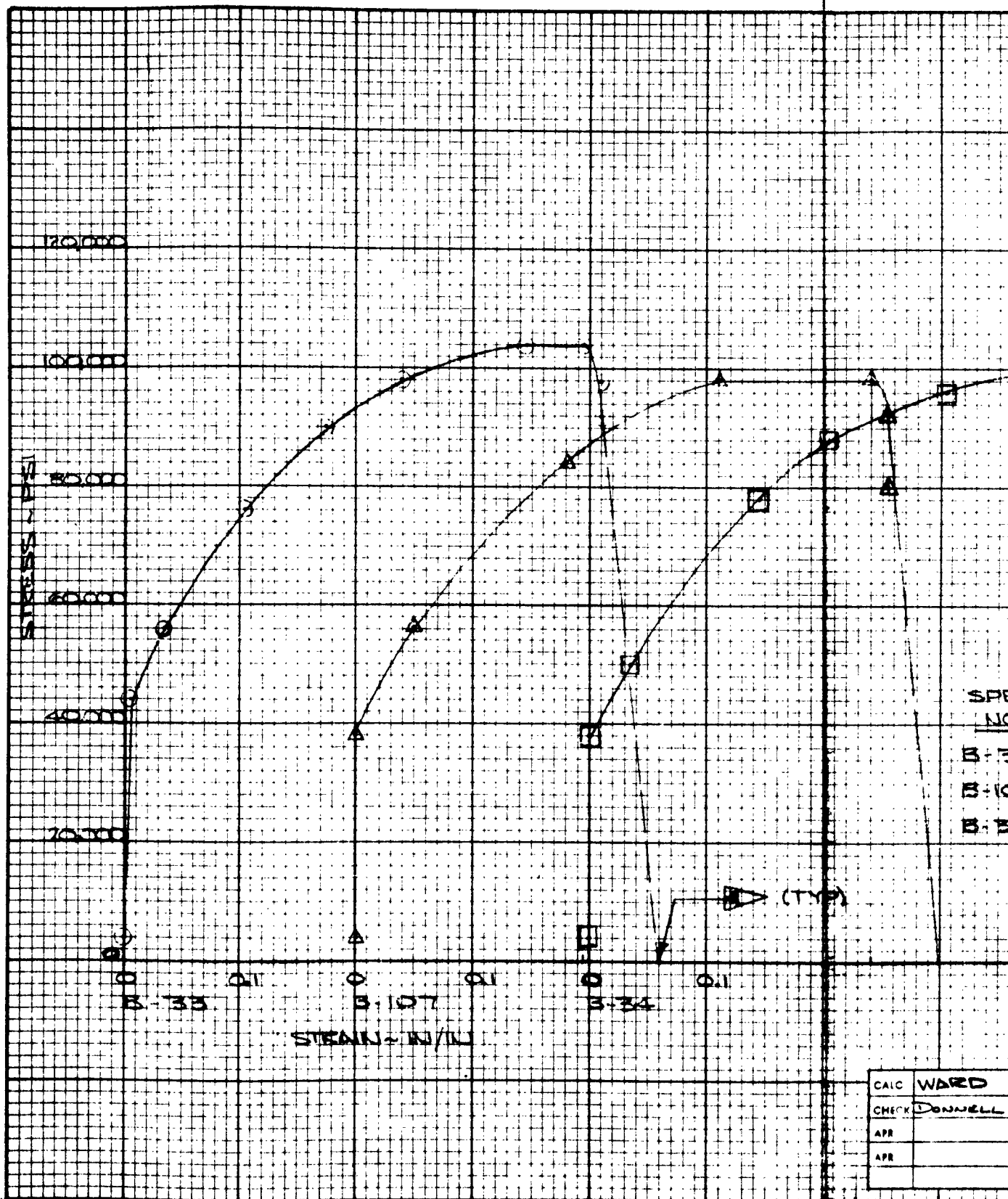
STRAIN RATE
- IN/IN/MIN
190 (TYP.)

2

SPECIMEN NO.	AREA - SQ. IN.	FTU - PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOS.
B-10	.0646	88,500	LONG.	72	AIR
B-11	.0641	86,100	LONG.	72	AIR
*B-12	.0640	97,300	LONG.	72	AIR

CALC	GUTHRIE	127.61	REVISED	DATE	STRESS - STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	METZLER	1-28-61				DZ-80086
APR.	1-21	1-24-61				PAGE 1-72
APR.						

CONTRACT NO

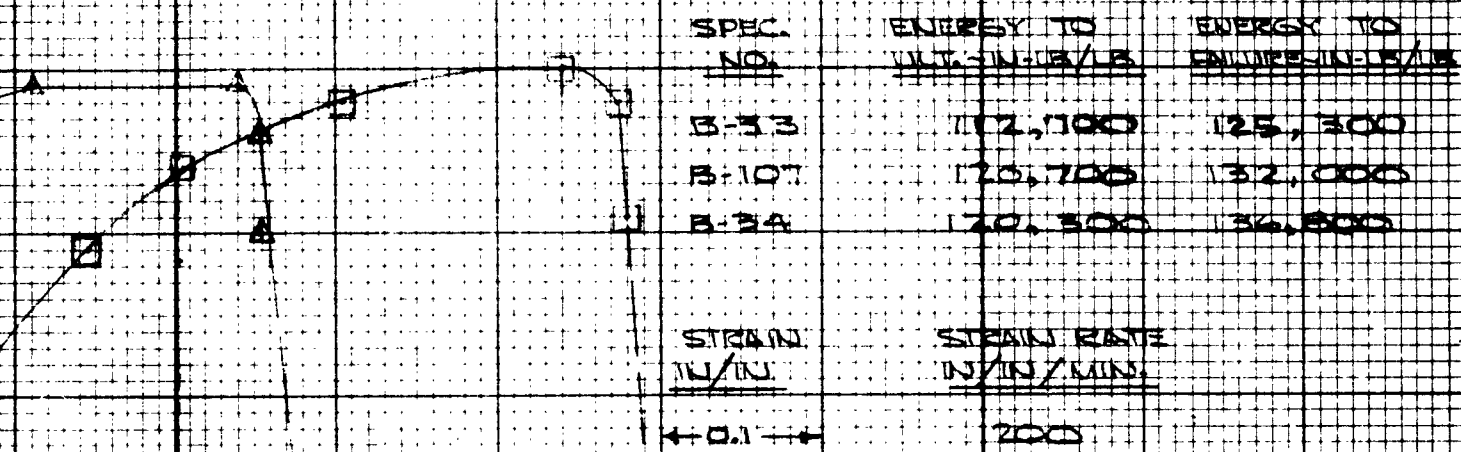


DATA SHEET

CALC	WARD
CHECK	DONNELL
APR	
APR	

CONTRACT NO.

2

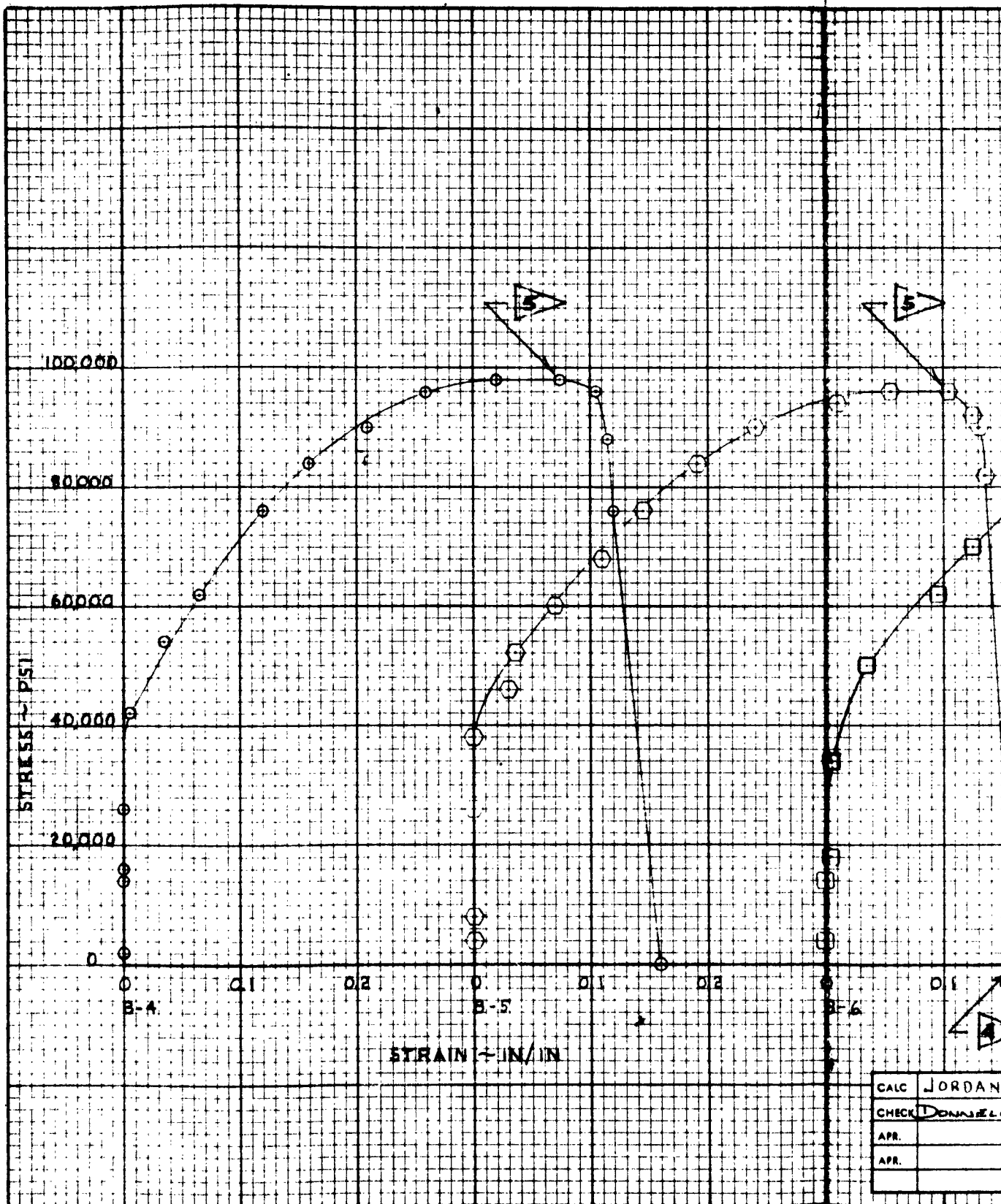


SPEC. NO.	AREA, SQ. IN.	FTU, PSI	GRAIN DIRECTION	TEST TEMP., °F	TEST ATMOS.
B-33	.0640	104,000	LONG.	+65	NITROGEN
B-107	.0638	98,000	LONG.	+65	NITROGEN
B-34	.0640	100,000	LONG.	+65	NITROGEN

SEE PAGE 1-10 FOR NOTES

CALC WARD 3-28-61 CHECK DONNELL 4-12-61 APR APR	REVISED DATE	STRESS-STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-73
--	-----------------	---	--

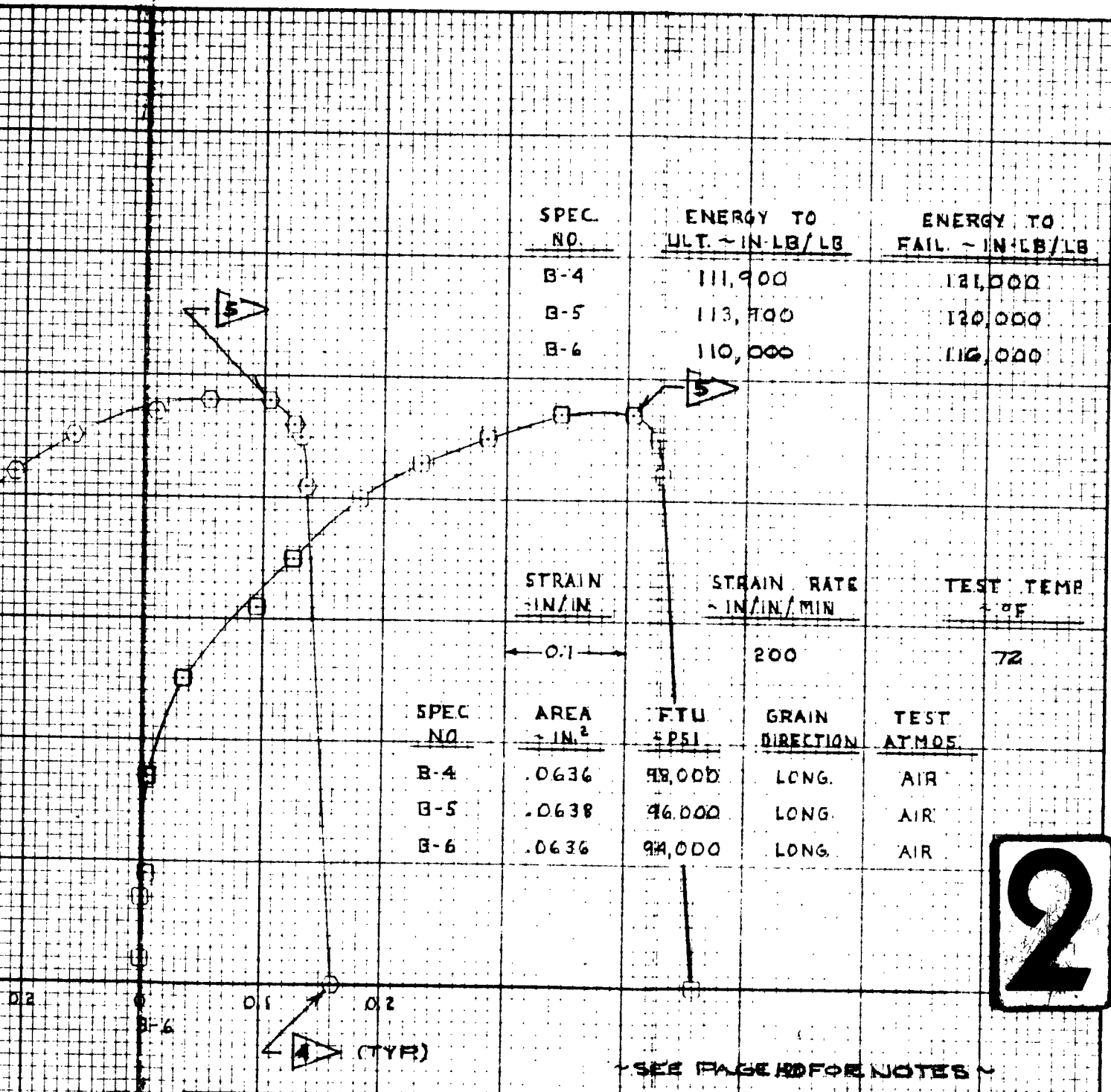
CONTRACT NO.



DATA SHEET

CALC	JORDAN
CHECK	DONNELLY
APR.	
APR.	

CONTRACT NO.



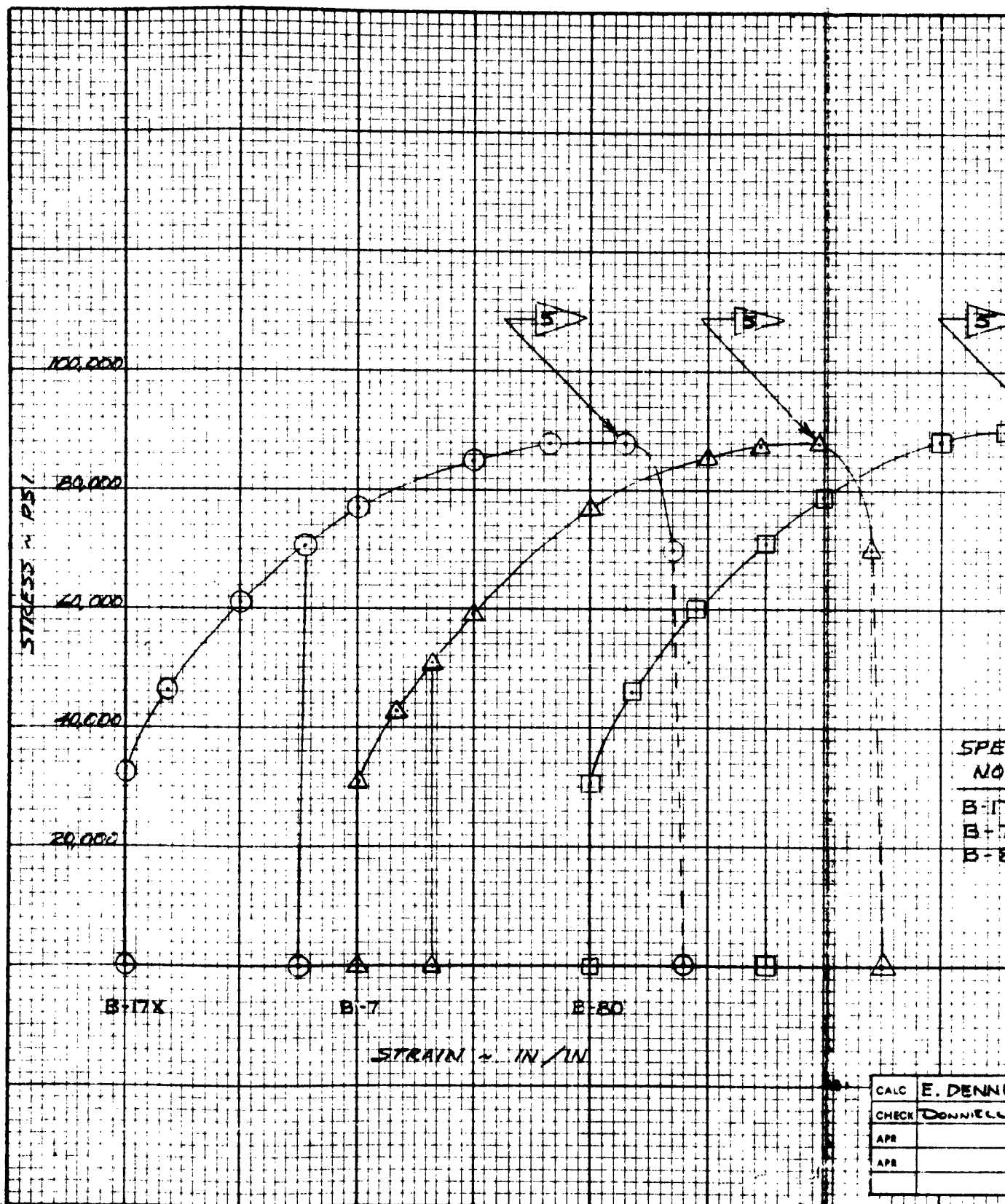
SPEC. NO.	ENERGY TO ULT. ~ IN-LB/LB	ENERGY TO FAIL. ~ IN-LB/LB
B-4	111,900	121,000
B-5	113,700	120,000
B-6	110,000	116,000

STRAIN ~ IN/IN	STRAIN RATE ~ IN/IN/MIN	TEST TEMP ~ °F
0.1	200	72

SPEC NO.	AREA ~ IN. ²	FTU ~ PSI	GRAIN DIRECTION	TEST ATMOS.
B-4	.0636	98,000	LONG.	AIR
B-5	.0638	96,000	LONG.	AIR
B-6	.0636	94,000	LONG.	AIR

2

<table border="1"> <tr> <td>CALC</td> <td>JORDAN</td> <td>4-28</td> <td>REVISED</td> <td>DATE</td> </tr> <tr> <td>CHECK</td> <td>DONNELL</td> <td>5-1-64</td> <td></td> <td></td> </tr> <tr> <td>APR.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>APR.</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	CALC	JORDAN	4-28	REVISED	DATE	CHECK	DONNELL	5-1-64			APR.					APR.					STRESS - STRAIN CURVES INCONEL 127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A DE-80086 PAGE 174
CALC	JORDAN	4-28	REVISED	DATE																		
CHECK	DONNELL	5-1-64																				
APR.																						
APR.																						

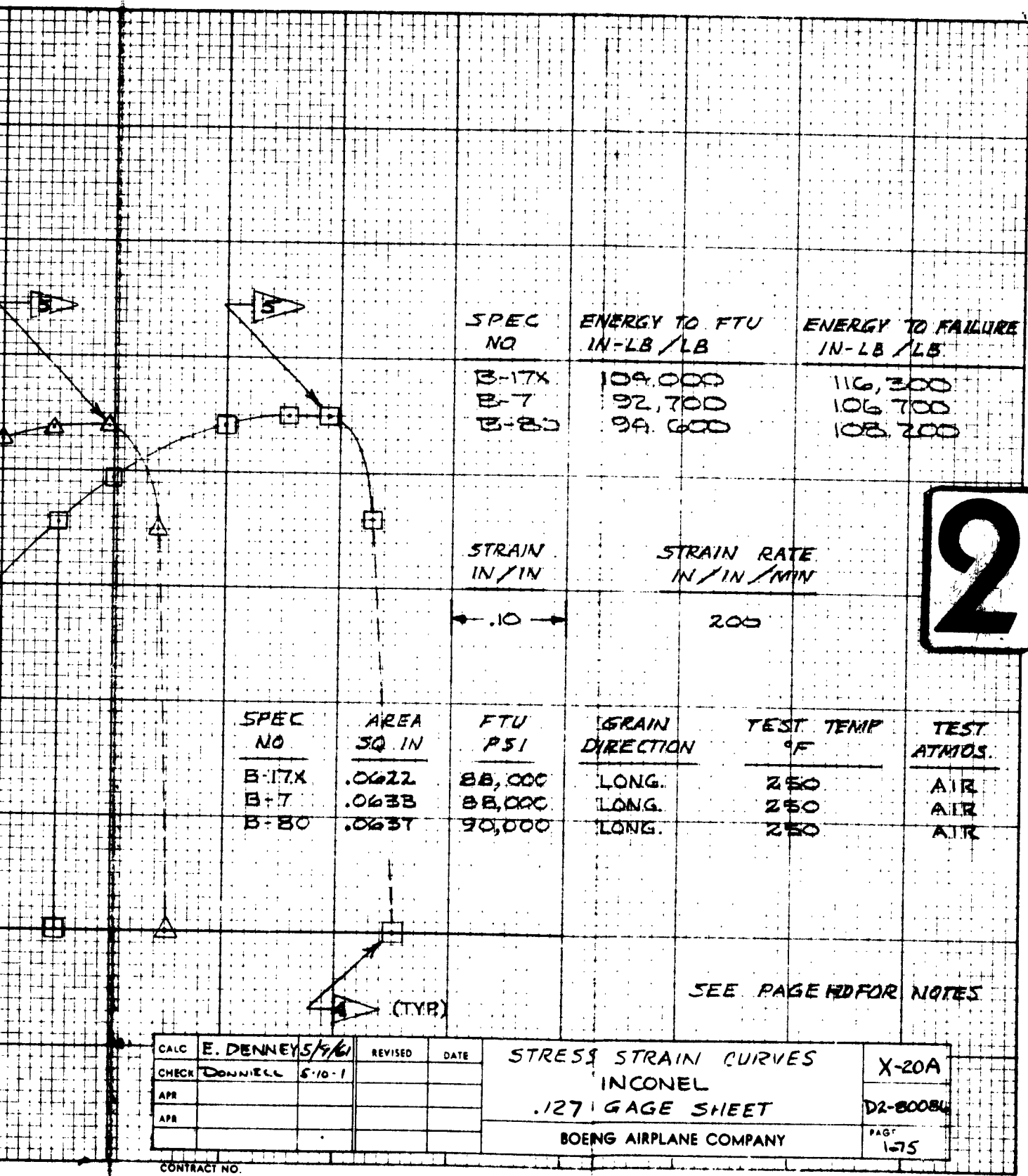


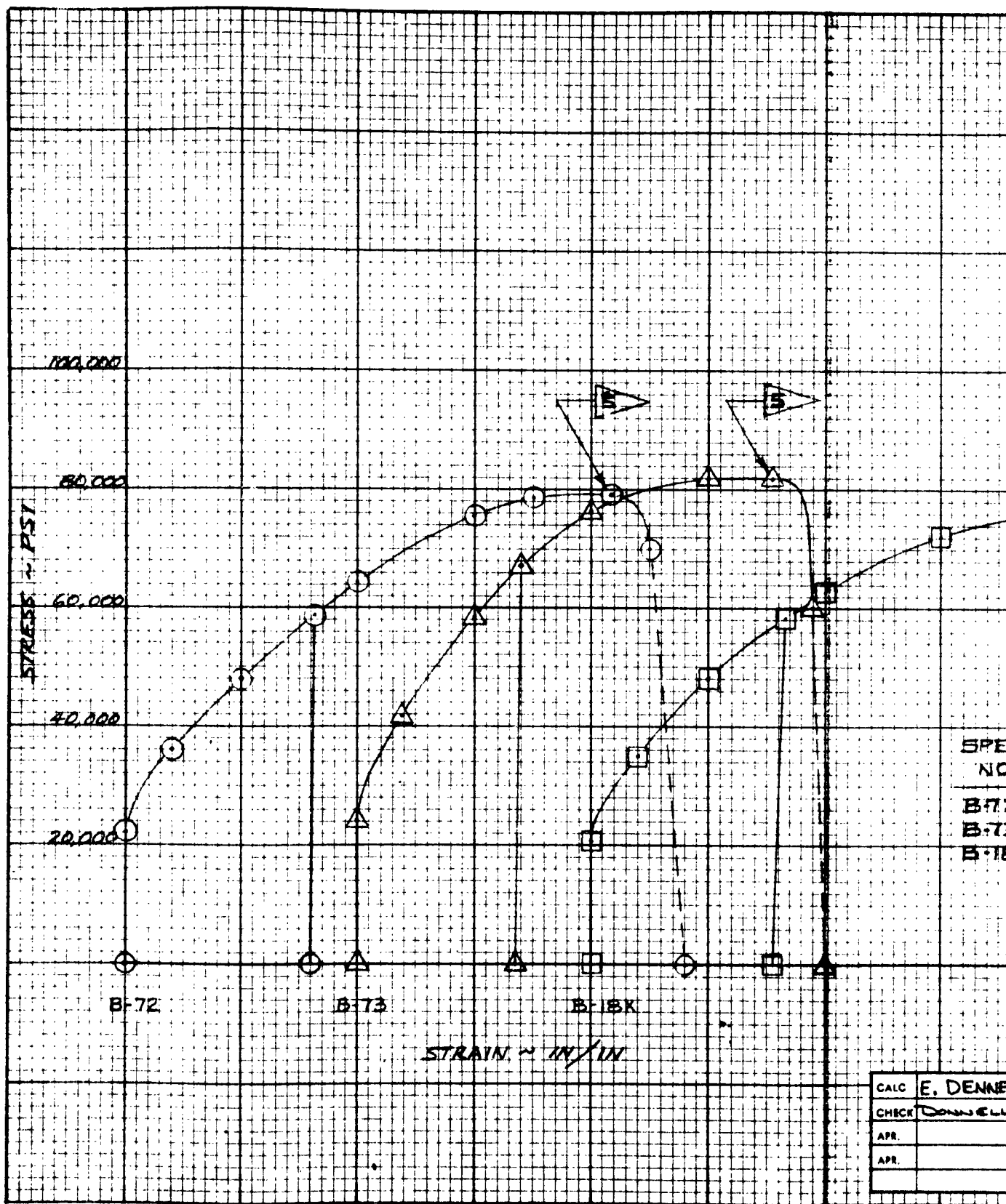
SPE
NO
B-17X
B-7
E-80

CALC	E. DENNIS
CHECK	DONNELL
APR	
APR	

DATA SHEET

CONTRACT NO.



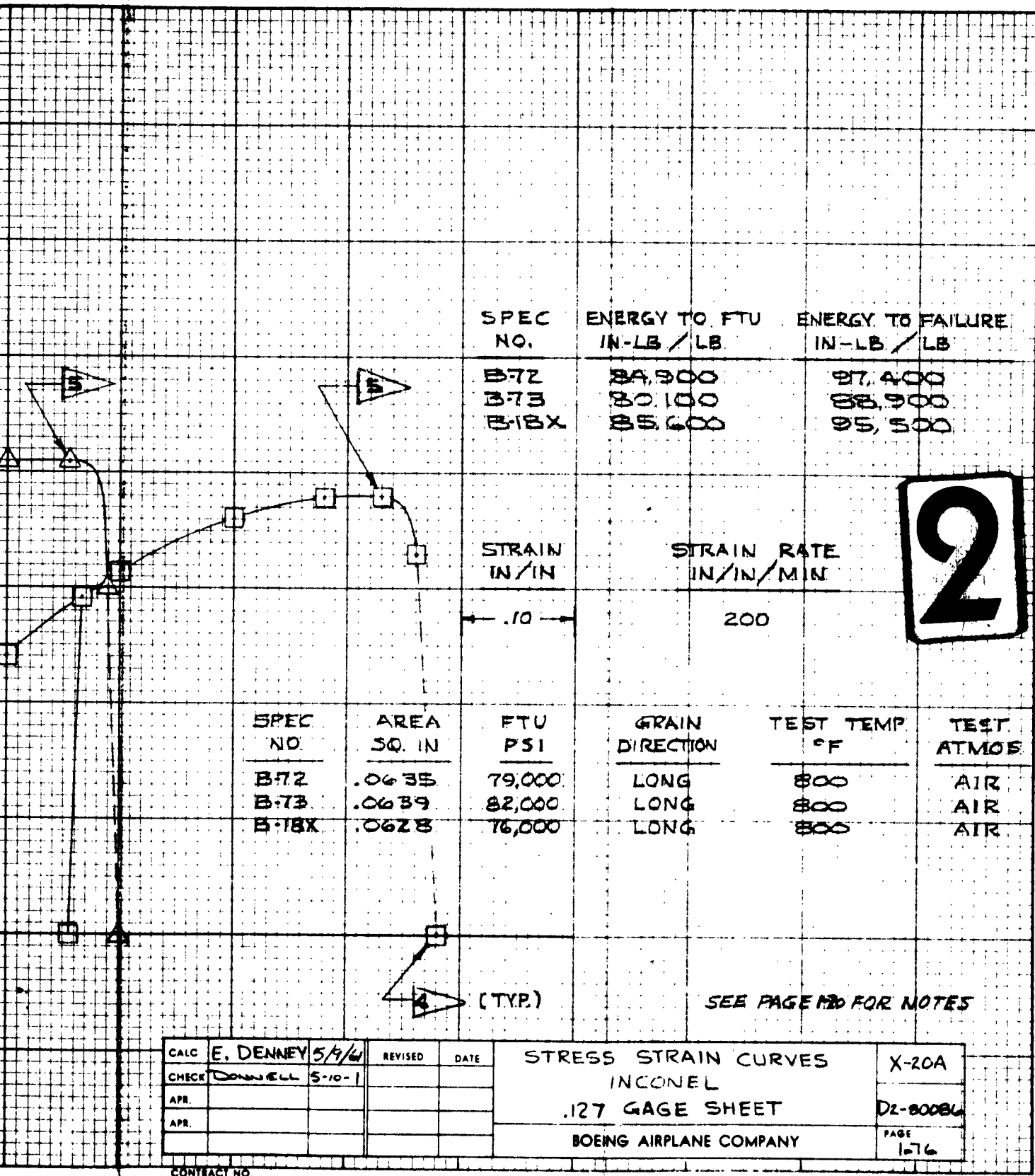


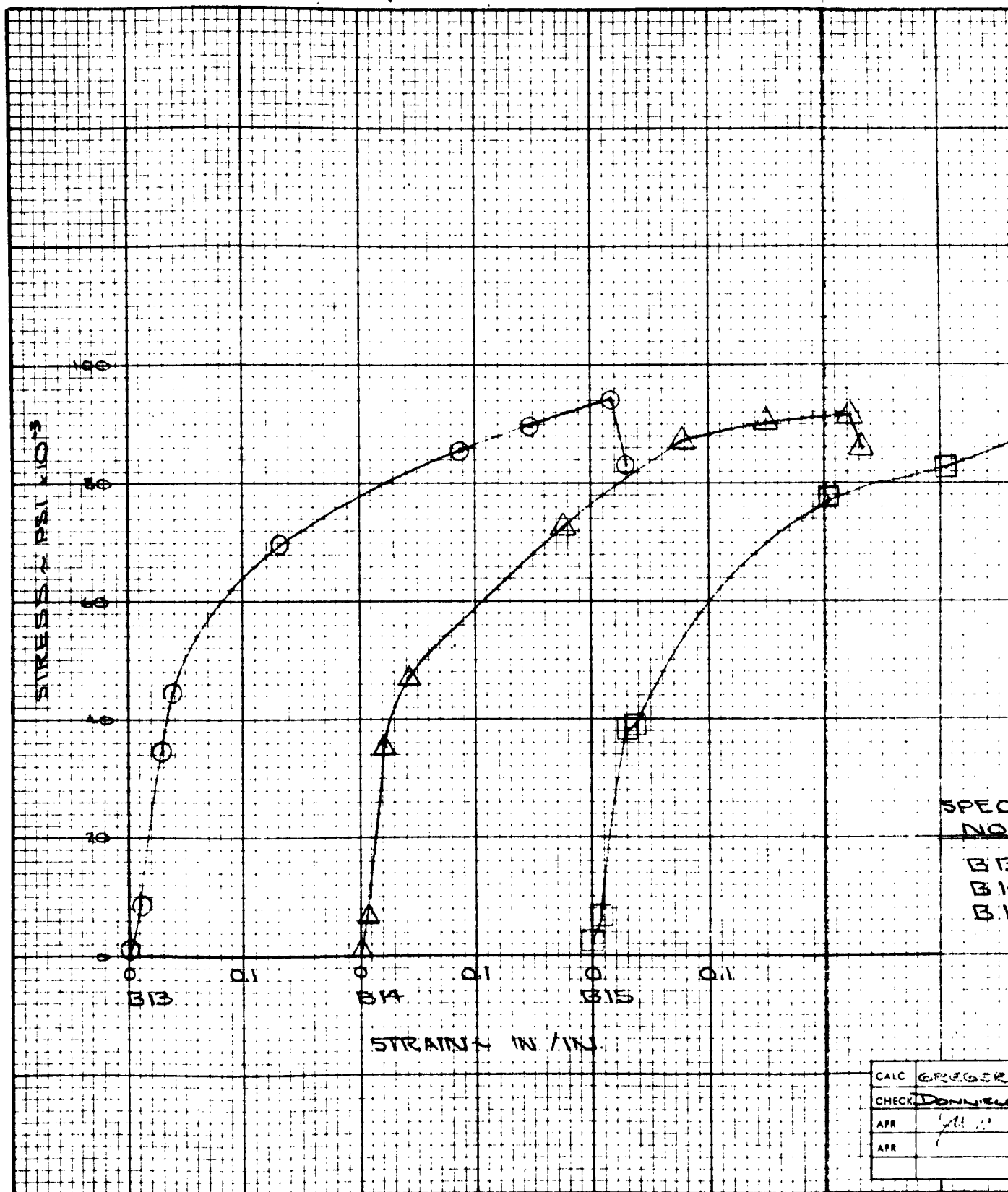
SPE
NO
B-72
B-73
B-18K

CALC	E. DENNE
CHECK	Donnell
APR.	
APR.	

DATA SHEET

CONTRACT NO.



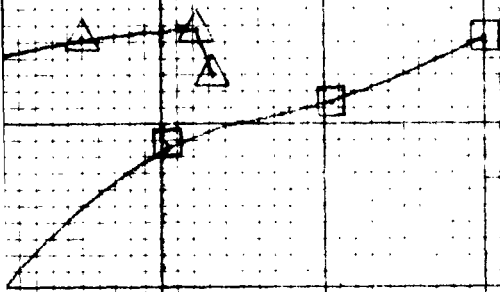


SPEC
NO
B13
B14
B15

CALC	GREGOR
CHECK	DONNELL
APR	4/11
APR	

DATA SHEET

CONTRACT NO.



SPEC NO.	ENERGY TO YLT. IN. LB/LB	ENERGY TO FAIL. IN. LB/LB
B13	100,500	104,200
B14	101,000	104,900
B15	92,000	99,000

STRAIN ~ IN. / IN.	STRAIN RATE ~ IN. / IN. / MIN.
-----------------------	-----------------------------------

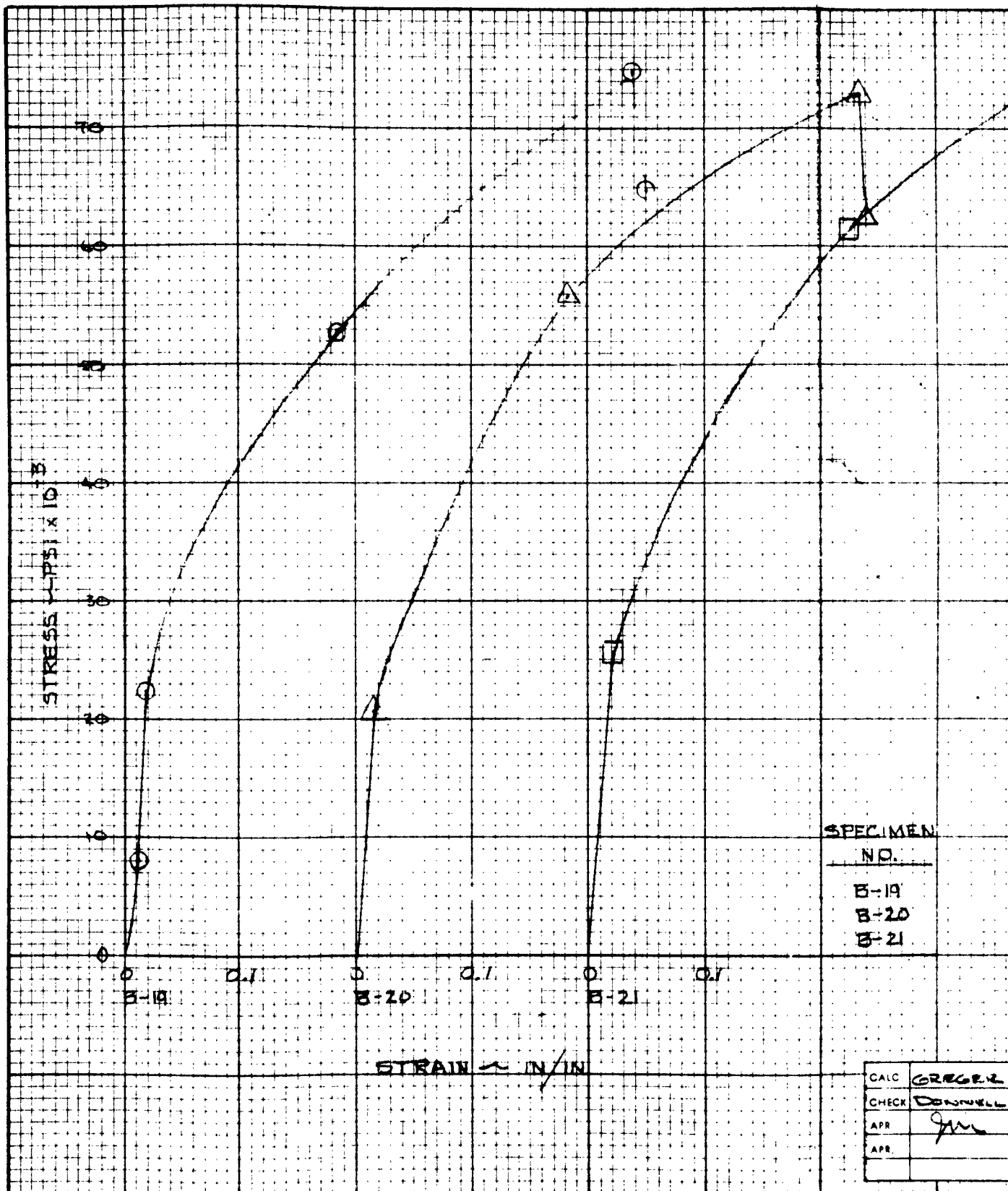
← 0.1 →	250 IN. / IN. / MIN.
---------	----------------------

SPEC NO.	AREA ~ SQ. IN.	FTU ~ PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOS.
B13	.0645	94,300	LONG.	72	AIR
B14	.0639	91,800	LONG.	72	AIR
B15	.0646	90,600	LONG.	72	AIR

2

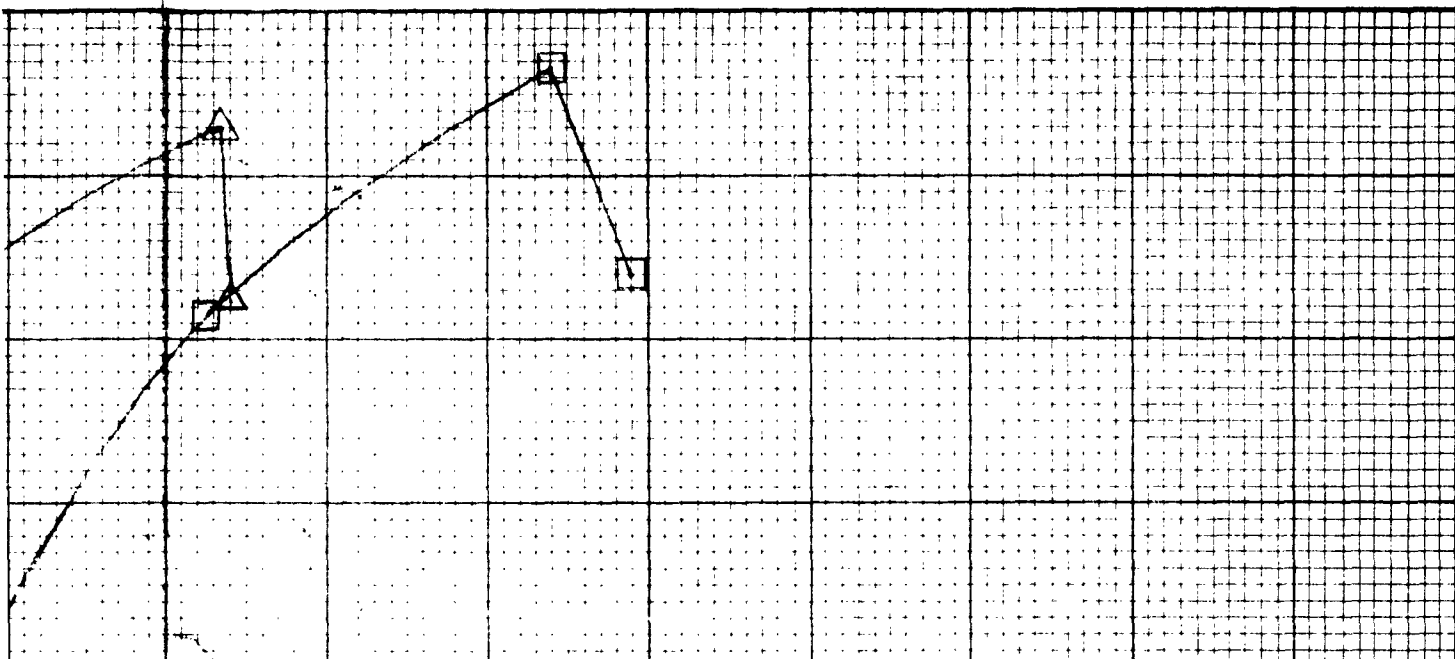
CALC	GREGG	1-27-1	REVISED	DATE	STRESS - STRAIN CURVES INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	DONNELL	1-30-1				D2-80066
APR		1-30-1				PAGE
APR						1-27

CONTRACT NO.



DATA SHEET

CONTRACT NO.



SPEC
NO.

B-19
B-20
B-21

ENERGY TO
ULT. IN-15/16

76,500
75,700
82,970

ENERGY TO
FAIL. IN-15/16

80,870
79,500
94,370

STRAIN
IN/IN

0.1

STRAIN RATE
IN/IN/MIN.

200 (TYP)

2

SPECIMEN
NO.

B-19
B-20
B-21

AREA
SQ. IN.

.0647
.0648
.0647

FTU
PSI

74,300
75,000
76,500

GRAIN
DIRECTION

LONG.
LONG.
LONG.

TEST
TEMP (°F)

800
800
800

TEST
ATMOS.

AIR
AIR
AIR

CALC	GREGG	1-27-1	REVISED	DATE
CHECK	DONNELL	1-30-1		
APR	JAN	1-30-1		
APR				

STRESS - STRAIN CURVES
INCONEL
.127 GAGE SHEET

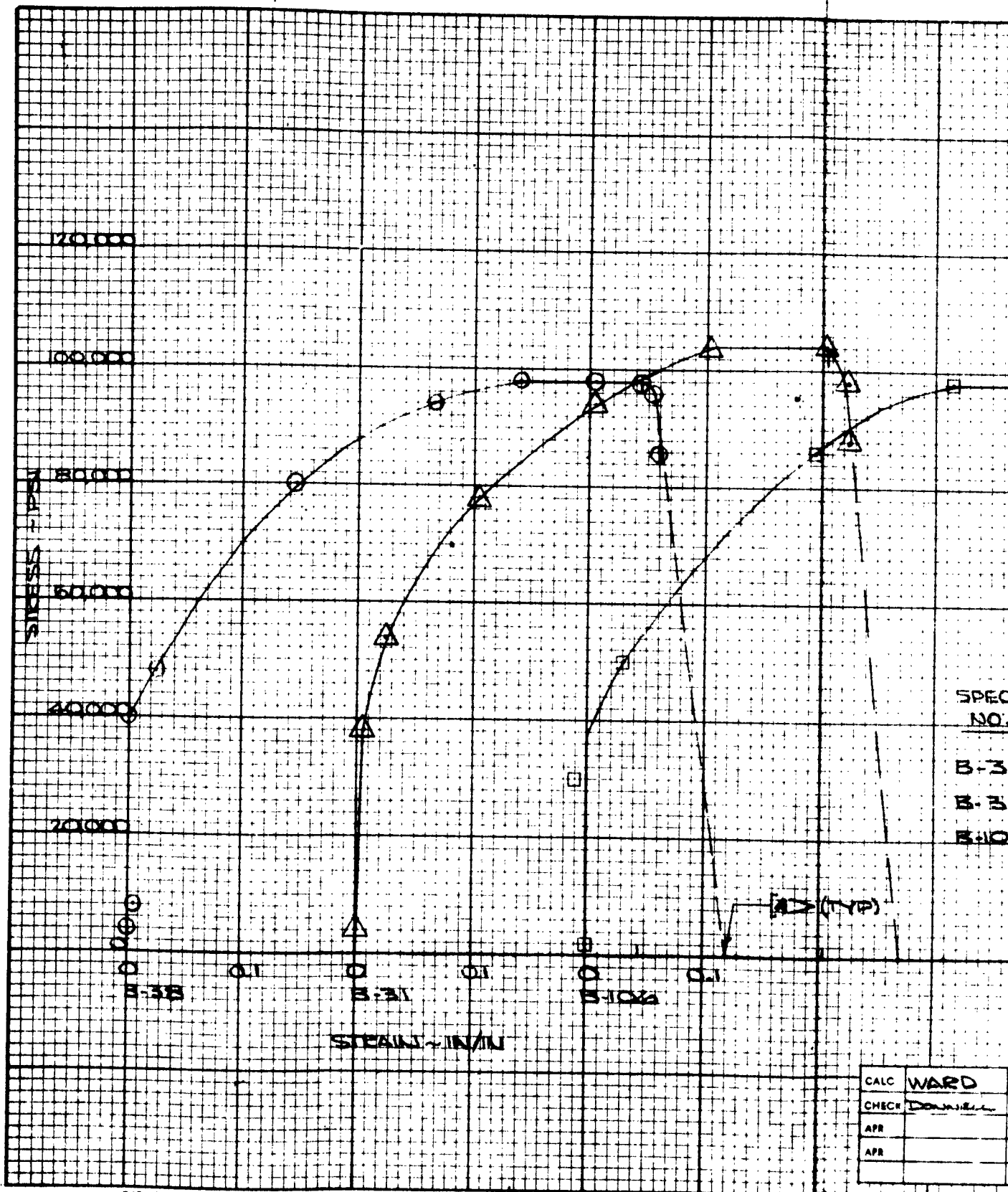
BOEING AIRPLANE COMPANY

X-20A

D2-80086

PAGE
176

CONTRACT NO.



SPEC
NO.

B-3

B-3

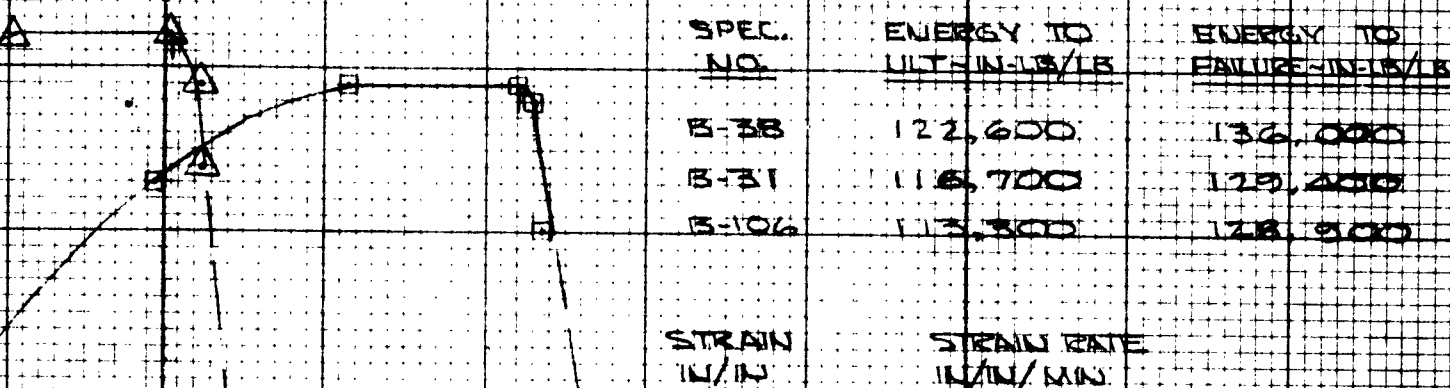
B-10

CALC	WARD
CHECK	Downell
APR	
APR	

DATA SHEET

CONTRACT NO

2



SPEC. NO.	ENERGY TO ULT-IN-LB/LB	ENERGY TO FAILURE-IN-LB/LB
B-38	122,600	136,000
B-31	116,700	129,200
B-106	113,800	128,900

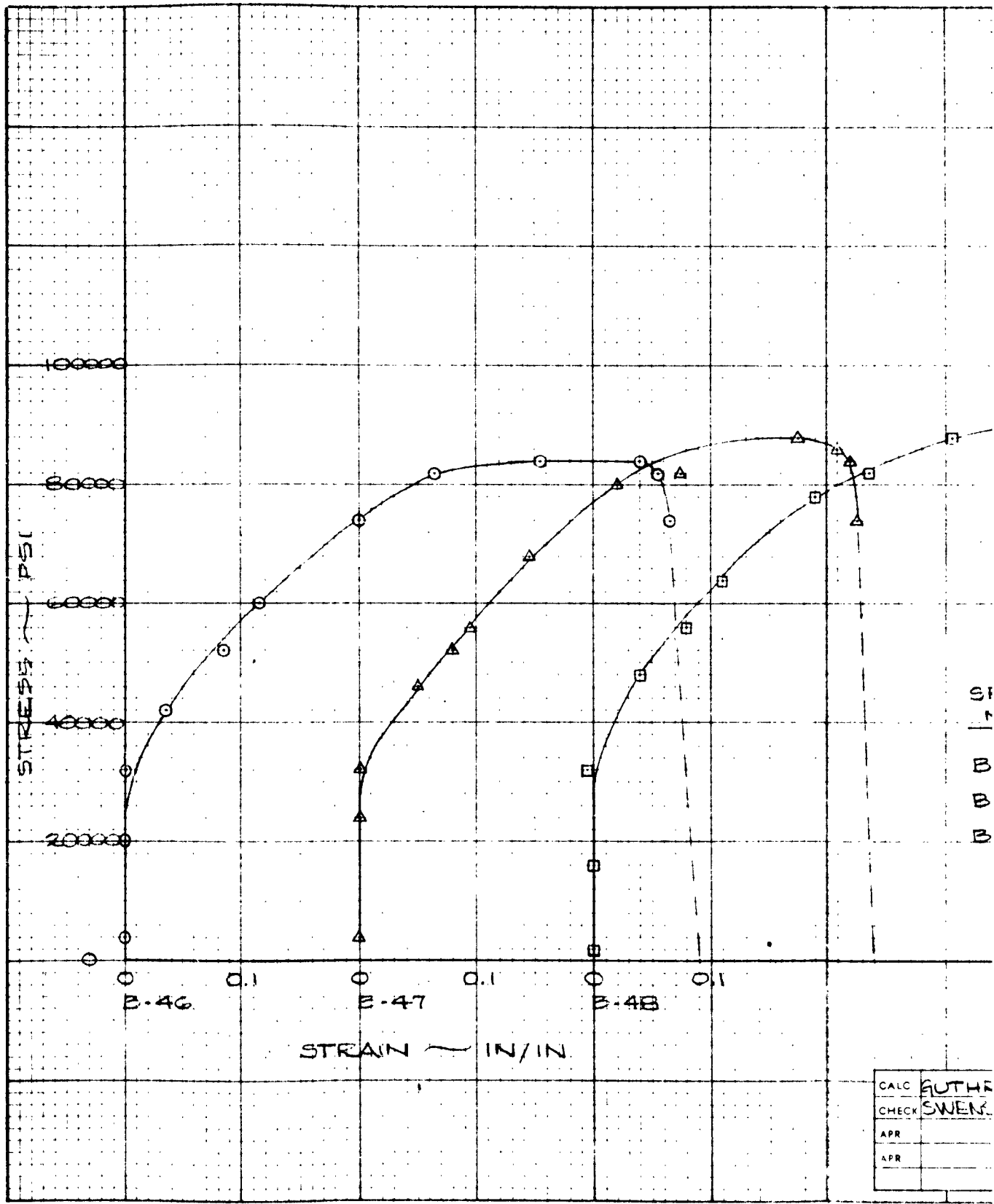
SPEC. NO.	AREA SQ. IN.	FTU PSI	GRAIN DIRECTION	TEST TEMP - °F	TEST ATMOS.
B-38	.0637	98,000	LONG.	-65	NITROGEN
B-31	.0632	104,000	LONG.	-65	NITROGEN
B-106	.0632	98,000	LONG.	-65	NITROGEN

SEE PAGE 120 FOR NOTES

CALC	WARD	3-28-1	REVISED	DATE	STRESS-STRAIN CURVES INCONEL -127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	Daniell	4-12-61				D2-80086
APP						
APP						
						PAGE 179

CONTRACT NO

1

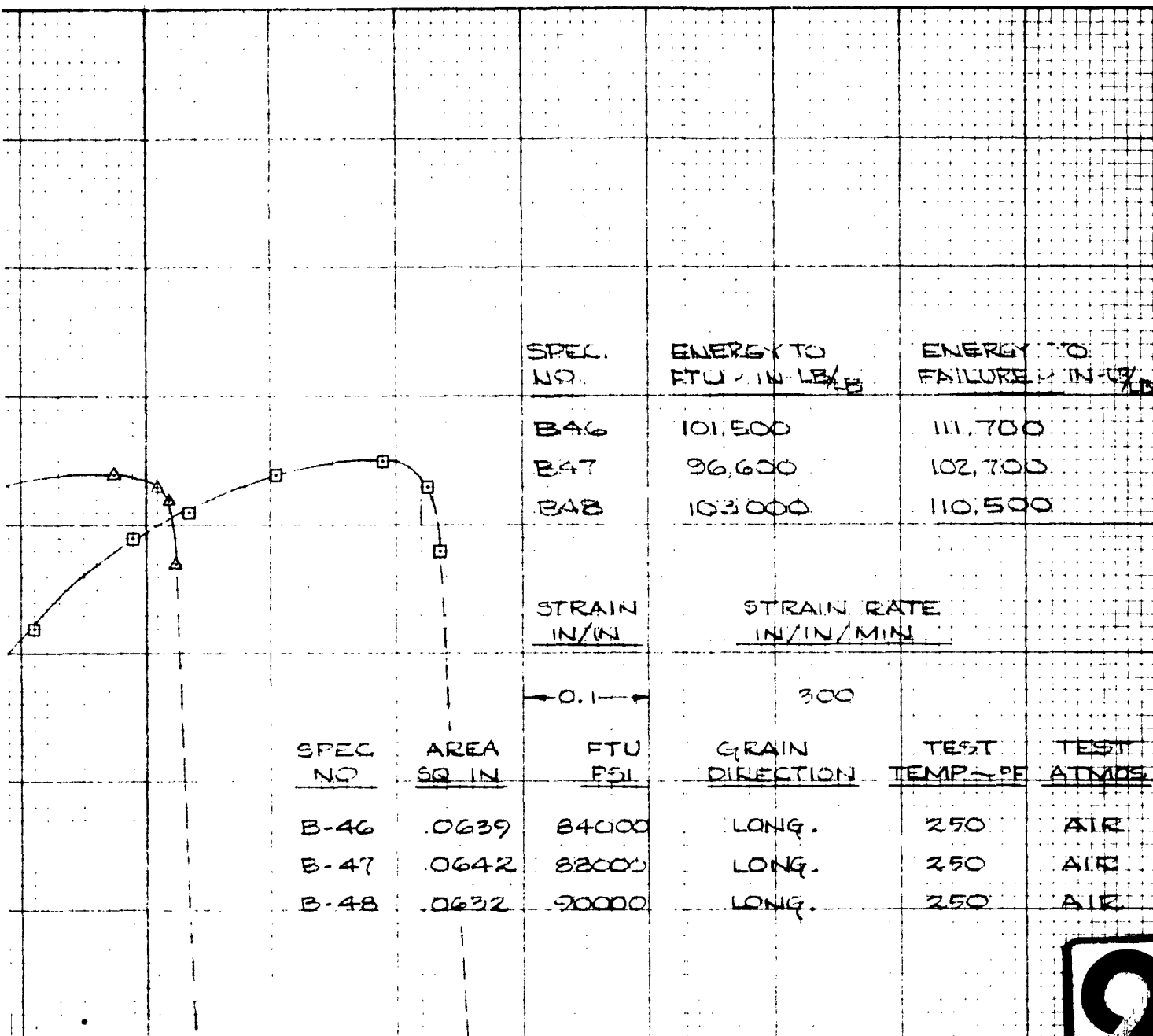


ST
B
B
B

CALC	RUTHER
CHECK	SWEN
APR	
APR	

DATA SHEET

CONTRACT NO

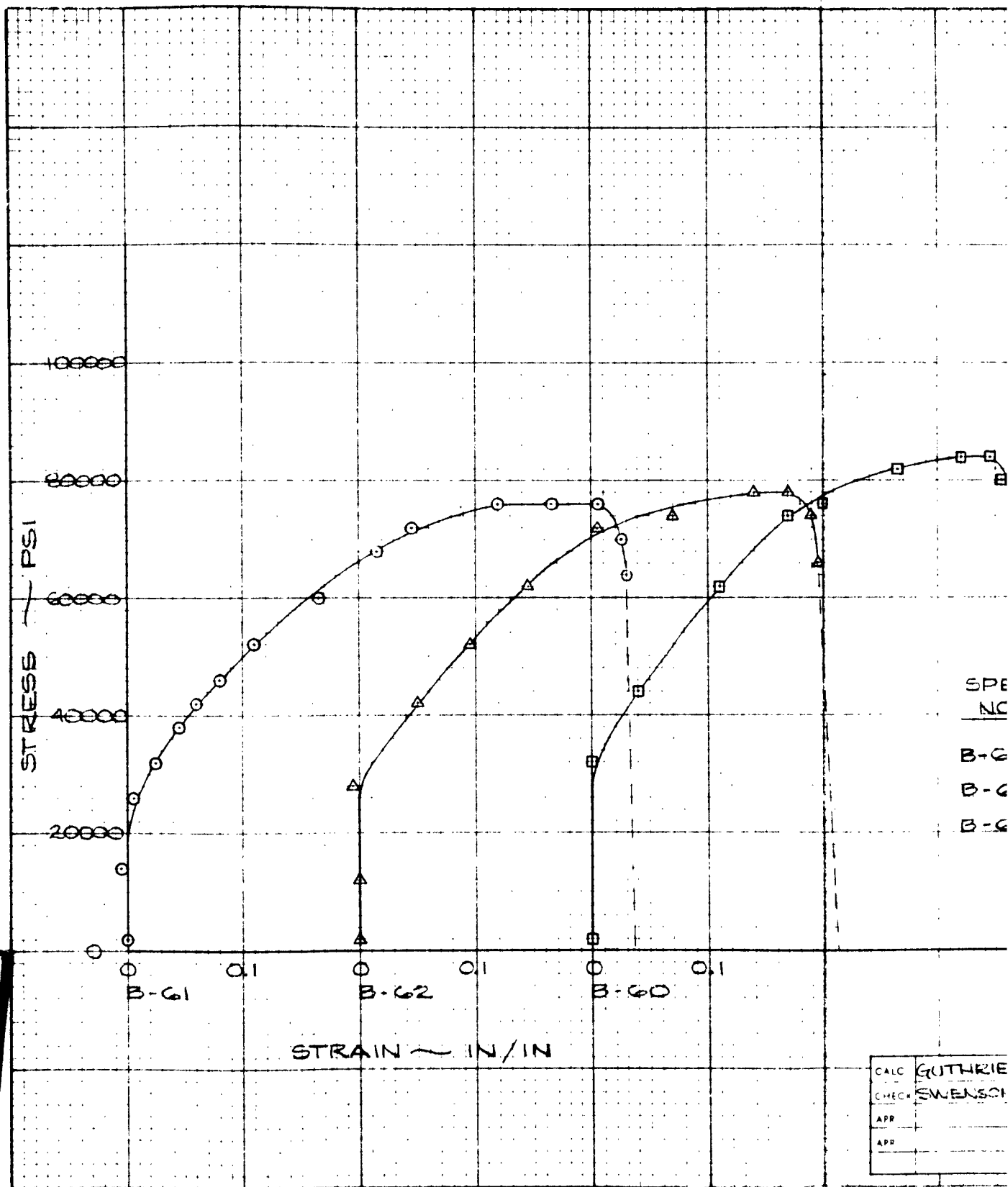


SEE PAGE 1-20 FOR NOTES

CALC	GUTHRIE 4-13-1	REVISED	DATE	STRESS - STRAIN CURVES INCONEL 127 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80084 PAGE 120
CHECK	SWENSON 4-13-1				
APR					
APR					

CONTRACT NO.

2



DATA SHEET

CALC	GUTHRIE
CHEC	SWENSON
APP	
APP	

CONTRACT NO

SPEC NO.	ENERGY TO FTU IN-IN/LB	ENERGY TO FAILURE IN-IN/LB
B-61	83,200	88,500
B-62	79,600	85,500
B-60	79,200	86,500

STRAIN IN/IN STRAIN RATE IN/IN/MIN
 0.1 300

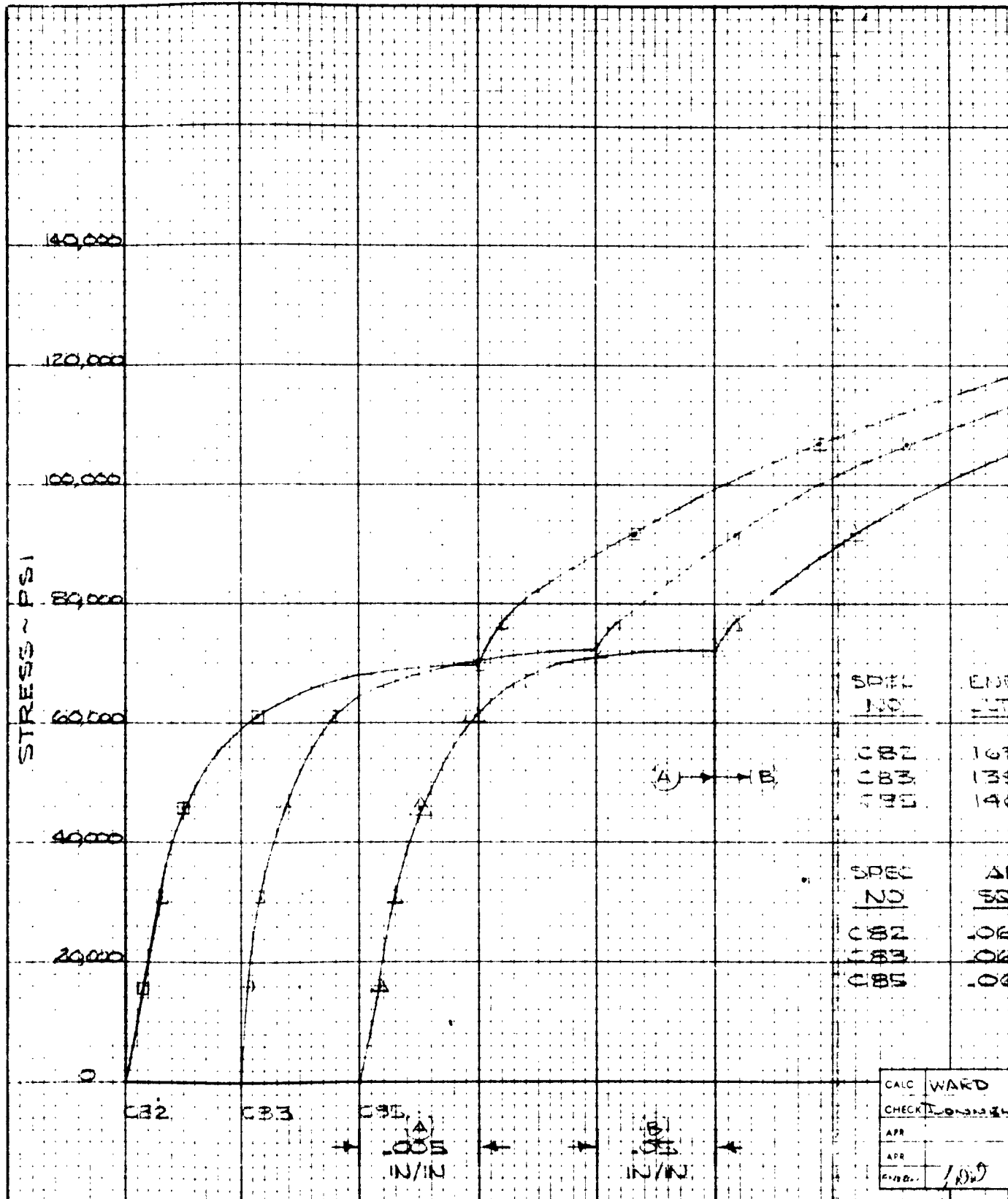
SPEC NO.	AREA SQ IN	FTU PSI	GRAIN DIRECTION	TEST TEMP ~ °F	TEST ATMOS
B-61	.0638	76000	LONG.	600	AIR
B-62	.0631	78000	LONG.	600	AIR
B-60	.0635	84000	LONG.	600	AIR

SEE PAGE 1-20 FOR NOTES

CALC GUTHRIE 4.14.1 CHECK SWENSON 4.19.1 APP APP	REVISED DATE STRESS-STRAIN CURVES X-20A INCONEL .127 GAGE SHEET BOEING AIRPLANE COMPANY	D2-80086 PAGE 181
---	--	----------------------

CONTRACT NO

2

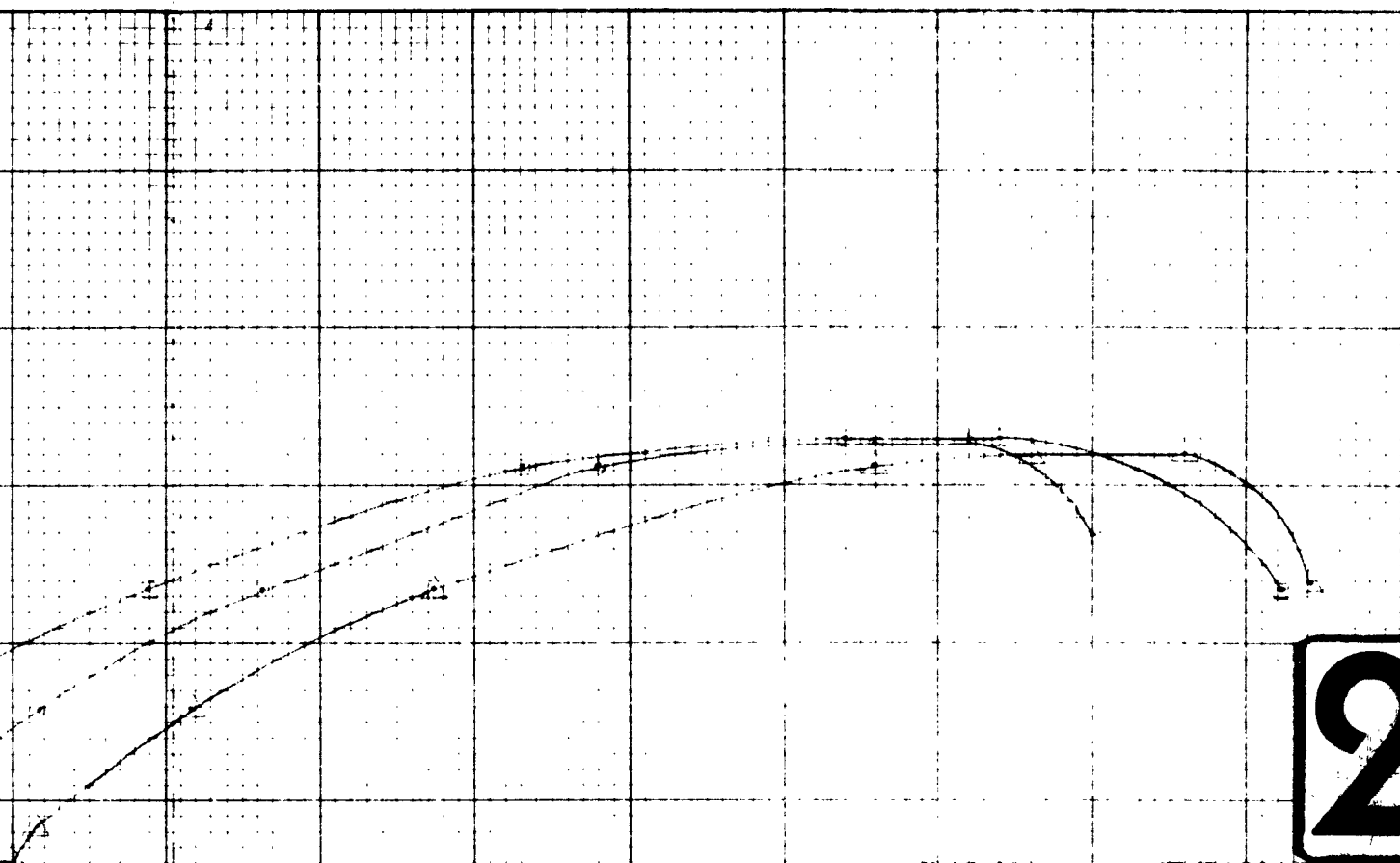


DATA SHEET

CALC	WARD
CHECK	LONGIN
APP	
APP	
DATE	1/10/69

CONTRACT NO

2

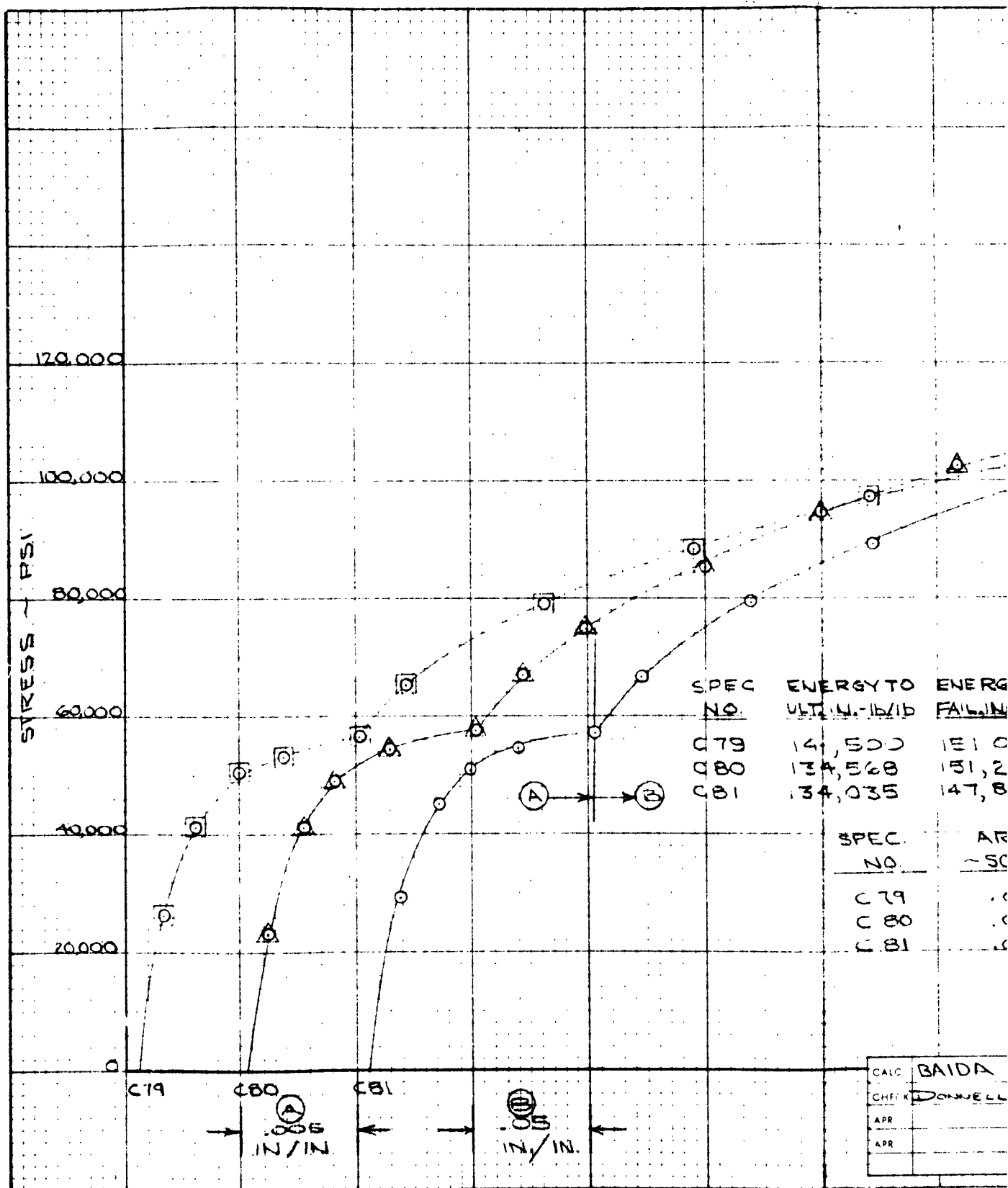


SPEC NO.	ENERGY TO EXT. INCHES	TENERGY TO FAILURE IN. B/3	TYPICAL STRAIN IN/IN	TYPICAL STRAIN RATE IN/IN/MIN
CB2	167,600	202,000	A) = .005 B) = .05	A) = .005 B = .0
CB3	138,800	156,200		
CB5	146,500	163,000		

SPEC NO.	AREA SQ. IN.	FTU PSI	GRAN DIRECTION	TEST TEMP °F	TEST ATMOSPHERE
CB2	.0654	123,100	LONG.	-65	NITROGEN
CB3	.0656	125,800	LONG.	-65	NITROGEN
CB5	.0653	124,000	LONG.	-65	NITROGEN

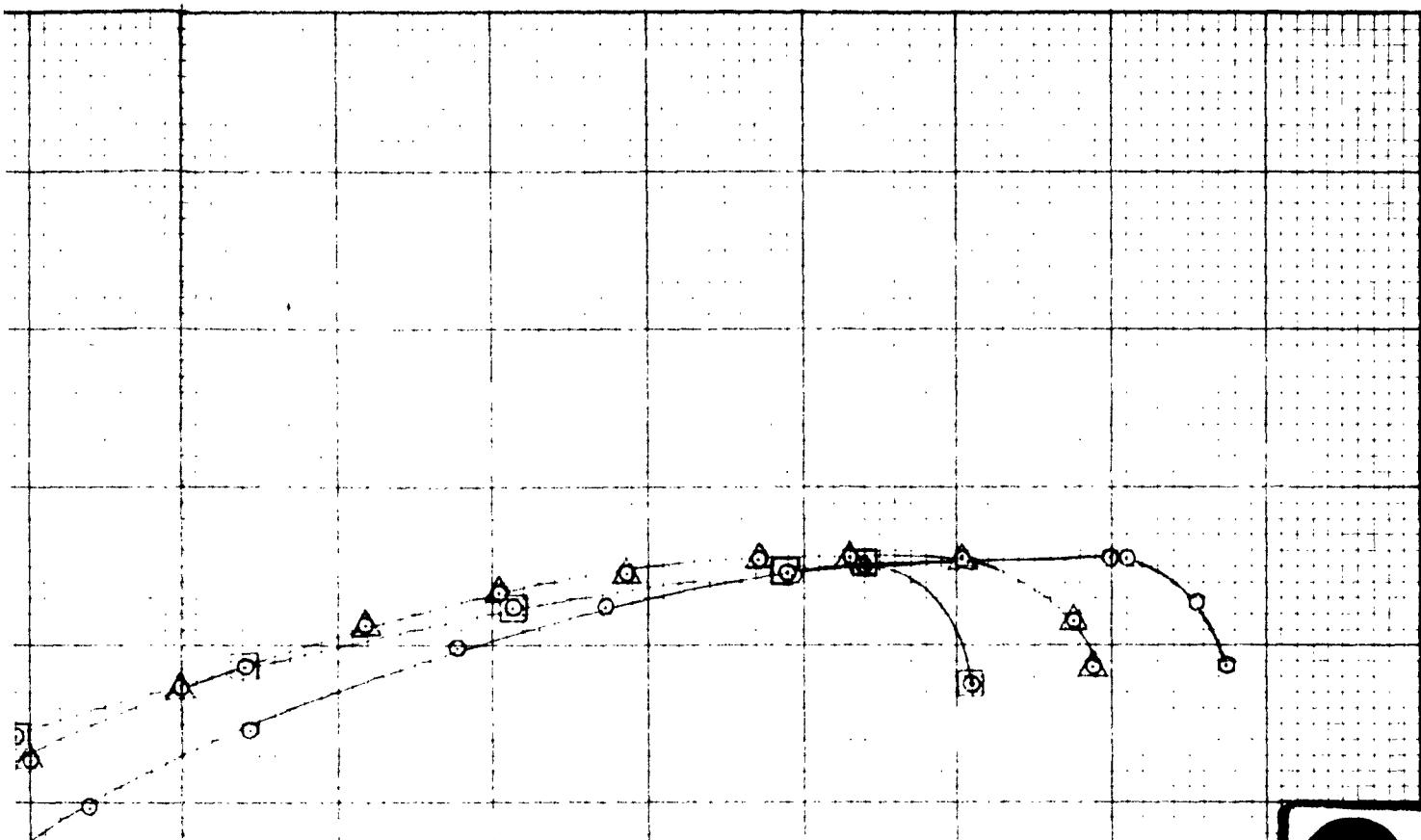
CALC	WARD	2240	REVISED	DATE	STRESS-STRAIN CURVES HASTELLOY "X" .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	LONGSTON	3-6-61				D2-800A
APP						
APP						
DATE	1/20/62					1-82

CONTRACT NO.



DATA SHEET

CONTRACT NO



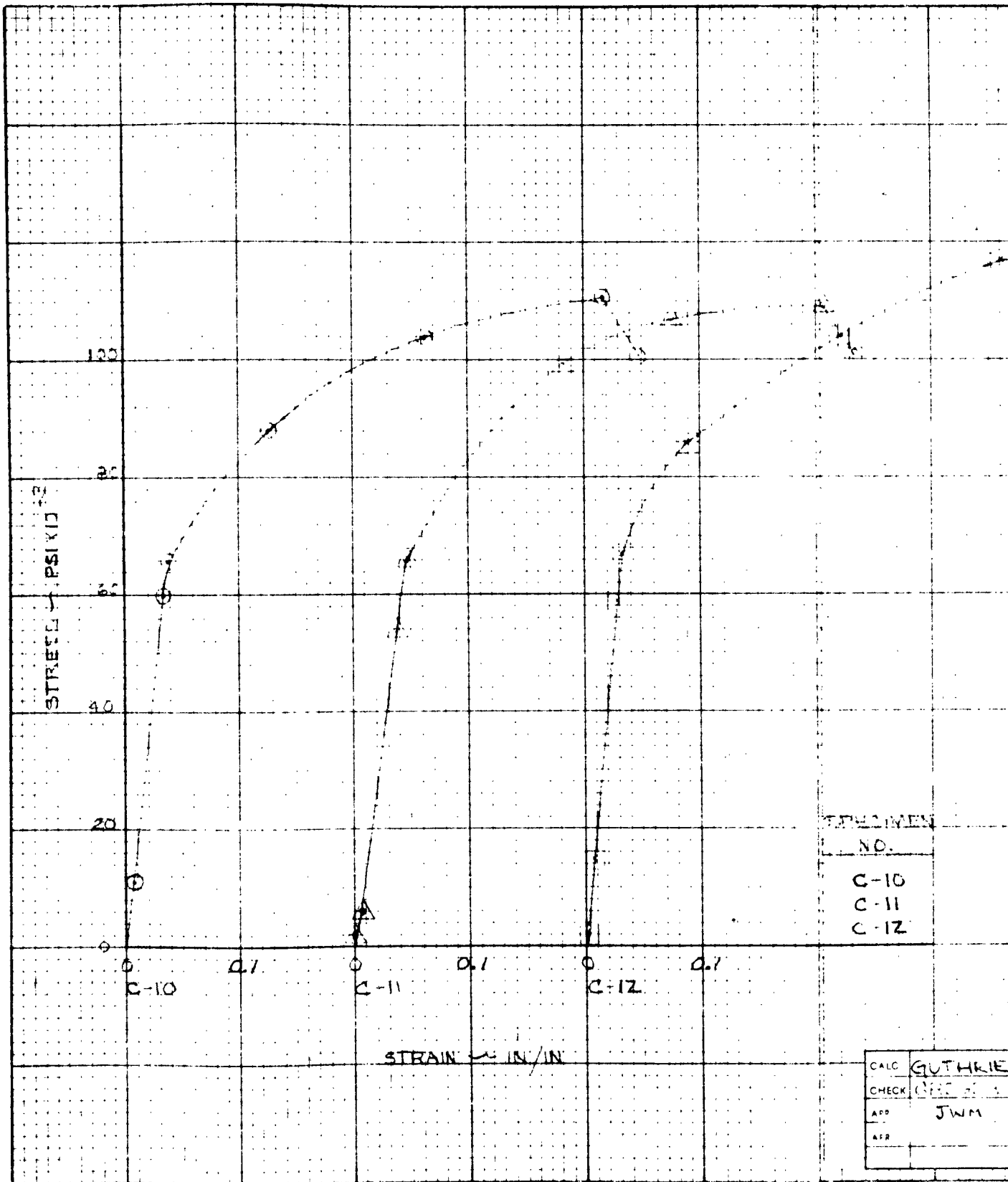
2

SPEC NO.	ENERGY TO ULT. IN.-LB/IN.	ENERGY TO FAIL. IN.-LB/IN.	TYP. STRAIN RATE IN./IN./MIN.
C 79	141,500	151,000	(A) = .005
C 80	134,568	151,268	(B) = .05
C 81	134,035	147,865	(B) = .10

SPEC. NO.	AREA - SQ. IN.	FTU - PSI	GRAIN DIRECT	TEST TEMP. (°F)	TEST ATMOS.
C 79	.0661	110,700	LONG	72	AIR
C 80	.0660	111,200	LONG	72	AIR
C 81	.0655	111,100	LONG	72	AIR

CALC	BAIDA	1-4-61	REVISED	DATE	STRESS - STRAIN CURVES X-20A HASTELLOY X .125 GAGE SHEET BOEING AIRPLANE COMPANY	D2-80086 Page 3
CHECK	DONNELLY	1-14-61				
APR						
APR						

CONTRACT NO

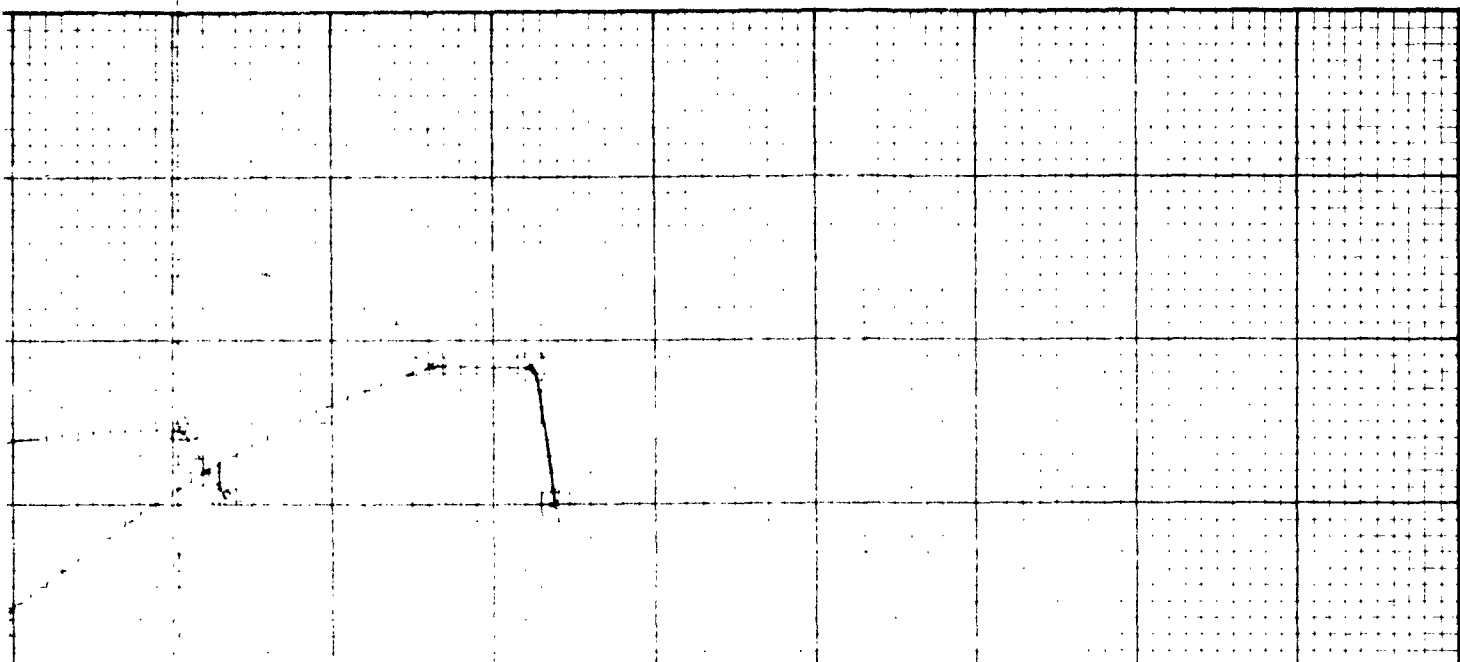


SPECIMEN
NO.
C-10
C-11
C-12

CALC	GUTHRIE
CHECK	GUTHRIE
APP	JWM
AFR	

CONTRACT NO

DATA SHEET



SPEC NO.	ENERGY TO ULT. IN-16/16	ENERGY TO FAIL. IN-16/16
C-10	130,900	142,400
C-11	127,300	137,000
C-12	140,400	146,000

2

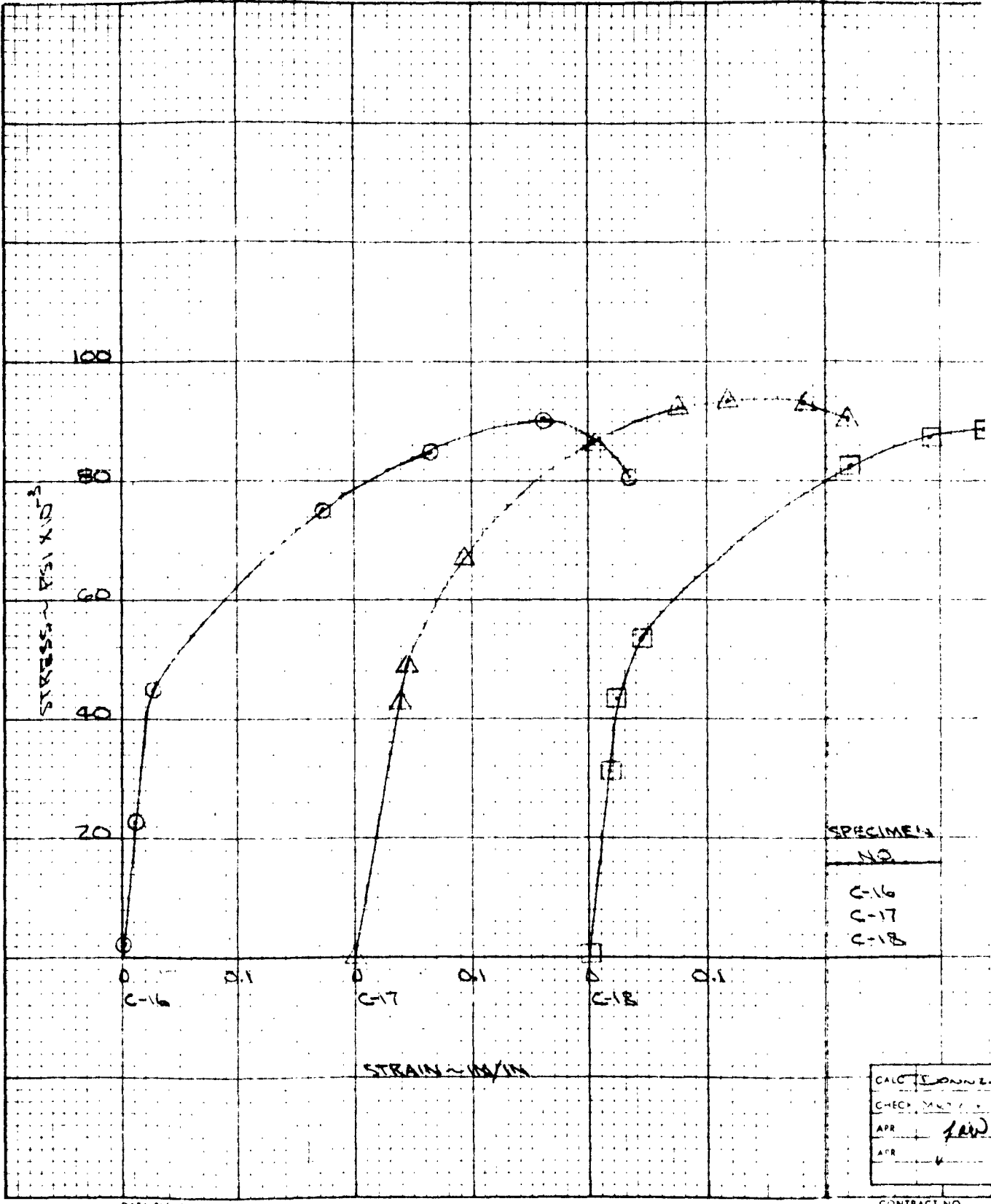
STRAIN
IN/IN
0.1

STRAIN RATE
IN/IN/MIN
SPEC C-10 ~ 170
SPEC C-11 ~ 170
SPEC C-12 ~ 170

SPECIMEN NO.	AREA SQ. IN.	FTD PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOS.
C-10	.0663	110,400	LONG.	72	AIR
C-11	.0660	109,100	LONG.	72	AIR
C-12	.0661	117,000	LONG.	72	AIR

CALC GUTHRIE CHECK JWM APP 	12/7/61 12/7/61 1-7A 21	REVISED 	DATE 	STRESS - STRAIN CURVES HASTELLOY "X" .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE L84
--	-------------------------------	-------------	----------	---	----------------------------------

CONTRACT NO



1

CALC	Done
CHECK	✓
APR	1/20
APR	✓



SPEC. NO.	ENERGY TO ULT. IN-LE/LB	ENERGY TO FAIL. IN-LE/LB
C-16	88,000	108,700
C-17	99,000	111,800
C-18	87,500	88,500

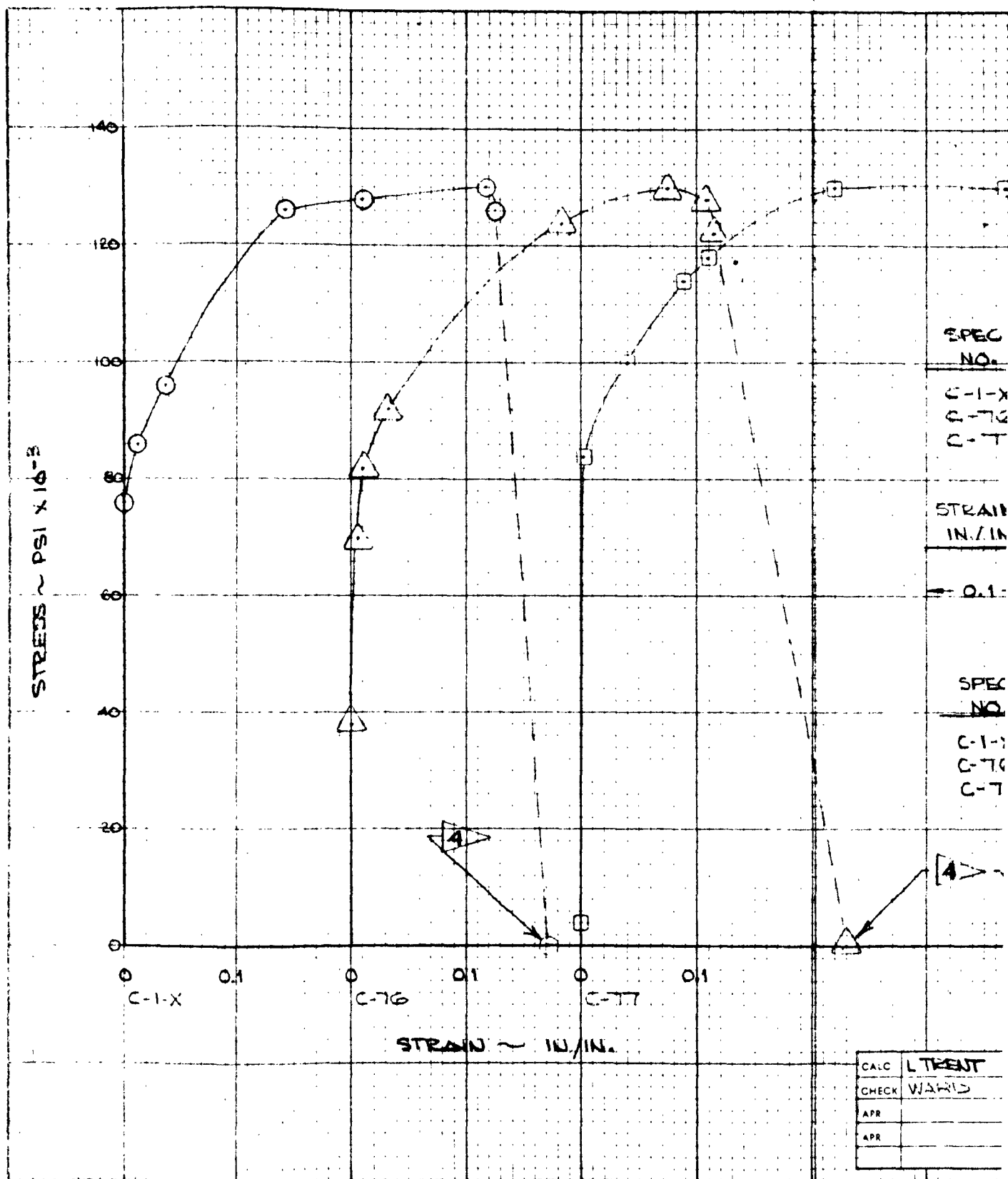
STRAIN -IN/IN	STRAIN RATE -IN/IN/MIN
0.1	185 TYP.

2

SPECIMEN NO.	AREA -SQ IN.	FTU -PSI	GRAIN DIRECTION	TEST TEMP (°F)	TEST ATMOSP.
C-16	.0451	90,150	LONG.	600°	AIR
C-17	.0454	93,370	LONG.	600°	AIR
C-18	.0452	89,500	LONG.	600°	AIR

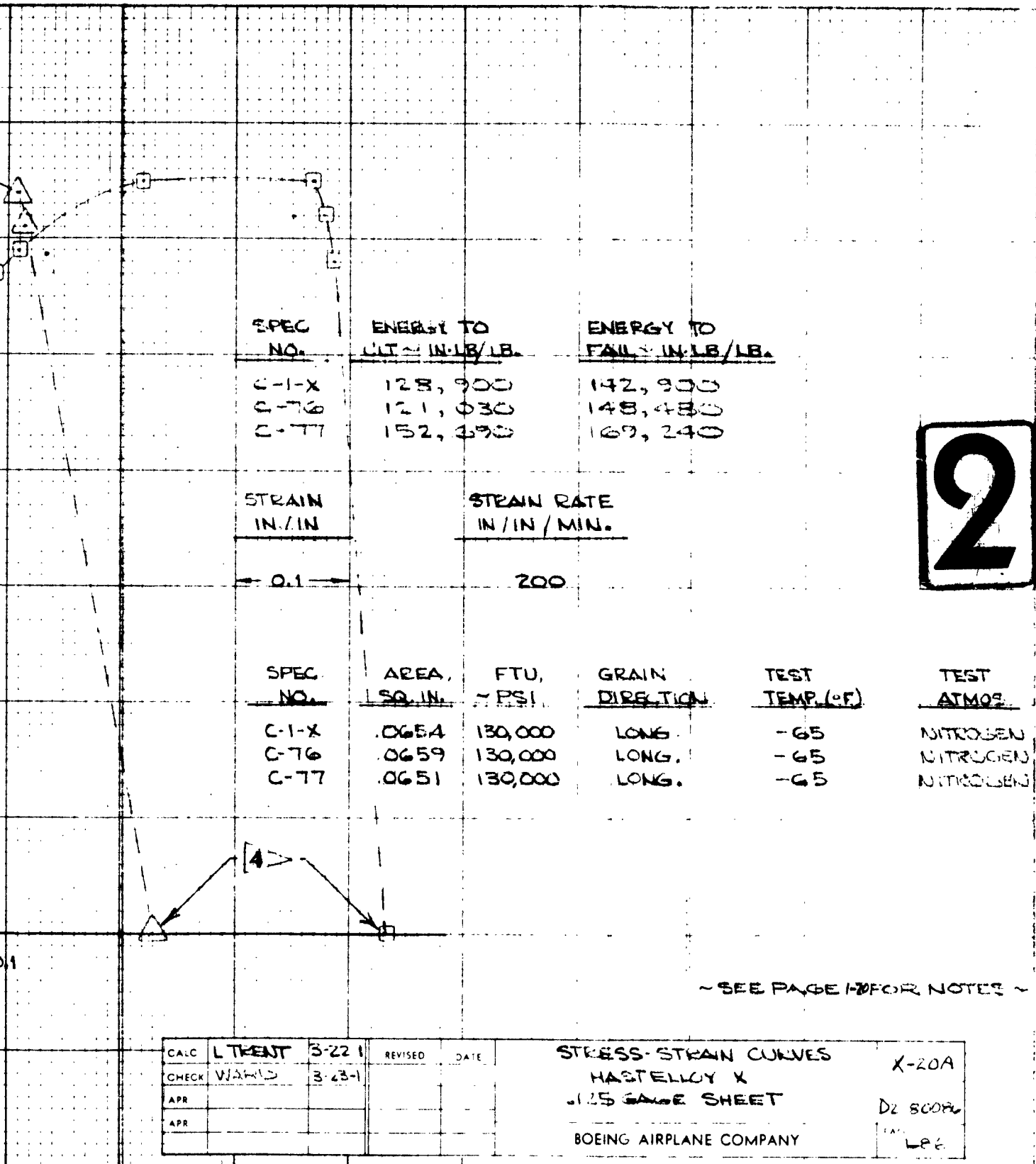
CALC. <i>Donnell</i>	1-28-1	REVISED	DATE	STRESS-STRAIN CURVES HASTELLOY "X" .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A DZ-80086 PAGE 1-25
CHECK <i>Donnell</i>	1-28-1				
APP <i>Law</i>	1-28-1				
APP					

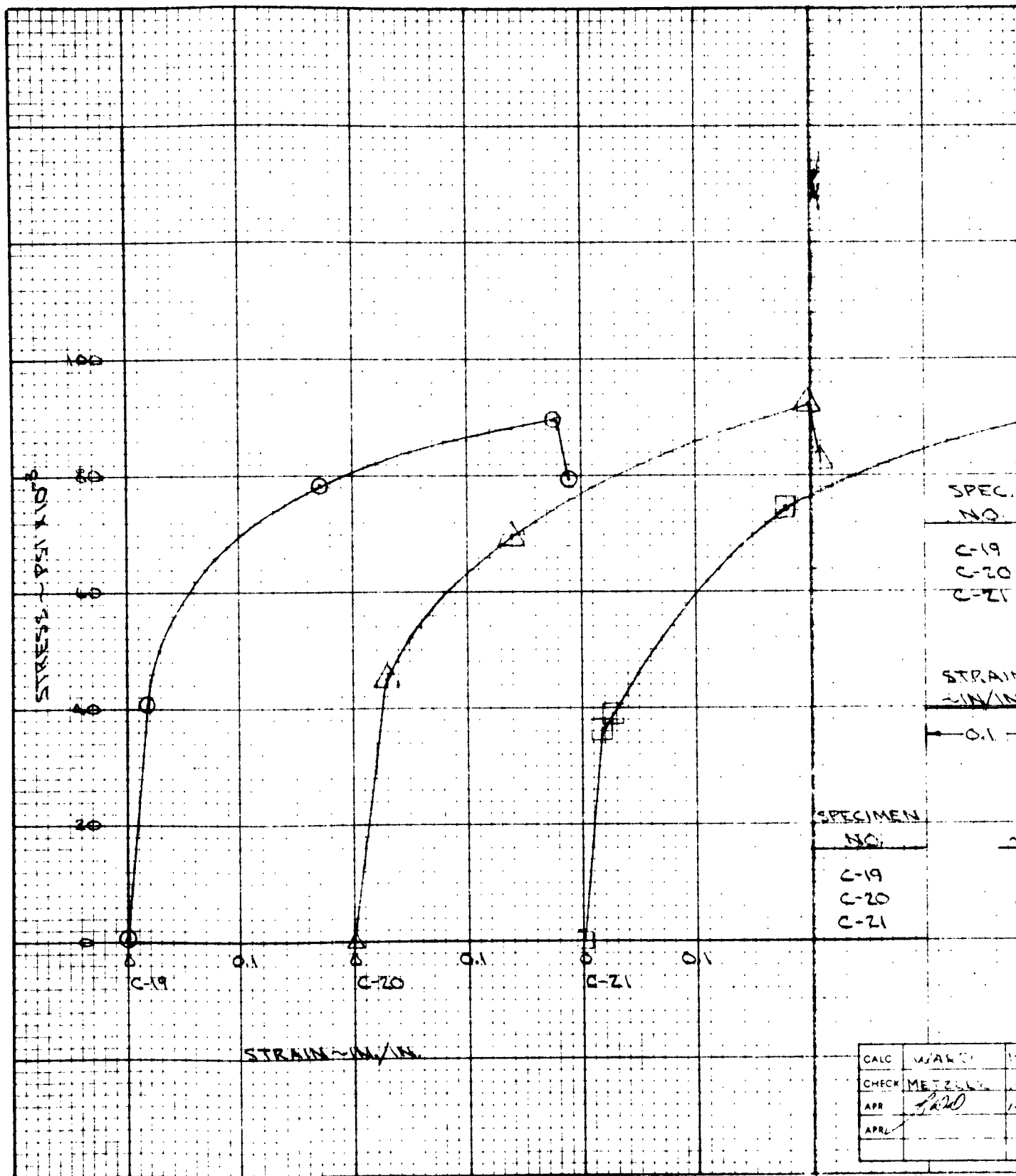
CONTRACT NO.



DATA SHEET

CONTRACT NO.

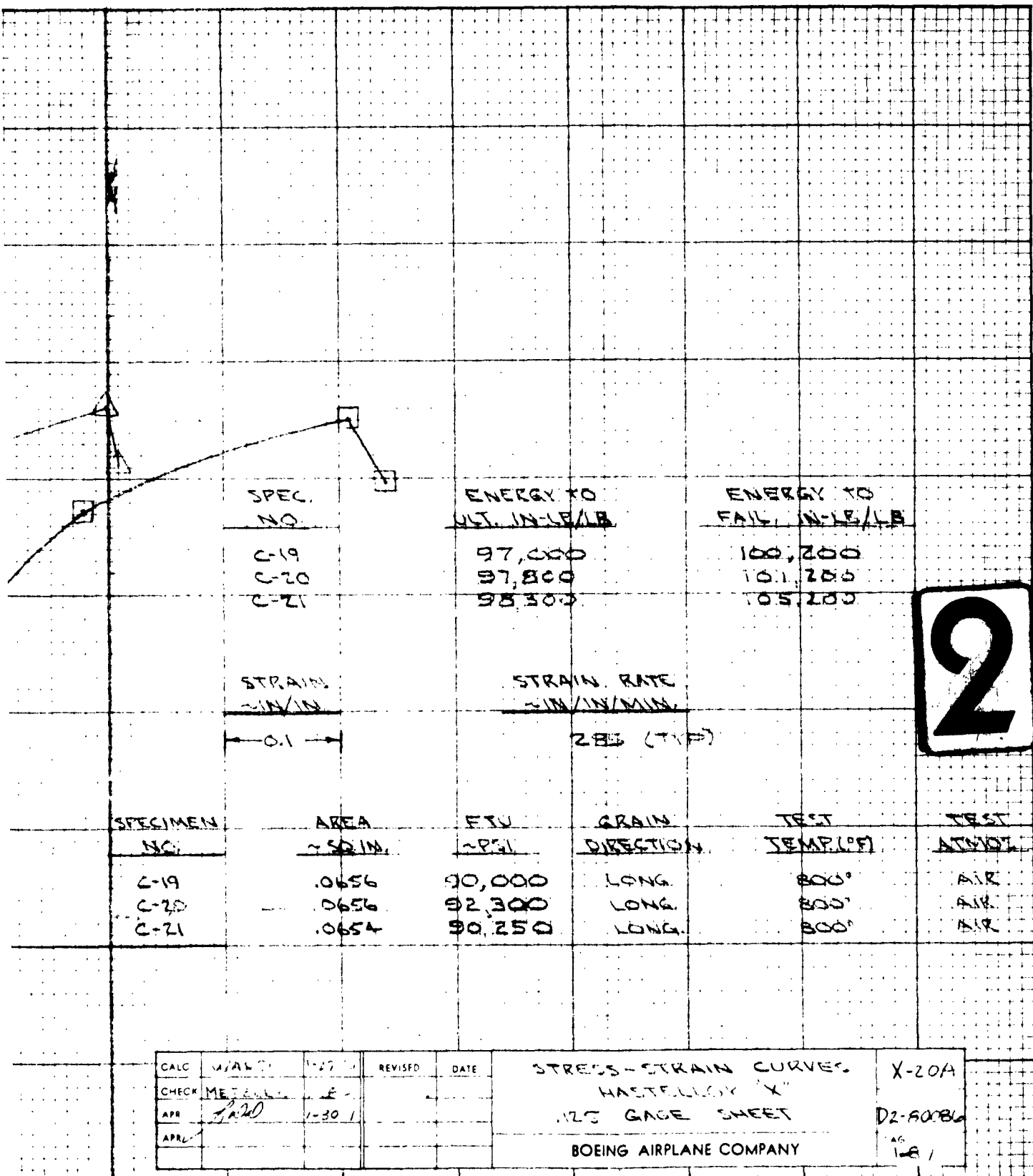




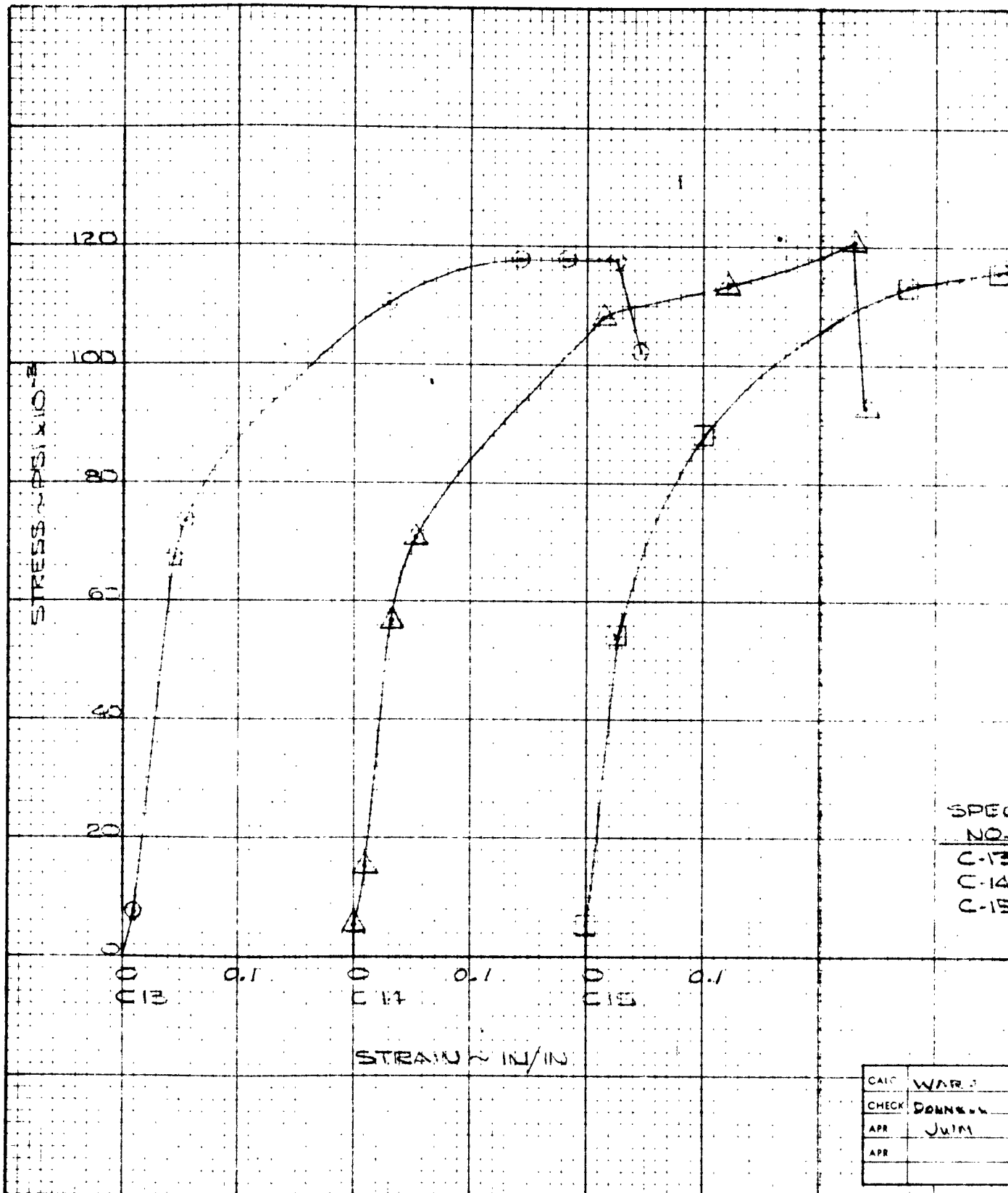
DATA SHEET

CALC	W/ALC	1
CHECK	METZGER	1
APR	4/20	1
APR		

CONTRACT NO



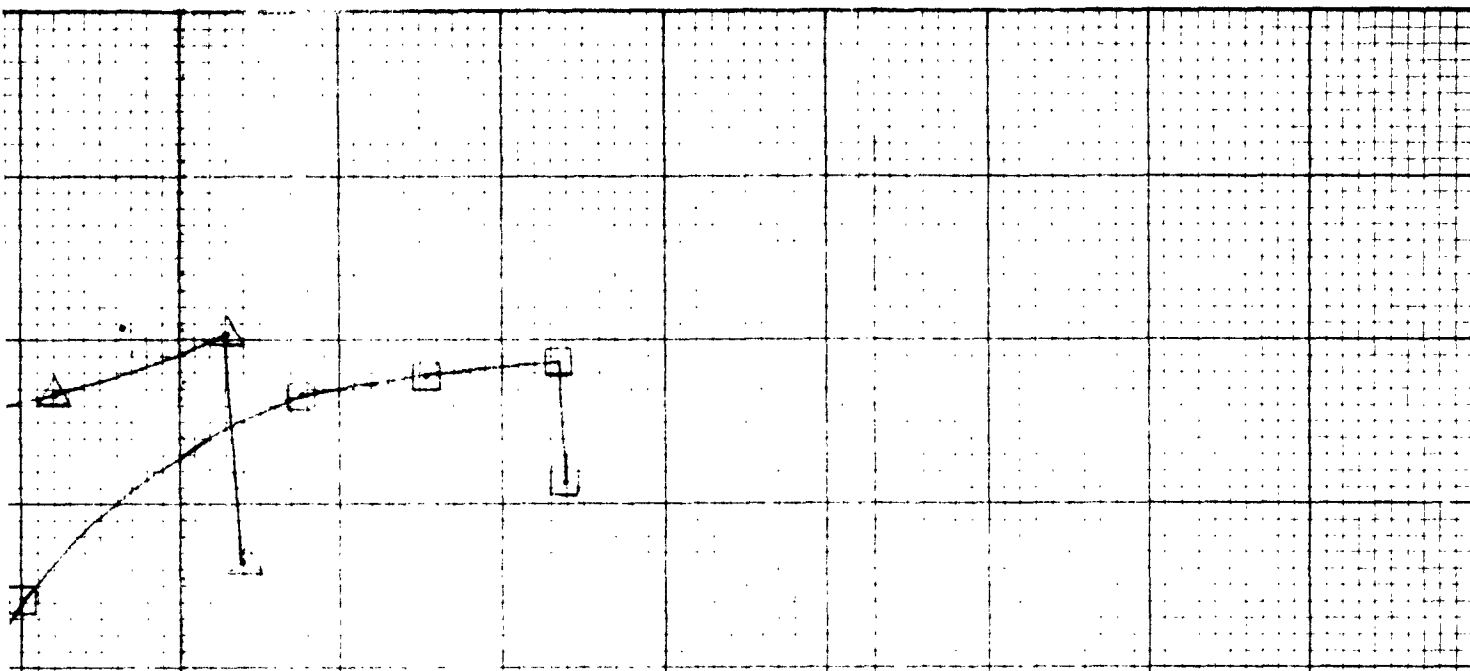
CONTRACT NO



DATA SHEET

CALC	WARR
CHECK	DOUGLAS
APR	JULY
APR	

CONTRACT NO



SPEC. NO.	ENERGY TO ULT. IN-LB/LB	ENERGY TO FAILURE IN-LB/LB
C-13	142,800	150,300
C-14	142,500	146,200
C-15	142,400	148,500

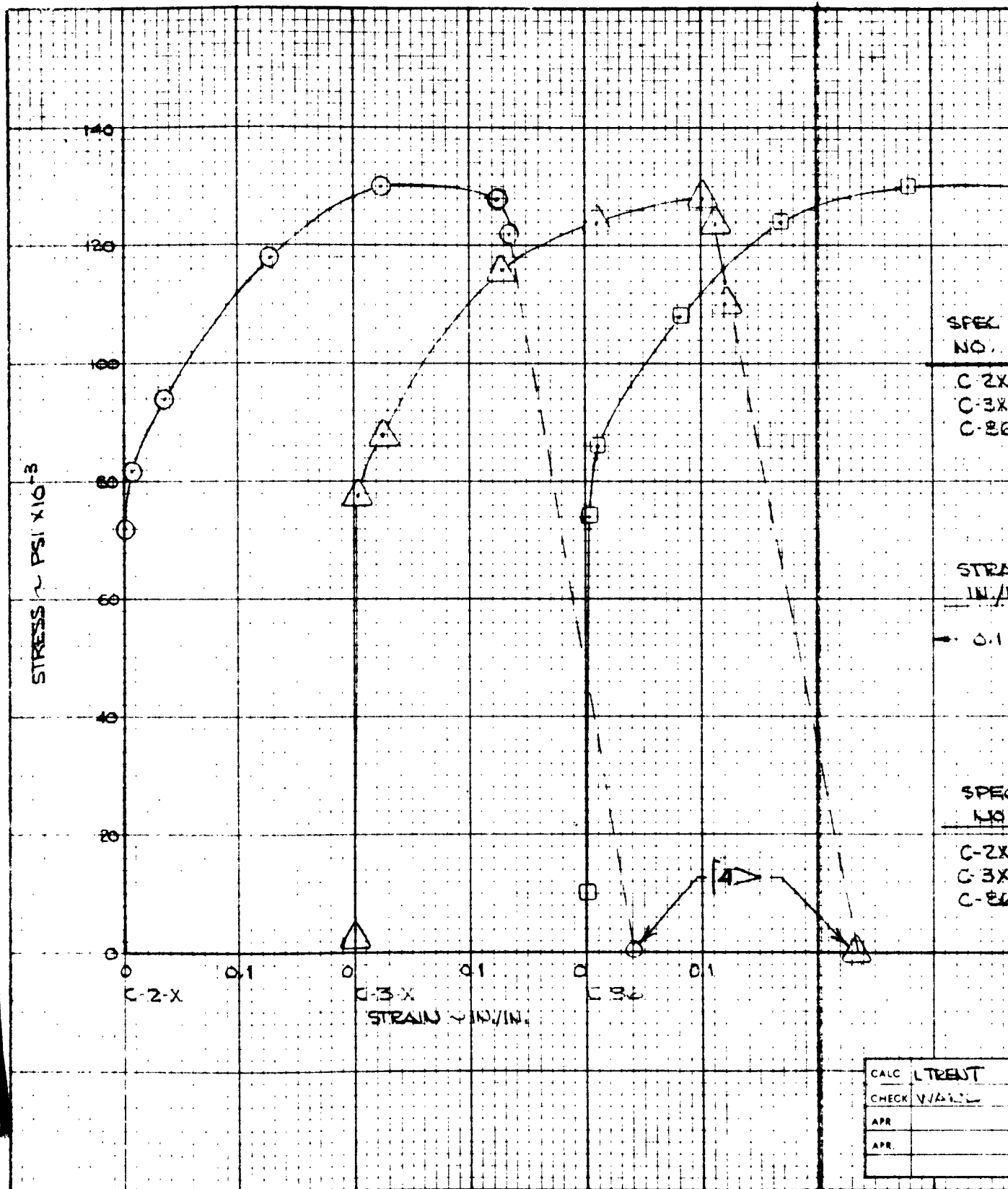
STRAIN IN/IN	STRAIN RATE IN/IN/MIN
0.1	295

SPEC NO.	AREA SQ. IN.	FTU PSI	STRAIN DIRECTION	TEST TEMPERATURE	TEST ATMOSP.
C-13	.0659	117,970	LONG.	72	AIR
C-14	.0655	120,610	LONG.	72	AIR
C-15	.0656	117,350	LONG.	72	AIR

CALC	WATSON	1-27-61	REVISED	DATE	STRESS-STRAIN CURVES HASTELLOY "X" 1/2" GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-88
CHECK	DOUGLAS	1-28-61				
APP	JULIAN	1-28-61				
APP						

CONTRACT NO.

2



DATA SHEET

CONTRACT NO

CALC	L TRENT
CHECK	V. J. A. L.
APR	
APR	

SPEC
NO.

ENERGY TO
ULT ~ IN LB/LB.

ENERGY TO
FAIL ~ IN LB/LB.

C-2X
C-3X
C-86

133,290
117,240
153,520

138,000
147,790
180,760

STRAIN
IN./IN.

STRAIN RATE
IN./IN./MIN.

0.1

300

2

SPEC
NO.

AREA
SQ IN.

FTU
PSI

GRAIN
DIRECTION

TEST
TEMP (°F)

TEST
ATMOS.

C-2X
C-3X
C-86

.0651
.0648
.0656

128,000
128,000
130,000

LONG.
LONG.
LONG.

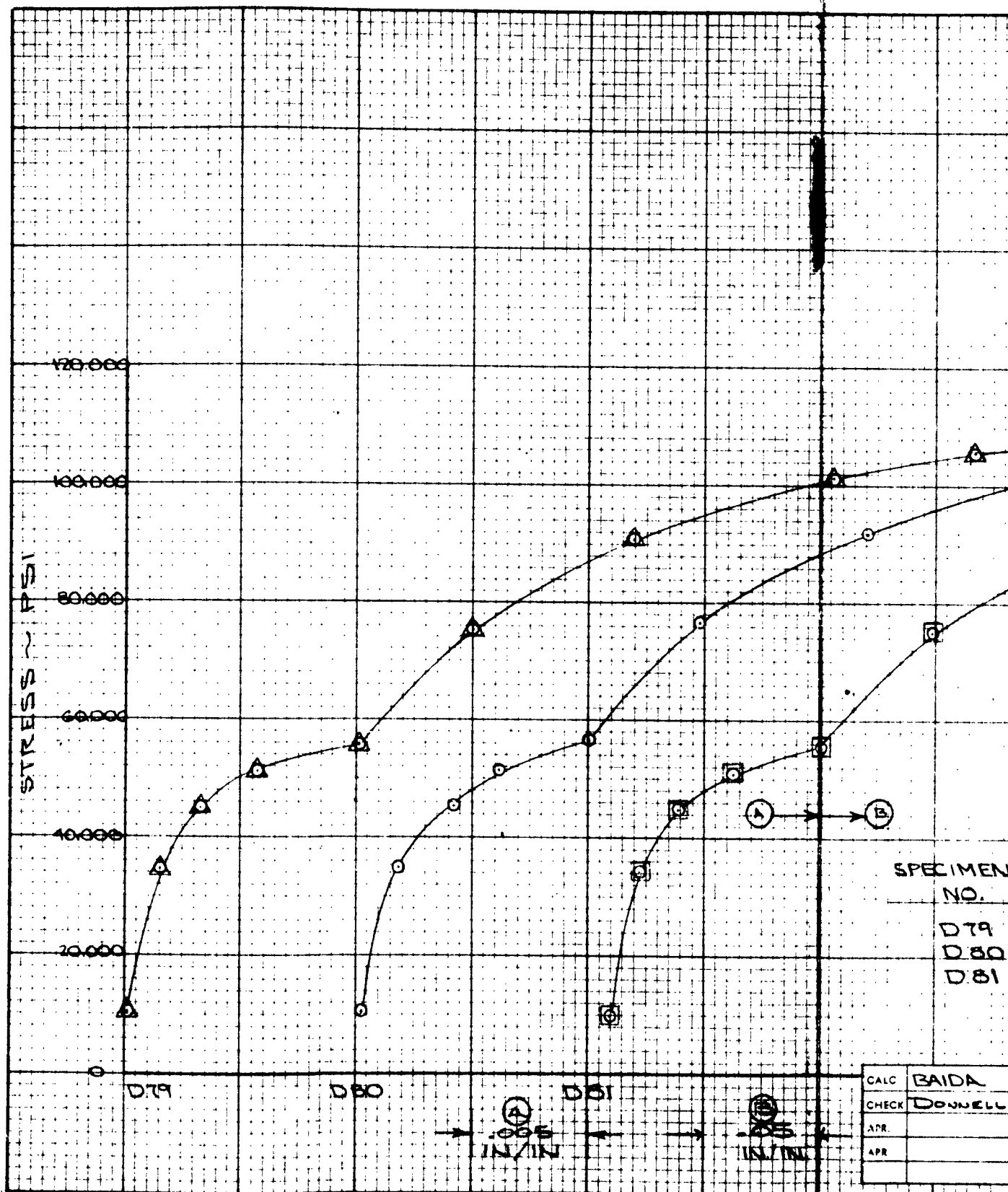
-65
-65
-65

NITROGEN
NITROGEN
NITROGEN

~ SEE PAGE 120 FOR NOTES ~

CALC	L TRENT	3-22-1	REVISED	DATE	STRESS-STRAIN CURVES HASTELLOY -125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-2
CHECK	V/A/L	3-23				
APR						
APR						

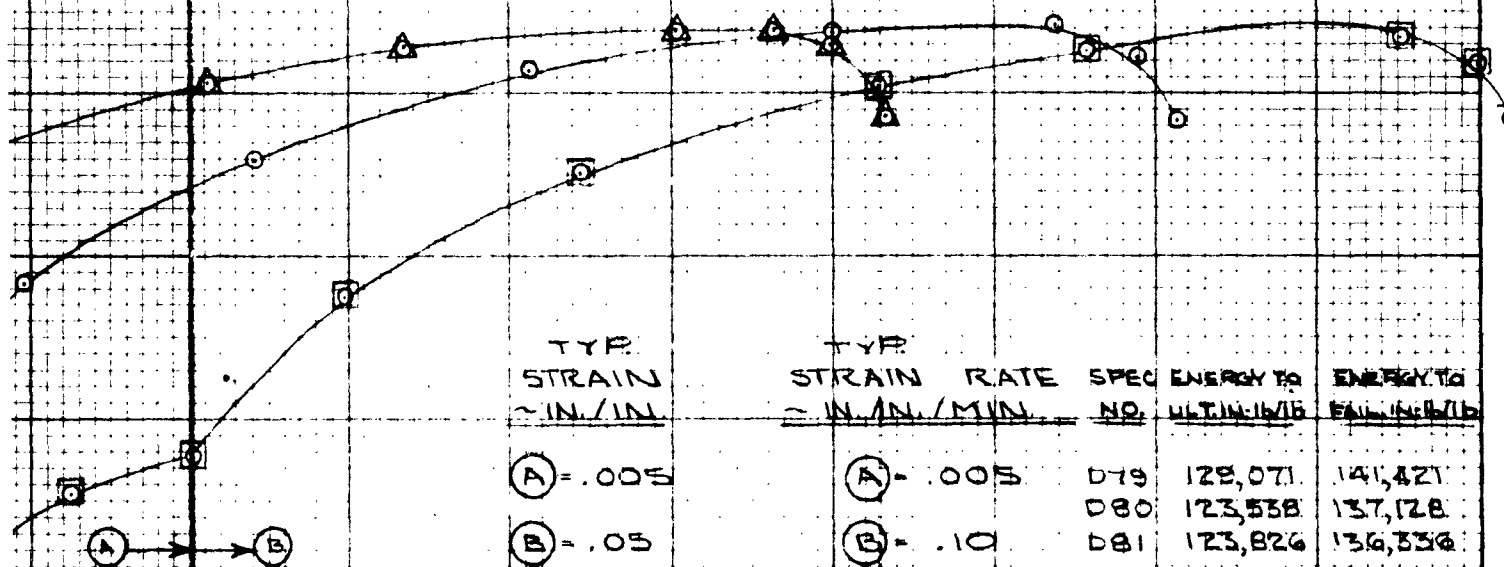
CONTRACT NO.



DATA SHEET

CONTRACT NO.

2

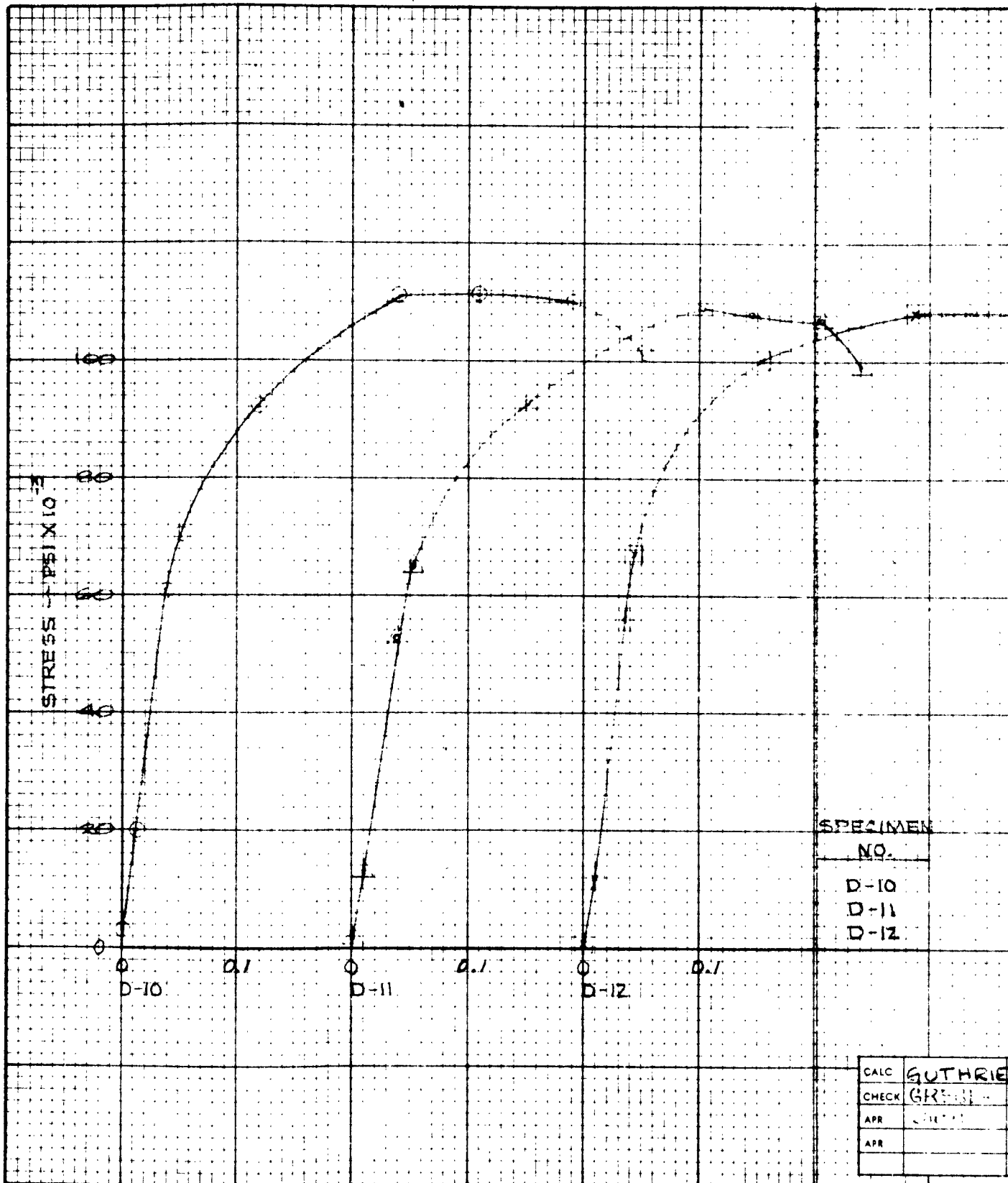


SPECIMEN NO.	AREA ~SQ. IN.	FTU ~PSI.	GRAIN DIRECT	TEST TEMP (°F)	TEST ATMOS.
D79	.0658	107,900	LONG.	72	AIR
D80	.0648	108,300	LONG.	72	AIR
D81	.0661	106,800	LONG.	72	AIR

TYP. STRAIN ~IN./IN.	TYP. STRAIN RATE ~IN./IN./MIN.	SPEC NO.	ENERGY TO YIELD ~IN.-LB/IN.	ENERGY TO FAIL ~IN.-LB/IN.
(A) = .005	(A) = .005	D79	128,071	141,421
(B) = .05	(B) = .10	D80	123,538	137,128
		D81	123,826	136,336

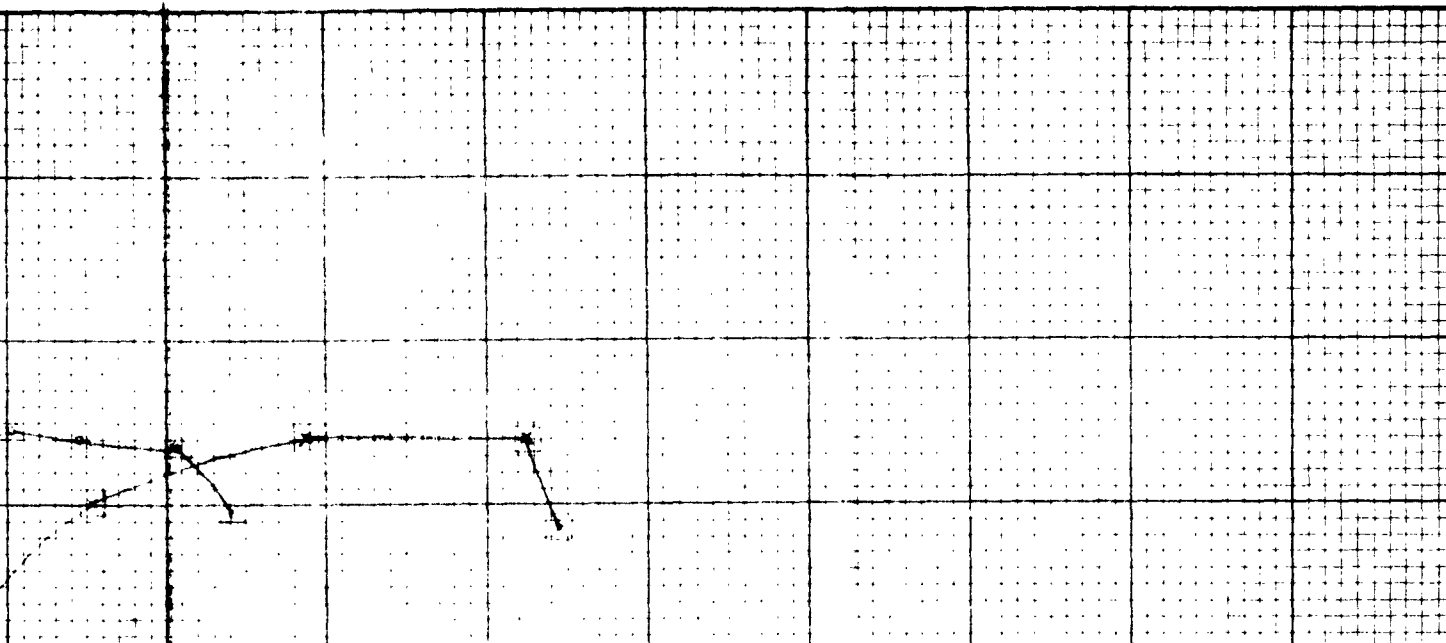
CALC	BADA	1-561	REVISED	DATE	STRESS - STRAIN CURVES 19-9 DL .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80096 PAGE 1290
CHECK	DONNELL	1-19-1				
APR.						
APR.						

CONTRACT NO



DATA SHEET

CONTRACT NO.



<u>SPEC NO.</u>	<u>ENERGY TO ULT. IN-LB/IN</u>	<u>ENERGY TO FAIL. IN-LB/IN</u>
D-10	127,600	150,000
D-11	127,000	138,500
D-12	138,900	146,500

STRAIN
IN/IN

← 0.1 →

STRAIN RATE
IN/IN/MIN.

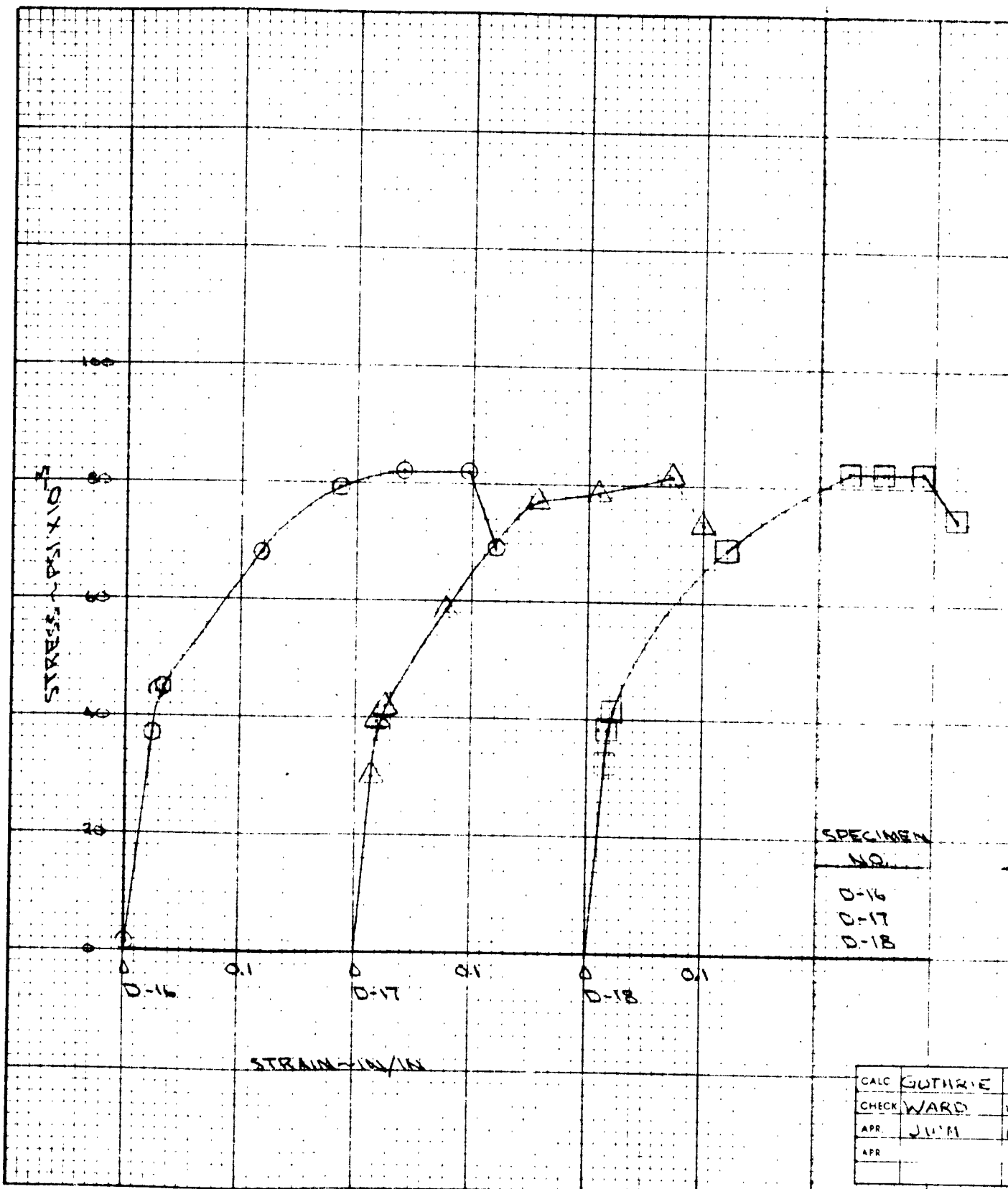
180 (TYR)

2

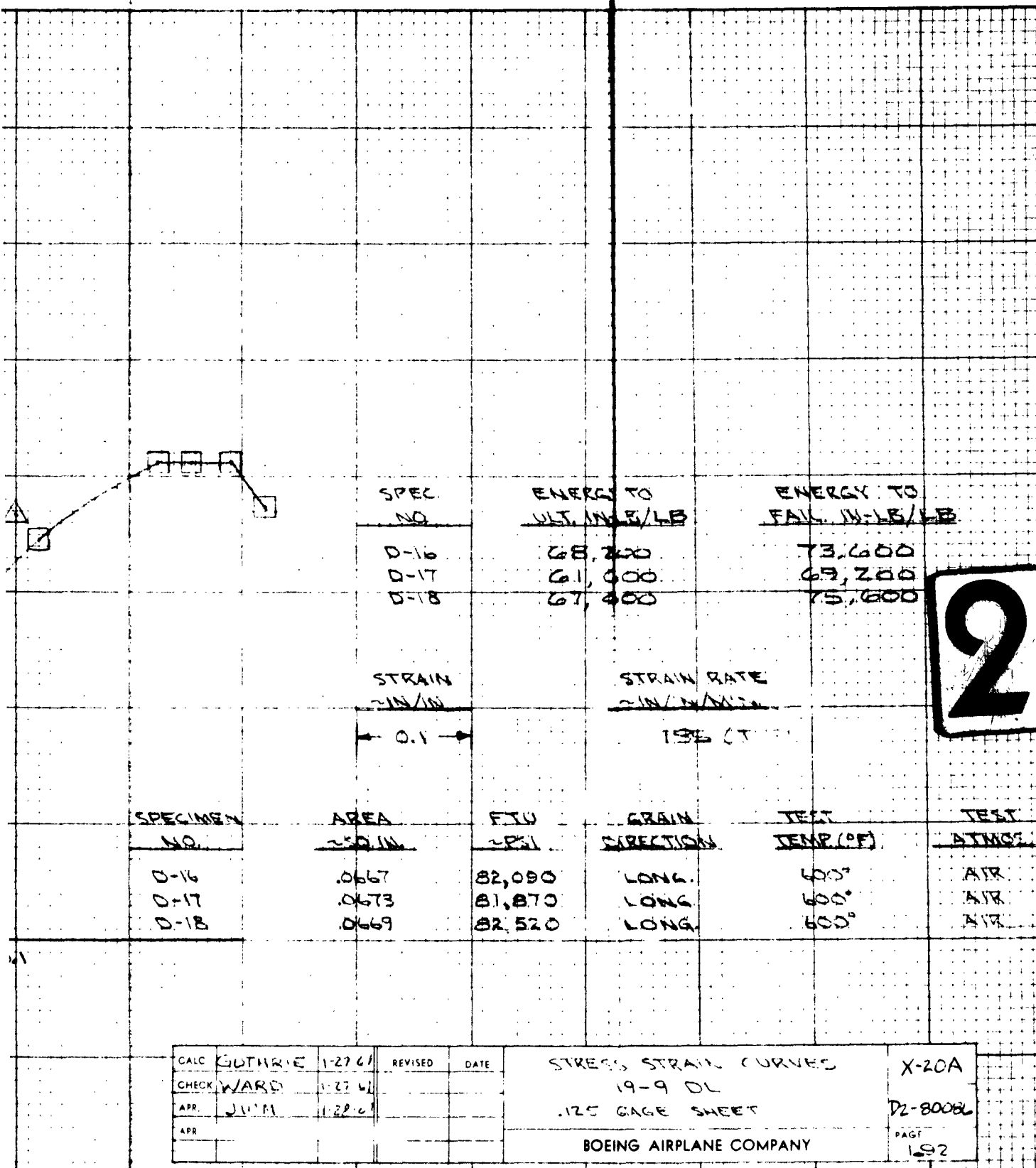
<u>SPECIMEN NO.</u>	<u>AREA SQ. IN.</u>	<u>FTU PSI</u>	<u>GRAIN DIRECTION</u>	<u>TEST TEMP. (°F)</u>	<u>TEST ATMOS.</u>
D-10	.0661	111,000	LONG.	72	AIR
D-11	.0667	109,000	LONG.	72	AIR
D-12	.0663	108,400	LONG.	72	AIR

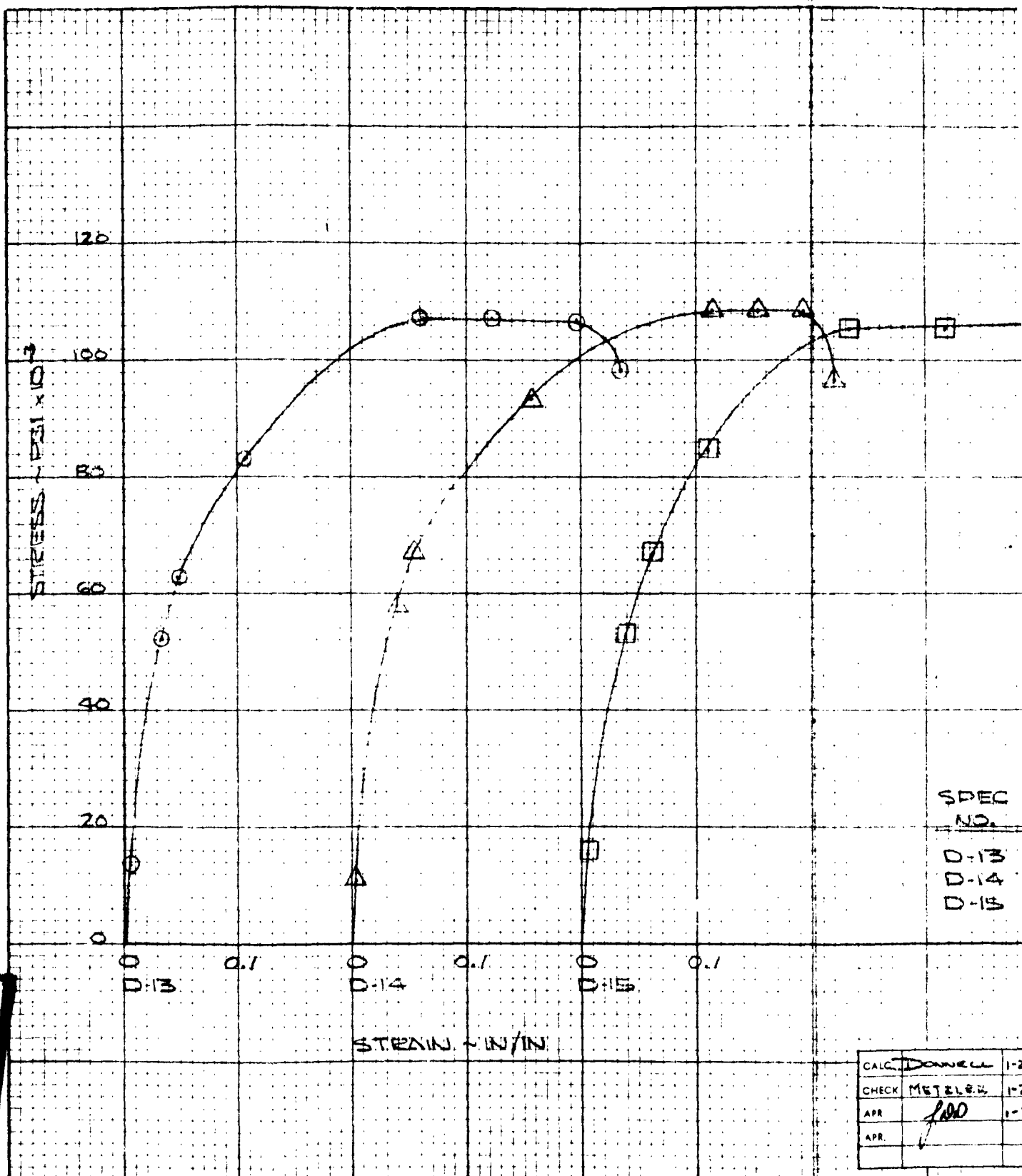
CALC	GUTHRIE	1-27-61	REVISED	DATE	STRESS - STRAIN CURVES 19-9DL .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-25A D2-90086 PAG. 1 L91
CHECK	GR...	1-27-61				
APR		1-27-61				
APR						

CONTRACT NO.



DATA SHEET

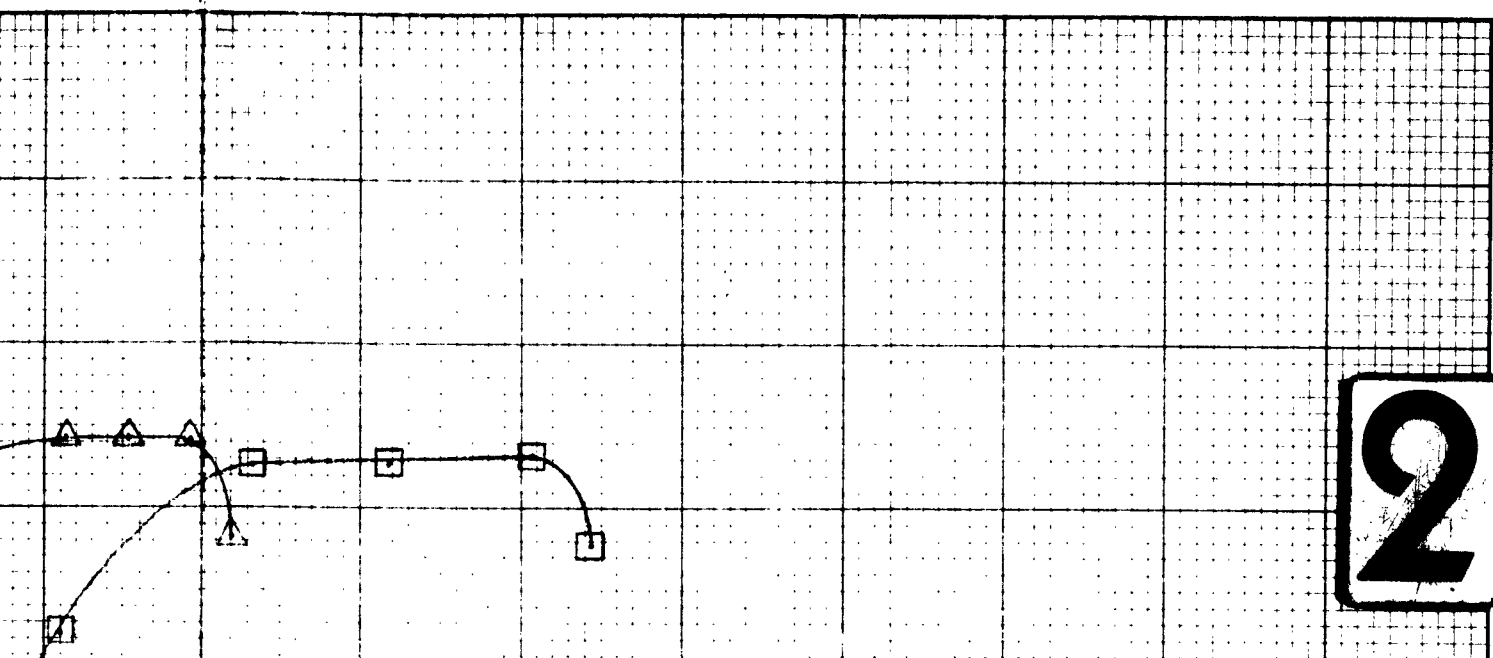




DATA SHEET

CONTRACT NO.

2



SPEC NO.	ENERGY TO ULT. ~ IN-LB./LB.	ENERGY TO FAILURE ~ IN-LB./LB.
D-13	125,200	140,000
D-14	122,000	132,000
D-15	124,000	141,000

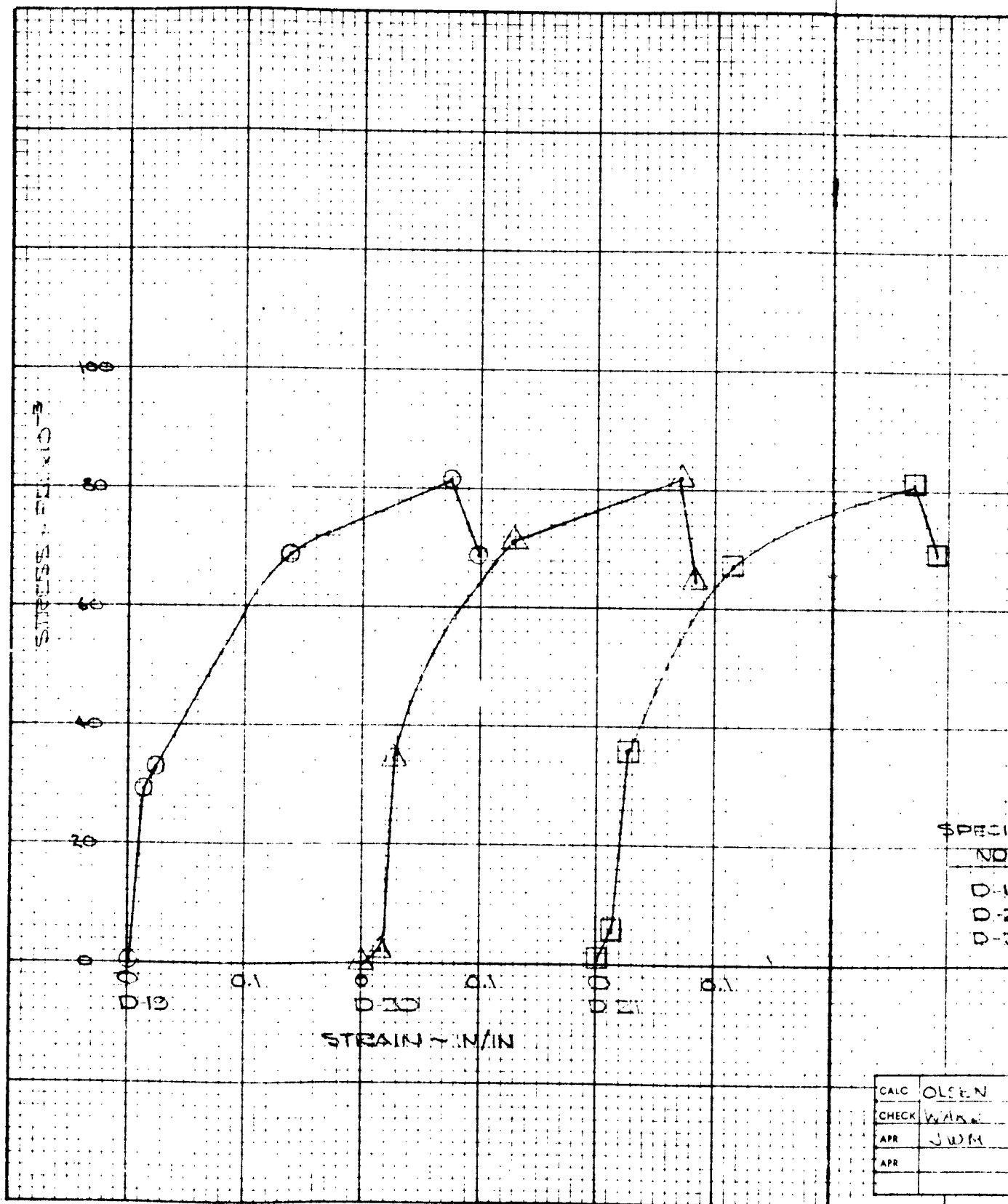
STRAIN ~ IN/IN
 ← 0.1 →

STRAIN RATE ~ IN/IN/MIN
 295 TYP.

SPEC NO.	AREA ~ SQ. IN.	FTU PSI	GRDIN DIRECTION	TEST TEMPE	TEST ATMO.
D-13	.0666	107,900	LONG.	72	AIR
D-14	.0663	108,300	LONG.	72	AIR
D-15	.0665	106,400	LONG.	72	AIR

CALC. <u>DONELL</u> CHECK <u>METELER</u> APR. <u>1-28-1</u> APR. <u>1-28-1</u>	1-28-1 1-28-1 1-28-1	REVISED 	DATE 	STRESS-STRAIN CURVES 19-9DL .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-20086 PAGE 1-9-1
---	----------------------------	---------------------	------------------	--	---------------------------------

CONTRACT NO.



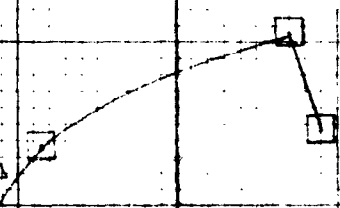
SPECI
NO
D-1
D-2
D-3

CALC	OLSEN
CHECK	WALSH
APR	JWM
APR	

DATA SHEET

CONTRACT NO

2



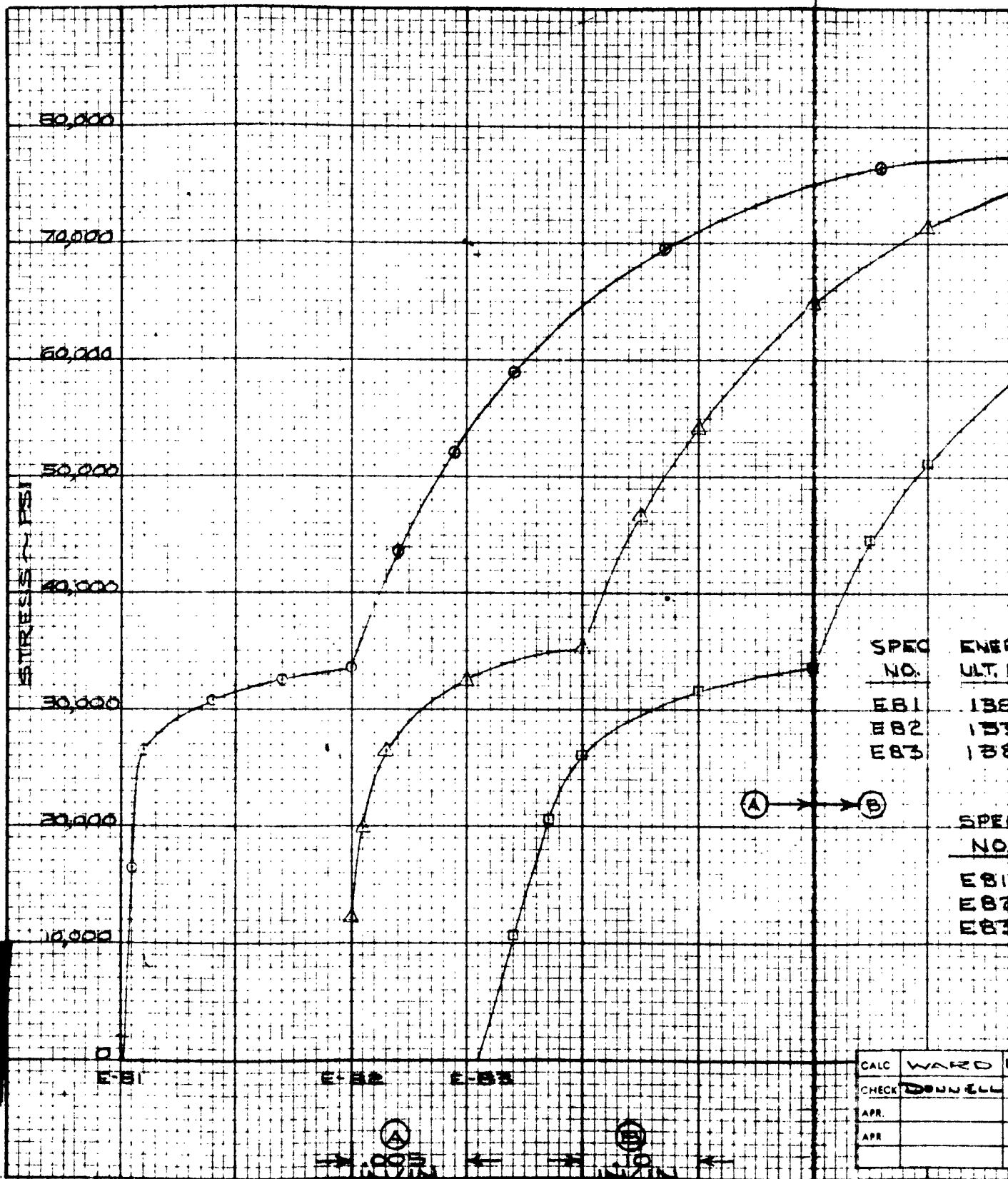
SPEC. NO.	ENERGY TO ULT. - IN.-LB./LB.	ENERGY TO FAILURE - IN.-LB./LB.
D-19	58,600	64,300
D-20	58,100	61,500
D-21	58,100	63,000

STRAIN -IN./IN.	STRAIN RATE -IN./IN./MIN.
0.1	295 (TYP)

SPECIMEN NO.	AREA -SQ. IN.	FTU -PSI	STRAIN DIRECTION	TEST TIME	TEST ATMOS.
D-19	.0665	81,700	LONG.	800	AIR
D-20	.0672	82,100	LONG.	800	AIR
D-21	.0662	81,200	LONG.	800	AIR

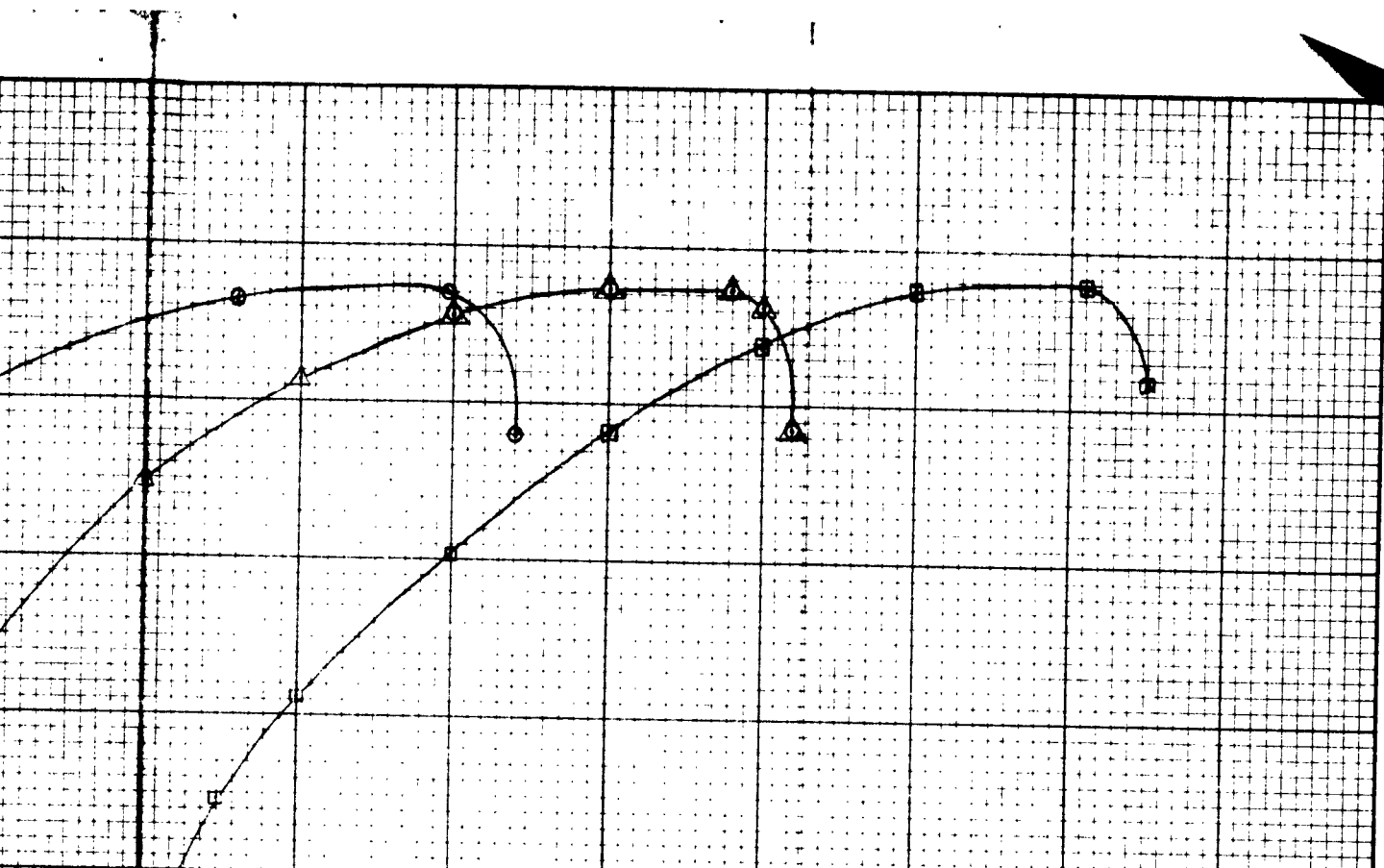
CALC	OLSEN	12/51	REVISED	DATE	STRESS-STRAIN CURVES 19-3DL .125 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A
CHECK	WALSH	12/51				D2-80086
APP	SWAN	12/51				PAGE
APP						694

CONTRACT NO



CALC	WARD
CHECK	DONNELL
APR.	
APR.	

CONTRACT NO.



SPEC NO.	ENERGY TO ULT. IN-1B/1B	ENERGY TO FAIL. IN-1B/1B	TYPE STRAIN ~IN./IN.	TYPE STRAIN RATE ~IN./IN./MIN.
E81	138,053	149,103	(A)=0.005	(A)=0.005
E82	133,694	144,094	(B)=1.0	(B)=1.0
E83	138,329	148,529		

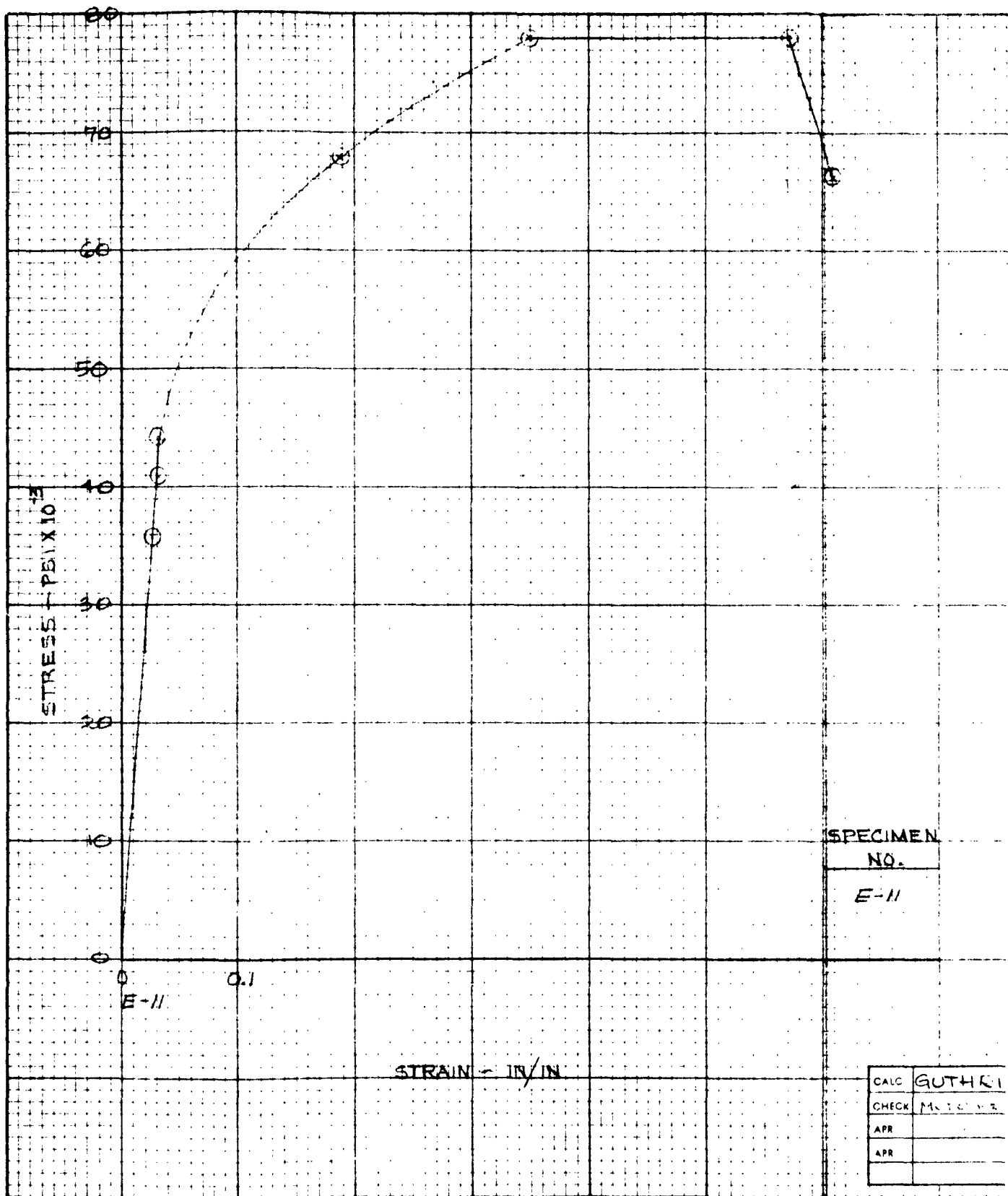
(A) → (B)

SPEC NO.	AREA ~SQ IN.	FTU ~PSI	GRAIN DIRECT.	TEST TEMP(°F)	TEST ATMS
E81	.0563	77,400	LONG.	72	AIR
E82	.0574	77,400	LONG.	72	AIR
E83	.0570	78,000	LONG.	72	AIR

2

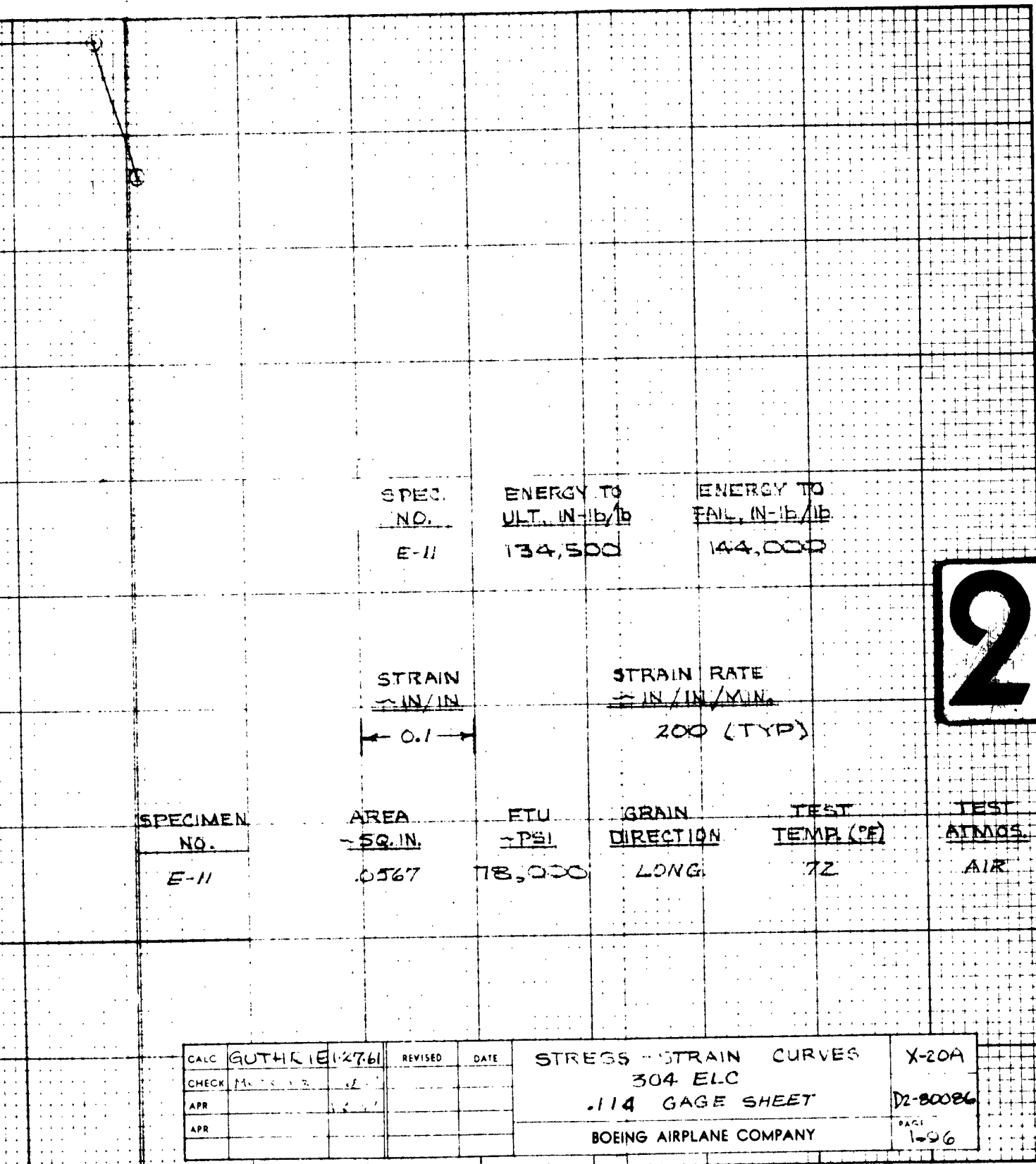
CALC WARD 1-4-1 CHECK DONNELL 1-14-1 APR. APR.	REVISED DATE	STRESS-STRAIN CURVES 304 ELC .114 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-00186 1-95
---	-----------------	---	---------------------------

CONTRACT NO.



DATA SHEET

CONTRACT NO



SPEC.
NO.
E-11

ENERGY TO
ULT. IN-lb/lb
134,500

ENERGY TO
FAIL. IN-lb/lb
144,000

STRAIN
~IN/IN
0.1

STRAIN RATE
~IN/IN/MIN.
200 (TYP)

2

SPECIMEN
NO.
E-11

AREA
~SQ. IN.
.0567

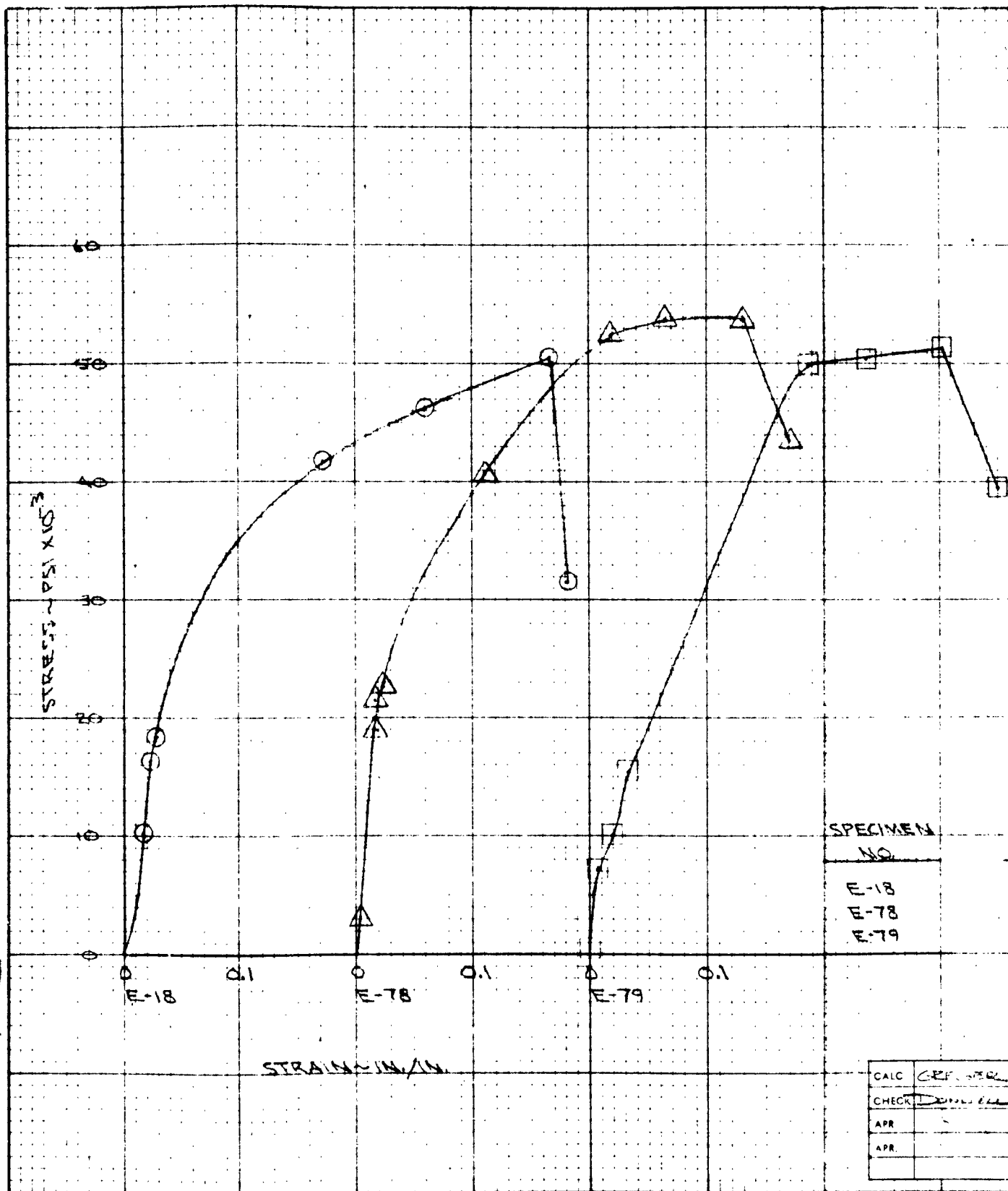
FTU
~PSI
78,000

GRAIN
DIRECTION
LONG.

TEST
TEMP. (°F)
72

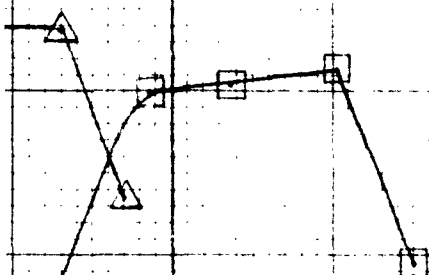
TEST
ATMOS.
AIR

CALC	GUTHRIE 12761	REVISED	DATE	STRESS - STRAIN CURVES 304 ELC .114 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-96
CHECK	M. S. Z.				
APR					
APR					



DATA SHEET

CONTRACT NO



SPEC.
NO.

E-18
E-78
E-79

ENERGY TO
ULT. IN-LB/IN

48,500
49,100
38,960

ENERGY TO
FAIL IN-LB/IN

50,600
55,800
46,400

STRAIN
~IN/IN

0.1

STRAIN RATE
~IN/IN/MIN

100 (TYP)

2

SPECIMEN
NO.

E-18
E-78
E-79

AREA
~SQ. IN.

.0566
.0575
.0560

FTU
~PSI

50,500
54,000
51,300

GRAIN
DIRECTION

LONG.
LONG.
LONG.

TEST
TEMP. (°F)

600°
600°
600°

TEST
ATMOS.

AIR
AIR
AIR

CALC	CRF	1-27-1	REVISED	DATE
CHECK	CRF	1-30-1		
APR				
APR				

STRESS-STRAIN CURVES

304 ELC

114 GAGE SHEET

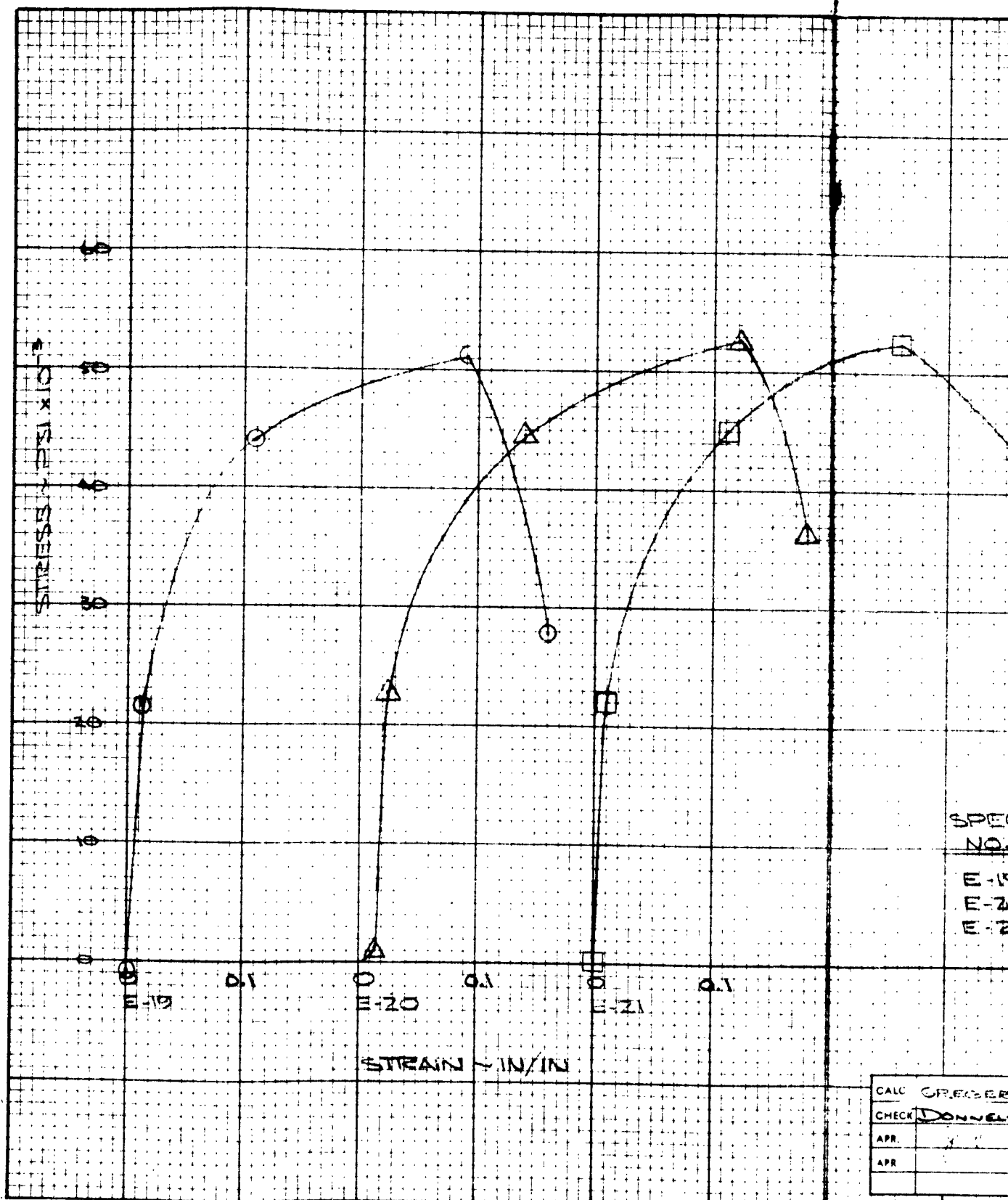
BOEING AIRPLANE COMPANY

X-20A

D2-80086

PAGE
1037

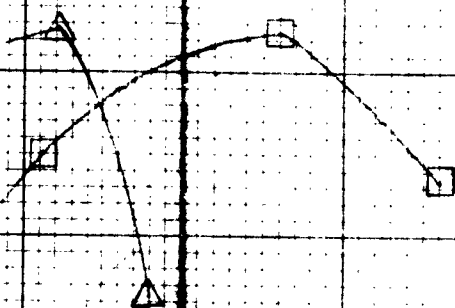
CONTRACT NO.



DATA SHEET

CONTRACT NO.

2



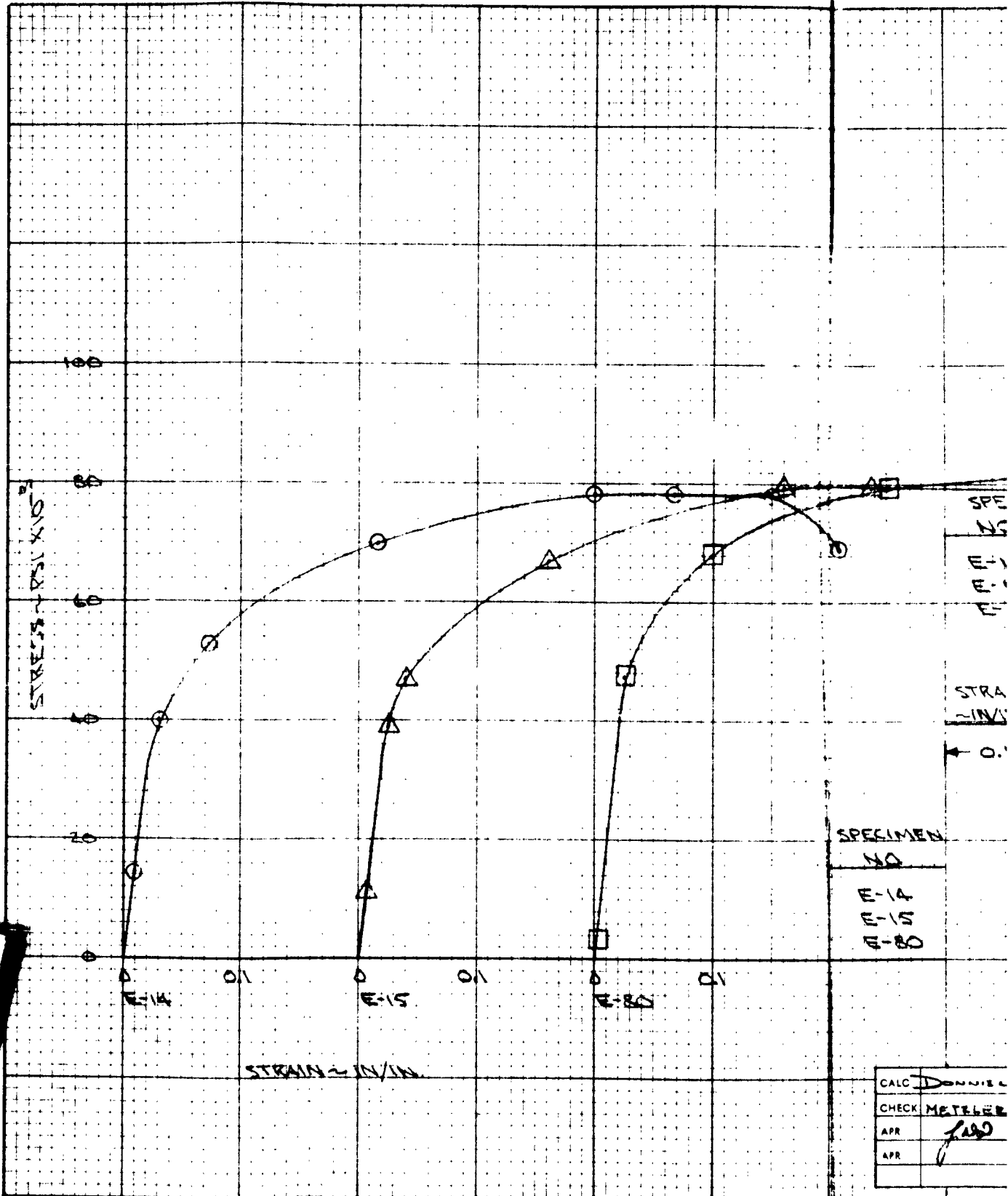
SPEC. NO.	ENERGY TO YLT. IN-LB/LB	ENERGY TO FAILURE IN-LB/LB
E-19	42,300	52,600
E-20	48,900	55,200
E-21	55,800	55,400

STRAIN IN/IN	STRAIN RATE IN/IN/MIN
0.1	285 (TYP)

SPEC. NO.	AREA SQ IN	FTU LBS	GRAIN DIRECTION	TEST TEMP °F	TEST ATMOS
E-19	.0577	51,200	LONG.	800	AIR
E-20	.0569	53,700	LONG.	800	AIR
E-21	.0571	52,500	LONG.	800	AIR

CALC GREGER 1-27-1 CHECK DONNELL 1-30-1 APR 1 1951 APR 1 1951	REVISED DATE	STRESS-STRAIN CURVES 304 ELL .114 GAGE SHEET BOEING AIRPLANE COMPANY	X-20A D2-80086 PAGE 1-98
--	-----------------	---	--------------------------------

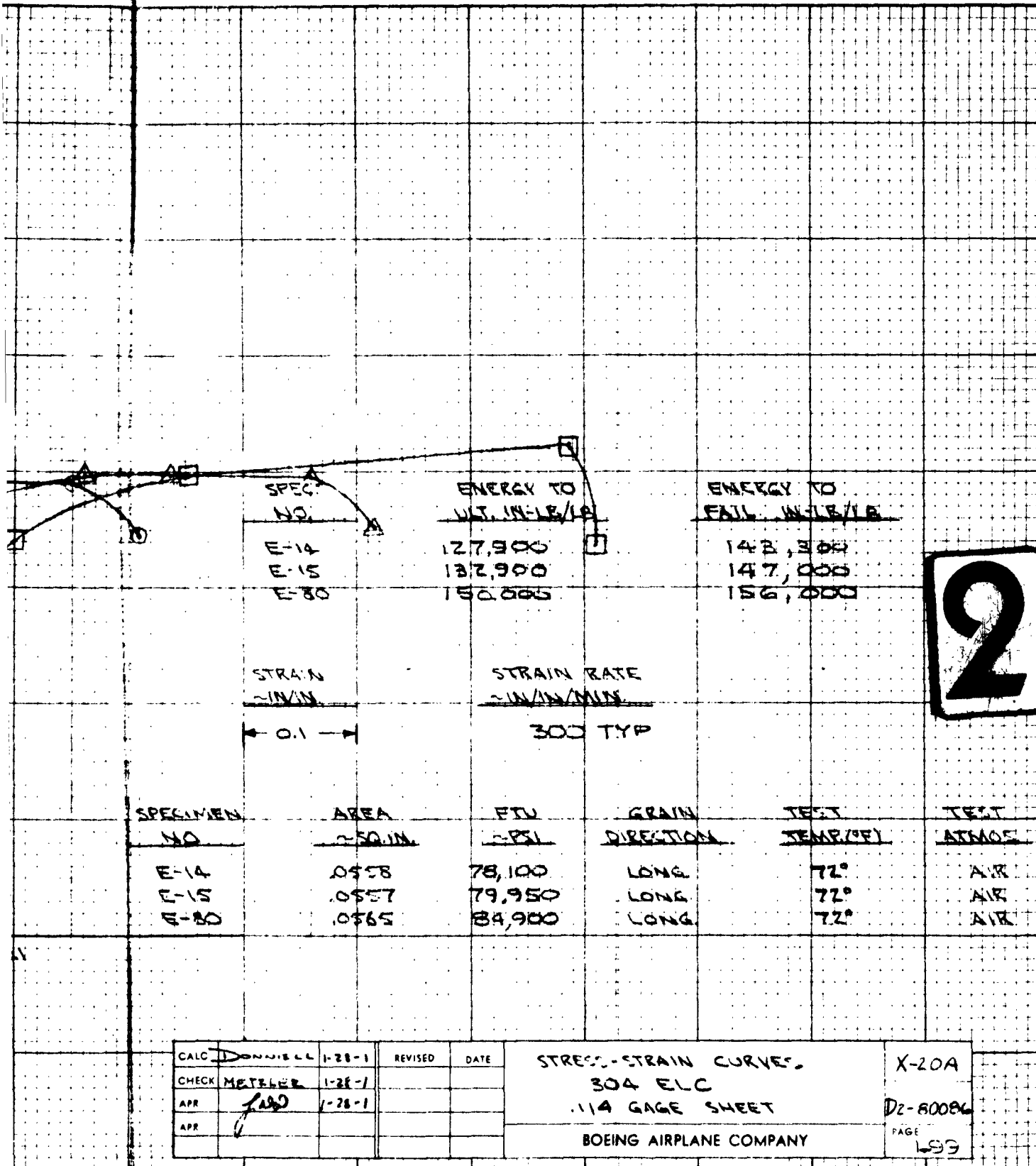
CONTRACT NO



DATA SHEET

CALC	DONNIE
CHECK	METELER
APR	<i>[Signature]</i>
APR	

CONTRACT NO



THE BOEING COMPANY

NUMBER D2-80086 MODEL NO. X-20
TITLE Main Landing Gear Energy System Development

2-3142

PREPARED BY

A. Grant 5/22/63
A. Grant

SUPERVISED BY

R. R. Logan 5/27/63
R. R. Logan

APPROVED BY

D. Baber 5-27-63
D. Baber

RELIABILITY
APPROVAL

P. Kuwizgal 5-28-63
(DATE)

A.K. Hepler 4/6

SECTION TITLE PAGE U3 428 0000 REV. V/61

AF33(657)-7132
CONTRACT NO.

5-76200-5590-05638-3-25353
CHARGE NUMBER

98

VOL.
SEC. 2

NO. D2-80086
PAGE 1 OF 46
221-02 46

2.1 SUMMARY

- 2.1.1 This report contains the results of impact and static load testing of ten (10) main landing gear energy strap test specimens (full-scale) and three (3) standard tensile specimens, all fabricated from the same heat of Inconel material.
- 2.1.2 The impact tests were conducted at specimen temperatures and impact velocities simulating three landing sink rates. Ten full-scale specimens were impact tested.
- 2.1.3 The static load tests were conducted at room temperature to determine the maximum energy absorbing capacity of the previously impact tested specimens and to determine the static tensile properties of the material.
- 2.1.4 Impact test results obtained included specimen load and deflection versus time curves, permanent angular displacement of the specimen pivot end due to strap terminal-pin friction, and specimen elongation and section change over the specimen length.
- 2.1.5 Static test results obtained included load versus deflection curves for the two (2) energy strap specimens and load versus strain curves for the three (3) standard tensile specimens.

2.2	TABLES OF CONTENTS	PAGE
2.1	Summary	2-2
2.2	Table of Contents	2-3
2.3	References	2-4
2.4	Introduction	2-5
2.5	Test Specimen	2-6
2.6	Test Setup and Instrumentation	2-6
2.7	Test Procedure	2-7
2.8	Test Results	2-7
2.9	Test Observations	2-7
Table 2.1	Required Impact Test Parameters	2-8
Table 2.2	Impact Test Results	2-9
Table 2.3	Impact Test Results	2-10
Table 2.4	Impact Test Results	2-11
Table 2.5	Impact Test Pivot End Rotation Results	2-12
Table 2.6	Static Test Results	2-13
Table 2.7	Static Test Results	2-14
Figure 2.1	Impact Test Specimen Sketch	2-15
Figure 2.2	Static Test Specimen Sketch	2-15
Figure 2.3	Energy Strap Section Measurement Location	2-16
Figure 2.4	Energy Strap Test Specimen	2-17
Figure 2.5	Energy Strap Pivot End	2-18
Figure 2.6	Pivot End - Rene' 41 Pin	2-19
Figure 2.7	Quick Release Mechanism	2-20
Figure 2.8	Pivot End Test Fixture	2-21
Figure 2.9	Impact Test Setup - Schematic	2-22
Figure 2.10	Impact Test Setup - Impact V = 21.5 FPS	2-23
Figure 2.11	Impact Test Setup - Impact V = 8.75 FPS	2-24
Impact Test - Load and Deflection Curves		2-25 thru 2-42
Static Test - Load and Deflection Curves - Stress-Strain Curves		2-43 thru 2-46

2.3 REFERENCES

2.3.1	Main Landing Gear Energy System Development	EWA 5638 
2.3.2	Energy Strap (D/S) Installation (Test Only)	BAC 25-80333
2.3.3	Strap-Shock Absorber Main Landing Gear (Test Only)	BAC 29-80001
2.3.4	Tensile Specimen Round	BAC 23-7070
2.3.5	Energy Strap Test Specimen, Figure 2.4	Neg. No. FA-2A94975
2.3.6	Energy Strap Pivot End, Figure 2.5	Neg. No. FA-2A94977
2.3.7	Pivot End Rene' 41 Pin, Figure 2.6	Neg. No. FA-2A100490
2.3.8	Quick Release Mechanism, Figure 2.7	Neg. No. FA-2A95785
2.3.9	Pivot End Test Fixture, Figure 2.8	Neg. No. FA-2A100945
2.3.10	Impact Test Setup, Figure 2.10	Neg. No. FA-2A102524
2.3.11	Impact Test Setup, Figure 2.11	Neg. No. FA-2A102115



Refer to D2-6783-1 Structural Integrity Development and Test Program -
Detail Plan - Structures Technology

2.4 INTRODUCTION

2.4.1 This report is the result of work accomplished on EWA 3638,* Reference 2.3.1. This work was required to obtain energy-absorbing characteristics of a proposed main landing gear energy strap configuration, fabricated from Inconel material, over the applicable range of landing temperatures and dynamic loading rates.

* Refer to D2-6783-1 Structural Integrity Development and Test Program - Detail Plan - Structures Technology

2.5 TEST SPECIMEN

- 2.5.1 The ten (10) main gear energy strap impact load test specimens were fabricated per Reference 2.3.3. A sketch of the test specimens is shown on Pages 2-15 thru 2-18.
- 2.5.2 The five (5) static load test specimens consisted of two (2) of the previously impact-tested specimens, and three (3) standard tensile specimens fabricated per Reference 2.3.4. A sketch of the tensile test specimens is shown in Figure 2.2.
- 2.5.3 All test specimens were fabricated from the same heat of 2 3/8" diameter Inconel bar, annealed at 1875 $\pm$ 25°F for 30 minutes after machining, and then air cooled.

2.6 TEST SETUP AND INSTRUMENTATION

- 2.6.1 The impact load test setup utilized a falling weight dropped from a predetermined height (based on initial strap impact velocity requirement) onto the lower part of the test fixture, which was covered with a one inch layer of high density styrofoam. The styrofoam layer had a compressive yield strength of 120 to 140 PSI and acted as a shock absorber. The induced load was transmitted by the test fixture to the pivot beam. The pivot beam, in turn, transferred the load through a Rene' 41 pivot pin to the terminal of the energy strap specimen. As the energy strap deflected or elongated under the impact load application, the pivot beam rotated through an angle of rotation that simulates movement between the energy strap and the landing gear strut during a landing impact condition. The impact test setup is shown on Pages 2-20 thru 2-24.
- 2.6.2 The impact load test elevated temperature environment was obtained by surrounding the strap specimen with twelve (12) radiant heat lamps. These heat lamps were powered and controlled by an ignitron unit.
- 2.6.3 The impact load test instrumentation consisted of an electronic deflection indicator and a load cell to measure deflection and impact load and an oscillograph to record the load and the deflection with a common time base. A high-speed camera and a Vanguard Analyzer were used to calibrate and check the oscillograph deflection recording during the early phase of testing. Eight (8) spot-welded chromel-alumel thermocouples, equally spaced along the length of each specimen, were used to measure specimen temperatures.
- 2.6.4 The static load test specimens were tested in a 120,000-pound capacity Baldwin Universal Test Machine. The machine was equipped with a Model MD-2 Autographic Load Strain Recorder. A Baldwin Strain Pacer was used to insure a proper average strain rate. The strain to failure was measured using a Baldwin TS-MD Dual-Range Extensometer. All static tests were conducted at room temperature.

2.7 TEST PROCEDURE

- 2.7.1 In order to satisfy the required strap impact test parameters, as tabulated in Table 2.1, Page 2-8, several trial runs were conducted with simulated test specimens installed in the test system. The strap load-deflection data obtained from these runs were used to determine the energy-output characteristics of the test system.
- 2.7.2 The actual specimen being impact-tested was then placed in the test setup, using a new oxidized Rene' 41 pin for each test to simulate actual operating condition. The specimen was brought to the required stabilized temperature over the specimen length, the weight was dropped and the following data obtained:
1. Strap load versus time.
 2. Strap elongation versus time.
 3. Angular displacement of the strap pivot end.
 4. Elongation of measured sections along the strap length.
 5. Change of diameters at various sections along the strap length.
- 2.7.3 The static test specimens were placed in a Universal Test Machine and tested to failure. Strain versus load was recorded for the tensile round specimens, and load versus deflection was recorded for the previously impact-tested specimens.

2.8 TEST RESULTS

- 2.8.1 Maximum impact strap load, impact strap energy and strap per cent elongation are tabulated on Pages 2-9 thru 2-11. Angular displacement of the pivot end is shown on Page 2-12. Load versus time, deflection versus time, and load versus deflection curves are shown on Pages 2-25 thru 2-42.
- 2.8.2 Static test results showing ultimate and yield strength are tabulated on Pages 2-13 and 2-14. Static load versus deflection curves for the impact-tested specimens are shown on Page 2-43. Static load versus strain curves for the standard tensile specimens are shown on Pages 2-44 thru 2-46.

2.9 TEST OBSERVATIONS

- 2.9.1 All impact load tests were completed satisfactorily with the exception of the impact test on specimen number three. No data was obtained for this specimen due to premature release of the drop weight.
- 2.9.2 The five (5) specimens static tested in the Baldwin Universal Test Machine were completed satisfactorily.

TABLE 2.1

REQUIRED IMPACT TEST PARAMETERS
(REFERENCE 2.3.1)

Temperature °F	72	300	600	600	600
Gear Impact Velocity FT/SEC	10	10	4	7	10
Strap Impact Velocity FT/SEC	20.8	20.8	8.3	14.6	20.8
Strap Energy Input FT-LB	10,900	10,900	1,740	5,300	10,900

TABLE 2.1

REQUIRED IMPACT
TEST PARAMETERS

MAIN GEAR ENERGY

PART NO.				
SPECIMEN NO.		1	2	3
TEST RESULTS				
TEMP. - °F	2	72	72	APFX 100
WEIGHT DROPPED - LBS.	2	1562	1762	1762
DISTANCE OF DROP - INCH	2	82	86	86
STRAP IMPACT VEL - FT/SEC.	3	20.8	20.8	20.8
STRAP IMPACT VEL - FT/SEC.	4	21.0	21.5	21.5
STRAP DEFLECTION (MAX.) - INCH	2	5.6	7.0	5.8 MEASU
ANGULAR ROTATION OF PIVOT BEAM (α) - DEG.	5	21.0	27.0	—
TOTAL INPUT ENERGY OF THE SYSTEM - FT-LB.	6	11,700	13,950	—
STRAP ENERGY INPUT (RECORDED) - FT-LBS.	6 1	7,800	9,980	—
STRAP MAX. IMPACT LOAD - KIPS	2	21.0	22.3	—

1 STRAP ENERGY INPUT WAS OBTAINED FROM THE AREA UNDER THE LOAD-DEFL

2 MEASURED DATA

3 REQUIRED DATA (SEE TABLE 2.1)

4 CALCULATED DATA AS FOLLOWS:

$$V = \sqrt{2gH/6}$$

$$E_{CAL} = \frac{W_1H + (W_1 + W_2)\Delta}{12}$$

WHERE V - IS THE VELOCITY OF THE FALLING BODY AT IMPACT.

H - IS THE DISTANCE THE FALLING BODY WILL DROP BEFORE IMPACT.

E_{CAL} - IS THE TOTAL INPUT ENERGY OF THE SYSTEM

W₁ - IS THE WEIGHT OF THE FALLING BODY.

W₂ - IS THE WEIGHT OF THE TEST FIXTURE.

Δ - IS THE DEFLECTION OF THE TEST SPECIMEN.

5 SEE PAGE 2-22 FOR LOCATION OF ANGLE (α)

6 THE ENERGY LOSS IN THE SYSTEM WAS DUE TO THE FOLLOWING:

1) FRICTION BETWEEN THE FALLING WEIGHT AND THE TEST FIXTURE. (AND)

2) CRUSHING OF THE STYROFOAM LAYER ON THE TEST FIXTURE BASE PLATE AT IMPACT.

1

CALC
CHECK
APR
APR

MAIN GEAR ENERGY STRAPS

29-80001-3

	1	2	3	4	5	6	19	20	21	22
	72	72	APPR. 100	300	300	600	600	600	600	600
	1562	1762	1762	1762	1762	1762	1855	1855	1855	1855
	82	86	86	86	86	86	14.7	14.7	42.5	42.5
	20.8	20.8	20.8	20.8	20.8	20.8	8.3	8.3	14.6	14.6
	21.0	21.5	21.5	21.5	21.5	21.5	8.75	8.75	14.8	14.8
	5.6	7.0	5.8 MEASURE	7.78	7.94	8.68	2.50	2.63	5.34	5.71
	21.0	27.0		30.7	31.3	34.4	10.2	10.8	22.0	23.5
	11,700	13,950		14,110	14,140	14,282	2764	2789	7620	7692
	7,800	9,980		10,460	10,096	11,160	1815	2148	5188	5854
	21.0	22.3		21.3	20.2	20.9	11.4	12.2	15.9	15.7

ON THE AREA UNDER THE LOAD-DEFLECTION CURVE ON PAGE 2-25 THRU 2-42

Y AT IMPACT.
ILL DROP BEFORE IMPACT.
SYSTEM

DEN.

E (α)

DUE TO

WEIGHT AND THE

ER ON THE TEST

2

CALC	J. Lebo		REVISED	DATE	TABLE 2.2 IMPACT TEST RESULTS X-20 MAIN LANDING GEAR THE BOEING COMPANY	X-20
CHECK	<i>Grant</i>					DB-80086
APR						
APR						PAGE 2-9

105

SPECI- MEN NO		'A1'	'B1'	'C1'	'D1'	'E1'	'F1'	'G1'	'H1'	
1	DIAMETER									
2	% DIFF.	2	2	2	2	2	2	2	2	
3	DIA.	2	2	2	2	2	2	2	2	
4	% DIFF.	2	2	2	2	2	2	2	2	
5	DIA.	2	2	2	2	2	2	2	2	
6	% DIFF.	2	2	2	2	2	2	2	2	
19	DIA.	2	2	2	2	2	2	2	2	
20	% DIFF.	2	2	2	2	2	2	2	2	
21	DIA.	2	2	2	2	2	2	2	2	
22	% DIFF.	2	2	2	2	2	2	2	2	
FOR MEASUREMENT LOCATION SEE FIGURE 2.3										
DATA NOT RECORDED FOR SPECIMENS 1, 2, AND 3.										
% DIFF = CHANGE OF SECTION DIAMETER										
ORIGINAL DIAMETER OF SECTION										

CALC	Grant 5/1/5	REVISED	DATE	TABLE 2.4		X-20
CHECK	Chadman			MAIN GEAR ENERGY STRAP DIAMETER AND		
APR				PER-CENT CHANGE AFTER IMPACT TEST.		D2-80086
APR				THE BOEING COMPANY		PAGE 2-11

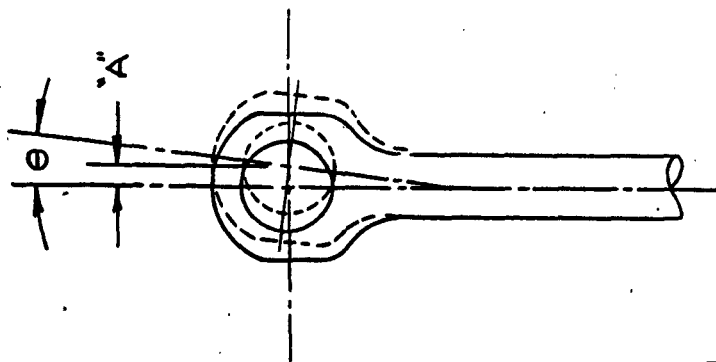


TABLE 2.5
IMPACT TEST RESULTS
PERMANENT ANGULAR DISPLACEMENT
OF STRAP PIVOT END

SPECIMEN NO.	ANGLE θ (DEGREES)	DEFLECTION "A" (INCHES)
1 	—	—
2	7.8	.23
3 	—	—
4	5.3	.15
5	6.0	.16
6	7.0	.21
19	1.7	.094
20	3.0	.13
21	8.8	.28
22	7.0	.24

 DATA NOT RECORDED



SPECIMEN NUMBER	SPECIMEN LENGTH BEFORE IMPACT TEST (INCHES)	SPECIMEN LENGTH BEFORE STATIC TEST (INCHES)	FINAL LENGTH AFTER STATIC TEST (INCHES)	TEMP. °F	DEFLECTION RATE (IN/MIN)
1	45.50	51.1	63.1	Room	1.5
3	45.50	51.3	62.7	Room	4.0

SPECIMEN NUMBER	ENERGY ABSORBED DURING IMPACT TEST (FT-LBS)	ENERGY ABSORBED DURING STATIC TEST (FT-LBS)	TOTAL ENERGY ABSORBED (FT-LBS)
1	7,800	25,420	33,200
3		25,830	_____

PREVIOUSLY IMPACT TESTED STRAP SPECIMEN
(REFERENCE PAGE 2-44 FOR STATIC TEST DATA)

DATA NOT RECORDED



TABLE 2.7

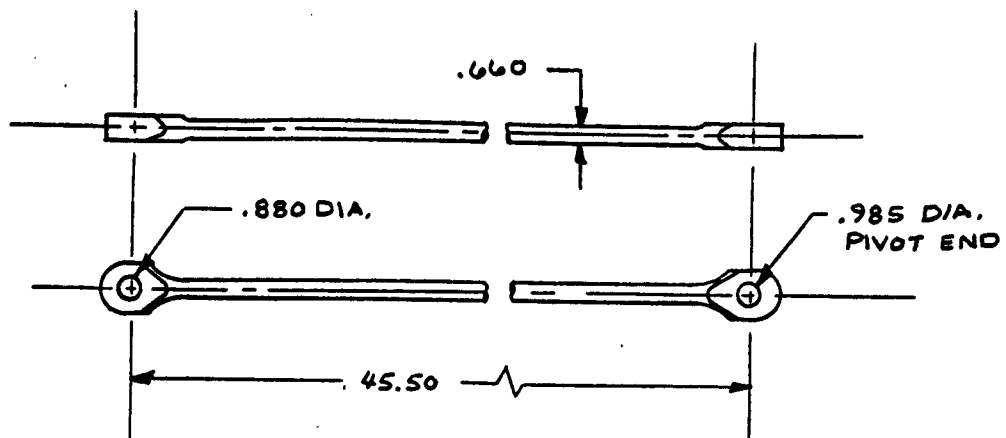
SPECIMEN NUMBER	ATMOSPHERE	GRAIN DIRECTION	TEST TEMP. (°F)	ULTIMATE STRENGTH (PSI)	YIELD STRENGTH (PSI)	ELONGATION % PER 2 INCHES
2-1	Air	Long- itudinal	Room	84,100	25,000	53
2-2	Air	Long- itudinal	Room	83,300	23,800	52
2-3	Air	Long- itudinal	Room	83,100	23,800	54

STANDARD TENSILE ROUND TEST SPECIMENS
(REFERENCE PAGES 2-44 THRU 2-46.)

TABLE 2.7
STATIC TEST RESULTS

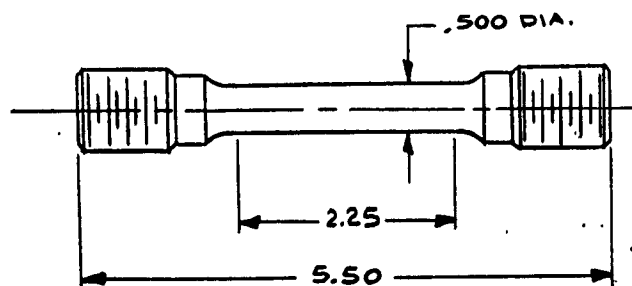


FIGURE 2.1



STRAP SHOCK ABSORBER MAIN LANDING GEAR
SPECIMEN NUMBER 29-80001-3

FIGURE 2.2



TENSILE SPECIMEN ROUND
SPECIMEN NUMBER 23-7070

FIGURE 2.1 & 2.2
TEST SPECIMEN

REFERENCE FIGURE 2.1
FOR RESULTS SEE
TABLE 2.3 & TABLE 2.4

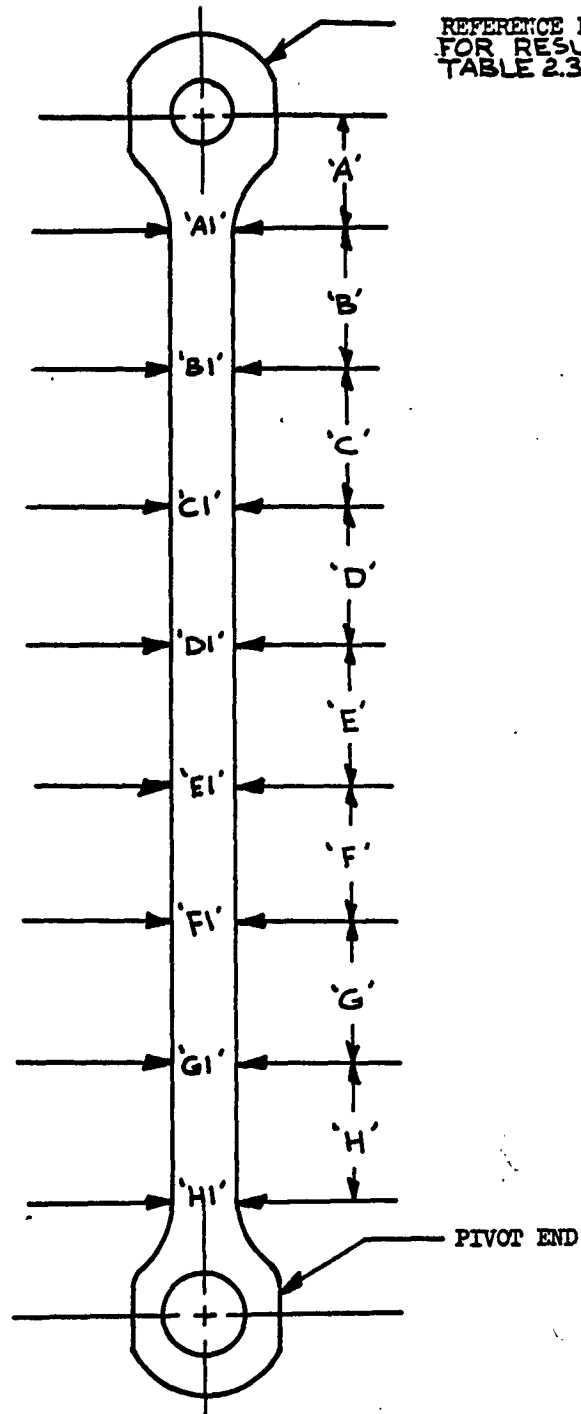


FIGURE 2.3

SECTION ELONGATION AND
DIAMETER MEASUREMENT
LOCATION (SKETCH)

U3 4288 2000 REV. 8/82

2-8142-2

113

REV SYM _____

BOEING

NO. D2-80086

SECT. 2

PAGE 2-16

114
B-1 ENERGY STRAP FOR B-1 LANDING GEAR
11-50-41 219977

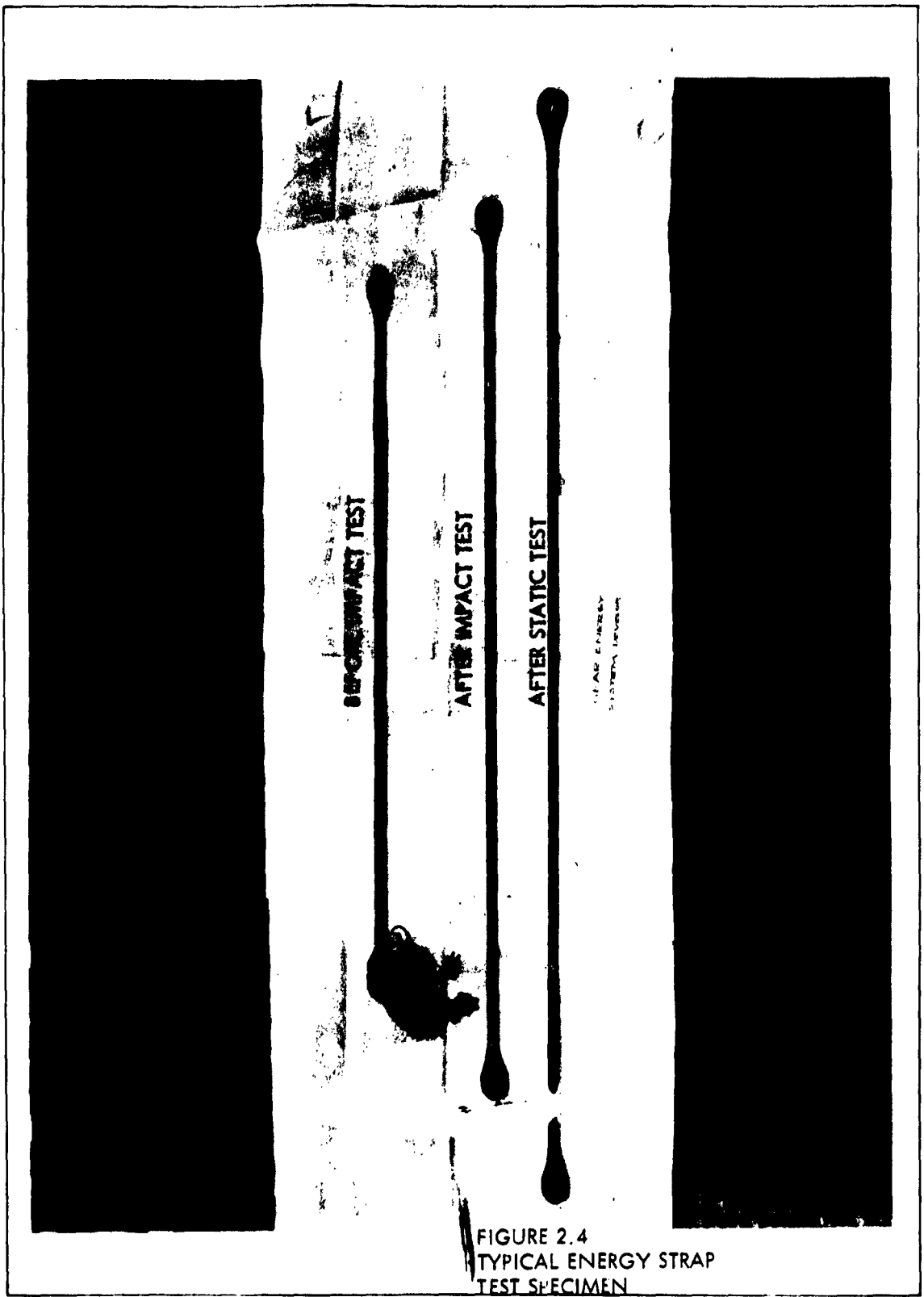


FIGURE 2.4
TYPICAL ENERGY STRAP
TEST SPECIMEN

U3-4071-1000 (was BAC 1046-L-R3)

AFTER IMPACT TEST

BEFORE IMPACT TEST

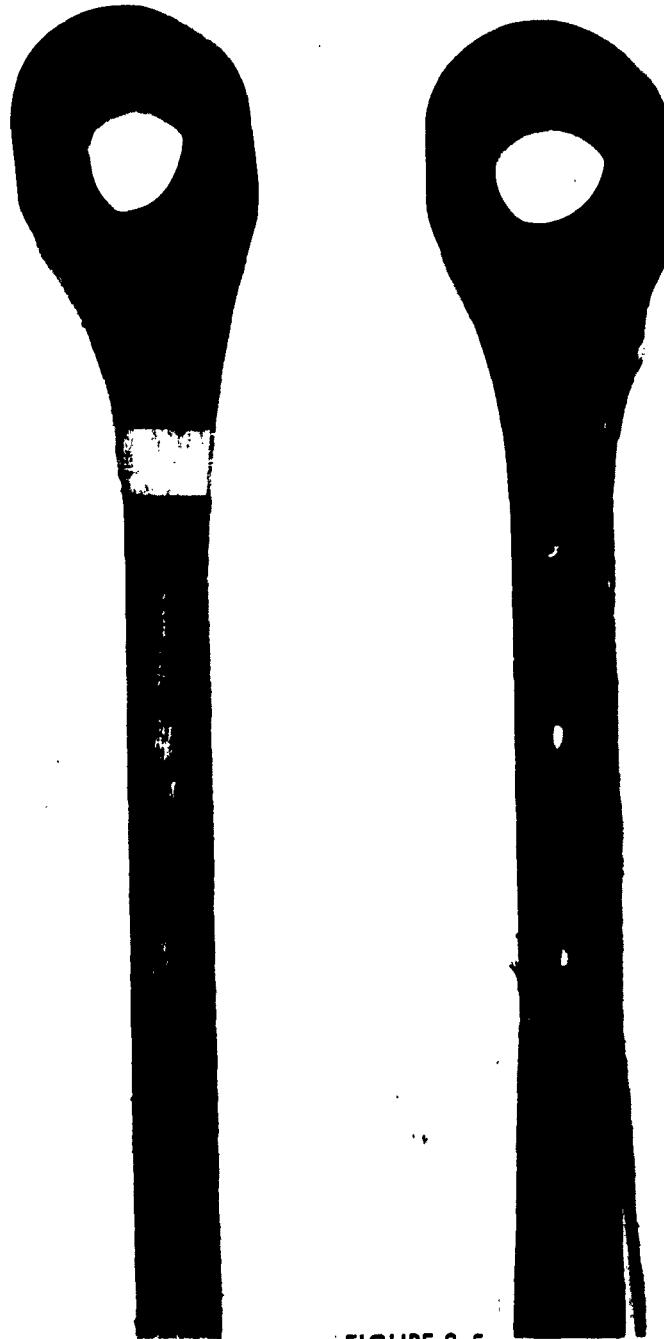


FIGURE 2.5
TYPICAL ENERGY STRAP
PIVOT END

12-30-41
260977
12-30-41

U3-4871-1000 (was SAC 1946-L-R3)

115

AFTER IMPACT TEST

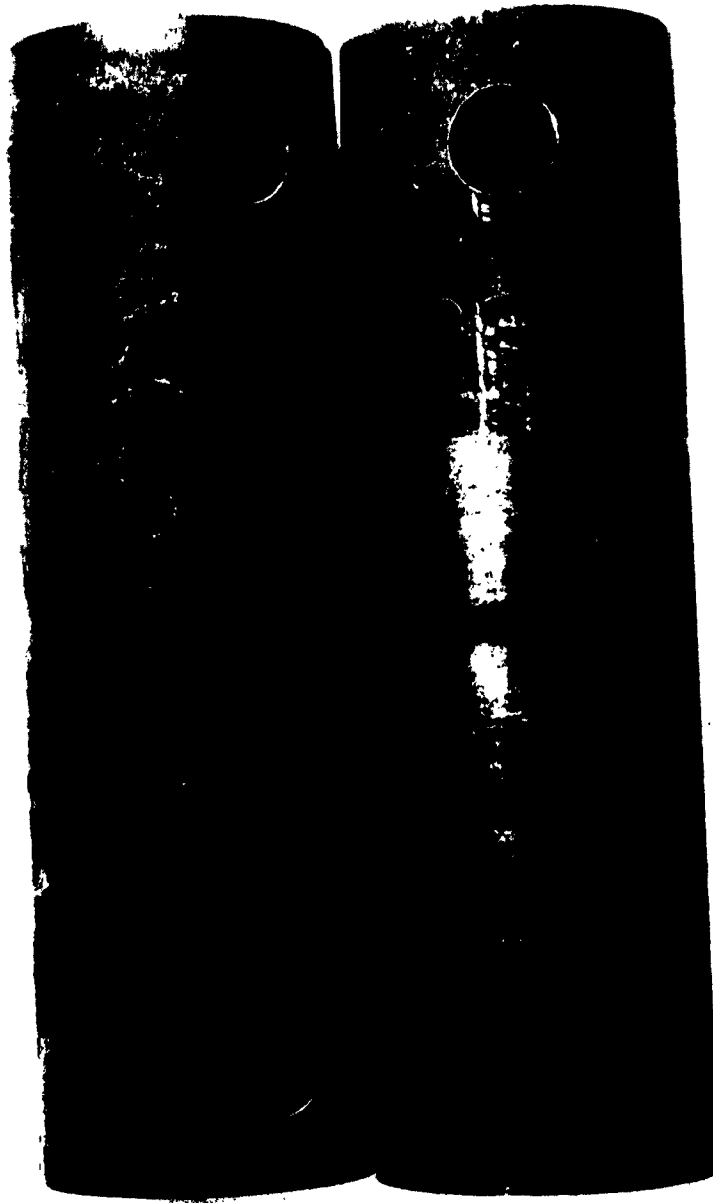


FIGURE 2.6
RENE' 41 PIVOT END



U2-4871-1000 (was BAC 1546-L-R3)

BOEING	NO. D2-8008 ✈
SEC 2	PAGE 2-19



FIGURE 2.7
IMPACT TEST QUICK
RELEASE MECHANISM

2A 1785
1 5-62

117

2410595

DE LAMINAR GASES TEST CHAMBER
EXPERIMENTAL MECHANICAL WORK
AND ST. MICHAEL ST. GENE POULSEN 8-7-66

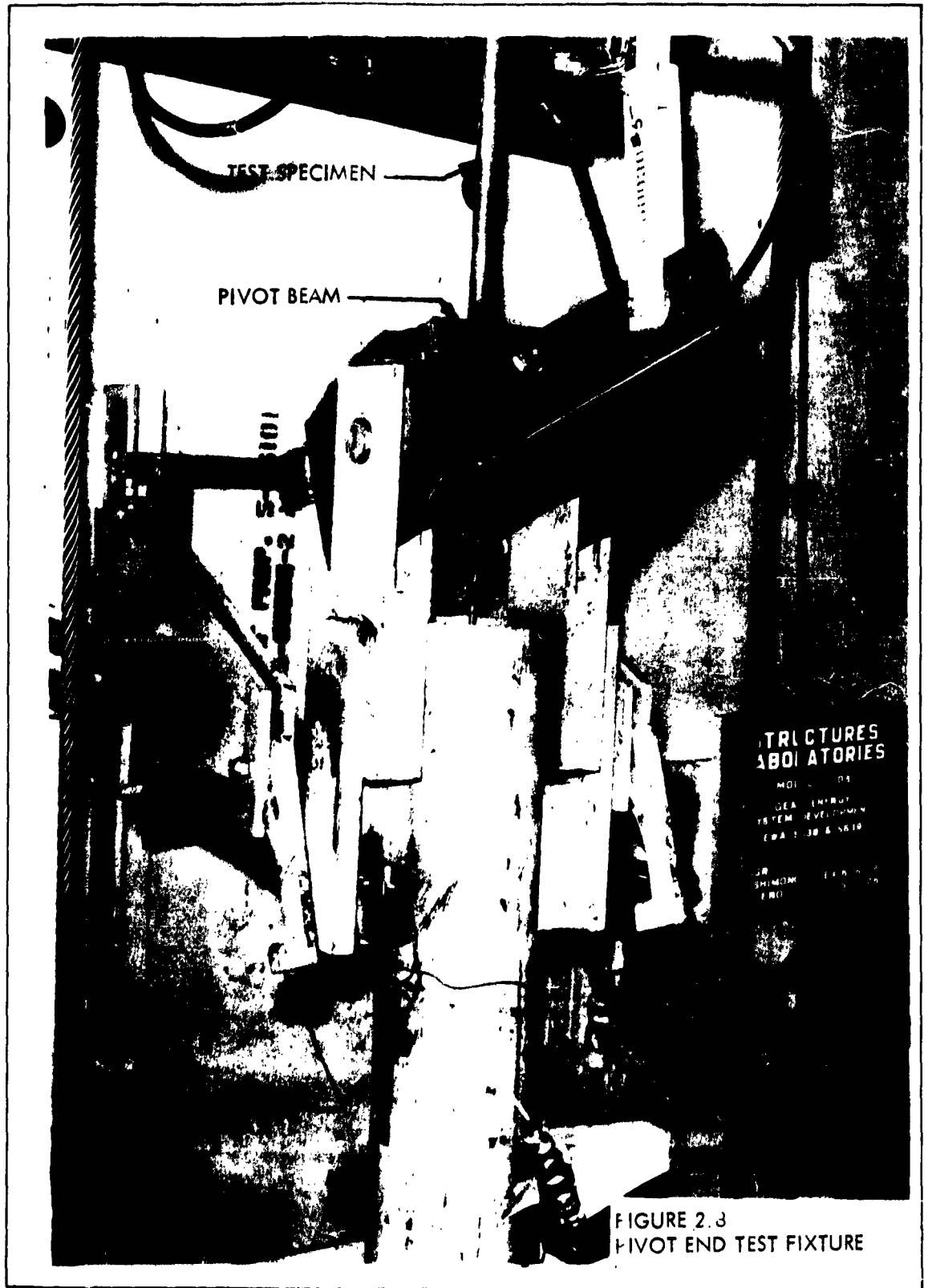


FIGURE 2.3
PIVOT END TEST FIXTURE

U3-4071-1000 (was SAC 1046-L-83)

118

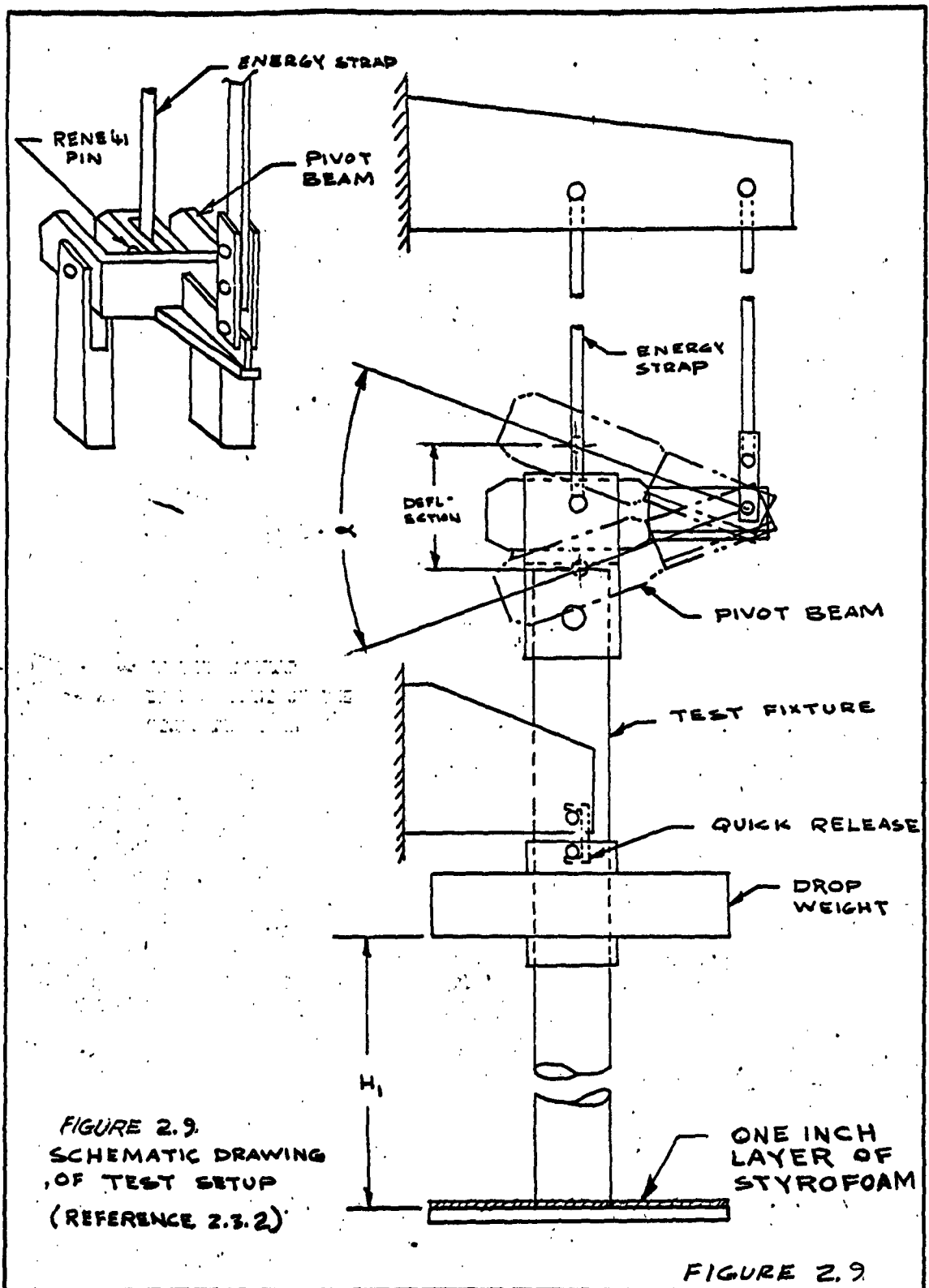


FIGURE 2.9

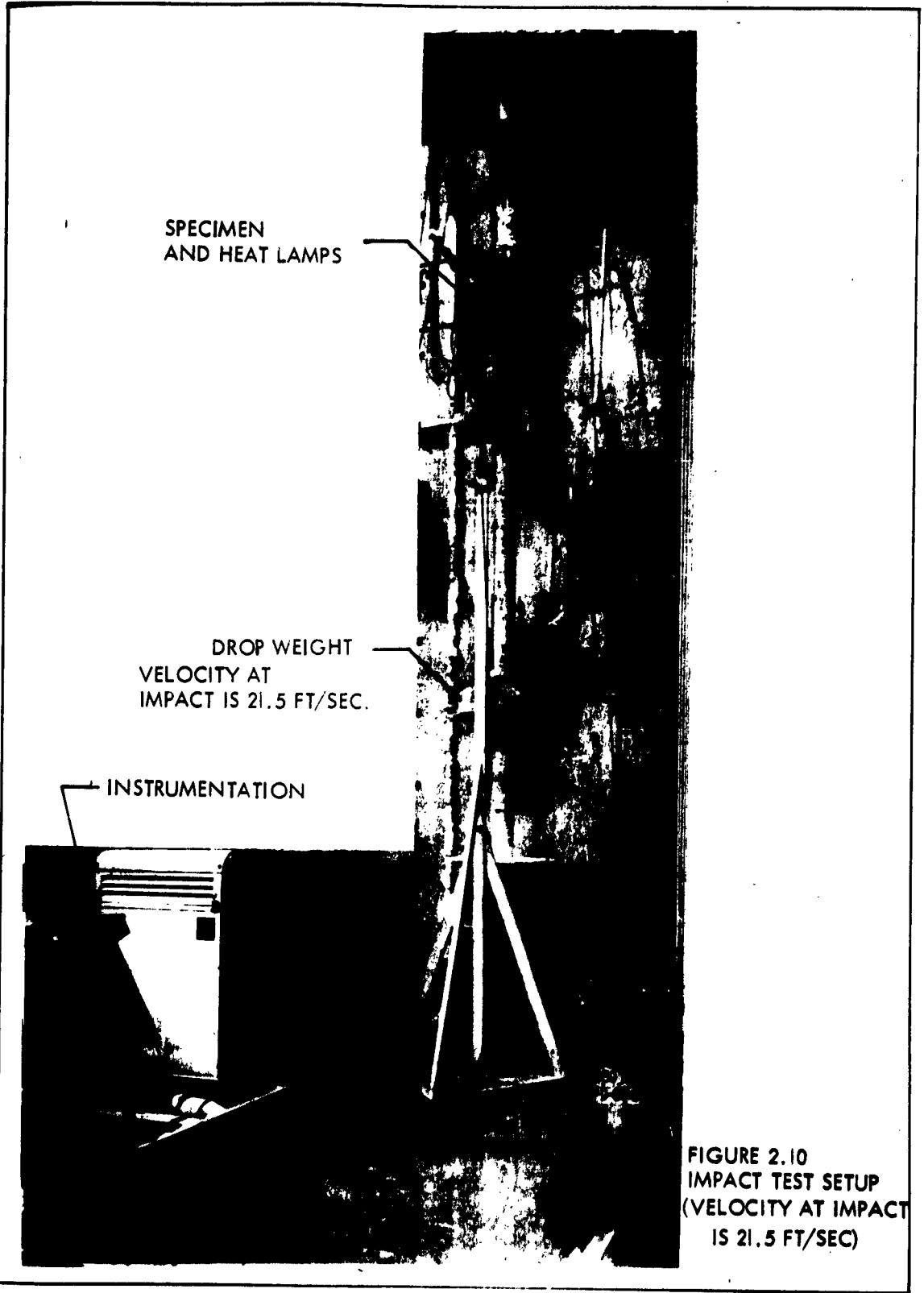


FIGURE 2.10
IMPACT TEST SETUP
(VELOCITY AT IMPACT
IS 21.5 FT/SEC)

U9-4871-1000 (was SAC 1946-L-83)

120

DROP WEIGHT
VELOCITY AT IMPACT
IS 1.75 FT/SEC.

INSTRUMENTATION

DE-I MBL.. STAP TEST SETS HAVE LAMINATED
CIRCUIT BOARD SYSTEMS INSTALLED. ALL GOOD
4 PT/SEC TEST GOOD. 2-65-62

BOEING	NO. D2-80086
SEC 2	PAGE 2-24

SPECIMEN 29-80001-3
TEMPERATURE 72°F

LOAD ~ KIPS

21.0

5.73

DEFLECTION

TIME ~ SECONDS

DEFLECTION ~ INCHES

CALC	J. Lebo	12-26-1	REVISED	DATE
CHECK				
APR				
APR				

LOAD & DEFLECTION VS
TIME SPECIMEN No. 1

X-20

D2-80086

THE BOEING COMPANY

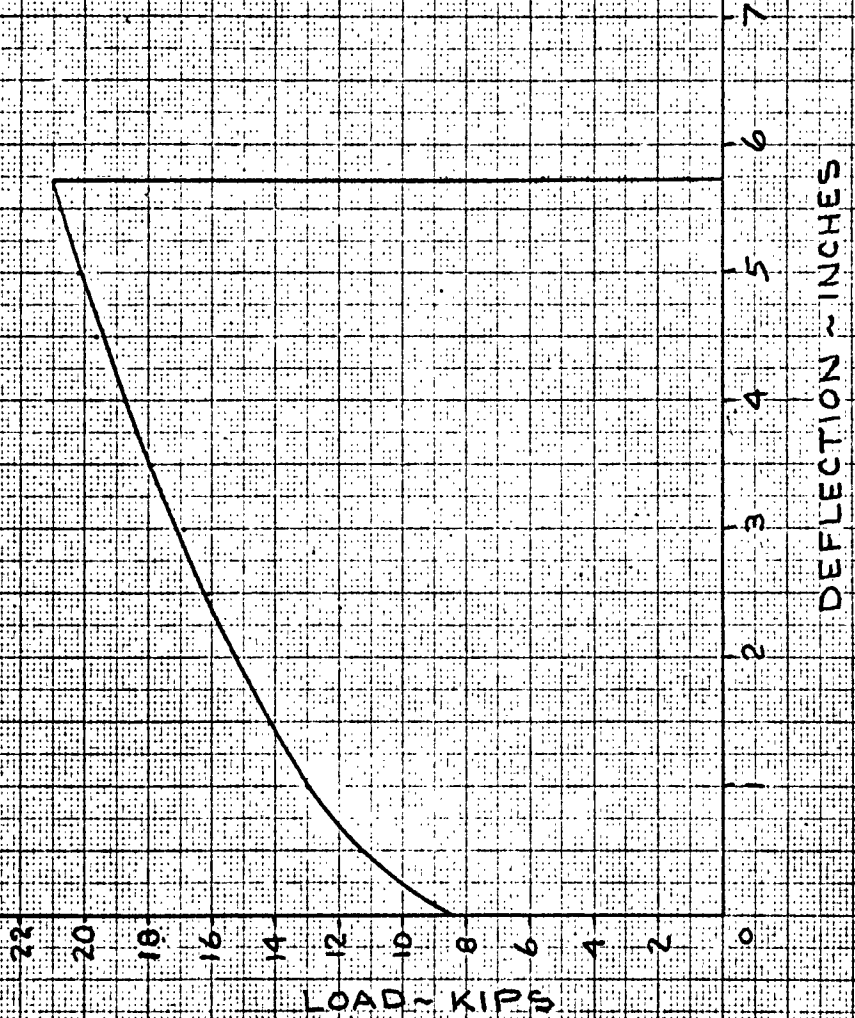
PAGE
2-25

SPECIMEN 29-80001-3

TEMPERATURE 72°F

E = 93,566 INCH-LBS

* 7.80 KIPS - FT.



CALC	J.h.k.100	12-26	REVISED	DATE
CHECK				
APR				
APR				

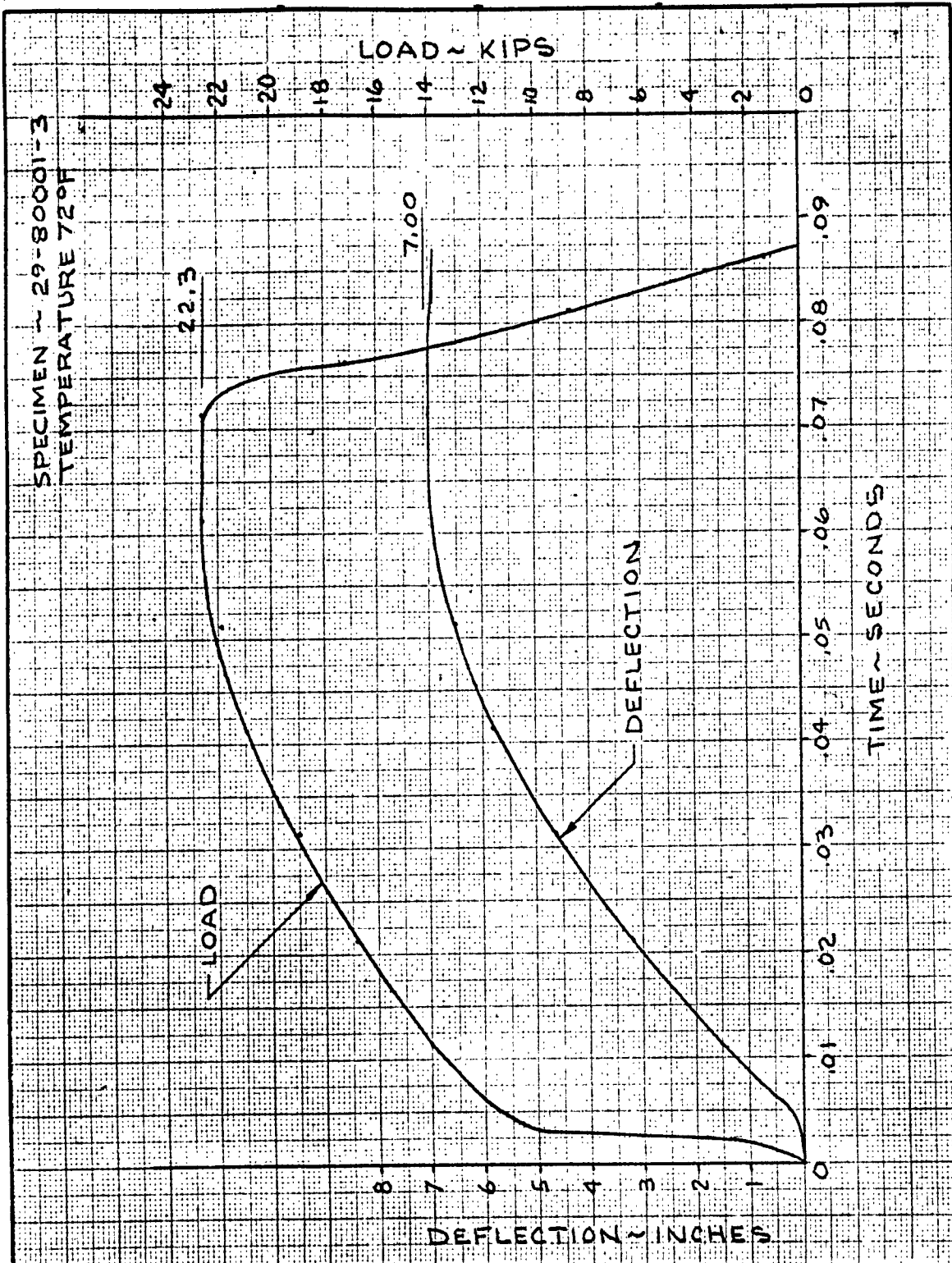
LOAD vs DEFLECTION
SPECIMEN No. 1

THE BOEING COMPANY

X-20

D2-80086

PAGE
2-26



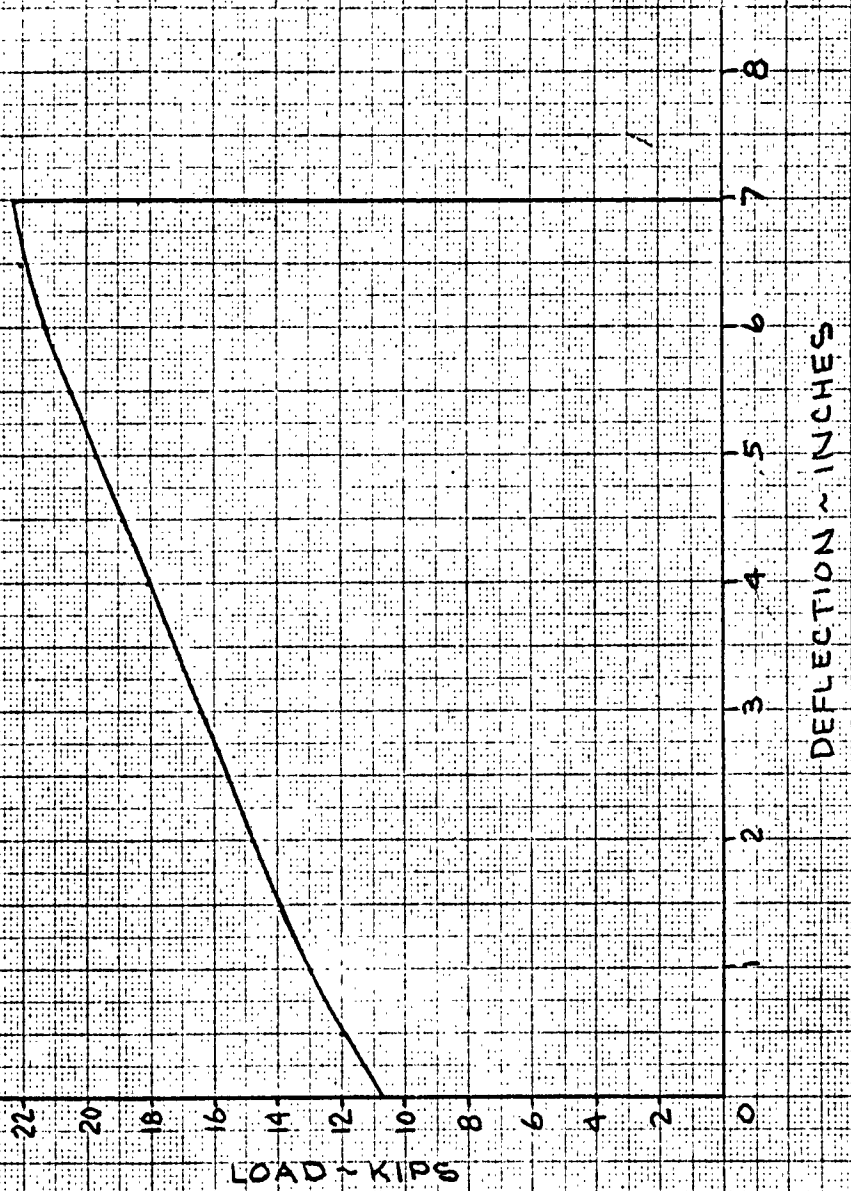
CALC	J. Lebo	12-21-1	REVISED	DATE
CHECK				
APR				
APR				

LOAD & DEFLECTION VS
 TIME ~ SPECIMEN No. 2

THE BOEING COMPANY

X-20
 DE-50086
 PAGE
 2-27

SPECIMEN ~ 29-80001-3
 TEMPERATURE 72°F
 E = 119,747 IN-LBS
 = 9.99 KIPS-FT



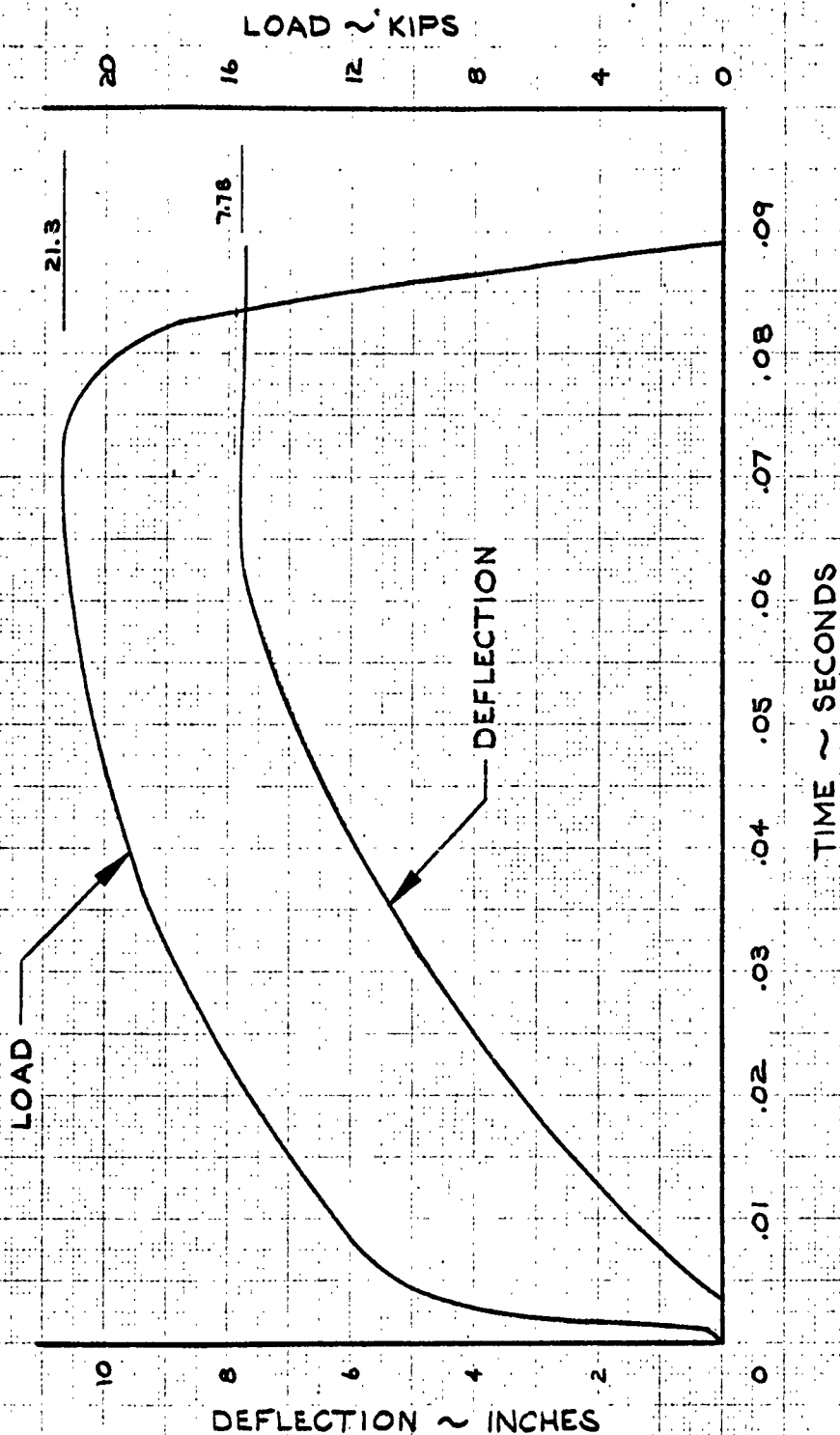
CALC	J. L. Lobo	12-21-1	REVISED	DATE
CHECK				
APR				
APR				

LOAD VS DEFLECTION
 SPECIMEN No. 2

THE BOEING COMPANY

X-20
 D2-80086
 PAGE 2-28

SPECIMEN 29-80001-3
TEMPERATURE 300°F



CALC	J. Lebo	12-19-1	REVISED	DATE
CHECK				
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 4

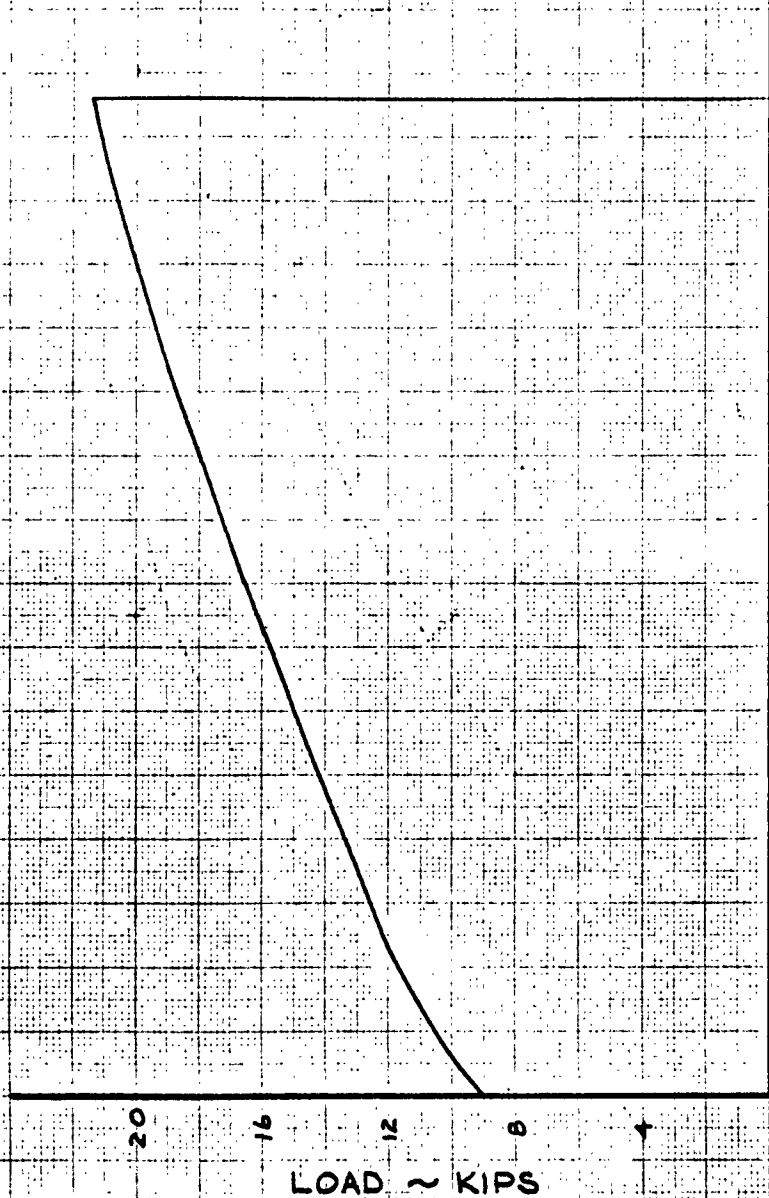
THE BOEING COMPANY

X-20

D2-80086

PAGE
2-29

SPECIMEN 29-80001-3
 TEMPERATURE = 300°F
 ENERGY = 125.532 IN-LBS
 = 10.46 K-FT



CALE	J. Lebo	12-19-41	REVISED	DATE
CHECK				
APR				
APR				

LOAD VS DEFLECTION
 SPECIMEN NO. 4

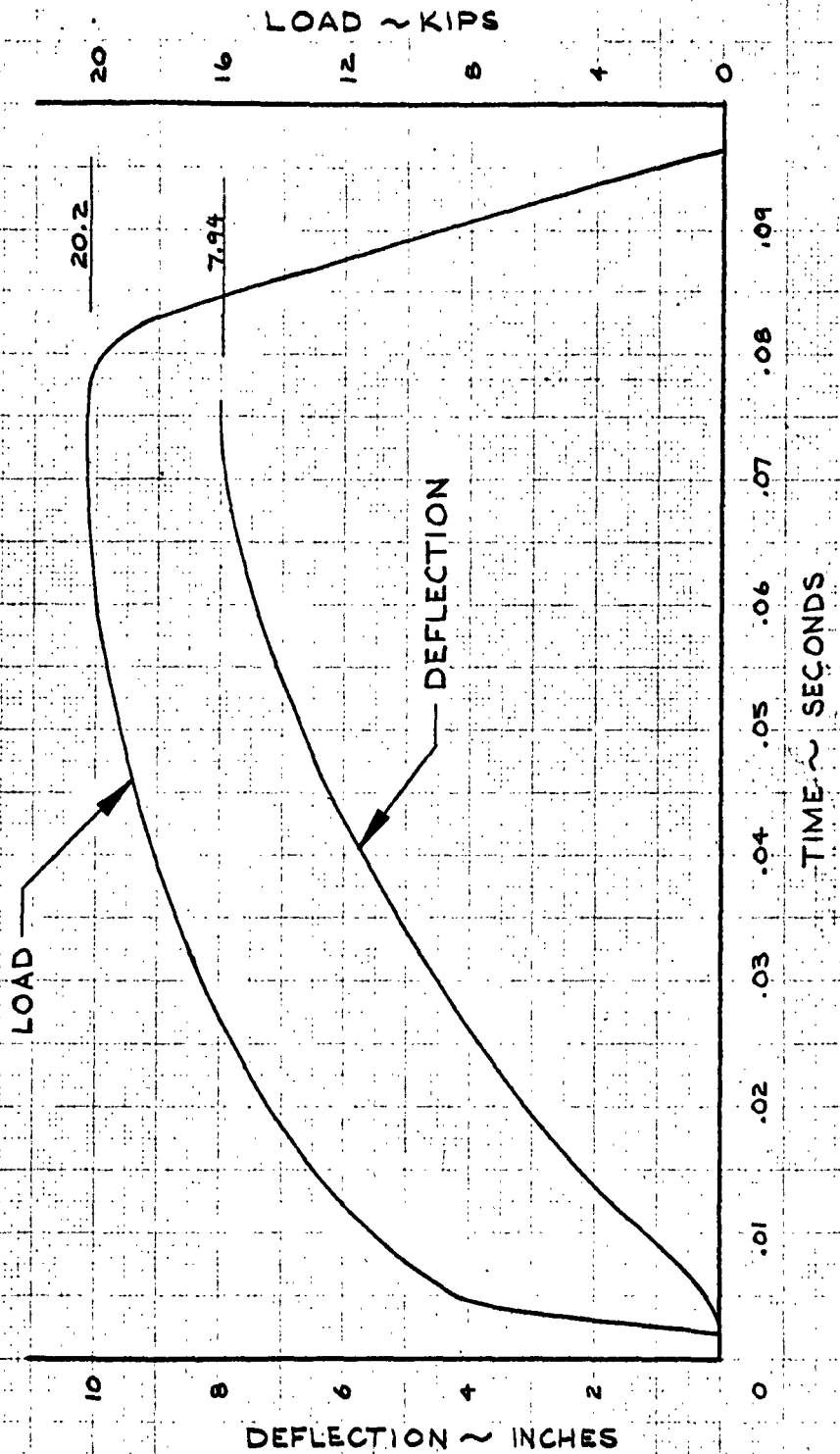
THE BOEING COMPANY

X-20

D2-80086

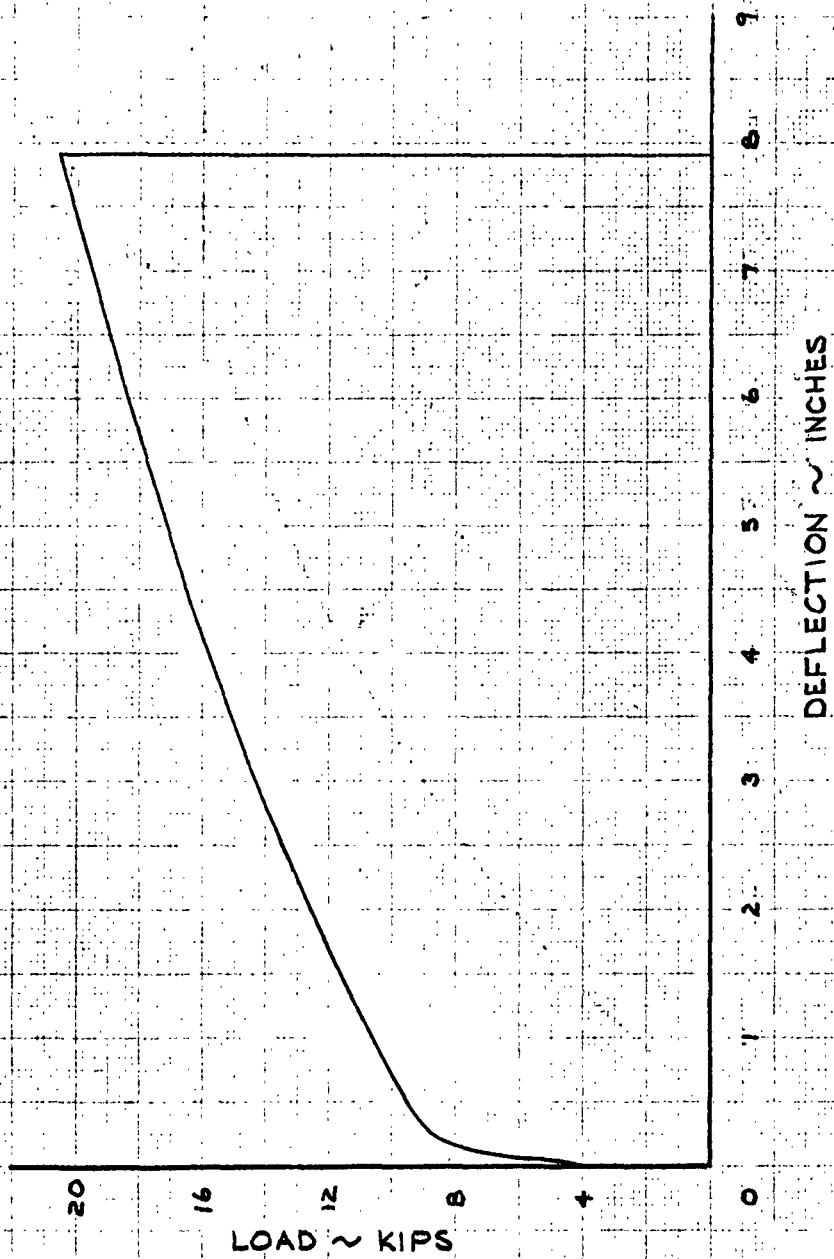
PAGE
 2-30

SPECIMEN 29-80001-3
TEMPERATURE 300°F



CALC	J. Lebo	12-19-41	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 5	X-20
CHECK						D2-80086
APR						
APR						
					THE BOEING COMPANY	PAGE 2-31

SPECIMEN 29-80001-3
 TEMPERATURE = 300°F
 ENERGY = 121,155 IN-LBS
 = 10.10 K-FT

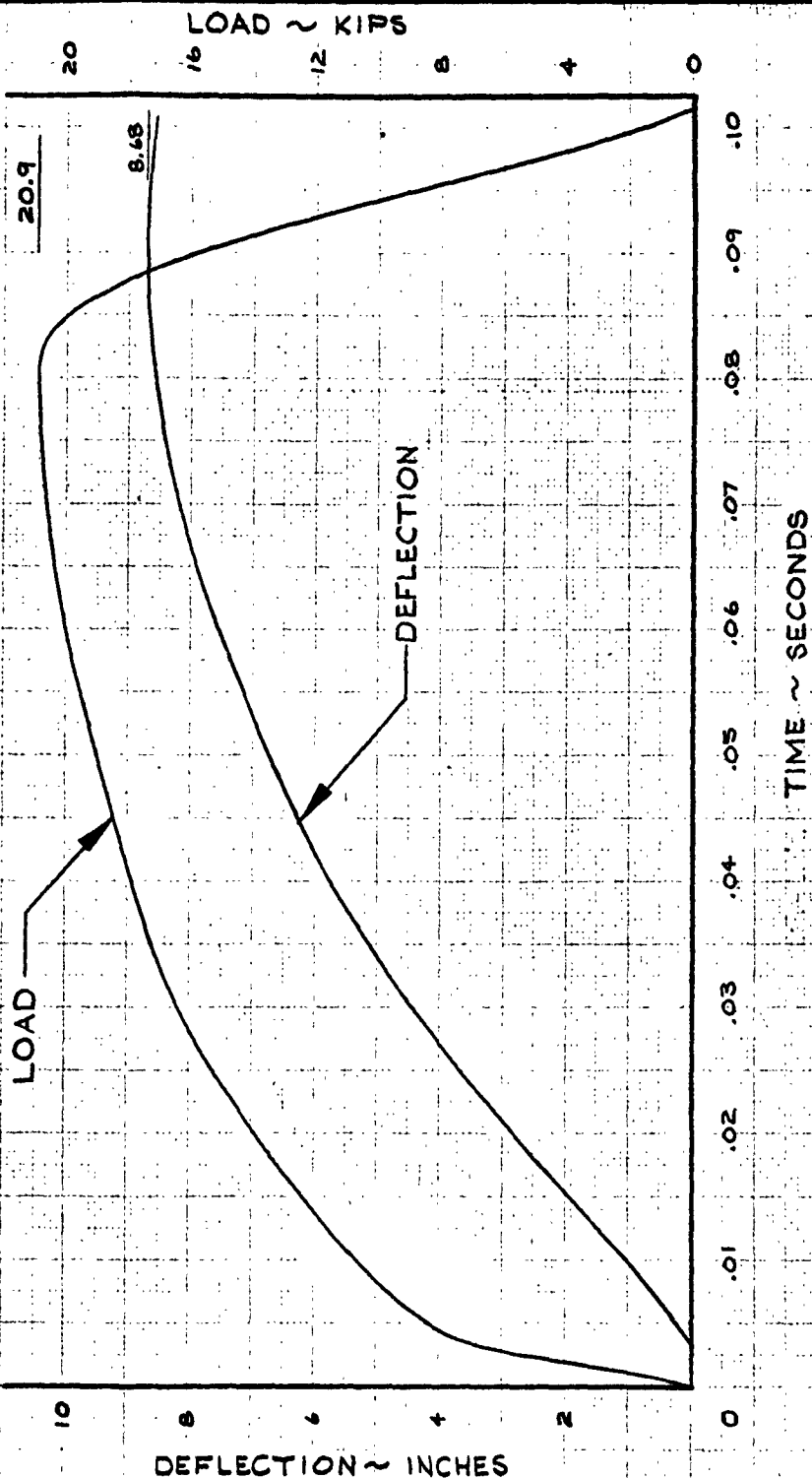


CALC	J. Lebo	12-19	1	REVISED	DATE
CHECK					
APR					
APR					

LOAD VS DEFLECTION SPECIMEN NO. 5		X-20
		D2-80086
THE BOEING COMPANY		PAGE 2-32

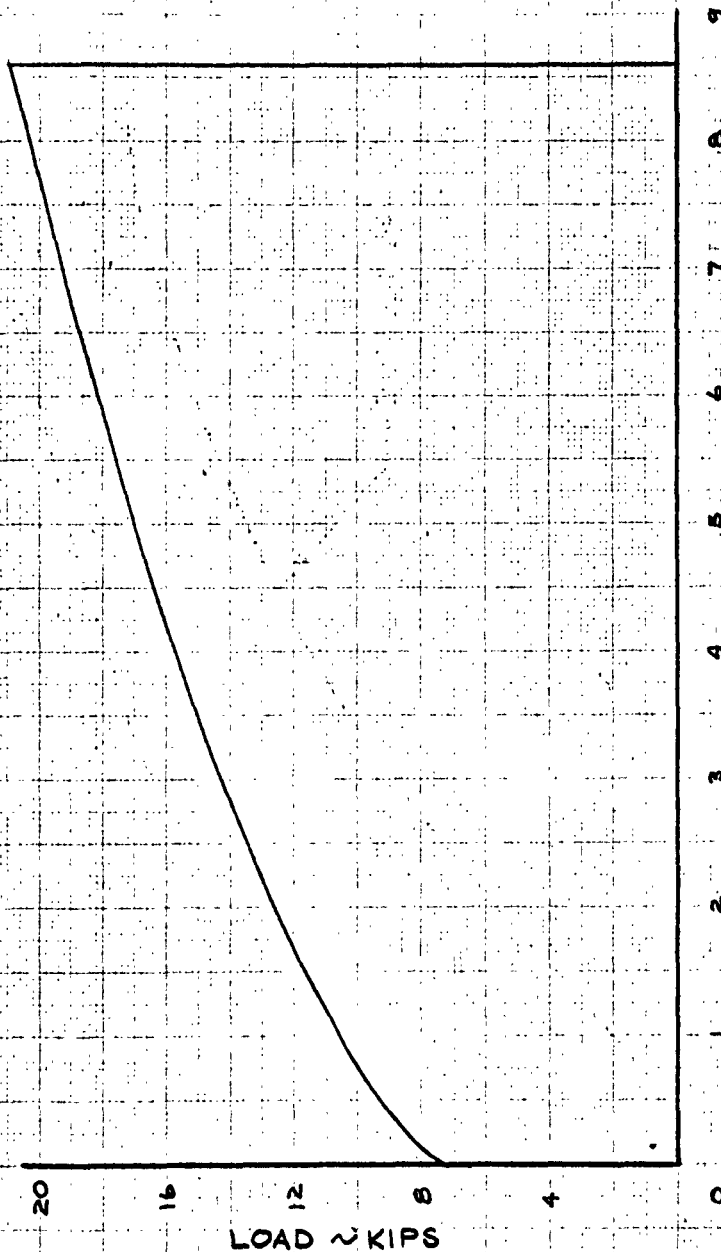
129

SPECIMEN 29-80001-3
TEMPERATURE 600°F



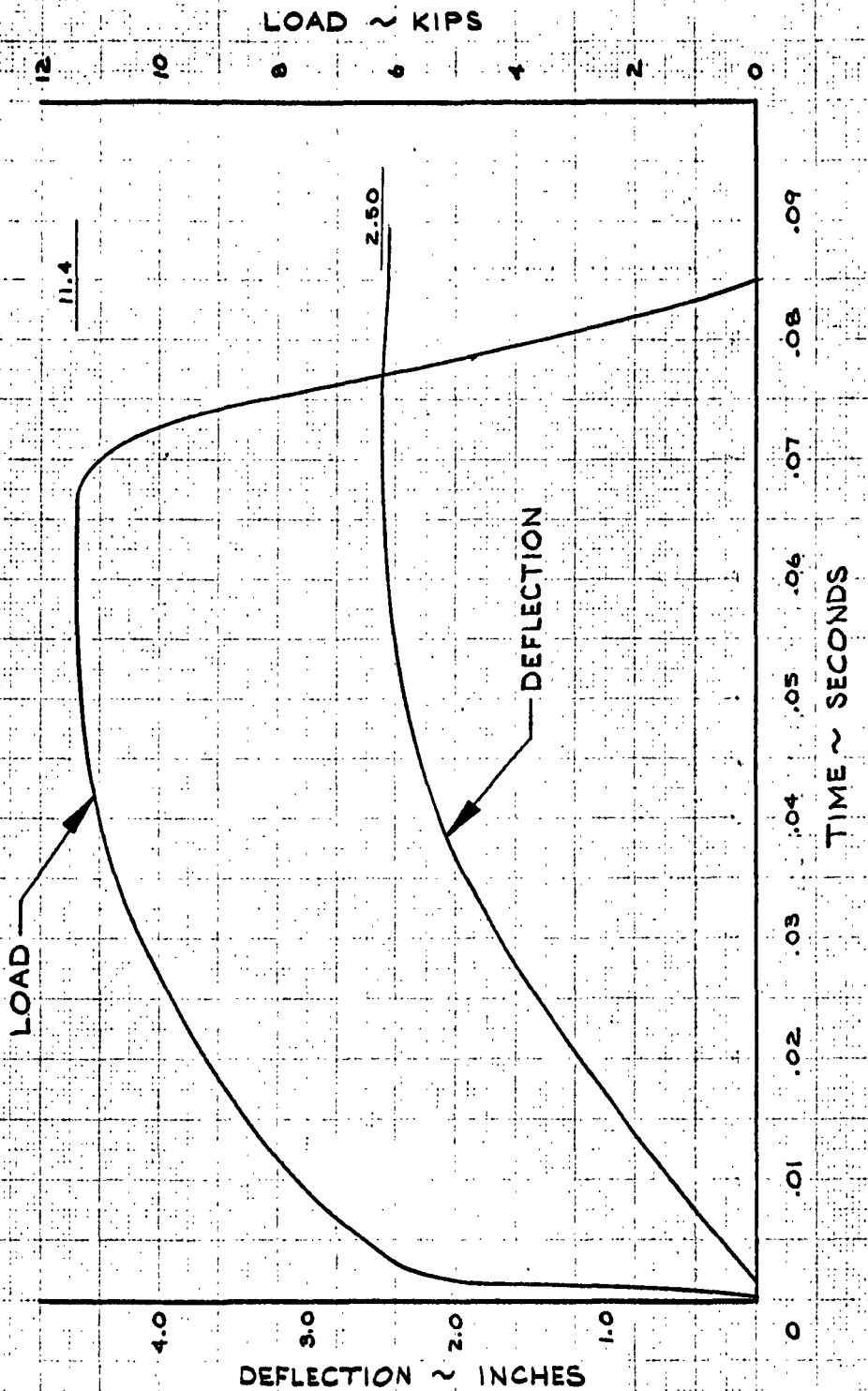
CALC	J. Lebo	12-19	1	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 6	X-20
CHECK							D2-80086
APR							
APR							
THE BOEING COMPANY							PAGE 2-33

SPECIMEN 29-80001-3
 TEMPERATURE = 600°F
 ENERGY = 133,958 IN-LBS
 = 11.16 K-FT



CALC	J. Lebo	12-19-1	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 6	X-20
CHECK						D2-80086
APR						PAGE
APR					THE BOEING COMPANY	2-34

SPECIMEN 29-80001-3
TEMPERATURE 600°F



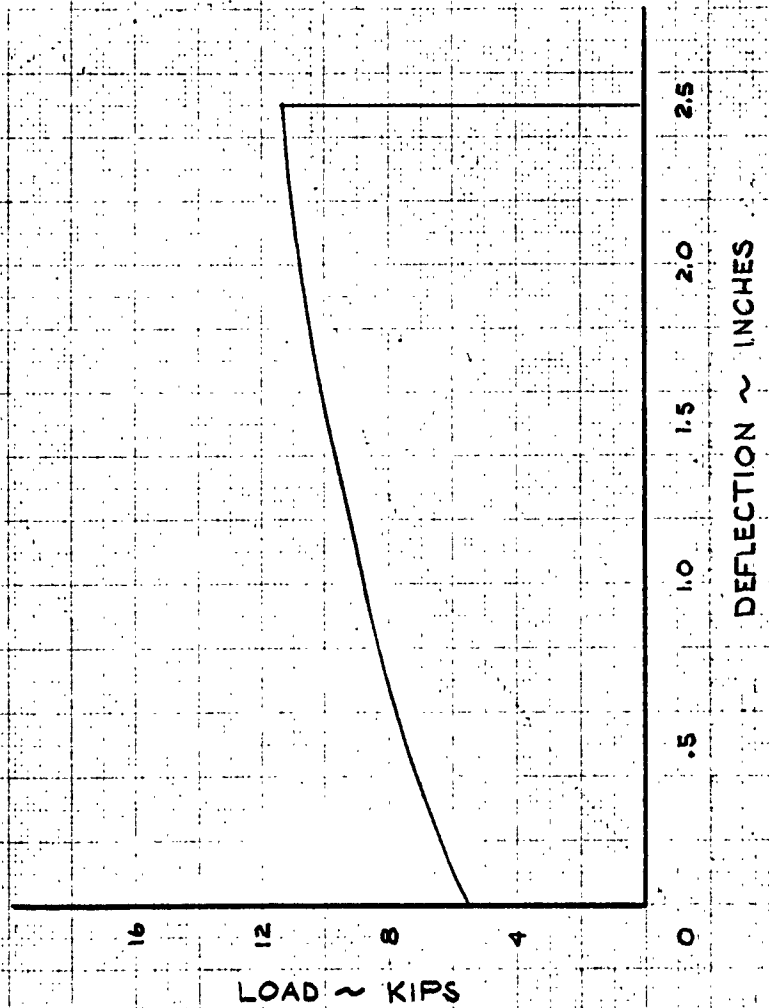
CALC	J. Lebo	2-27-2	REVISED	DATE
CHECK	Jorgensen	2-28-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 19

THE BOEING COMPANY

X-20
D2-80086
PAGE
2-55

SPECIMEN 29-80001-3
 TEMPERATURE = 600°F
 ENERGY = 21,775 INCH-LBS
 = 1.815 KIPS-FT



CALC	J. Lebo	2-27-2	REVISED	DATE
CHECK	Jorgensen	2-28-2		
APR				
APR				

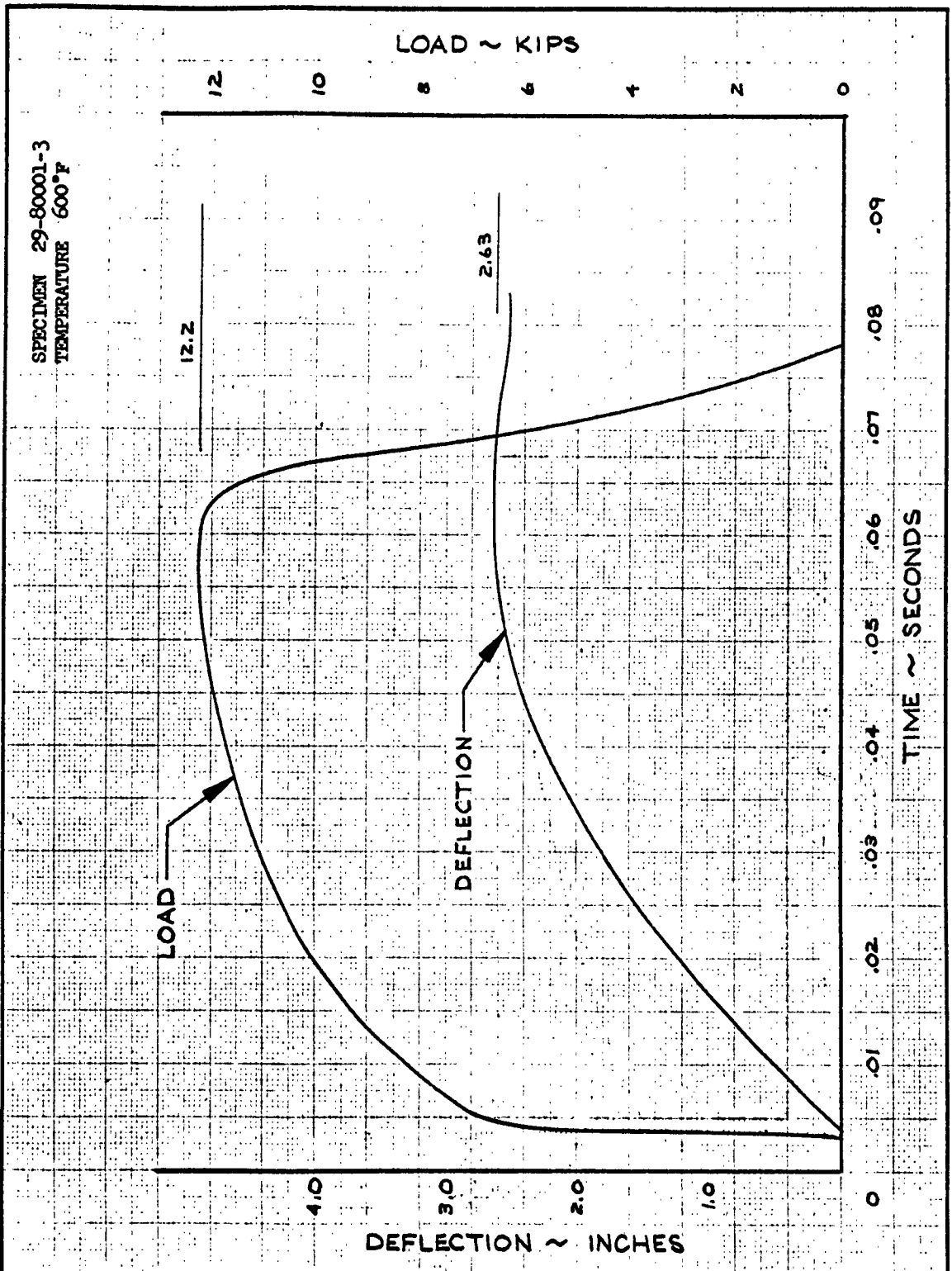
LOAD VS DEFLECTION
 SPECIMEN NO. 19

X-20

D2-80086

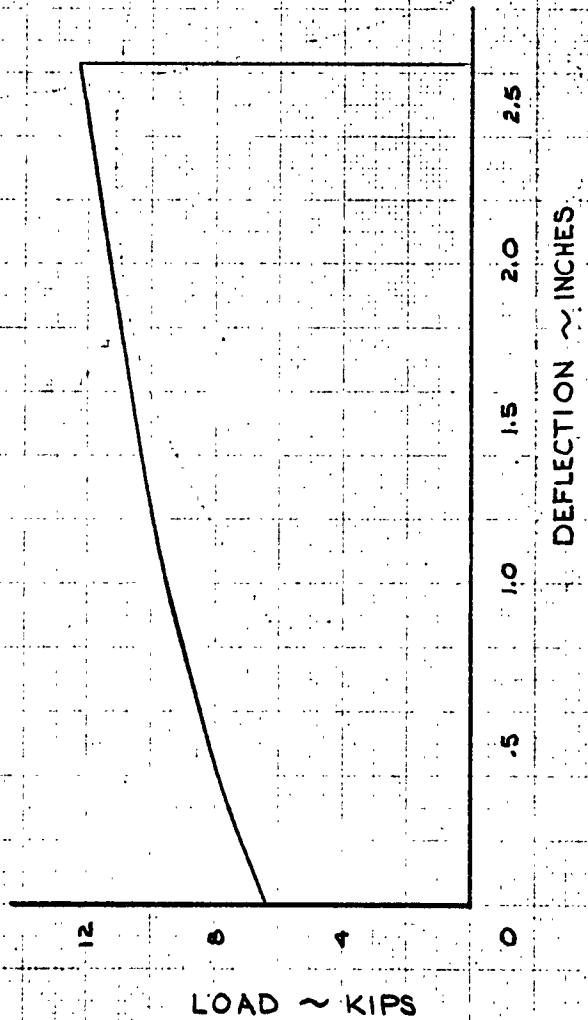
THE BOEING COMPANY

PAGE
 2-36



CALC	J. Lebo	2-27-	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 20	X-20
CHECK	Jorgensen	2-28-				D2-80086
APR						
APR					THE BOEING COMPANY	PAGE 2-37

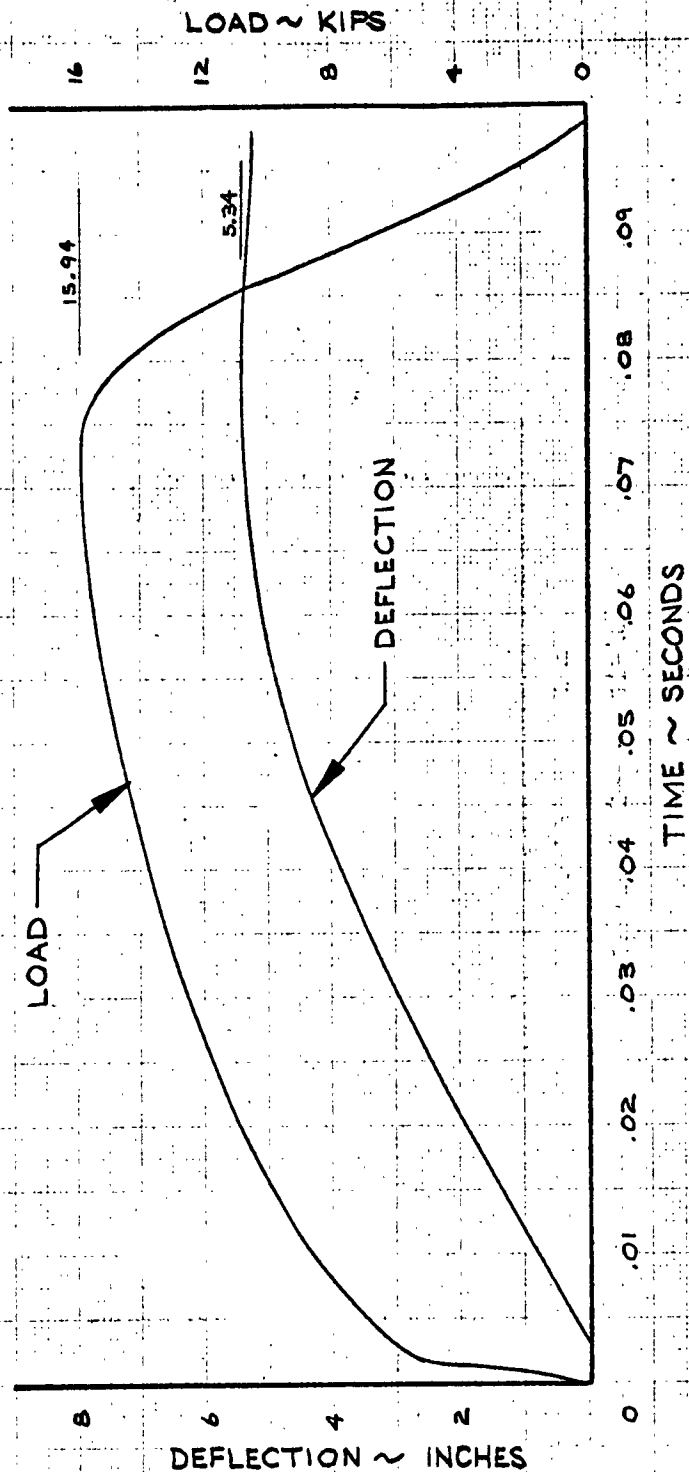
SPECIMEN 29-80001-3
 TEMPERATURE = 600°F
 ENERGY = 25,774 INCH-LBS
 = 2.15 KIPS-FT



CALC	J. Iebo	2-27-	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 20	X-20
CHECK	Jorgensen	2-28-				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						2-38

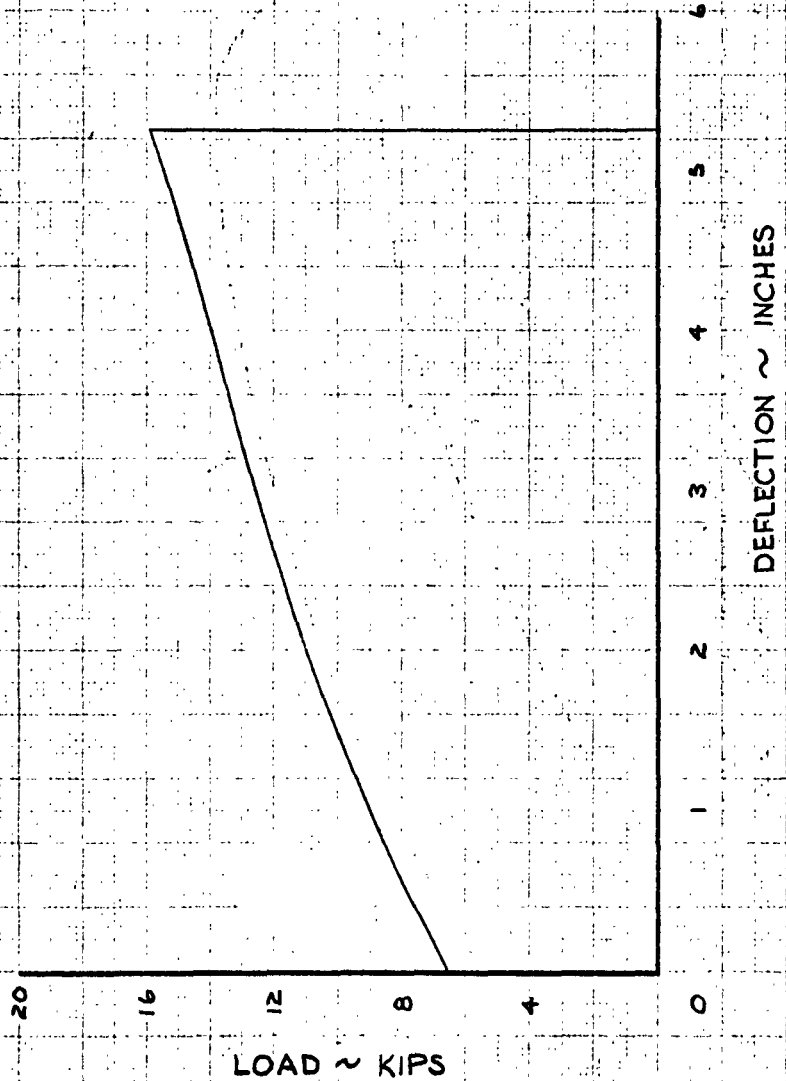
135

SPECIMEN 29-80001-3
TEMPERATURE 600°F



CALC	J. Lebo	3-1-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 21	X-20
CHECK	Jorgensen	3-7-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						2-89

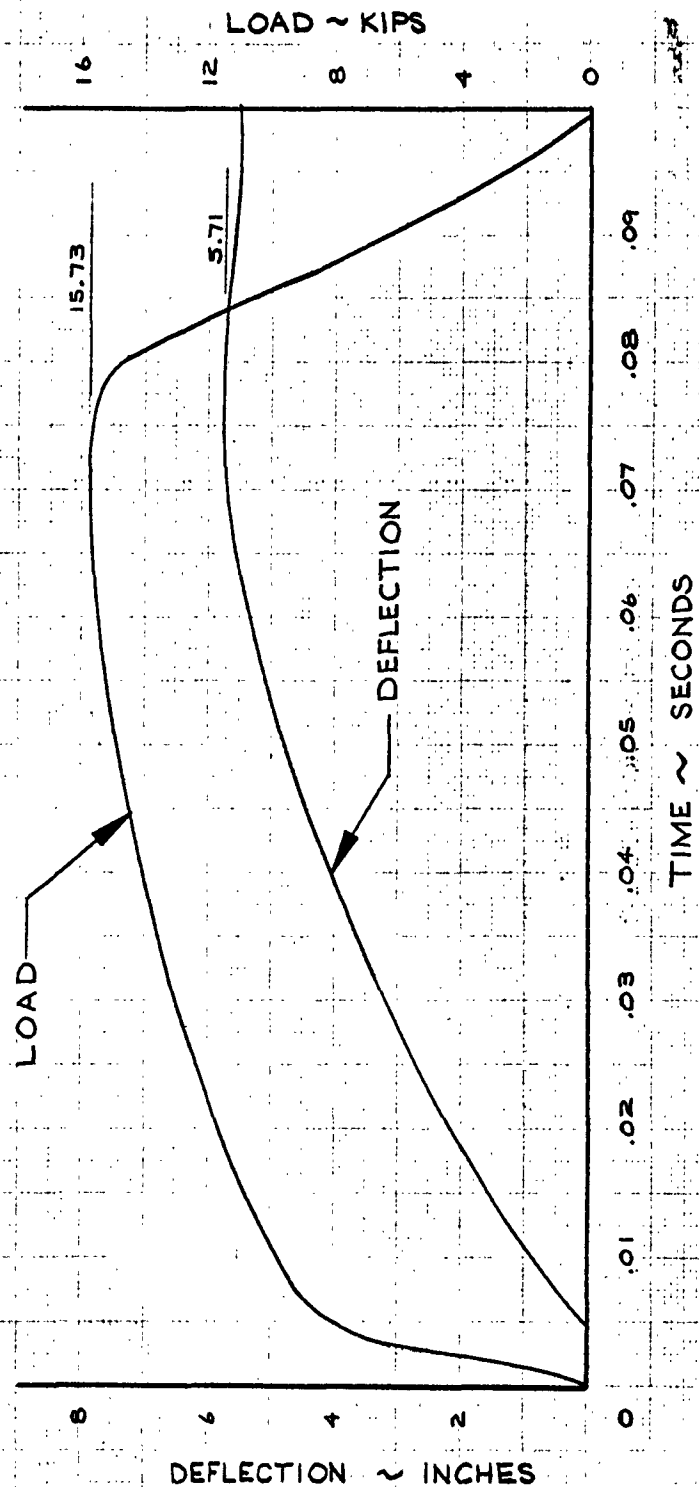
SPECIMEN 29-80001-3
 TEMPERATURE = 600°F
 ENERGY = 62,259 INCH-IBS
 = 5.19 KIPS-FT



CALC	J. Lebo	3-1-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 21	X-20
CHECK	Jorgensen	3-7-2				D2-80086
APR						
APR						
THE BOEING COMPANY						PAGE 2-40

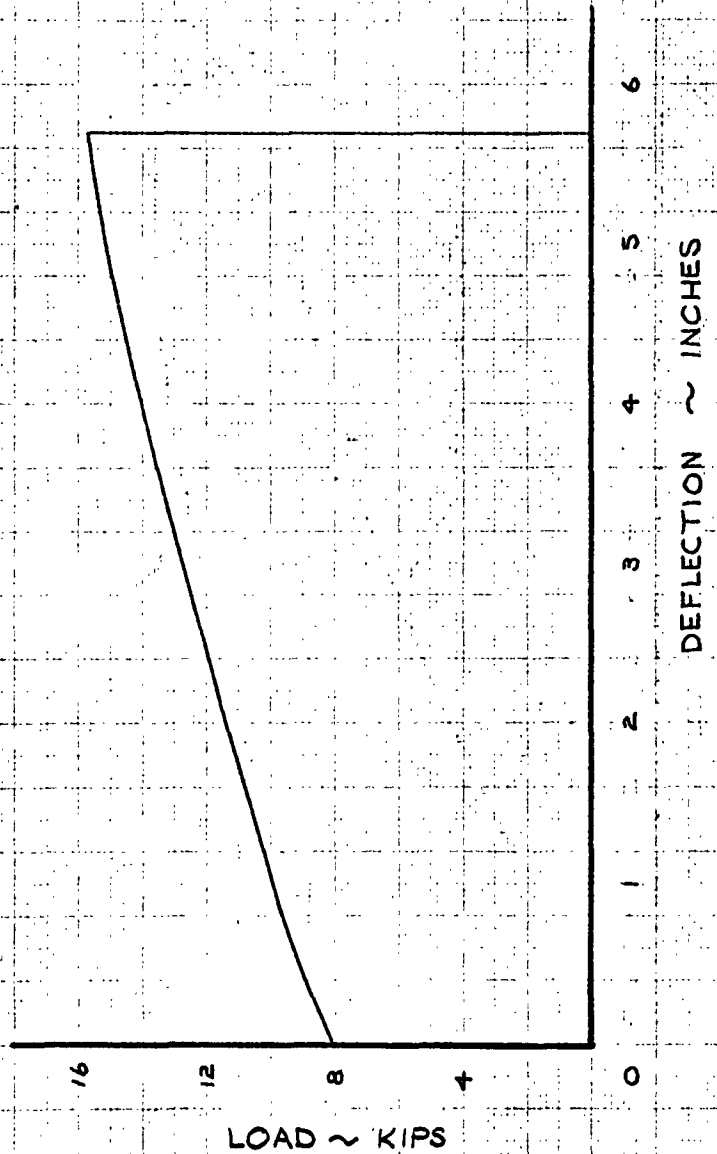
137

SPECIMEN 29-80001-3
TEMPERATURE 600°F

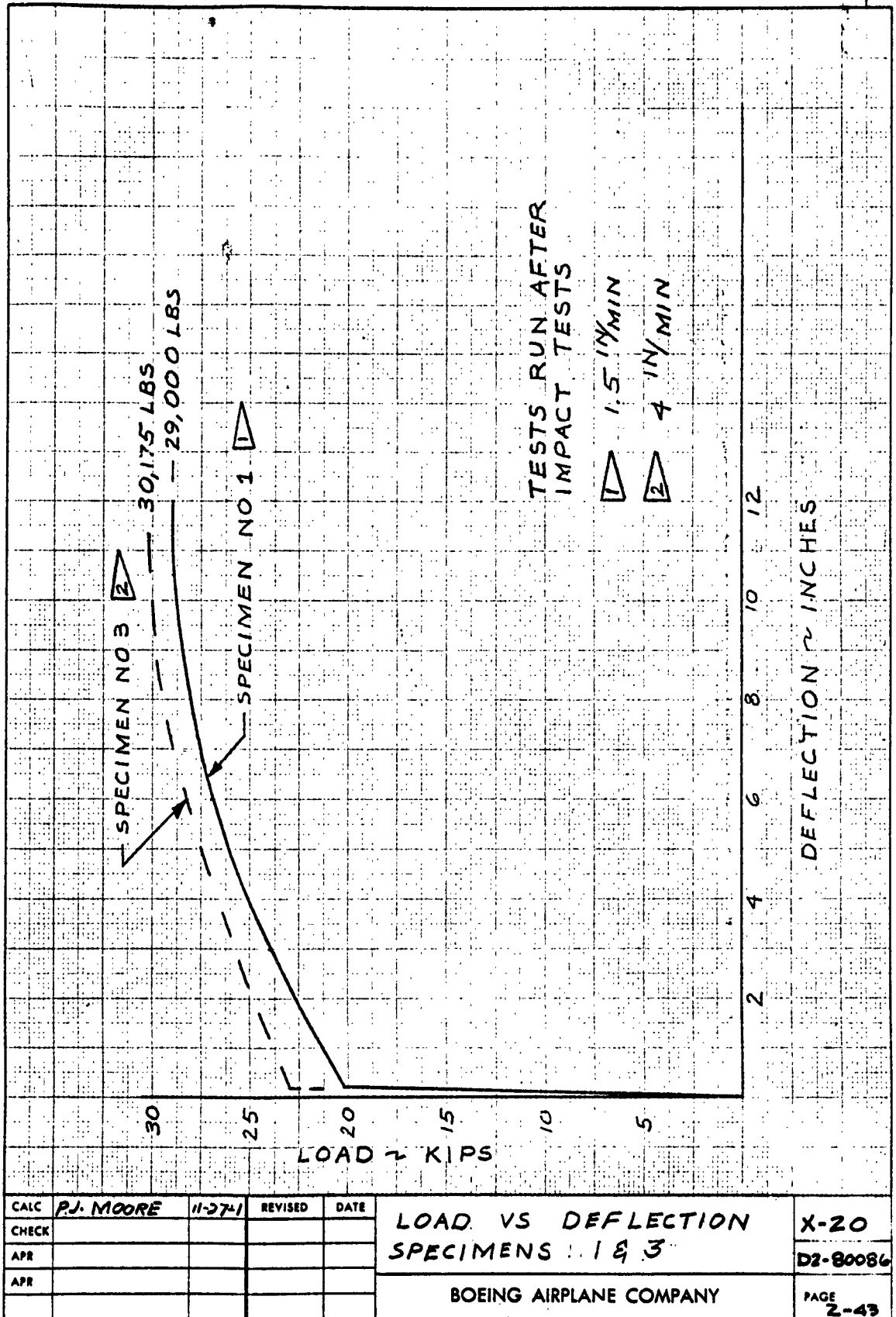


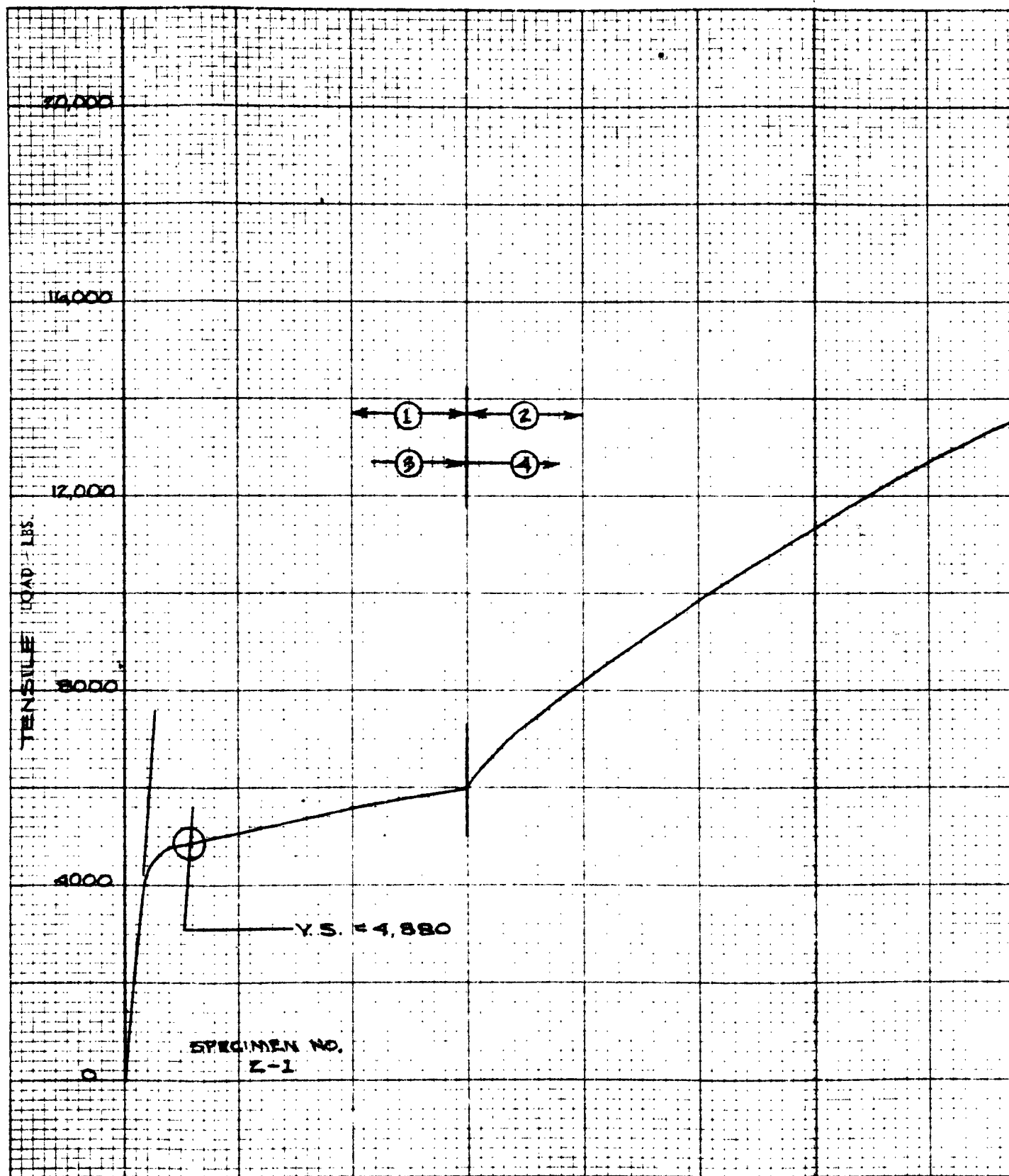
CALC	J. Lebo	3-2-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 22	X-20
CHECK	Jorgensen	3-7-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						2-41

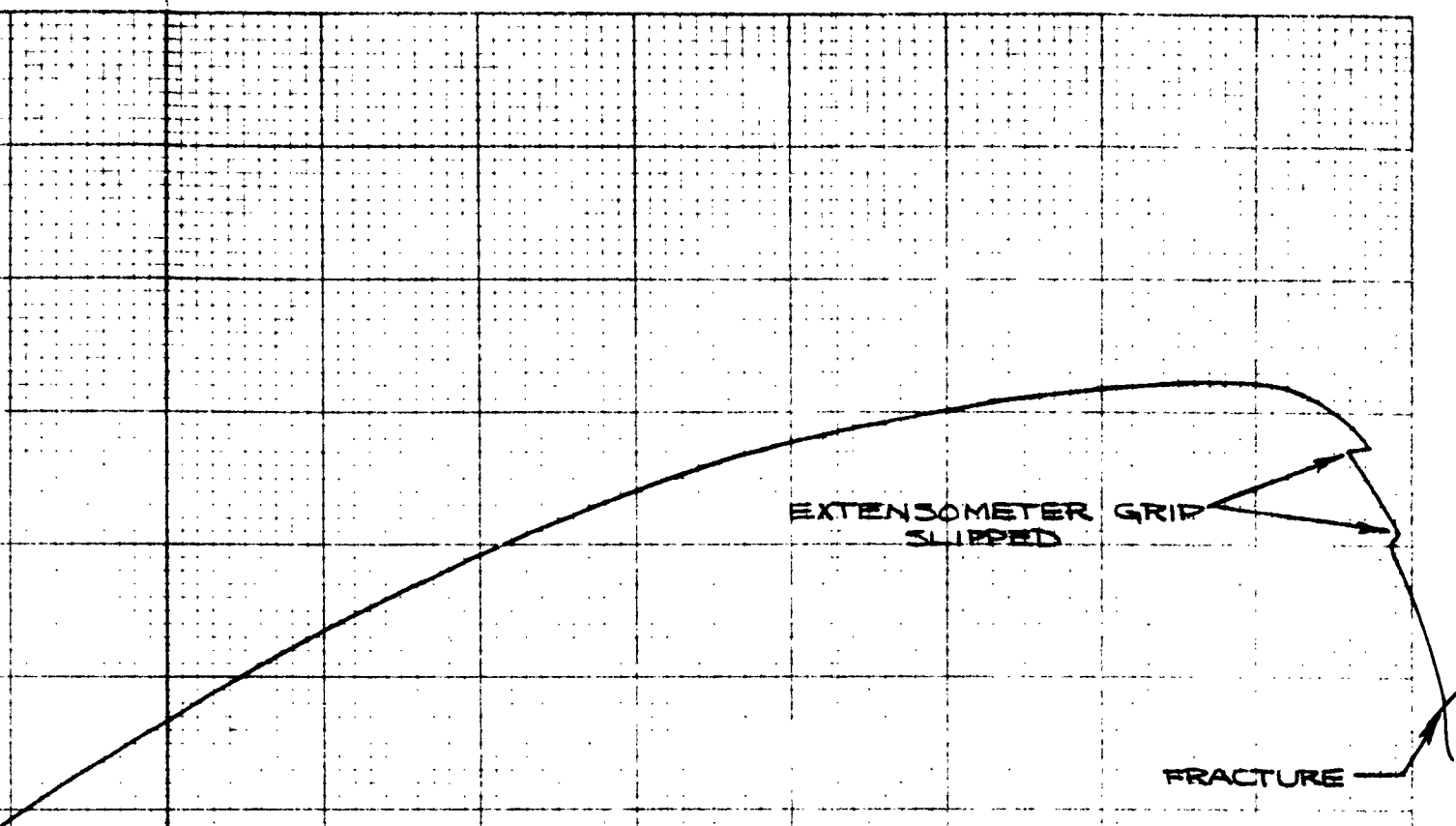
SPECIMEN 29-80001-3
 TEMPERATURE = 600°F
 ENERGY = 70,252 INCH-LBS
 = 5.85 KIPS-FT.



CALC	J. Lebo	3-2-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 22	X-20
CHECK	Jorgensen	3-7-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						2-42



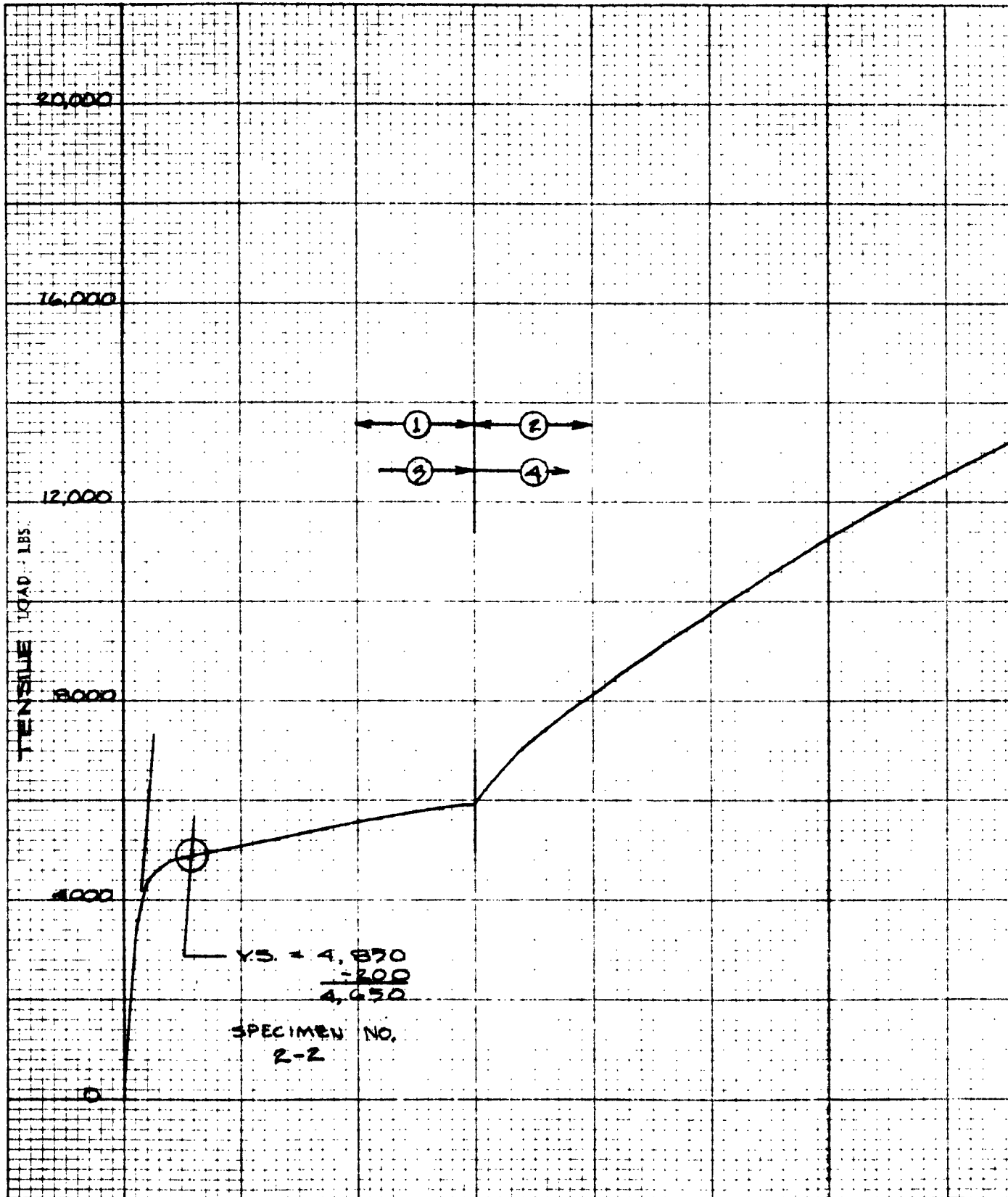


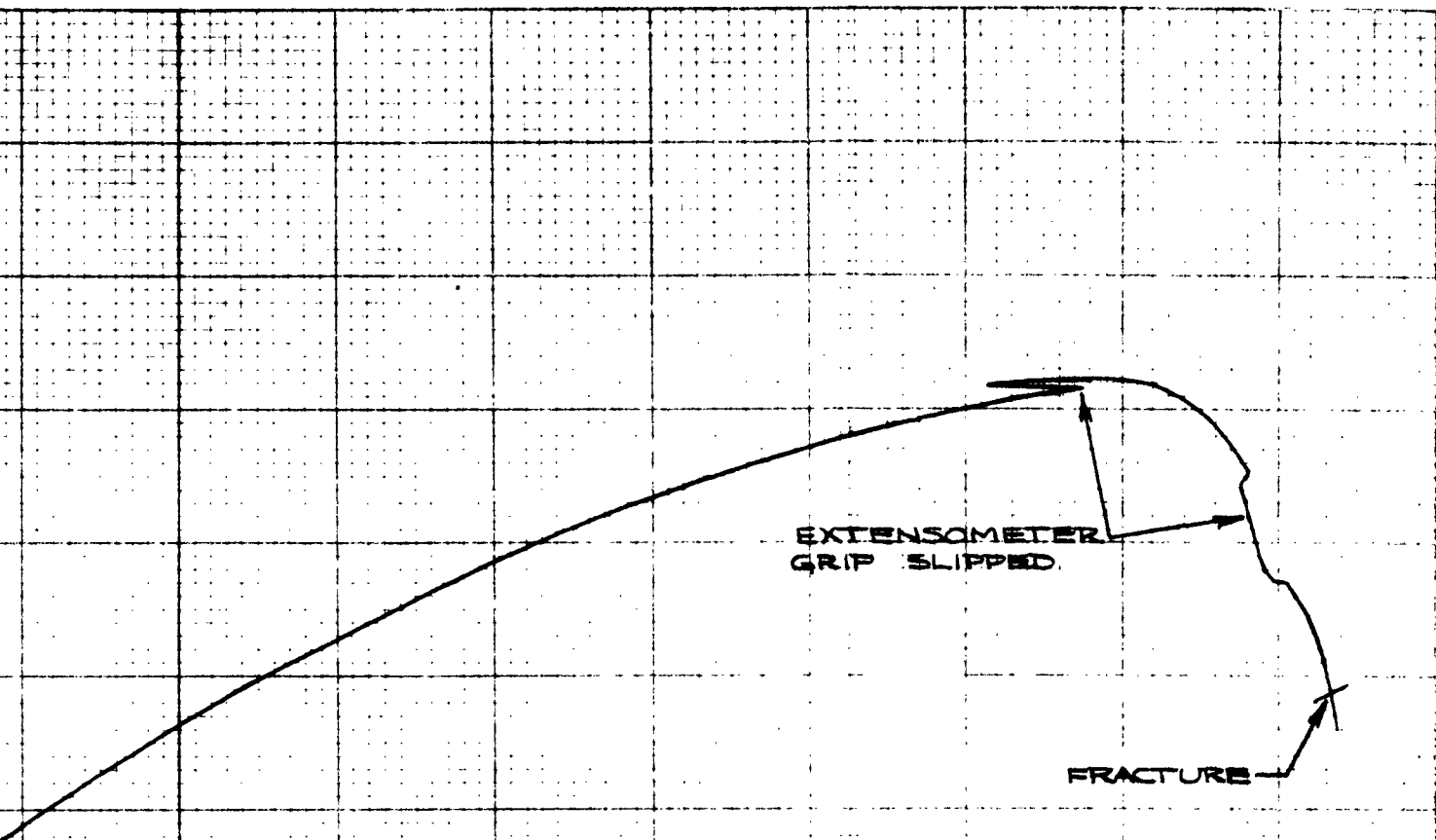


2

STRAIN IN/IN	STRAIN RATE IN/IN-MIN	LOAD RATE MIN	DEFLECTION IN
① .005	③ .005		
② .050	④ 0.10		

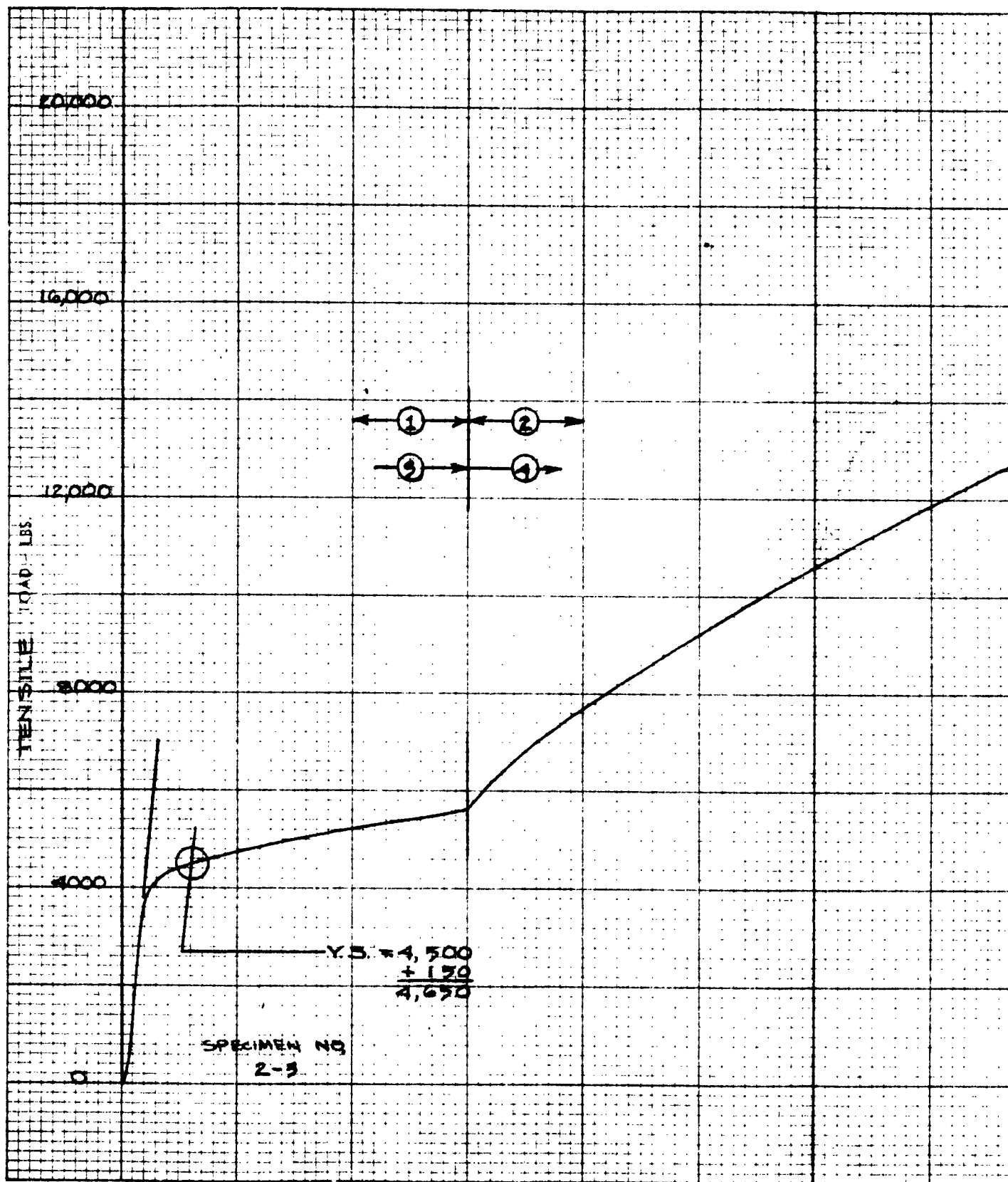
ELS 1003

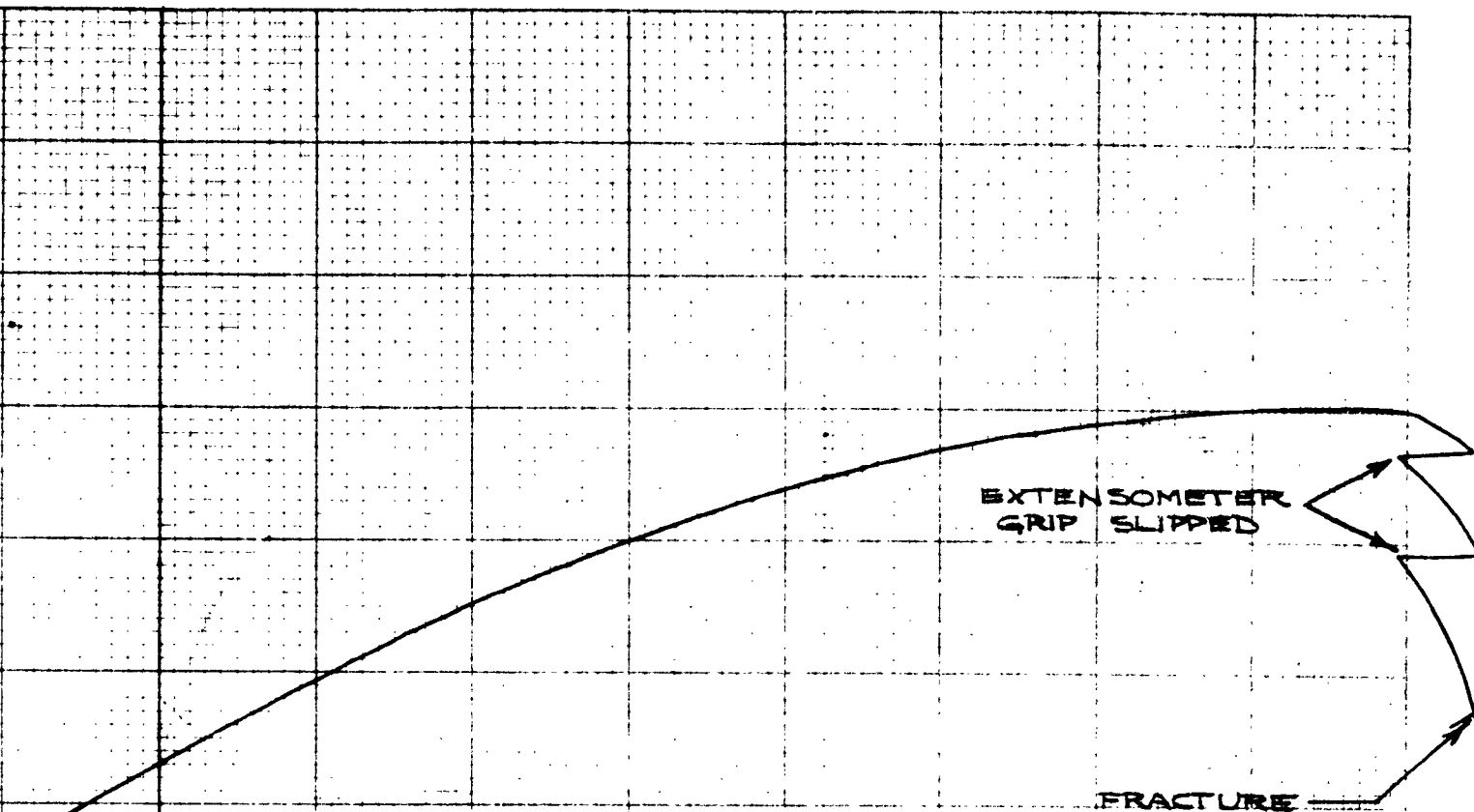




2

STRAIN IN, IN	STRAIN RATE IN/IN MIN	LOAD RATE LBS/IN	DEFLECTION IN
① .005	③ .005		
② .070	④ 0.10		
ELS 14303 CTR			
CHECKED BY: _____ APPR: _____			





2

STRAIN PERCENT	STRAIN RATE IN./IN. MIN.	LOAD RATE MIN.	DISPLACEMENT
① .005	③ .005		
② .050	④ .010		

PLS 140/5

BOEING

TPP

MS D2-80086

SEC 2

PAGE 2-46

THE BOEING COMPANY

NUMBER D2-80086 MODEL NO. X-20

TITLE NOSE LANDING GEAR ENERGY SYSTEM DEVELOPMENT

2-5142

PREPARED BY J. Grant 5/27/63

SUPERVISED BY R. R. Logan 5/27/63

APPROVED BY W. R. Baber 5-27-63

RELIABILITY APPROVAL W. R. Baber 5-28-63
(DATE)

A.K. Hefley 4/1/63

SECTION TITLE PAGE U3 4288 0000 REV. 1/61

AF33(657)-7132
CONTRACT NO.

5-76200-5590-05639-3-25353
CHARGE NUMBER

VOL. 3 | NO. D2-80086
SEC. 3 | PAGE 1 OF

32 of 56

3.1 SUMMARY

- 3.1.1 This report contains the results of impact, static, and rapid load testing of twelve (12) nose landing gear energy strap test specimens (full scale) and three (3) standard tensile specimens, all fabricated from the same heat of Inconel material.
- 3.1.2 The impact tests were conducted at specimen temperatures and impact velocities simulating three landing sink rates. Twelve (12) full-scale specimens were impact tested.
- 3.1.3 The static tests were conducted on three (3) full-scale strap specimens which had previously been impact tested at elevated temperatures and three (3) standard tensile specimens to determine maximum energy-absorbing capacities and Inconel basic tensile properties, respectively. The full-scale energy strap specimens were tested at elevated temperatures and the standard specimens were tested at room temperature and at .005 in/in/min strain rate.
- 3.1.4 The rapid load test was conducted on one (1) previously impact tested specimen at elevated temperature to determine total elongation and total energy to failure.
- 3.1.5 Impact tests results obtained included specimen load and deflection versus time curves, permanent angular displacement of the specimen pivot end (due to strap terminal-pin friction), and specimen elongation and section change over the specimen length.
- 3.1.6 Static test results obtained included load versus deflection curves for the three (3) energy strap specimens and load versus strain curves for the three (3) standard tensile specimens.
- 3.1.7 Rapid load test results obtained consisted of load and deflection data at elevated temperature.

3.2

TABLE OF CONTENTS

	PAGE
3.1 Summary	3-2
3.2 Table of Contents	3-3
3.3 References	3-4
3.4 Introduction	3-5
3.5 Test Specimen	3-6
3.6 Test Setup and Instrumentation	3-6
3.7 Test Procedure	3-7
3.8 Test Results	3-8
3.9 Test Observation	3-8
Table 3.1 Impact Test Required Load Parameters	3-9
Table 3.2 Impact Test Results	3-10
Table 3.3 Impact Test Results	3-11
Table 3.4 Impact Test Results	3-12
Table 3.5 Impact Test Pivot End Rotation Results	3-13
Table 3.6 Static and Rapid Rate Test Results	3-14
Table 3.7 Static Test Results	3-15
Figure 3.1 Impact Test Specimen	3-16
Figure 3.2 Static Test Specimen	3-16
Figure 3.3 Energy Strap Section Section Measurement Location - Sketch	3-17
Figure 3.4 Energy Strap Test Specimen	3-18
Figure 3.5 Pivot End - Rene' 41 Pin	3-19
Figure 3.6 Pivot End - Test Fixture	3-20
Figure 3.7 High Temperature Environment	3-21
Figure 3.8 Impact Test Setup - Schematic	3-22
Figure 3.9 Impact Test Setup - High Temperature	3-23
Figure 3.10 Impact Test Setup - Low Temperature	3-24
Figure 3.11 Rapid Loading Test Setup	3-25
Impact Test - Load and Deflection Plots	3-26 thru 3-49
Static Test - Load, Deflection, and Strain Plots	3-50 thru 3-55
Rapid Rate Test - Load and Deflection Plots	3-56

3.3 REFERENCES

3.3.1	Nose Landing Gear Energy System Development	EWA 5-639	1
3.3.2	Energy Straps (D/S) Installation (Test Only)	BAC 25-80333	
3.3.3	Tensile Specimen Round	BAC 23-7070	
3.3.4	Strap-Shock Absorber, Nose Landing Gear (Test Only)	BAC 29-80000	
3.3.5	Figure 3.4, Energy Strap Test Specimen	Neg. No. FA-2A95784	
3.3.6	Figure 3.5, Rene' 41 Pivot Pin - Impact Test	Neg. No. FA-2A95782	
3.3.7	Figure 3.6, Pivot End - Impact Test Fixture	Neg. No. FA-2A100537	
3.3.8	Figure 3.7, Impact Test Setup - High Temperature Environment	Neg. No. FA-2A95783	
3.3.9	Figure 3.9, Impact Test Setup - High Temperature Environment	Neg. No. FA-2A95350	
3.3.10	Figure 3.10, Impact Test Setup - Low Temperature Environment	Neg. No. FA-2A101036	
3.3.11	Figure 3.11, Rapid Loading Test Setup	Neg. No. FA-2A104409	

1 Refer to D2-6783-1 Structural Integrity Development and Test Program -
Detail Plan - Structures Technology

3.4 INTRODUCTION

3.4.1 This report is the result of work accomplished on EWA 5-639,* Reference 3.3.1. The work was required to obtain energy-absorbing characteristics of a proposed nose landing gear energy strap configuration, fabricated from Inconel material, over the applicable range of landing temperatures and dynamic loading rates.

Refer to D2-6783-1 Structural Integrity Development and Test Program -
Detail Plan - Structures Technology

3.5 TEST SPECIMEN

- 3.5.1 The twelve (12) main gear energy strap impact load test specimens were fabricated per Reference 3.3.4. A sketch of the test specimens is shown in Figure 3.1, 3.3, and 3.4.
- 3.5.2 The six (6) static load test specimens consisted of three (3) of the previously impact tested specimens and three (3) standard tensile specimens fabricated per Reference 3.3.3. A sketch of the test specimens is shown in Figure 3.2.
- 3.5.3 The rapid load test specimen consisted of one (1) of the previously impact tested specimens.
- 3.5.4 All test specimens were fabricated from the same heat of 4" diameter Inconel bar, annealed at 1875 $\pm$ 25°F for 30 minutes after machining and then air cooled.

3.6 TEST SETUP AND INSTRUMENTATION

- 3.6.1 The impact load test setup utilized a falling weight dropped from a predetermined height (based on initial strap impact velocity requirement) onto the lower part of the test fixture, which was covered with a one inch layer of high density styrofoam. The styrofoam layer had a compressive yield strength of 120 to 140 PSI and acted as a shock absorber. The induced load was transmitted by the test fixture to the pivot beam. The pivot beam, in turn, transferred the load through a Rene' 41 pivot pin to the terminal of the energy strap specimen. As the energy strap deflected under the impact load application, the pivot beam rotated through an angle of rotation that simulates movement between the energy strap and the landing gear strut during a landing impact condition.
- 3.6.2 The elevated temperature environment was obtained by surrounding the strap specimen with twelve (12) radiant heat lamps. The heat lamps were powered and controlled by an ignitron unit. The low temperature environment was obtained by applying carbon dioxide gas into a plywood box which encased the test specimen.
- 3.6.3 The impact load test instrumentation consisted of an electronic deflection indicator and a load cell to measure deflection and impact load and an oscillograph to record the load and deflection with a common time base. A high speed camera and a Vanguard analyzer were used to calibrate and check the oscillograph recording during the early phase of testing. Eight spot welded chromel-alumel thermocouples, equally spaced along the length of each specimen, were used to measure the temperature of the elevated temperature tested specimens. Three (3) chromel-alumel thermocouples, one (1) placed at the center and one (1) at each end, were used to measure the temperature of the low temperature tested specimens.
- 3.6.4 The three (3) standard tensile specimens tests were conducted in a 120,000 pound capacity Baldwin Universal test machine at room temperature. The machine was equipped with a model MD-2 autographic load-strain recorder. A Baldwin strain pacer was used to insure a proper average strain rate. The strain to failure was measured using a Baldwin TS-MD dual range extensometer.

- 3.6.5 Three (3) of the previously impact tested specimens (numbers 12, 13, and 14) were tested to failure in the one million pound capacity test machine at elevated temperatures. The elevated temperature environment was obtained by surrounding the strap specimen with radiant heat lamps. These heat lamps were powered and controlled by an ignitron unit.
- 3.6.6 The static load test instrumentation consisted of a 70,000 pound capacity load cell to measure load, a reel type deflection transducer to measure the pin-to-pin deflection, and an X-Y plotter and adaptor console to record load versus deflection. Four (4) spot welded chromel-alumel thermocouples equally spaced along the length of each specimen were used to measure specimen temperature.
- 3.6.7 The rapid rate deflection test setup consisted of a hydraulic bench, used in conjunction with accumulators, a servo valve, and needle valves, to actuate a hydraulic cylinder. The hydraulic cylinder ram and fitting was attached to the energy strap through an adaptor. The elevated temperature environment of 800° F. was supplied by radiant heat lamps, powered and controlled by an ignitron unit.
- 3.6.8 Instrumentation consisted of a load cell and crescent deflection indicator to measure load and deflection. A record of load and deflection was provided by a Visicorder high speed strip chart recorder. Specimen temperature was measured by spot welded chromel-alumel thermocouples equally spaced along the length of each specimen.
- 3.7 TEST PROCEDURE
- 3.7.1 In order to meet the required impact test load parameters as tabulated in Table 3.1, several trial runs were conducted with simulated test specimens installed in the test system. The strap load-deflection data obtained from these runs were used to determine the energy output characteristics of the test system.
- 3.7.2 The actual specimen being impact tested was then placed in the test setup with a new oxidized Rene' 41 pin installed for each test to simulate actual operating condition. The specimen was brought to the required stabilized temperature over the specimen length, the weight was dropped, and the following data obtained:
1. Strap load versus time.
 2. Strap deflection versus time.
 3. Angular displacement of the strap pivot end.
 4. Elongation of measured sections of the strap.
 5. Change of diameter at various sections along the strap length.
- 3.7.3 The static test specimens were placed in a universal test machine and tested to failure. Strain versus load was recorded for the standard tensile specimens and load versus deflection was recorded for the three (3) previously impact tested specimens.

3.7.4 The rapid rate deflection test specimen was placed in the test setup, heated until a stabilized temperature of 800° F. was obtained over the full length, and loaded by a quick acting hydraulic actuator. Load and deflection data was recorded.

3.8 TEST RESULTS

3.8.1 Maximum impact strap load, impact strap energy, and strap per cent elongation are tabulated on pages 3-10 thru 3-12. Angular displacement of the pivot end is shown on page 3-13. Load versus time, deflection versus time, and load versus deflection curves are shown on pages 3-26 through 3-49.

3.8.2 Static test results showing ultimate and yield strength are tabulated on pages 3-14 and 3-15. Static load versus deflection curves, for the previously impact tested specimens, are shown on pages 3-50 through 3-52. Static load versus strain curves for the standard tensile specimens are shown on pages 3-53 through 3-55.

3.8.3 Rapid rate deflection test results are shown on page 3-14. Load versus deflection curve is shown on page 3-56.

3.9 TEST OBSERVATIONS

3.9.1 Impact tests were satisfactorily completed on the nose gear energy straps. Equipment functioned properly and data was recorded for each test.

3.9.2 All specimens tested to failure in the Universal Test Machine produced satisfactory data.

3.9.3 One specimen was tested in the rapid-rate load setup. Equipment functioned properly and satisfactory data was obtained.

TABLE 3.1
REQUIRED IMPACT TEST PARAMETERS
(REFERENCE 3.3.1)

Temperature °F	-65	72	600	600	600
Gear Impact Velocity (FT/SEC)	17	17	12	17	17
Strap Impact Velocity (FT/SEC)	20.3	20.3	14.3	20.3	20.3
Strap Energy Input (FT-LB)	32,600	32,600	16,200	32,600	32,600

TABLE 3.1
REQUIRED IMPACT
TEST PARAMETERS

152

US-207-1-000



PART NO.	29-80000-2			
SPECIMEN NO.	7	8	9	10
TEST RESULTS				
TEMP. ~°F	2 600	600	72	72
WEIGHT DROP ~ LBS.	2 4860	4860	4860	4860
DISTANCE OF DROP ~ INCH	2 44	41.3	76	76
STRAP IMPACT VEL ~ FT/SEC.	3 14.3	14.3	20.3	20.3
STRAP IMPACT VEL FT/SEC.	4 15.4	14.9	20.2	20.2
STRAP DEFLECTION (MAX.) ~ INCH	2 6.31	5.56	6.70	6.72
ANGULAR ROTATION OF PIVOT BEAM (°) ~ DEG.	5 2 30.7	27.0	31.6	31.7
TOTAL INPUT ENERGY OF THE SYSTEM FT-LB	6 4 20,752	19,310	33,893	33,902
STRAP ENERGY INPUT (RECORD) ~ FT-LBS.	6 1 2 18,200	16,609	26,914	27,236
STRAP MAX. IMPACT LOAD KIPS	2 45.4	47.2	63.5	62.8

1 STRAP ENERGY INPUT WAS OBTAINED FROM THE AREA UNDER THE LOAD-DEFL

2 MEASURED DATA

3 REQUIRED DATA (SEE TABLE 2.1)

4 CALCULATED DATA AS FOLLOWS:

$$V = \sqrt{gh/6}$$

$$E_{CAL} = \frac{W_1 H + (W_1 + W_2) \Delta}{12}$$

WHERE V - IS THE VELOCITY OF THE FALLING BODY AT IMPACT.

H - IS THE DISTANCE THE FALLING BODY WILL DROP BEFORE IMPACT.

E_{CAL} - IS THE TOTAL INPUT ENERGY OF THE SYSTEM.

W₁ - IS THE WEIGHT OF THE FALLING BODY.

W₂ - IS THE WEIGHT OF THE TEST FIXTURE.

Δ - IS THE DEFLECTION OF THE TEST SPECIMEN

5 SEE PAGE 3-23 FOR LOCATION OF ANGLE (°)

6 THE ENERGY LOSS IN THE SYSTEM WAS DUE TO THE FOLLOWING:

- 1) FRICTION BETWEEN THE FALLING WEIGHT AND THE TEST FIXTURE. (AND)
- 2) CRUSHING OF THE STYROFOAM LAYER ON THE TEST FIXTURE BASE PLATE AT IMPACT.

1

CALC
CHECK
APR
APR

NOSE GEAR ENERGY STRAPS

29-80000-2				29-80000-3	29-80000-2				29-80000-3		
7	8	9	10	11	12	13	14	15	16	17	18
600	600	72	72	72	600	600	800	800	72	-65	-65
4860	4860	4860	4860	4860	5275	5275	5275	5275	5275	5275	5275
44	41.3	76	76	76	79	79	79	79	79	79	79
14.3	14.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
15.4	14.9	20.2	20.2	20.2	20.6	20.6	20.6	20.6	20.6	20.6	20.6
6.31	5.56	6.70	6.72	8.10	9.43	9.06	9.78	9.06	9.80	8.96	8.60
30.7	27.0	31.6	31.7	38.4	45.1	43.2	46.8	43.2	47.0	42.8	41.0
20,752	19,310	33,893	33,902	34,543	39,434	39,230	39,609	39,250	39,619	39,200	39,020
18,200	16,609	26,914	27,236	28,496	33,029	32,983	33,323	32,877	33,459	33,263	32,561
45.4	47.2	63.5	62.8	54.4	55.5	58.0	54.8	57.8	53.0	57.3	58.0

FROM THE AREA UNDER THE LOAD-DEFLECTION CURVE ON PAGE 3-26 THRU 3-49

BODY AT IMPACT.
 WILL DROP BEFORE IMPACT.
 SYSTEM.
 DY.
 RE.
 SPECIMEN

NOLE (~)

AS DUE

ING WEIGHT
 ID)

LAYER
 PLATE



CALC	J. Jabo	REVISED	DATE	TABLE 3.2 IMPACT TEST RESULTS X-20 NOSE LANDING GEAR	X-20
CHECK	Grant				D2-80086
APR					
APR					PAGE 2-10
				THE BOEING COMPANY	



FOR MEASUREMENT LOCATION SEE FIGURE 3.3

$$\% \text{ DIFF} = \frac{\text{CHANGE OF SECTION LENGTH}}{\text{ORIGINAL LENGTH OF SECTION}}$$

SPECI- MEN NO.		'A'	'B'	'C'	'D'	'E'	'F'	'G'
7	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 7.6	* 19.0	* 17.0	* 16.6	* 17.0	* 19.6	* 19.6
8	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 6.2	* 14.6	* 15.0	* 15.4	* 15.6	* 15.4	* 13.6
9	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 11.2	* 18.8	* 18.8	* 20.0	* 20.0	* 20.0	* 20.0
10	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 8.6	* 18.8	* 18.8	* 19.2	* 19.2	* 19.2	* 20.0
11	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 10.6	* 22.4	* 23.6	* 21.2	* 23.6	* 23.6	* 25.0
12	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.0	* 27.6	* 27.6	* 27.6	* 27.6	* 27.6	* 27.6
13	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.0	* 25.0	* 27.6	* 30.0	* 25.0	* 25.0	* 20.0
14	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.0	* 30.0	* 30.0	* 30.0	* 30.0	* 30.0	* 30.0
15	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.0	* 25.0	* 25.0	* 25.0	* 25.0	* 25.0	* 25.0
16	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.0	* 27.6	* 27.6	* 27.6	* 27.6	* 27.6	* 27.6
17	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 10.0	* 24.0	* 24.0	* 24.0	* 24.0	* 24.0	* 24.0
18	DISTANCE	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	% DIFF	* 15.6	* 25.0	* 25.0	* 25.0	* 25.0	* 25.0	* 25.0

CALC	<i>Shunt</i>	5/1/2	REVISED	DATE	TABLE 3.3		X-20
CHECK	<i>Shunt</i>				MAIN GEAR ENERGY STRAP SECTION LENGTHS		D2-80086
APR					AND PERCENT ELONGATION AFTER IMPACT TEST		
APR					THE BOEING COMPANY		PAGE 3-11

153

				 FOR MEASUREMENT LOCATION SEE FIGURE 3.3.									
				$\% \text{ DIFF} = \frac{\text{CHANGE OF SECTION DIAMETER}}{\text{ORIGINAL DIAMETER OF SECTION}}$									
SPECI- MEN NO.		'A1'	'B1'	'C1'	'D1'	'E1'	'F1'	'G1'					
7	DIA.	.990	.990	.988	.989	.989	.989	.991					
	% DIFF	-7.78	-7.47	-7.69	-7.79	-7.79	-7.79	-5.85					
8	DIA.	.9903	.9905	.9890	.9882	.9890	.9887	.9910					
	% DIFF	-6.80	-6.61	-7.18	-6.70	-7.18	-7.15	-5.55					
9	DIA.	.987	.987	.986	.987	.987	.988	.989					
	% DIFF	-8.31	-8.21	-8.42	-8.51	-8.31	-8.40	-8.80					
10	DIA.	.986	.985	.986	.985	.983	.985	.988					
	% DIFF	-8.42	-8.53	-8.52	-8.63	-8.75	-8.63	-9.21					
11	DIA.	.883	.883	.883	.881	.880	.880	.879					
	% DIFF	-9.74	-9.74	-10.08	-10.22	-10.34	-10.45	-10.35					
12	DIA.	.986	.987	.988	.988	.987	.977	.985					
	% DIFF	-11.26	-11.14	-11.23	-10.73	-11.14	-11.16	-9.75					
13	DIA.	.989	.989	.987	.985	.987	.989	.988					
	% DIFF	-11.02	-10.72	-11.55	-10.76	-10.84	-10.41	-10.32					
14	DIA.	.985	.987	.987	.985	.987	.988	.985					
	% DIFF	-12.49	-11.34	-11.85	-11.78	-11.75	-11.23	-8.53					
15	DIA.	.988	.989	.988	.987	.987	.987	.987					
	% DIFF	-11.03	-10.92	-10.83	-10.64	-10.64	-10.64	-8.21					
16	DIA.	.879	.880	.878	.879	.880	.883	.880					
	% DIFF	-10.35	-10.80	-11.39	-11.26	-11.36	-11.78	-10.23					
17	DIA.	.883	.883	.884	.885	.884	.884	.884					
	% DIFF	-11.21	-10.99	-10.86	-10.40	-10.29	-10.29	-10.41					
18	DIA.	.882	.882	.883	.883	.882	.882	.883					
	% DIFF	-10.20	-9.86	-9.85	-9.85	-9.86	-9.98	-10.31					

CALC <i>Grant</i> 5/1/83 CHECK <i>Anderson</i> APR APR	REVISED 	DATE 	TABLE 3.4 MAIN GEAR ENERGY STRAP DIAMETER AND PER-CENT CHANGE AFTER IMPACT TEST.	X-20 D2-80086 PAGE 3-12
THE BOEING COMPANY				

SPECIMEN NO.	ANGLE θ (DEGREES)	DEFLECTION "A" (INCHES)
7	5.5	.30
8	8.9	.47
9	3.5	.17
10	10.25	.56
11	9.25	.44
12	9.8	.45
13	8.25	.39
14	10.0	.48
15	8.8	.44
16	7.5	.30
17	5.0	.24
18	7.5	.35

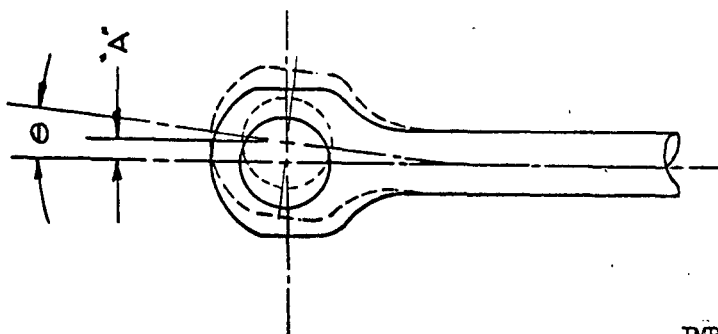


TABLE 3.5
IMPACT TEST RESULTS
PERMANENT ANGULAR DISPLACEMENT
OF STRAP PIVOT END

U3-4871-1000



TABLE 3.5

SPECIMEN NUMBER	SPECIMEN LENGTH BEFORE IMPACT TEST (INCHES)	SPECIMEN LENGTH BEFORE STATIC OR RAPID RATE TEST (INCHES)	FINAL LENGTH AFTER STATIC OR RAPID RATE TEST (INCHES)	TEMP. °F	DEFLECTION RATE (IN/MIN)
12	38.80	47.72	54.61	600	2.5
13	38.80	47.34	54.65	600	2.5
14	38.80	48.28	55.65	800	2.5
15 	38.80	47.44	52.24	800	510.

SPECIMEN NUMBER	ENERGY ABSORBED DURING IMPACT TEST (FT-LBS)	ENERGY ABSORBED DURING STATIC OR RAPID RATE TEST (FT-LBS)	TOTAL ENERGY ABSORBED (FT-LBS)
12	33,030	26,450	59,480
13	32,980	33,670	66,650
14	33,320	32,680	66,000
15 	32,880	15,520	48,400

PREVIOUSLY IMPACT TESTED STRAP SPECIMENS
(REFERENCE PAGES 3-50 THRU 3-52 FOR STATIC TEST DATA)
(REFERENCE PAGE 3-56 FOR RAPID RATE TEST DATA)

 RAPID RATE DEFLECTION TEST

TABLE 3.6

STATIC AND
RAPID RATE
TEST RESULTS

U3-8971-1088

157

BOEING
SECT. 3

NO. D2-80086

PAGE 3-14



SPECIMEN NO.	ATMOSPHERE	GRAIN DIRECTION	TEST TEMP. °F	ULTIMATE STRENGTH (PSI)	YIELD STRENGTH (PSI)	ELONGATION % PER 2 INCHES
4-1 	AIR	LONG-ITUDINAL	74	95,700	36,700	48
4-2 	AIR	LONG-ITUDINAL	74	92,900	34,700	50
4-3 	AIR	LONG-ITUDINAL	74	92,900	34,300	50

 STANDARD TENSILE ROUND TEST SPECIMEN.
(REFERENCE PAGES 3-53 THRU 3-55 FOR STRESS STRAIN CURVES)

TABLE 3.7
STATIC TEST RESULTS
STANDARD TENSILE SPECIMENS

US 4286 2000 REV. 8/62

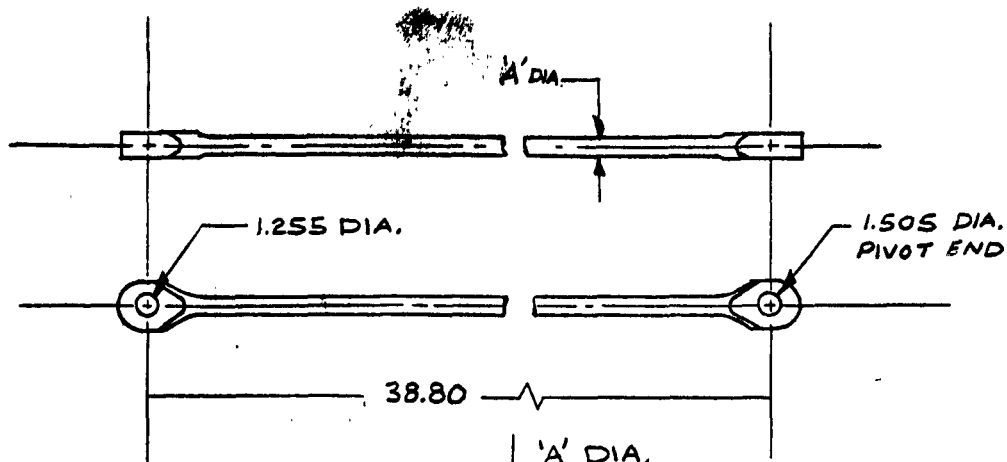
2-5142-2

158

REV SYM _____

BOEING | NO. D2-80086
| SECT. 3 | PAGE 3-15

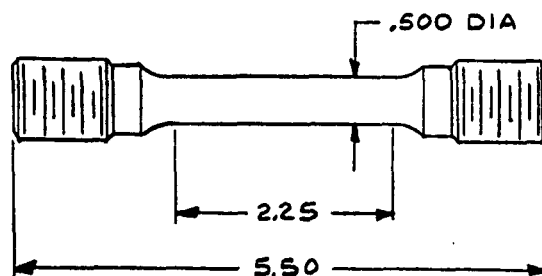
FIGURE 3.1



	'A' DIA.
RE-ENTRY (-2)	.980
AIR DROP (-3)	.875

STRAP SHOCK ABSORBER NOSE LANDING GEAR
SPECIMEN NUMBER 29-80000-2 & 29-80000-3

FIGURE 3.2



TENSILE SPECIMEN ROUND
SPECIMEN NUMBER 23-7070

FIGURE 3.1 & 3.2
TEST SPECIMEN

REFERENCE FIGURE 3.1
FOR RESULTS SEE
TABLE 3.3 & TABLE 3.4

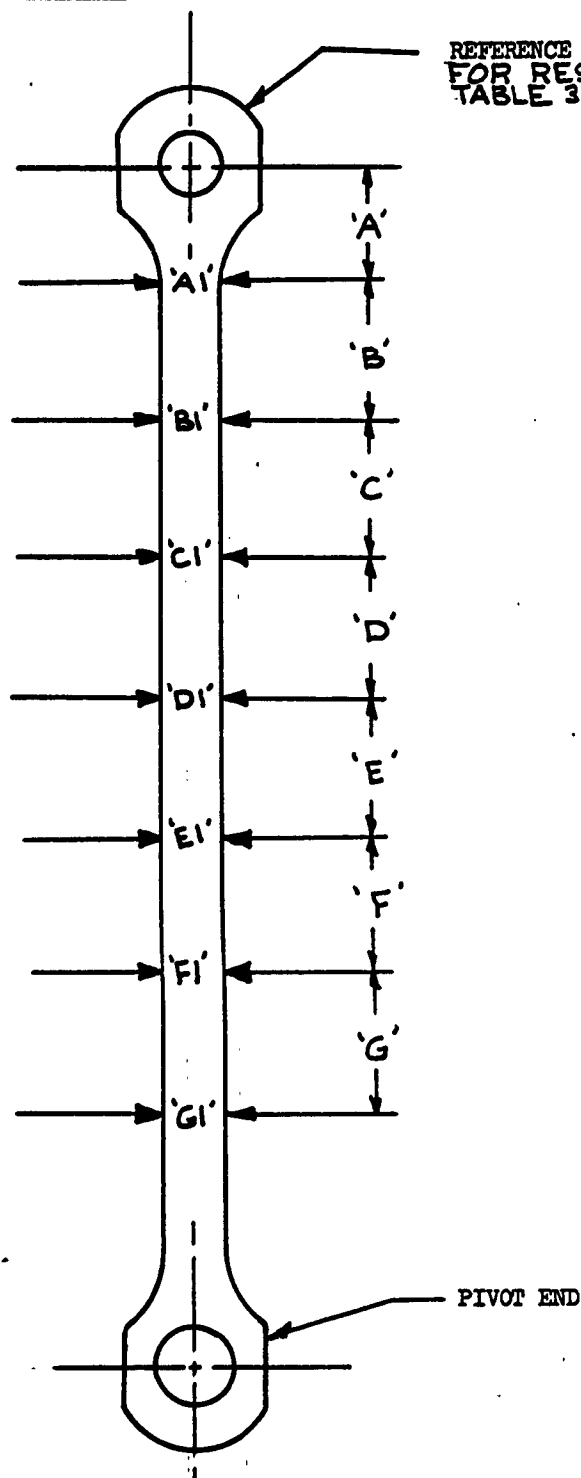


FIGURE 3.3

SECTION ELONGATION AND
DIAMETER MEASUREMENT
LOCATION (SKETCH)

U3 4800 2000 REV. 8/63

2-5142-2

160

REV SYM _____

BOEING

NO. D2-80086

SECT. 3

PAGE 3-17

5-62
2A95784

161

BEFORE IMPACT TEST

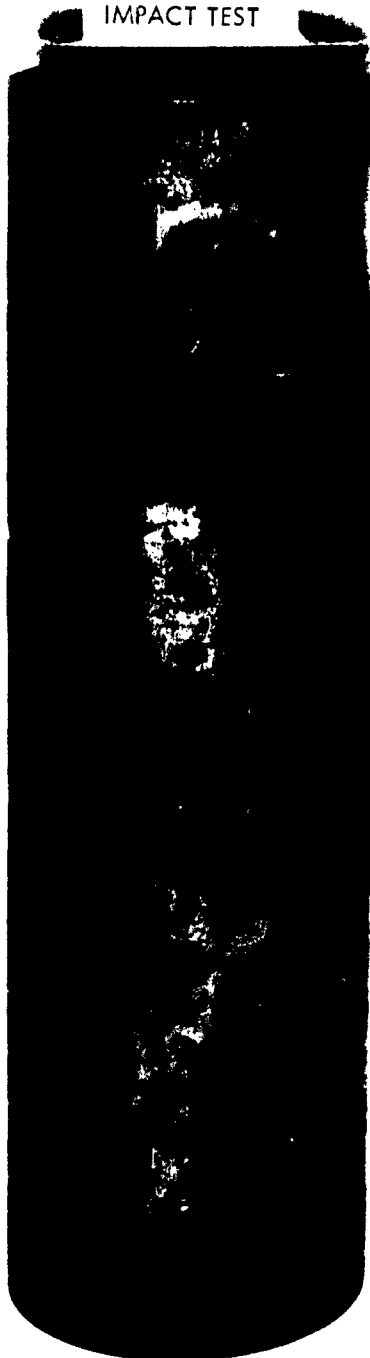
AFTER IMPACT TEST

FIGURE 3.4
ENERGY STRAP
TEST SPECIMEN

SEC 3

NO. D2-80086
PAGE 3-18

BEFORE
IMPACT TEST



AFTER
IMPACT TEST



2495782
-5-62

162

FIGURE 3,5
RENE' 41 PIVOT PIN

SEC 3

NO. D2-80086

PAGE 3-19

27 * THESE LIMITING CASE ENERGY SPARE
 PART FOR STICK SPEED 17.5% S.E.
 1.5% 11.2.2
 1.5% 11.2.2

2A100537

163

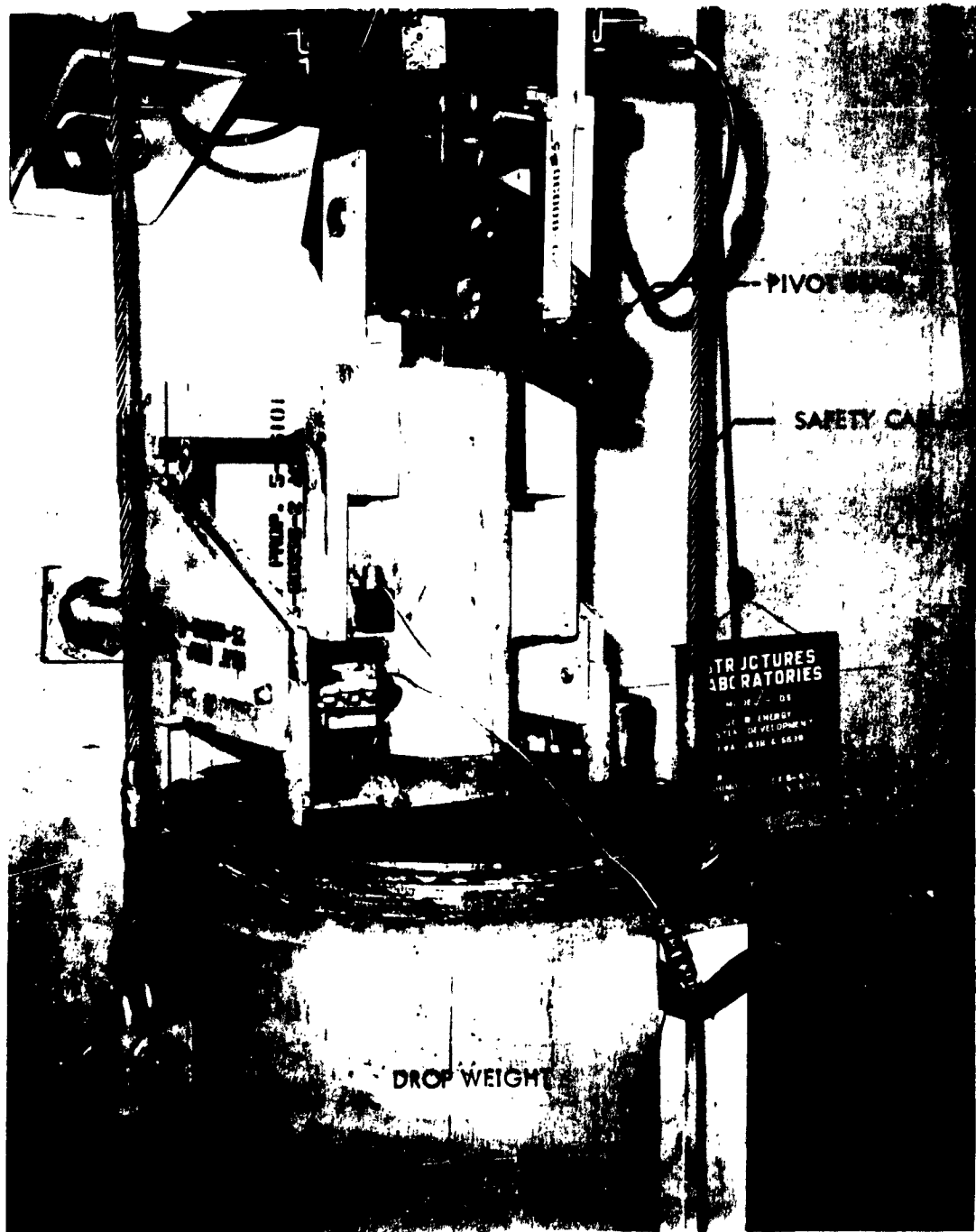


FIGURE 3.6
 PIVOT END TEST FIXTURE

U3-4971-1000 (was BAC 1544-L-83)

LOAD CELL

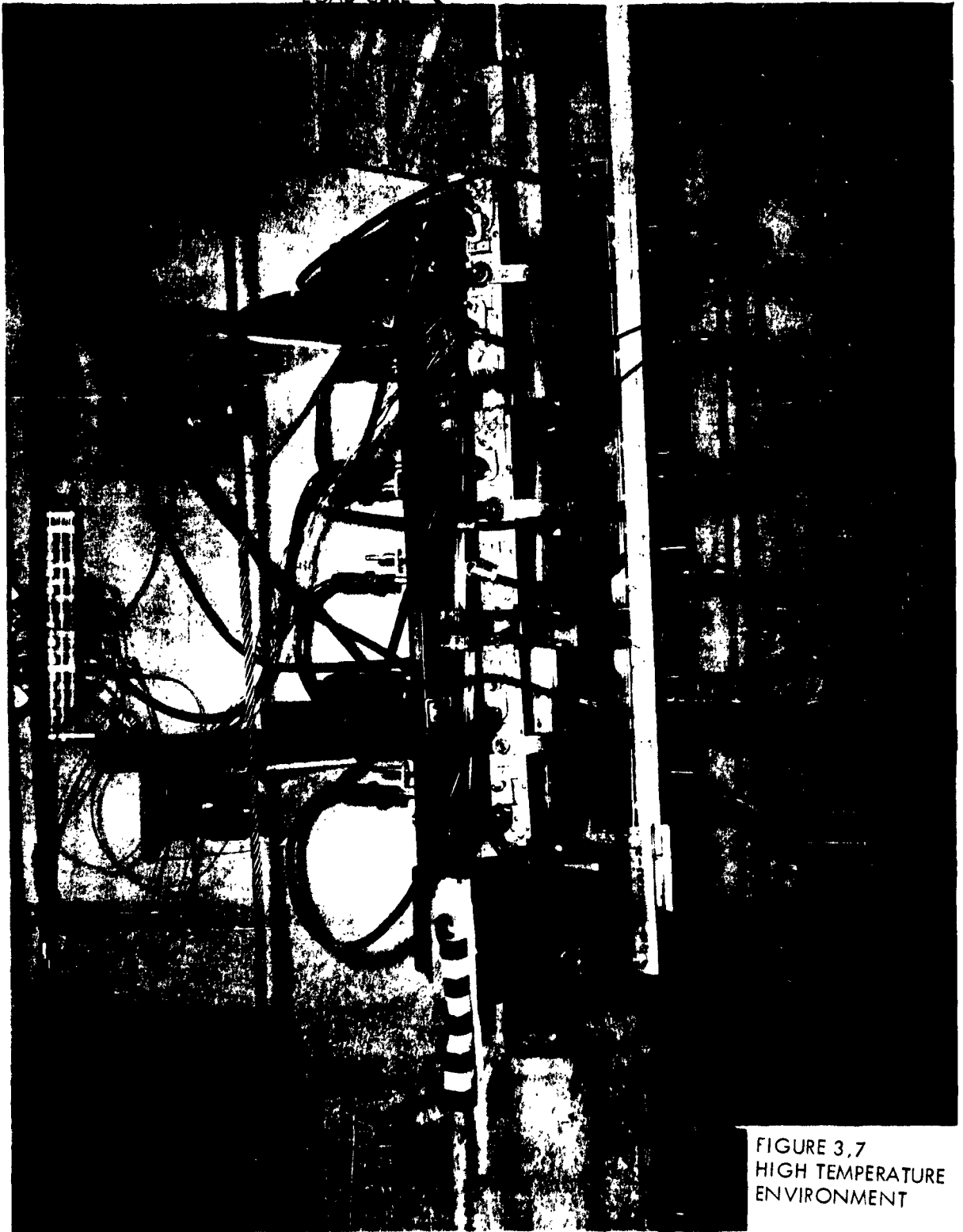


FIGURE 3,7
HIGH TEMPERATURE
ENVIRONMENT

495783
S-62

164

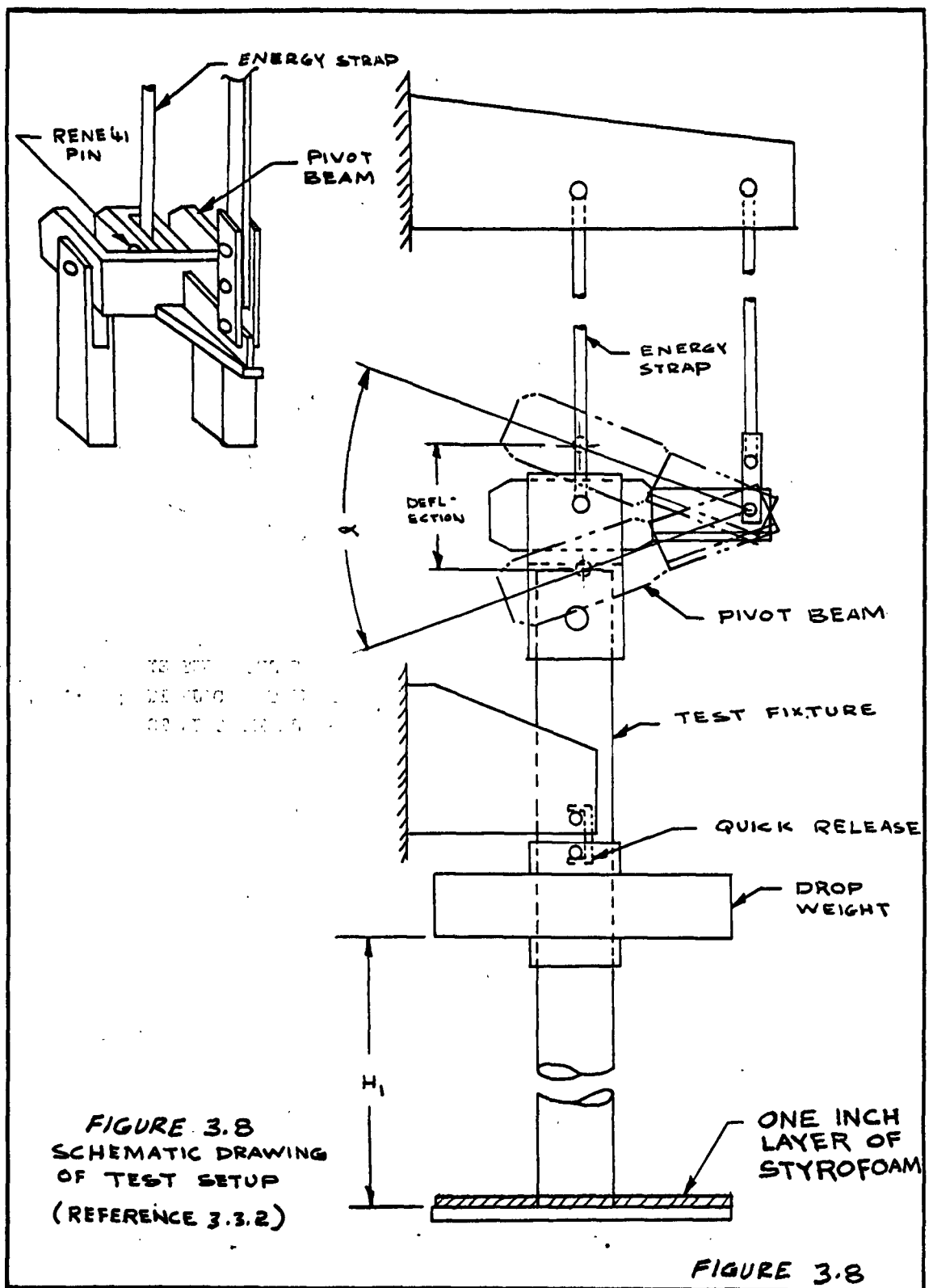


FIGURE 3.8

2495350

SPRINKLER - BRUNNEN SPRAY TEST SETUP
LAWSON GUN (BRUNNEN SYSTEM 100)
1-5-61

SPECIMEN AND HEAT LAMPS

DROP WEIGHT

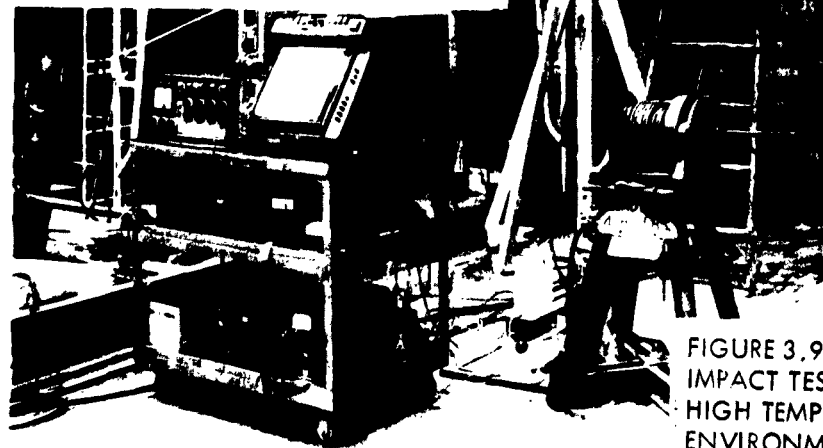
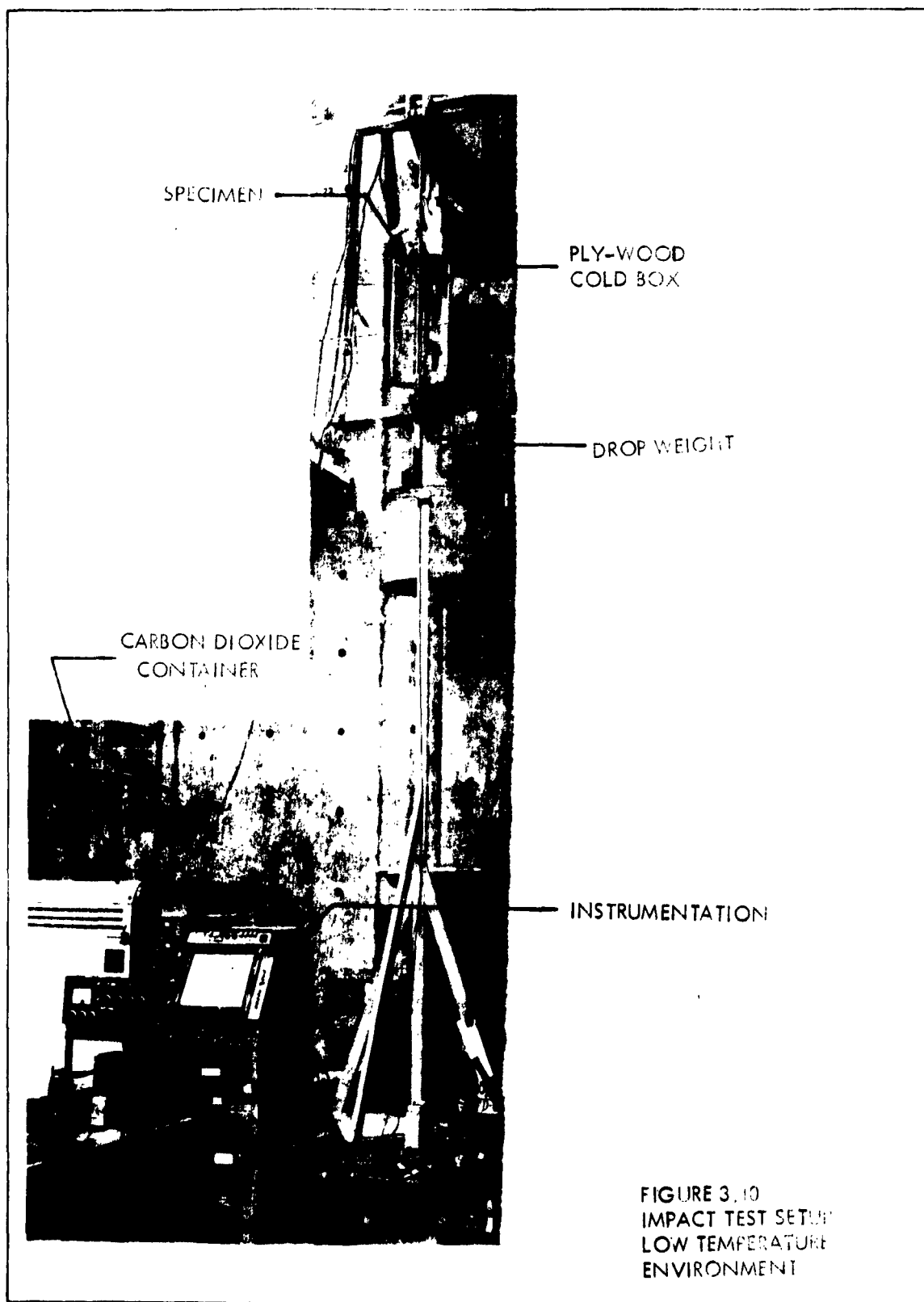


FIGURE 3.9
IMPACT TEST SETUP
HIGH TEMPERATURE
ENVIRONMENT

U3-4971-1000 (was BAC 1046-L-R3)

166



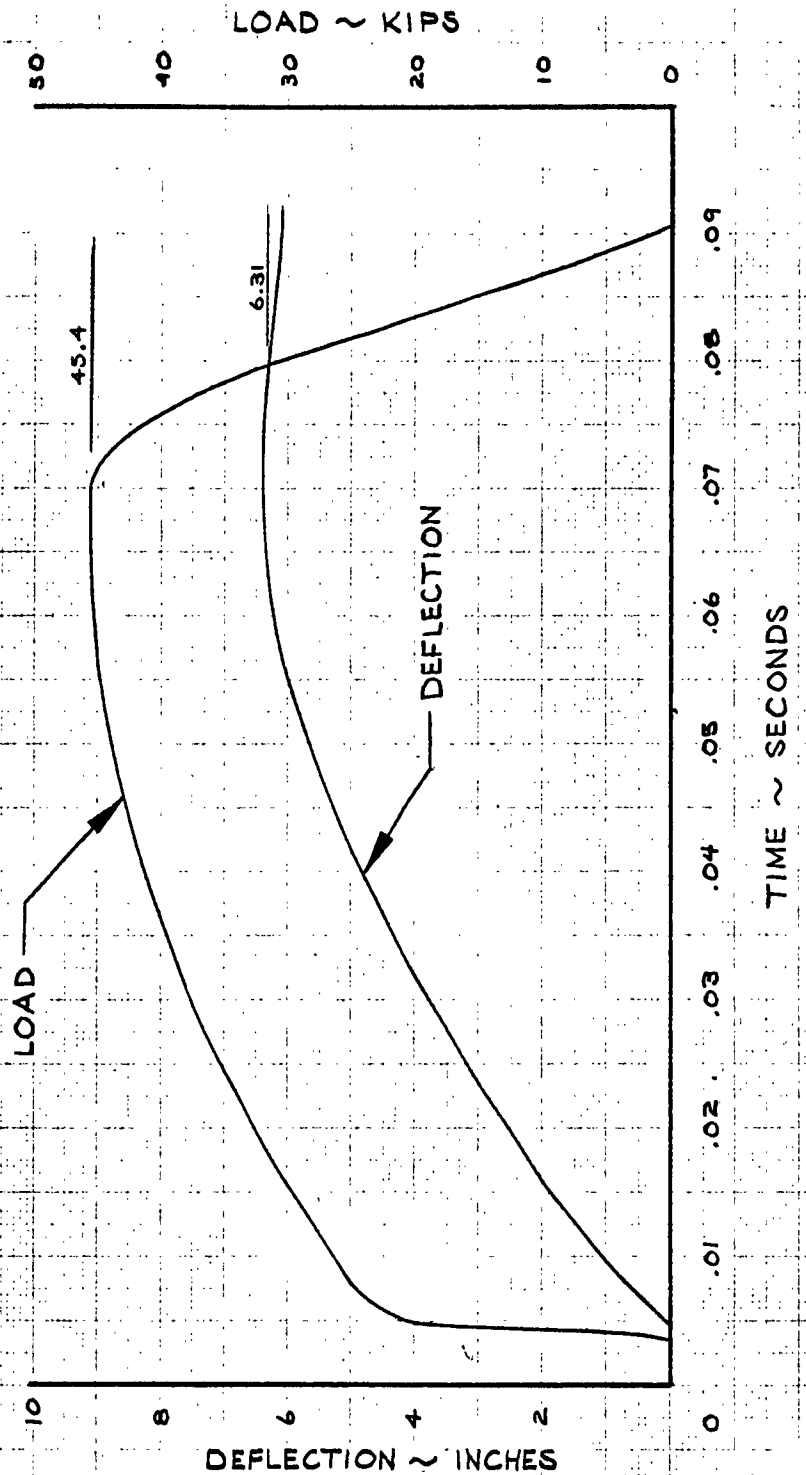
DO-1
CAND
TEST,
INAP TEST SETUP BOX
REENTRY SYSTEM INSTRUMENT
OFFICE NO. 2
2410036
2-13-62

U3-4071-1000 (was SAC 1846-L-82)



FIGURE 3.11
RAPID LOADING
TEST SETUP

SPECIMEN 29-80000-2
TEMPERATURE 600°F



CALC	J. Lebo	1-2-2	REVISED	DATE
CHECK	Jorgensen	1-9-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 7

THE BOEING COMPANY

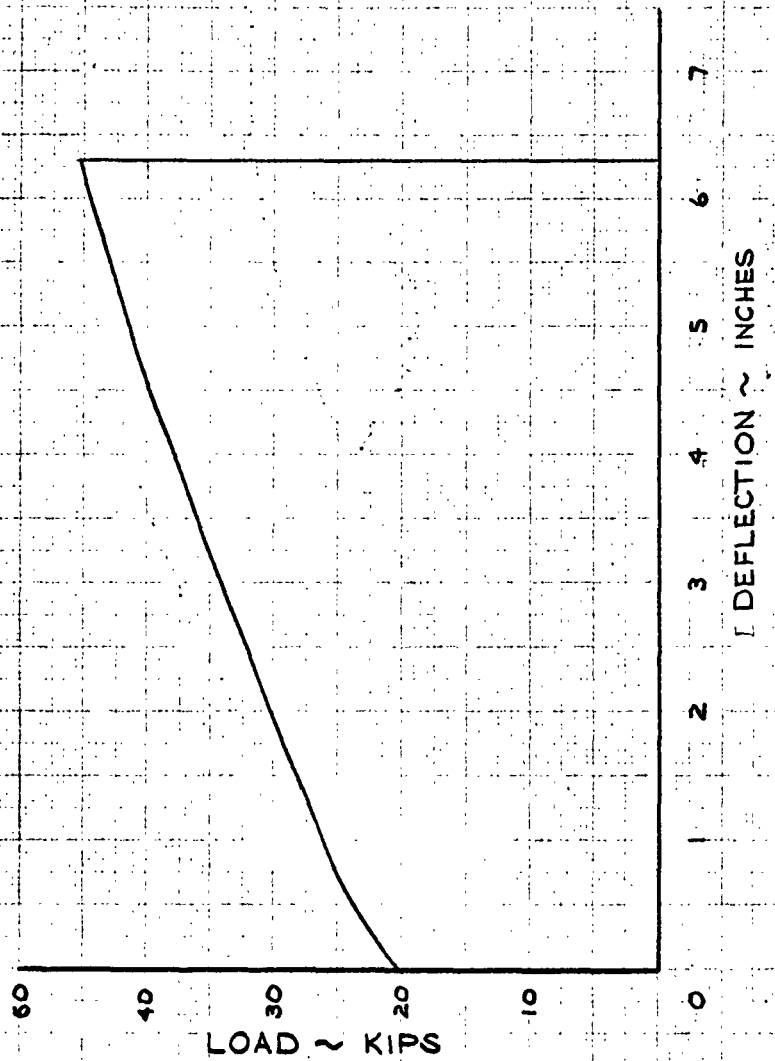
X-20

D2-80086

PAGE
3-26

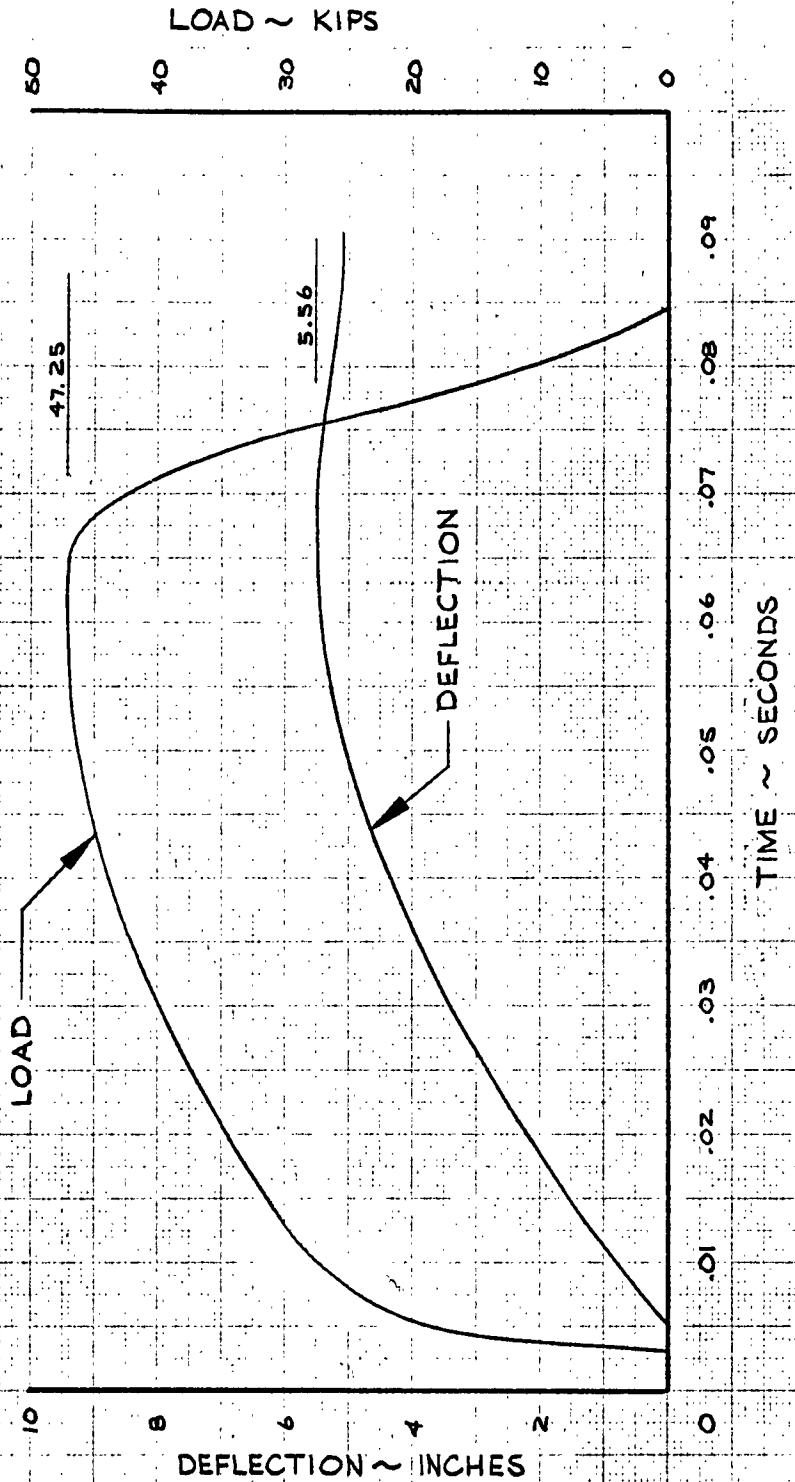
159

SPECIMEN 29-80000-2
 TEMPERATURE = 600°F
 ENERGY = 218,461 INCH-LES
 = 18.20 KIP-FT



CALC	J. Lebo	1-2-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 7	X-20
CHECK	Jorgensen	1-9-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-27

SPECIMEN 29-80000-2
TEMPERATURE 600°F



CALC	J. Lebo	1-8-2	REVISED	DATE
CHECK	Jorgensen	1-11-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 8

THE BOEING COMPANY

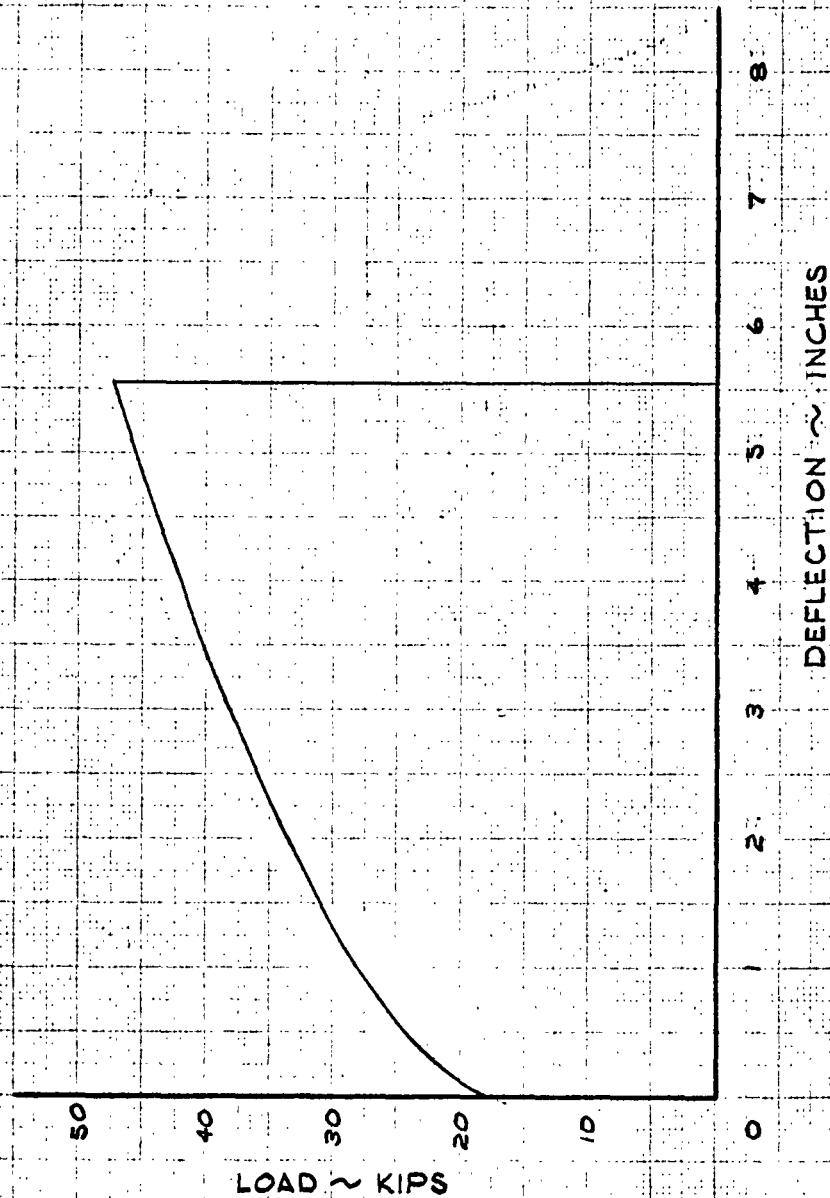
X-20

D2-80086

PAGE

3-28

SPECIMEN 29-80000-2
 TEMPERATURE = 600°F
 ENERGY = 199,314 INCH-LBS
 = 16.61 KIPS-FT



CALC	J. Lebo	1-8-2	REVISED	DATE
CHECK	H. Jorgensen	1-11-2		
APR				
APR				

LOAD VS DEFLECTION
 SPECIMEN NO. 8

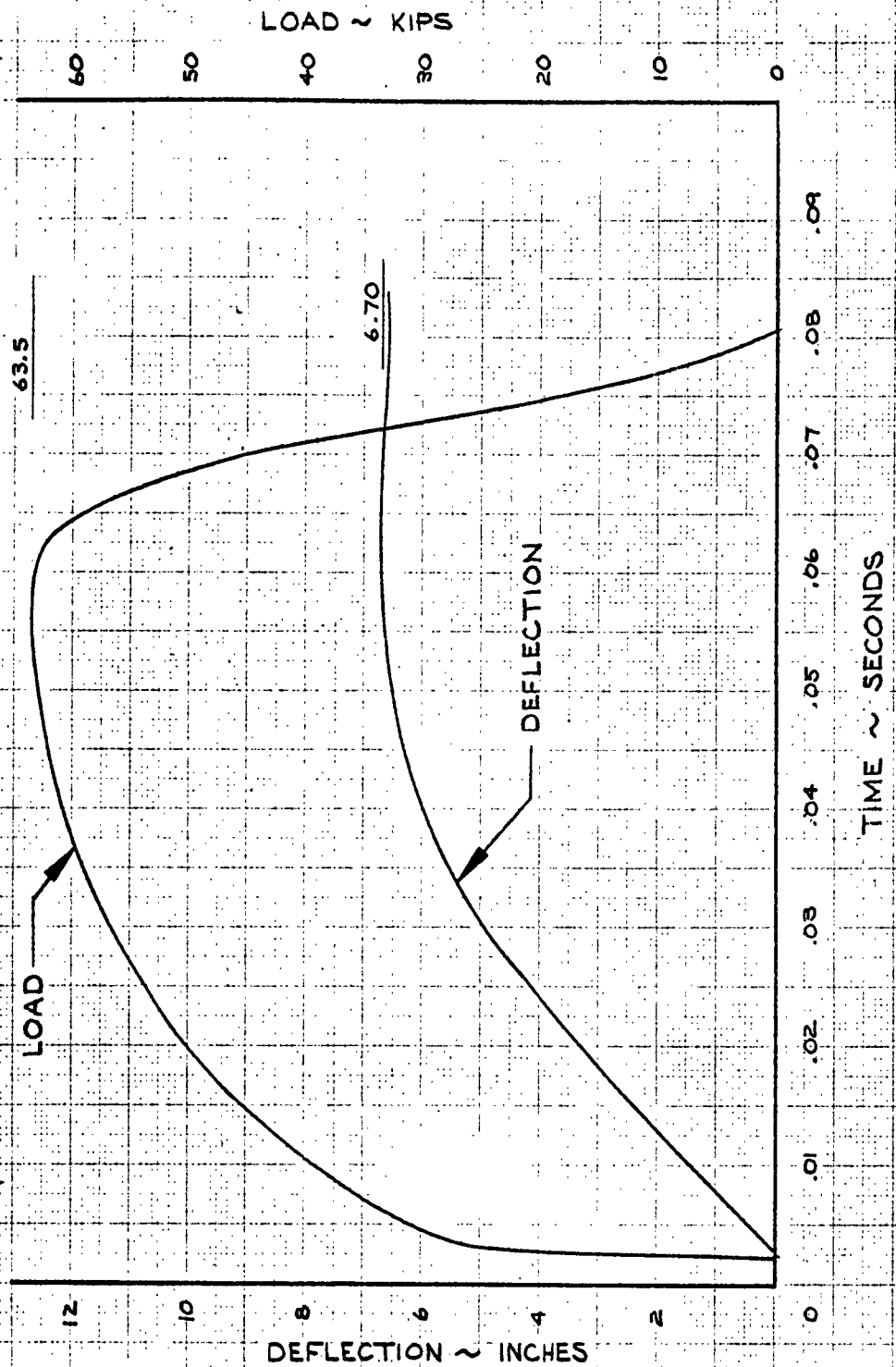
THE BOEING COMPANY

X-20

D2-80086

PAGE
 3-29

SPECIMEN 29-80000-2
TEMPERATURE 600°F



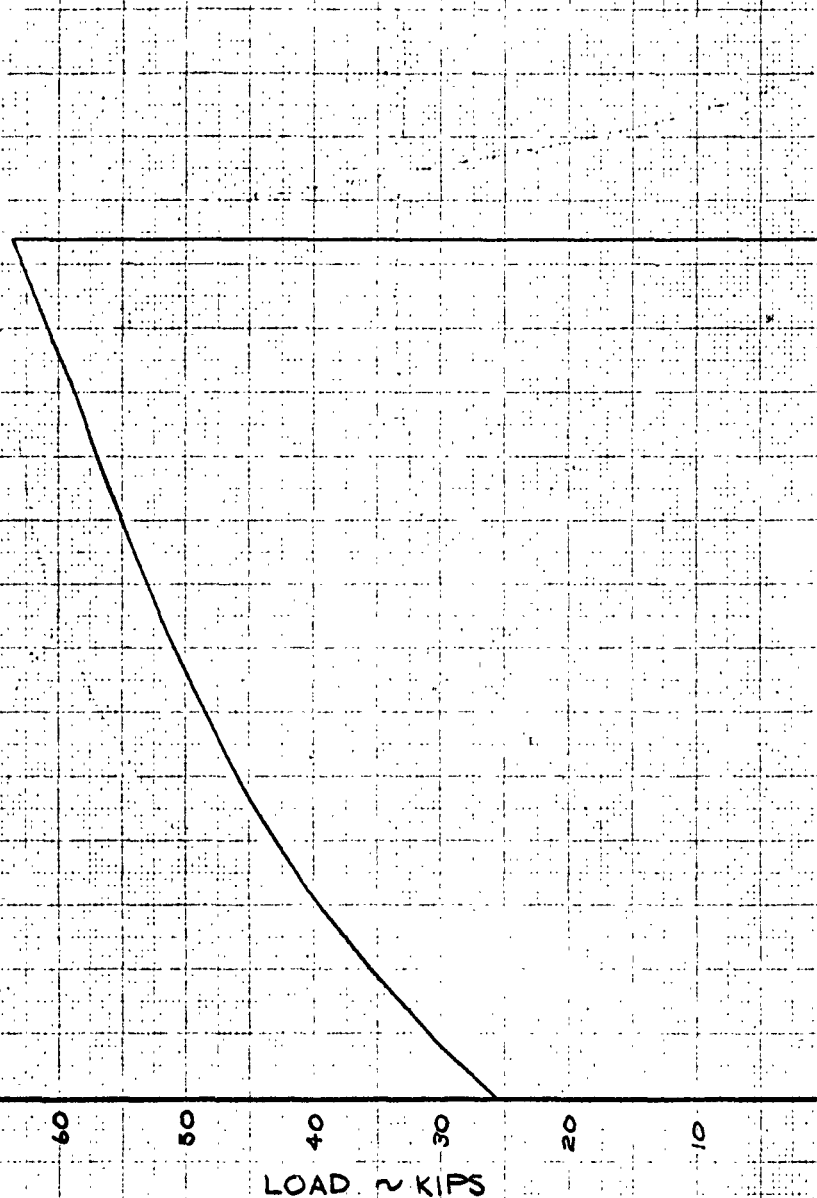
CALC	J. Lebo	1-15-2	REVISED	DATE
CHECK	HKT	1-18-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 9

THE BOEING COMPANY

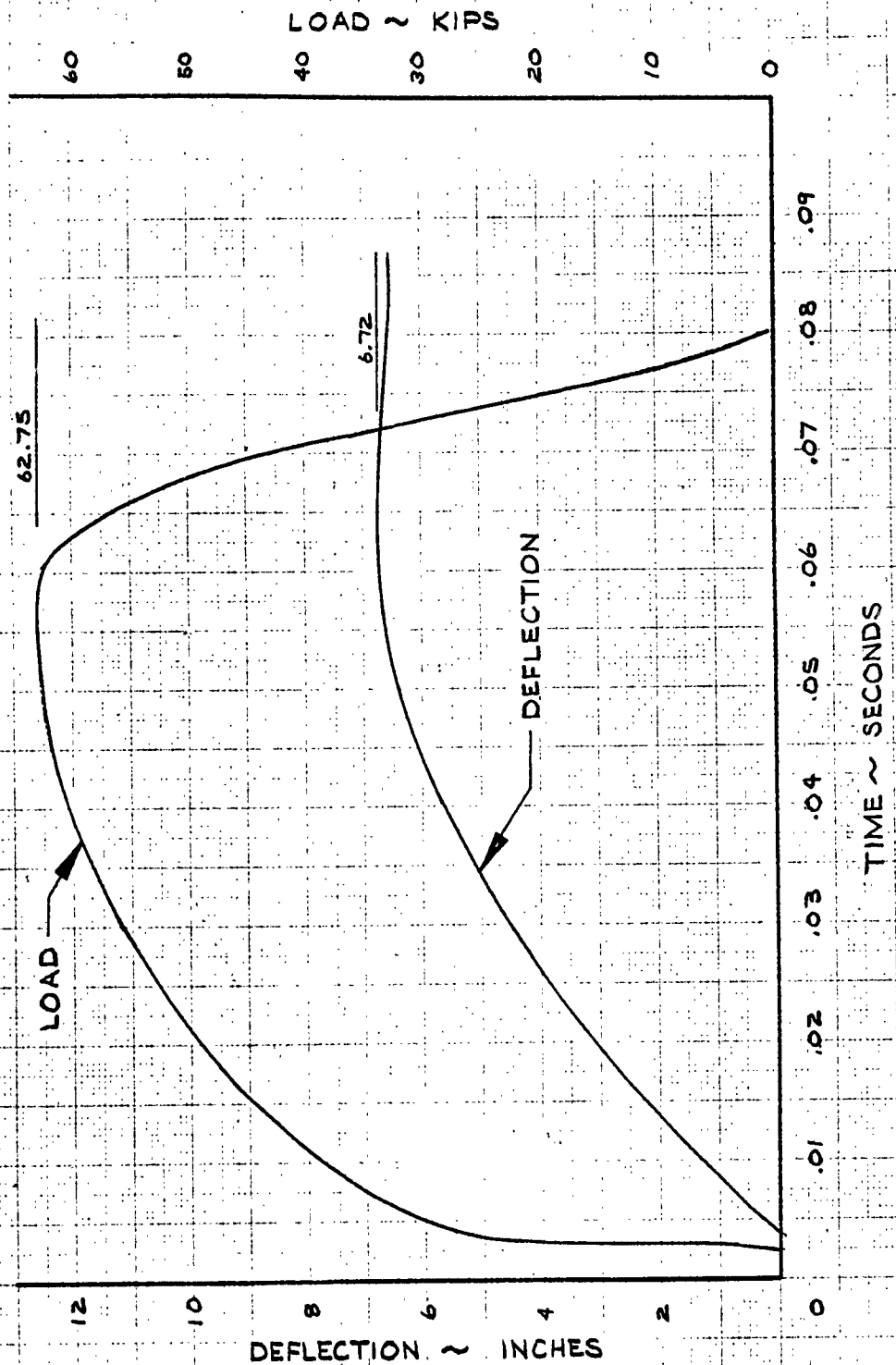
X-20
D2-80086
PAGE
3-30

SPECIMEN 29-80000-2
 TEMPERATURE = 600°F
 ENERGY = 322,964 INCH-LBS
 ENERGY = 26.92 KIPS-FT



CALC	J. Lebo	1-15-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 9	X-20
CHECK	HKJ	1-18-2				D2-80086
APR						
APR						
					THE BOEING COMPANY	PAGE 3-31

SPECIMEN 29-80000-2
TEMPERATURE 72°F



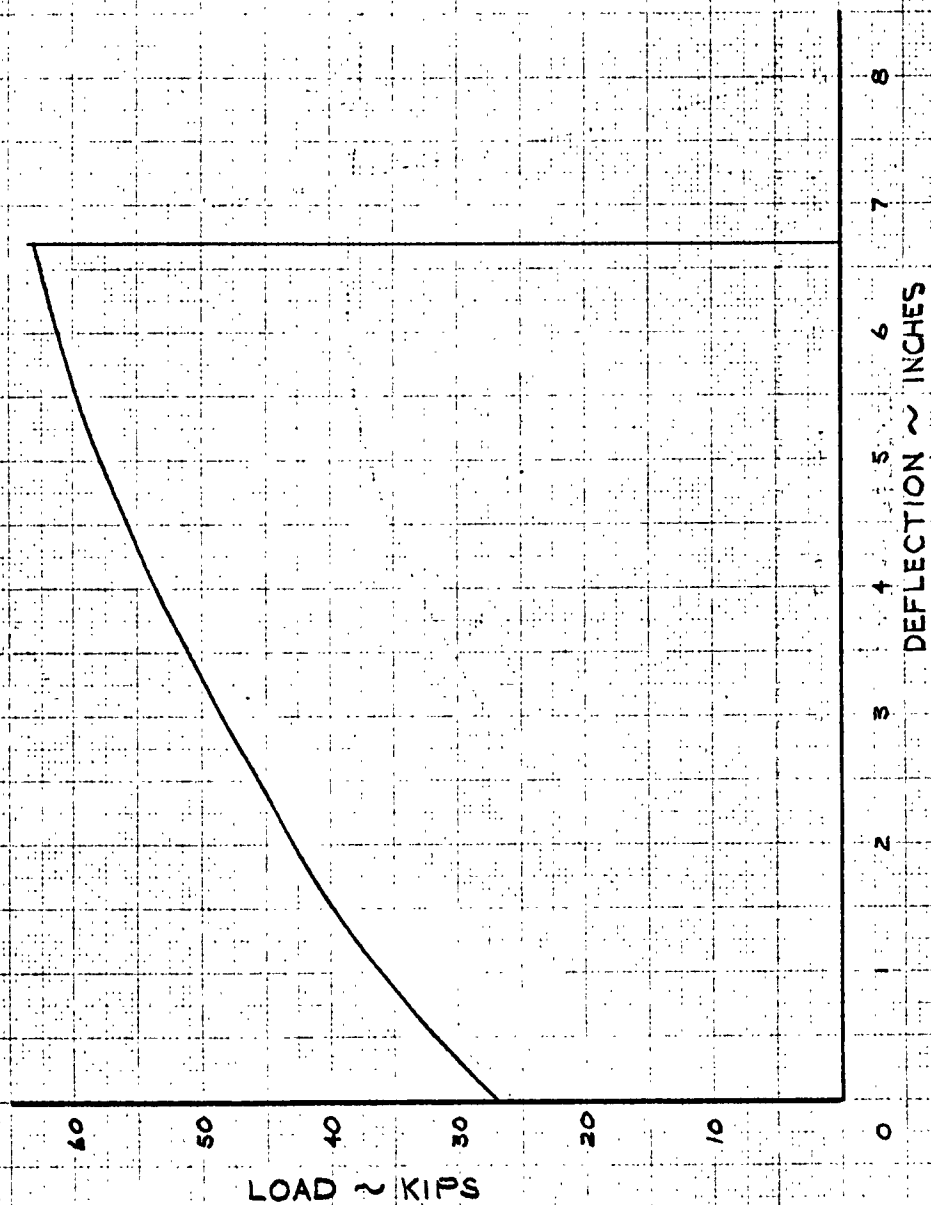
CALC	J. Lebo	1-16-2	REVISED	DATE
CHECK	HKJ	1-18-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 10

THE BOEING COMPANY

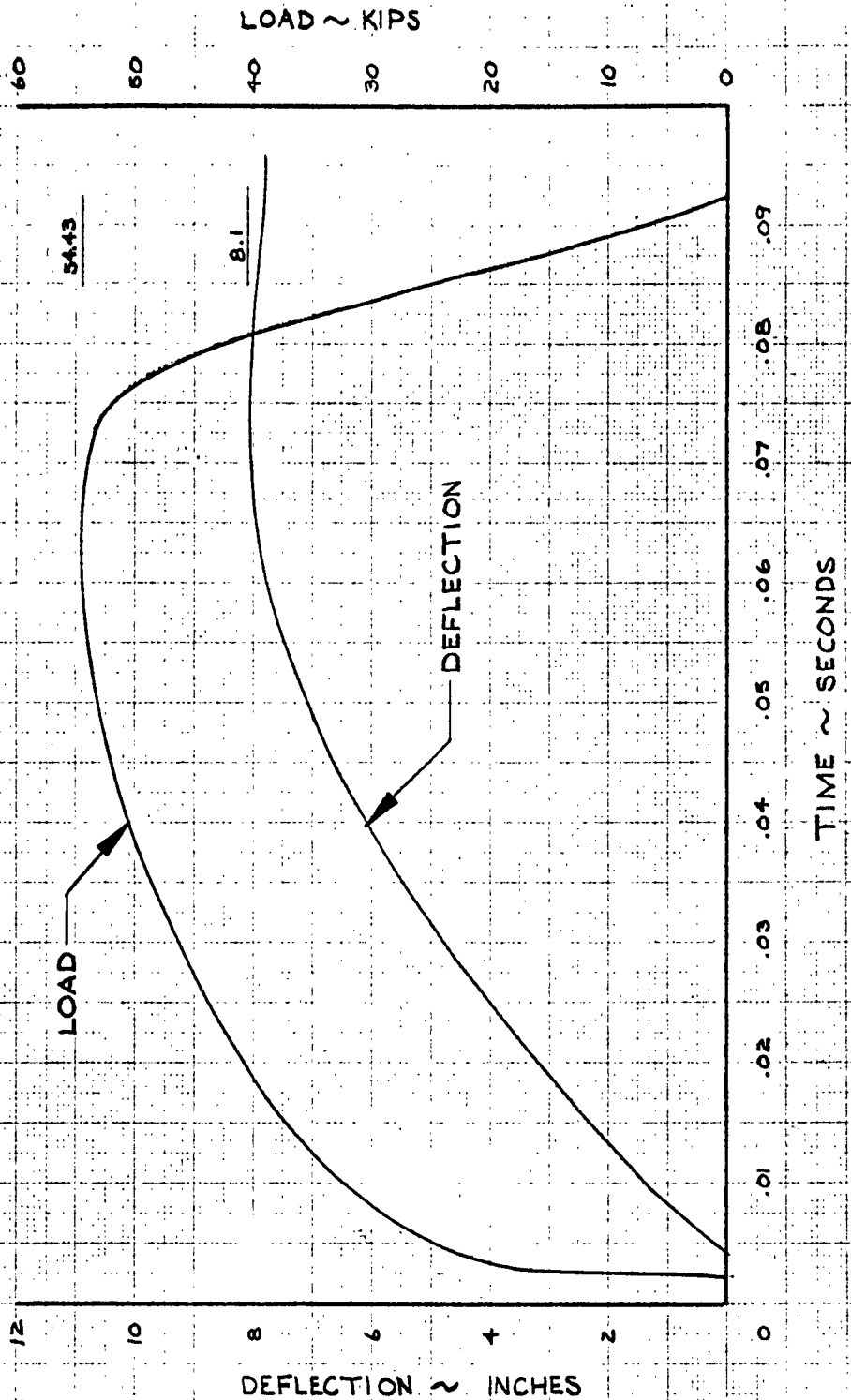
X-20
D2-80086
PAGE
3-32

SPECIMEN 29-80000-2
 TEMPERATURE = 72°F
 ENERGY = 326,832 INCH-LBS
 = 27.24 KIPS-FT



CALC	J. Iebo	1-17-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 10	X-20
CHECK	HKJ	1-18-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-33

SPECIMEN 29-80000-3
TEMPERATURE 72°F



CALC	J. Lebo	1-17-2	REVISED	DATE
CHECK	HKJ	1-18-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 11

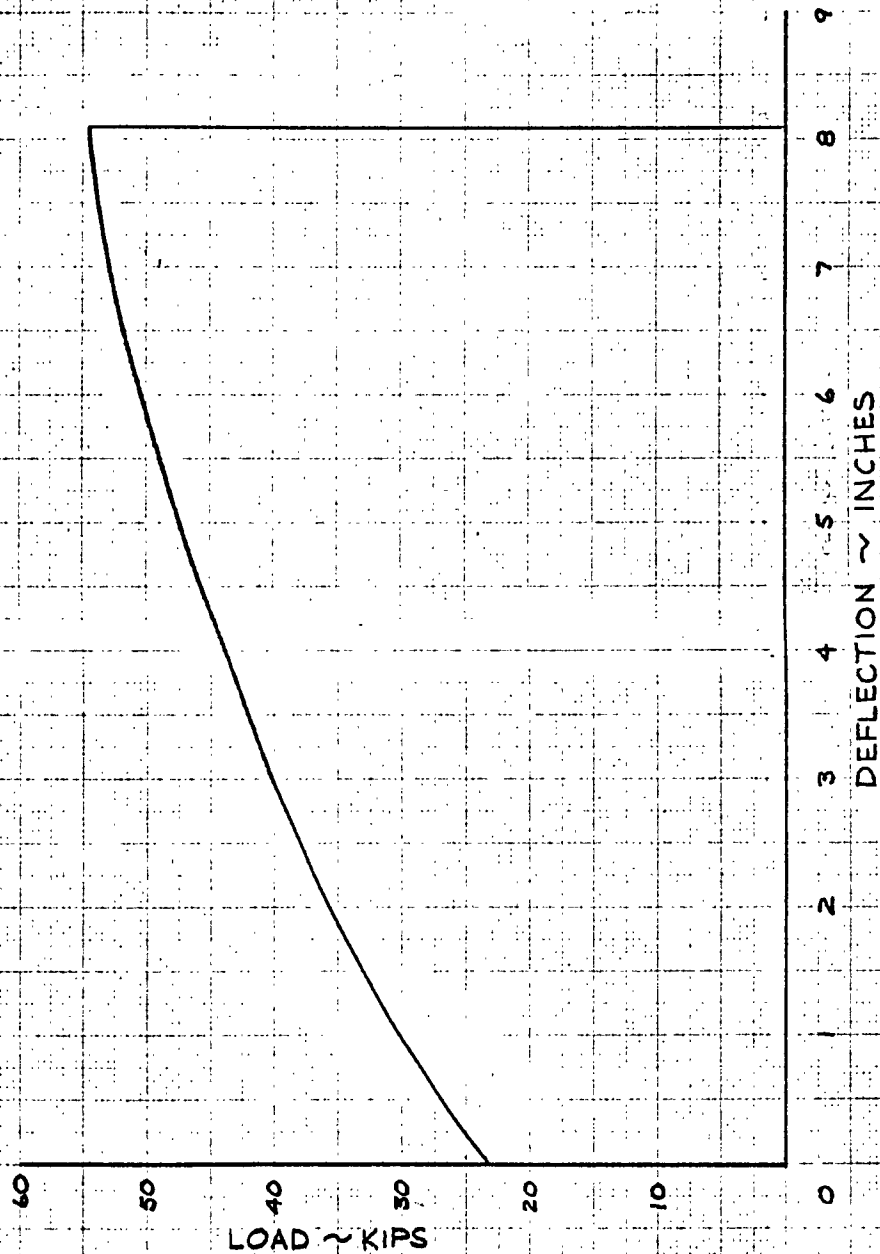
THE BOEING COMPANY

X-20

D2-80086

PAGE
3-34

SPECIMEN 29-80000-3
 TEMPERATURE = 72°F
 ENERGY = 341,950 INCH-LBS
 = 28.50 KIPS-FT



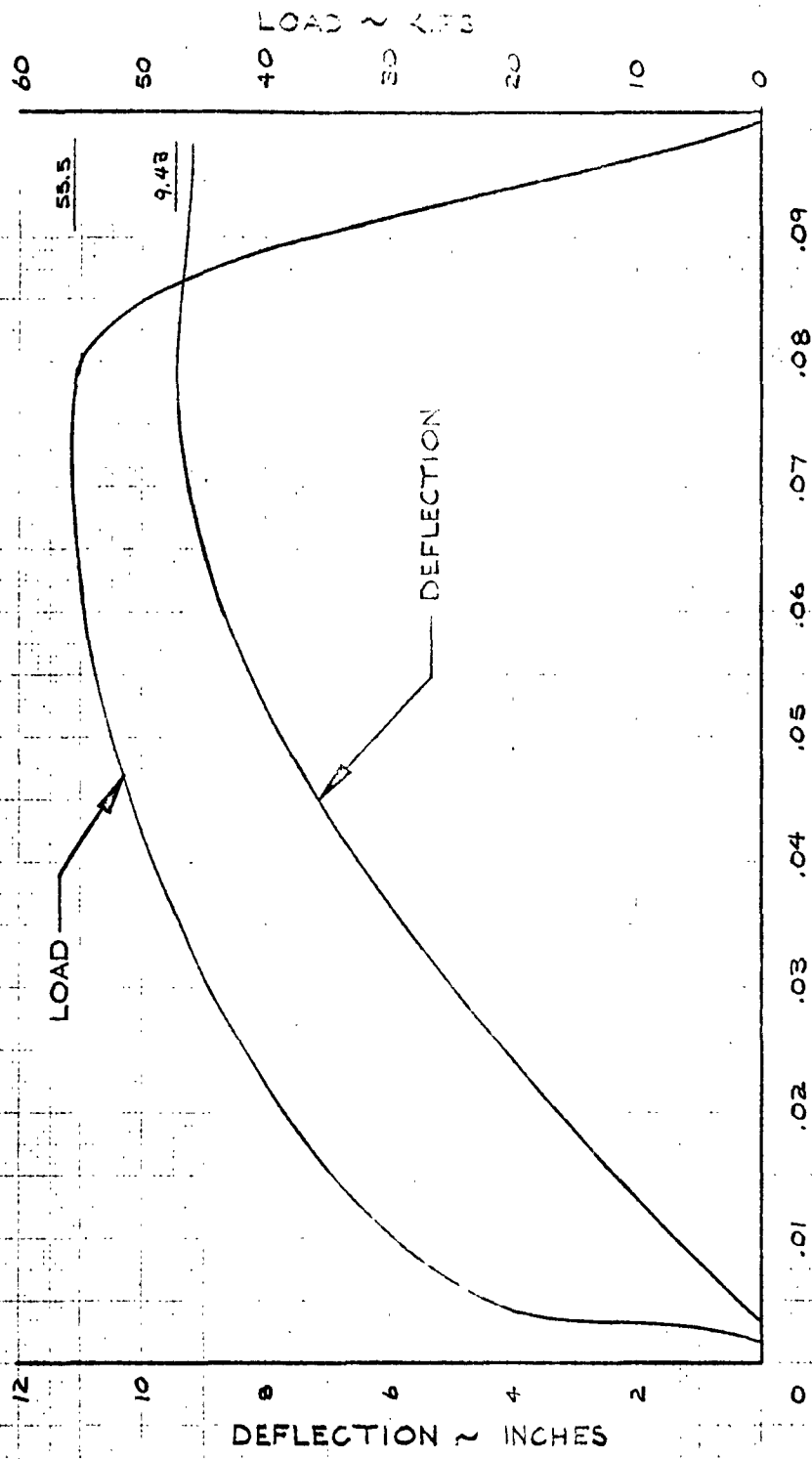
CALC	J. Iebo	1-17-82	REVISED	DATE
CHECK	HKJ	1-18-82		
APR				
APR				

LOAD VS DEFLECTION
 SPECIMEN NO. 11

THE BOEING COMPANY

X-20
 D2-80086
 PAGE
 3-35

SPECIMEN 29-80000-2
TEMPERATURE 600°F



CALC	J. Lebo	1-262	REVISED	DATE
CHECK	Jorgensen	1-302		
APR				
APR				

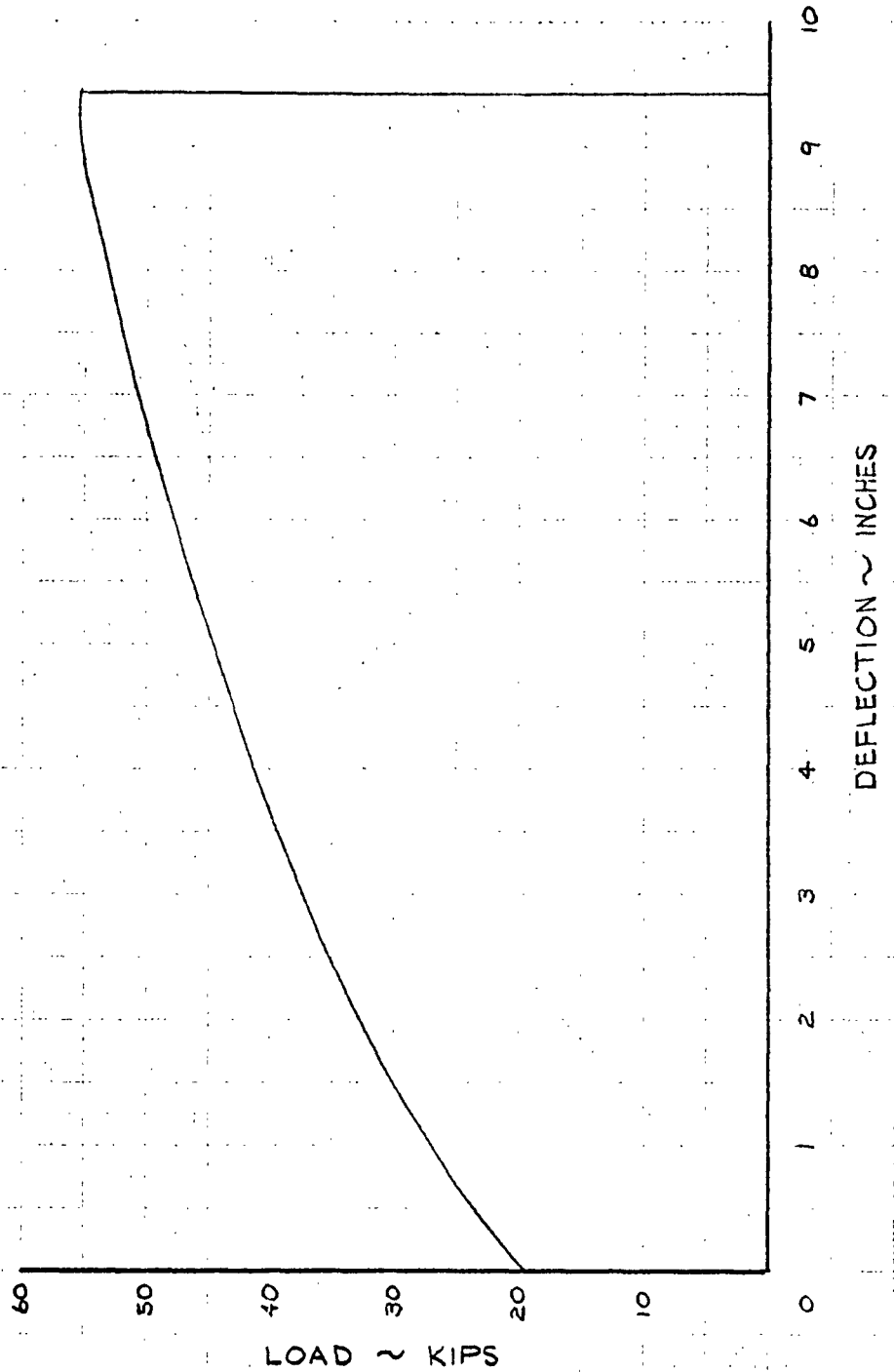
LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 12

THE BOEING COMPANY

X-20
D2-80086
PAGE
3-36

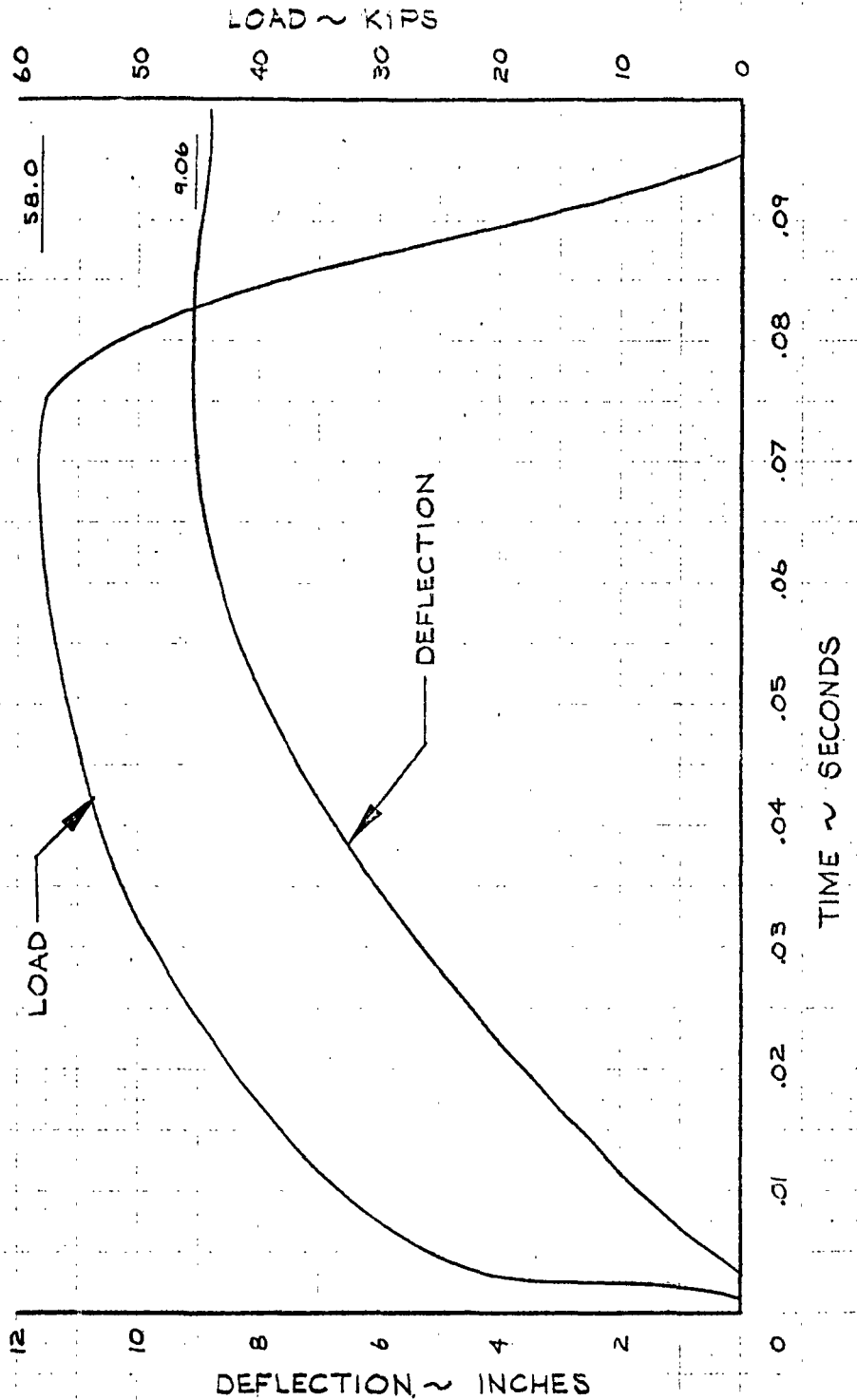
129

SPECIMEN 29-80000-2
 TEMPERATURE = 600°F
 ENERGY = 396,352 INCH-LBS
 = 33.03 KIPS-FT



CALC	J. Lebo	1-26-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 12	X-20
CHECK	Jorgensen	1-30-2				D2-80086
APR						
APR						
					THE BOEING COMPANY	PAGE 3-37

SPECIMEN 29-80000-2
TEMPERATURE 600°F



CALC	J. Lebo	L-292	REVISED	DATE
CHECK	Jorgensen	L-30-2		
APR				
APR				

LOAD & DEFLECTION VS
TIME
SPECIMEN NO. 13

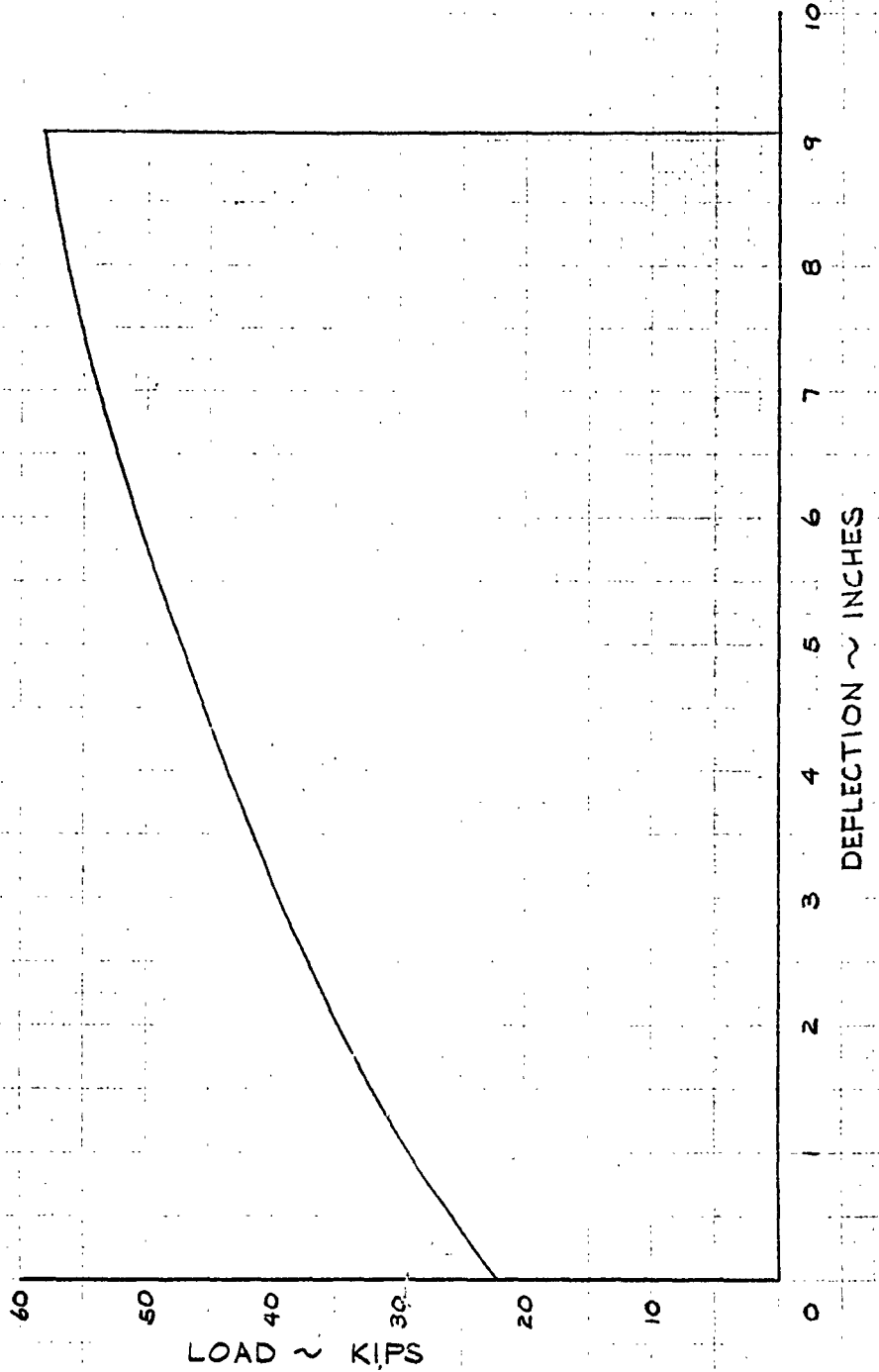
THE BOEING COMPANY

X-20

D2-80086

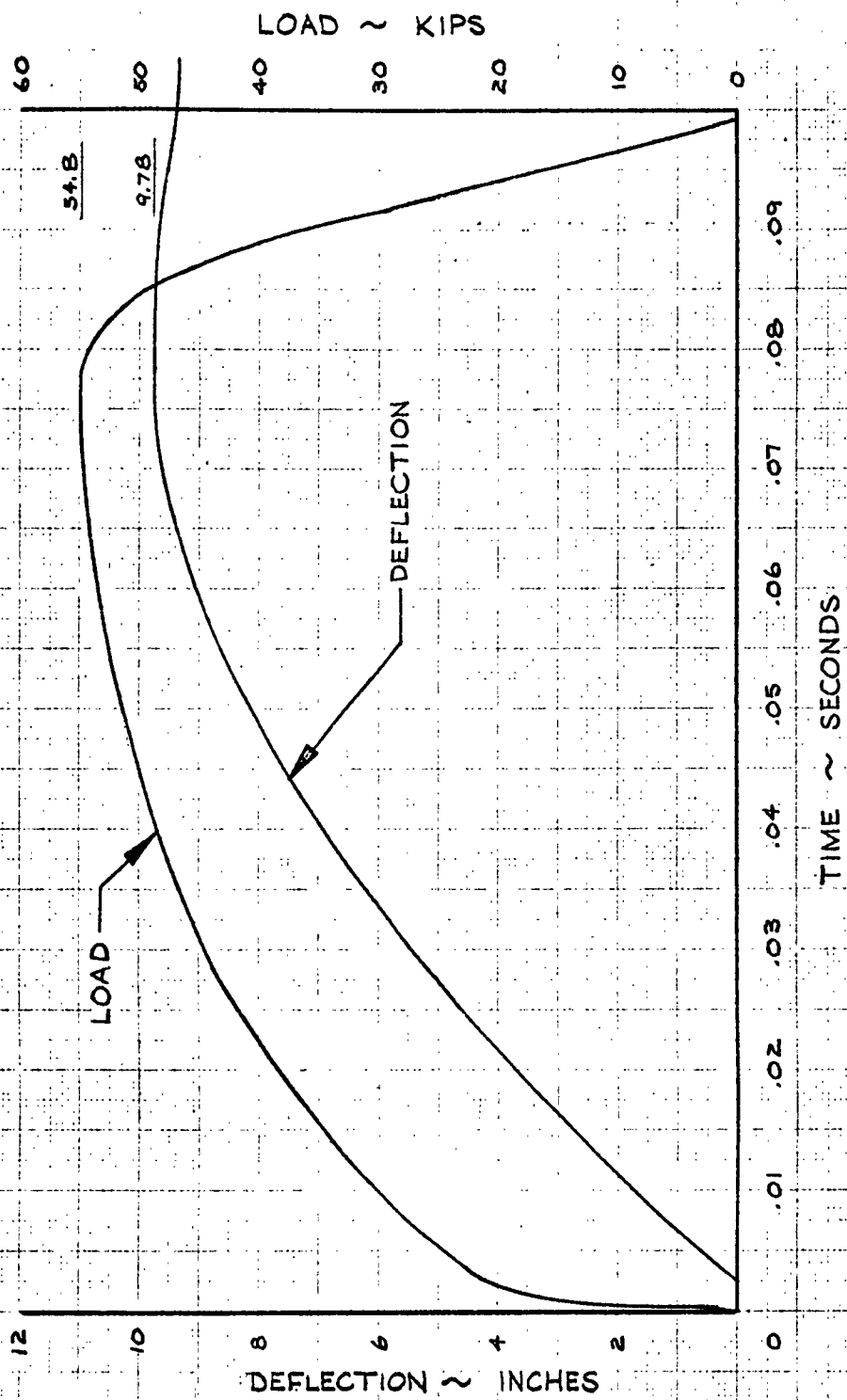
PAGE
3-38

SPECIMEN 29-80000-2
 TEMPERATURE = 600 °F
 ENERGY = 395,795 INCH-LBS
 = 32.98 KIPS FT



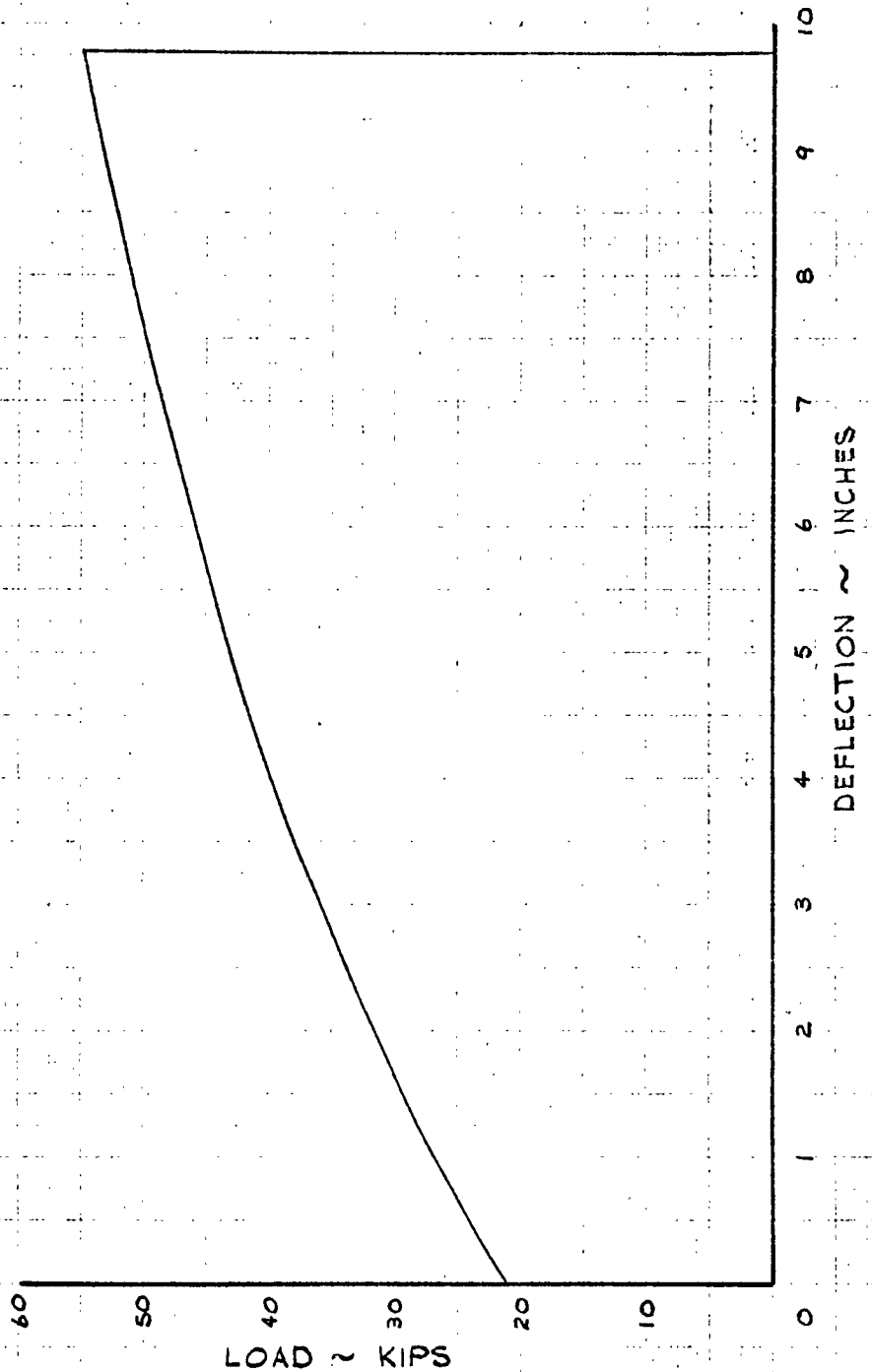
CALC	L. Jebo	1-29-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 13	X-20
CHECK	Jorgensen	1-30-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						2-39

SPECIMEN 29-80000-2
TEMPERATURE 800°F



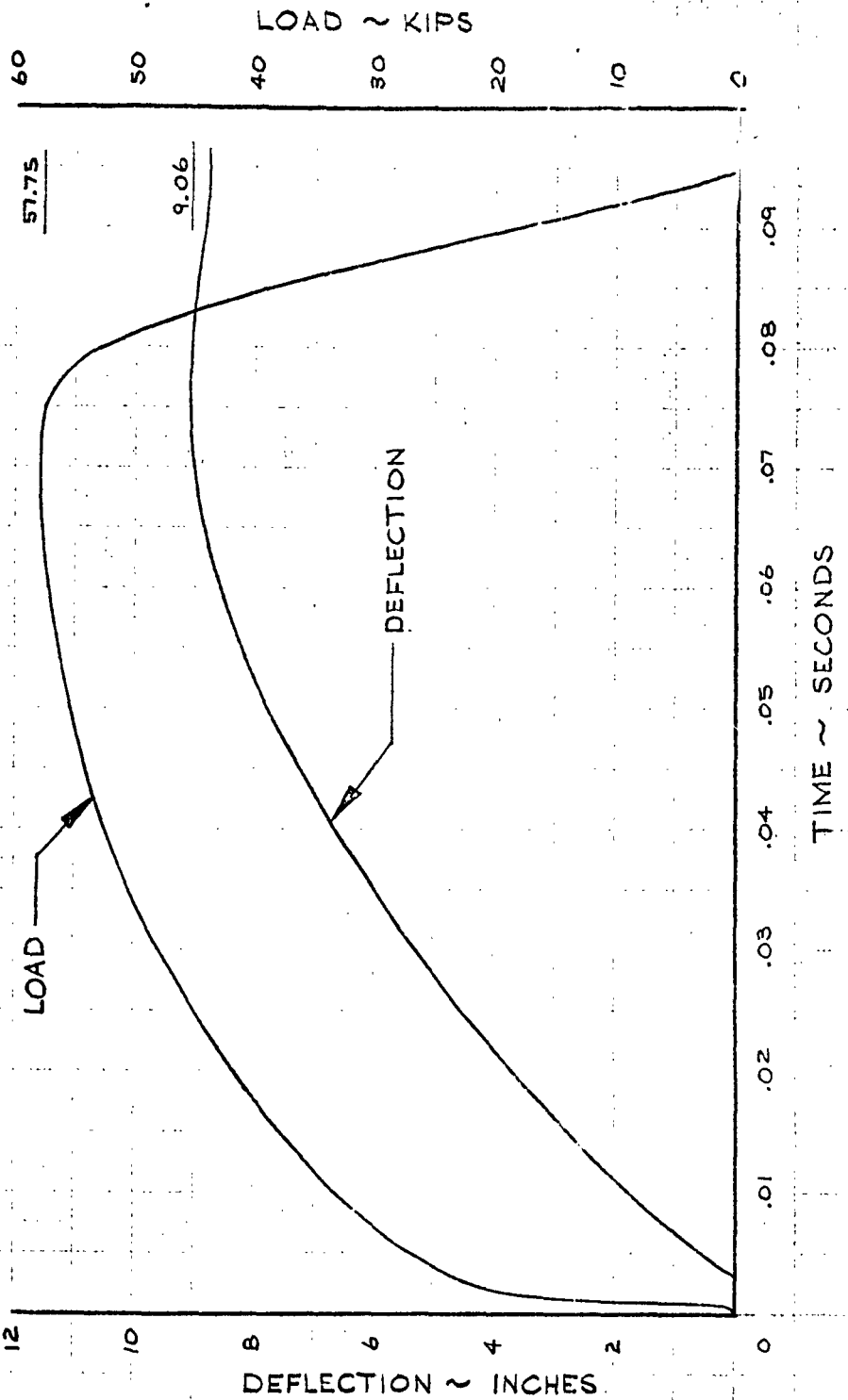
CALC	J. Lebo	2-7-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 14	X-20
CHECK	Jorgensen	2-8-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-40

SPECIMEN 29-80000-2
 TEMPERATURE = 800°F
 ENERGY = 399,880 INCH-LES
 = 33.32 KIPS-FT



DESIGNED	J. Jorgensen	2-7-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 14	X-20
CHECKED	Jorgensen	2-8-2				D2-80086
APR						
APR						
					THE BOEING COMPANY	PAGE 3-41

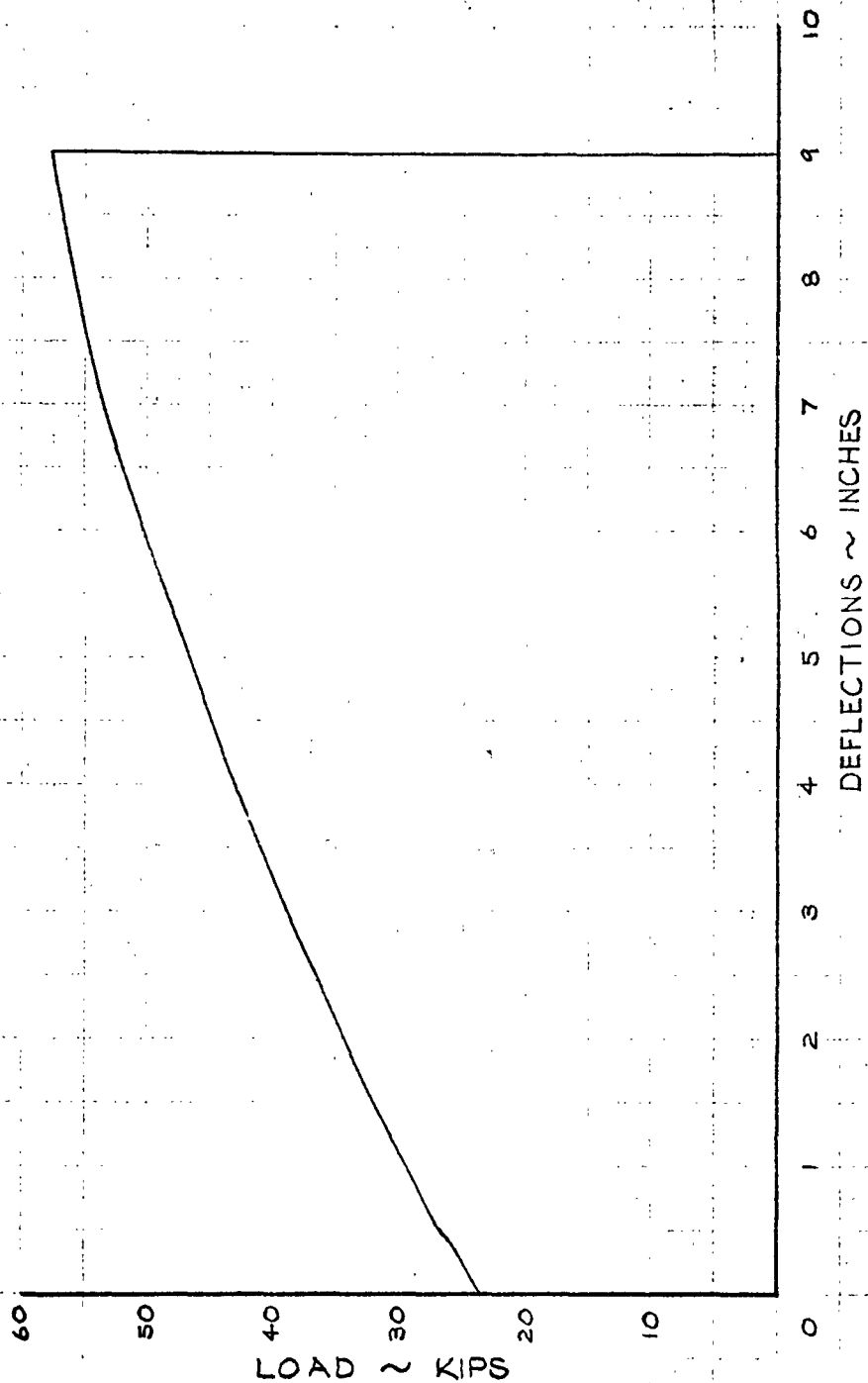
SPECIMEN 29-80000-2
TEMPERATURE 800°F



CALC	J. Lebo	2-7-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 15	X-20
CHECK	Jorgensen	2-8-2				D2-80086
APR						PAGE
APR						3-42
THE BOEING COMPANY						

185

SPECIMEN 29-80000-2
 TEMPERATURE = 800°F
 ENERGY = 394,527 INCH-LBS
 = 32.88 KIPS-FT



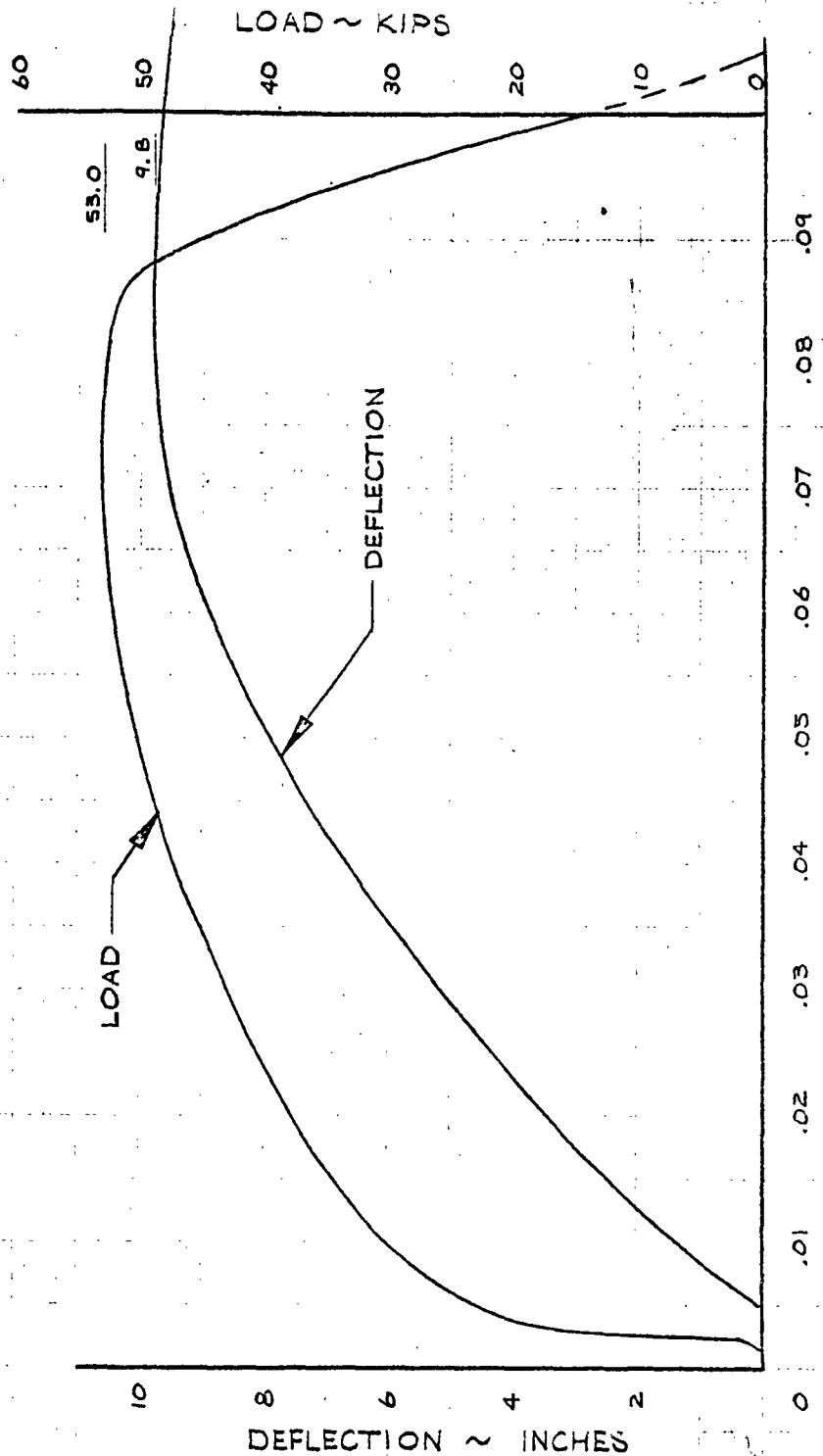
CALC	J. Lebo	2-7-2	REVISED	DATE
CHECK	Jorgensen	2-8-2		
APR				
APR				

LOAD VS DEFLECTION
 SPECIMEN NO. 15

THE BOEING COMPANY

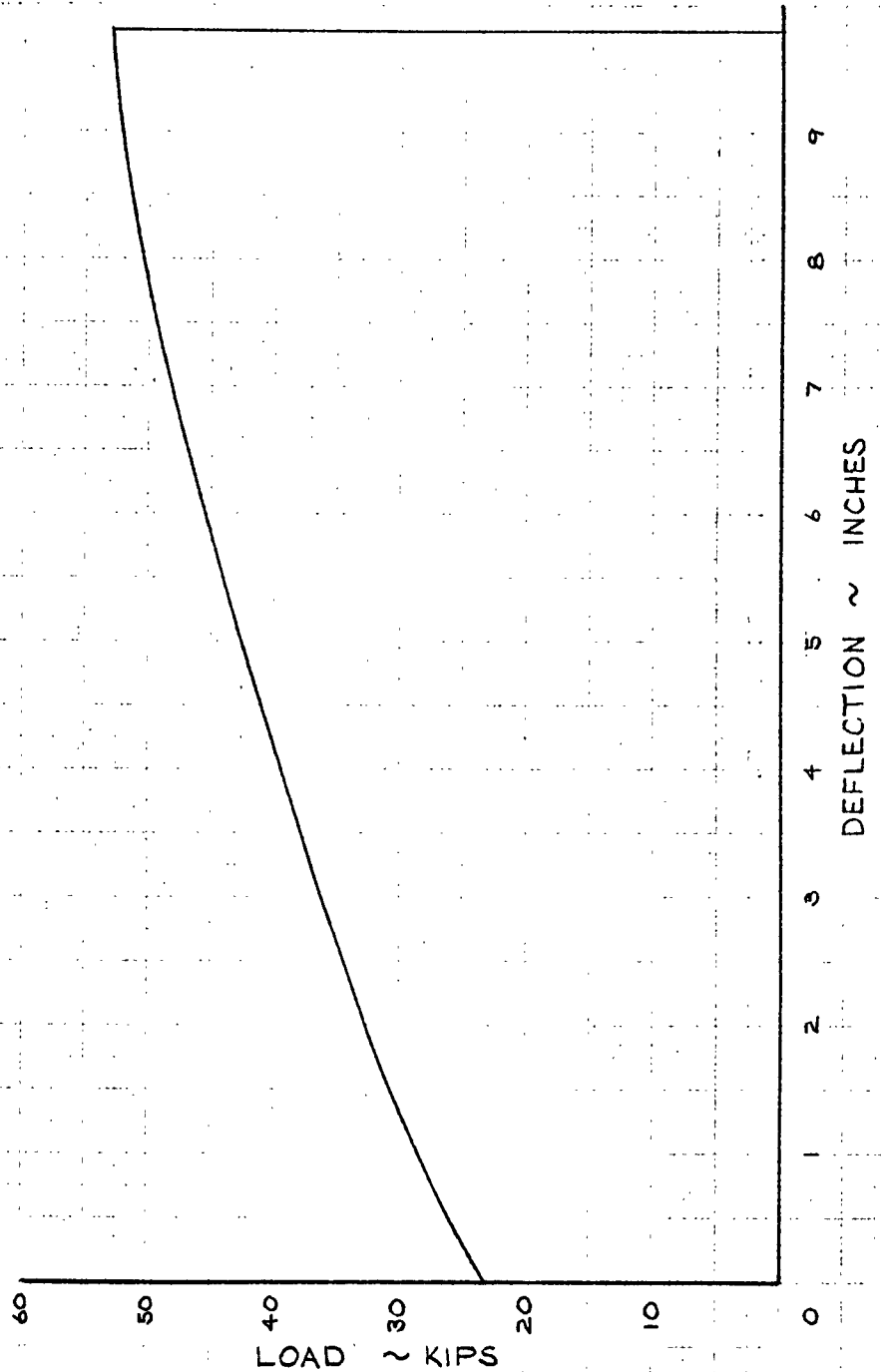
X-20
 D2-80086
 PAGE
 3-43

SPECIMEN 29-80000-3
TEMPERATURE 72°F

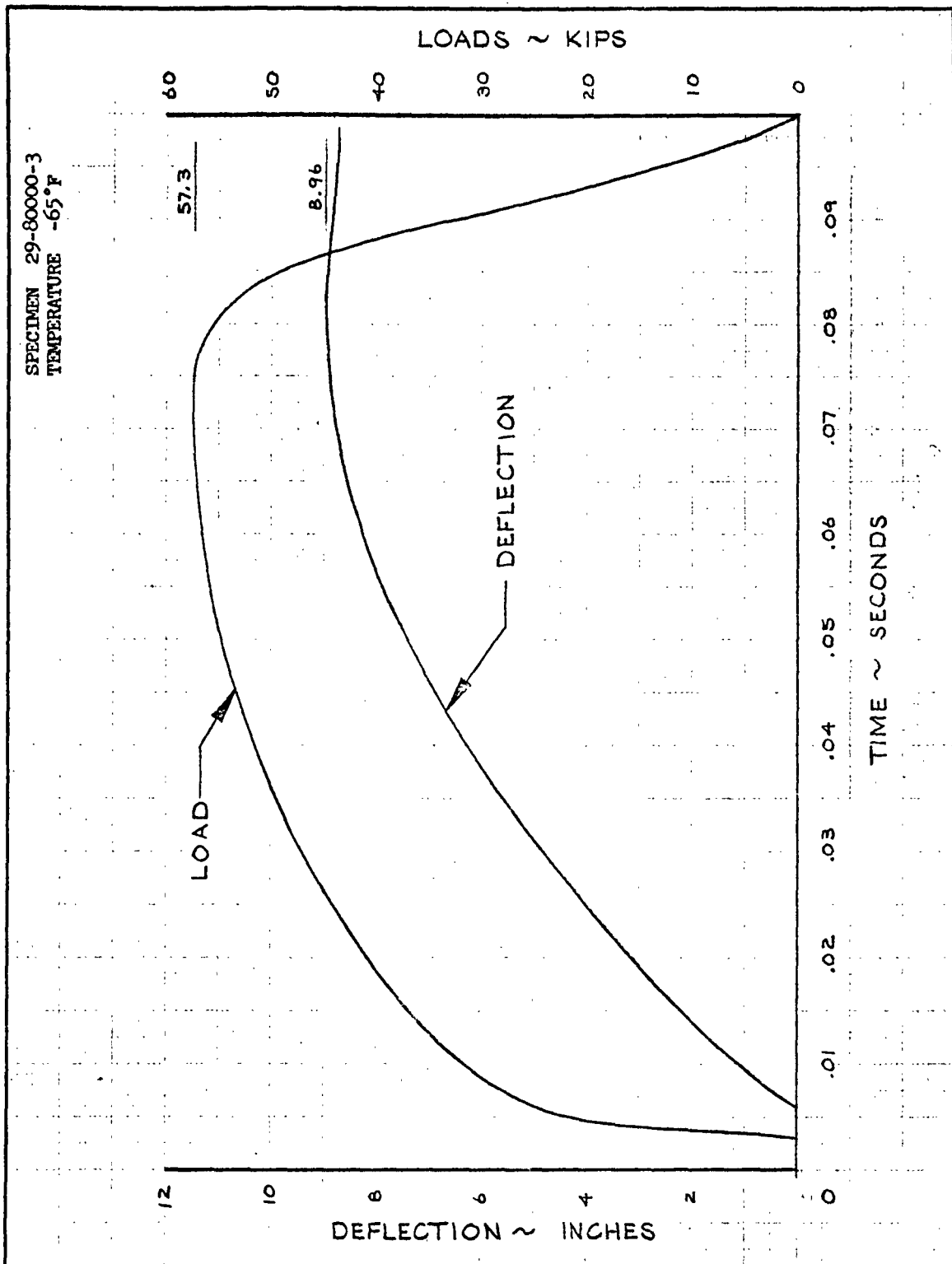


CALC	J. Lebo	2-8-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 16	X-20
CHECK						D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-44

SPECIMEN 29-80000-3
 TEMPERATURE = 72°F
 ENERGY = 401,506 INCH-LBS
 = 33.46 KIPS-FT



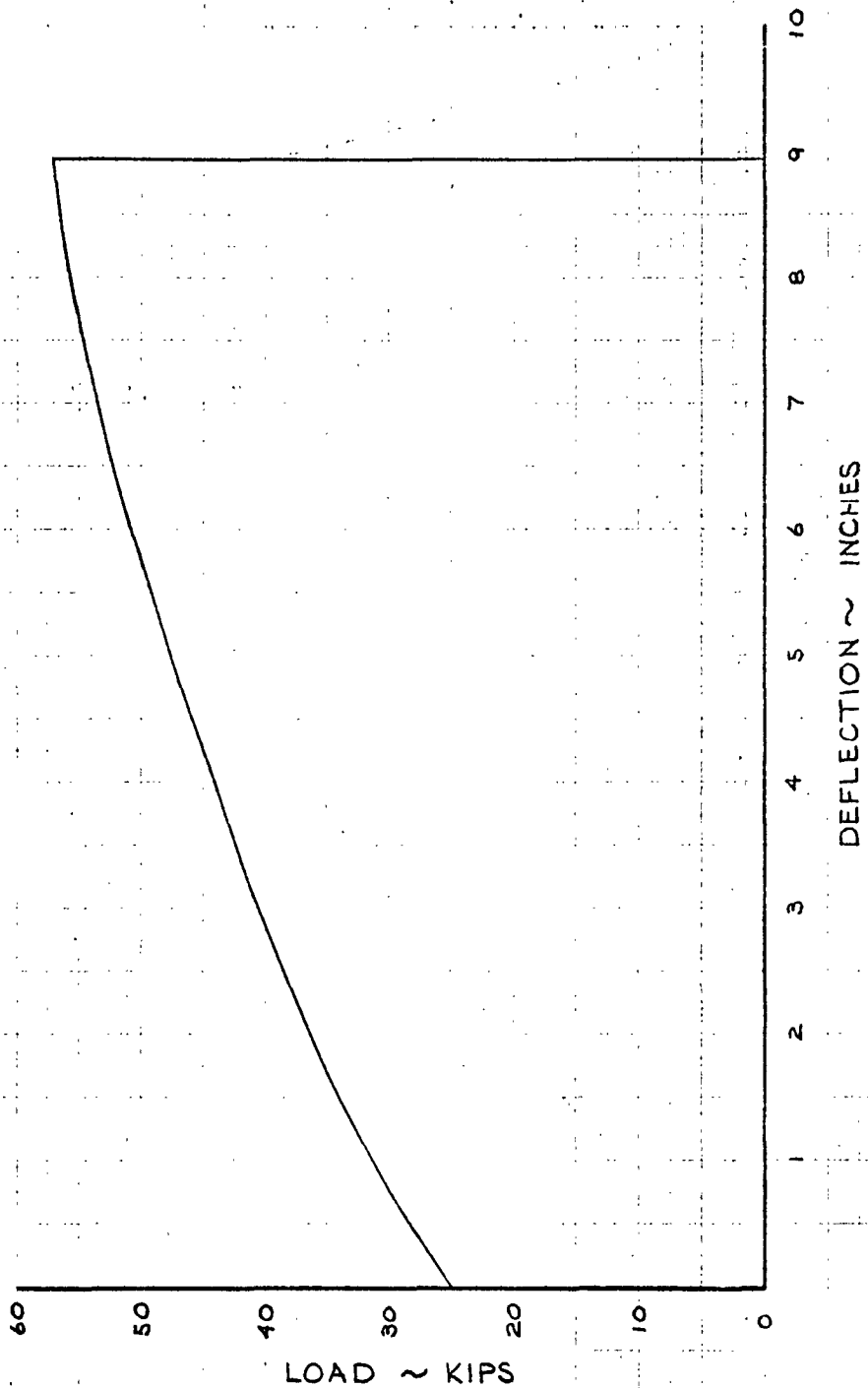
CALC	J. Lebo	2-8-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 16	X-20
CHECK						D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-45



CALC	J. Lebo	2-19-2	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 17	X-20
CHECK	Jorgensen	2-20-2				D2-80086
APR					THE BOEING COMPANY	PAGE
APR						3-46

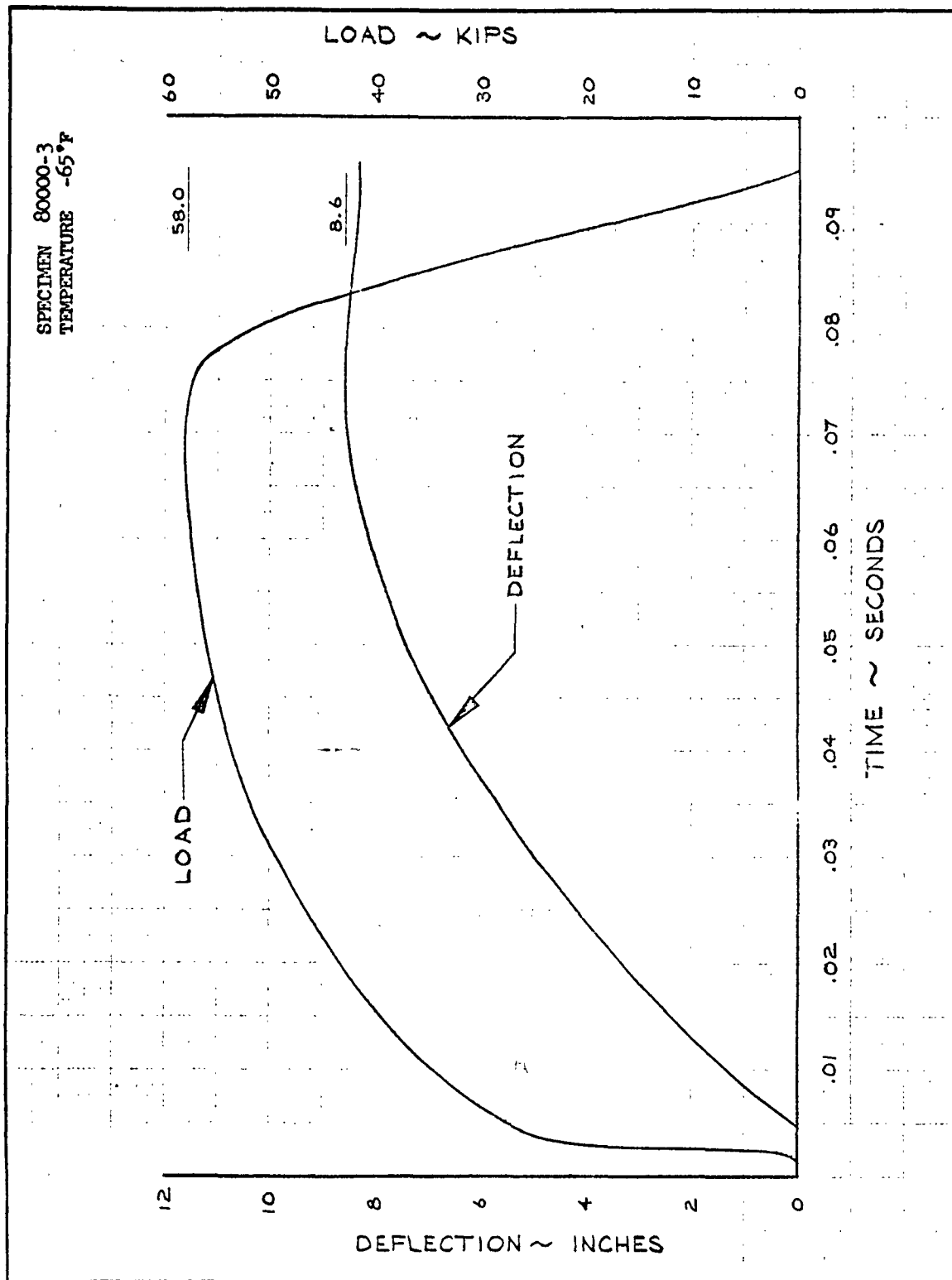
189

SPECIMEN 29-80000-3
 TEMPERATURE = -65°F
 ENERGY = 399,155 INCH-LBS
 = 33.27 KIPS-FT



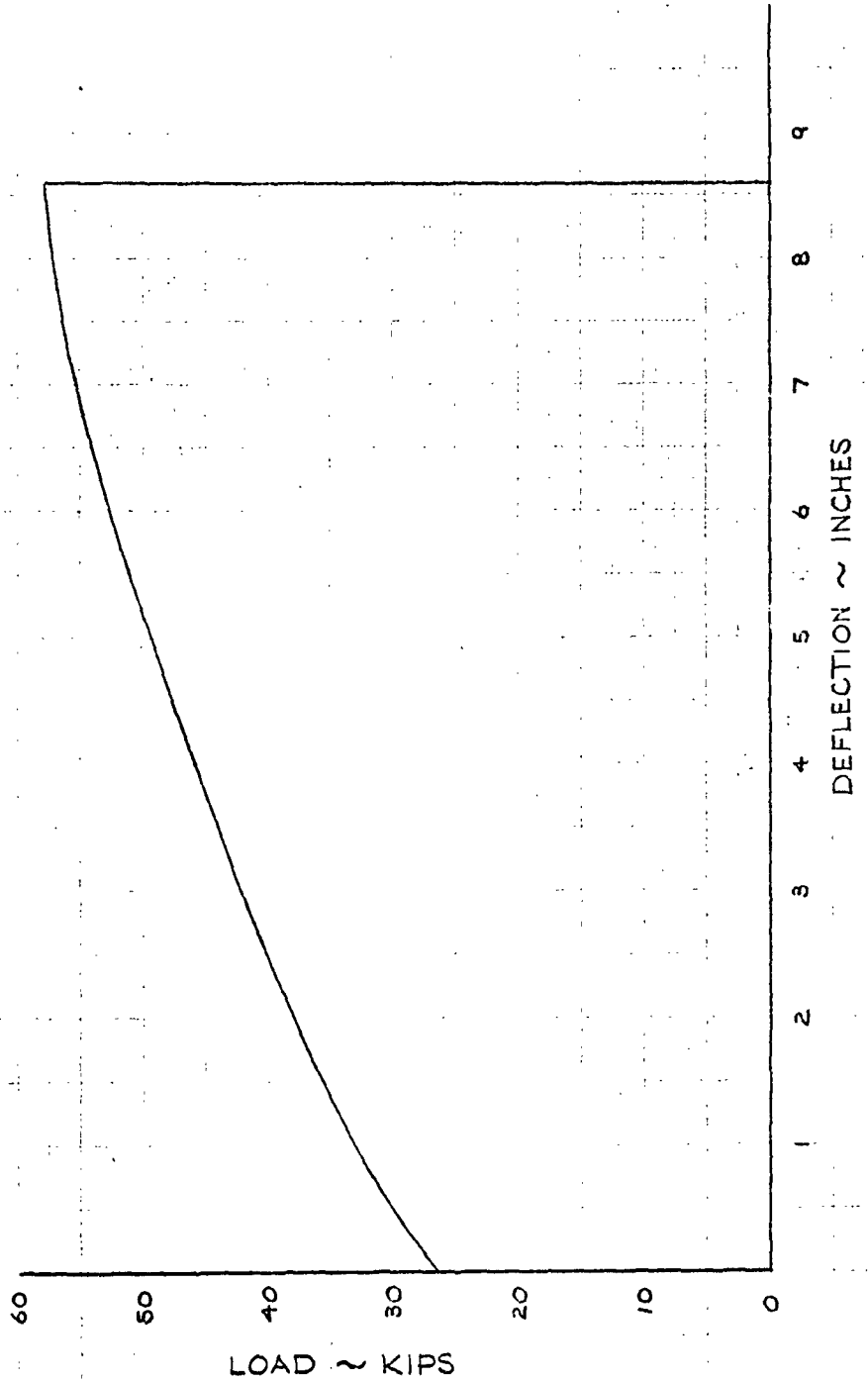
CALC	J. Lebo	2-19-2	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 17	X-20
CHECK	Jorgensen	2-20-2				02-80086
APR						
APR						
					THE BOEING COMPANY	PAGE 3-47

190



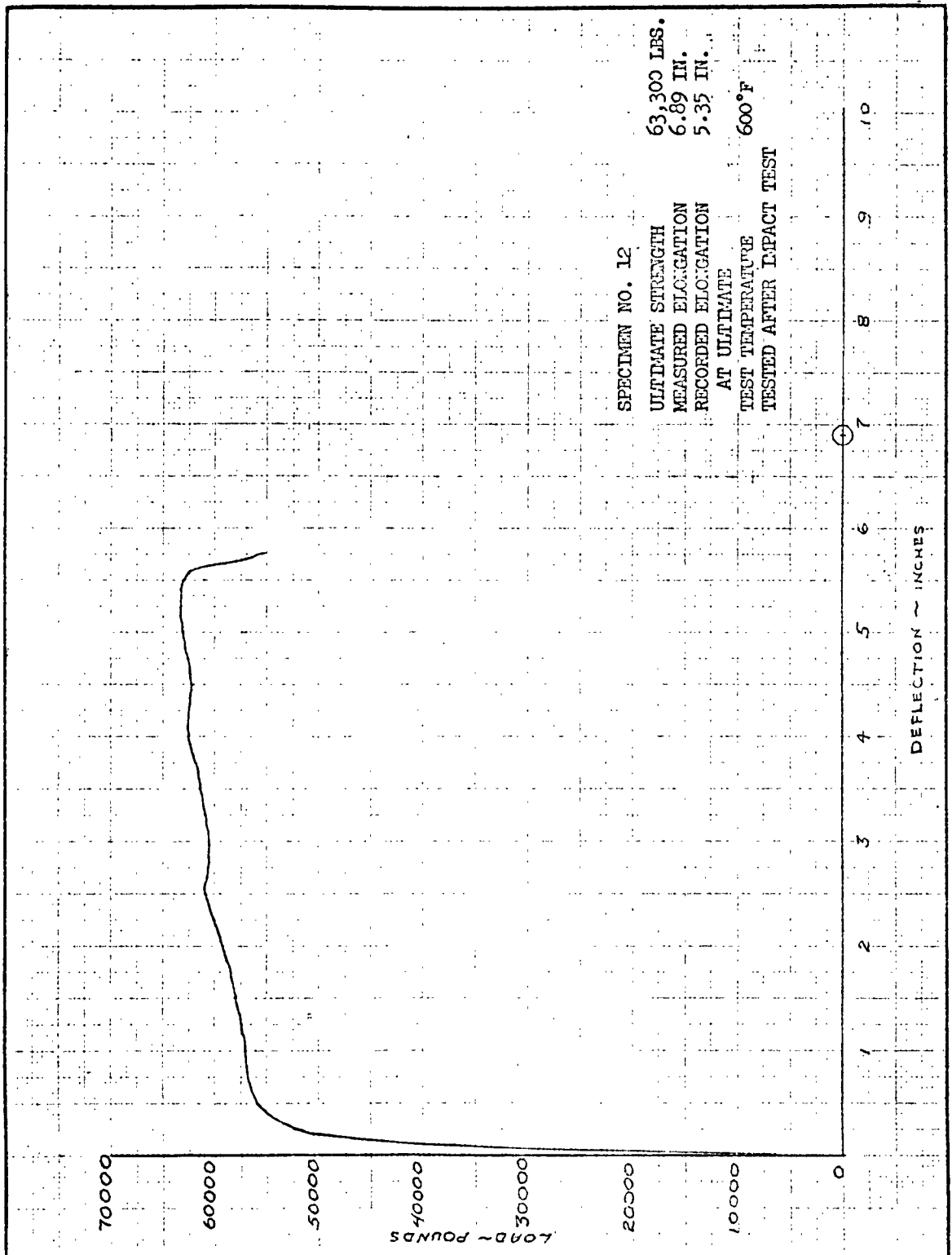
CALC	J. Tebo	2-21-5	REVISED	DATE	LOAD & DEFLECTION VS TIME SPECIMEN NO. 18	X-20
CHECK	Jorgensen	2-21-5				02-80036
APR						
APR					THE BOEING COMPANY	PAGE 3-48

SPECIMEN 29-80000-3
 TEMPERATURE = -65°F
 ENERGY = 390,732 INCH-LBS
 = 32.56 KIPS-FT



CALC	J. Lebo	2-21-6	REVISED	DATE	LOAD VS DEFLECTION SPECIMEN NO. 18	X-20
CHECK	Jorgensen	2-21-2				
APR						
APR						
					THE BOEING COMPANY	PAGE 3-49

192

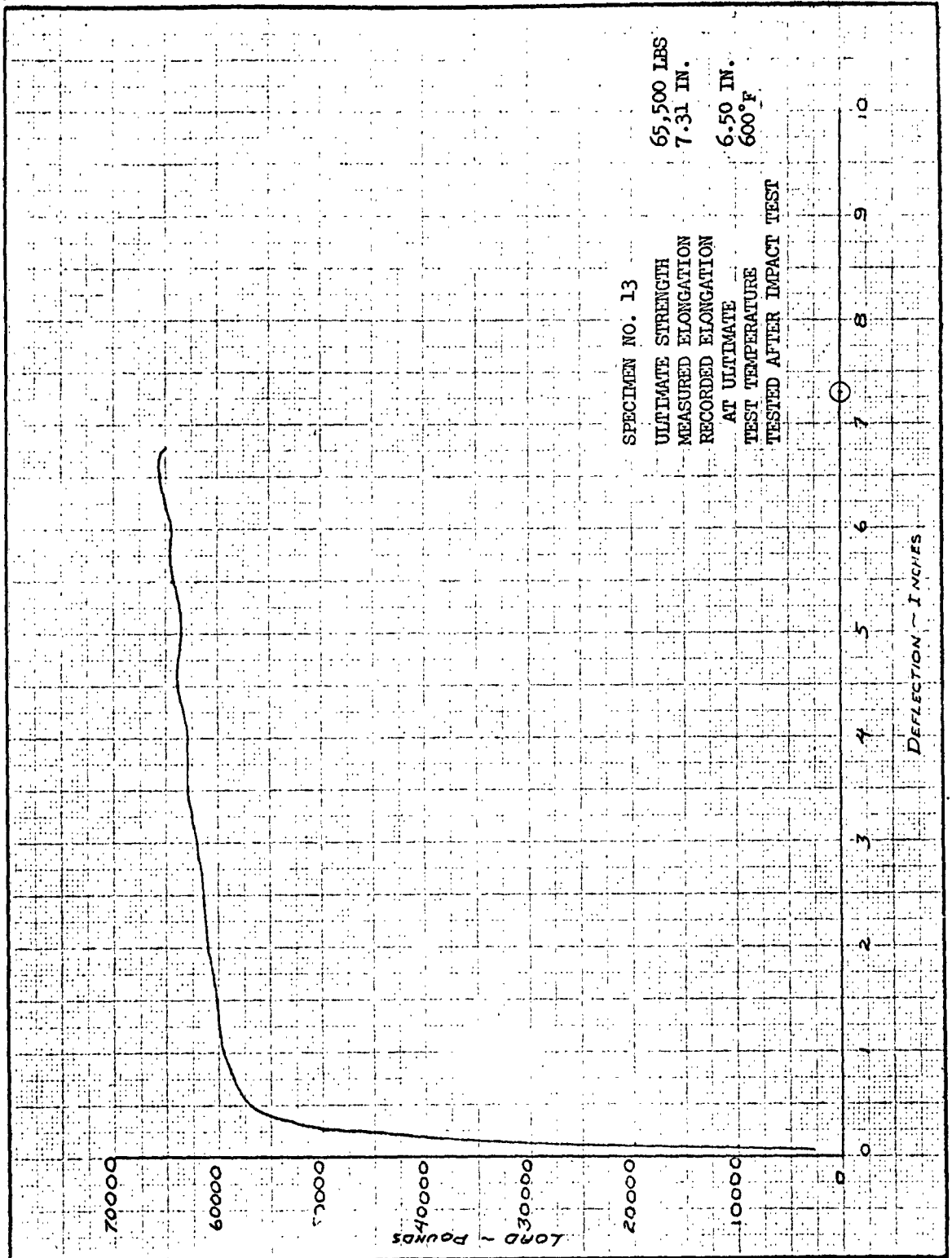


SPECIMEN NO. 12
 ULTIMATE STRENGTH 63,300 LBS.
 MEASURED ELONGATION 6.89 IN.
 RECORDED ELONGATION 5.35 IN.
 AT ULTIMATE
 TEST TEMPERATURE 600°F
 TESTED AFTER IMPACT TEST

CALC	L WESS	723-2	REVISED	DATE	STATIC LOADING LOAD VS DEFLECTION D.S. LANDING GEAR ENERGY STRAP BOEING AIRPLANE COMPANY	X-20
CHECK	McDANIEL	727-67				DZ-80026
APR						PAGE
APR						3-50

193

194

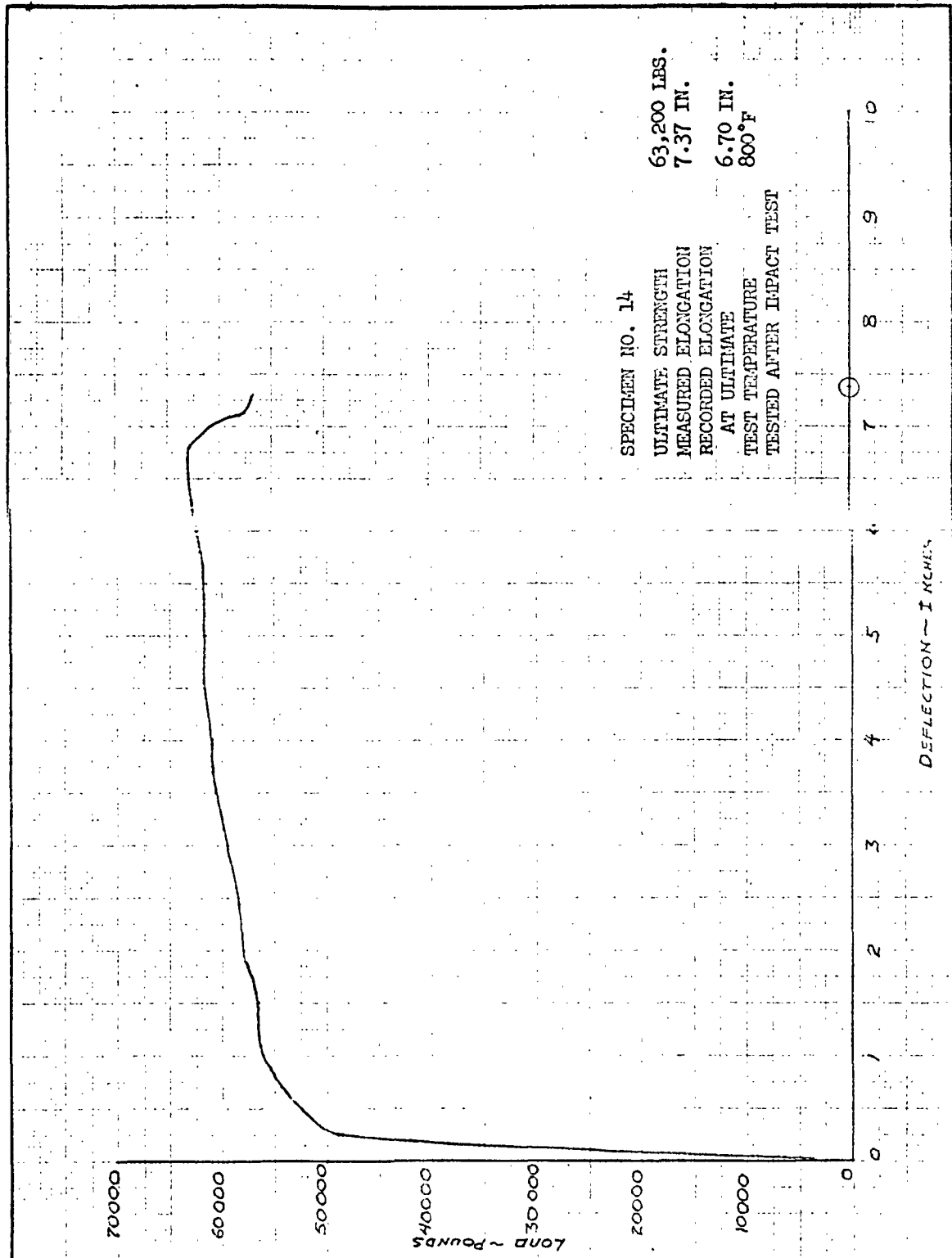


SPECIMEN NO. 13
 ULTIMATE STRENGTH 65,500 LBS
 MEASURED ELONGATION 7.31 IN.
 RECORDED ELONGATION AT ULTIMATE 6.50 IN.
 TEST TEMPERATURE 600°F
 TESTED AFTER IMPACT TEST

CALC	L. WESS	7-23-62	REVISED	DATE
CHECK	MCDANIEL	7-27-62		
APR				
APR				

STATIC LOADING
 LOAD vs. DEFLECTION
 D.S. LANDING GEAR ENERGY STRAP
 BOEING AIRPLANE COMPANY

X-20
 D2-80085
 PAGE 3-51

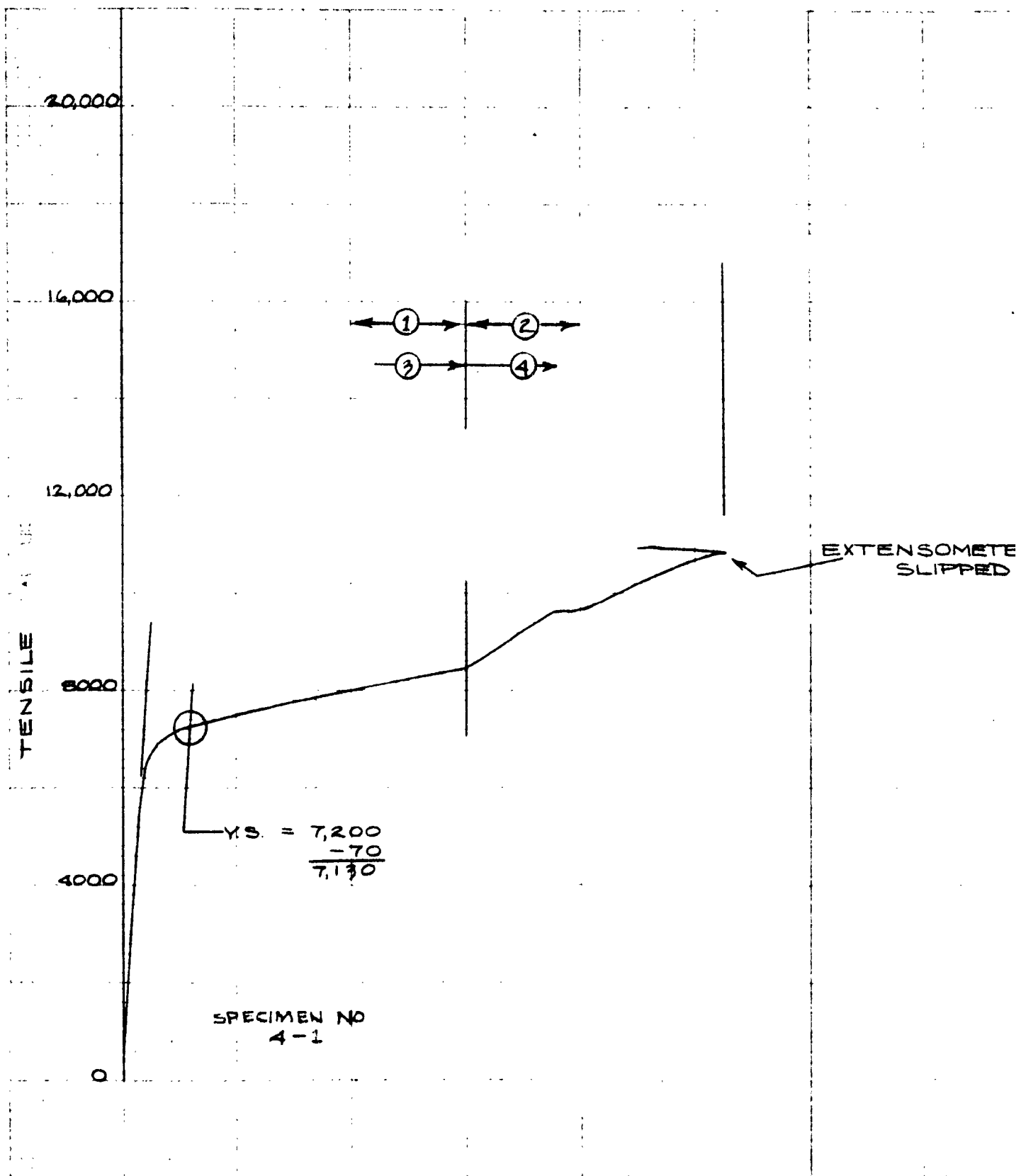


CALC	L. WESS	7-23-2	REVISED	DATE
CHECK	MCDANIEL	7-27-6		
APR				
APR				

STATIC LOADING
 LOAD VS DEFLECTION
 D.S. LANDING GEAR ENERGY STRAP
 BOEING AIRPLANE COMPANY

X-20
 D2-8071
 PAGE 3-6

195



EXTENSOMETER GRIP
SLIPPED

2

① .005 ③ .005
② .020 ④ 0.10

CALC ELS 450/2 OPR

CHECK APPD

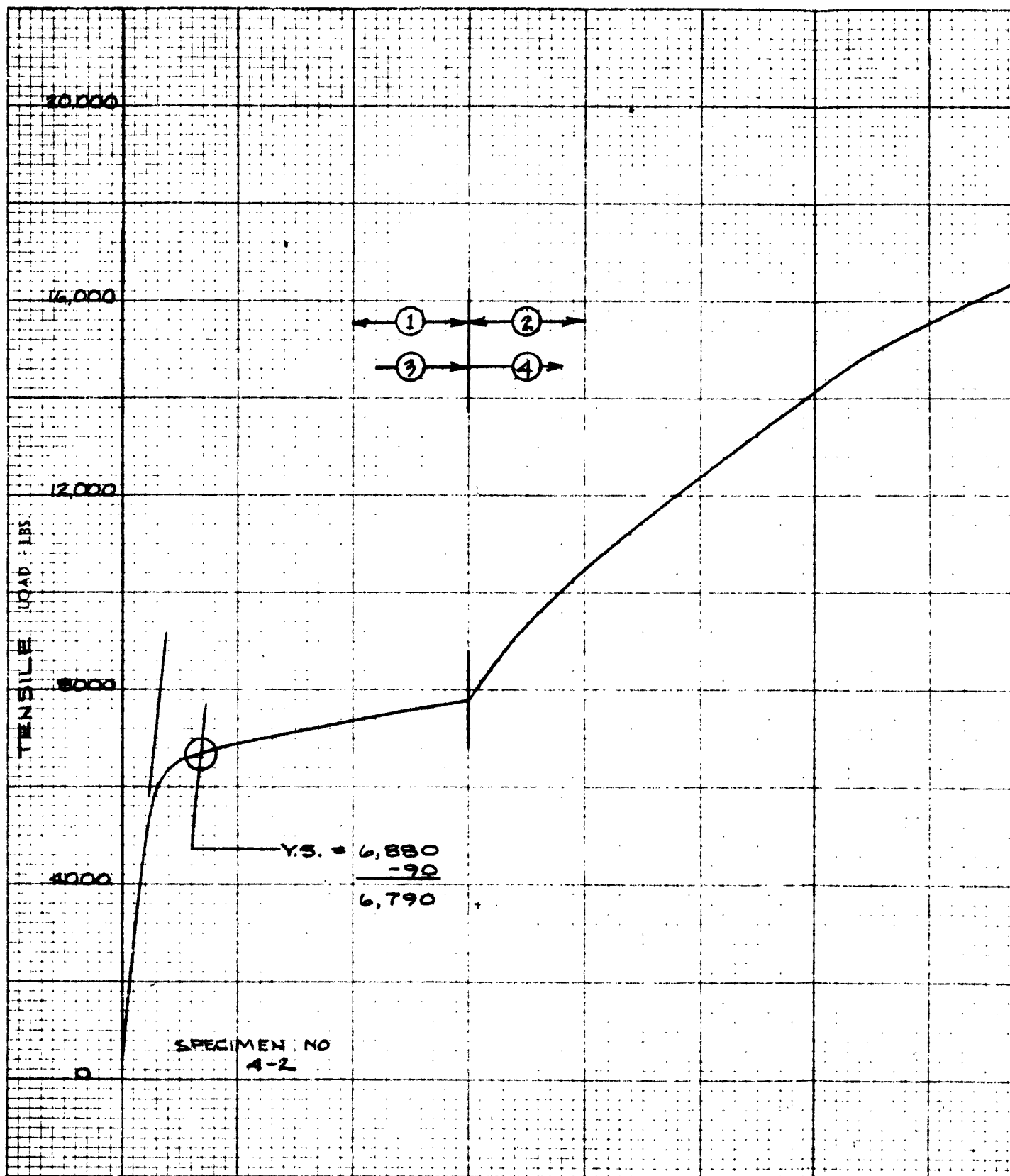
REL

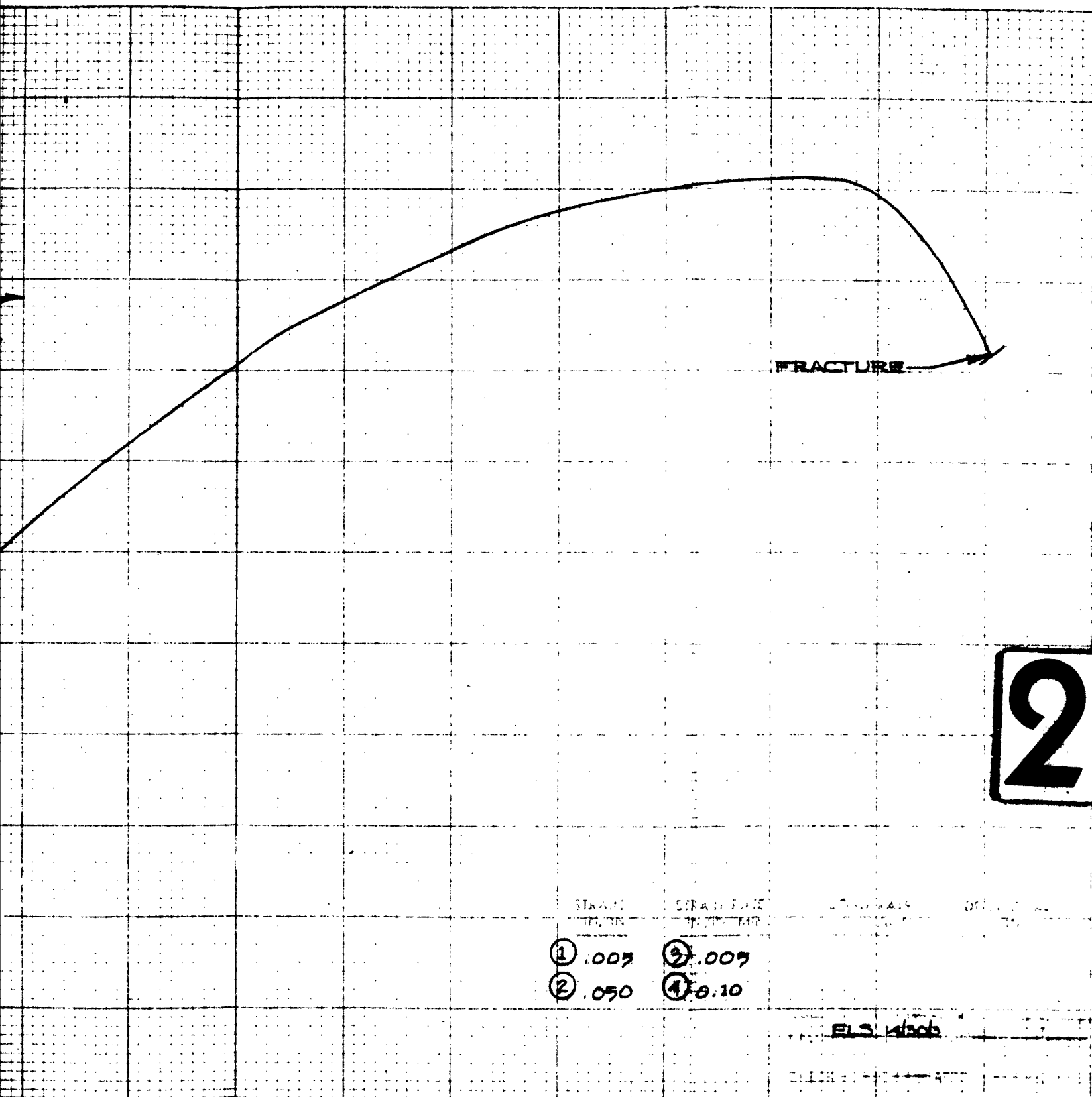
SEC 3

NO D2-80086

1

For 120K machine only





2

STRAIN IN IN	STRESS IN IN
① .005	② .005
③ .050	④ 0.10

ELC 4306

HOEING

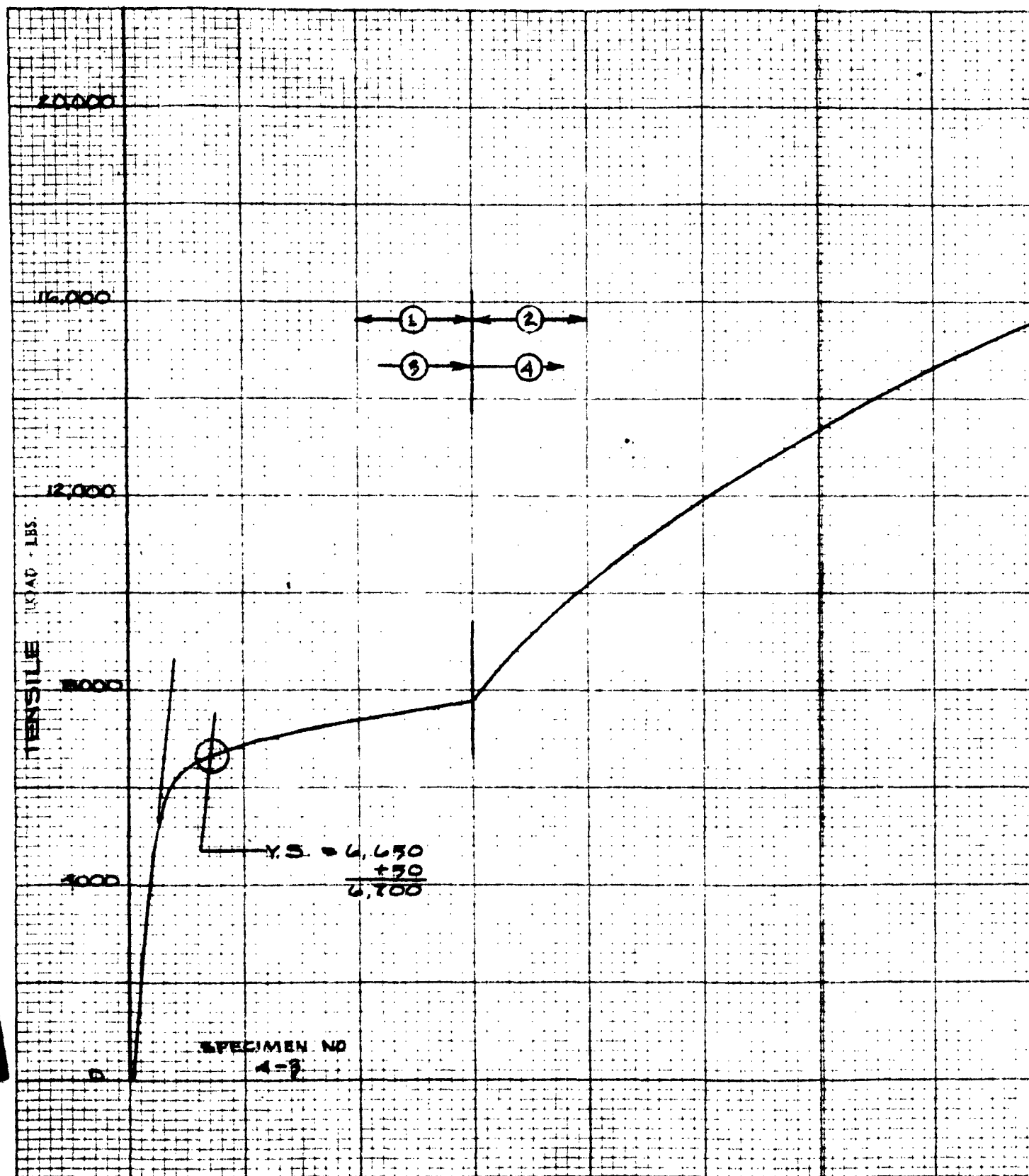
TIR

SEC 3

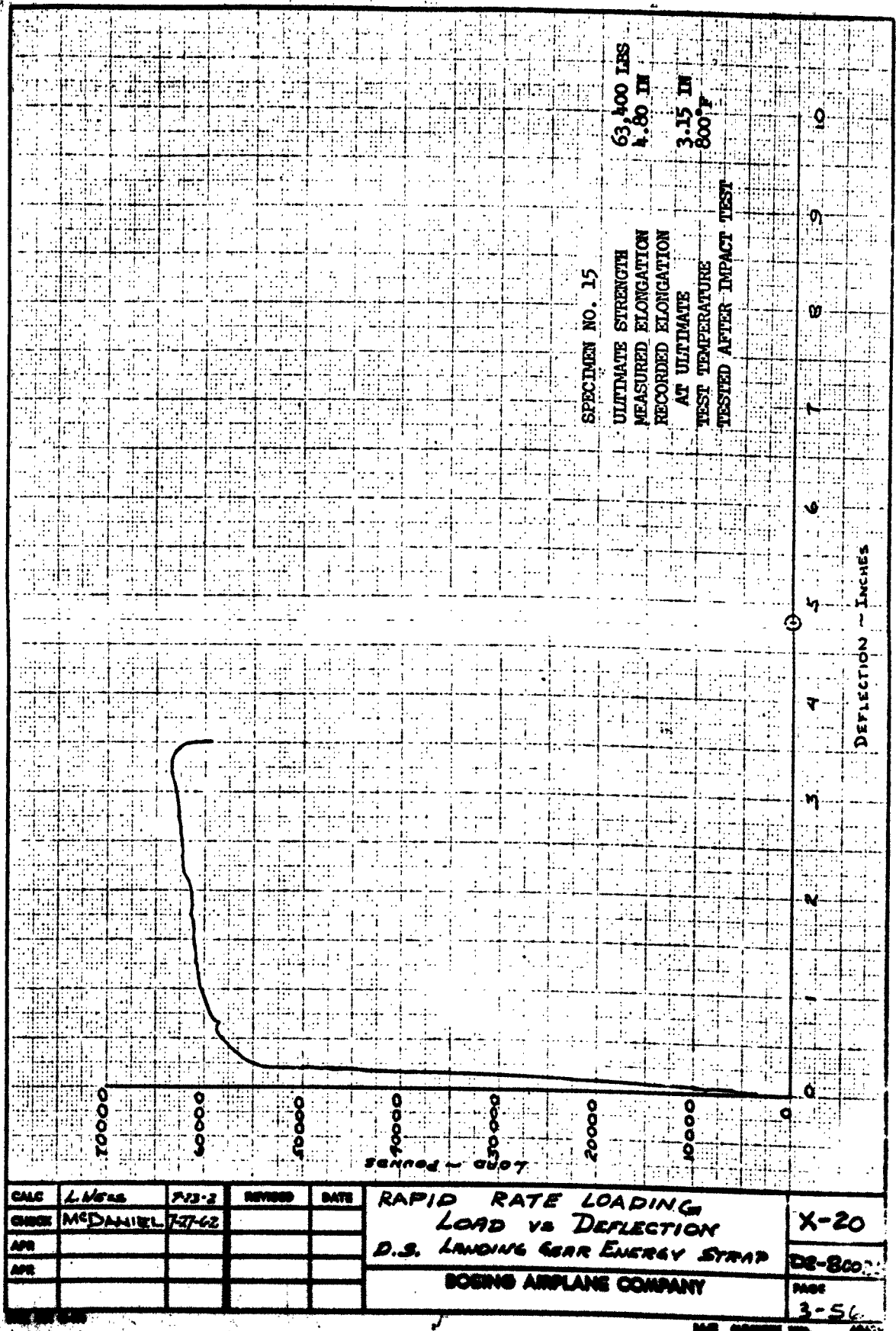
NO D2-80000

PAGE 2 - 24

For 120 K machine only



199



CALC	L.V.S.	7-13-62	REVISED	DATE	RAPID RATE LOADING LOAD vs DEFLECTION D.S. LANDING GEAR ENERGY STRAP BOEING AIRPLANE COMPANY	X-20
CHCK	MCDANIEL	7-27-62				
APR						DE-800
APR						PAGE 3-56