AD-A955 944

ASD TR 61-7-576
ASTIA NR:
OTS NR:

ASD TECHNICAL REPORT 61-7-576
MAY 1961

AD 264571
264572
264711
264685

VOLUME V

TITANIUM DEVELOPMENT PROGRAM

G. D. LINDENEAU
D. H. LOVE
J. K. NEARY
H. A. BUEHLER
G. F. FOELSCH

GENERAL DYNAMICS/CONVAIR
A Division of General Dynamics Corporation

Contract AF 33(600)34876
ASD Project: 7-576

FINAL TECHN[illegible] [illegible]GINEERING REPORT
December 1957 - May 1961

Typical airframe structures, fuselage frames, wing leading edge, bleed air ducts, tail cone, shear and compression panels of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increasing of 100° F from room temperature to maximum temperatures of 800° F and 900° F depending on the part.

Fabrication Branch
Manufacturing Technology Laboratory
United States Air Force Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

ASD TR 61-7-576
A. TIA NR:
OTS NR:

ASD TECHNICAL REPORT 61-7-576
MAY 1961

VOLUME V

TITANIUM DEVELOPMENT PROGRAM

G. D. LINDENEAU
D. H. LOVE
J. K. NEARY
H. A. BUEHLER
G. F. FOELSCH

GENERAL DYNAMICS/CONVAIR
A Division of General Dynamics Corporation

Contract AF 33(600)34876
ASD Project: 7-576

FINAL TECHNICAL ENGINEERING REPORT
December 1957 - May 1961

Typical airframe structures, fuselage frames, wing leading edge, bleed air ducts, tail cone, shear and compression panels of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increasing of 100° F from room temperature to maximum temperatures of 800° F and 900° F depending on the part.

Fabrication Branch
Manufacturing Technology Laboratory
United States Air Force Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

ABSTRACT-SUMMARY

ASD TECHNICAL REPORT 61-7-576
MAY 31, 1961

TITANIUM DEVELOPMENT PROGRAM

VOLUME V

G.D. Lindeneau
D.H. Love
J.K. Neary
H.A. Buehler
G.F. Foelsch

GENERAL DYNAMICS/CONVAIR
A Division of General Dynamics Corporation

Typical airframe structures, fuselage frames, wing leading edge, bleed air ducts, tail cone, shear panels and compression panels of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increasing increments of 100 degrees from room temperature to maximum temperatures of 800 F and 900 F, depending on the part. Riveted and resistance welded construction was evaluated in the fuselage frame and wing leading edge. Other components were either fusion welded, resistance welded, riveted or brazed. Components were subjected to static and repeated loadings with the exception of compression panels which had axial and side loads supplied. All components satisfactorily withstood static test loads. Under repeated load test, the resistance welded fuselage frame and wing leading edge, although adequate, did not perform as well as the riveted versions. Repeated load tests of resistance welded shear panels showed marginal results. Other components performed satisfactorily under repeated load conditions.

Tests of spotwelded construction in the fuselage frame and wing leading edge demonstrated the need of large margins in spotweld strengths at ends of members joined by spotwelding. Although Ti-4Al-3Mo-1V is not an optimum weldable alloy, the spotwelded assemblies of these components were considered adequate from repeated load tests at elevated temperature even though they did not perform as well as riveted construction. For example, the riveted fuselage frame withstood approximately 200% more repeated loads than the one of spotwelded construction.

Air ducts in fusion welded, seam welded and riveted and brazed configurations satisfactorily withstood static and repeated test load requirements. The seam welded construction sustained the highest pressure in the burst tests.

All resistance welded shear panels sustained design static test loads. The repeated load tests indicate that much more data is needed. The tests were not conclusive and fell short of expectations. Notch factors due to spotwelding need further investigation.

Three types of compression panels in Ti-4Al-3Mo-1V and three types of compression panels in Ti-13V-11Cr-3Al withstood combined compression load and side load from pressure in excess of design loads. Panels in Ti-13V-11Cr-3Al exhibited a brittle type of failure - probably due to low elongation in the material.

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States 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.

Qualified requesters may obtain copies of this report from ASTIA, Document Service Center, Arlington Hall Station, Arlington 12, Virginia

Copies of ASD Technical Reports should not be returned to the Aeronautical Systems Division unless return is required by security considerations, contractural obligations, or notice on a specific document.

F O R E W O R D

This is the fifth of five volumes comprising the Final Technical Engineering Report covering the work performed under Contract AF 33(600)34876. This work was conducted by General Dynamics/Convair, A Division of General Dynamics during the period, December 1957 to May 1961. This volume describes the structural testing and evaluation of the test assemblies made from the selected alloys of titanium. The manuscript was released 31 May 1961 for publication as an ASD Technical Report.

This contract was initiated under ASD Manufacturing Methods Project 7-576 "Titanium Development Program." It was administered under the direction of Mr. R. T. Jameson, ASRCTF, project engineer, Fabrication Branch of the Manufacturing Technology Laboratory (ASRCT), Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

Program work was conducted by the Applied Manufacturing Research, Operating Controls and Methods Department under the direction of A. P. Langlois, the project director, with the assistance of the Engineering Department. S. R. Carpenter was the engineering coordinator for the program; J. F. Murphy was the Applied Manufacturing Research project leader. Others who have contributed heavily to this program are C. W. Alesch, G. D. Lindeneau, D. H. Love, J. K. Neary, H. A. Buehler, G. F. Foelsch, E. D. Green, and R. D. Woodward.

The primary objective of the Air Force Manufacturing Methods Program is to increase producibility and improve the quality and efficiency of fabrication of aircraft, missiles and components thereof. This report is disseminated in order that methods and equipment developed may be made available throughout industry, thereby reducing costs or increasing capabilities, resulting in "More Air Force Per Dollar."

Your comments are solicited on the potential use of the information contained in this report as it applies to your present or future production programs. Suggestions concerning additional manufacturing methods development required on this or other subjects will be appreciated.

****

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Charles F. H. Begg

CHARLES F. H. BEGG
Colonel, USAF
Chief, Manufacturing Technology
  Laboratory
Directorate of Materials & Processes

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

TABLE OF CONTENTS*

*Tables of Contents, Lists of Tables and Lists of Figures for each section, A through G, precede each section in the text.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

TABLE OF CONTENTS

LIST OF TABLES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

I. INTRODUCTION

This report was prepared in order to present the results of the static and fatigue tests of the spotwelded and riveted bulkheads. These specimens were manufactured according to the procedures developed during previous phases of the Titanium Development Project.

Deflection, permanent set, and strain data are presented for the room-temperature static tests. Deflection and permanent set data are presented for the elevated-temperature static tests.

The objectives were to compare the characteristics of the spotwelded and riveted bulkheads.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

II. SUMMARY

Two bulkhead specimens, one riveted and one spotwelded, were tested. Each specimen was static tested to 128% design ultimate load at 800 F and then fatigue tested to failure.

The spotwelded assembly failed after 37,200 cycles of 44.5% design ultimate skin shear load at 800 F. The riveted assembly sustained 92,629 cycles of 44.5% design ultimate load, plus 5,000 cycles of 53.2% design ultimate, and failed after 33,000 cycles of 66.6% design ultimate load. The riveted specimen was overheated and repaired in one area after 12,003 cycles at 800 F.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING

1. Test Specimens:

Two canted bulkhead specimens were manufactured from 4Al-3Mo-1V titanium alloy at Convair-San Diego. One specimen was a spotwelded assembly, as shown in Figure A-1 (page 7) and the other riveted, as shown in Figure A-2 (page 9). Photographs before and after assembly are shown in Figures A-3 through A-6 (pages 11 through 14).

The first skin on the riveted bulkhead exhibited delayed cracking around the holes drilled for attachment of the shear load fixtures. There were approximately 72 hours between the drilling operation and observance of the cracks. Crack photographs are shown in Figures A-7, A-8, and A-9 (pages 15, 16 and 17).

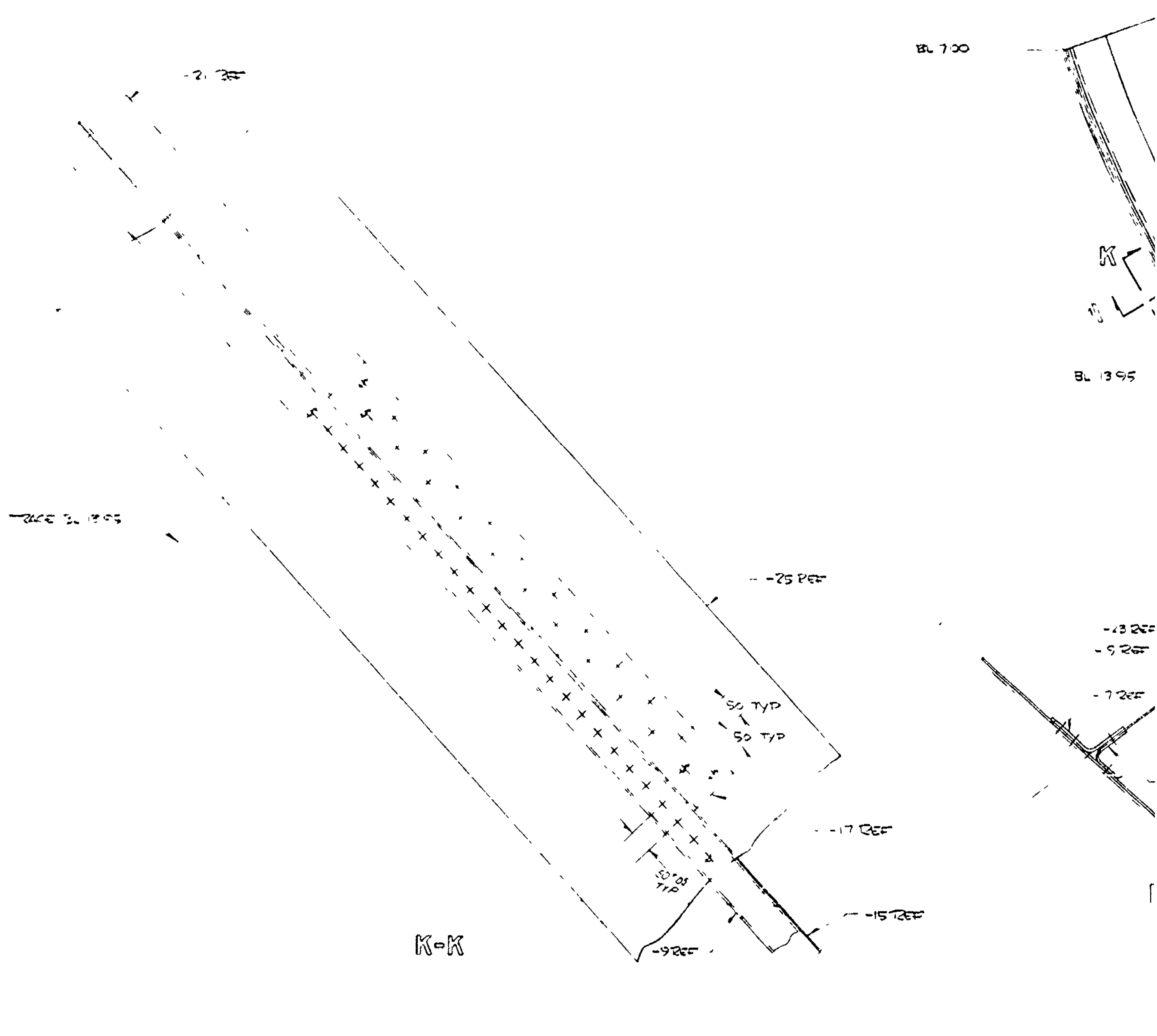
It is believed that excessive hydrogen content and drill heat may have contributed to the cracking. Hydrogen analysis was made on this skin and found to have approximately 350 PPM hydrogen content. A comparison of the skins is shown in Table A-1 (page 18).

The skin was replaced prior to test.

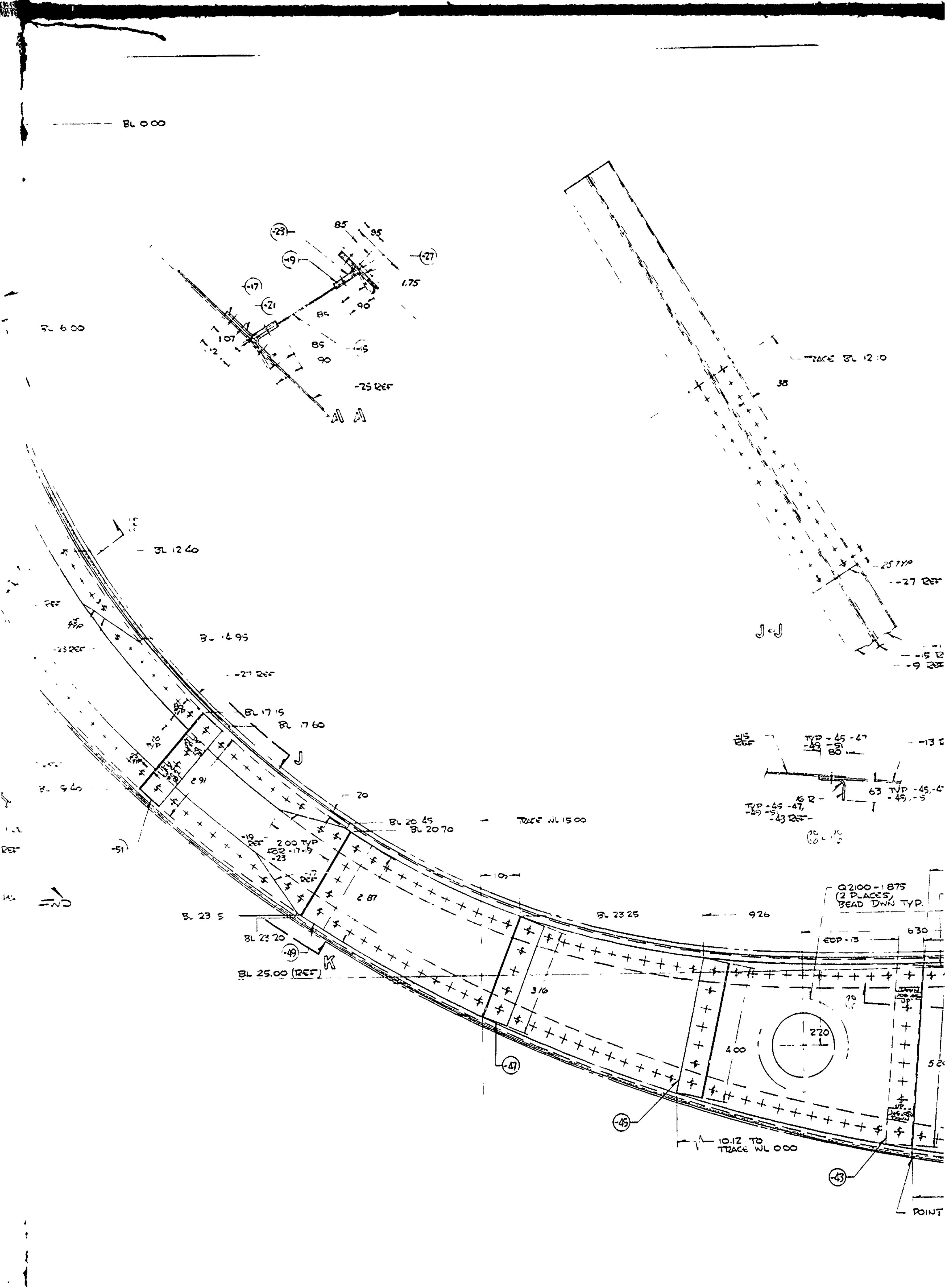
2. Test Procedure:

The test specimens were tested in the special quartz lamp oven shown in Figures A-10 through A-14 (pages 19 through 23). The specimen temperatures were controlled by thermocouples attached to the bulkhead web. The thermocouple signal was fed into the Research, Inc. heat programmer, Figure A-15 (page 24), and matched with a calibrated signal from the function generator drum, Figure A-16 (page 25). The programmer forwarded a power demand signal to the ignitrons, Figure A-17 (page 26), which in turn controlled the power to the oven.

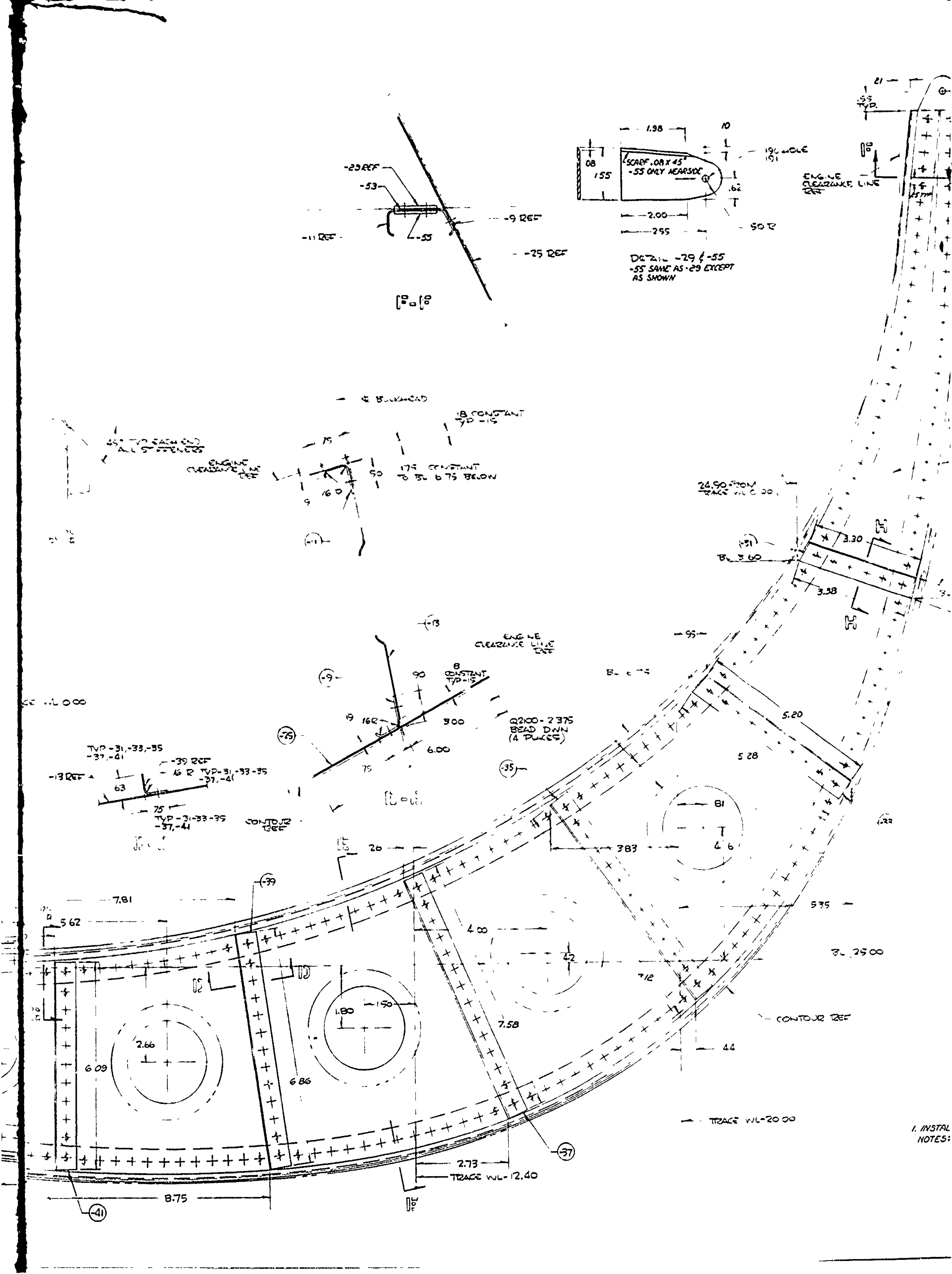
Figure A-1 - FUSELAGE CANTED BULKHEAD; Spot Welded Assembly - Engineering Drawing 29-01004, Sheet 1 of 2


-21 REF
TAKE BL 13.95
-25 REF
50 TYP
50 TYP
-17 REF
-15 REF
-9 REF
BL 7.00
K
BL 13.95
-13 REF
-9 REF
-7 REF

K-K



BL 0.00
BL 6.00
-25 REF
A A
TRACE BL 12.10
38
-25 TYP
-27 REF
J J
BL 12.60
BL 14.95
-23 REF
-27 REF
BL 17.15
BL 17.60
J
2.91
BL 9.40
-20
BL 20.45
BL 20.70
TRACE WL 15.00
-51
2.00 TYP
2.87
BL 23.5
BL 23.20
BL 23.25
9.26
K
BL 25.00 (REF)
3.16
4.00
2.20
-47
-45
-43
10.12 TO
TRACE WL 0.00
Q2100-1.875
(2 PLACES)
BEAD DWN TYP.
6.30
POINT



-29 REF
-53
-11 REF
-55
-9 REF
-25 REF
1.98
10
08
155
SCARF .08 X 45°
-55 ONLY NEARSIDE
.62
2.00
2.55
.50 R
DETAIL -29 & -55
-55 SAME AS -29 EXCEPT
AS SHOWN
ENGINE
CLEARANCE LINE
REF
18 CONSTANT
TYP -15
45° TYP EACH END
ALL STIFFENERS
179 CONSTANT
TO BL 6.75 BELOW
24.90 FROM
TRACE WL 0.00
3.30
BL 3.60
3.38
5.20
5.28
Q2100-2375
BEAD DWN
(4 PLACES)
6.00
3.00
TYP -31, -33, -35
-37, -41
-39 REF
-13 REF
-16 R TYP-31, -33-35
-37, -41
TYP -31-33-35
-37, -41
CONTOUR
REF
3.83
7.81
5.62
4.00
5.35
BL 25.00
CONTOUR REF
7.58
6.09
2.66
1.80
1.50
6.86
44
TRACE WL-20.00
2.73
TRACE WL-12.40
8.75
-41
-37
-39
-35
-9
-31
-13
-25
1. INSTAL
NOTES:

DASH NO.	DESCRIPTION	STOCK SIZE
55	PLATE	.040X1.0X3.1
53	WEB	.032X4.1X14.7
51	STIFFENER	.040×1.5×3.0
49		.040×1.5×2.9
47		.040×1.5×3.2
45		.040×1.5×4.1
43		.040×1.5×5.3
41		.040×1.4×6.1
39		.040×1.4×6.9
37		.040×1.4×7.6
35		.040×1.4×7.2
33		.040×1.4×5.4
31	STIFFENER	.040×1.4×3.4

Figure A-1 Page 7

29-0100
SH. 1 OF 2
AUTH EWO 23

REQUIREMENTS PER ASSY	PART NO.	OPP / SHN DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL / FINAL COND OF HT TREAT SEE MFG STDS BLOCK	MATL SPECIFICATION	SEE FINISH SPECIFICATIONS	ZONE	INSP CLASS
		29	PLATE	.060×1.6×3.1						
		27	CAP	.040X1.8X19.0						
		26	DOUBLER	.040×6.0×96.0						
		23	ANGLE	.050X2.7X40.8						
		21	ANGLE	.050X2.0X81.0						
		19	ANGLE	.050X1.9X20.0						
		17	ANGLE	.050×2.1×27.0						
		15	WEB	.020X3.5X40.0						
		13	WEB	.020X12.5X37.0						
		11	ANGLE	.050×1.9×84.0						
		9	ANGLE	.050×1.9×96.0						
		7	SUB ASSY.							

LIST OF MATERIAL

RIVET CODE PER NAS 523
F MFG HEAD FAR SIDE
N MFG HEAD NEAR SIDE
DIAMETER IN 32NDS
BASIC CODE
D DIMPLE
NO. OF DIMPLED SHEETS
C COUNTERSINK
LENGTH DASH NO.
BASIC CODE

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES: .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR ±0°30'
ALL MACHINED SURFACES ✓ REF MIL STD-10
INSTALL RIVETS PER 0Z001 AND FLAT HEAD SCREWS PER 0Z002
SPOTFACE AND COUNTERBORE CORNER RADIUS
HT TR AL ALY PER MIL-H-6088
HT TR STEEL PER MIL-H-6875

PRODUCIBILITY / GOVT / CHECKER / GR ENGR / MATERIAL / TOOLING / STR ENGR / WEIGHTS / DESIGN / DFTSMN

DASH NO. | CHG RECORD NO. | SERIAL NO. | NEXT ASSY | USED ON | CALC UNIT | NEXT ASSY | FINAL ASSY
APPLICATION | QTY RECD

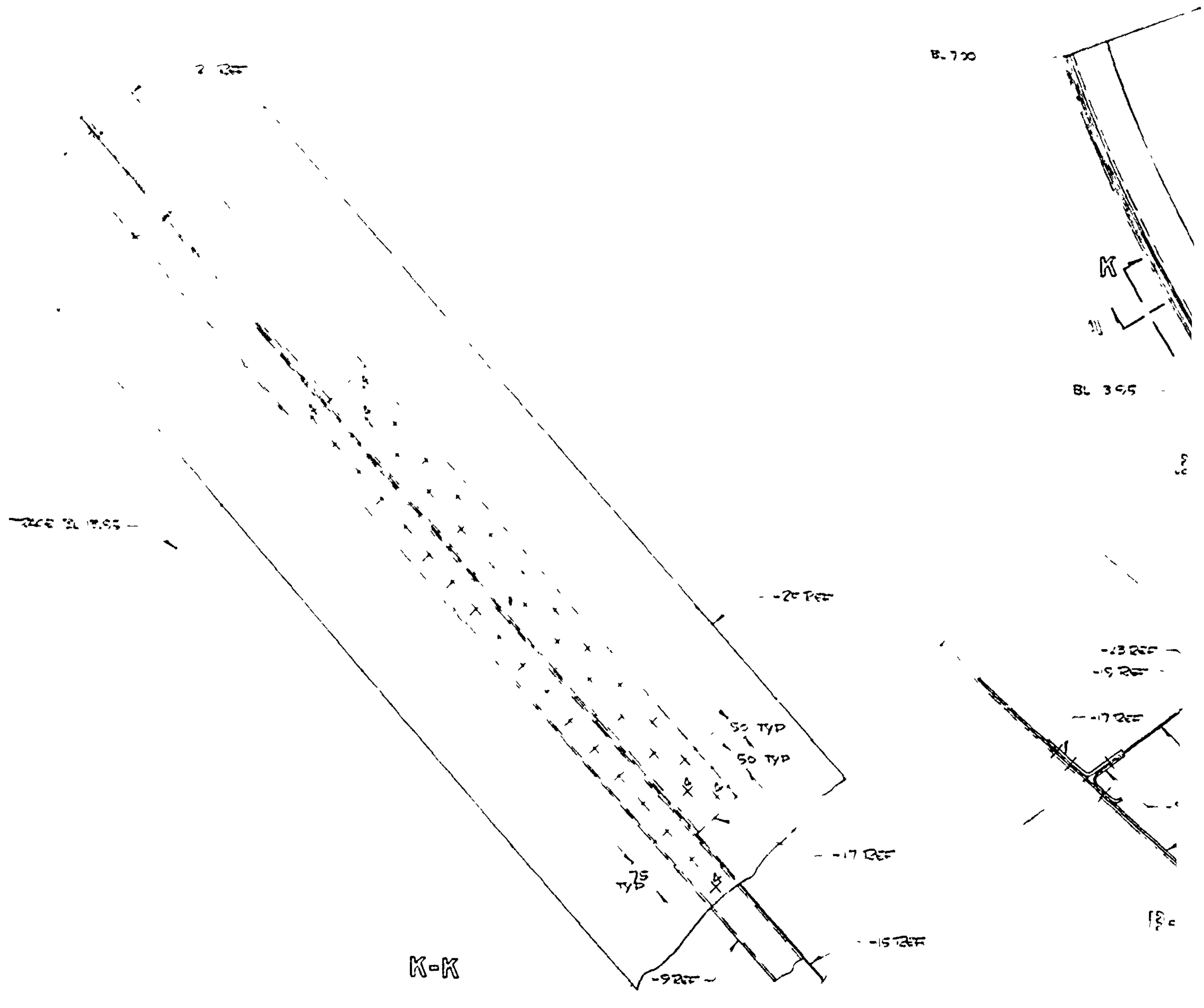
BULKHEAD INSTL.— FUS STA 672.38 CANTED, TITANIUM TEST

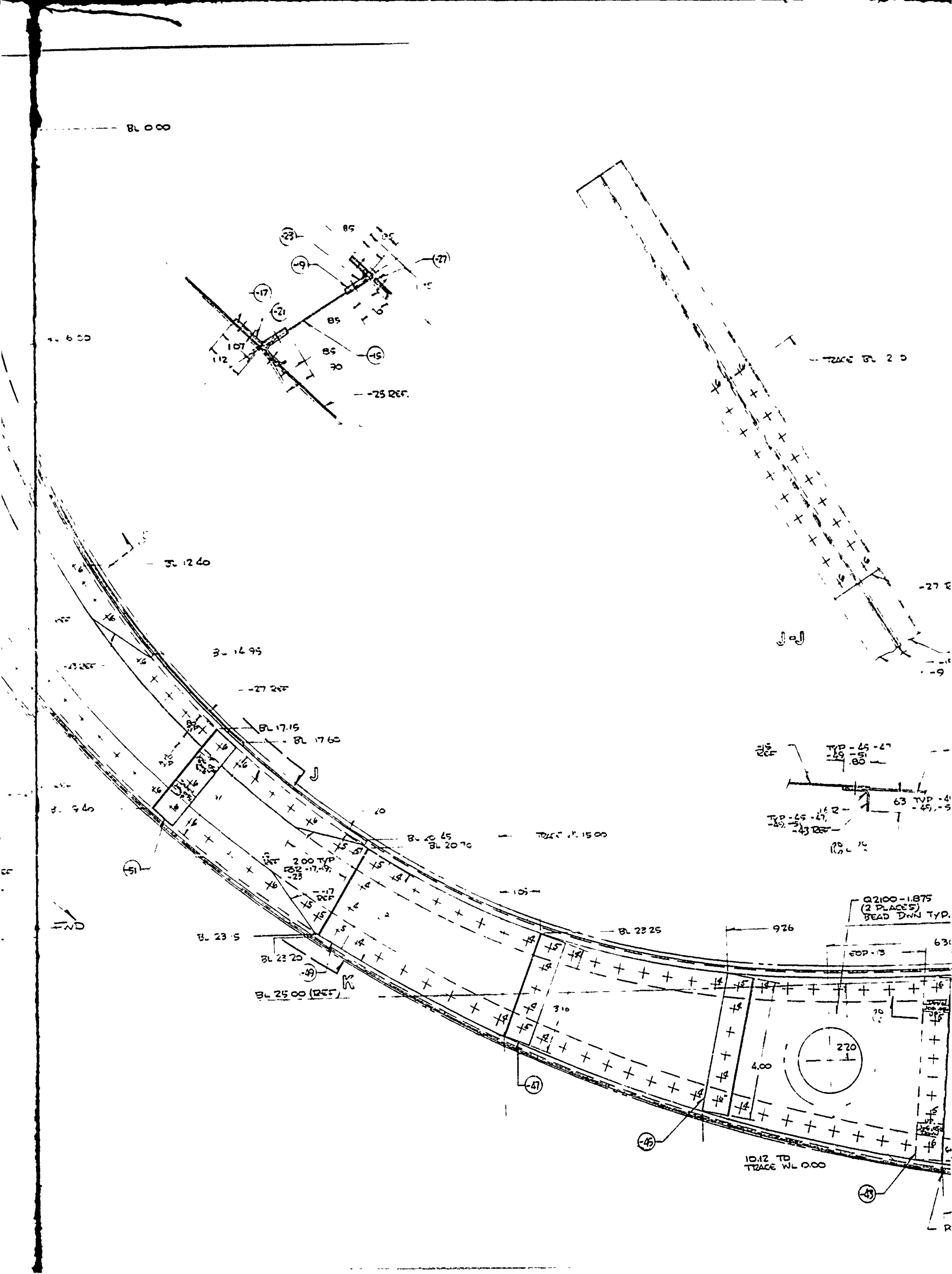
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

DWG SIZE J 29-0100
SCALE FULL
SHEET 1 OF 2
FORM 6

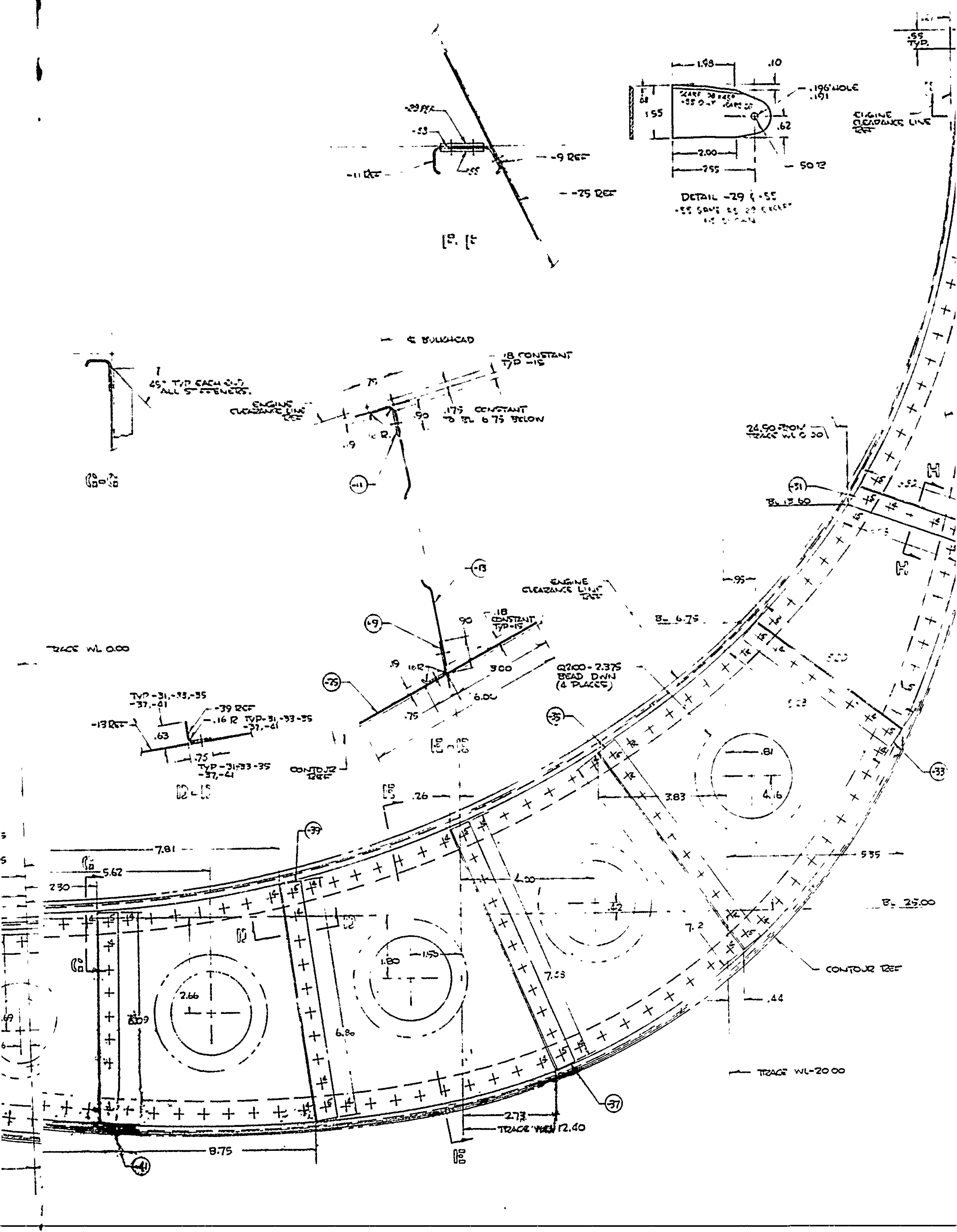
IN A

Figure A-2 - FUSELAGE CANTED BULKHEAD; Riveted Assembly - Engineering Drawing 29-01004, Sheet 2 of 2


K-K
50 TYP
50 TYP
75 TYP
-17 REF
-15 REF
-9 REF
-20 REF
BL 395
K



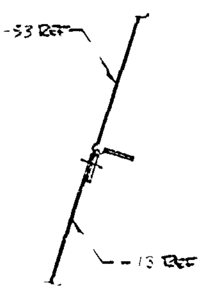
BL 0.00
-25 REF.
TRACE BL 2
BL 12.60
BL 14.95
-27 REF
BL 17.15
BL 17.60
J
BL 20.65
BL 20.70
TRACE WL 15.00
BL 23.15
BL 23.20
BL 23.25
BL 25.00 (REF)
K
2.00 TYP
Q2100-1.875
(2 PLACES)
BEAD DWN TYP.
9.26
4.00
2.20
10.12 TO
TRACE WL 0.00



DETAIL -29 & -55
.196 HOLE .191
ENGINEE CLEARANCE LINE REF
-9 REF
-25 REF
-11 REF
℄ BULKHEAD
.18 CONSTANT TYP -15
45° TYP EACH END ALL STIFFENERS.
ENGINE CLEARANCE LINE REF
.175 CONSTANT TO BL 6.75 BELOW
24.50 FROM TRACE WL 0.00
BL 13.60
BL 6.75
TRACE WL 0.00
Q200 - 2.375 BEAD DWN (4 PLACES)
TYP -31,-33,-35 -37,-41
-39 REF
-13 REF
.16 R TYP -31,-33-35 -37,-41
TYP -31,-33-35 -37,-41
CONTOUR REF
BL 25.00
CONTOUR REF
TRACE WL-20.00
TRACE WL 12.40
7.81
5.62
8.75
3.83
5.35

— BL 0.00

REVISIONS								
EFF ON	INCORP	SYM	DESCRIPTION	ZONE	DATE	APPROVAL	EFF ON	INCORP



H-H

PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL
NAS 528M6		RIVETS		
NAS 508M5		RIVETS		
NAS 508M4		RIVETS		
	55	PLATE	.062 × .6 × [illegible]	
	53	WEB	.032 × 6. × 1.7	
	51	STIFFENER	.040 × 1.5 × 30	
	49		.040 × 1.5 × 29	
	47		.040 × 1.5 × 3[illegible]	
	[illegible]		[illegible] × 1.5 × 41	
	43		.040 × 1.5 × 53	
	41		.040 × 1.4 × 61	
	39		.040 × 1.4 × 69	
	37		.040 × 1.4 × 76	
	35		.040 × 1.4 × 72	
	33		.040 × 1.4 × 54	
	31	STIFFENER	.040 × 1.6 × [illegible]	

Figure A-2

PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL
	29	PLATE	[illegible] × 1.6 × 31	
	27	CAP	.040 × 1.8 × 190	
	25	DOUBLER	.040 × 6.0 × 90.2	
	23	ANGLE	.050 × 1.7 × 10.3	
	21	ANGLE	.050 × 2.0 × [illegible]	
	19	ANGLE	[illegible] × 1.9 × [illegible]	
	17	ANGLE	.050 × 2.[illegible] × [illegible]	
	15	WEB	.020 × 5.5 × 40.[illegible]	
	13	WEB	.020 × 12.5 × 57.0	
	11	ANGLE	[illegible] × 1.9 × [illegible]	
	9	ANGLE	.032 × 1.9 × [illegible]	
	7	SUB ASSY		

REQUIREMENTS PER ASSY — LIST OF MATERIAL

2 ALL RIVETS NAS508 UNLESS OTHERWISE NOTED
+— DENOTES RIVET DIA IN 32ND'S
1 INSTALL RIVETS IN ACCORDANCE WITH O-05035

NOTES:

DASH NO.	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY
				TEST		QTY REQD	

APPLICATION

RIVET CODE PER NAS 523 — BASIC CODE — DIMPLE — NO. OF DIMPLED SHEETS — C COUNTERSINK — LENGTH DASH NO.

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES .X ±.1, .XX ±.03, .XXX ±.010, ANGULAR ±0°30'
ALL MACHINED SURFACES ✓ REF MIL-STD-10
INSTALL RIVETS PER [illegible]
FLAT HEAD SCREWS PER [illegible]
SPOTFACE AND COUNTERBORE CORNER RADIUS [illegible]
HT TR ALALY PER MIL-H-[illegible]
HT TR STEEL PER MIL-H-[illegible]

PRODUCIBILITY — GOVT — CHECKER — GR ENGR — MATERIAL — TOOLING — STR ENGR — WEIGHTS — DESIGN — DFTSMN

REVISIONS						
EFF ON	INCORP	SYM	DESCRIPTION	ZONE	DATE	APPROVAL
		A	ADDED NOTE 2 & NAS 508 RIVETS		4/3/59	

D

C

B

PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL
NAS 508M6		RIVETS		
NAS 508M5		RIVETS		
NAS 508M4		RIVETS		
	53	PLATE	.062 × 6 × 8	
	52	WEB	.032 × 6 × 17	
	51	STIFFENER	.040 × 1.5 × 3.0	
	49		.040 × 1.5 × 2.9	
	47		.040 × 1.5 × 3.6	
	45		.040 × 1.5 × 4.1	
	43		.040 × 1.5 × 5.3	
	41		.040 × 1.6 × 6.1	
	39		.040 × 1.6 × 6.9	
	37		.040 × 1.6 × 7.6	
	35		.040 × 1.6 × 7.7	
	33		.040 × 1.6 × 5.4	
	31	STIFFENER	.040 × 1.6 × 8.6	

Figure A-2

29-01004
SHEET 2 OF 2 | A
AUTH EWO 2380

PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND OR HT TR (ASH)	FINAL	MATL SPECIFICATION	SEE FINISH SPECIFICATIONS	ZONE	INSP CLASS	CALC UNIT WT
	29	PLATE	.040 × 1.6 × 2.1								
	27	CAP	.040 × 1.8 × .90								
	25	DOUBLER	.040 × 6.0 × 9.2								
	23	ANGLE	.050 × 1.7 × 10.3								
	21	ANGLE	.050 × 2.0 × 8								
	19	ANGLE	.050 × 1.9 × 25.0								
	17	ANGLE	.050 × 2.1 × 26.0								
	15	WEB	.020 × 9.5 × 40								
	13	WEB	.020 × 12.5 × 37.0								
	11	ANGLE	.050 × 1.9 × 26.0								
	9	ANGLE	.050 × 1.9 × 26								
	7	SUB ASSY									

REQUIREMENTS PER ASSY — LIST OF MATERIAL

A

... UNLESS OTHERWISE NOTED
... IN 32NDS
...ORDANCE WITH 0 05035

DASH NO.	CHG PER CHG NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY
				TEST			
APPLICATION						QTY REQD	

RIVET CODE PER NAS 523 — HEAD MARKING; DIAMETER IN 32NDS; BASIC CODE; D DIMPLE; NO. OF DIMPLED SHEETS; C COUNTERSINK; LENGTH DASH NO.

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES: .X ±.1; .XX ±.03; .XXX ±.010; ANGULAR ±0°30'
ALL MACHINED SURFACES ✓ REF MIL-STD-10
INSTALL RIVETS PER ... PLAT HEAD SCREWS PER ...
SPOTFACE AND COUNTERBORE CORNER RADIUS ...
HT TR AL ALY PER MIL-H-6088; HT TR STEEL PER MIL-H-6875

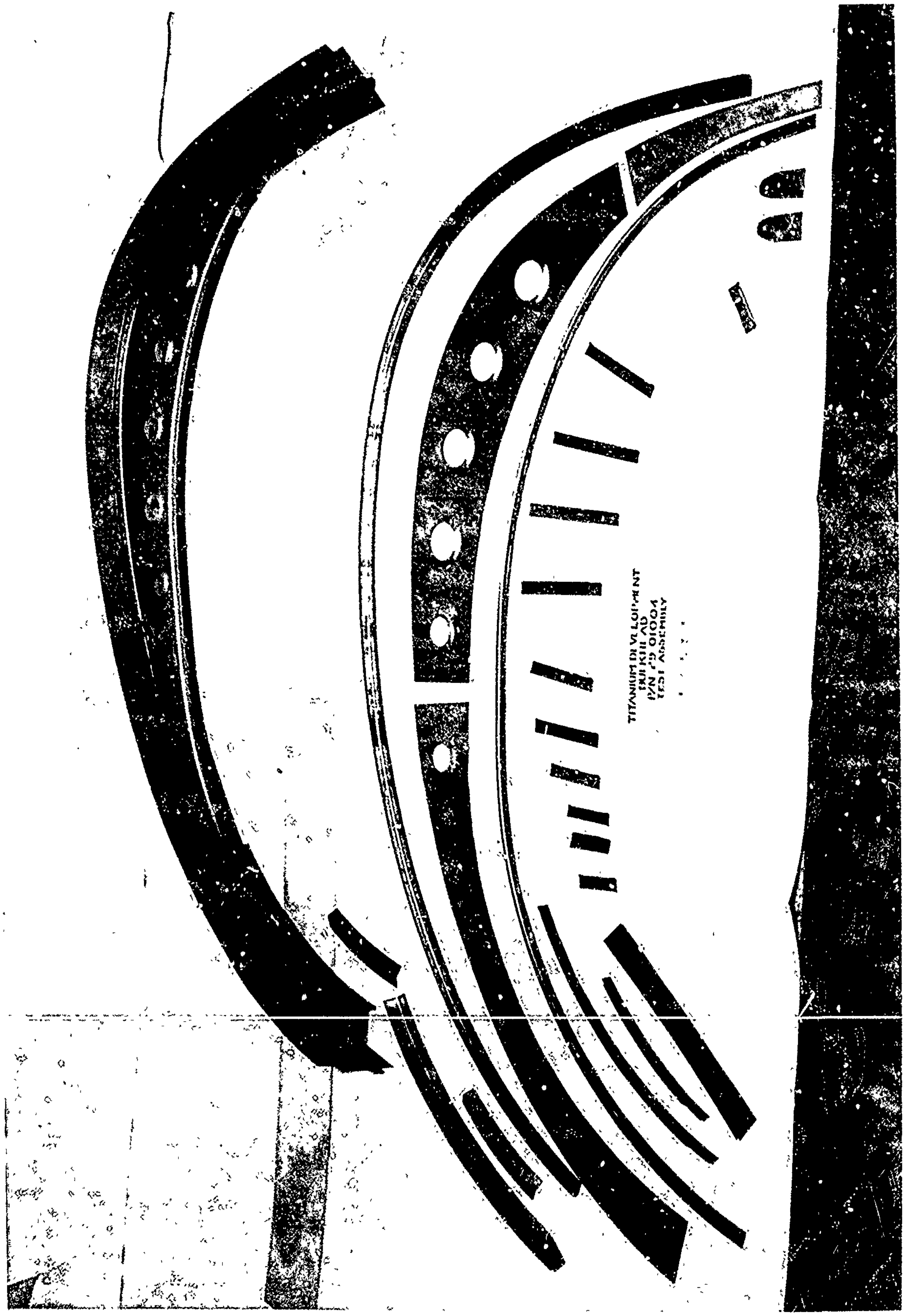
PRODUC-IBILITY / GOVT / CHECKER / GR ENGR / MATERIAL / TOOLING / STR ENGR / WEIGHTS / DESIGN / DFTSMN

BULKHEAD INSTL. – FUS STA 672.53 CANTED, TITANIUM TEST

SCALE FULL | REL

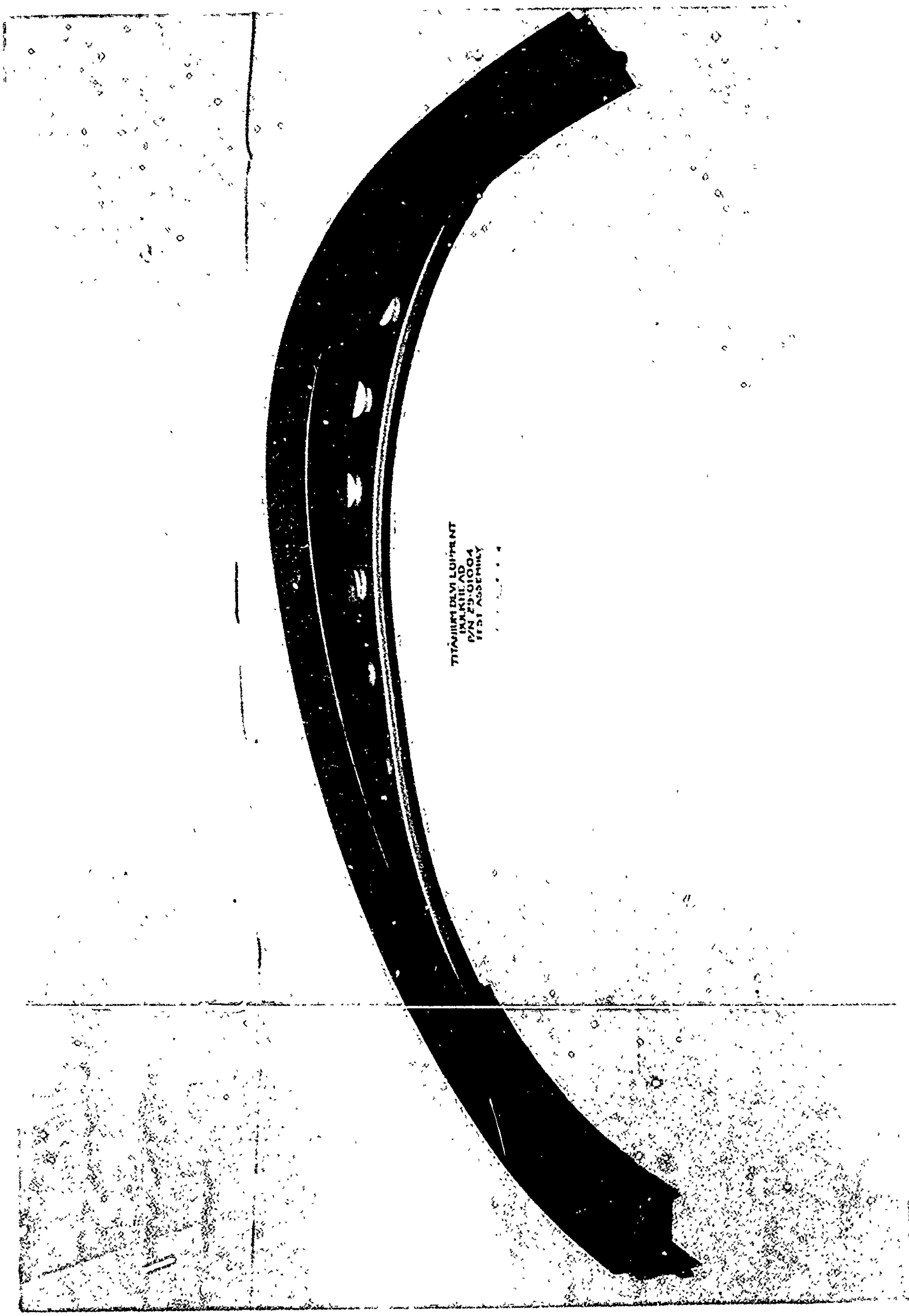
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

SIZE J | DWG 29-01004 | SHEET 2 OF 2



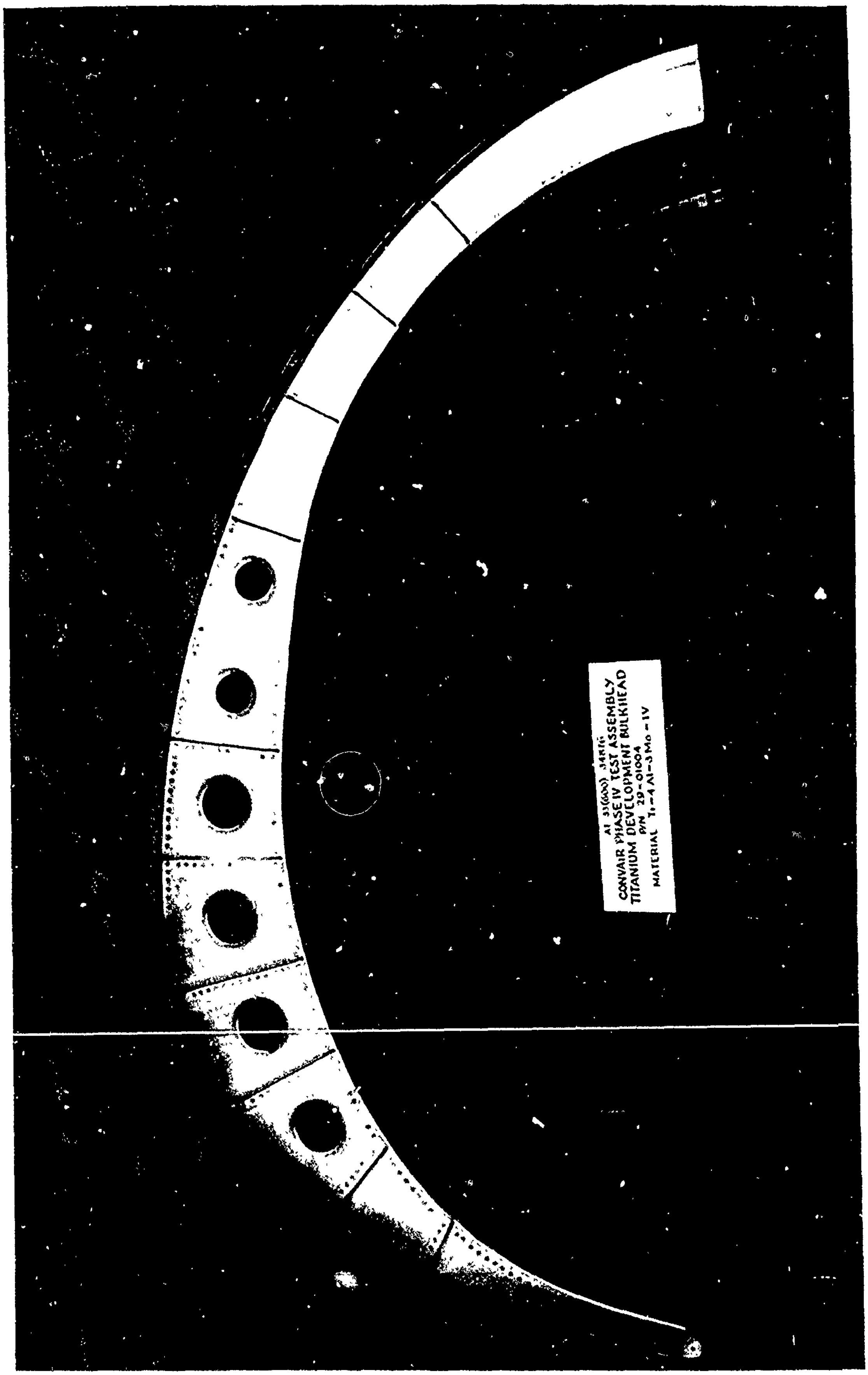
Convair Print 55695

Figure A-3 — FUSELAGE CANTED BULKHEAD; Specimen Details and Riveted Assembly.



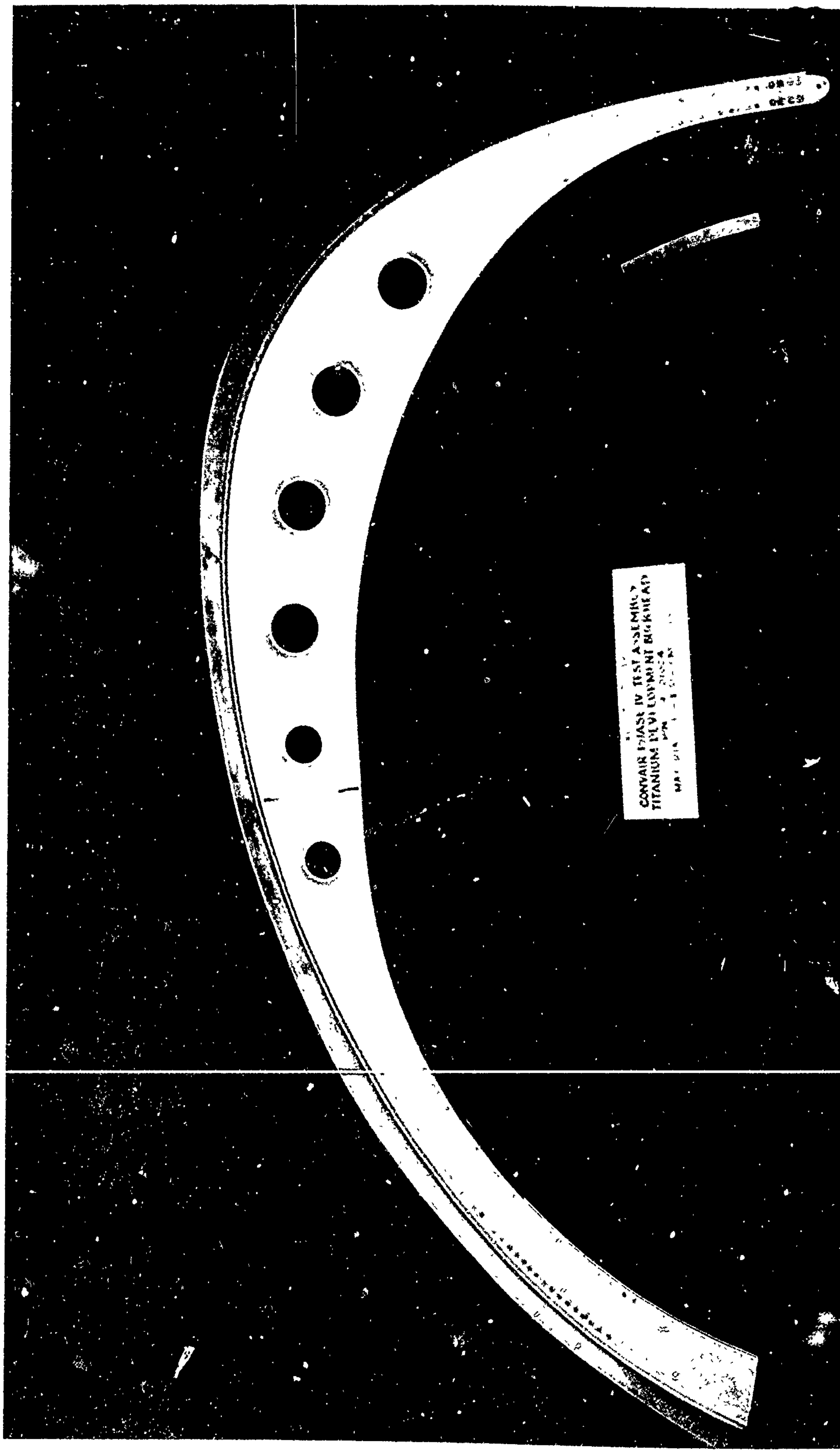
Convair Print 55698

Figure A-4 — FUSELAGE CANTED BULKHEAD; Riveted Assembly.



Convair Print 56585

Figure A-5 — FUSELAGE CANTED BULKHEAD; Spot Welded Assembly.



Convair Print 56586

Figure A-6 — FUSELAGE CANTED BULKHEAD; Spot Welded Assembly.

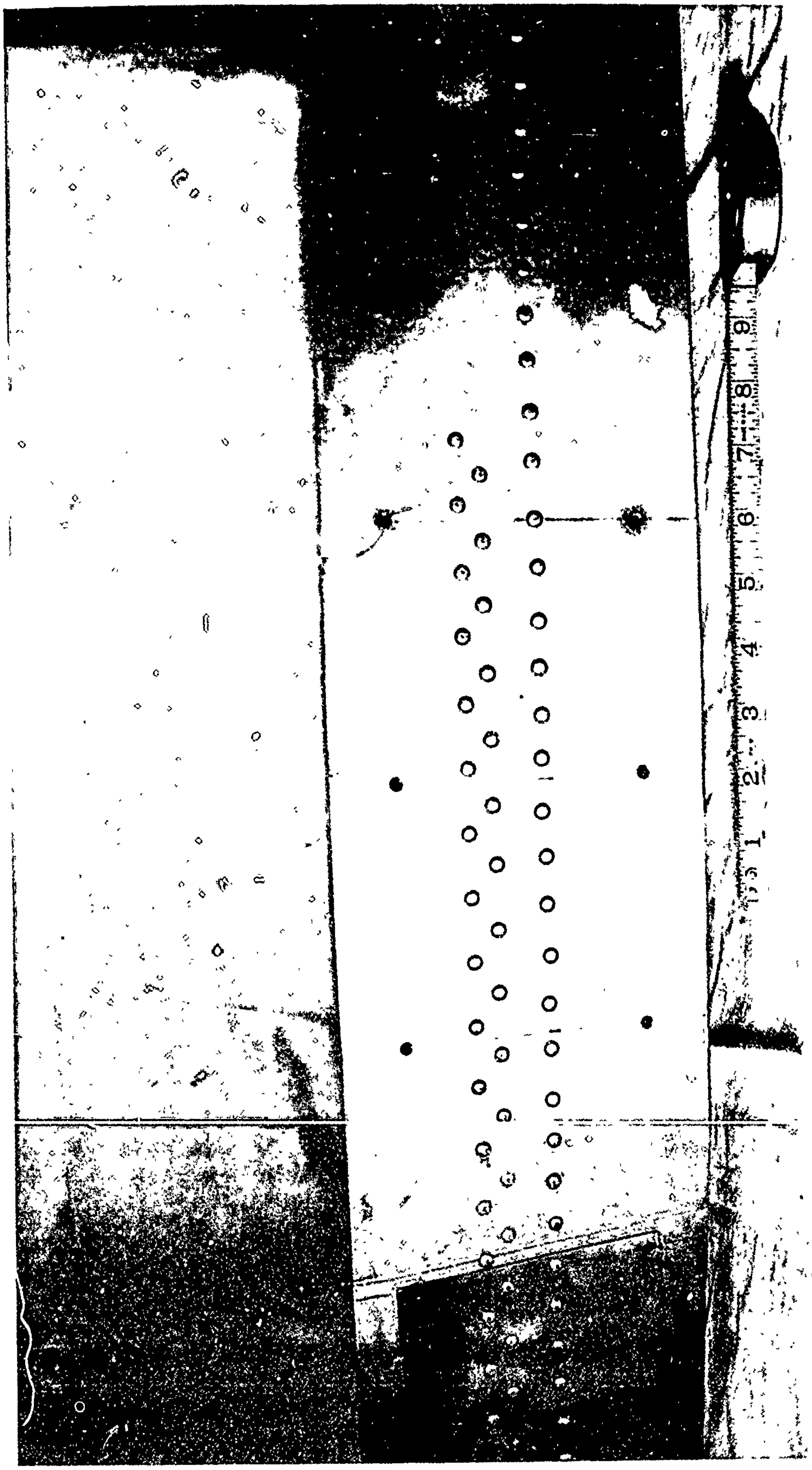
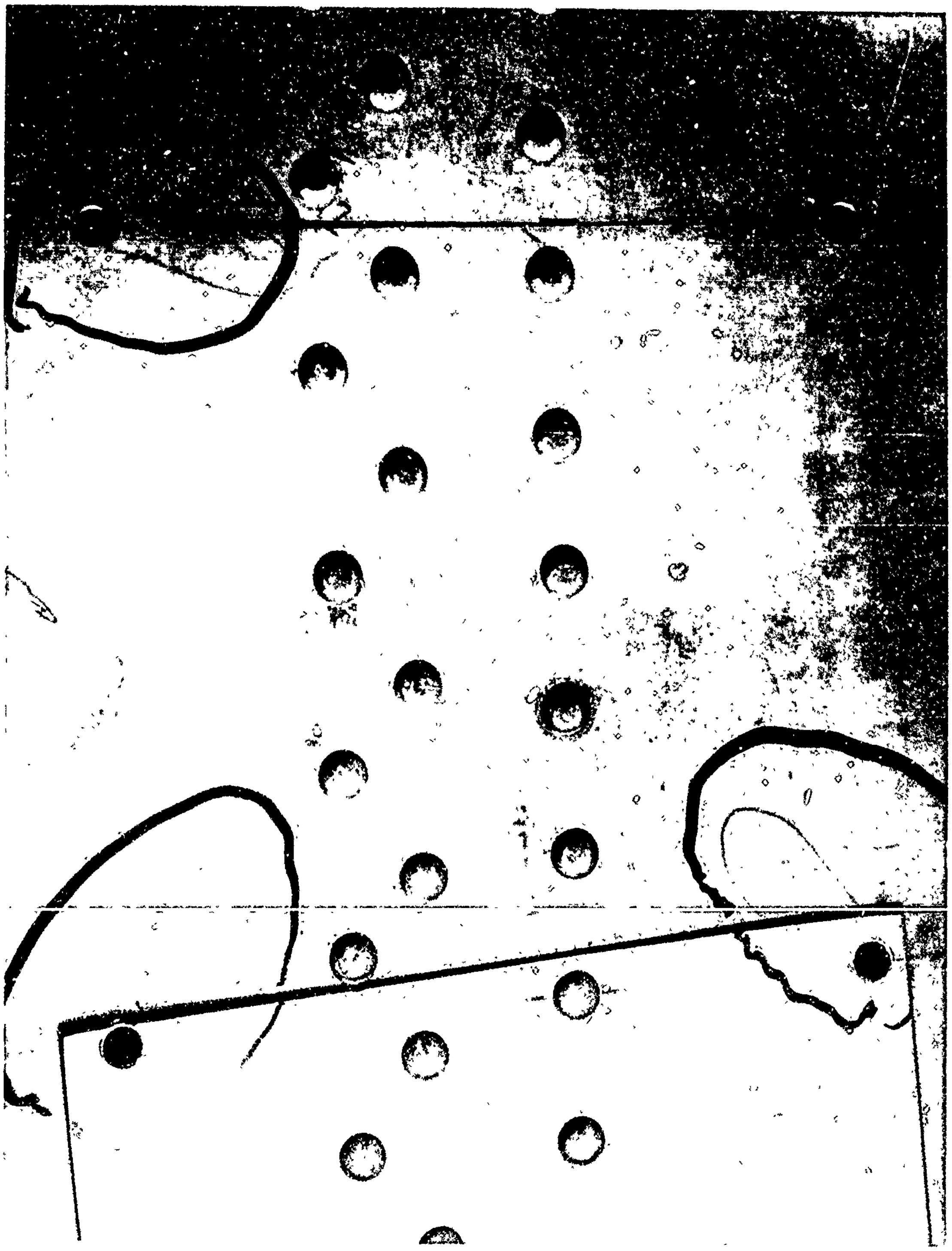


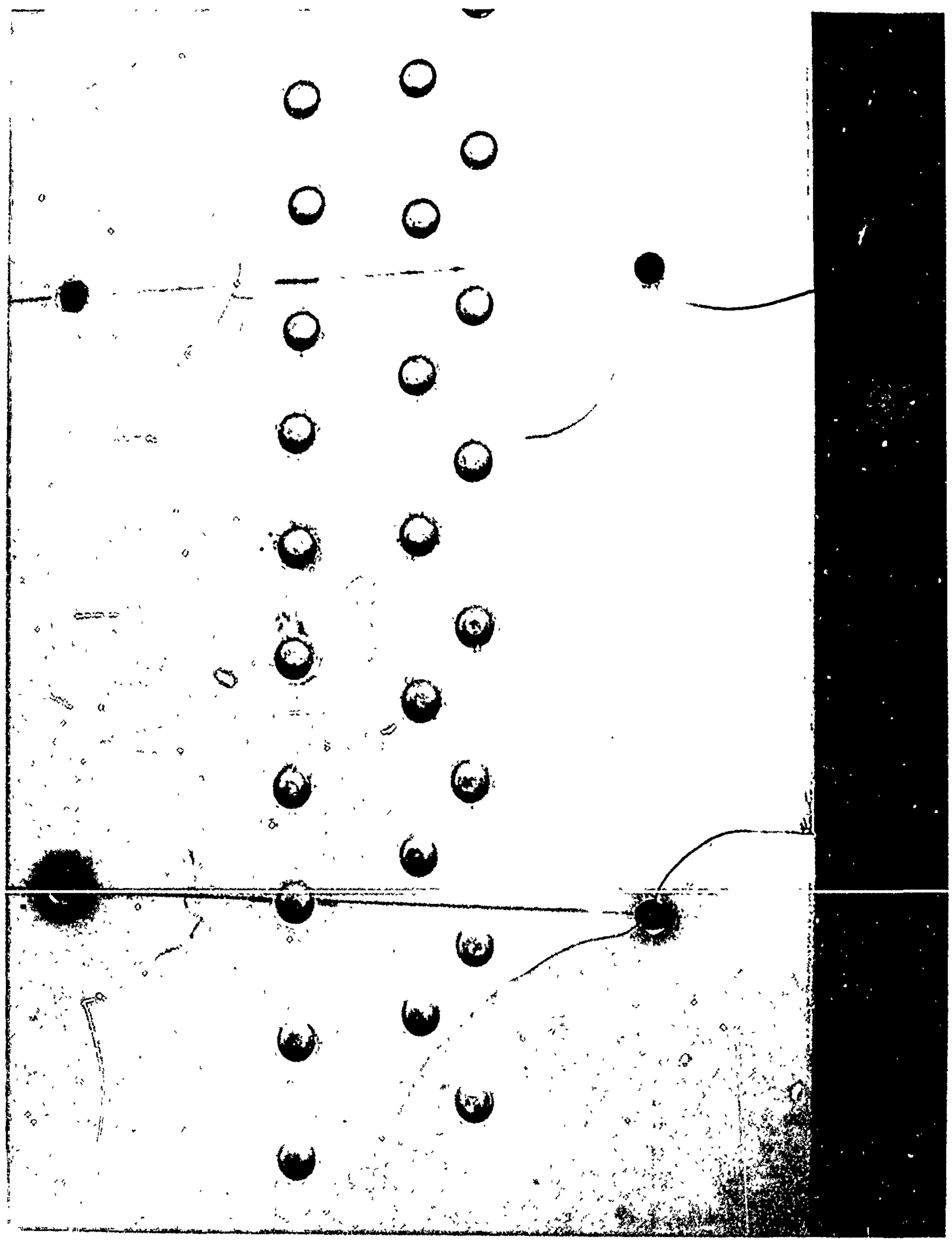
Figure A-7 — FUSELAGE CANTED BULKHEAD; Delayed Cracking after Drilling Operation.

Convair Print 57245



Convair Print 57247

Figure A-8 — FUSELAGE CANTED BULKHEAD; Delayed Cracking After Drilling Operation.

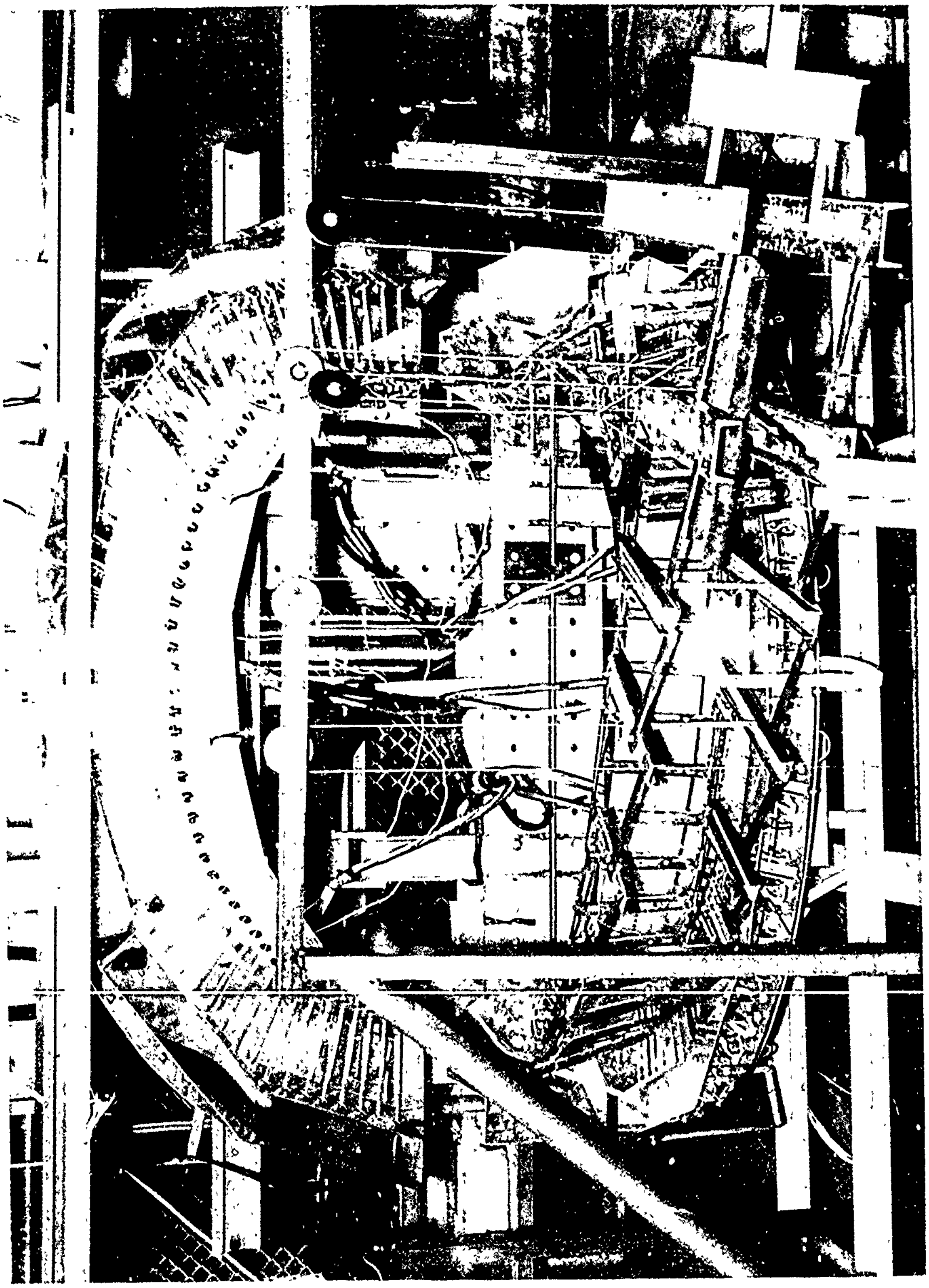


Convair Print 57246

Figure A-9 – FUSELAGE CANTED BULKHEAD; Delayed Cracking after Drilling Operation.

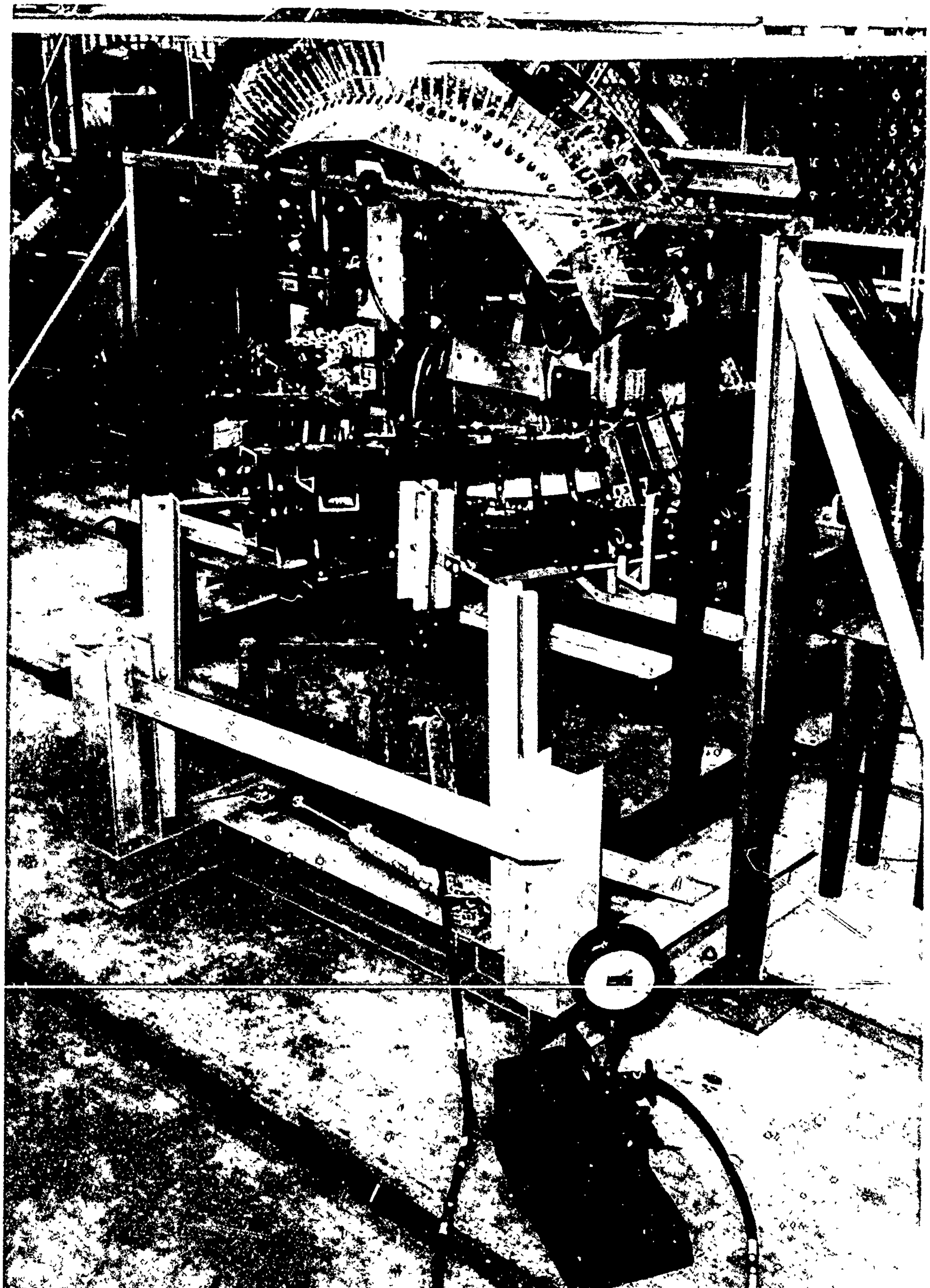
TABLE A-1 - A COMPARISON OF BULKHEAD SKINS

SKIN NO.	SPEC NO.	PHYSICAL PROPERTIES YIELD STRENGTH (psi)	ULTIMATE STRENGTH (psi)	ELONGATION (% in 2")	HYDROGEN CONTENT (ppm)	REMARKS
R-1	1	183,333	207,990	6.0	335	This skin exhibited delayed cracking after drilling for load points.
	2	183,878	209,112	5.0	350	
	3	This specimen failed in the grips			399	
	4	184,816	212,041	4.5	393	
	5	186,578	198,421	5.5	344	
	6	174,736	199,210	5.5	350	
R-2	1	176,903	202,284	5.5	94	This skin was subjected to the test program outlined for the riveted bulkhead prior to analysis.
	2	176,847	201,970	5.0	87	
	3	172,636	201,243	4.5	96	
	4	173,529	201,225	4.5	91	
	5	160,426	188,862	6.0	97	
	6	160,047	188,277	6.0	96	
S-1	1	166,666	193,502	3.5	106	This skin was subjected to the test program outlined for the spot.welded bulkhead prior to analysis.
	2	177,428	192,857	4.0	107	
	3	160,335	192,737	3.5	105	
	4	160,919	194,827	4.5	108	
	5	167,151	197,383	4.5	112	
	6	167,543	191,812	5.5	117	



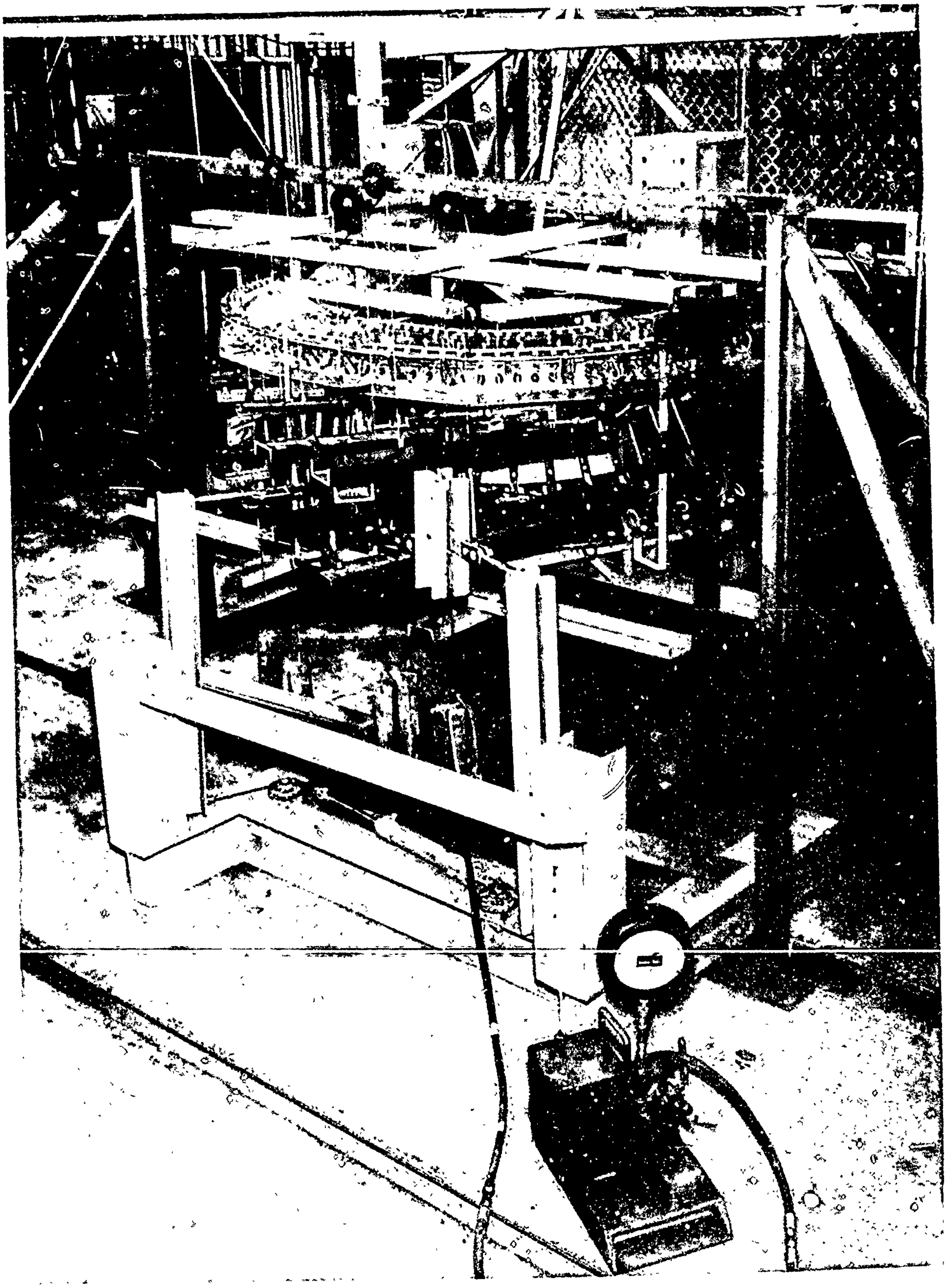
Convair Print 57910

Figure A-10 — FUSELAGE CANTED BULKHEAD; Static and Fatigue Test Set Up Showing the Specimen in Position in the Oven.



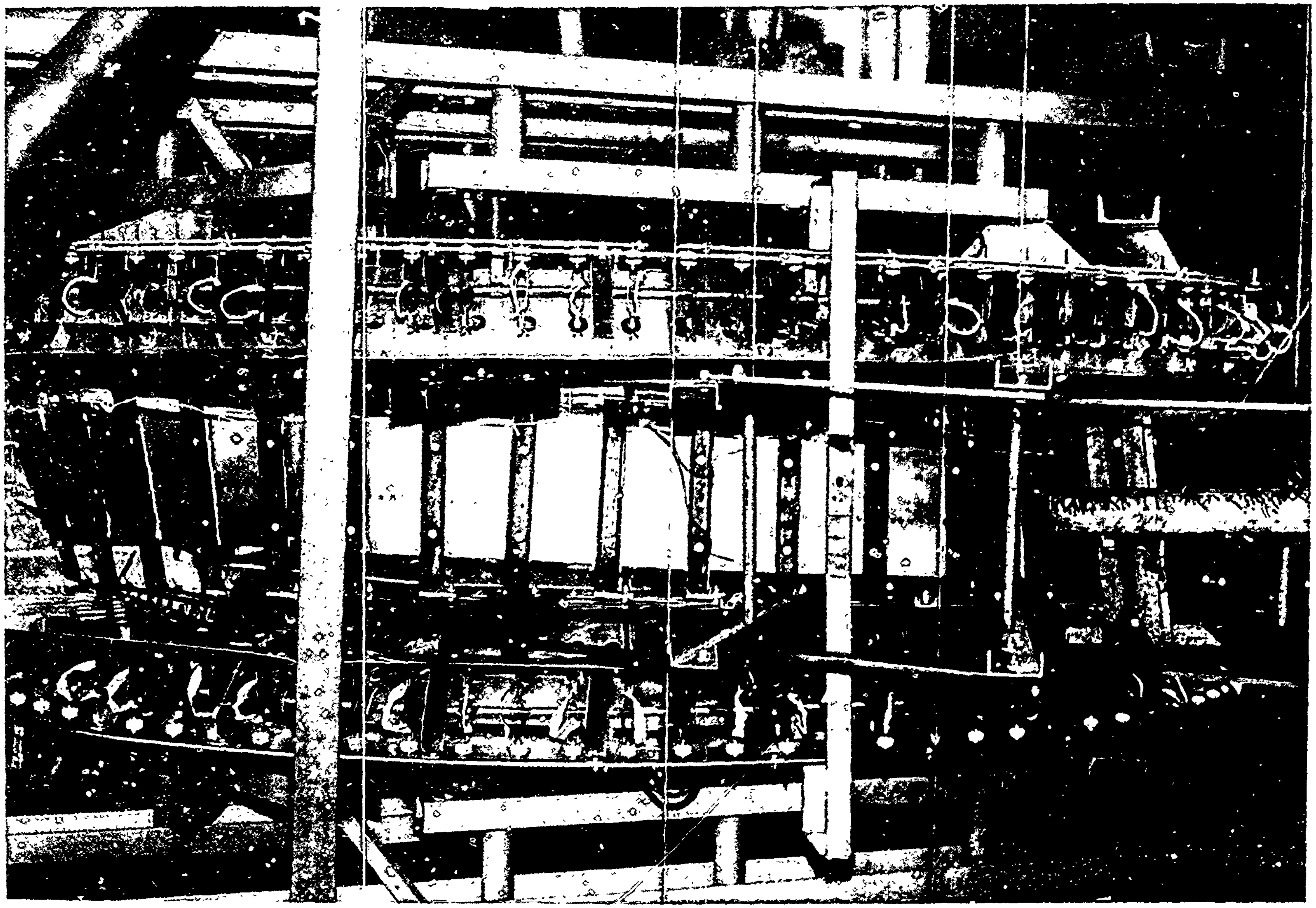
Convair Print 57906

Figure A-11 – FUSELAGE CANTED BULKHEAD; Static and Fatigue Test Set Up Showing the Specimen in Position in the Oven.



Convair Print 57907

Figure A-12 — FUSELAGE CANTED BULKHEAD; Static and Fatigue Test Set Up Showing the Specimen in Position in the Oven.



Convair Print 57908

Figure A-13 — FUSELAGE CANTED BULKHEAD; Static and Fatigue Test Set Up Showing the Specimen in Position in the Oven.

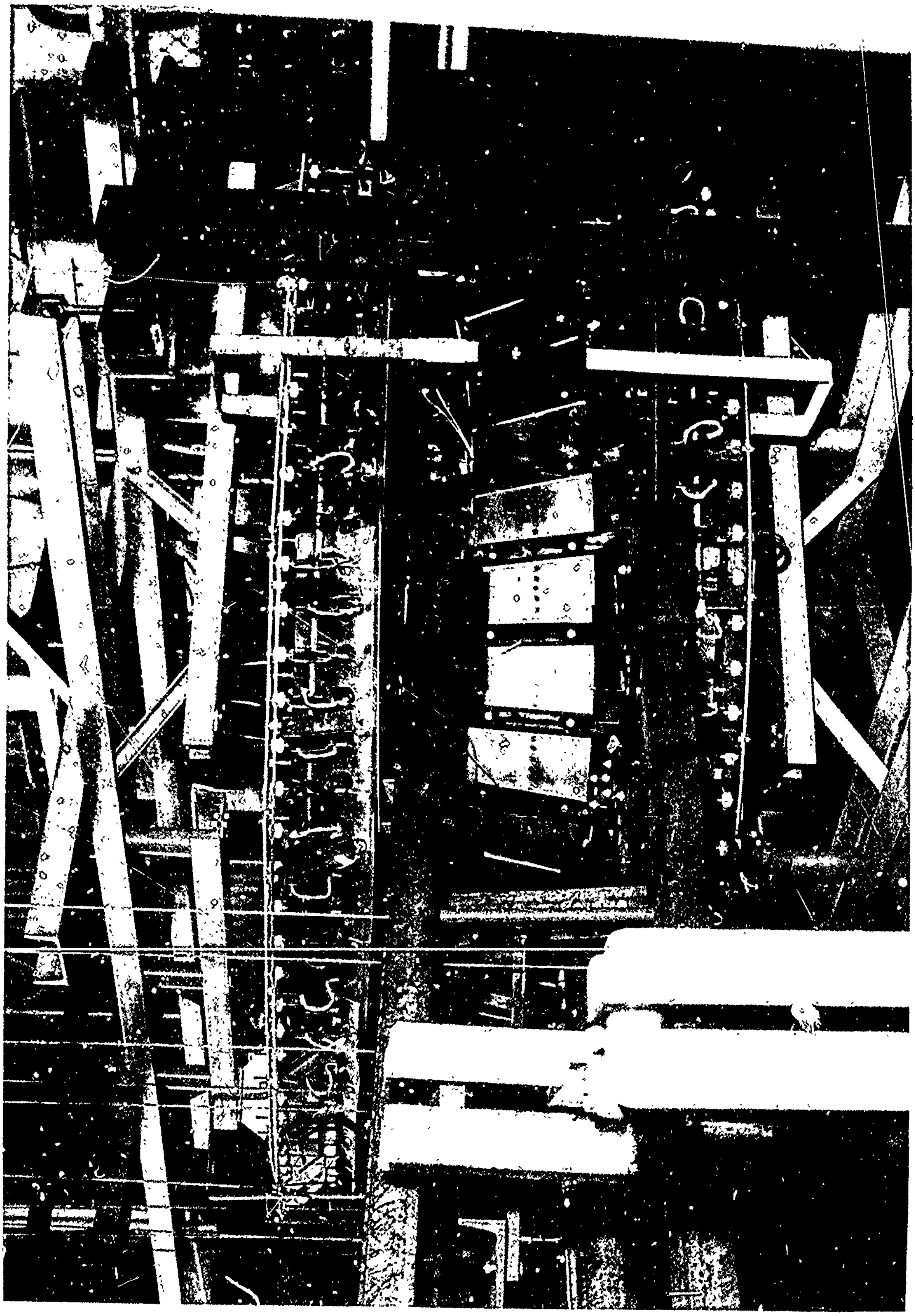
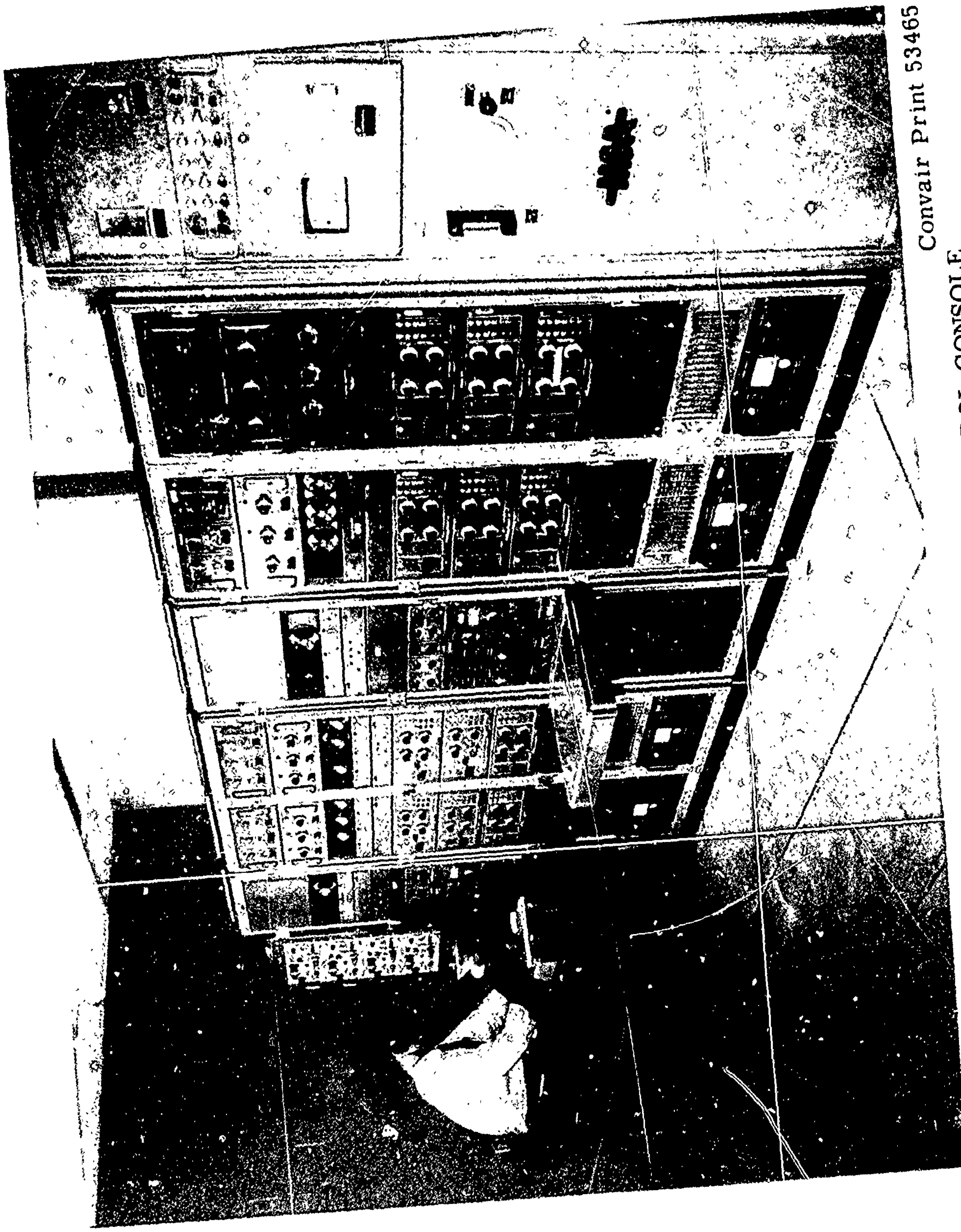


Figure A-14 — FUSELAGE CANTED BULKHEAD; Static and Fatigue Test Set Up Showing the Specimen in Position in the Oven.

Convair Print 57909



Convair Print 53465

Figure A-15 – HEAT PROGRAM CONTROL CONSOLE

Convair Print 41441

Figure A-16 — HEAT PROGRAMMER CONTROL BOARD AND FUNCTION GENERATOR DRUM; With a Typical Heat Program Curve.

Convair Print 41431

Figure A-17 — INGITRON POWER CONTROL CONSOLE.

III. 2. Test Procedure: (Cont'd)

The specimen was reinforced at the fixed end with suitable doublers and angles, Figure A-18 (page 28), in order to assure sufficient strength at the specimen-fixture attachment point. The flanges were laterally supported at three points.

The specimen was loaded through fixtures attached to the skin to provide a skin shear load at each load point. Each load point was integrated into a whippletree and lever system in order that all loads could be applied with one hydraulic cylinder, Figure A-12 (page 21). The schematic diagram for design ultimate load is shown in Figure A-19 (page 29). The design ultimate reaction load parallel to Buttock Line 00.0 is shown as 1432 pounds. This reaction load on this line was measured during the static tests.

Eight strain gages (for room temperature static tests), eight calibrated dial indicators (for all static tests), and fifteen thermocouples were installed on the specimen. The locations of the strain gages and thermocouples are shown in Figures A-1 and A-2 (pages 7 and 9), and the deflection points are shown in Figure A-20 (page 30).

The following test schedule was performed in the order shown on both the spotwelded and riveted bulkheads:

a. Static Tests -

Room Temperature to 80% design ultimate

200 F to 66.6% design ultimate or design limit

300 F to 66.6% design ultimate

400 F to 66.6% design ultimate

500 F to 66.6% design ultimate

600 F to 66.6% design ultimate

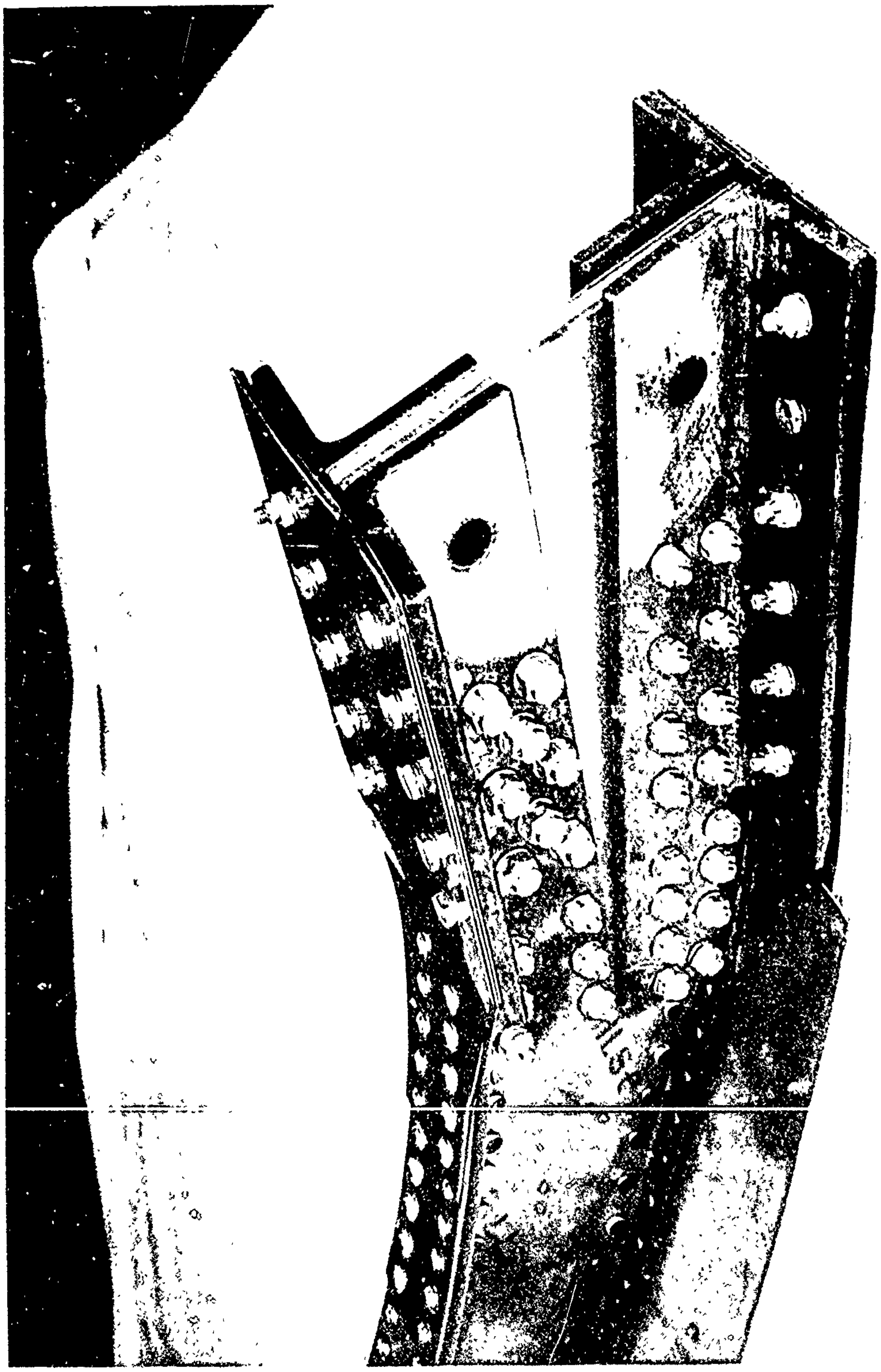
700 F to 66.6% design ultimate

800 F to 66.6% design ultimate

900 F to 66.6% design ultimate

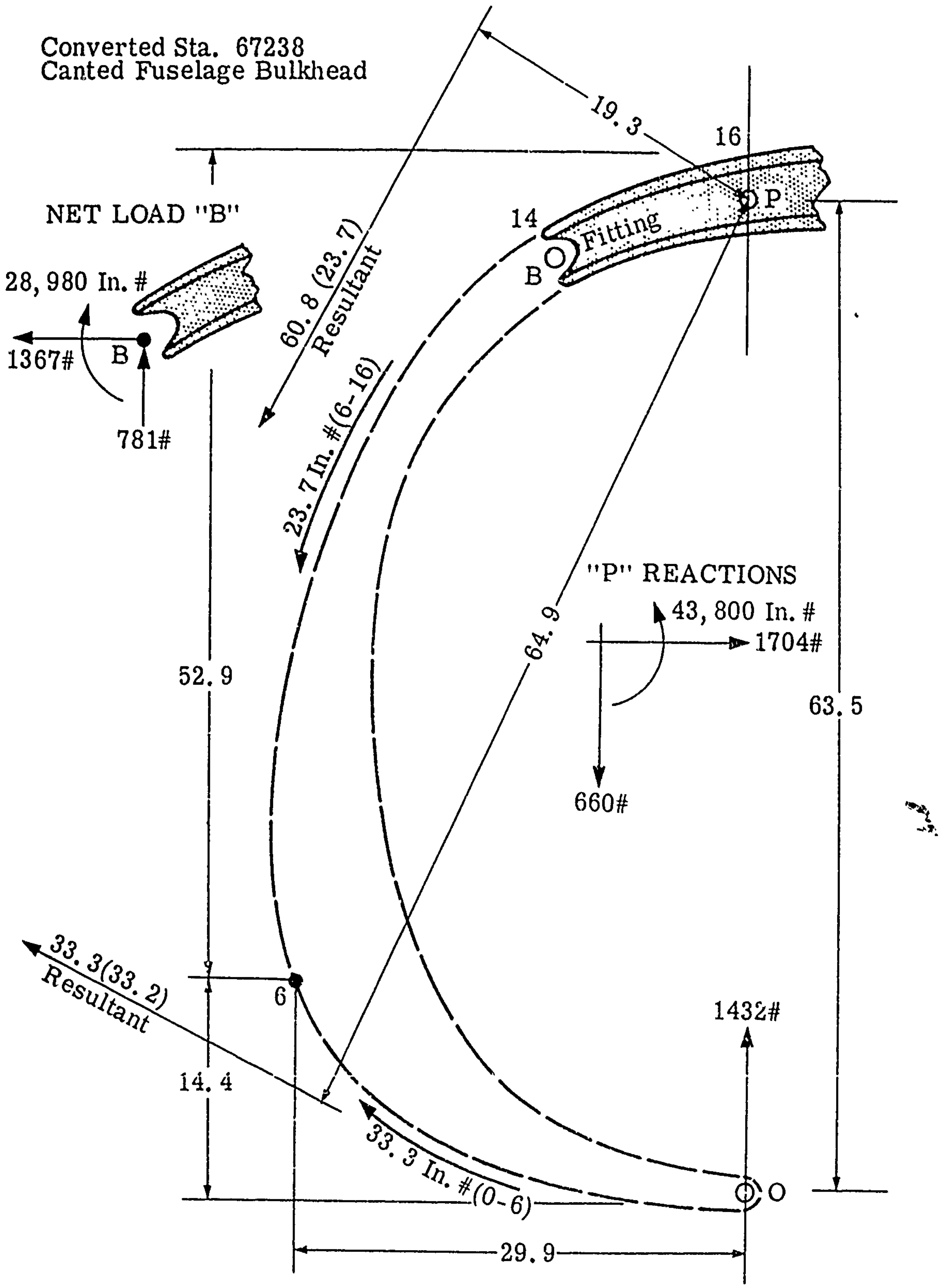
800 F to 128% design ultimate

Note: Strain data were taken at load increments in the room temperature tests. Deflection data were taken at load increments in all static tests.



Convair Print 57249

Figure A-18 — FUSELAGE CANTED BULKHEAD; Specimen Reinforcement at the Fixed End.



Point "O" (1432#) Free to Rotate About "P"

Figure A-19. SCHEMATIC DIAGRAM FOR DESIGN ULTIMATE TEST LOAD

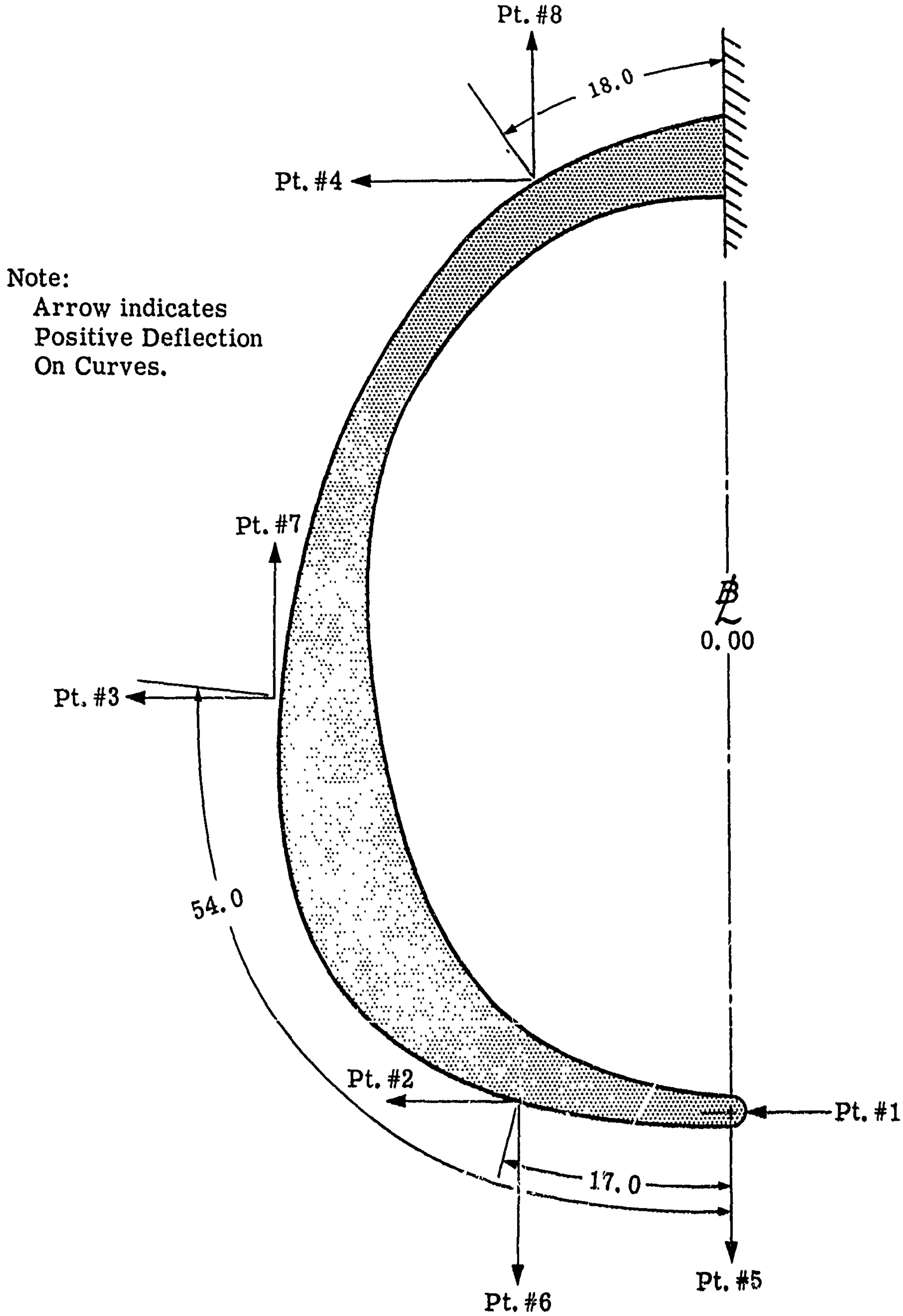


Figure A-20 — DEFLECTION-POINT LOCATIONS.

III. 2. Test Procedure: (Cont'd)

b. Fatigue Tests -

Room Temperature - 2,500 cycles - 44.5% design ultimate

200 F - 2,500 cycles - 44.5% design ultimate

400 F - 2,500 cycles - 44.5% design ultimate

600 F - 2,500 cycles - 44.5% design ultimate

800 F - 40,000 cycles - 44.5% design ultimate

c. Additional Fatigue Tests - Riveted Bulkhead Only -

800 F - 52,000 cycles - 44.5% design ultimate

800 F - 5,000 cycles - 53.4% design ultimate

800 F - 33,000 cycles 66.6% design ultimate

Fatigue tests were conducted at a rate of 40 load cycles per minute.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

IV. TEST RESULTS

The deflection and permanent set results are plotted in Figures A-21 through A-60 (pages 34 through 73). Figures A-61 through A-63 (pages 74 through 76), Spotwelded Bulkhead, and Figures A-64 through A-66 (pages 77 through 79), Riveted Bulkhead, show comparative deflection curves at various temperatures. Figures A-67 through A-72 (pages 80 through 85) show a comparison of the two bulkhead specimens at the indicated temperatures.

Room temperature strain gage data are plotted vs load in Figure A-73 (page 86), Riveted Bulkhead. Figures A-74 through A-76 (pages 87 through 89) show the reaction load parallel to buttock line 00. 0 for both specimens.

A brief summary of the spotwelded bulkhead test results is given in Tables A-2 and A-3 (pages 90 and 91), and of the riveted bulkhead tests, in Tables A-4 and A-5 (pages 92 and 93).

Specimen failure photographs are shown in Figures A-77 through A-83 (pages 94 through 100), Spotwelded, and Figures A-84 through A-92 (pages 101 through 109), Riveted.

A comparison of the deflection characteristics of the two assemblies at various temperatures showed them to be very similar at all load levels. It was also noted that the deflection of each specimen was similar at all temperatures up to 800 F. A change in structural stiffness was noted at 900 F and 800 F after 900 F.

The indicated stresses at room temperature were relatively low. This, combined with the low restraining bar load, shows the assembly, including the fixed end, was more rigid than anticipated. The specimen did not fail at 128% design ultimate, but had some slight permanent web buckles. The deflection curves showed the specimens were approaching yield strength at 100% design ultimate. The spotwelded specimen had one crack in the spotweld after the static tests.

The riveted bulkhead had a better fatigue life than the spotwelded assembly.

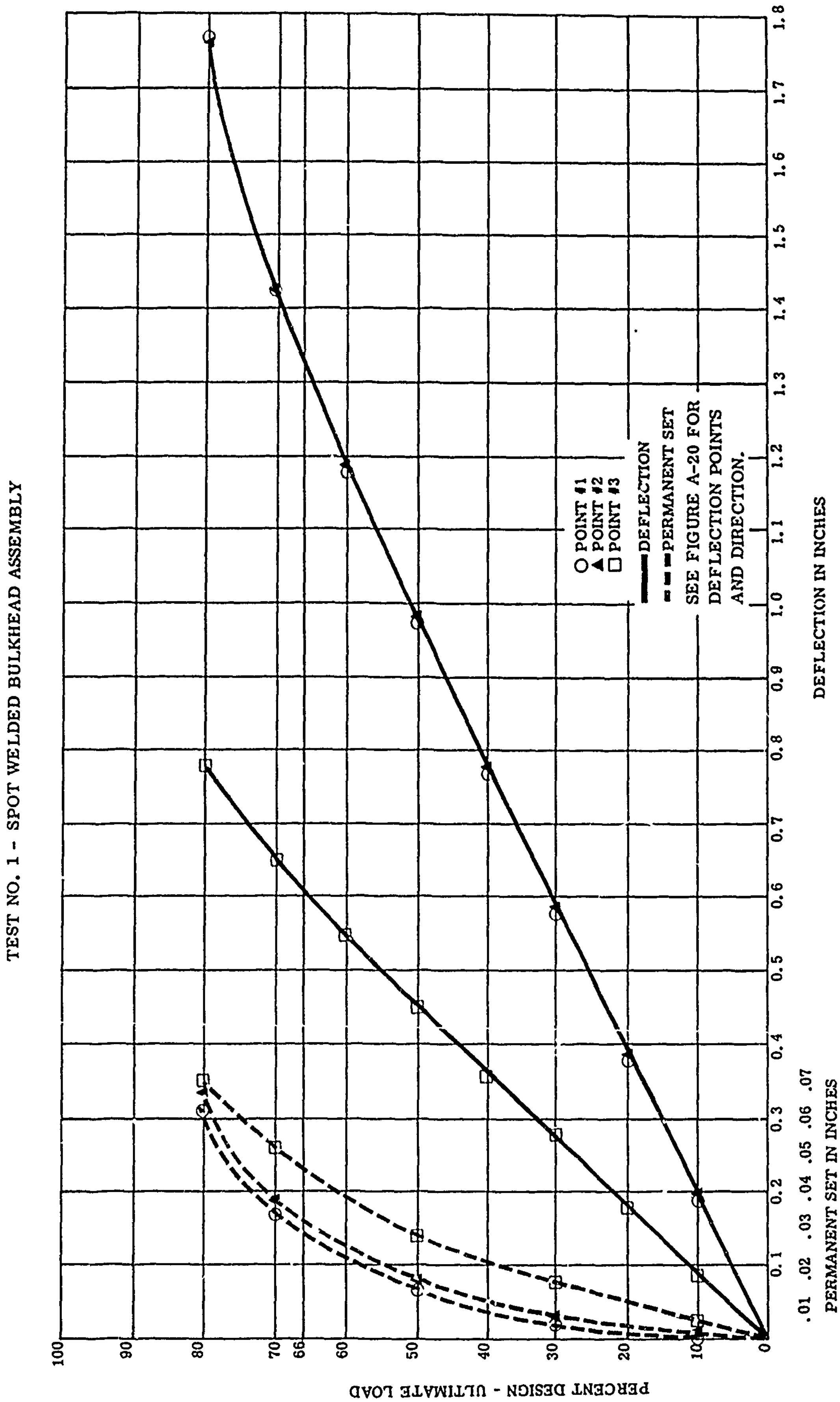


Figure A-21 DEFLECTION AND PERMANENT SET AT ROOM TEMPERATURE; Static Load Test

TEST NO. 1 - SPOT WELDED BULKHEAD ASSEMBLY

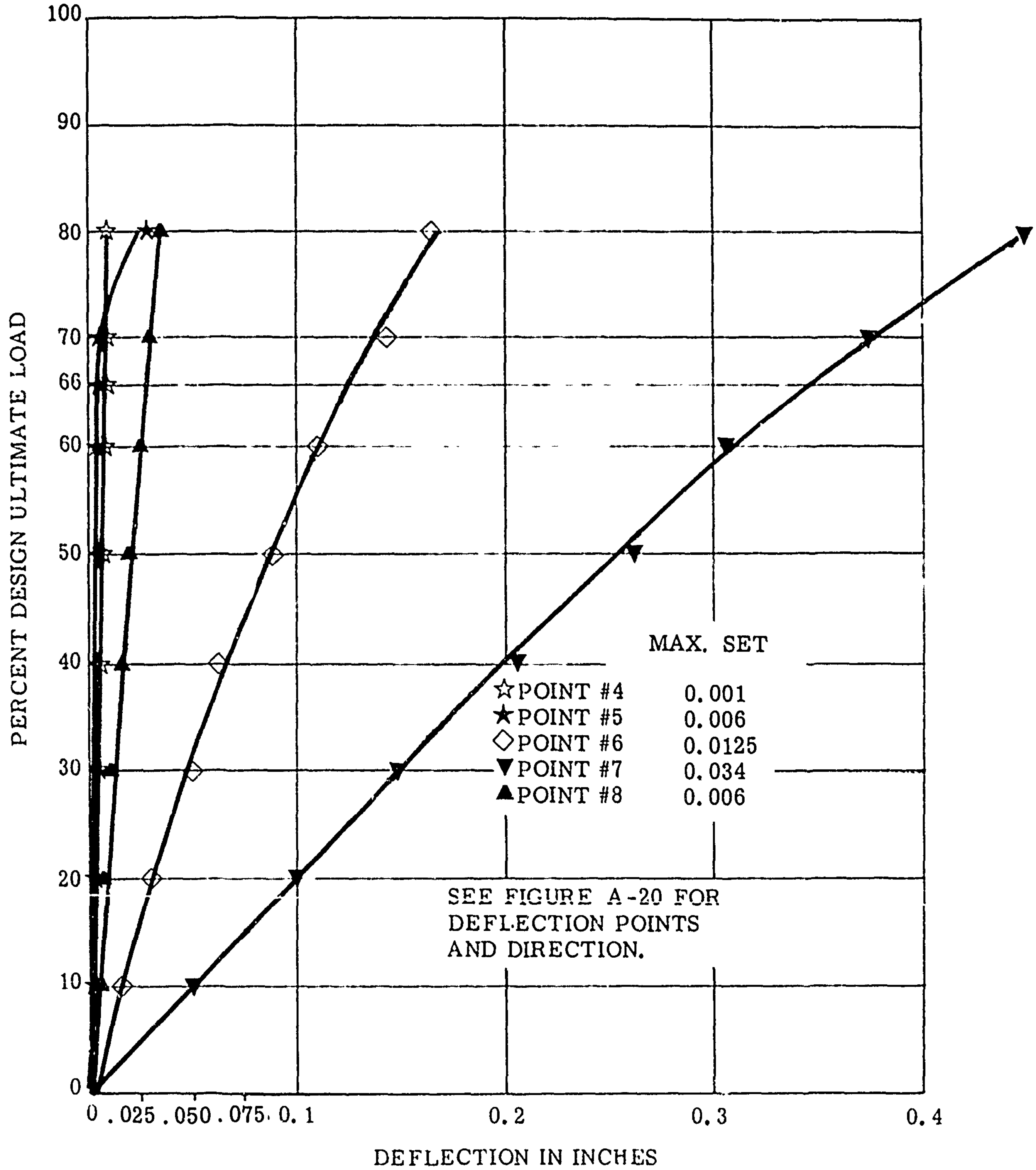


Figure A-22. DEFLECTION AND PERMANENT SET AT ROOM TEMPERATURE; Static Load Test

TEST NO. 2(a) - SPOT WELDED BULKHEAD ASSEMBLY

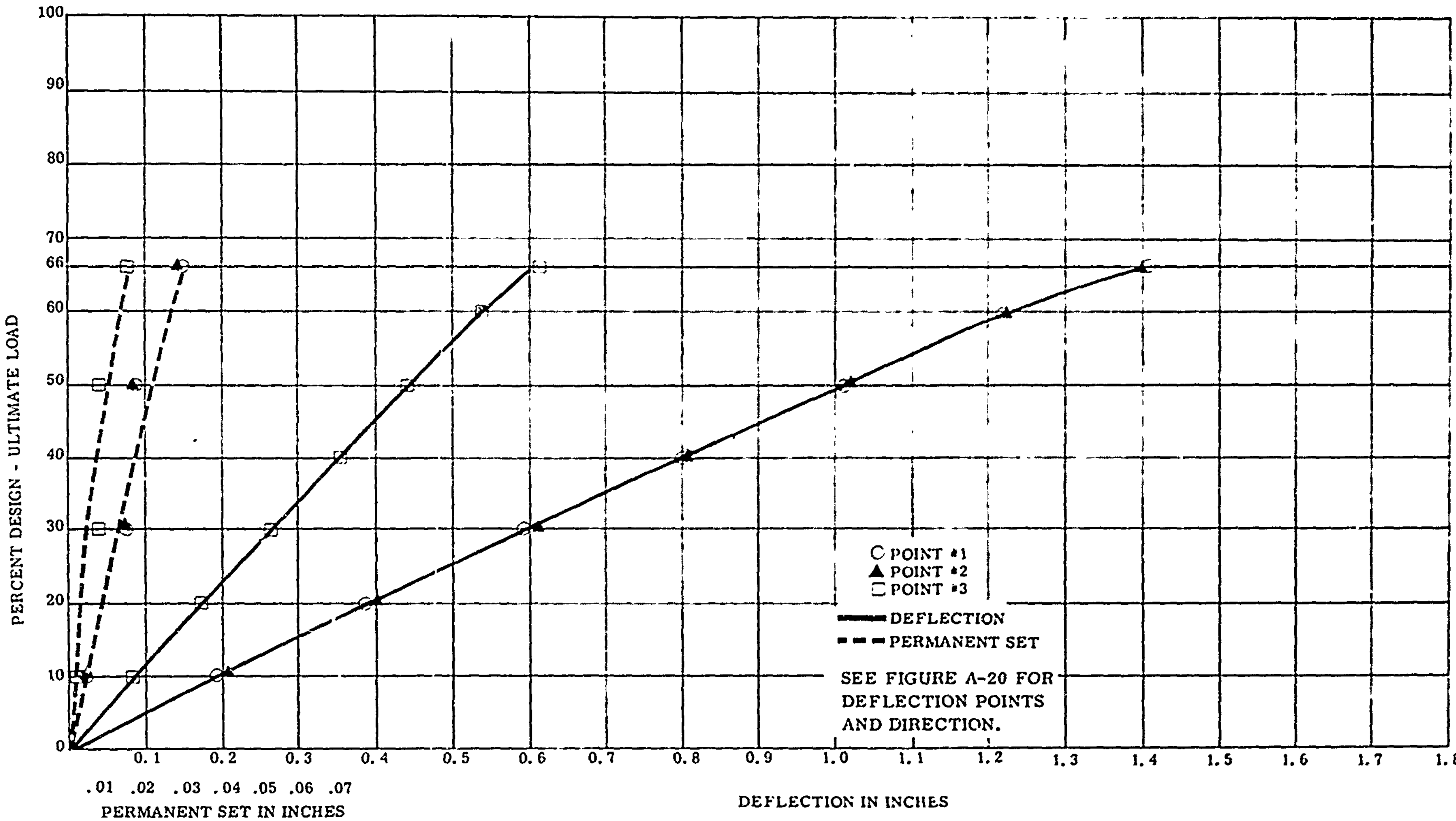


Figure A-23 DEFLECTION AND PERMANENT SET AT 200 F; Static Load Test

TEST NO. 2(a) - SPOT WELDED BULKHEAD ASSEMBLY

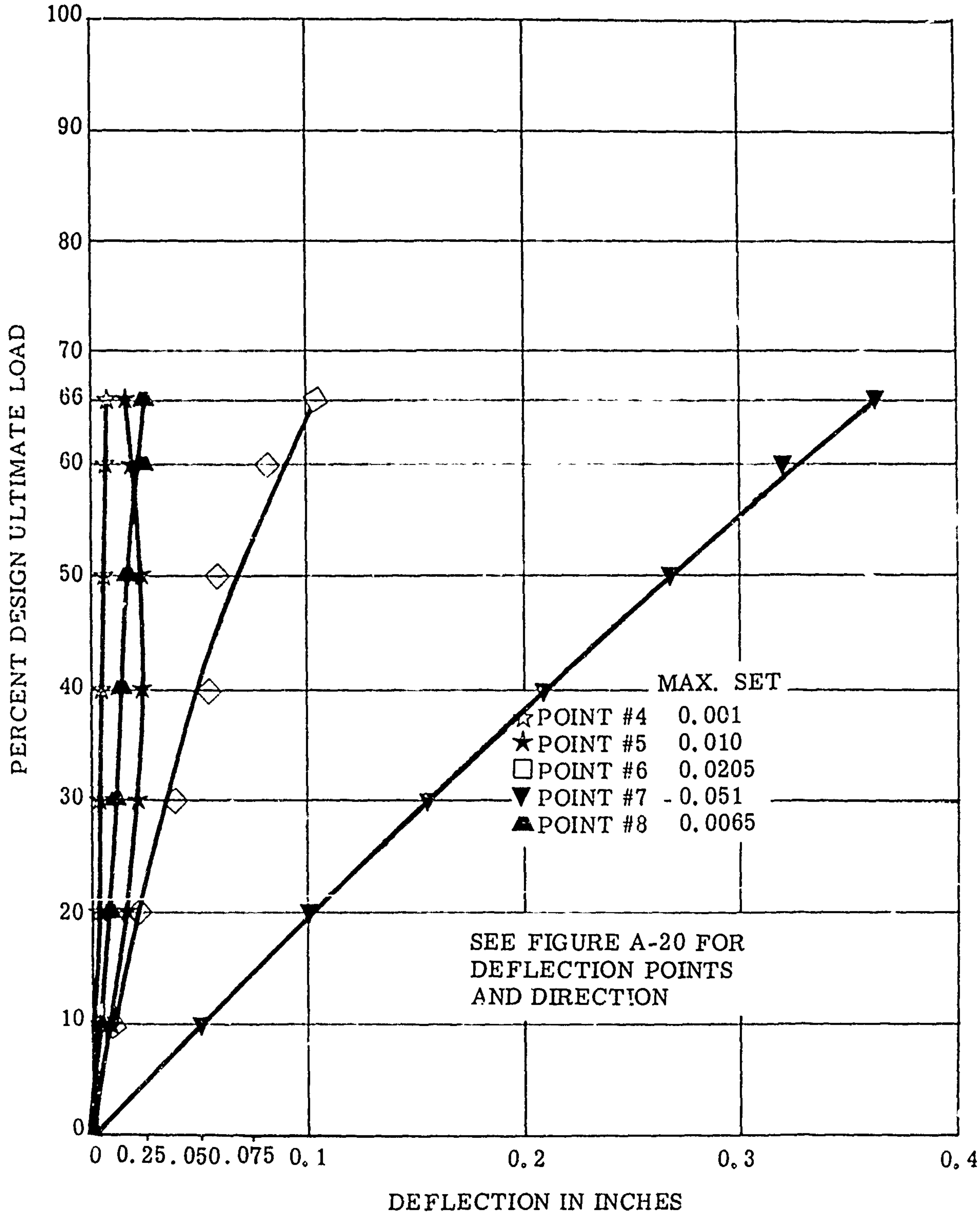


Figure A-24. DEFLECTION AND PERMANENT SET AT 200 F; Static Load Test

TEST NO. 2 (b) - SPOT WELDED BULKHEAD ASSEMBLY

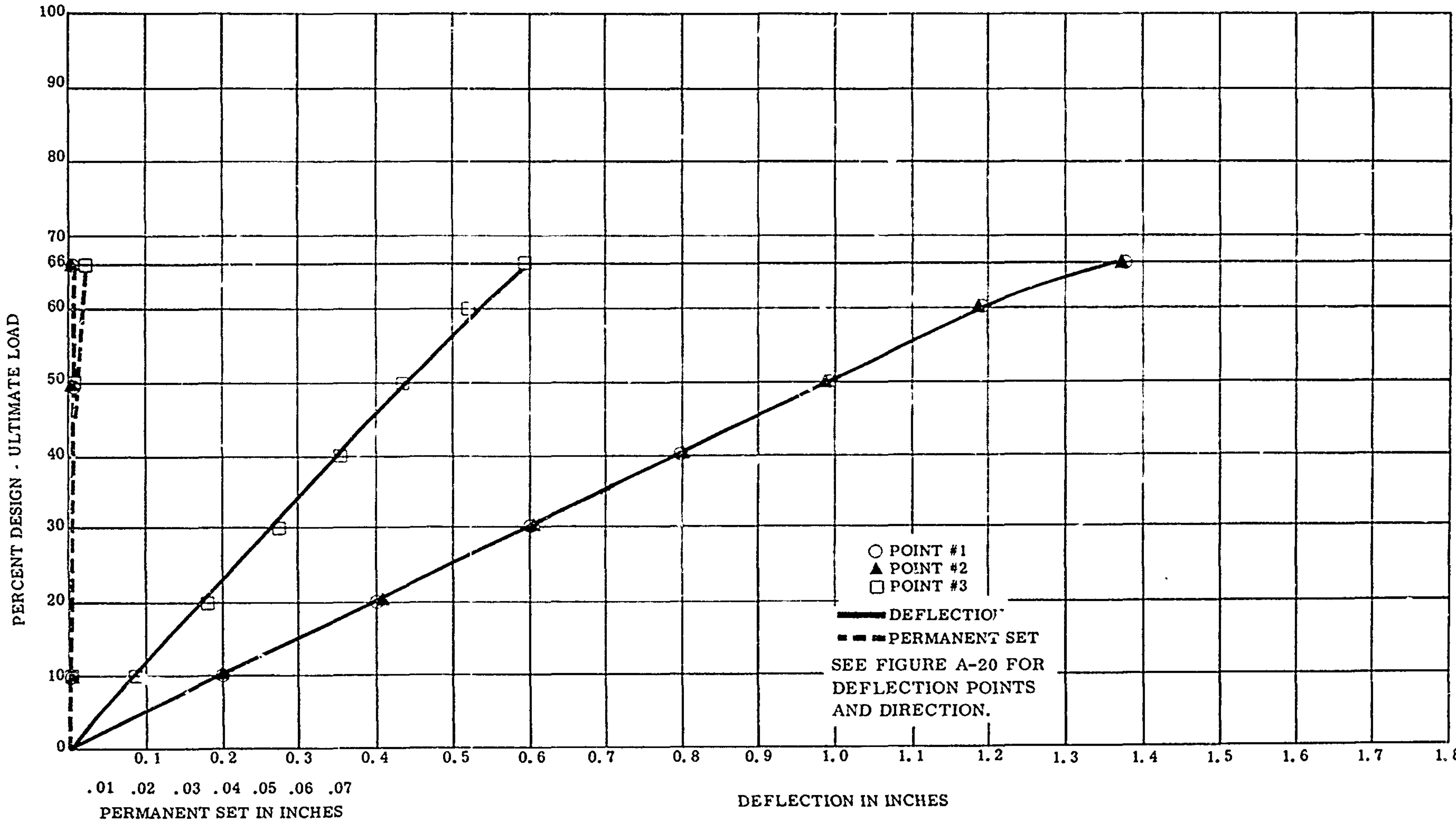


Figure A-25 DEFLECTION AND PERMANENT SET AT 300 F; Static Load Test

TEST NO. 2(b) - SPOT WELDED BULKHEAD ASSEMBLY

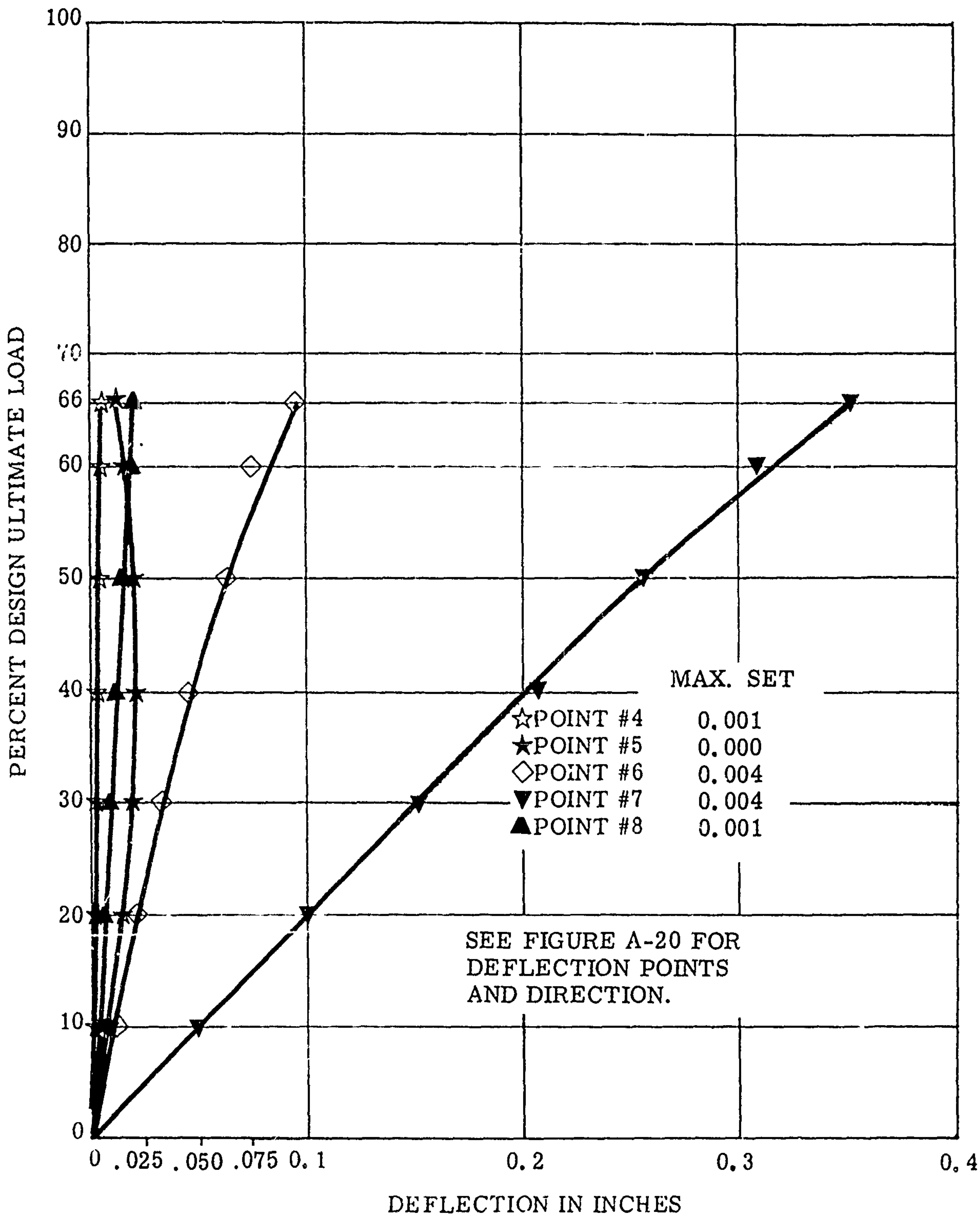


Figure A-26. DEFLECTION AND PERMANENT SET AT 300 F;
Static Test Load

TEST NO. 2 (c) - SPOT WELDED BULKHEAD ASSEMBLY

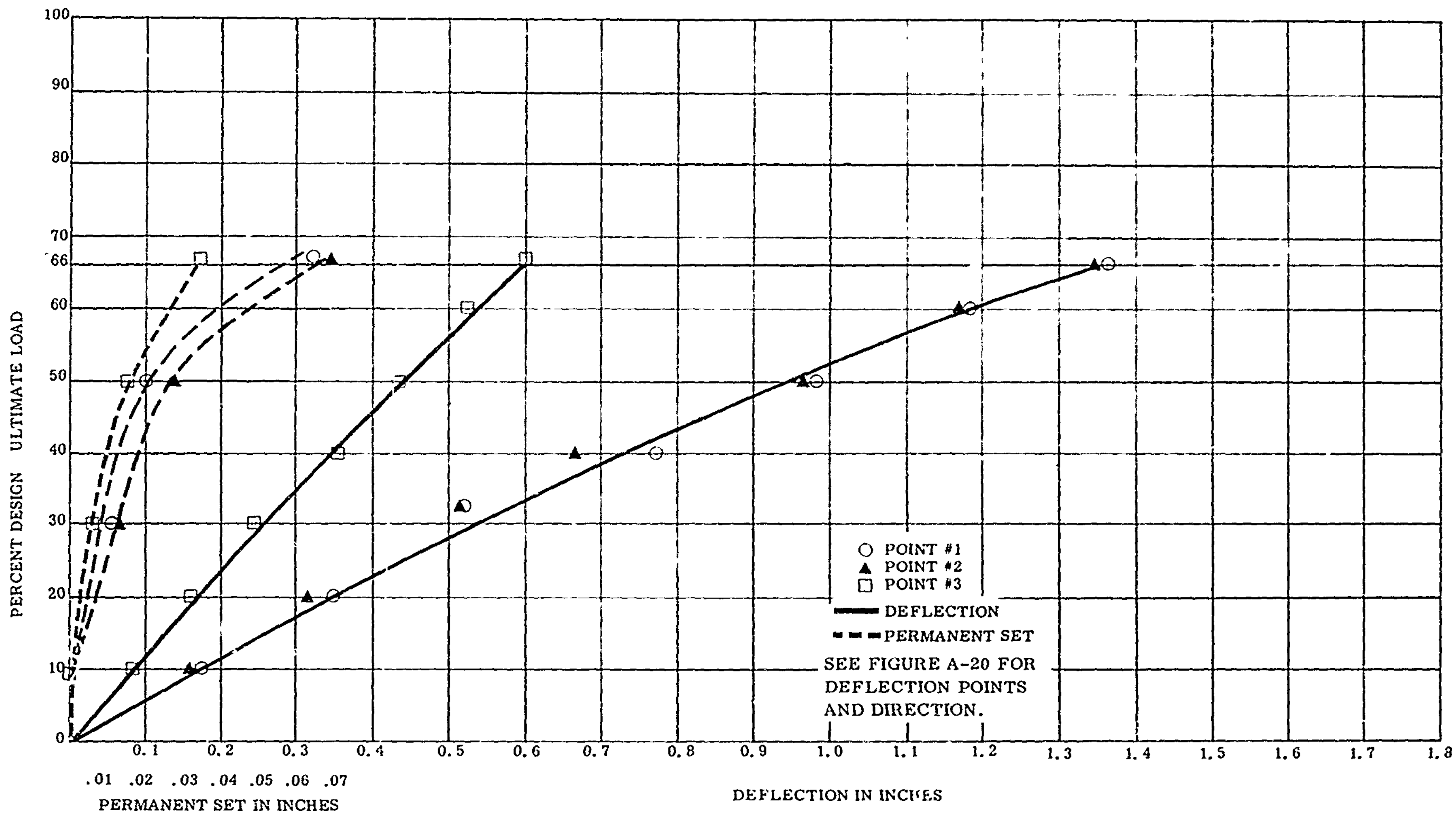


Figure A- 27 -- DEFLECTION AND PERMANENT SET AT 400F; Static Load Test.

TEST No. 2 (c) SPOT WELDED BULKHEAD ASSEMBLY

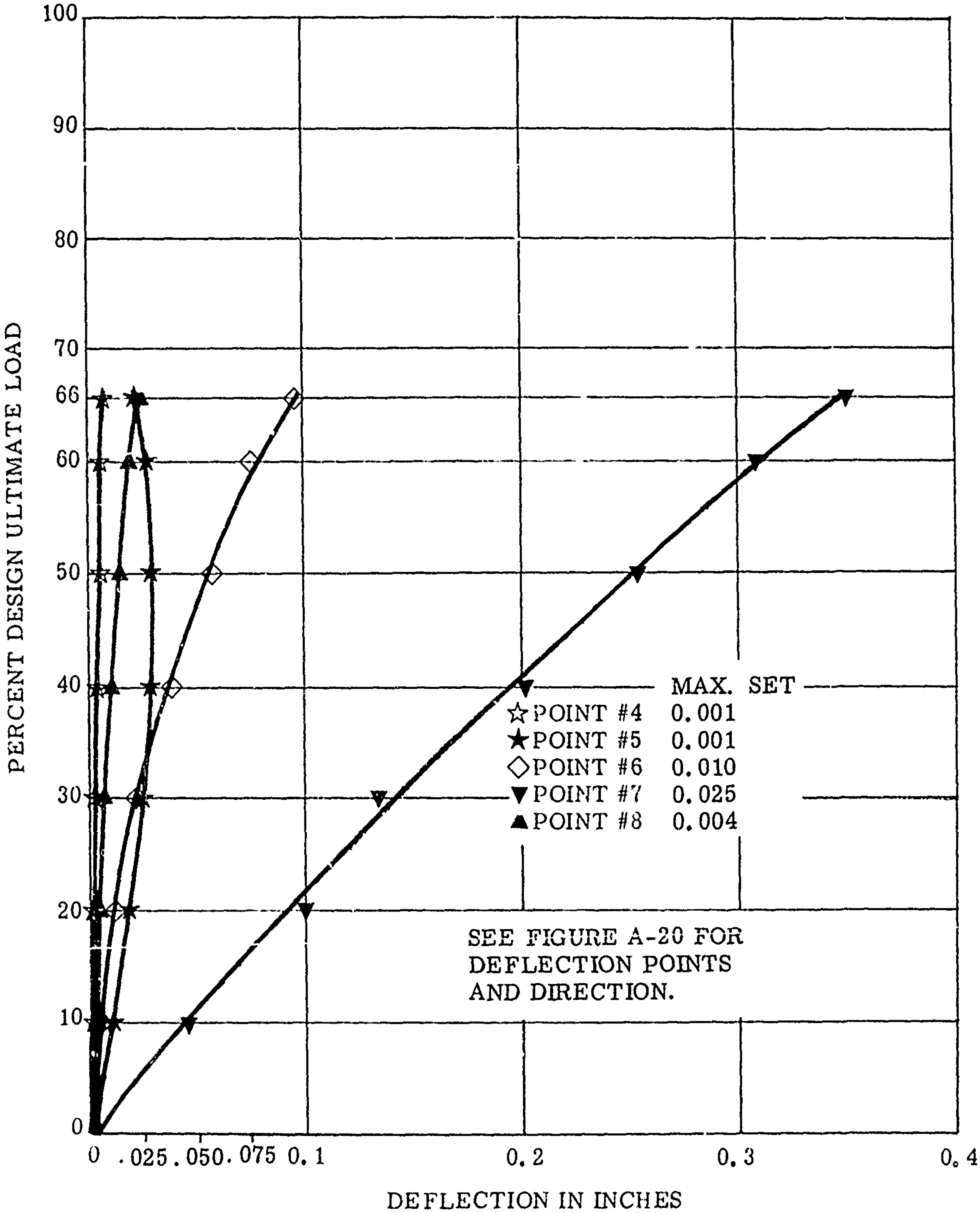


Figure A-28 DEFLECTION AND PERMANENT SET AT 400 F; Static Load Test

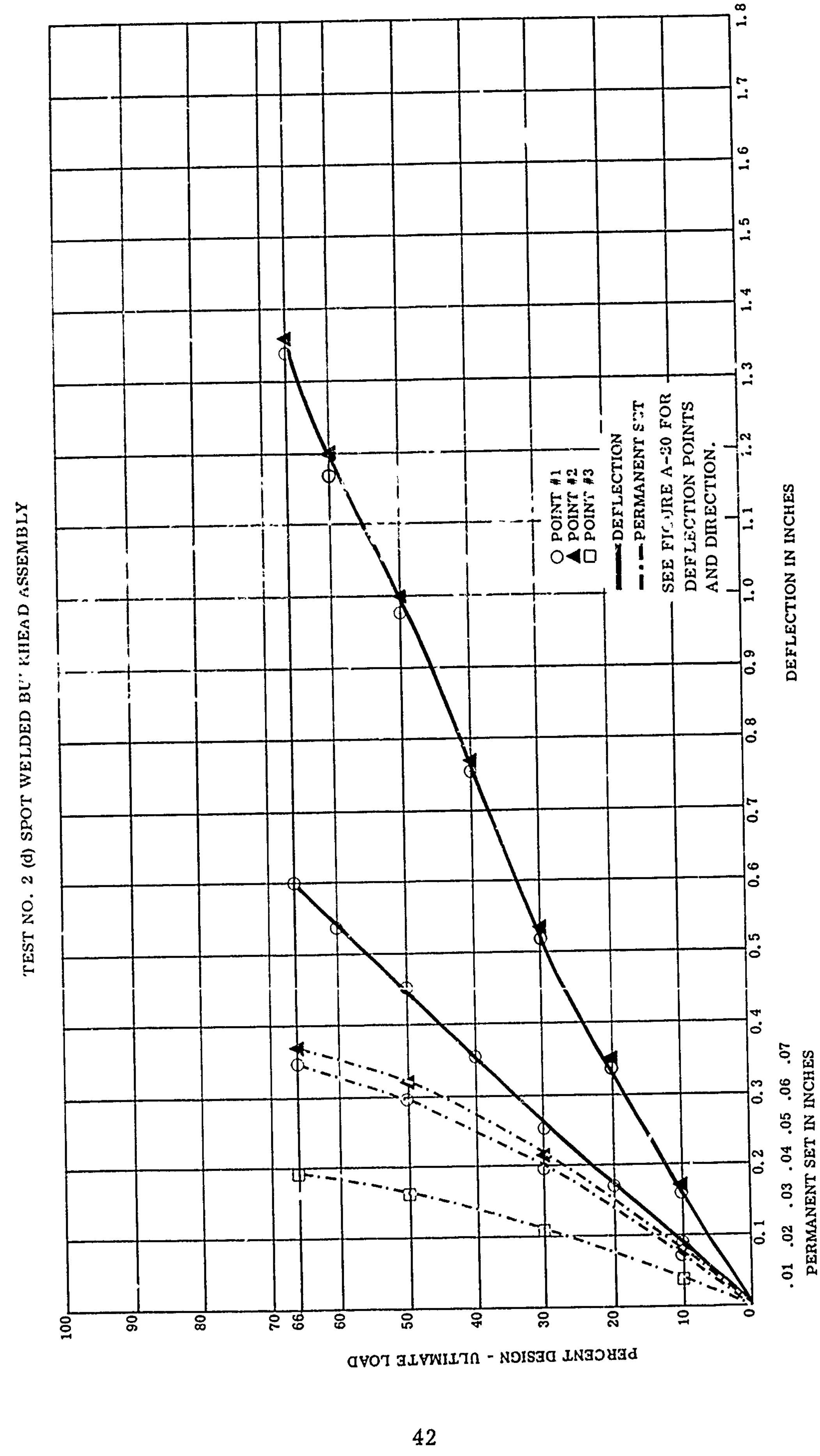


Figure A- 29 — DEFLECTION AND PERMANENT SET AT 500F; Static Load Test.

TEST NO. 2(d)-SPOT WELDED BULKHEAD ASSEMBLY

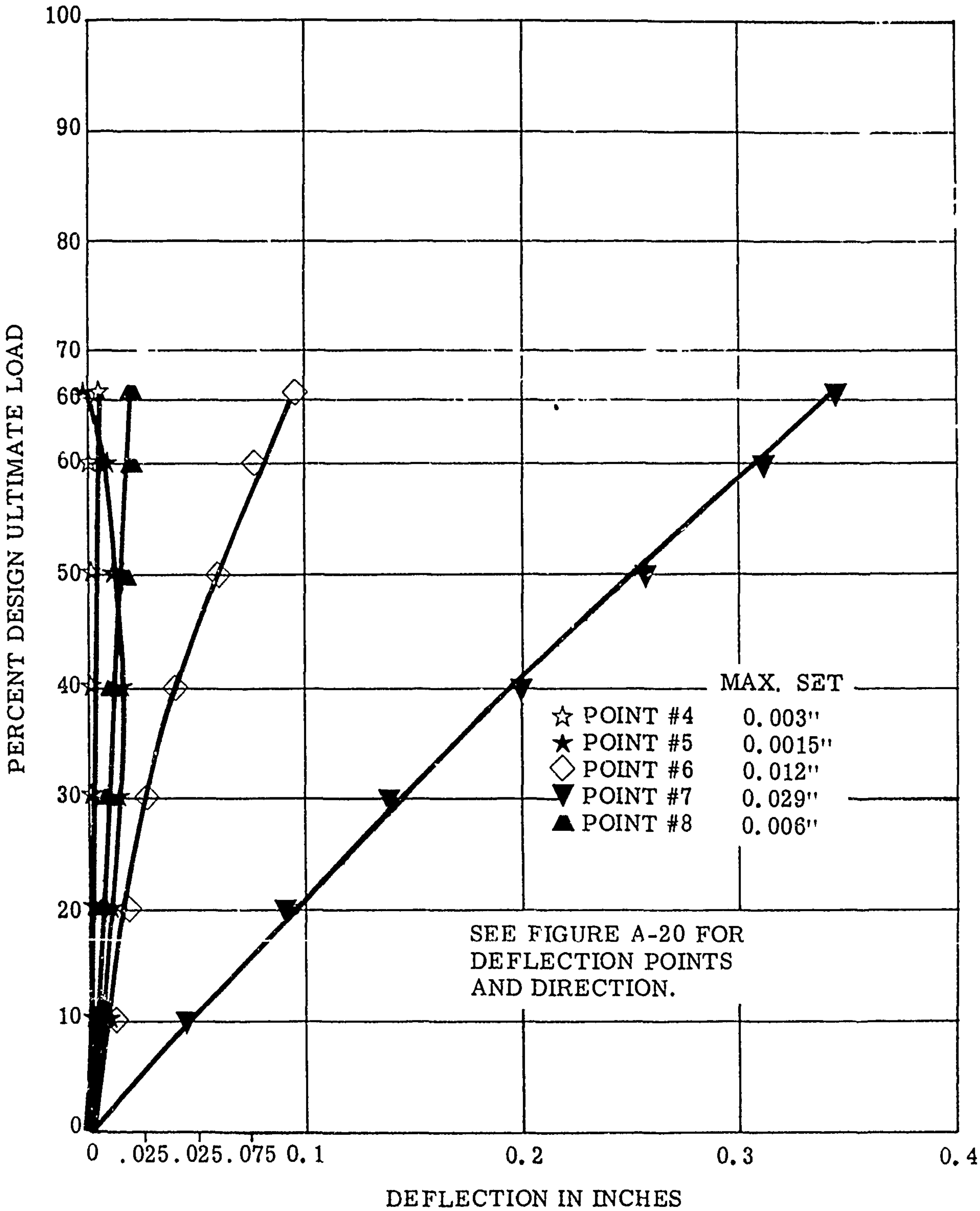


Figure A-30 DEFLECTION AND PERMANENT SET AT 500 F;
Static Load Test

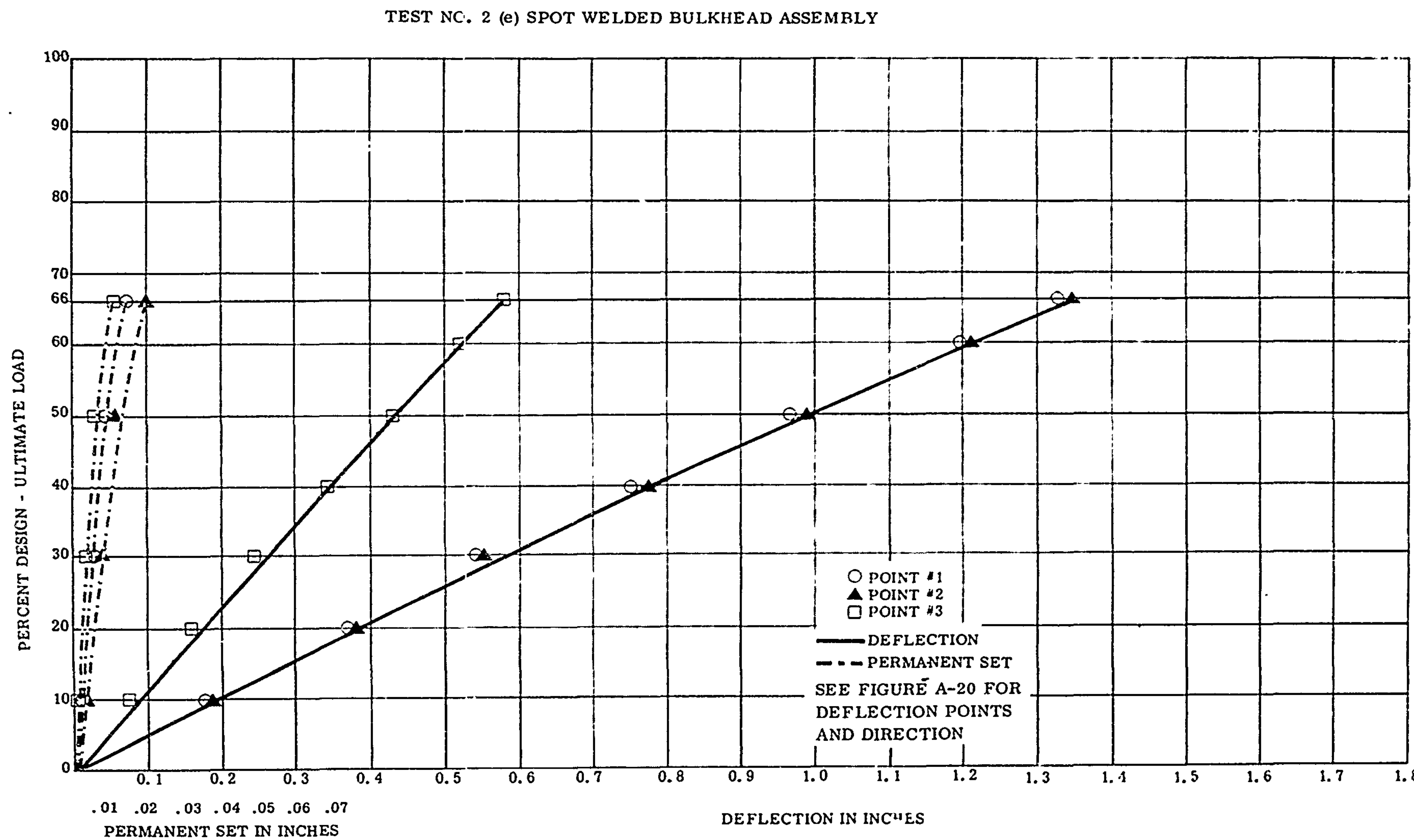


Figure A-31 DEFLECTION AND PERMANENT SET AT 600 F; Static Load Test

TEST NO. 2(e) - SPOT WELDED BULKHEAD ASSEMBLY

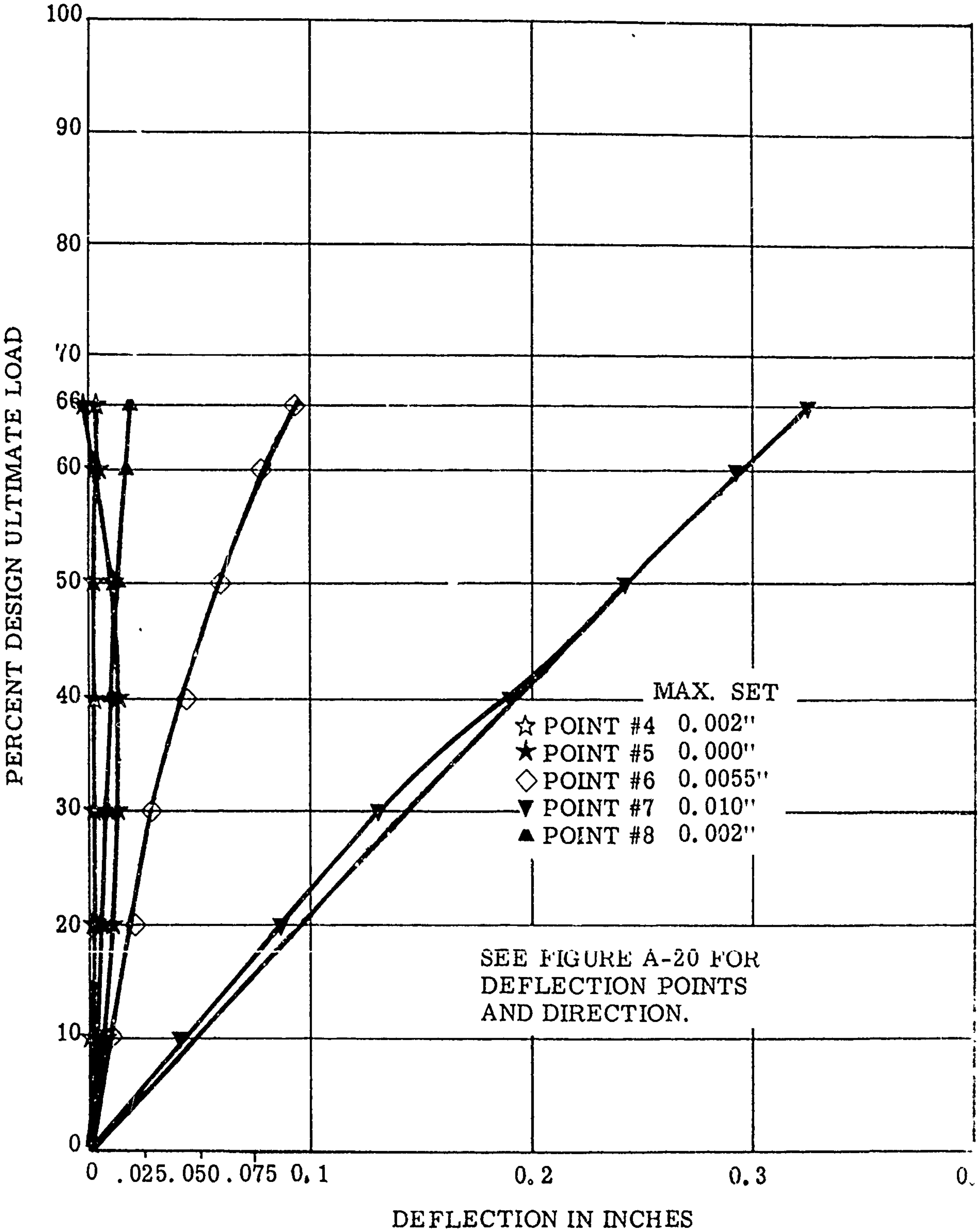


Figure A-32 DEFLECTION AND PERMANENT SET AT 600 F Static Load Test

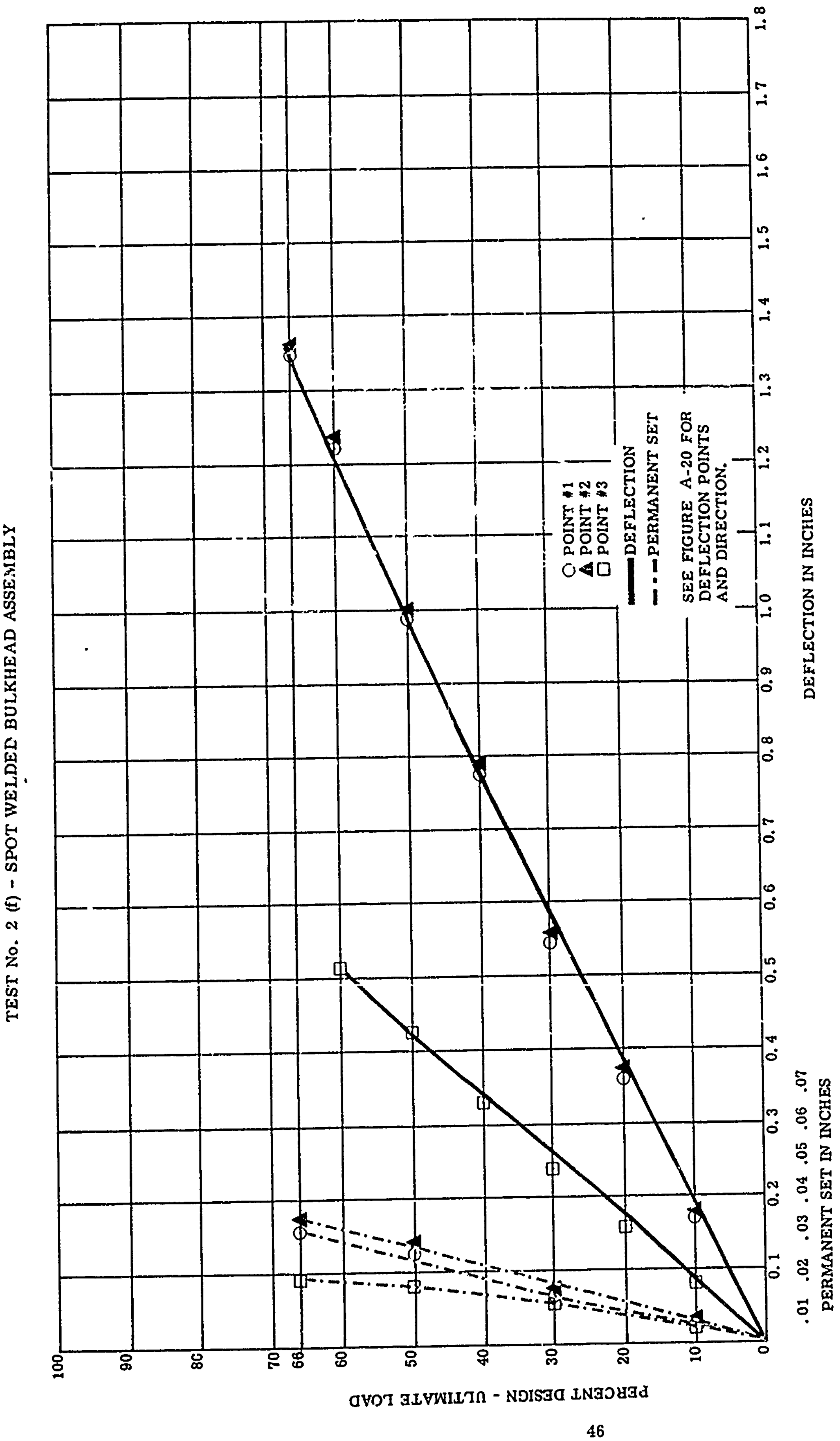


Figure A-33 DEFLECTION AND PERMANENT SET AT 700 F; Static Load Test

TEST NO. 2(f) SPOT WELDED BULKHEAD ASSEMBLY

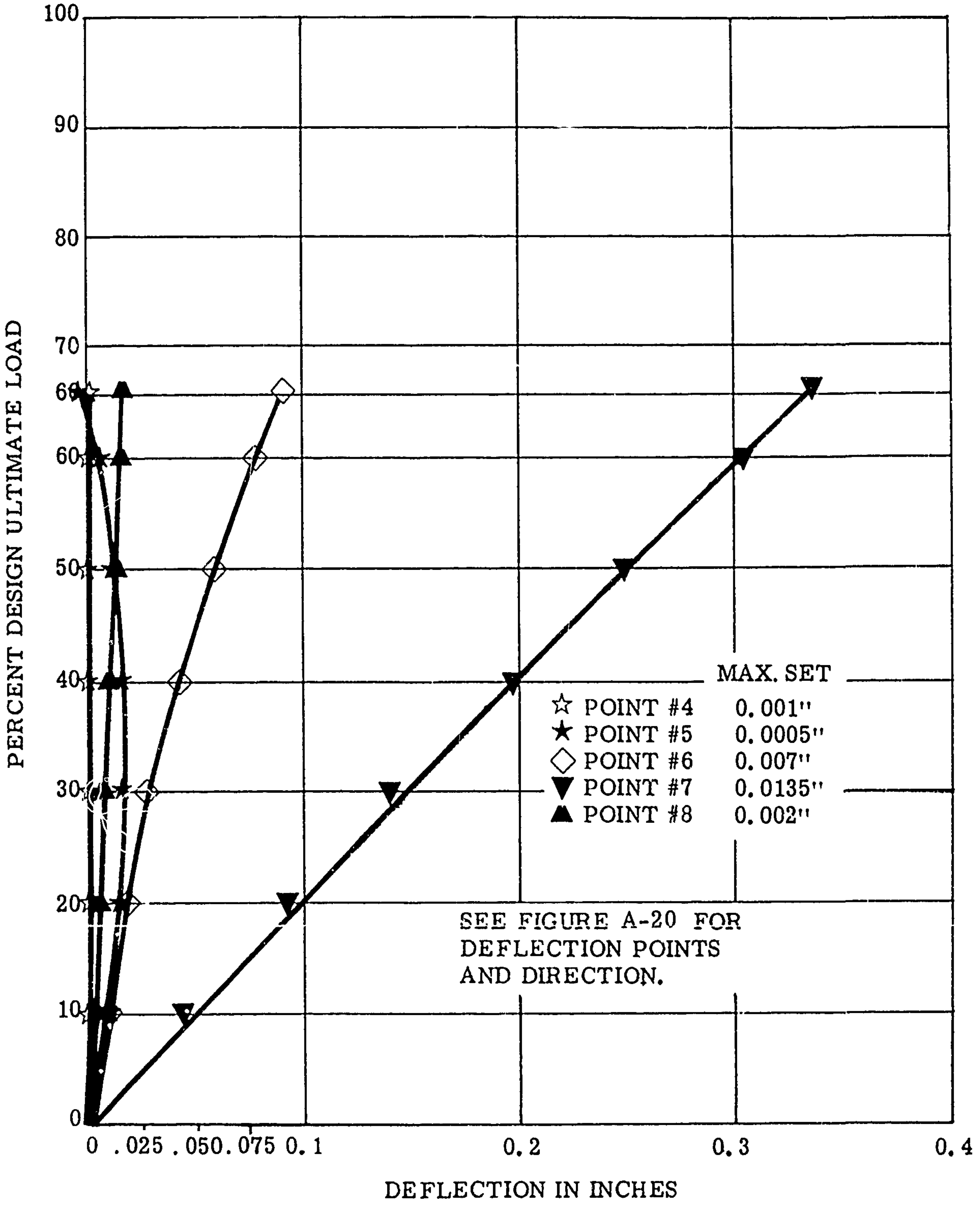


Figure A-34 DEFLECTION AND PERMANENT SET AT 700 F; Static Load Test

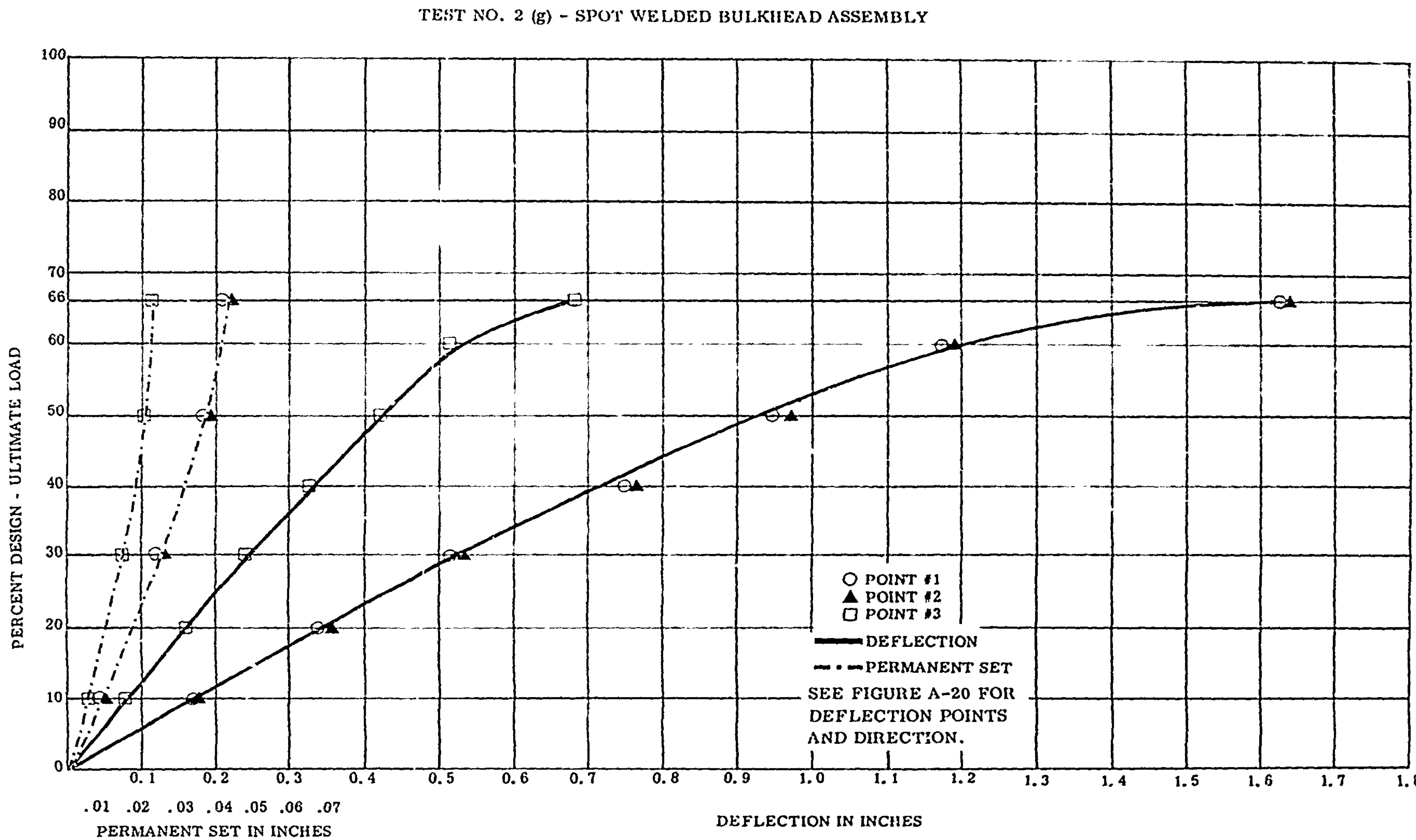


Figure A-35 — DEFLECTION AND PERMANENT SET AT 800F; Static Load Test

TEST NO. 2(g) SPOT WELDED BULKHEAD ASSEMBLY

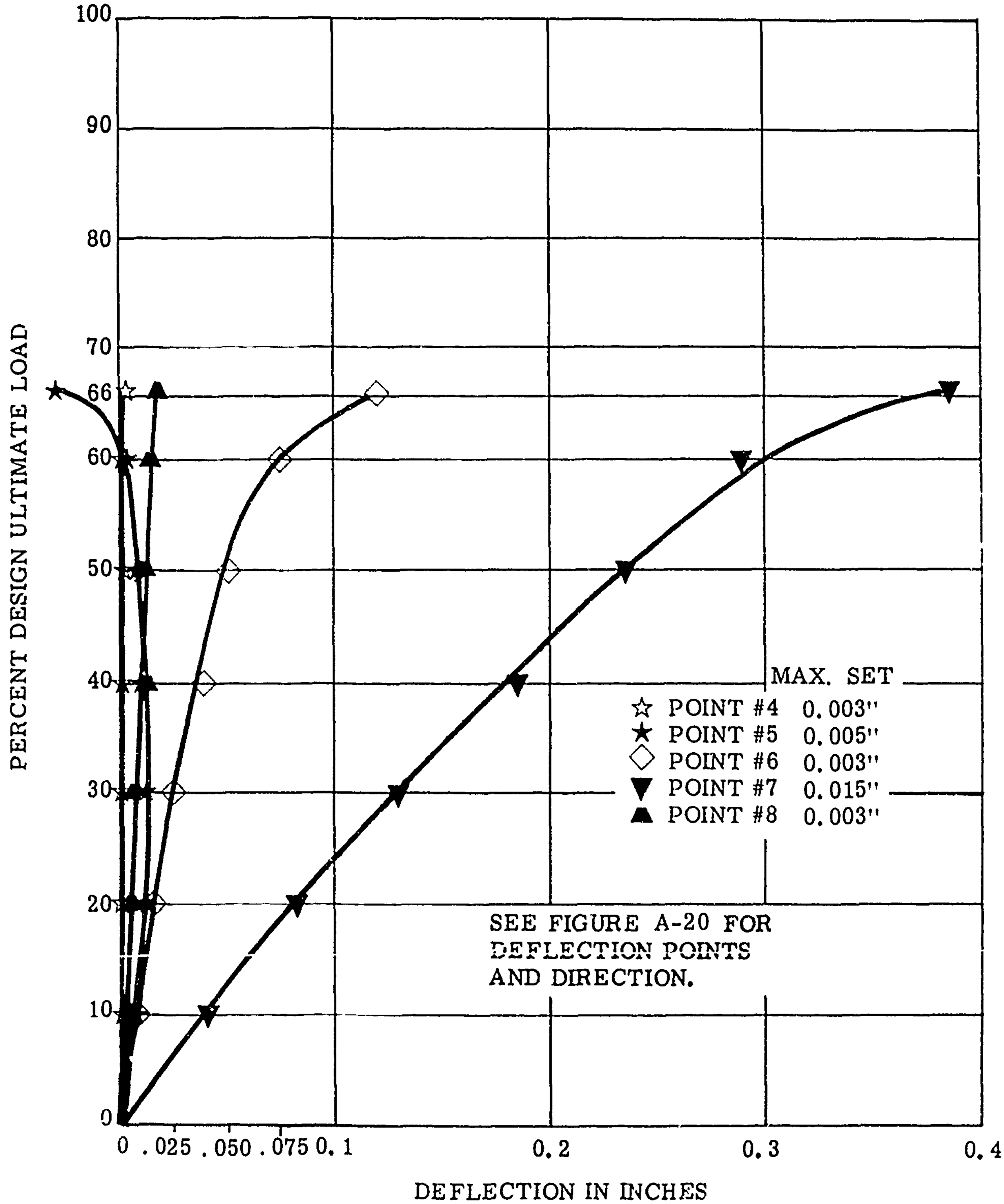


Figure A-36 DEFLECTION AND PERMANENT SET AT 800 F; Static Load Test

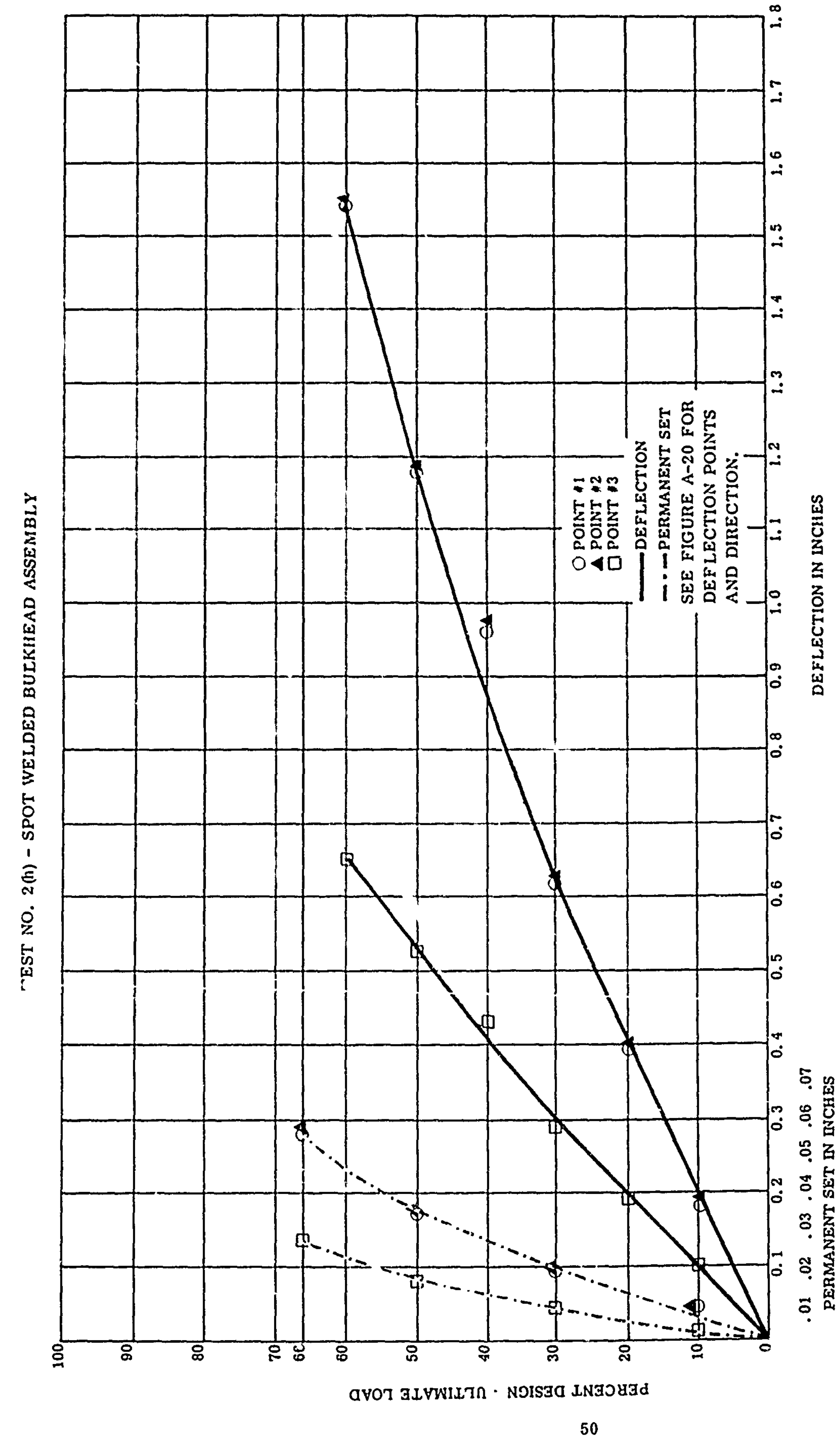


Figure A-37 DEFLECTION AND PERMANENT SET AT 900 F; Static Load Test

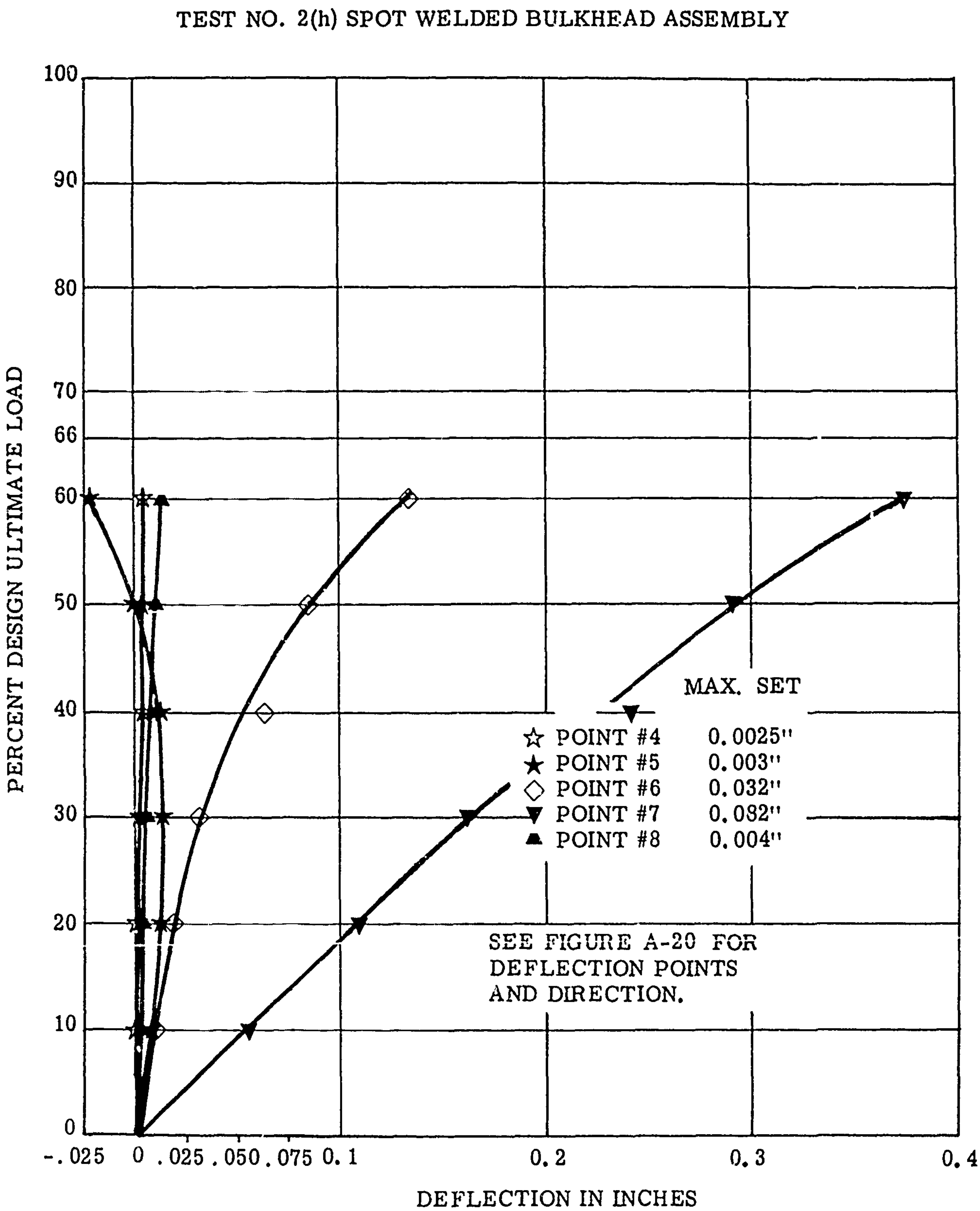


Figure A-38 DEFLECTION AND PERMANENT SET AT 900 F; Static Load Test

TEST NO. 3 - SPOT WELDED BULKHEAD ASSEMBLY
READINGS WERE DISCONTINUED AT 100% ULTIMATE
DESIGN LOAD. LOADING WAS CONTINUED TO 128%
ULTIMATE DESIGN LOAD WITHOUT FAILURE.

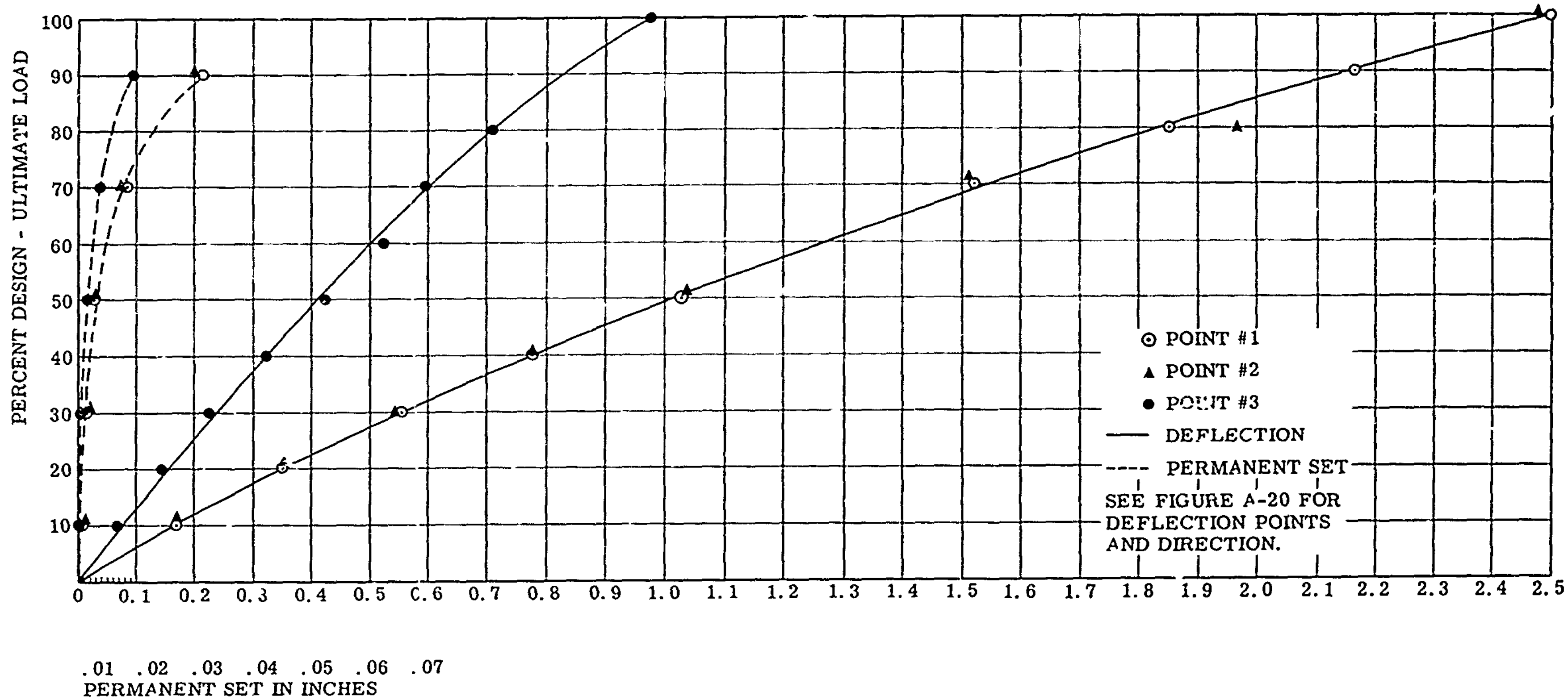


FIGURE A-39. DEFLECTION AND PERMANENT SET AT 800F; After 900F - 128% Design Ultimate Static Test

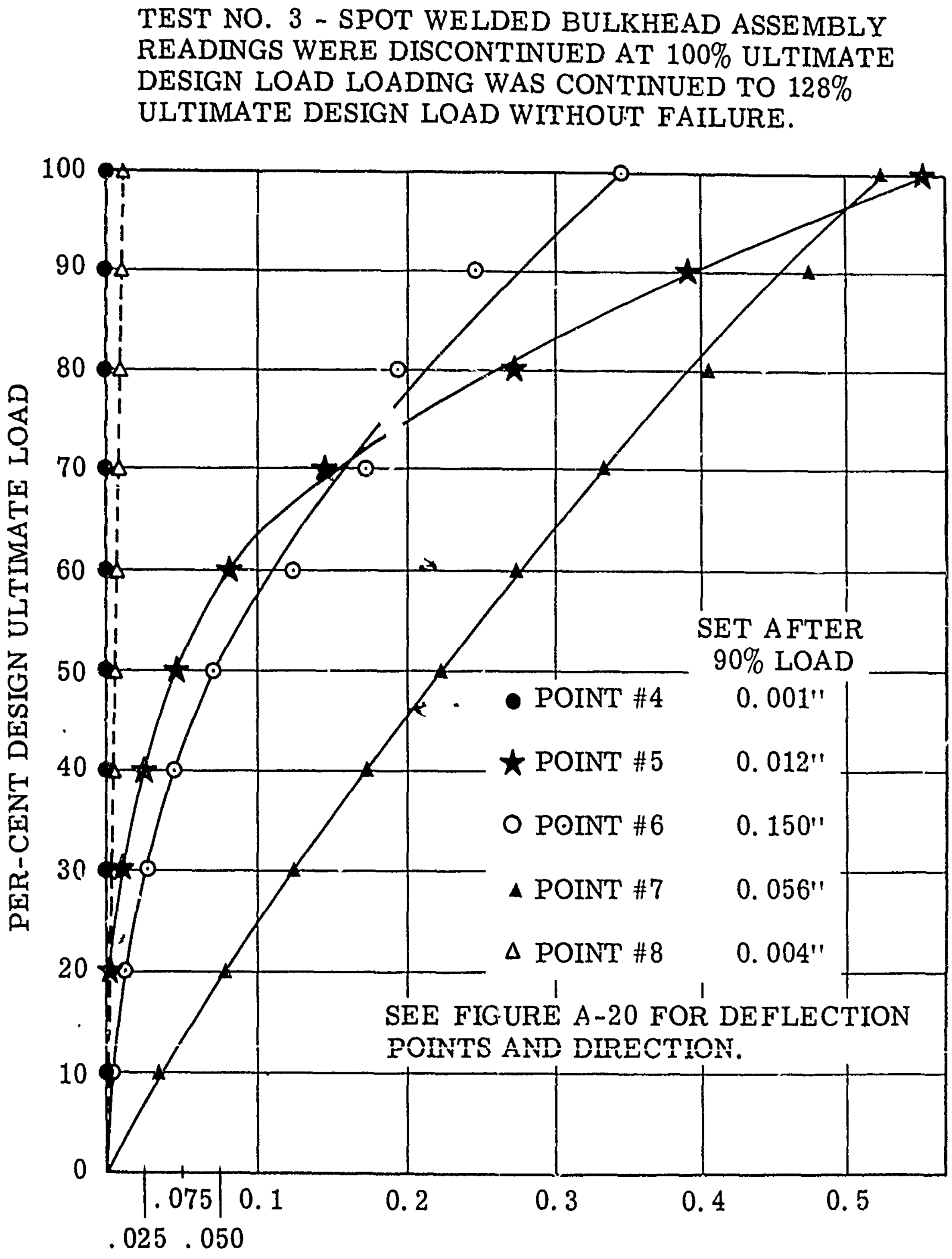


Figure A-40 DEFLECTION AND PERMANENT SET AT 800 F; After 900 F - 128% Design Ultimate Static Test

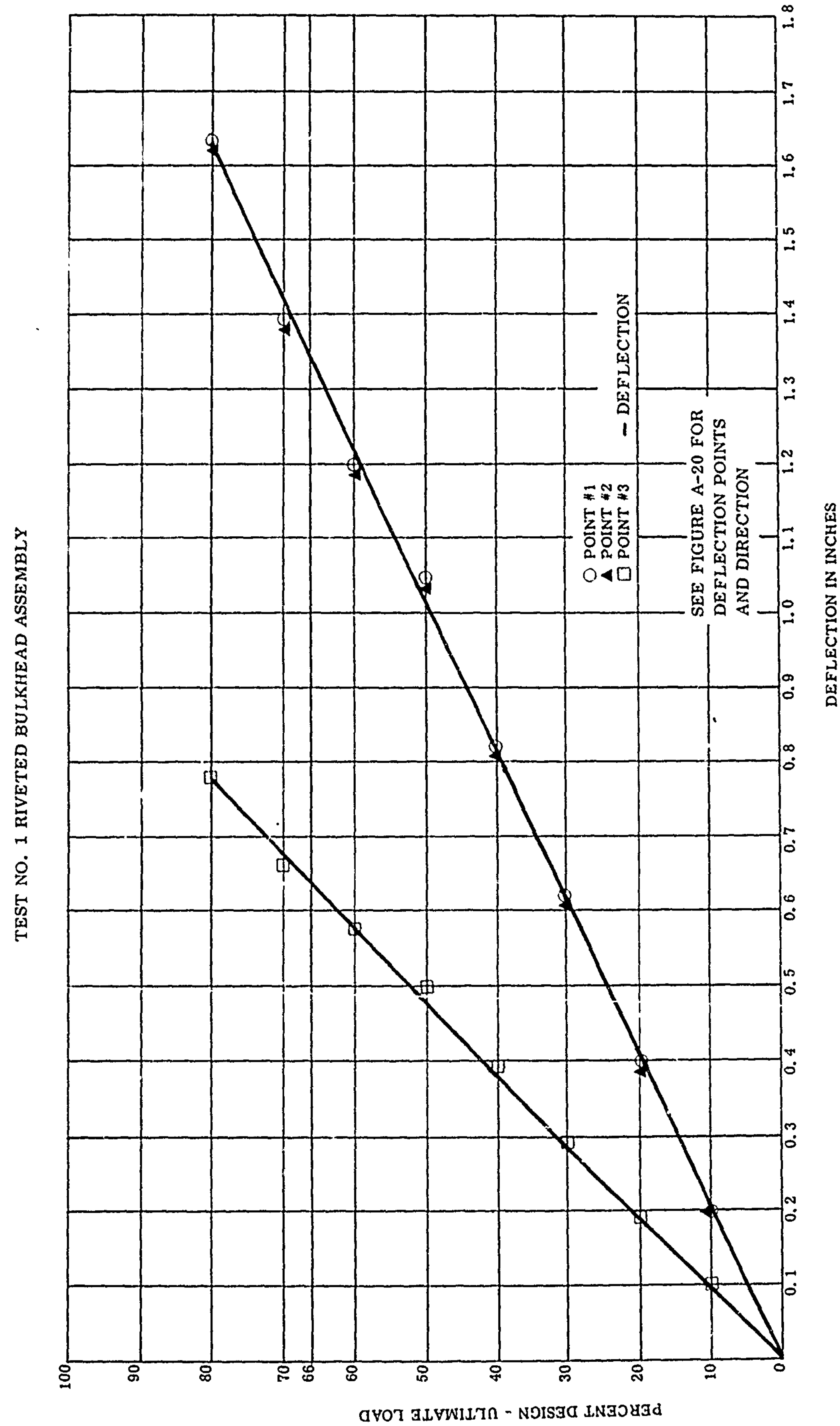


Figure A-41 DEFLECTION AT ROOM TEMPERATURE; Static Load Test

TEST NO. 1 RIVETED BULKHEAD ASSEMBLY

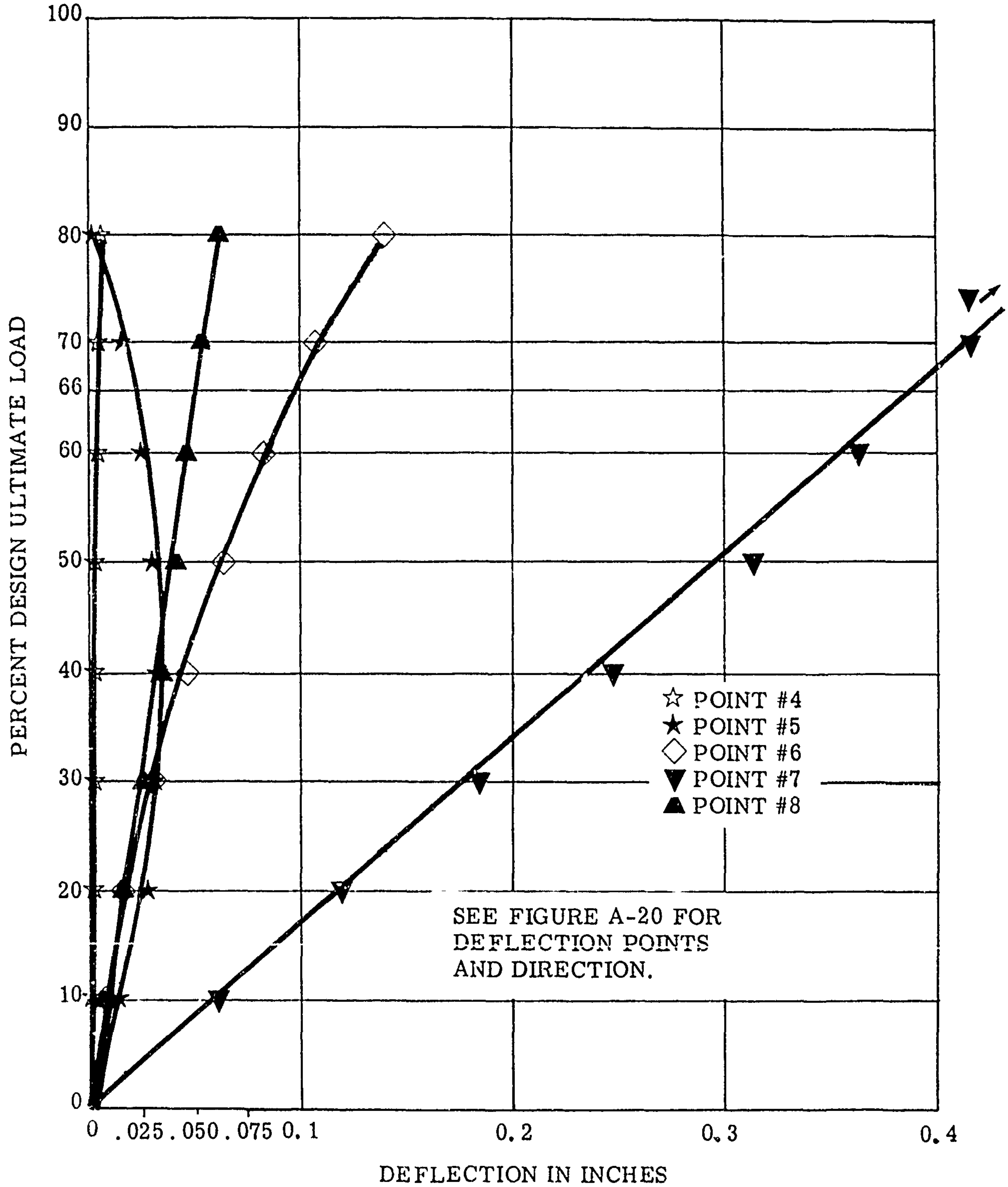


Figure A-42 DEFLECTION AT ROOM TEMPERATURE; Static Load Test

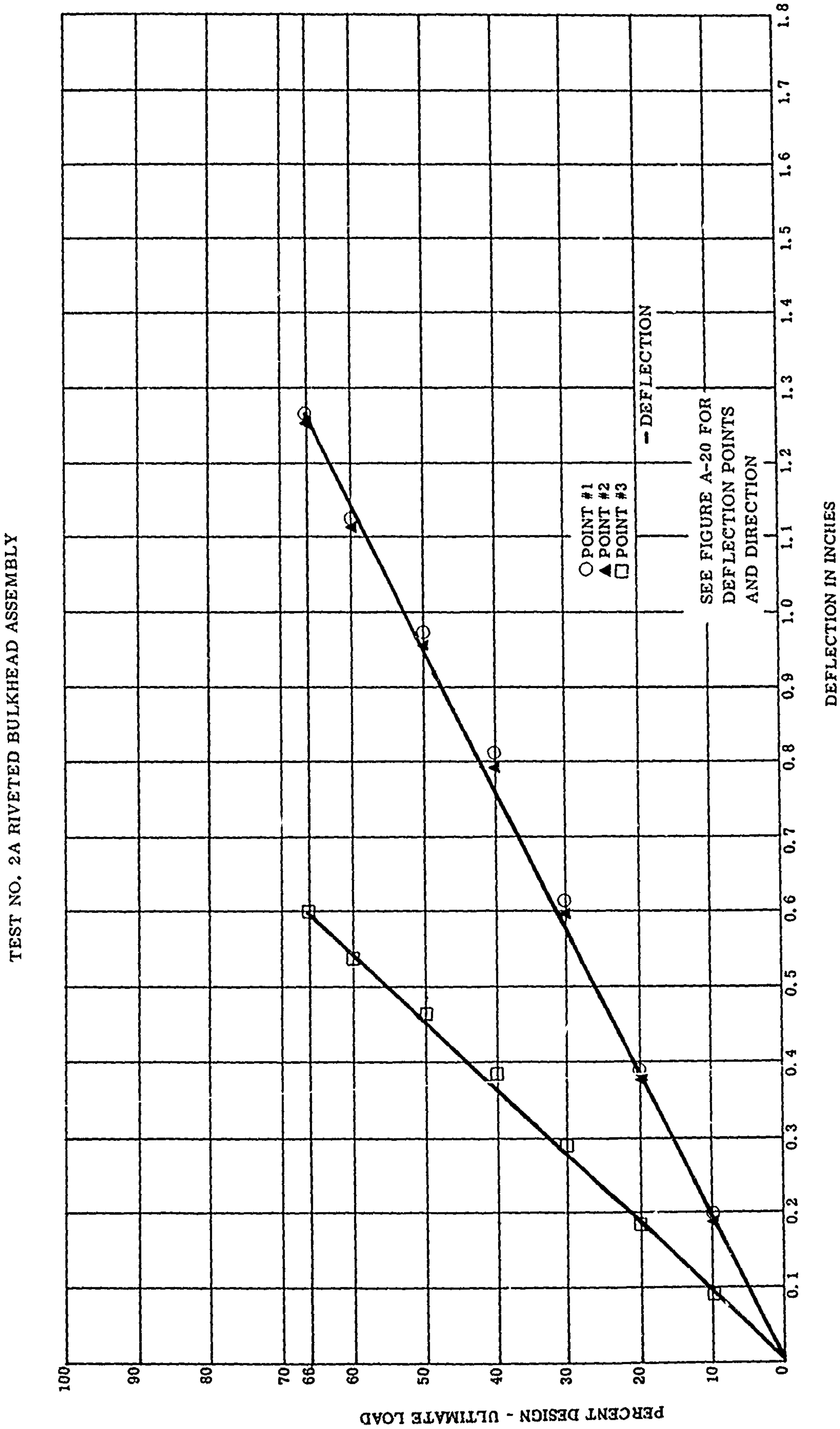


Figure A-43 DEFLECTION AT 200 F; Static Load Test

TEST NO. 2A RIVETED BULKHEAD ASSEMBLY

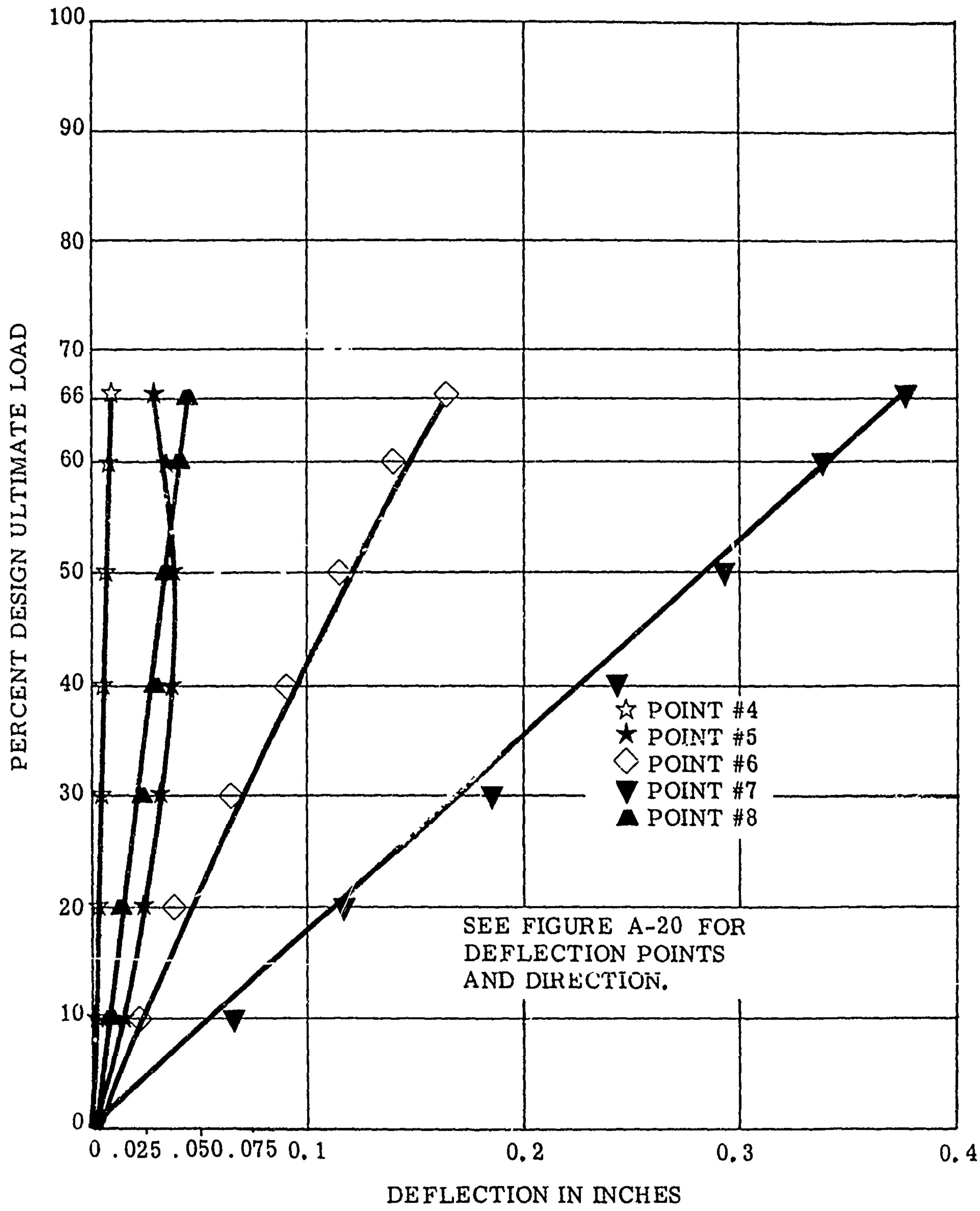


Figure A-44 DEFLECTION AT 200 F; Static Load Test

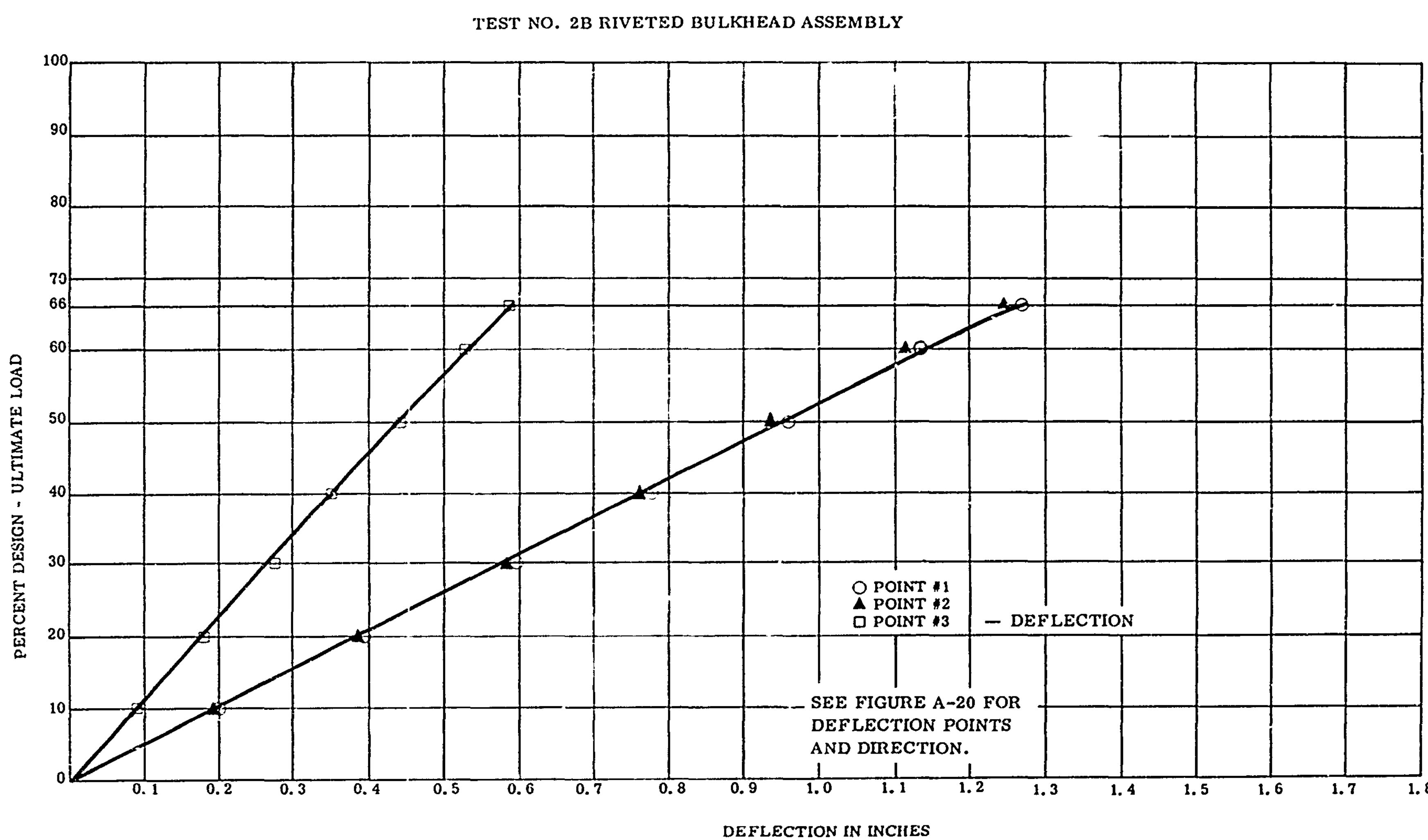


Figure A-45 — DEFLECTION AT 300F; Stat'- Load Test.

TEST NO. 2B RIVETED BULKHEAD ASSEMBLY

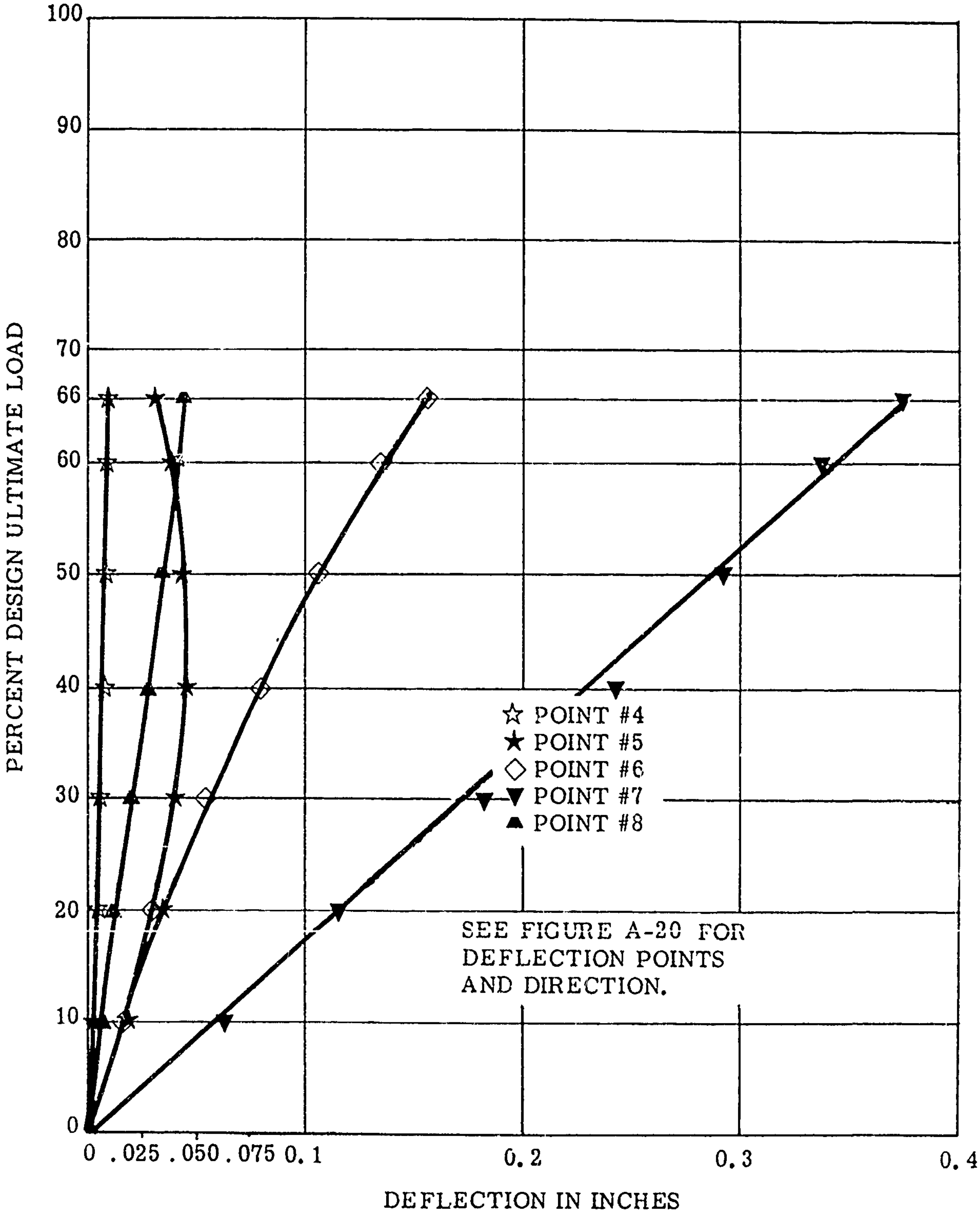


Figure A-46 DEFLECTION AT 300 F; Static Load Test

TEST NO. 2C RIVETED BULKHEAD ASSEMBLY

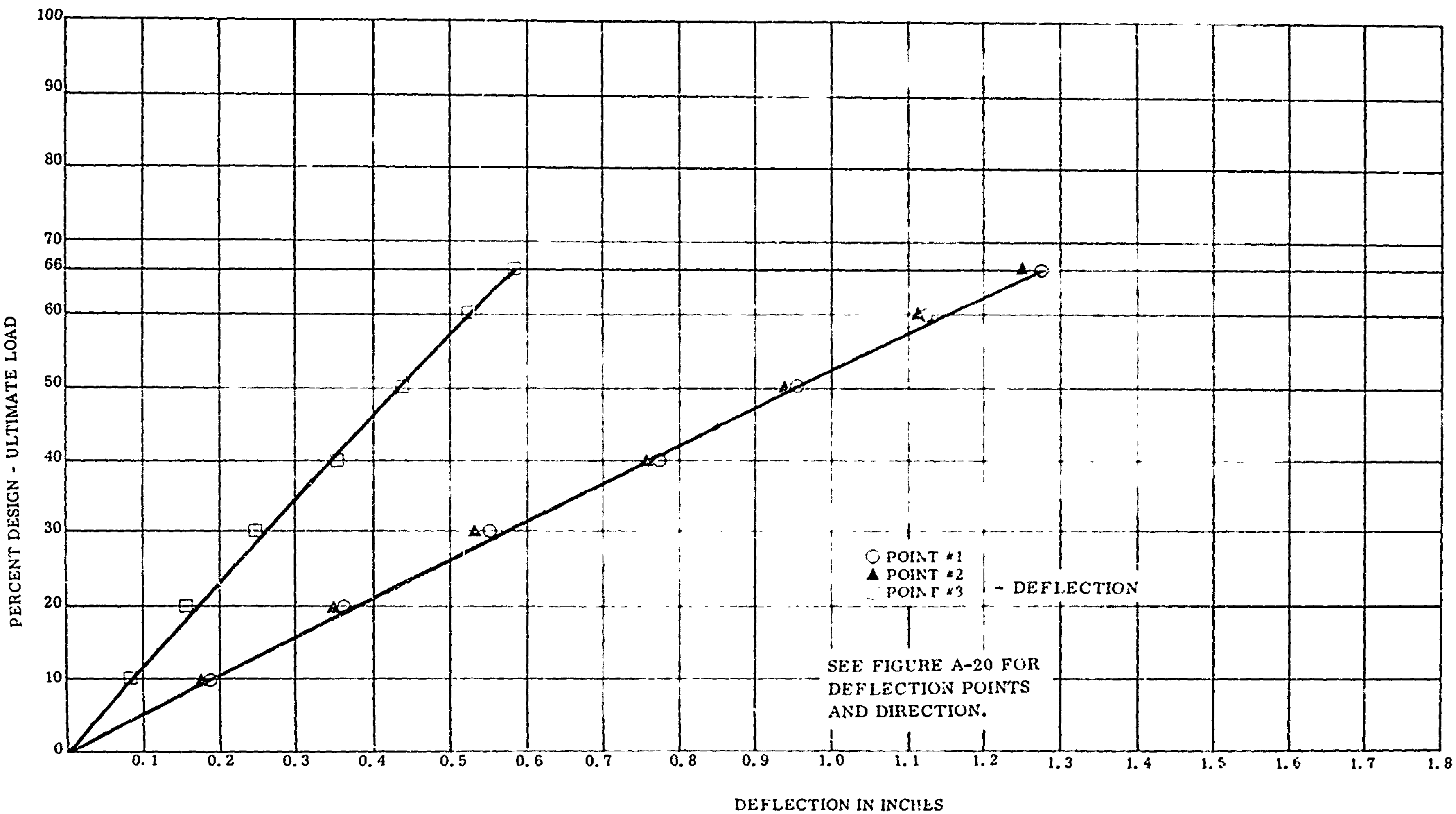


Figure A-47 DEFLECTION AT 400 F; Static Load Test

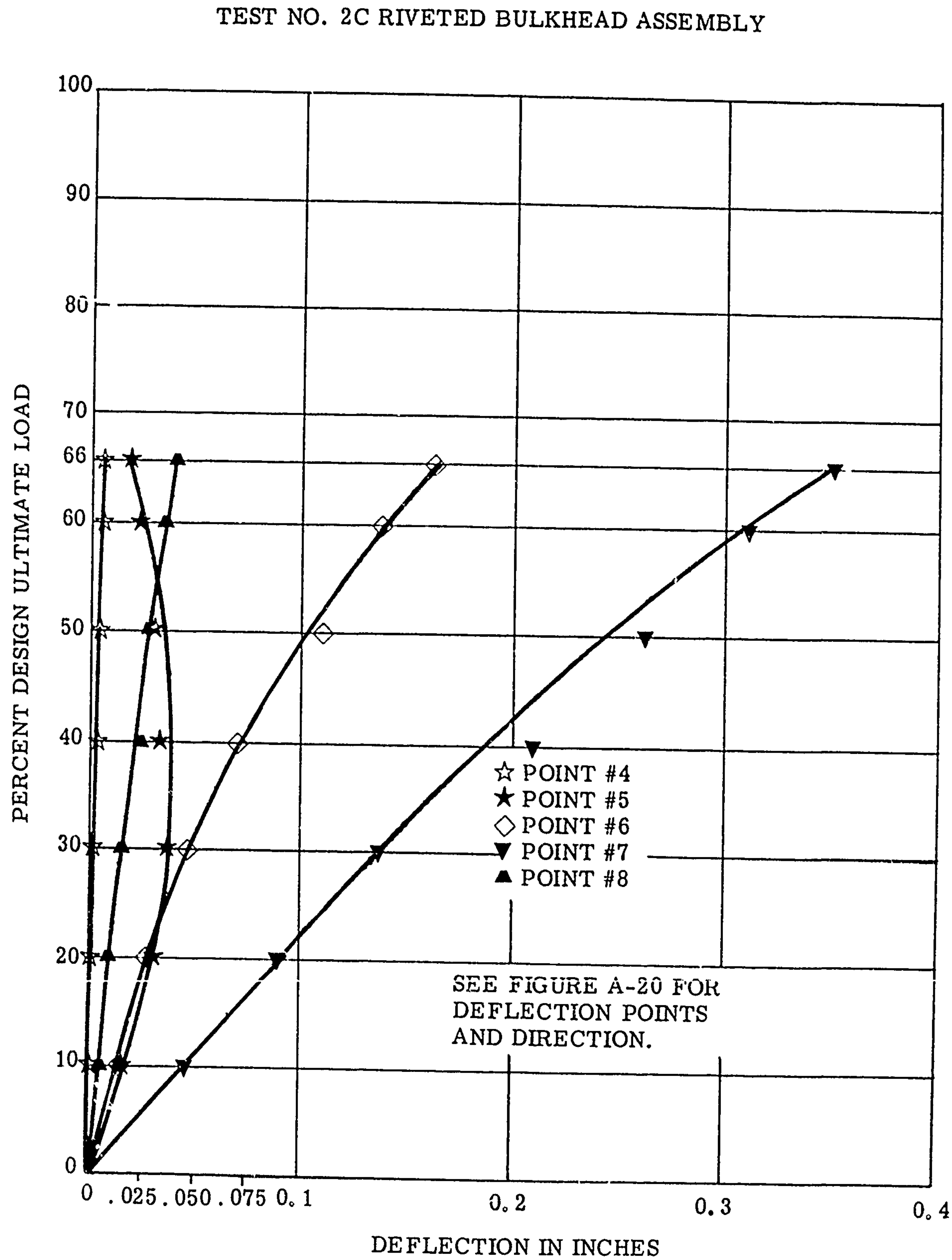


Figure A-48 DEFLECTION AT 400 F; Static Load Test

TEST NO. 2D RIVETED BULKHEAD ASSEMBLY

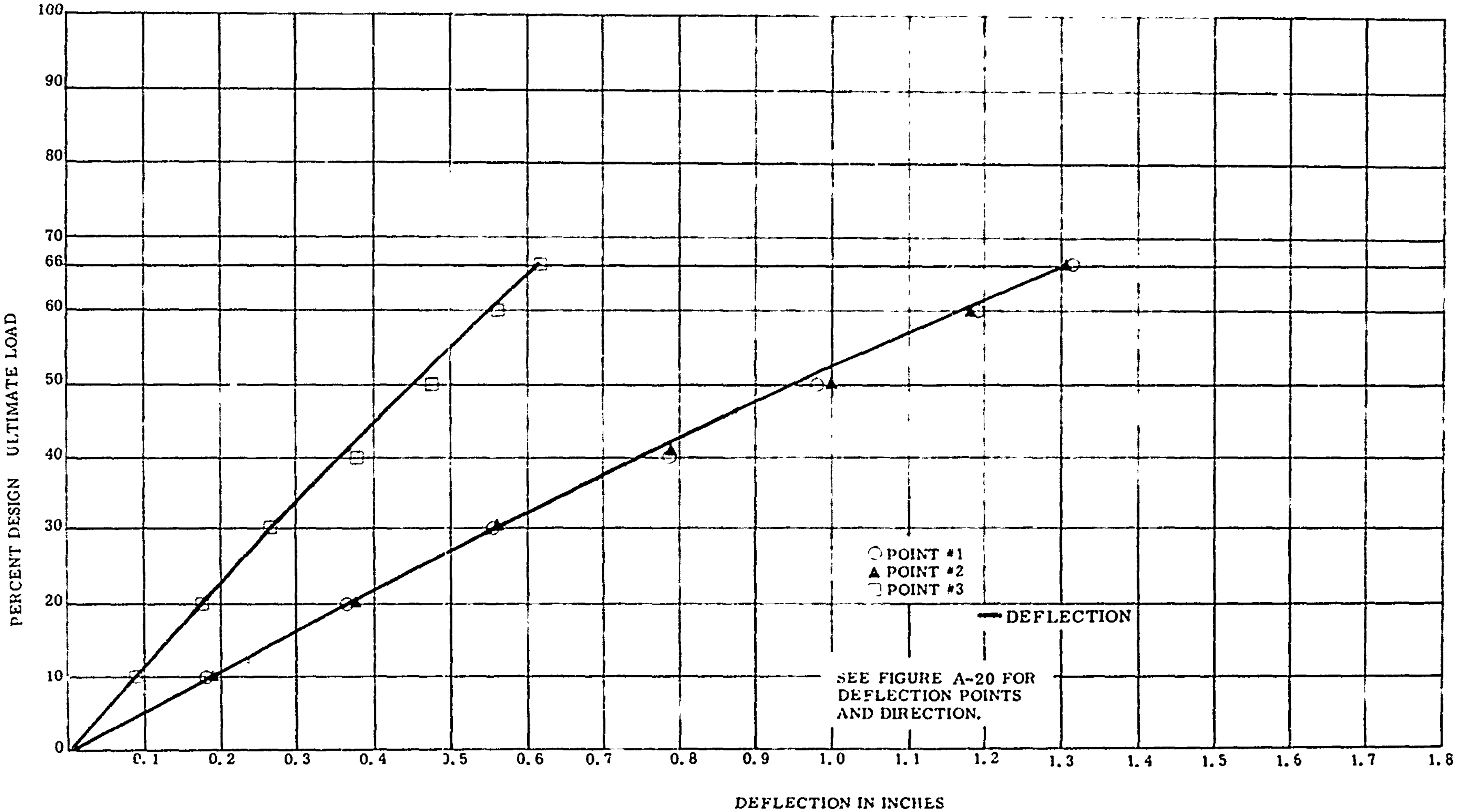


Figure A-49 DEFLECTION AT 500 F; Static Load Test

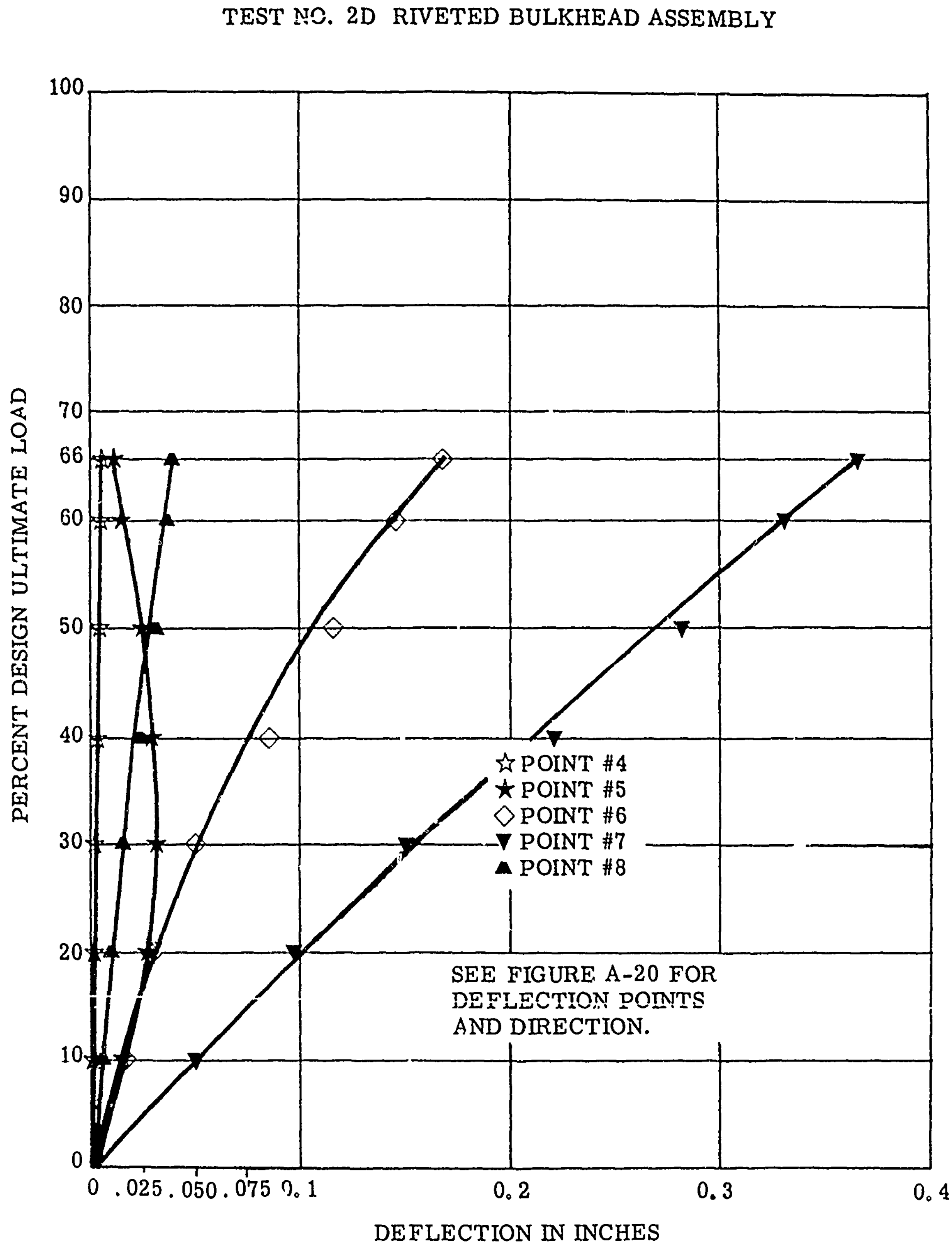
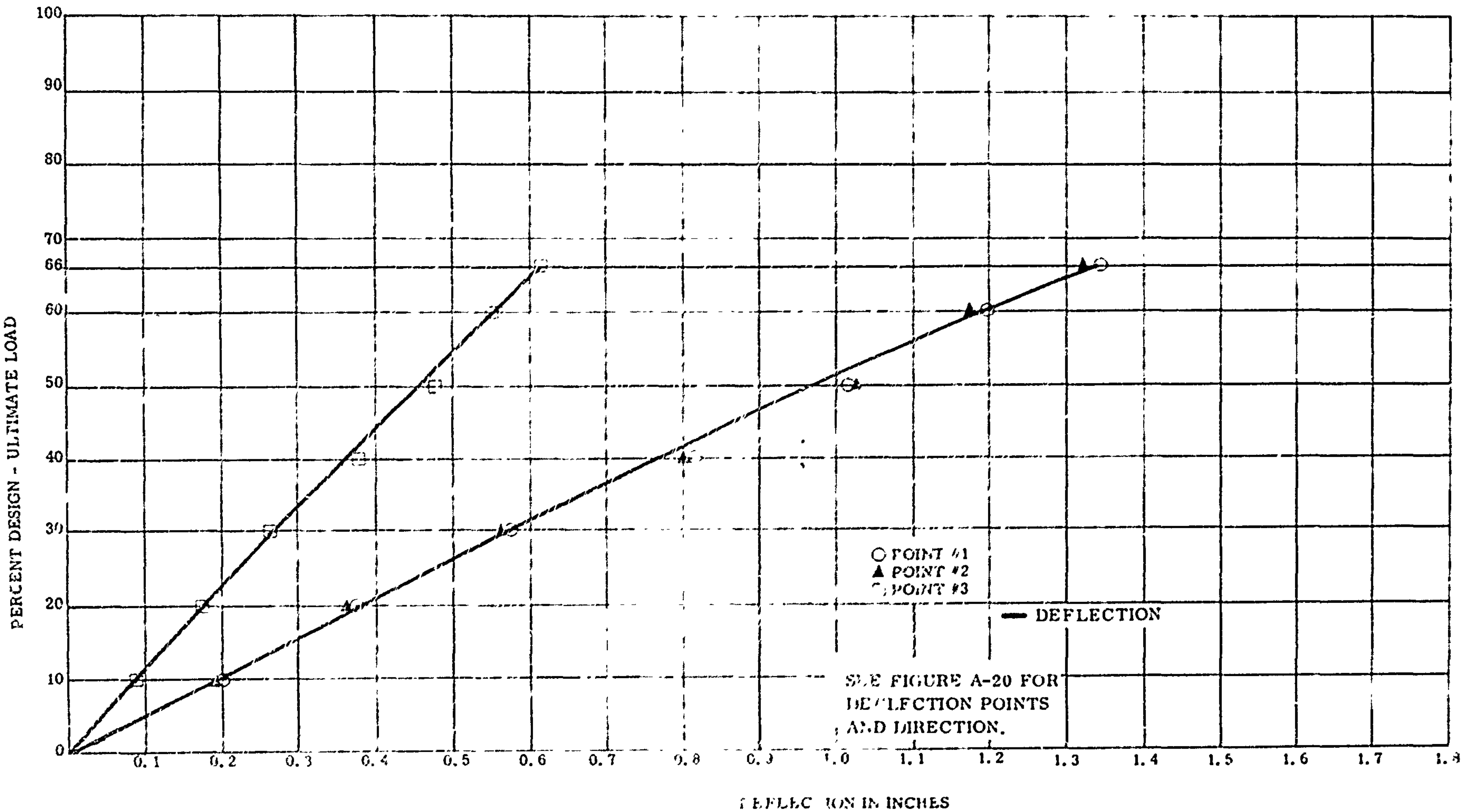


Figure A-50 DEFLECTION AT 500 F; Static Load Test

TEST NO. 2E RIVETED BULKHEAD ASSEMBLY



... AT 600 F; Static Load Test

TEST NO. 2E RIVETED BULKHEAD ASSEMBLY

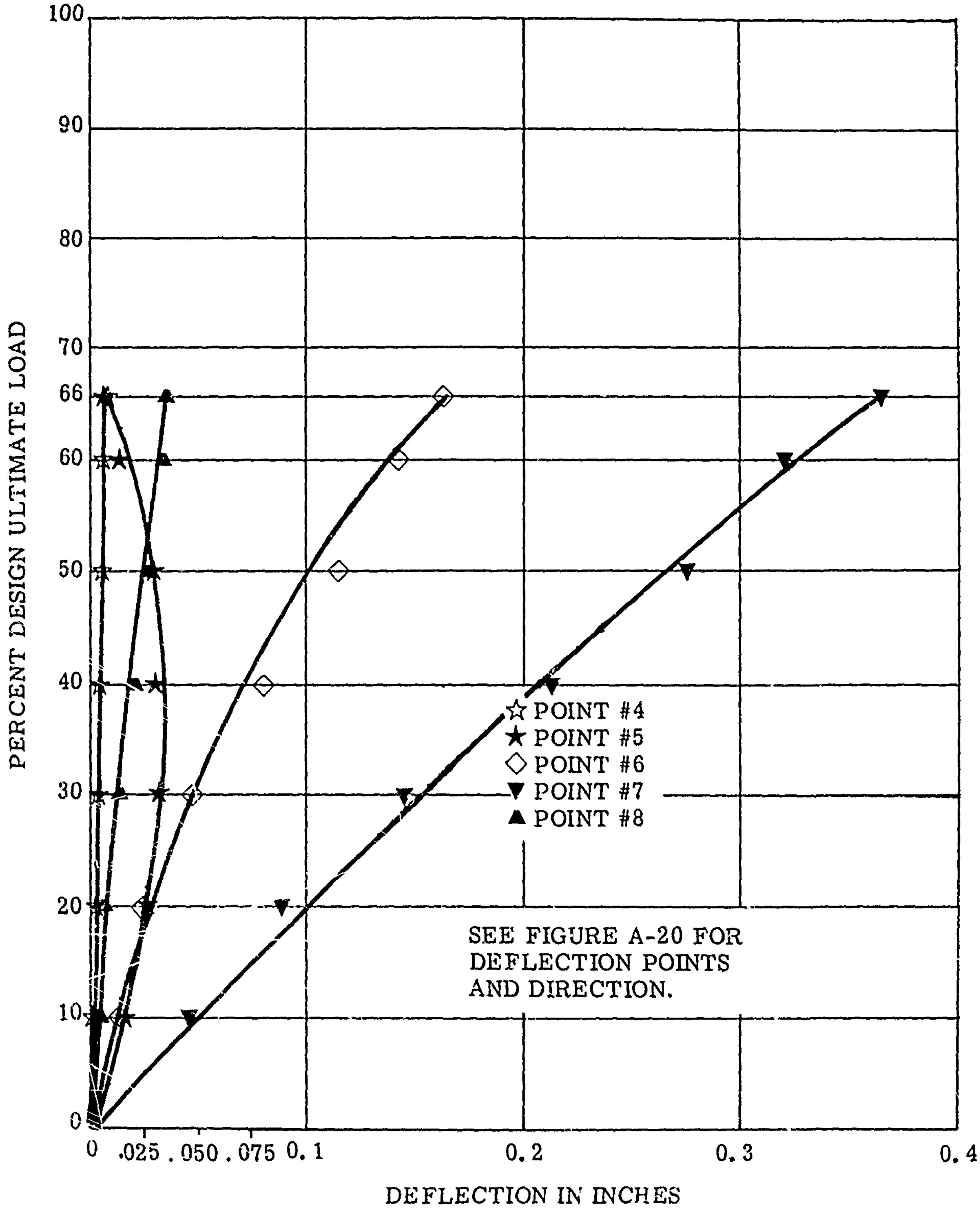


Figure A-52 DEFLECTION AT 600 F; Static Load Test

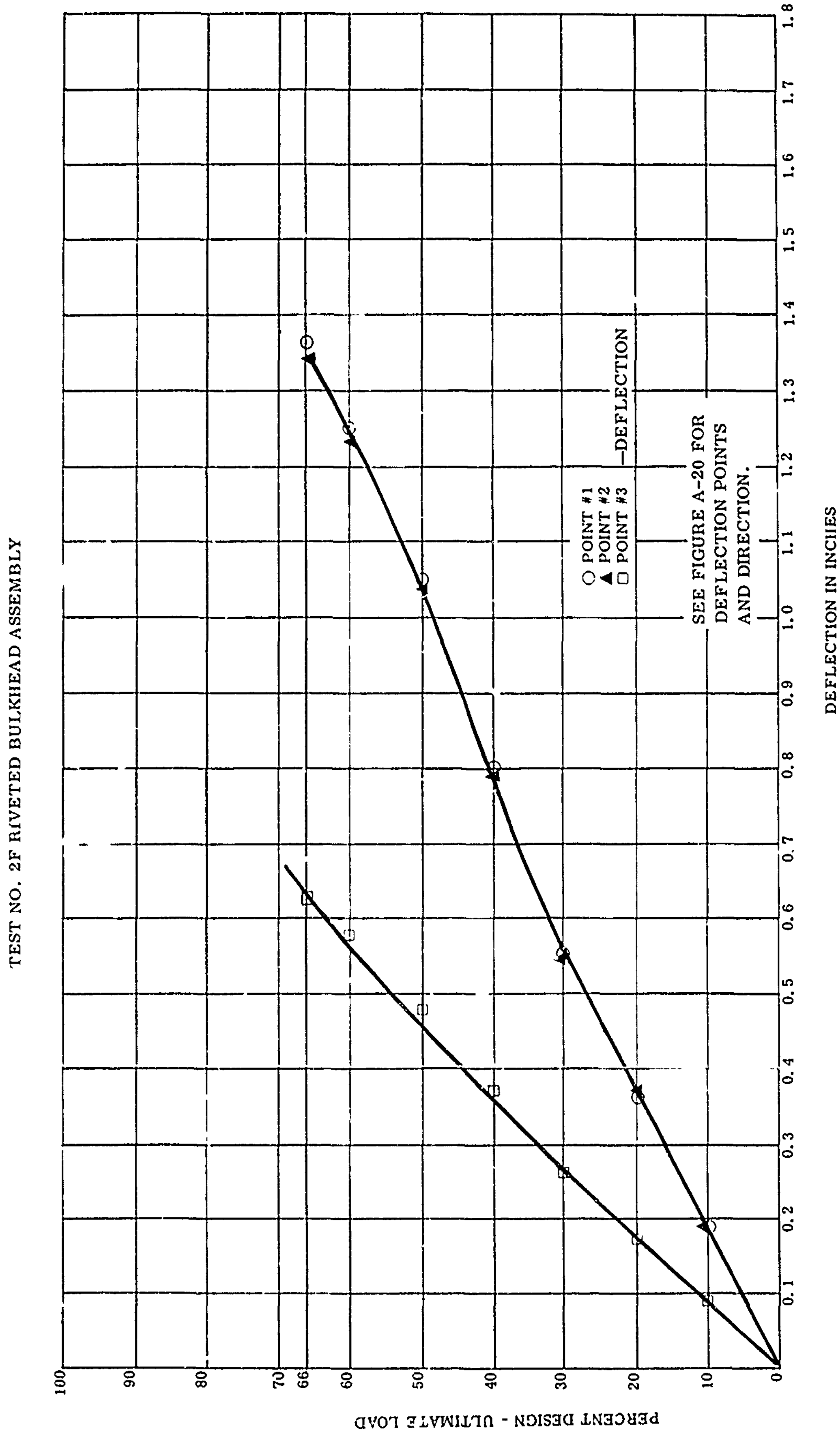


Figure A-53 — DEFLECTION AT 700F; Static Load Test.

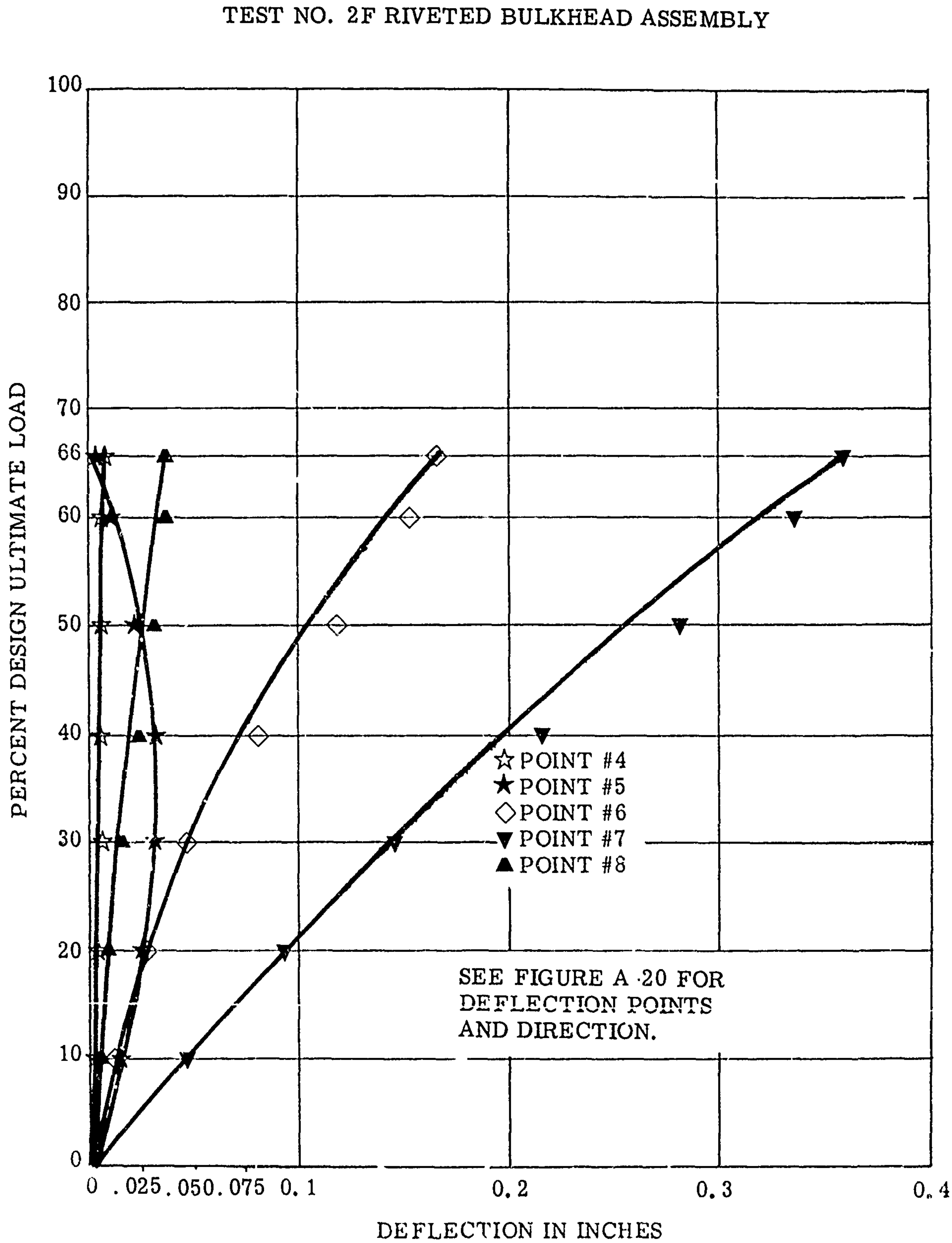


Figure A-54 DEFLECTION AT 700 F; Static Load Test

TEST NO. 2G RIVETED BULKHEAD ASSEMBLY

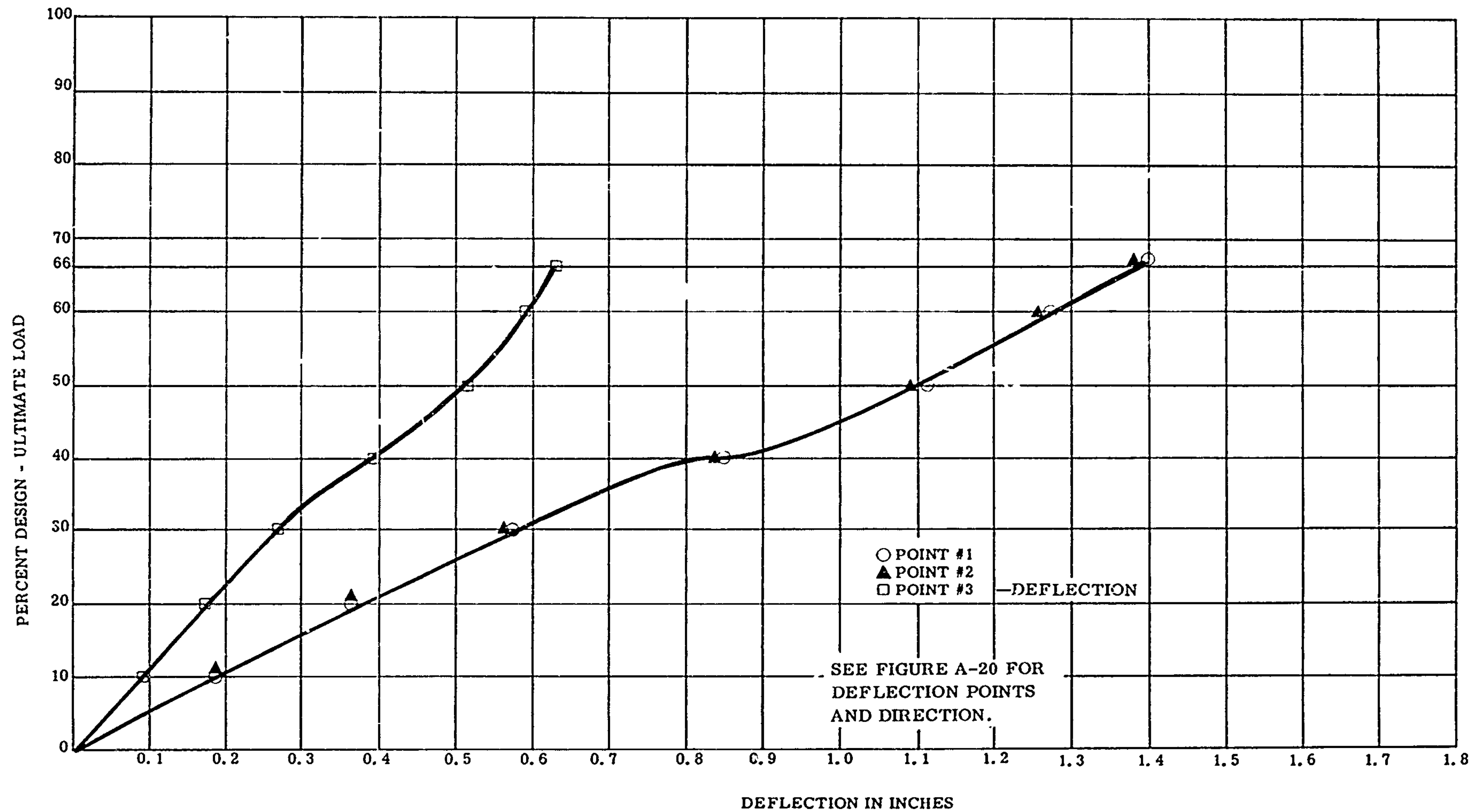


Figure A-55 — DEFLECTION AT 800F; Static Load Test.

TEST NO. 2G RIVETED BULKHEAD ASSEMBLY

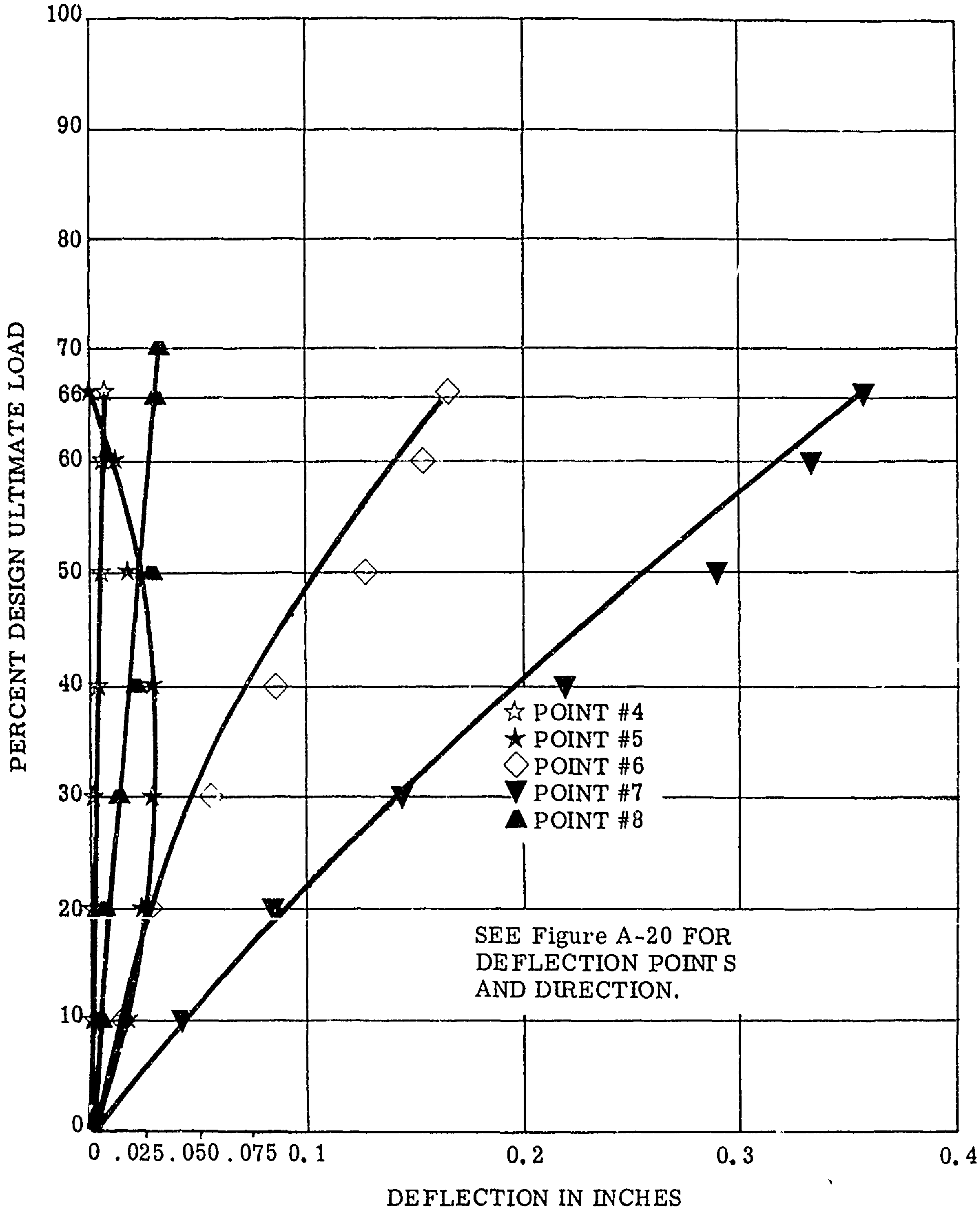


Figure A-56 DEFLECTION AND PERMANENT SET AT 800 F;
Static Load Test

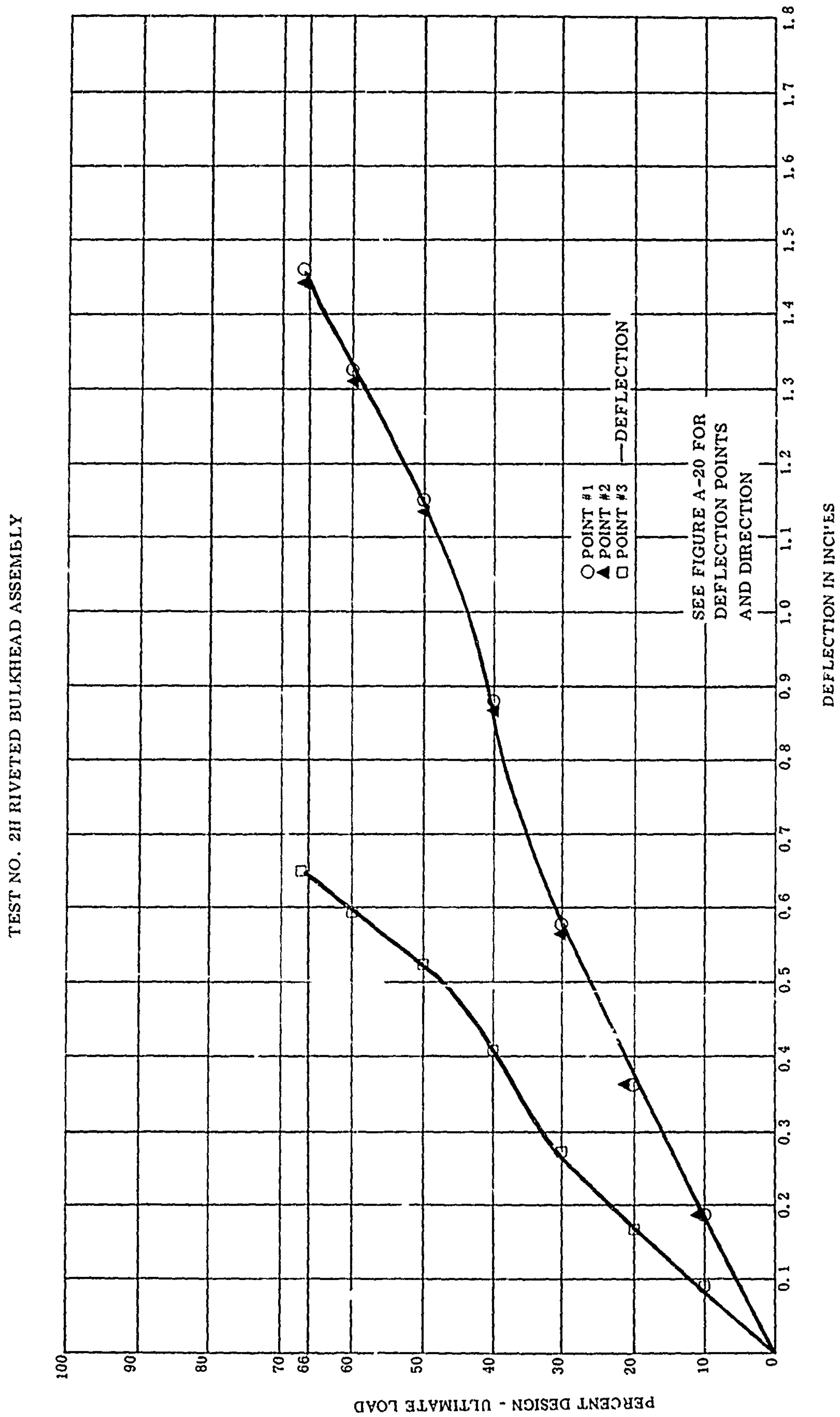


Figure A-57 — DEFLECTION AT 900F; Static Load Test.

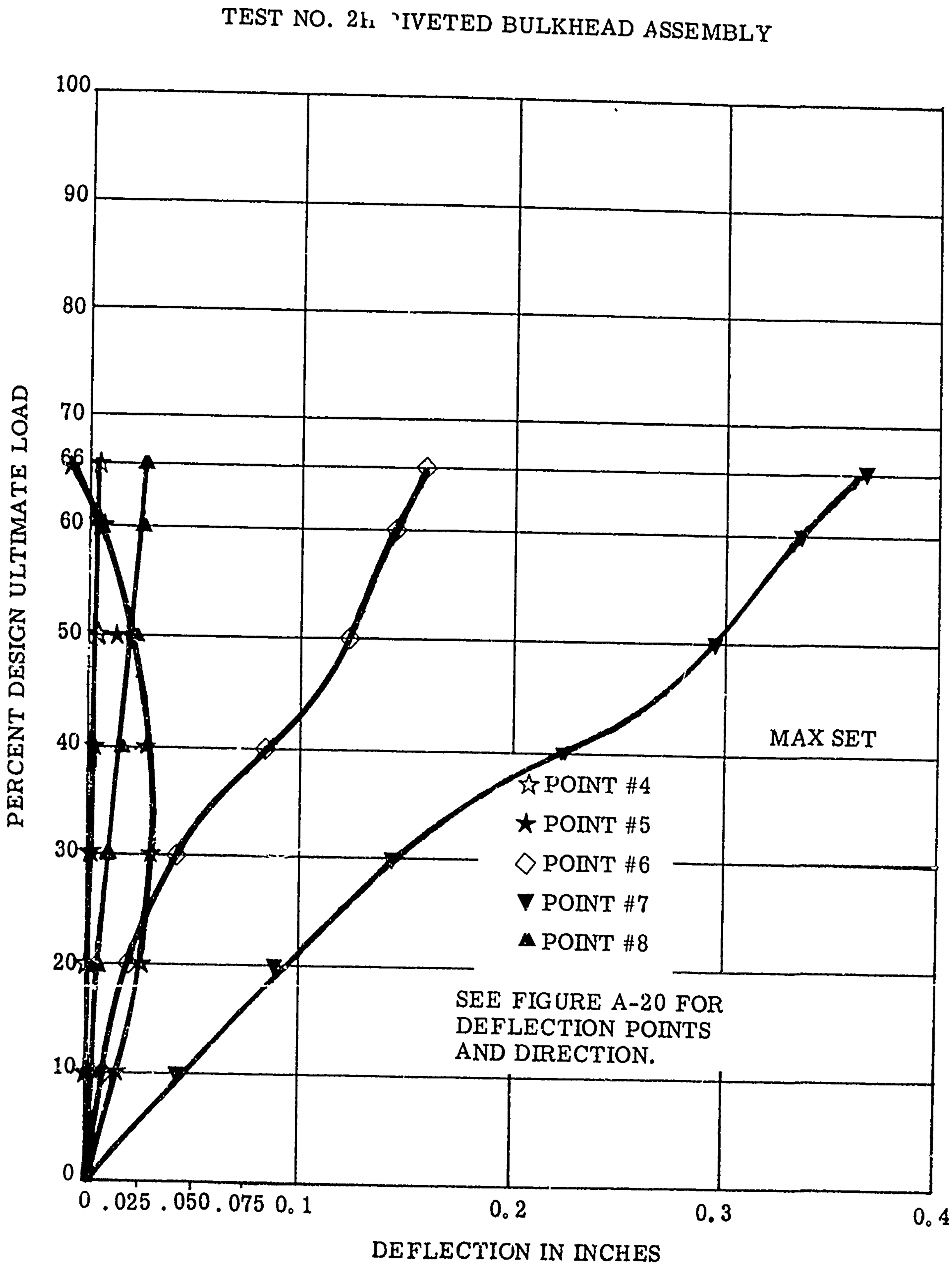


Figure A-58 DEFLECTION AND PERMANENT SET AT 900 F; Static Load Test

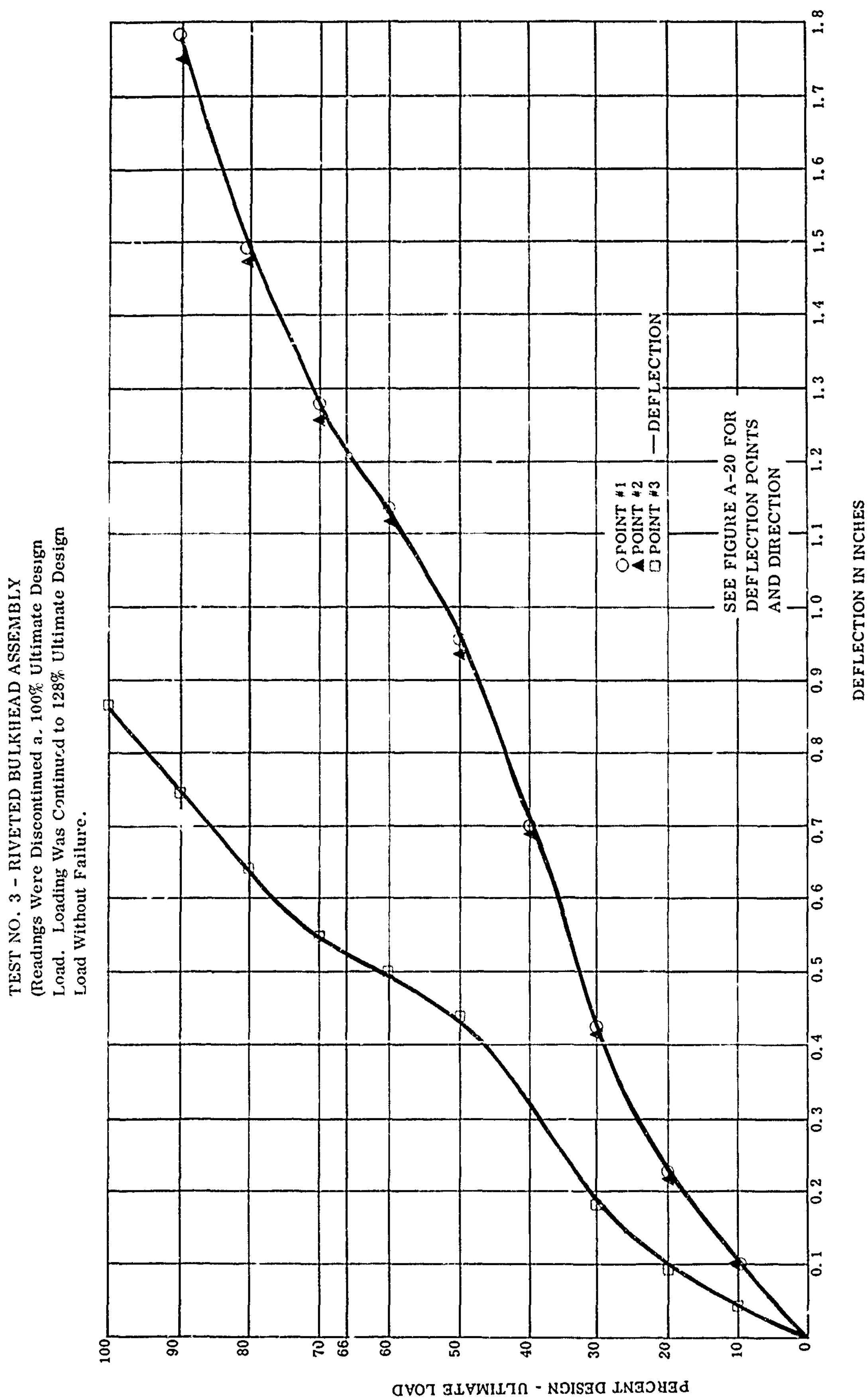


Figure A-59 — DEFLECTION AT 800F; After 900F - 128% Design Ultimate Static Test.

TEST NO. 3 - RIVETED BULKHEAD ASSEMBLY
(Readings Were Discontinued At 100% Ultimate Design Load. Loading Was Continued to 128% Ultimate Design Load Without Failure.

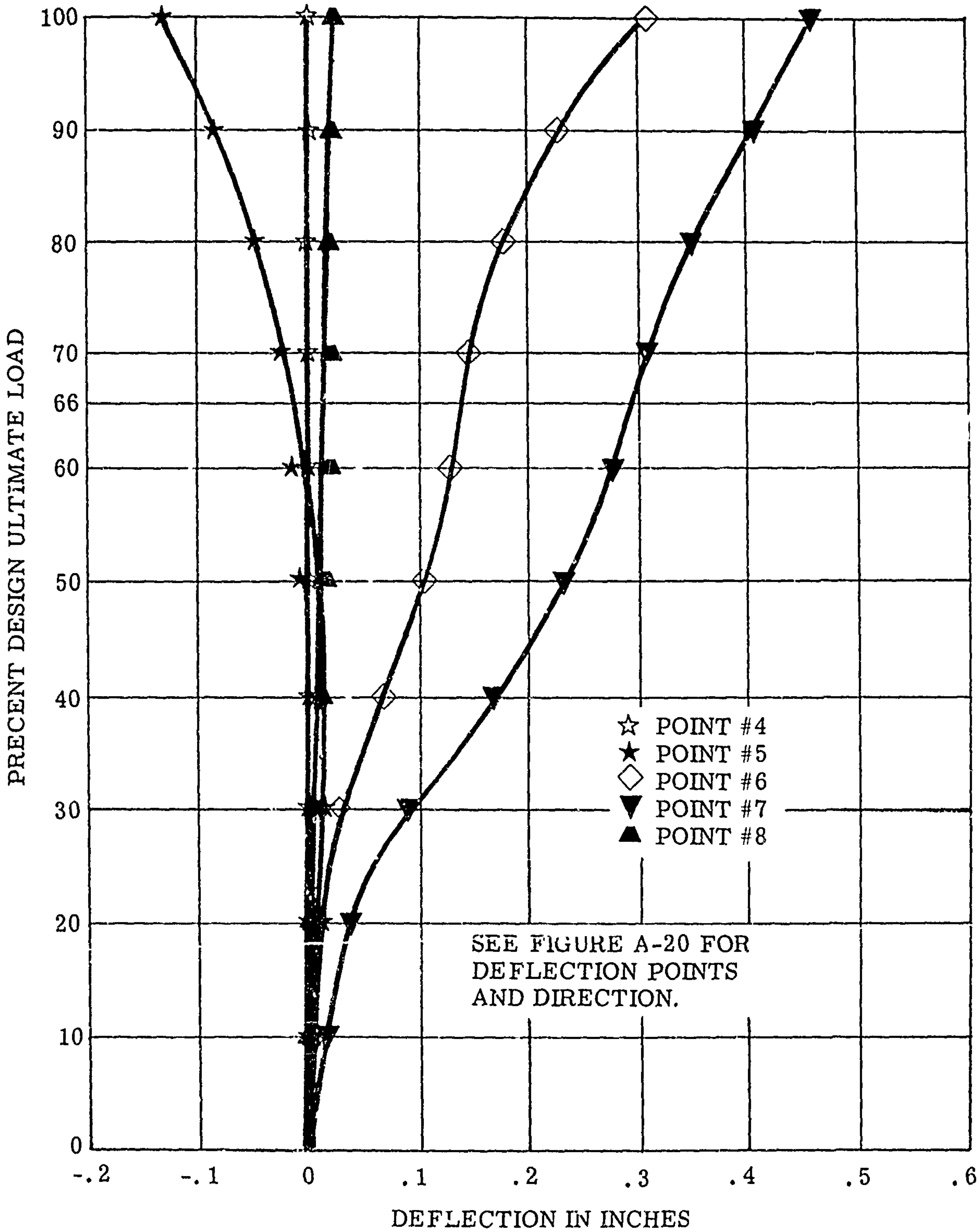


Figure A-60 — DEFLECTION AT 800F AFTER 900F; 128% Design Ultimate Static Test.

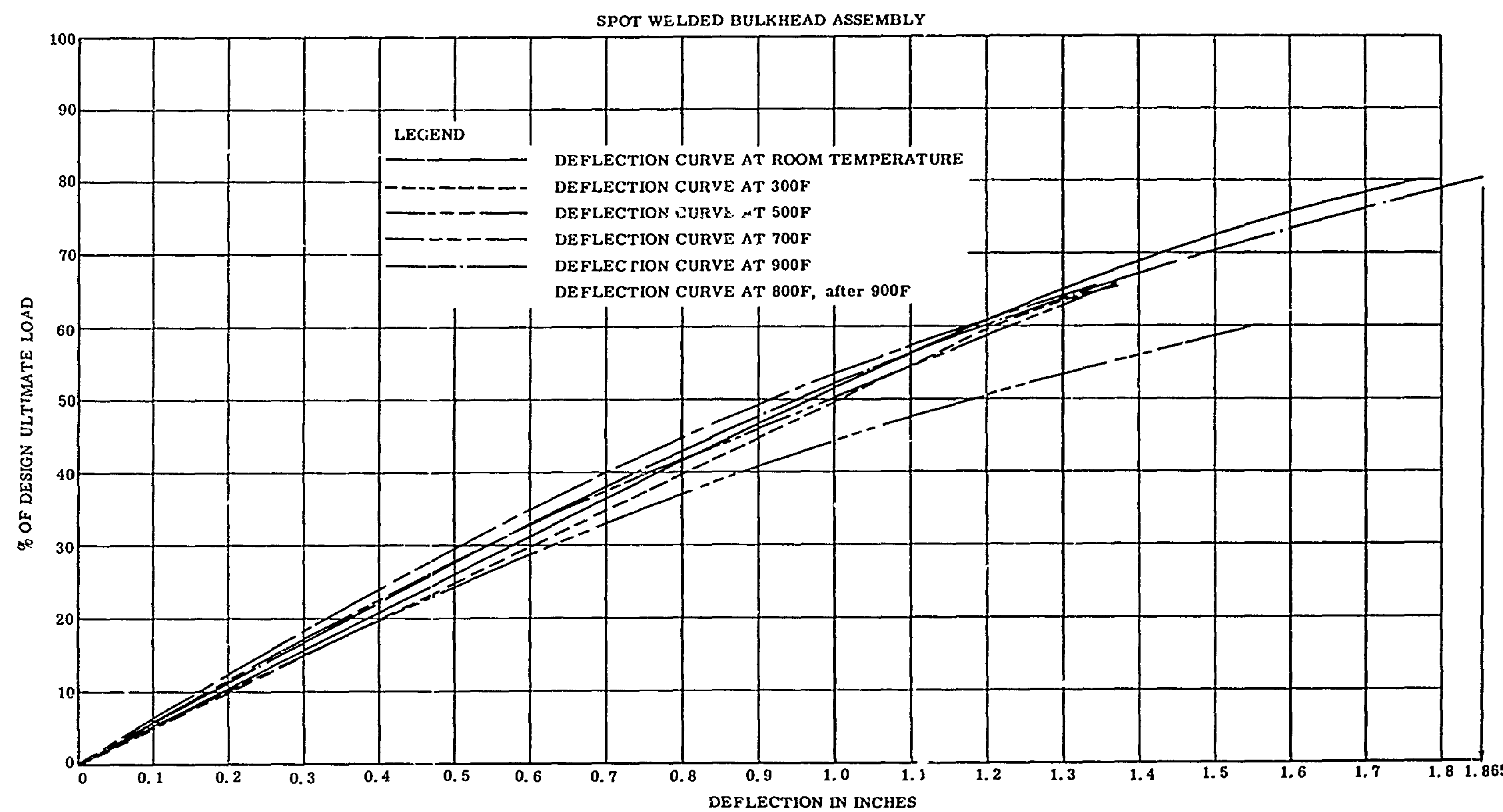


FIGURE A-61. DEFLECTION AT POINT #1 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

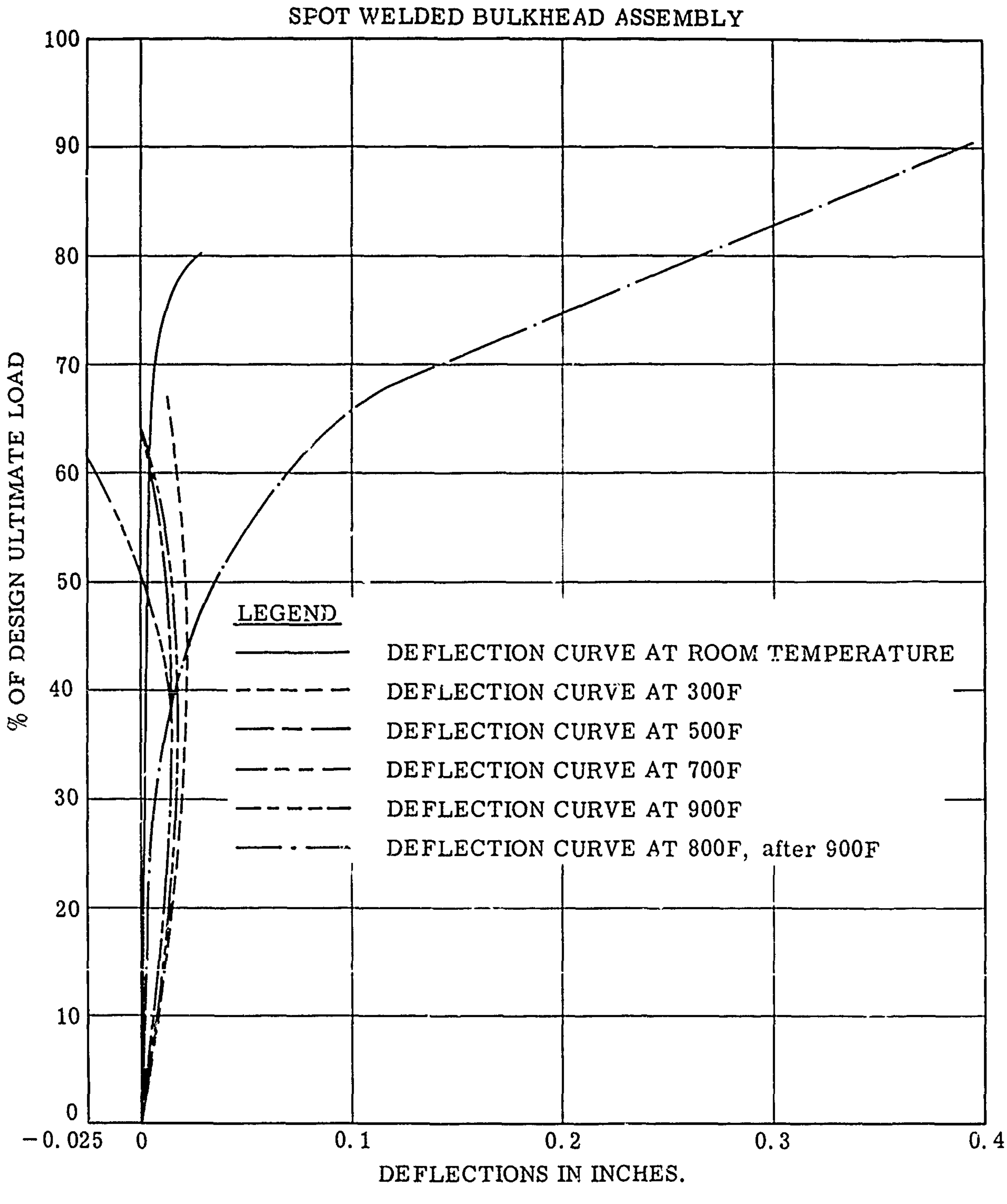


FIGURE A-62. DEFLECTION AT POINT #5 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

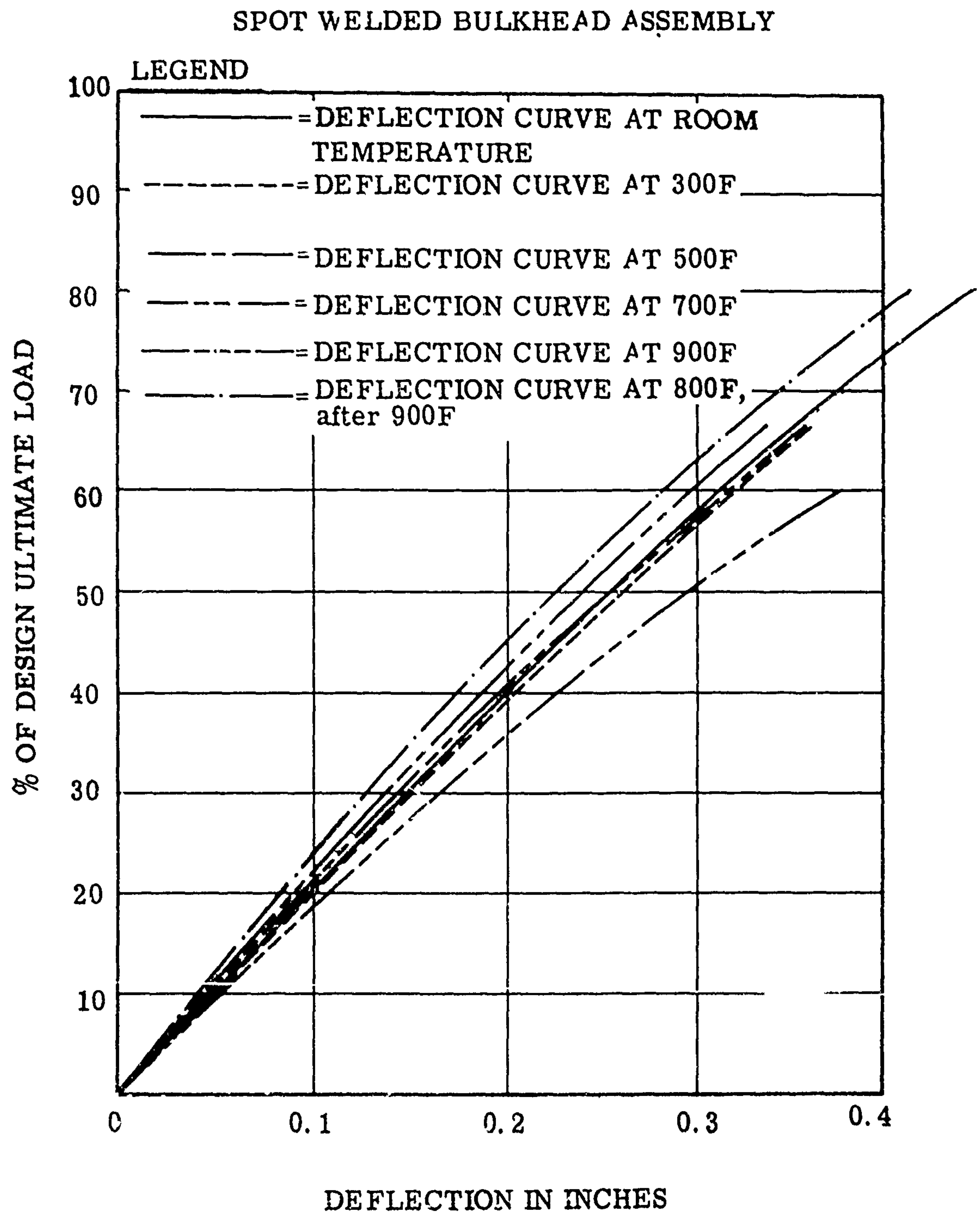


FIGURE A-63. DEFLECTION AT POINT #7 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

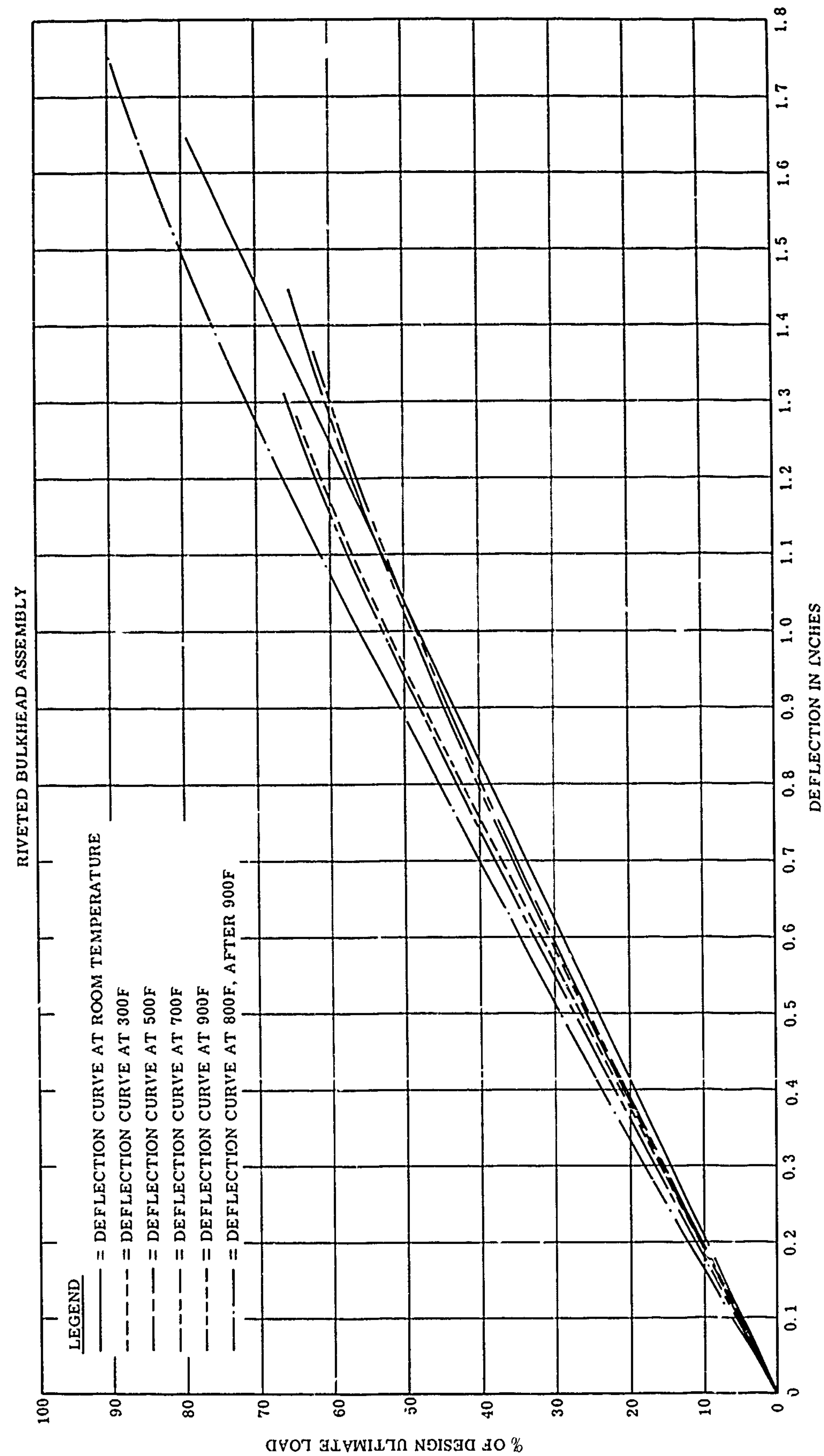


FIGURE A-64. DEFLECTION AT POINT #1 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

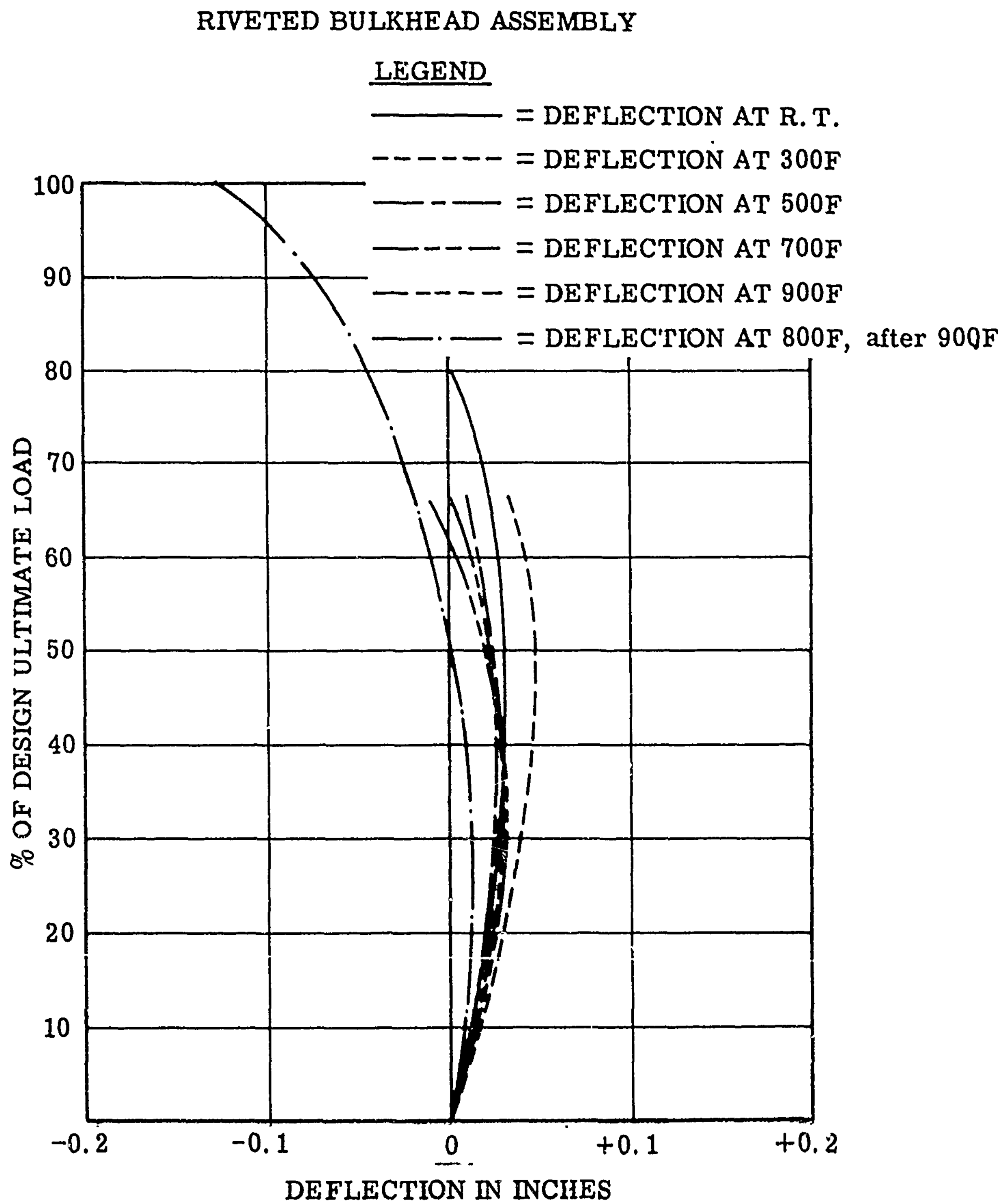


FIGURE A-65. DEFLECTION AT POINT #5 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

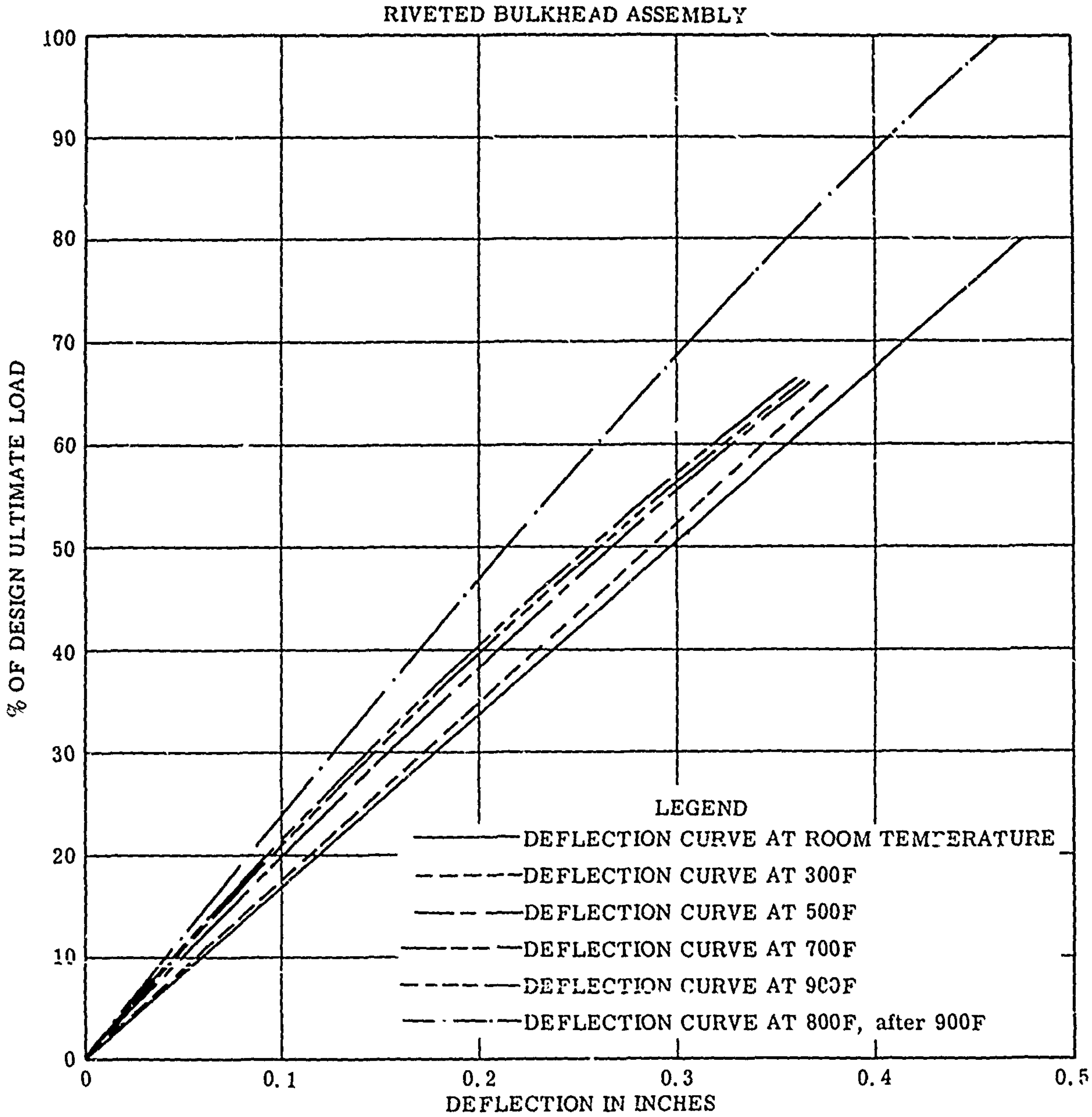


FIGURE A-66. DEFLECTION AT POINT #7 COMPARED AT SIX TEMPERATURES; From Room Temperature To 900F

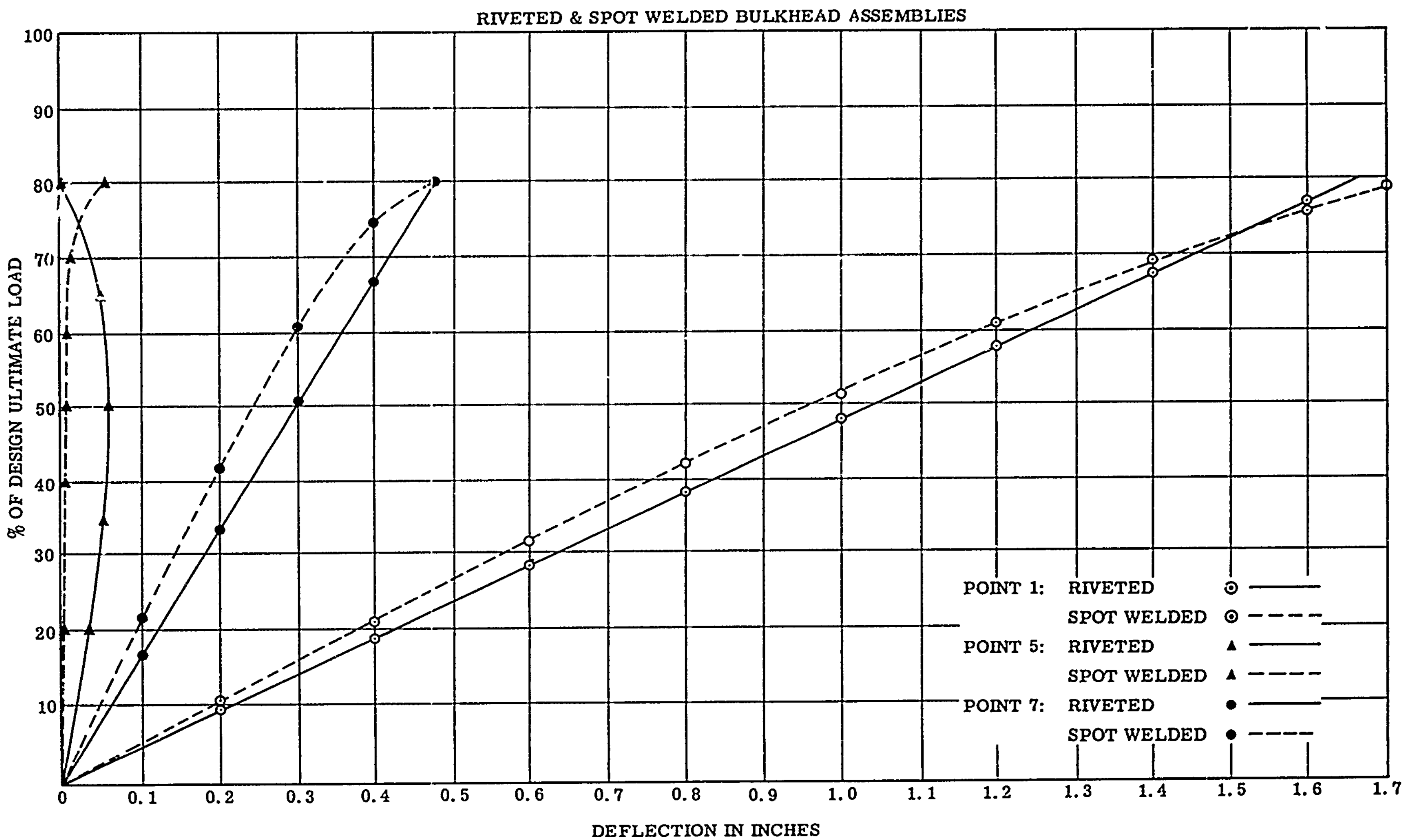


FIGURE A-67. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULKHEAD ASSEMBLIES; At Room Temperature

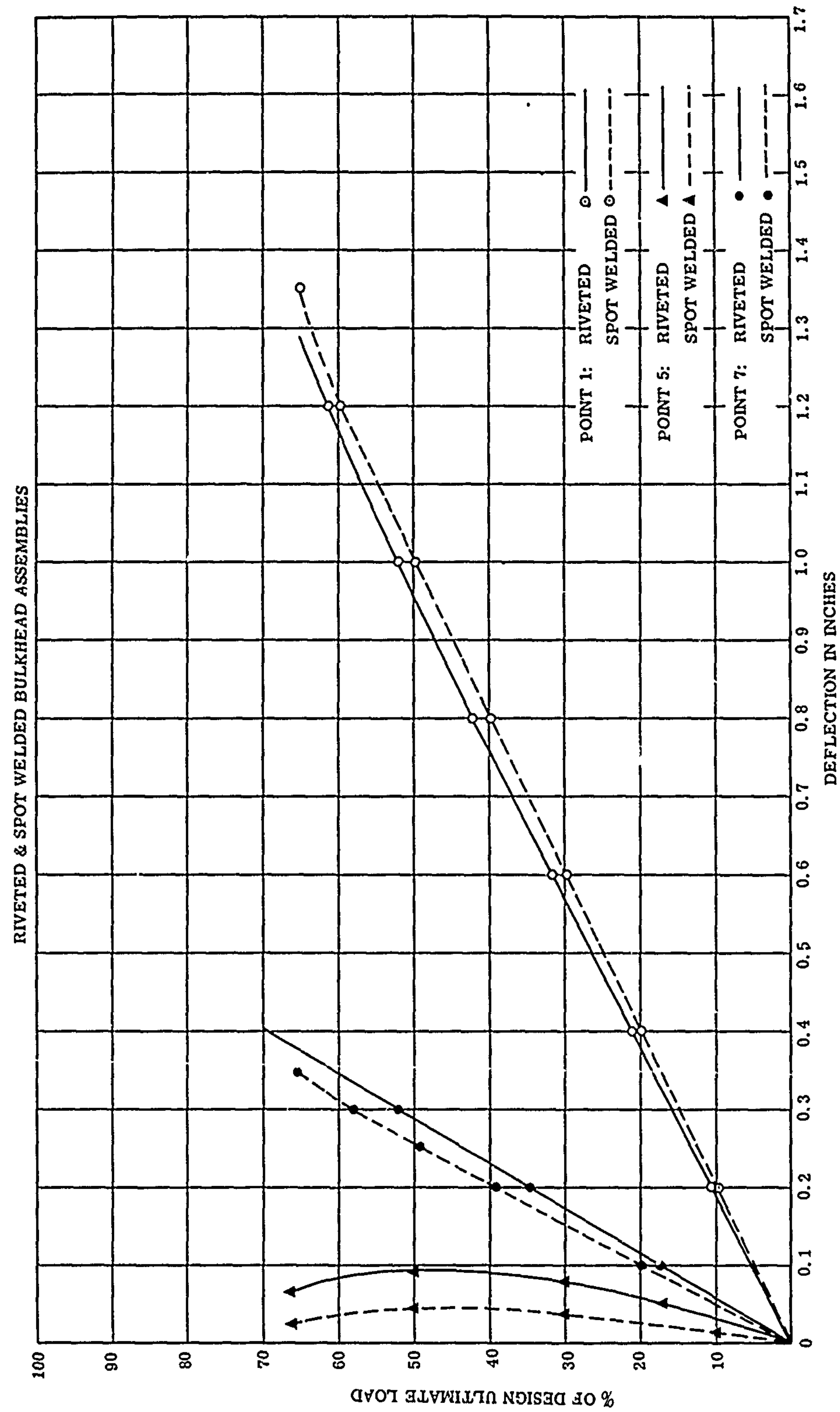


FIGURE A-68. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULK-HEAD ASSEMBLIES AT 300F

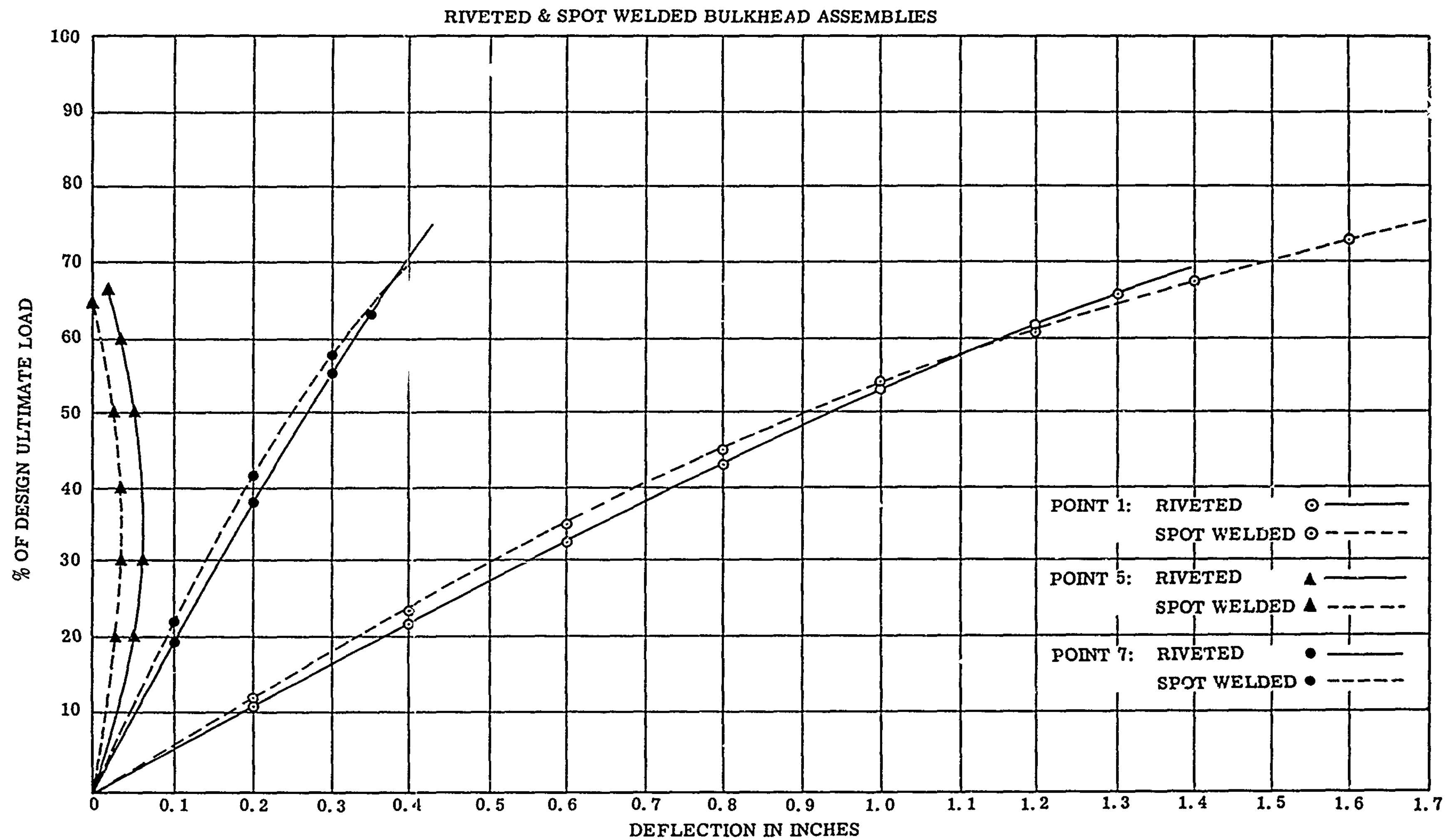


FIGURE A-69. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULKHEAD ASSEMBLIES; At 500F

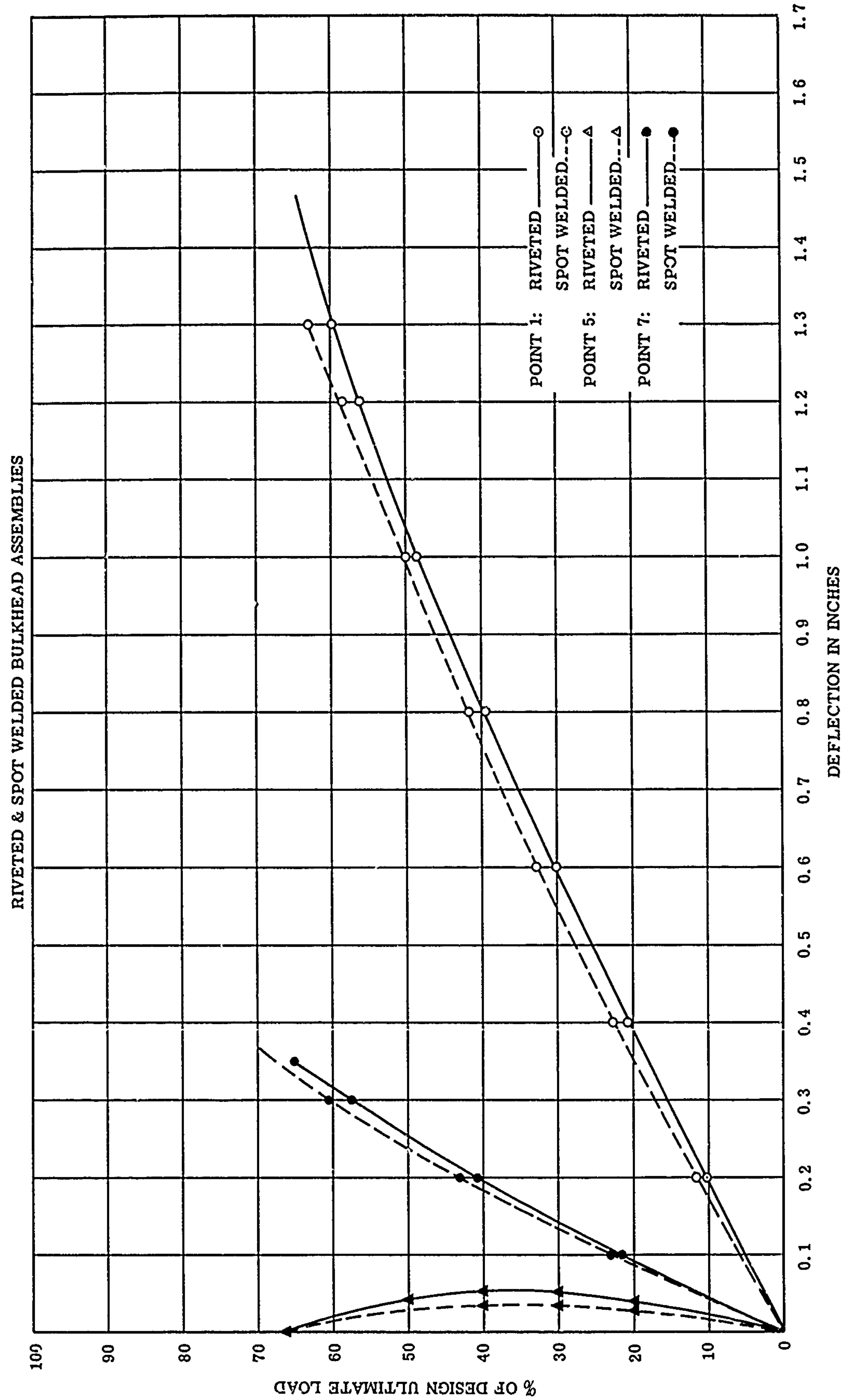


FIGURE A-70. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULKHEAD ASSEMBLIES; At 700F

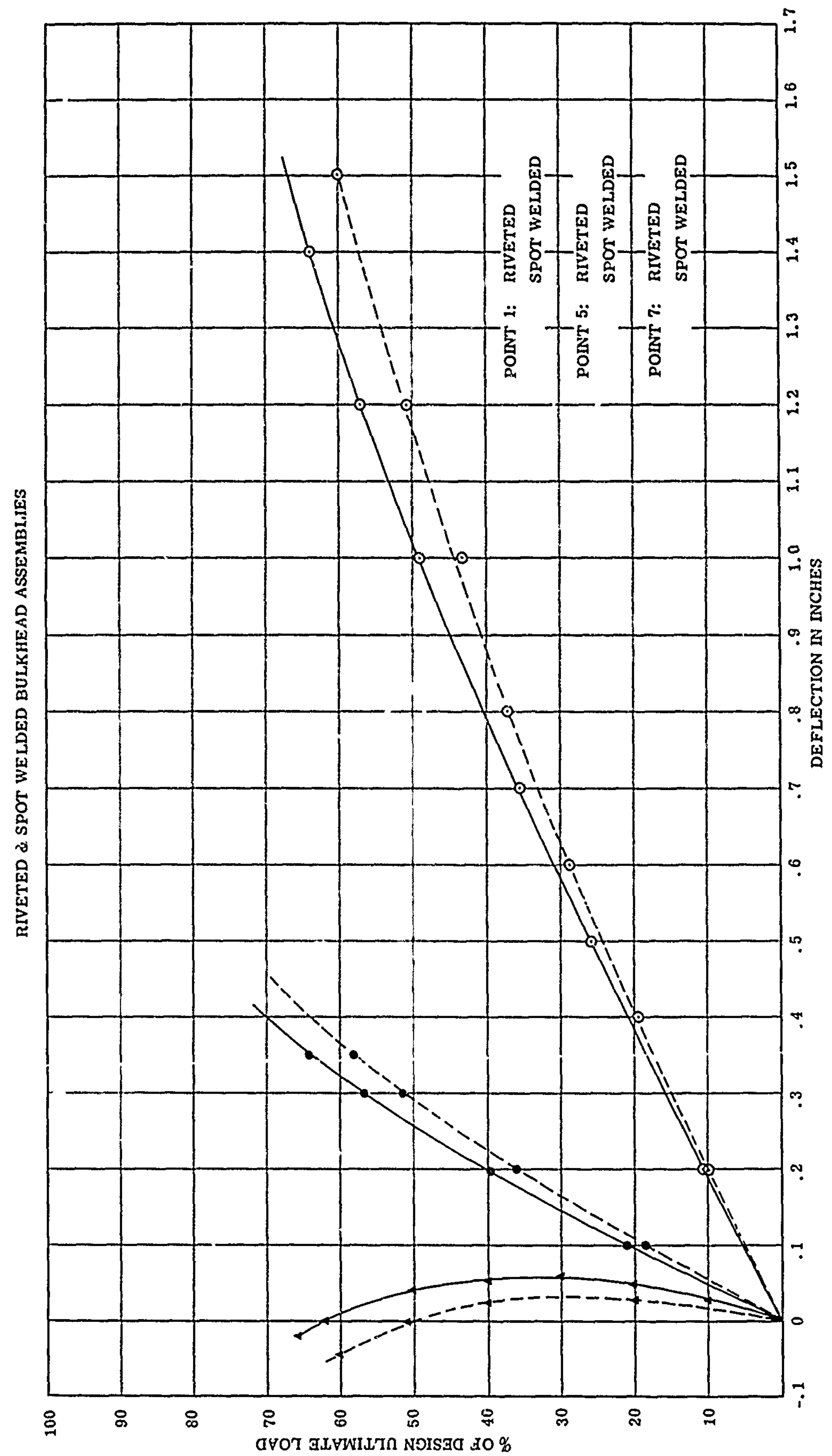


FIGURE A-71. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULKHEAD ASSEMBLIES; At 900F

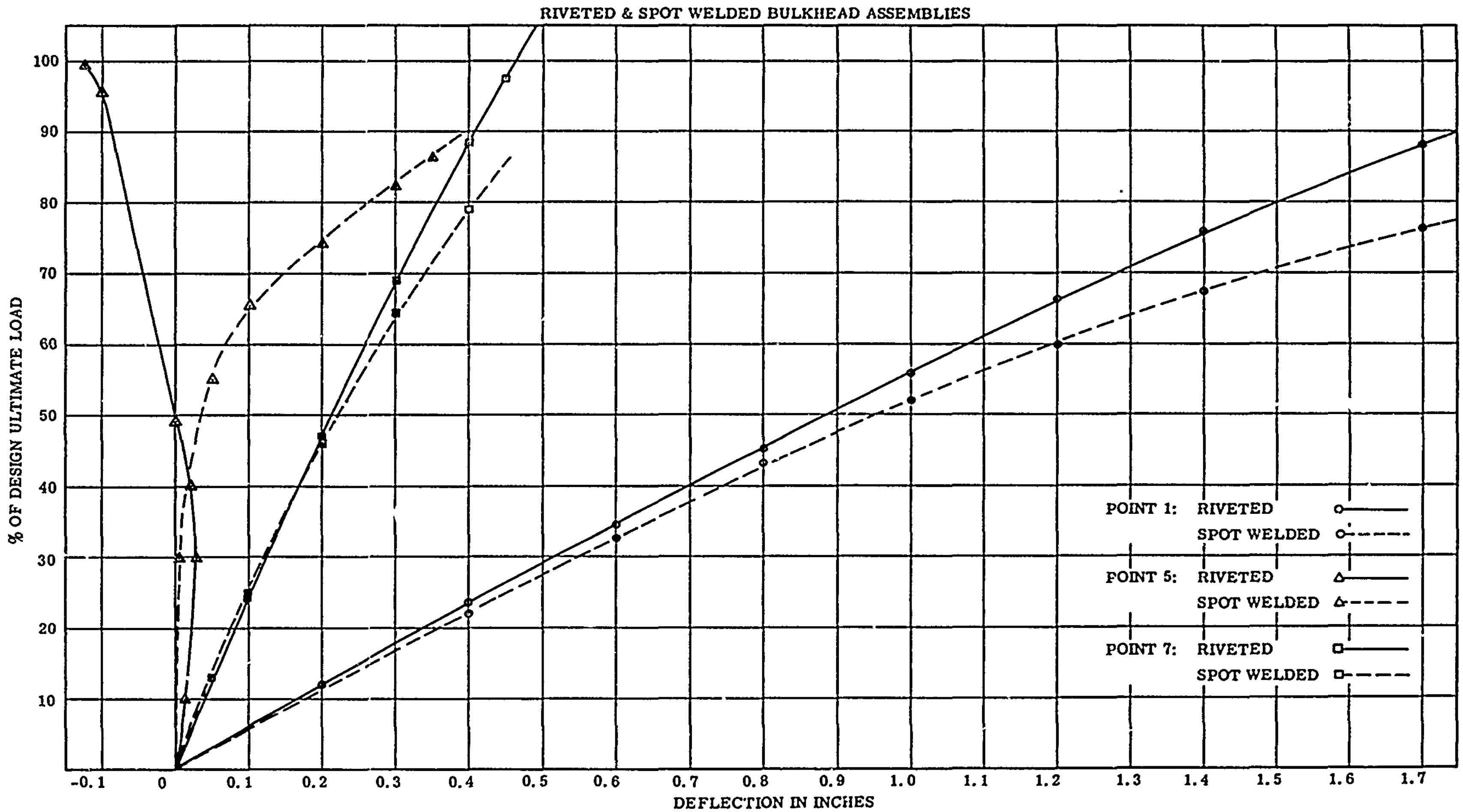


FIGURE A-72. COMPARISON OF DEFLECTIONS BETWEEN RIVETED AND SPOT WELDED BULKHEAD ASSEMBLIES; At 800F after 900F

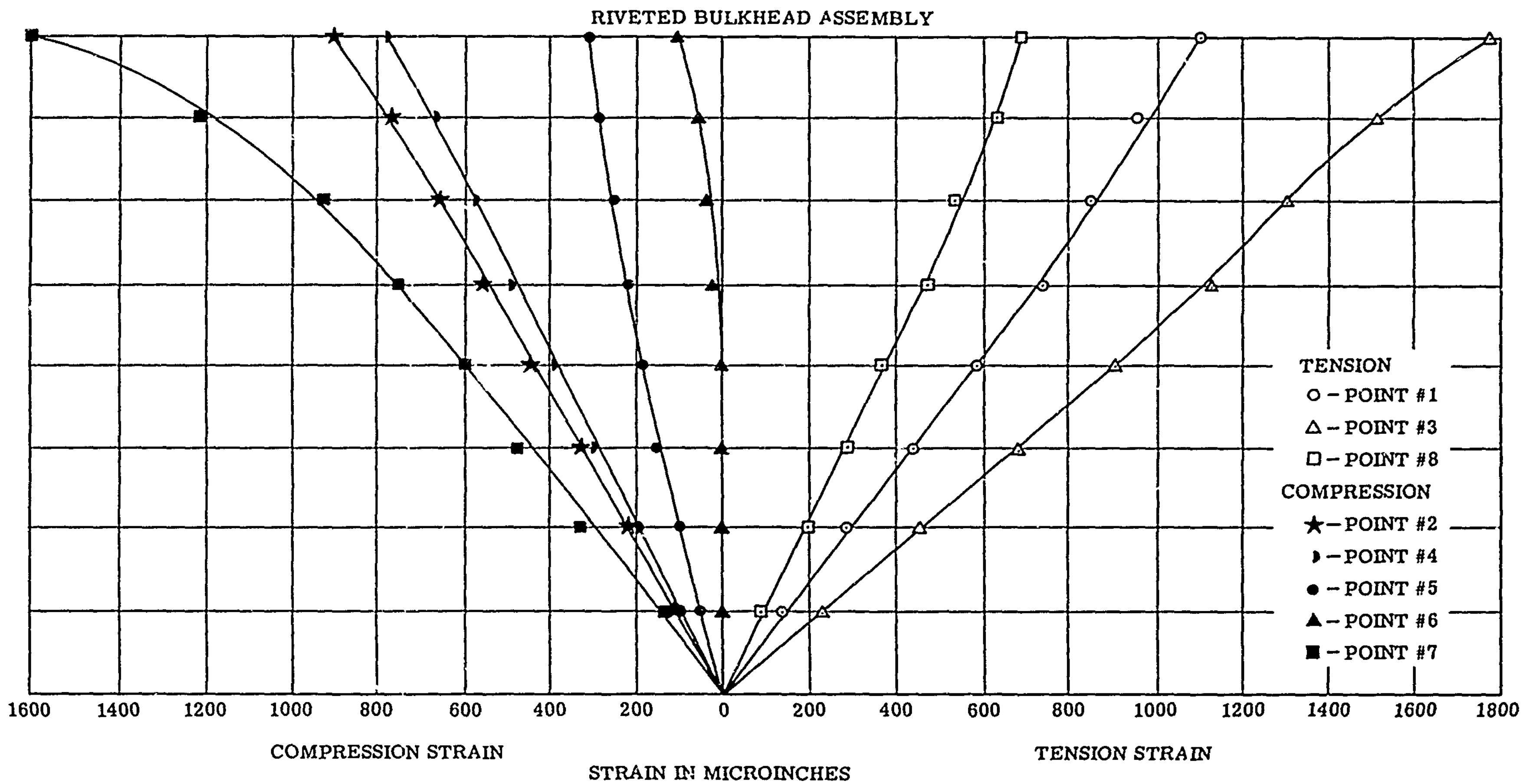


FIGURE A-73. STRAIN INDICATIONS VS % ULTIMATE LOAD ON THE RIVETED BULKHEAD ASSEMBLY; Room-Temperature Static Test

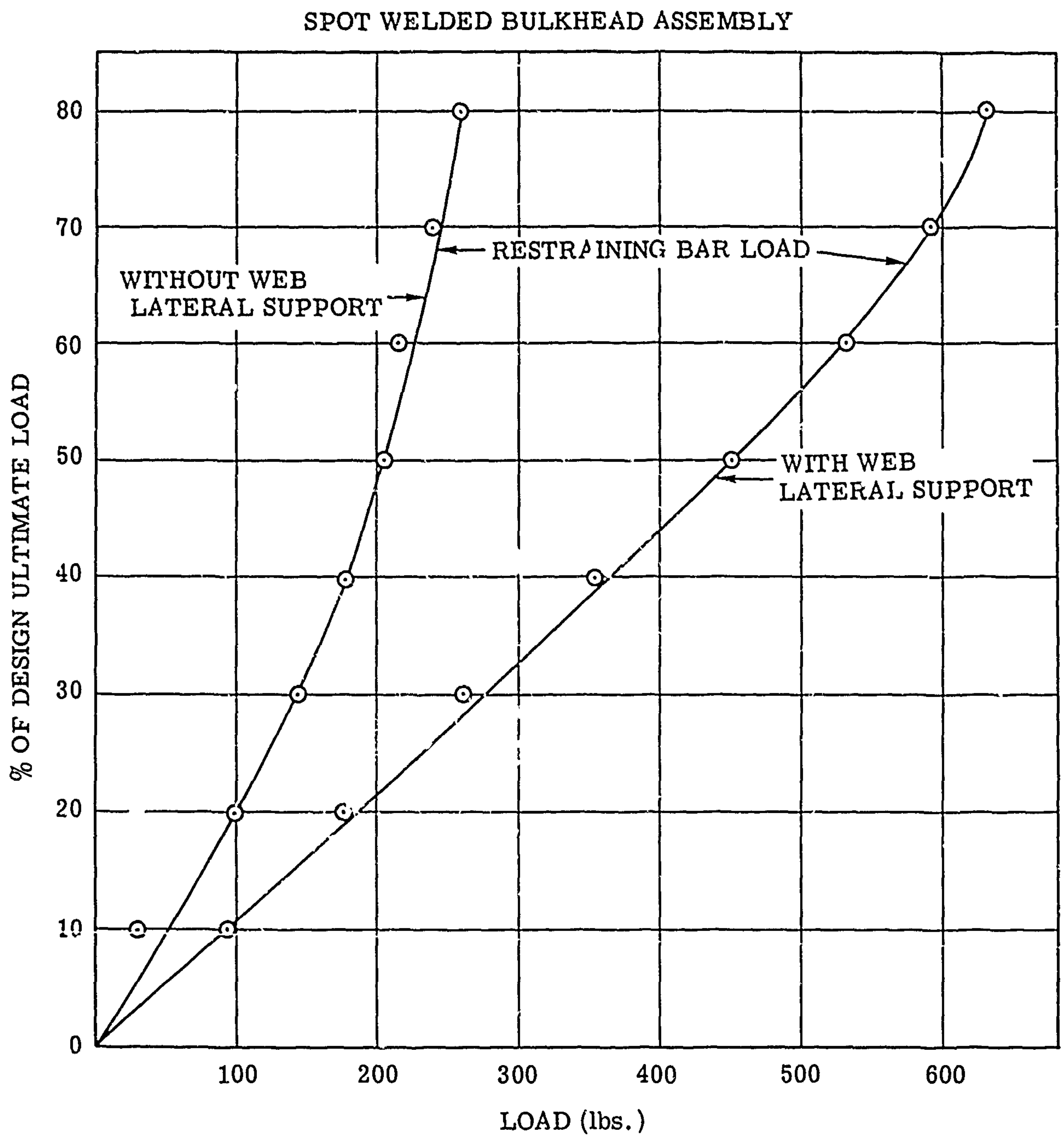


FIGURE A-74. COMPARISON OF RESTRAINING-BAR REACTION LOAD WITH AND WITHOUT WEB LATERAL RESTRAINT

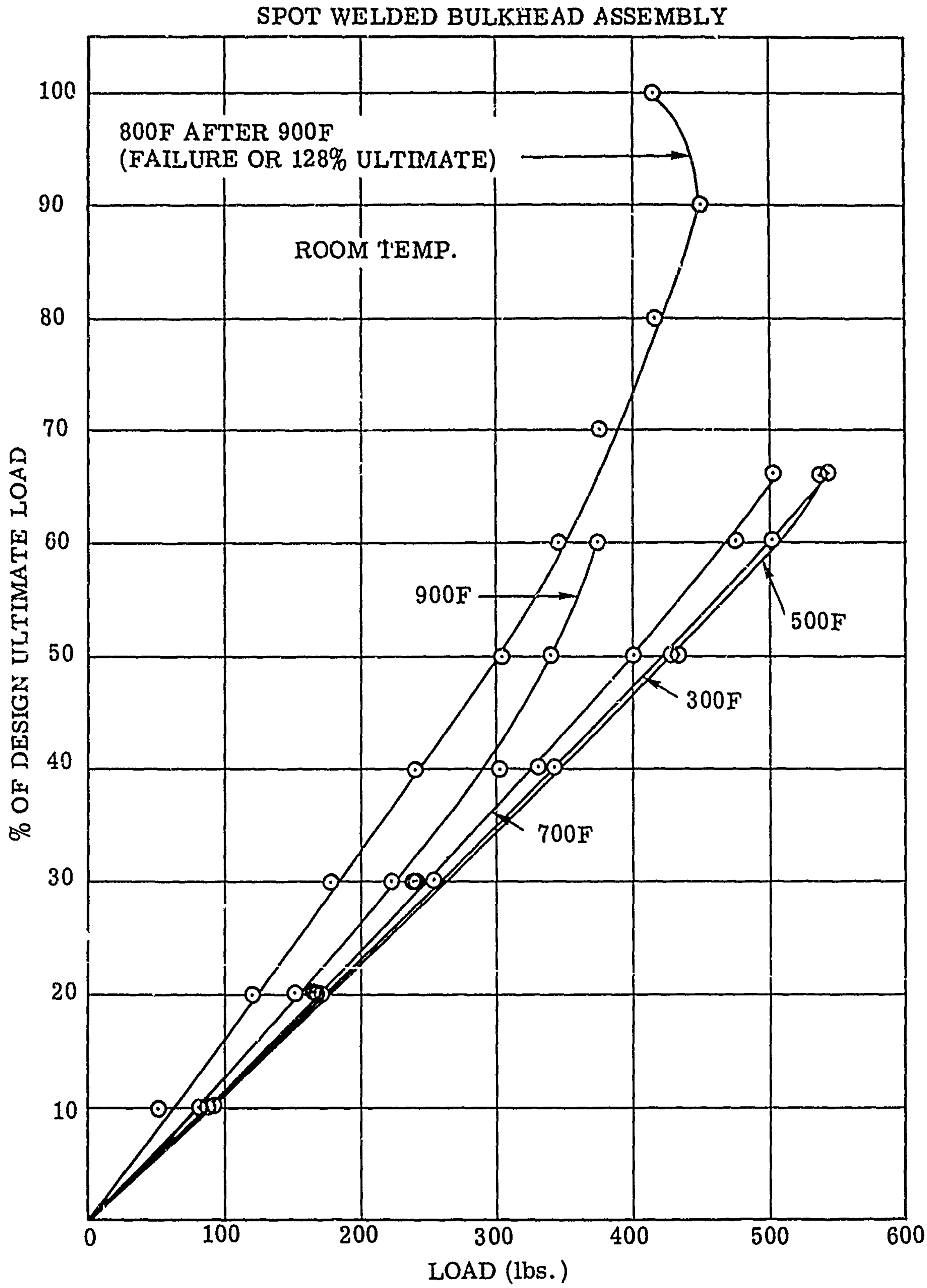


FIGURE A-75. BAR REACTION LOAD
VS % ULTIMATE LOAD; At Six Temperatures

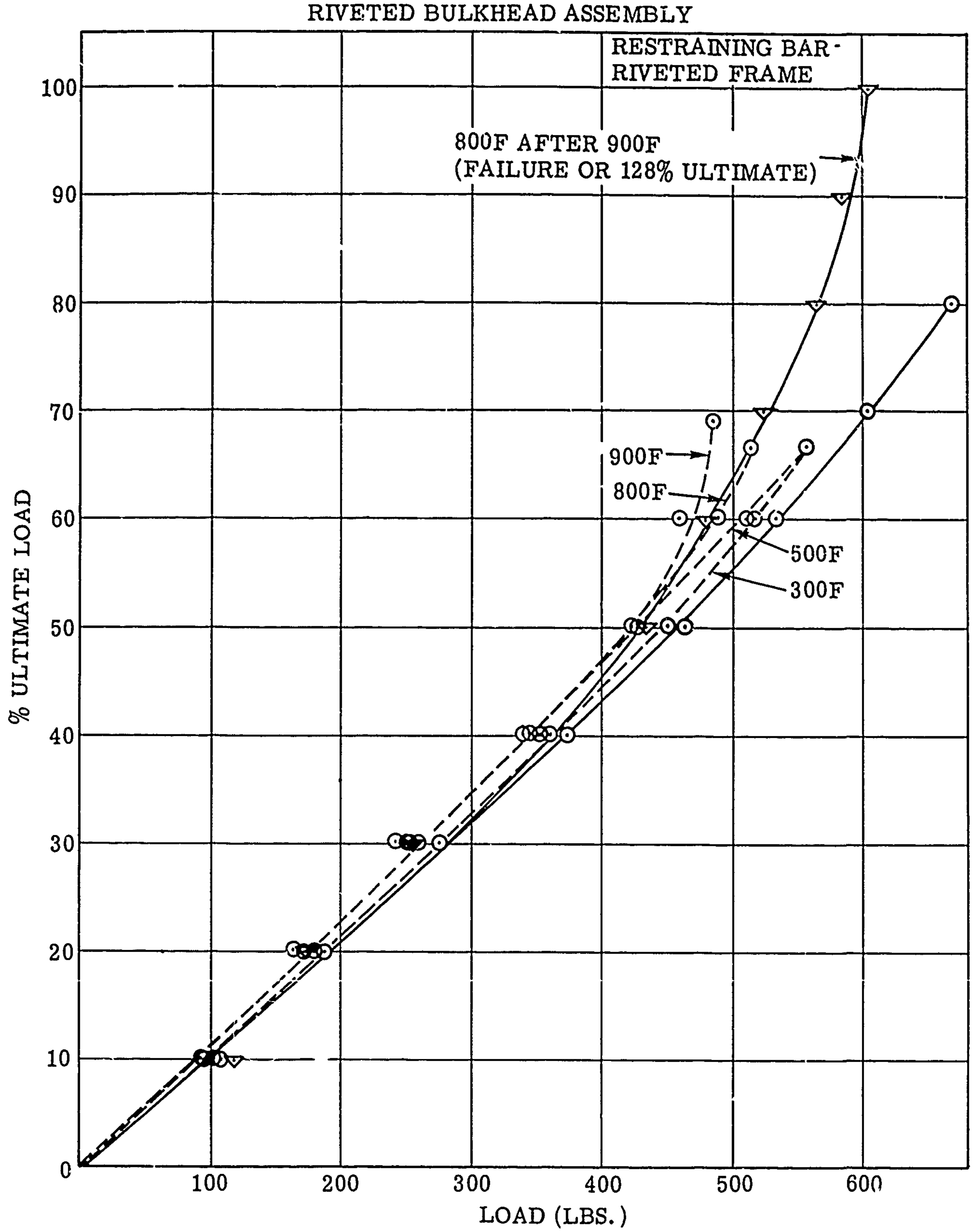


FIGURE A-76. RESTRAINING BAR REACTION LOAD VS % ULTIMATE LOAD AT SIX TEMPERATURES

TABLE A-2 - FUSELAGE CANTED BULKHEAD - SPOTWELDED
STATIC TEST OUTLINE AND RESULTS SUMMARY

TEST	TEMP (F)	MAX. LOAD (% ULT.)	DEFLECTION PLOTS FIGURE NOS.	STRAIN PLOTS FIGURE NOS.	FAILURE PHOTOS FIGURE NOS.	REMARKS
Static	R.T.	80.0	(1)	(1)	81	Severe elastic buckles in the inner and outer flanges - spotweld failure. Lateral restraints added to flanges. See Figure 74 for comparison of restraining bar load without and with lateral restraint on specimen flanges. Spotweld repaired - see Figure 81. Three-bolt repair only on second stiffener from free end.
Static	R.T.	80.0	21 & 22			No additional failures
Static	200	66.6	23 & 24	-		No additional failures
Static	300	66.6	25 & 26	-		No additional failures
Static	400	66.6	27 & 28	-		No additional failures
Static	500	66.6	29 & 30	-		No additional failures
Static	600	66.6	31 & 32	-		No additional failures
Static	700	66.6	33 & 34	-		No additional failures
Static	800	66.6	35 & 36	-		No additional failures
Static	900	66.6	37 & 38	-		No additional failures
Static	800	128.0	39 & 40	-	77	Small crack in spotweld at opposite end of stiffener repaired above. See repair only in Figure 77. Web and flanges severely buckled at load but only a small amount remained after load removed. Test discontinued since the specimen reached the limit of the flange restraints.

Note: (1) Data not presented because of flange and web deformations - insufficient lateral support.

TABLE A-3 - FUSELAGE CANTED BULKHEAD - SPOTWELDED
FATIGUE TEST OUTLINE AND RESULTS SUMMARY

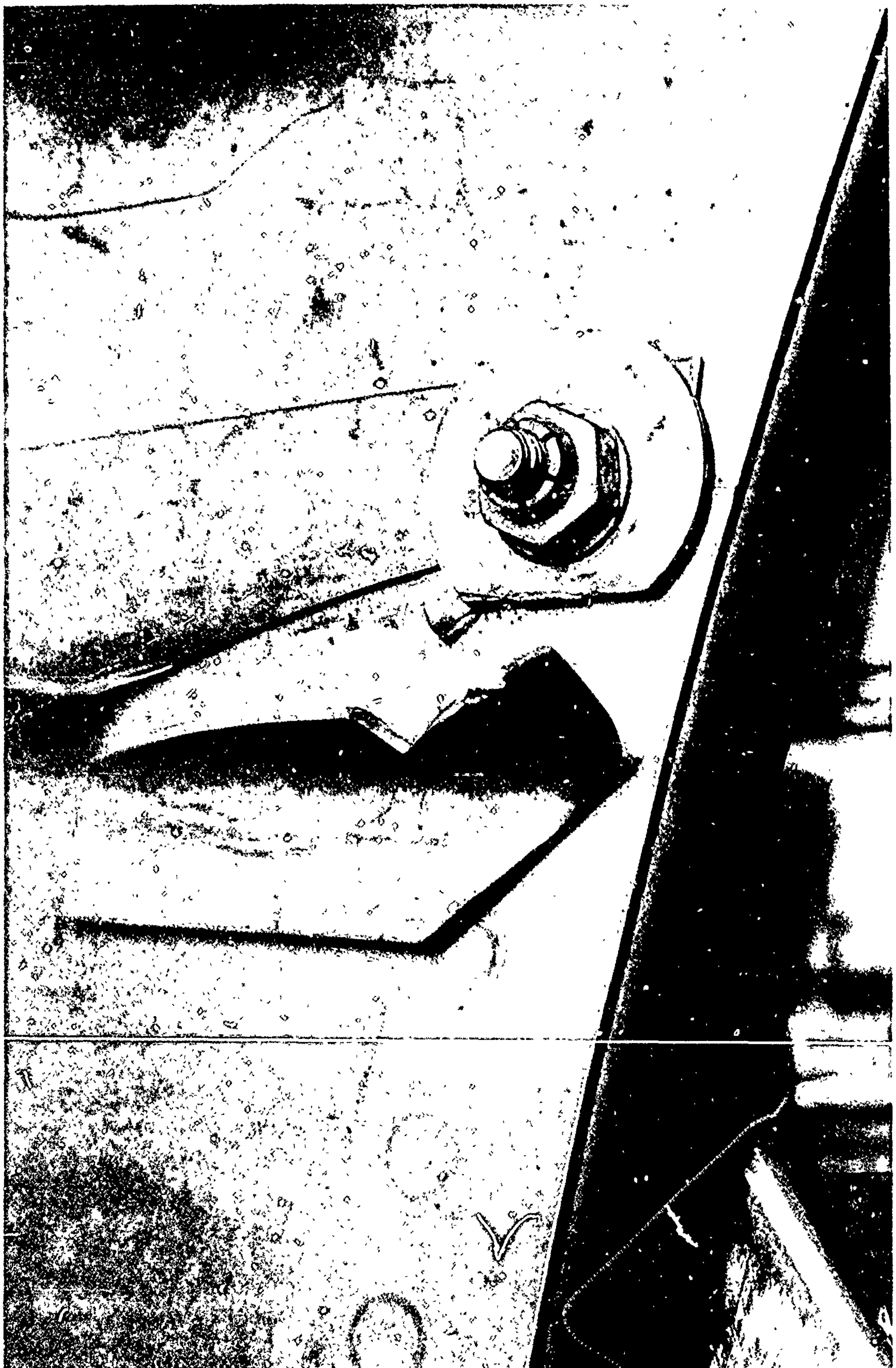
TEST	TEMP (F)	LOAD (% ULT.)	FATIGUE CYCLES AT CONDITION	TOTAL NO. FATIGUE CYCLES	FAILURE PHOTOS FIGURE NOS.	REMARKS
Fatigue	R.T.	44.5	2500	2500		No additional failures
Fatigue	200	44.5	2500	5000		
Fatigue	400	44.5	2500	7500		
Fatigue	600	44.5	2500	10,000	77,78,80	Specimen inspected - crank in spotweld at inboard flange and first stiffener from free end - Ref Figure 78. Repair shown in Figure 81. Also stiffener failed as shown in Figure 77.
Fatigue	800	44.5	3795	13,795		Crack started across second stiffener from free end at second spot.
Fatigue	800	44.5	4095	17,890		Above crack completely across stiffener allowing inner flange to roll.
Fatigue	800	44.5	19,310	37,200	79 thru 84	Major specimen failure - would not carry load. Inner flange and web failed. Plus additional single spot failures.

TABLE A-4 - FUSELAGE CANTED BULKHEAD - RIVETED
STATIC TEST OUTLINE AND RESULTS SUMMARY

TEST	TEMP (F)	MAX. LOAD (% ULT.)	DEFLECTION PLOTS FIGURE NOS.	STRAIN PLOTS FIGURE NOS.	FAILURE PHOTOS FIGURE NOS.	REMARKS
Static	R.T.	80.0	41 & 42	73		No failures noted
Static	200	66.6	43 & 44	-		No failures noted
Static	300	66.6	45 & 46	-		No failures noted
Static	400	66.6	47 & 48	-		No failures noted
Static	500	66.6	49 & 50	-		No failures noted
Static	600	66.6	51 & 52	-		No failures noted
Static	700	66.6	53 & 54	-		No failures noted
Static	800	66.6	55 & 56	-		No failures noted
Static	900	66.6	57 & 58	-		No failures noted
Static	800	128.0	59 & 60	-		No failures noted. Similar buckles to those on spot welded bulkhead.

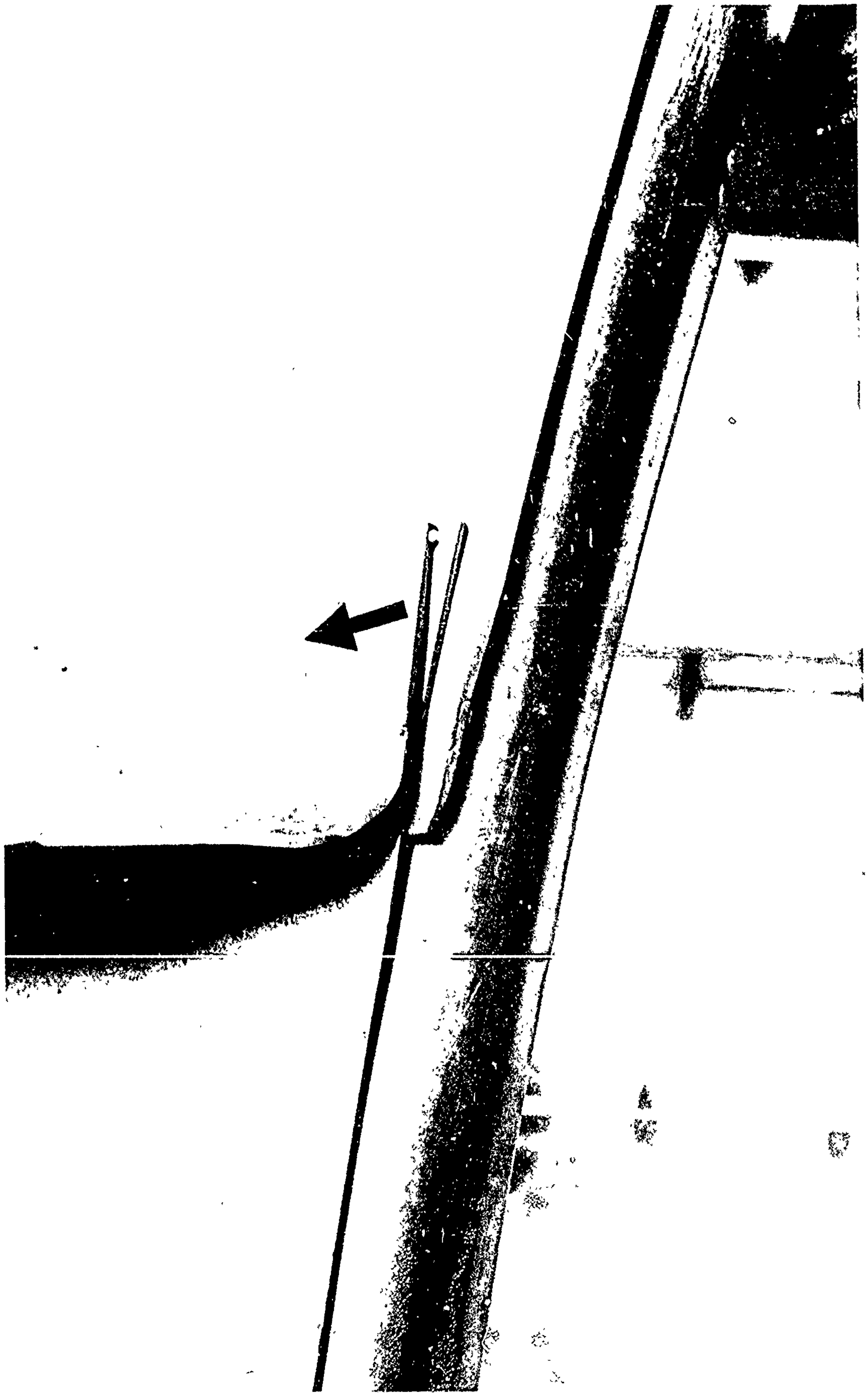
TABLE A-5 - FUSELAGE CANTED BULKHEAD - RIVETED FATIGUE TEST OUTLINE AND RESULTS SUMMARY

TEST	TEMP (F)	MAX. LOAD (% ULT.)	NO. OF FATIGUE CYCLES AT CONDITION	TOTAL NO. FATIGUE CYCLES	FAILURE PHOTOS FIGURE NOS.	REMARKS
Fatigue	R.T.	44.5	2500	2500		No failures noted
Fatigue	200	44.5	2500	5000		No failures noted
Fatigue	400	44.5	2500	7500		No failures noted
Fatigue	600	44.5	2500	10,000		No failures noted
Fatigue	800	44.5	6286	16,286		No failures noted
Fatigue	800	44.5	5483	21,769		No failures noted
Fatigue	800	44.5	860	22,629	84 thru 87	Temperature indicator malfunctioned - fixed end of specimen overheated and buckled. Reference Figures 84 thru 87. Specimen damage in same area as spotwelded frame major failure. This area repaired with doublers and test continued on remained of the specimen.
Fatigue	800	44.5	27,231	50,000		No additional failures
Fatigue	800	44.5	52,629	102,629		No additional failures
Fatigue	800	53.2	5000	107,629		No additional failures
Fatigue	800	66.6	29,000	136,629		Crack noted in web near free end of specimen.
Fatigue	800	66.6	4000	140,629	88 thru 92	Web Failures. Specimen will sustain load. Test discontinued.



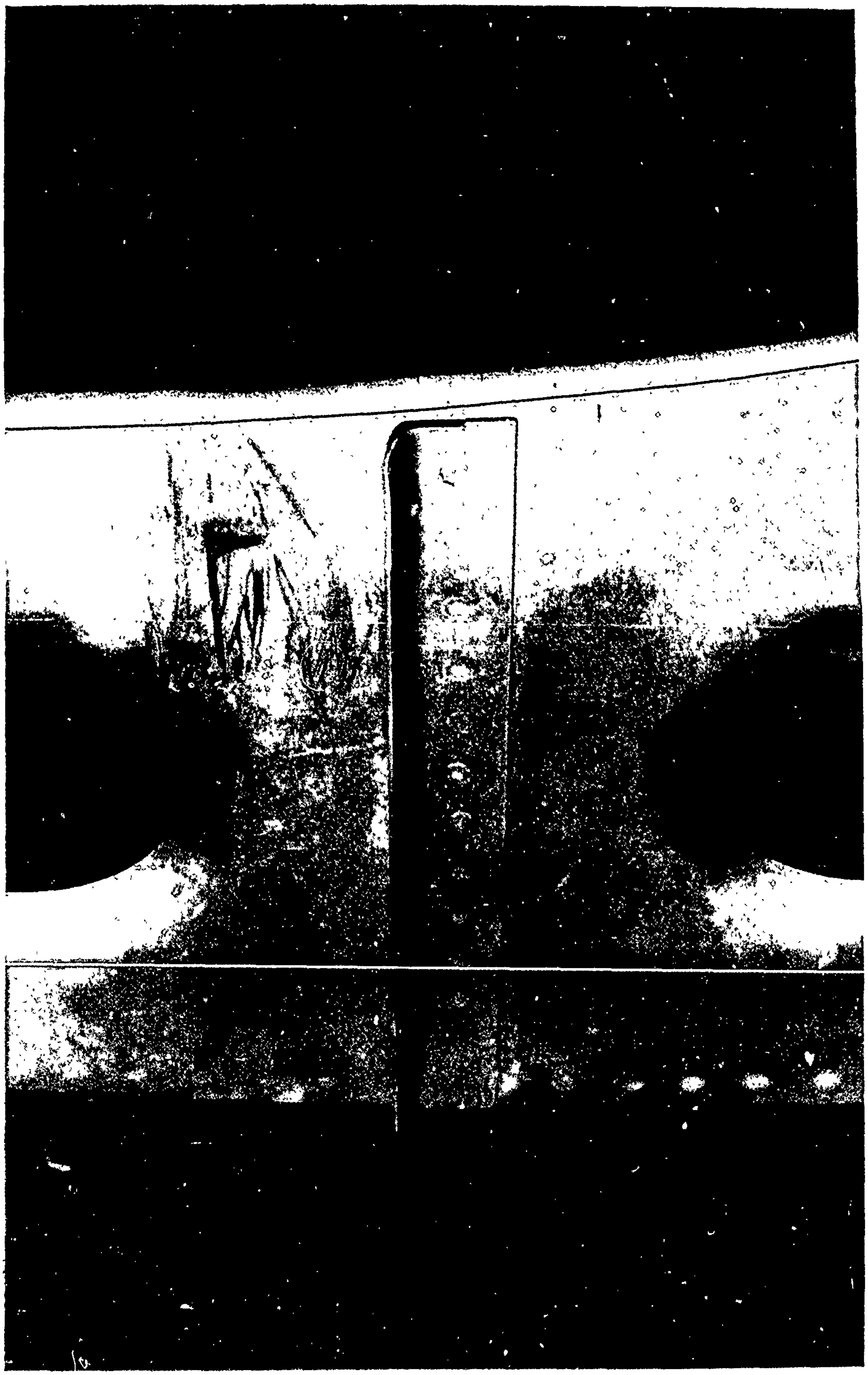
Convair Print 59753

Figure A-77 — SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY; Bolt and Washer Repair for Spot Weld Crack, During Static Test. Fatigue Failure Occurred After 10,000 Cycles (-33 Stiffener).



Convair Print 59754

Figure A-78 — SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Spot Weld Crack After 10, 000 Fatigue Cycles (-31 Stiffener).

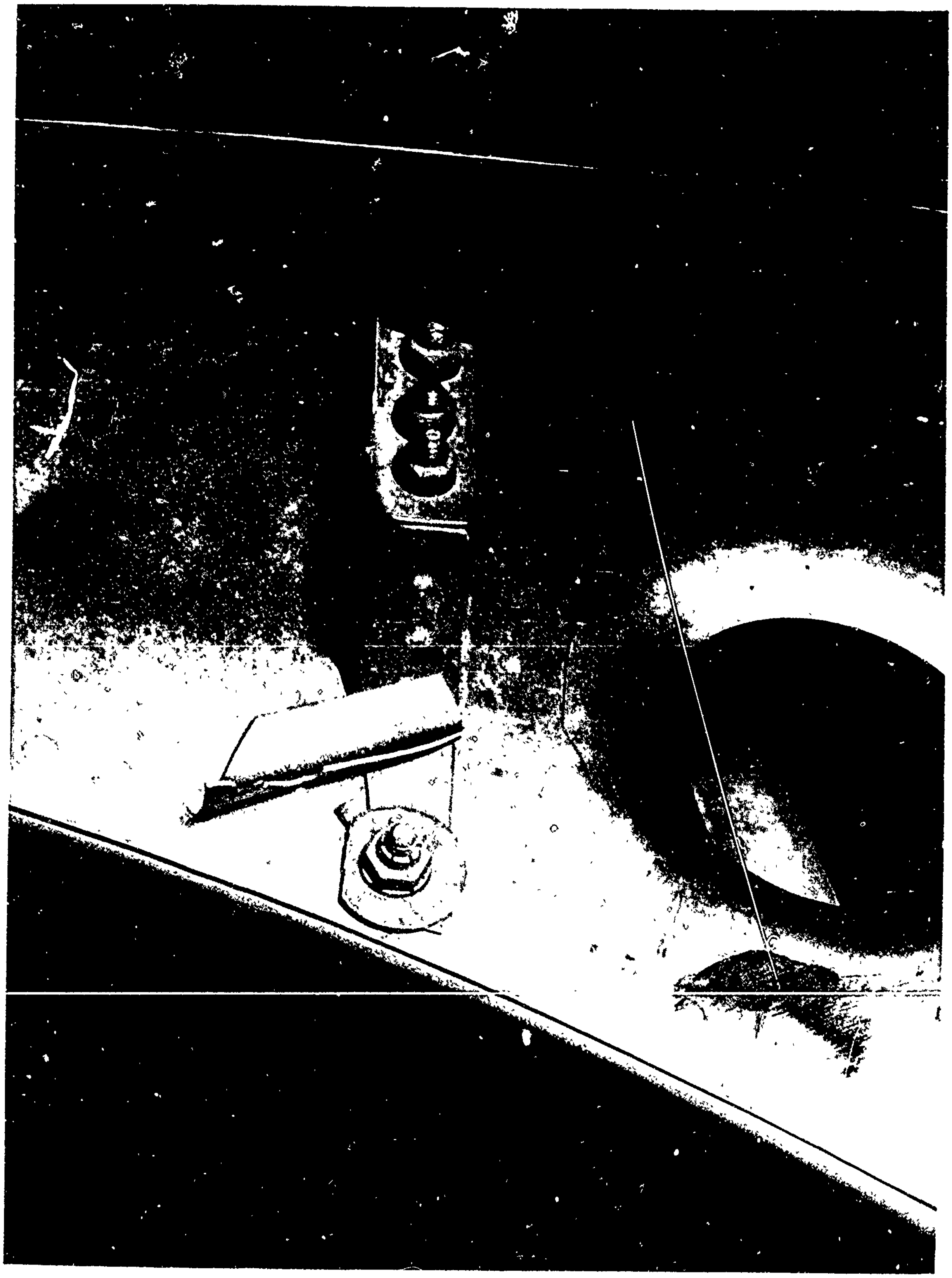


Convair Print 59798

Figure A-79 — SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Spot Weld Crack After 37, 200 Cycles.

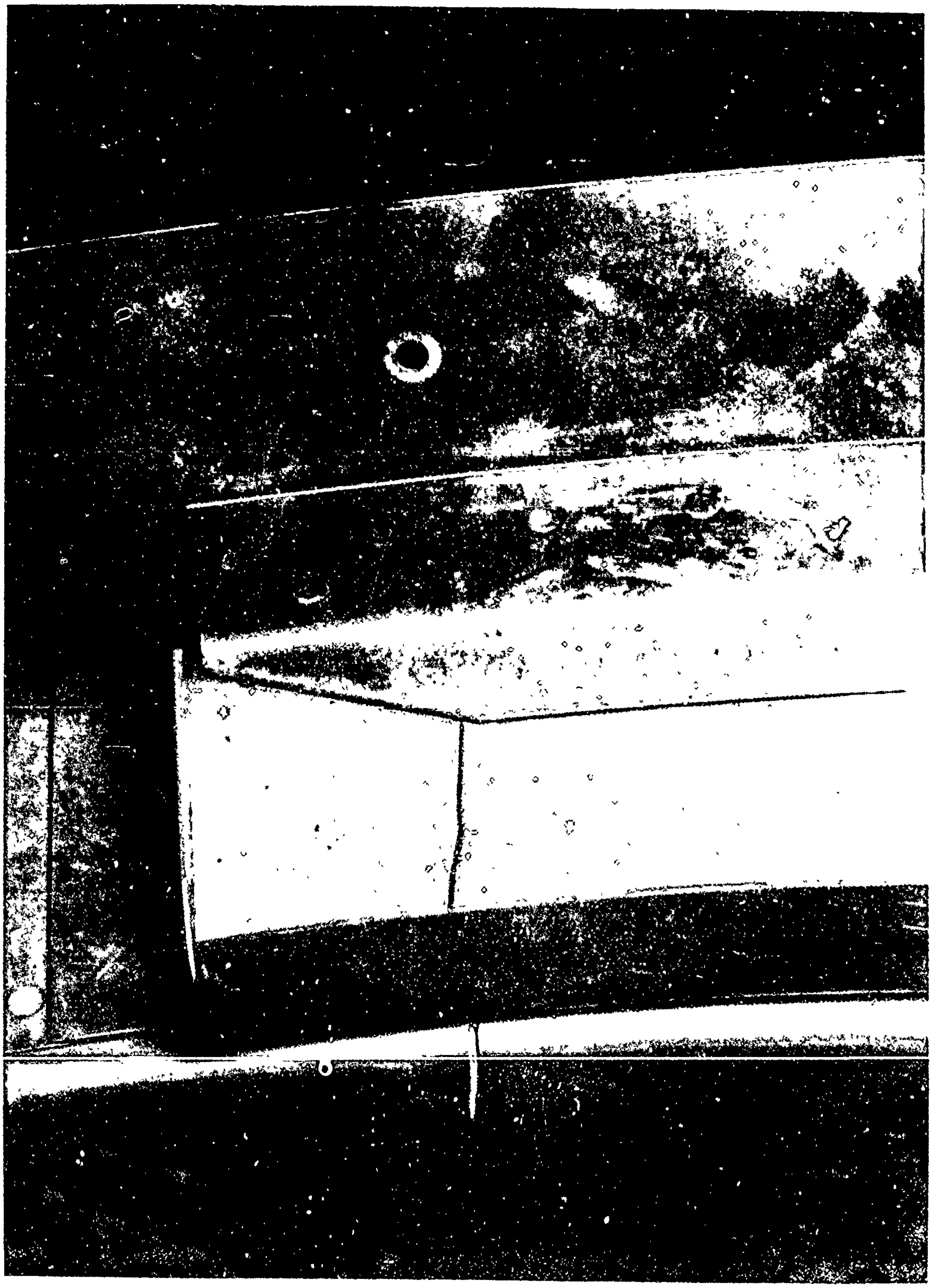
Convair Print 59794

Figure A-80 — SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Spot Weld Crack After 37,200 Cycles.



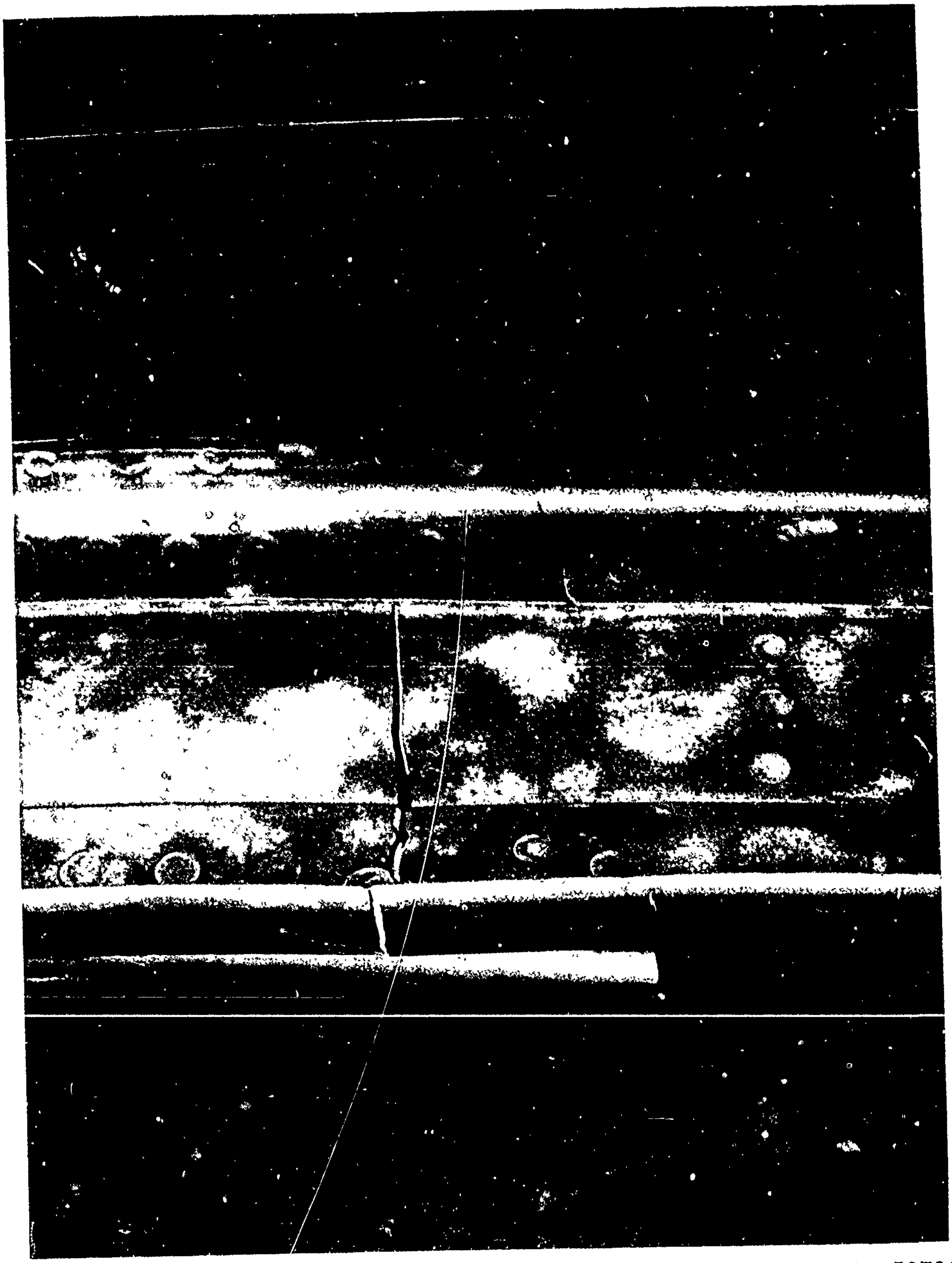
Convair Print 59797

Figure A-81 – SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY; Fatigue Failures and Repairs Made During Test.



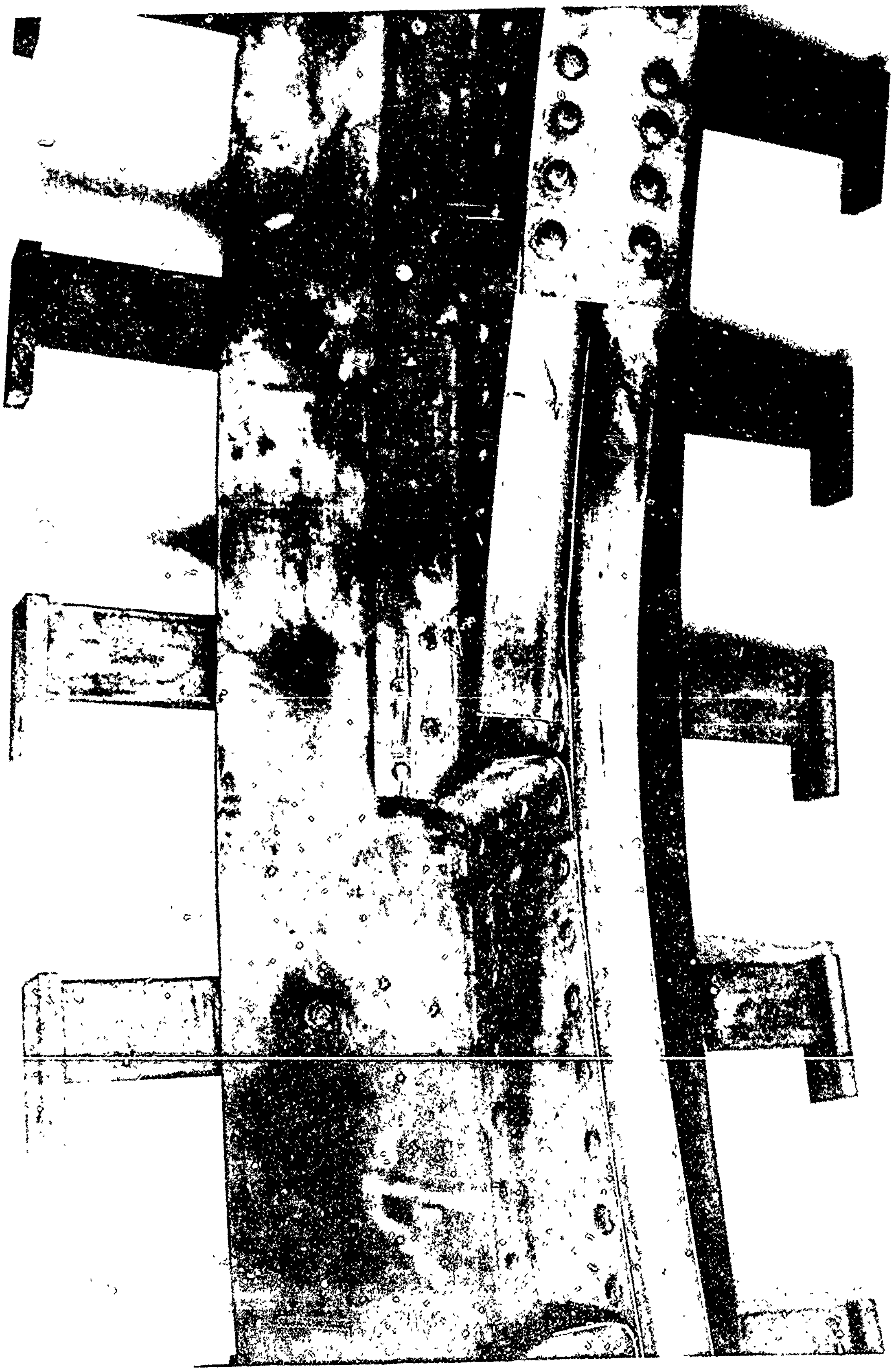
Convair Print 59795

Figure A-82 – SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY; Final Failure at 37,200 Cycles.



Convair Print 59796

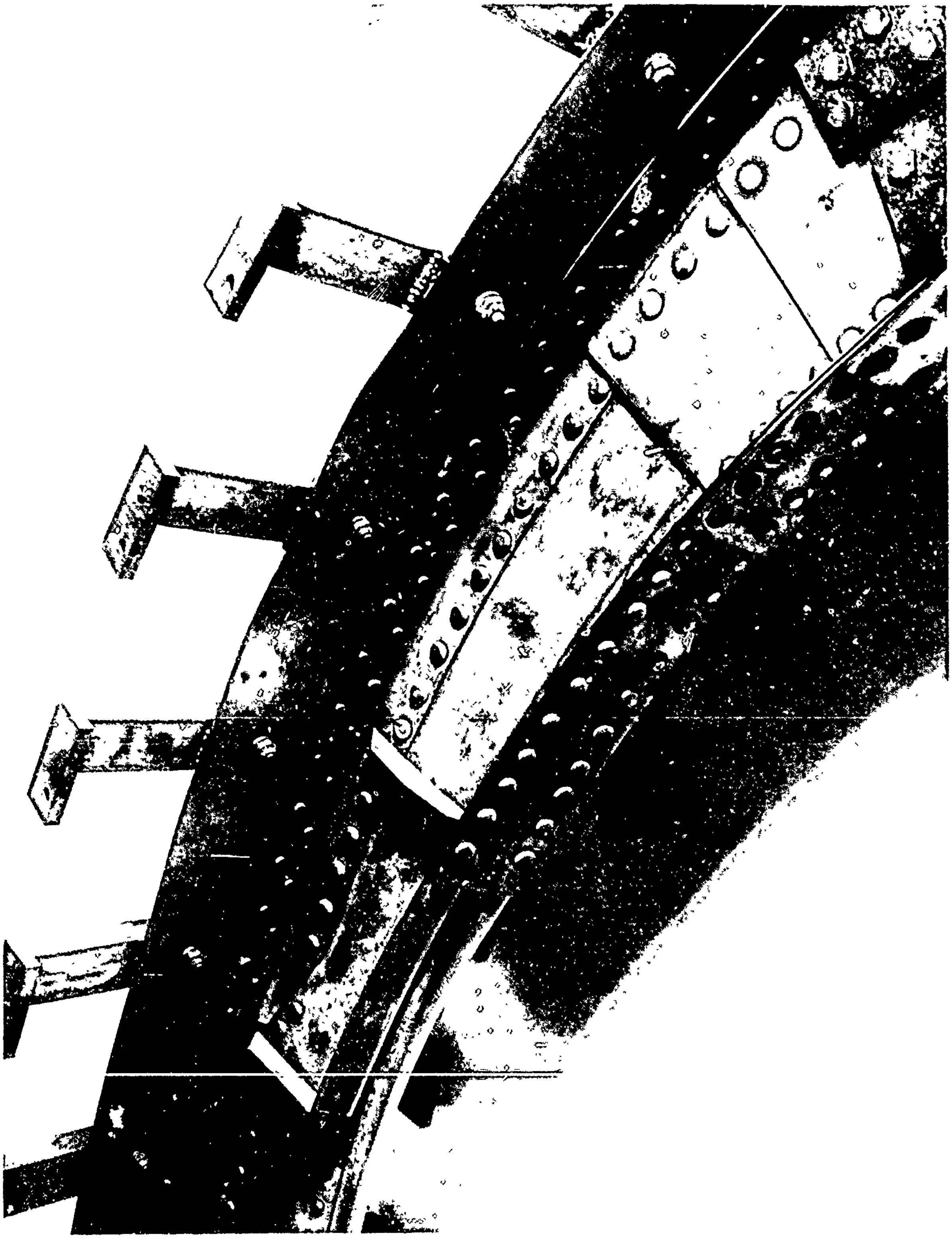
Figure A-83 – SPOT WELDED FUSELAGE CANTED BULKHEAD ASSEMBLY; Final Failure at 37,200 Cycles.



Convair Print 60712

Figure A-84 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY; After Overheating at 22, 629 Cycles.

Figure A-85 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY; Convair Print 60711
After Overheating at 22, 629 Cycles.

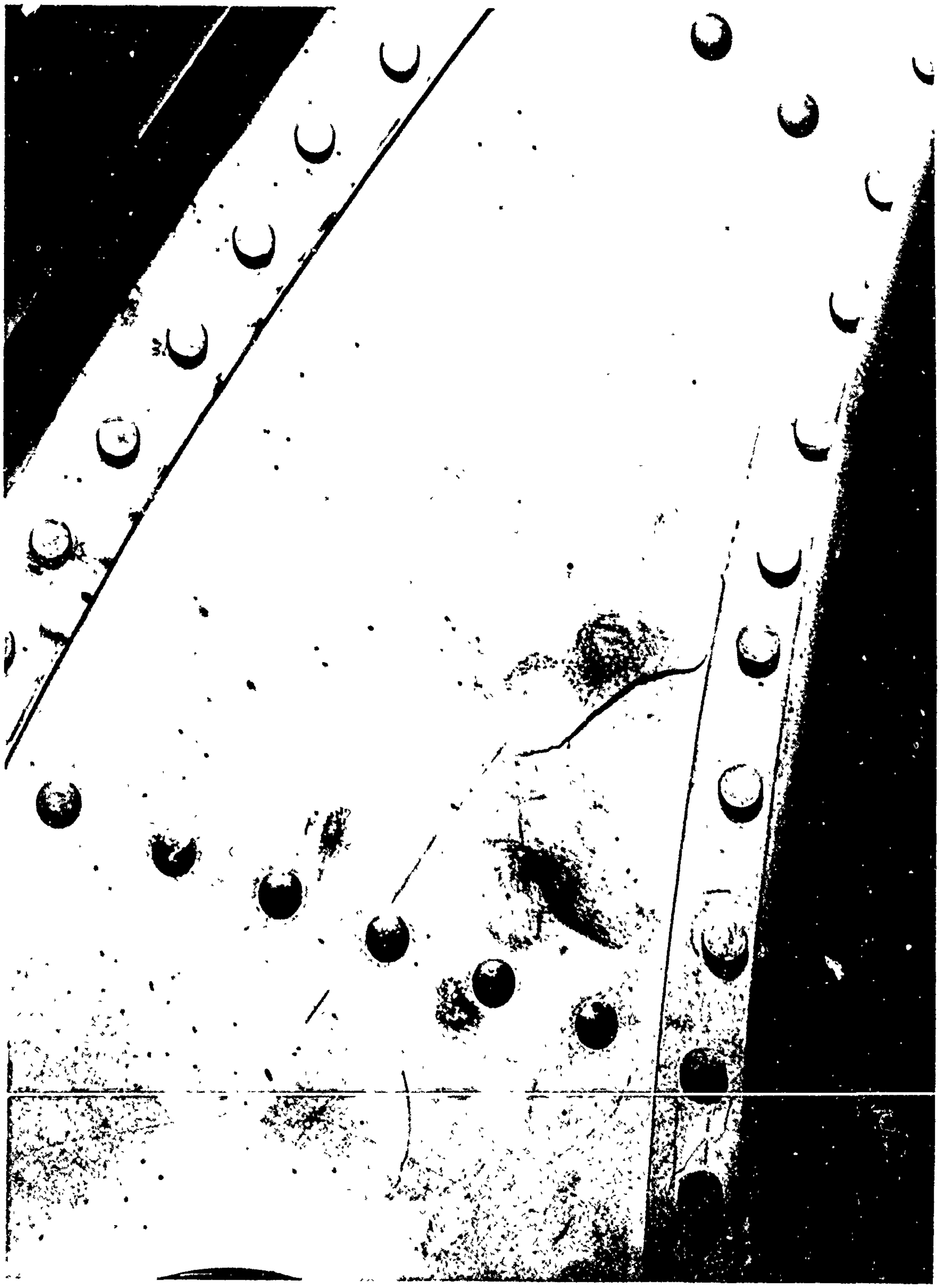


Convair Print 60710

Figure A-86 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY;
After Overheating at 22, 629 Cycles.

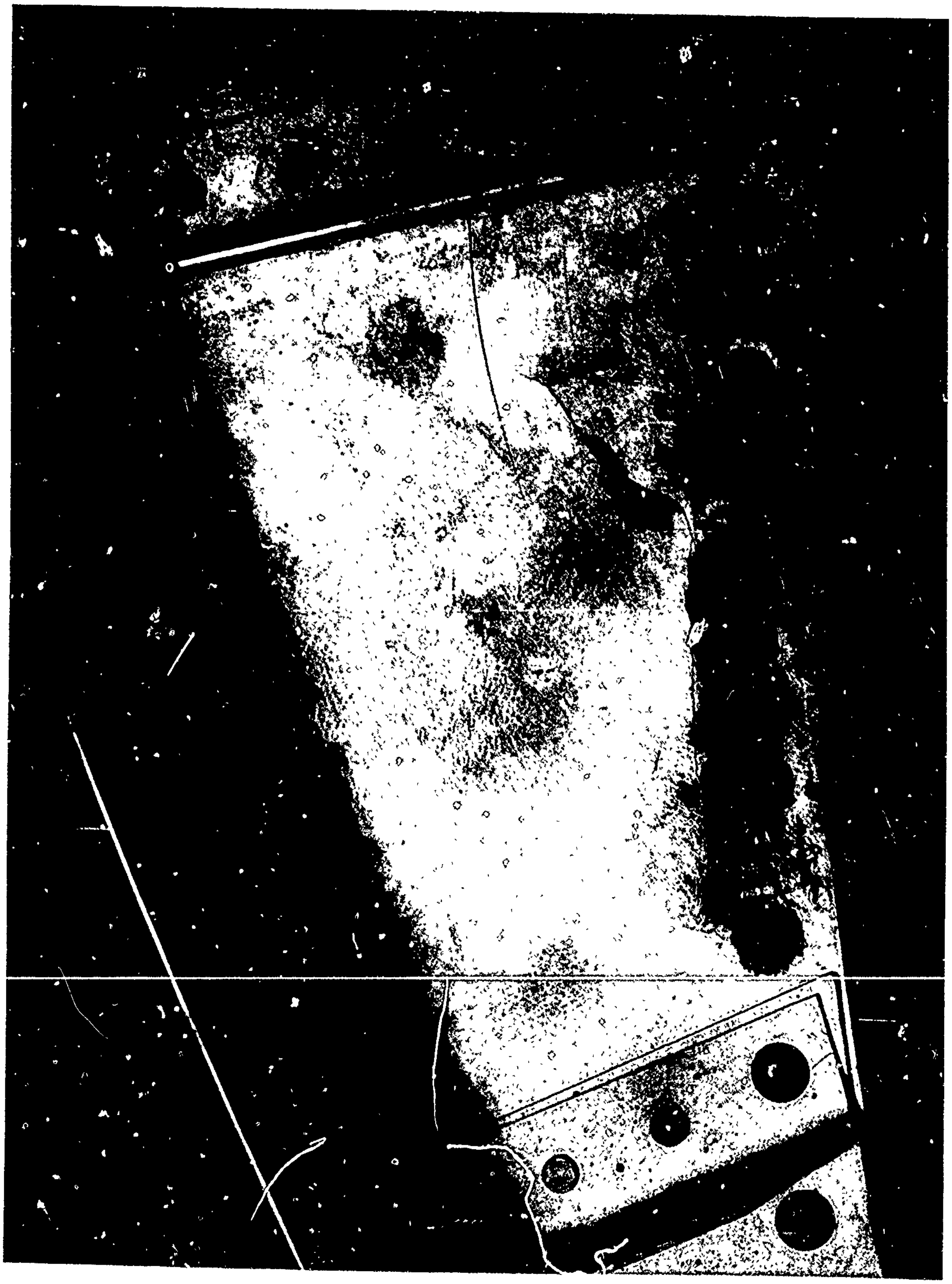
Convair Print 60713

Figure A-87 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY; After Overheating at 22, 629 Cycles.



Convair Print 63961

Figure A-88 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Web Fatigue Failure After 140, 629 Total Cycles.

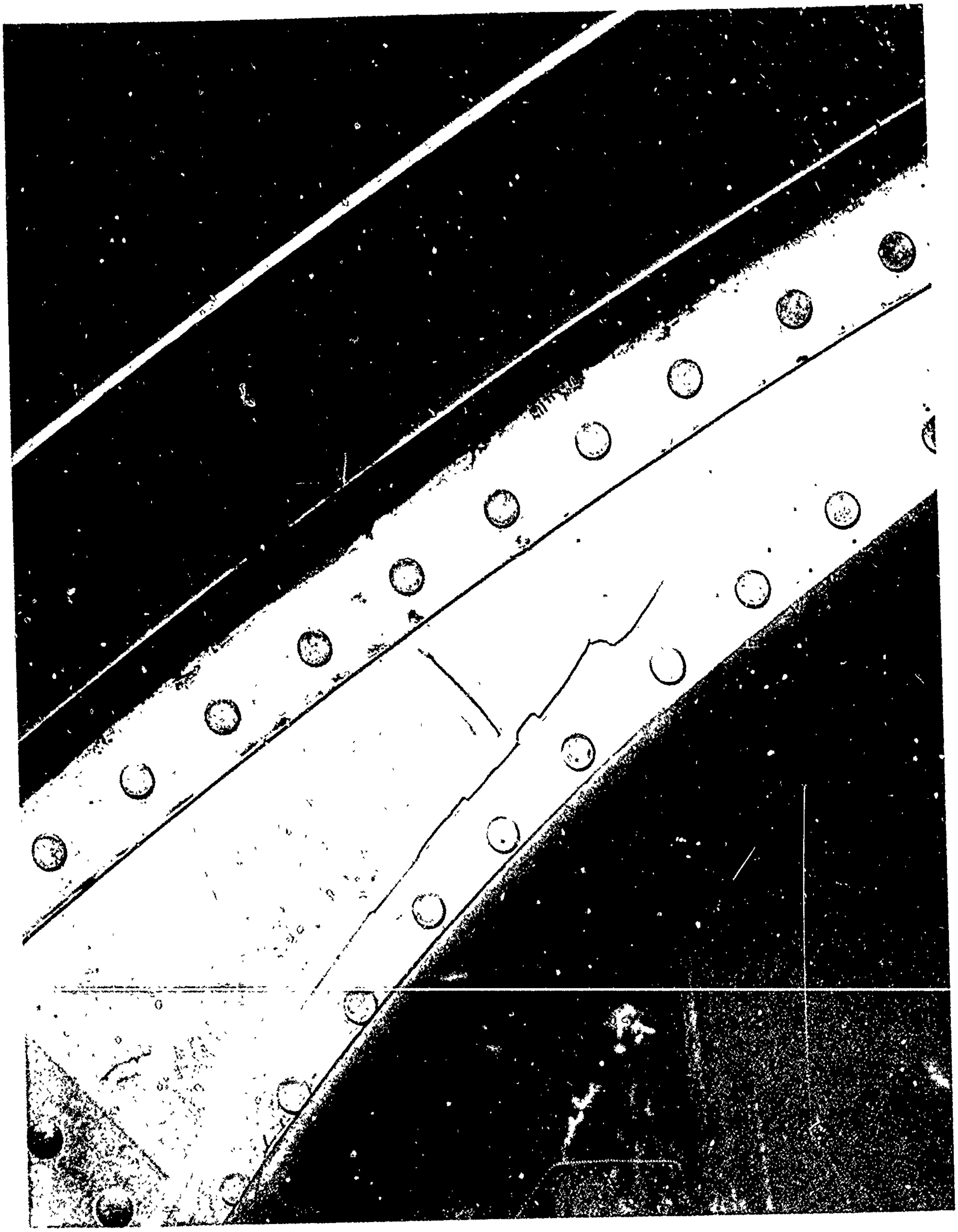


Convair Print 63963

Figure A-89 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Web Fatigue Failure After 140, 629 Total Cycles.

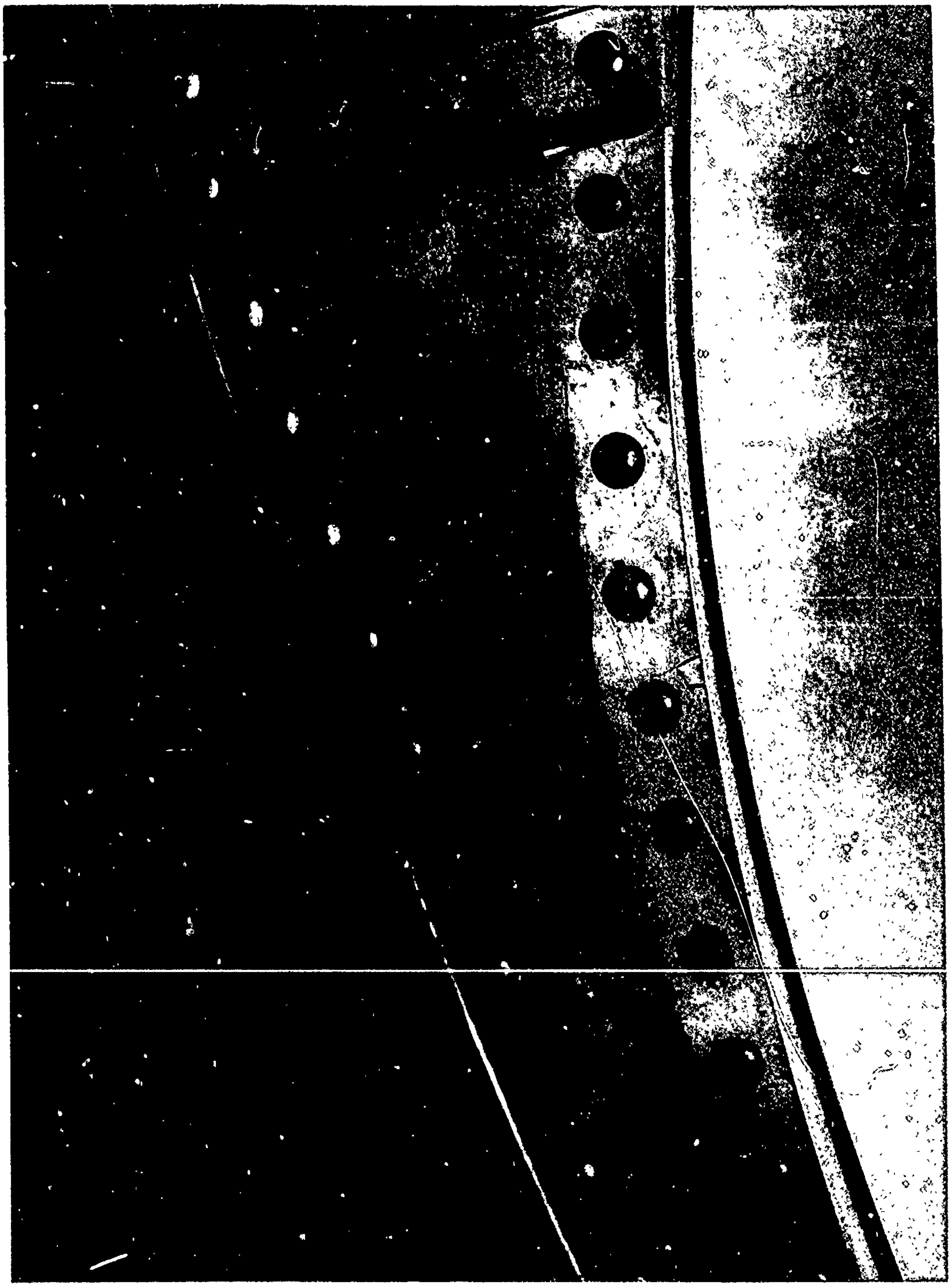
Convair Print 63962

Figure A-90 – RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY; Inner Flange Fatigue Failure After 140, 629 Cycles.



Convair Print 63959

Figure A-91 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY; Inner Flange Fatigue Failure After 140, 629 Cycles.



Convair Print 63960

Figure A-92 — RIVETED FUSELAGE CANTED BULKHEAD ASSEMBLY;
Inner Flange Fatigue Failure After 140, 629 Cycles.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

V. SUMMARY OF RESULTS

1. The riveted and spotwelded assemblies had similar deflection characteristics in the static tests.

2. Both assemblies sustained 128% design ultimate load at 800 F without a major failure

3. The riveted canted bulkhead had a better fatigue life than the spotwelded bulkhead.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

A. FUSELAGE CANTED BULKHEAD - STATIC AND FATIGUE TESTS

VI. CONCLUSIONS AND DISCUSSION

From a structural design viewpoint the element tests on the titanium bulkheads were the most significant, for they furnished evidence of the superiority of titanium over aluminum for certain applications. This observation is possible because of the opportunity to compare the test bulkheads with actual aluminum construction presently used on the F-106, a typical advanced design Mach 2 Interceptor. The bulkhead test specimens were fabricated to the loft lines of the F-106 canted frame at Station 672.38. This is a major bulkhead that supports the aft fin spar for which the loads and design parameters are well defined.

The F-106 aluminum designed bulkhead weighs 26.9 pounds, not including the fin spar attach fitting. Approximately six pounds of this weight is for skin splices, miscellaneous clips, and the weight of a small portion of the frame that was designed to resist other design loads. In contrast, weight of the part that was fabricated from titanium for the test program was 8.1 pounds (the total bulkhead, less the fin spar attach fitting, would weigh 16.2 pounds). It can be seen that the weight saving resulting from using titanium, for the particular part in question, is approximately 29% assuming that the margin of safety is the same for both parts.

In the F-106 aft engine compartment heat was significant, and the design of all frames in the area was predicated on 272 F for 40 hours duration. The properties of 2024 T4 aluminum alloy are approximately 88% of room temperature properties. There is a somewhat similar reduction for 4Al-3Mo-1V titanium; however, the properties of aluminum deteriorate much more rapidly with increase in temperature. In the event of an engine shroud failure or fire in the engine compartment, the titanium structure would have an additional fail safe type of advantage over the aluminum construction.

Either the spot welded or riveted structure seems to be adequate from a fatigue standpoint for the particular part in question.

VI. CONCLUSIONS AND DISCUSSION (Cont'd)

The F-106 preliminary flight loads spectra give the following lateral gust load factors:

12,769 cycles at 25% limit load

2,361 cycles at 50% limit load

218 cycles at 75% limit load

19 cycles at 100% limit load

1 cycle at 125% limit load

The above figures are preliminary data from a fatigue analysis being conducted on the F-106. The number of cycles is predicated on an interceptor life of 4000 flight hours.

The spot welded specimen sustained 37,200 cycles of 66.7% limit load at various elevated temperatures. Since most fatigue damage occurs as a result of a high number of cycles at low load levels, it is obvious that the fatigue life of the titanium specimens would have been adequate for the bulkhead in question.

The stress at the point of failure was calculated to be 44,300 lbs/sq. in. at ultimate load. The stress level during the fatigue cycle varied from 0 to 19,200 lbs/sq. in. at an average temperature of slightly less than 800 F. The only available information on fatigue for this alloy shows a maximum fatigue stress of approximately 50,000 lbs/sq. in. for a life of 40,000 cycles. This was with a notched specimen ($K_t = 3.5$) at room temperature with the load ratio = 0.6 (maximum stress minus mean stress divided by the mean stress), Ref: Titanium Engineering Bulletin No. 8, Titanium Metals Corp. of America, 233 Broadway, New York. The difference between the 19,700 lbs/sq. in. and the 50,000 lbs/sq. in. could be due to several reasons. The temperature undoubtedly reduced the fatigue life, the load ratio tested to (1.0) is more severe, and the notch factor was not accurately known. The failure occurred where a reinforcing angle ended and local stresses were probably much higher than the calculated stresses. However, the riveted bulkhead did not suffer a fatigue failure in this area. If we neglect scatter (usually very large in this type of test) it would seem that the spot welds have a much larger notch effect than do rivets, for this particular alloy.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

TABLE OF CONTENTS

LIST OF TABLES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

I. INTRODUCTION

This report was prepared to present the results of static and fatigue tests, at temperature, of titanium wing leading edges. The Wing Leading Edge Assembly is basically a conversion to titanium of the F-106A Interceptor Part 8-18205, Leading Edge Assembly. This part was redesigned to take advantage of the improvement in properties of titanium over aluminum at higher temperatures. In this case, Ti-4Al-3Mo-1V titanium alloy replaced 7075-T6 aluminum alloy.

Two titanium Wing Leading Edge Assemblies were tested; one statically, one in fatigue. The static specimen was tested in 20% steps to limit load at room temperature, 200 F, 300 F, 400 F, 500 F, 600 F, 700 F, 800 F and 900 F. A failure test was then conducted at 800 F. The fatigue specimen was tested at 66.7% of limit load for 160,000 cycles; 2500 cycles each at room temperature, 200 F, 400 F and 600 F, and 150,000 cycles at 800 F.

These tests were conducted to determine:

1. The load carrying characteristics of a titanium Wing Leading Edge at various temperatures up through 900 F.

2. The ultimate strength of the assembly at 800 F.

3. The fatigue life of the assembly at 800 F.

4. The comparative strengths of the spot welded and riveted halves.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

II. SUMMARY

The statically tested specimen of the Wing Leading Edge Assembly withstood all tests with no apparent failure. The same assembly specimen, when tested to failure at 800 F, failed at 189.5% of limit load (126.3% of design ultimate). The upper skin failed as a column near the attachment fixture, pulling several spotwelds and rivet heads.

The fatigue specimen showed many cracks in the internal structure of the spotwelded portion; the riveted portion had only a few popped rivet heads.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING

1. Test Specimens:

Two test specimens were manufactured according to Convair Engineering Drawing 29-01007, Figure B-1 (page 121). The sheet metal parts were made from Ti-4Al-3Mo-1V alloy. The skins on one half of each specimen were spotwelded to the ribs. The skins on the other half were riveted using countersunk monel rivets. Therefore, each of the two test specimens was effectively two specimens; one spotwelded and one riveted. The upper skin was reduced in thickness between the ribs by chemical etching.

2. Test Procedure:

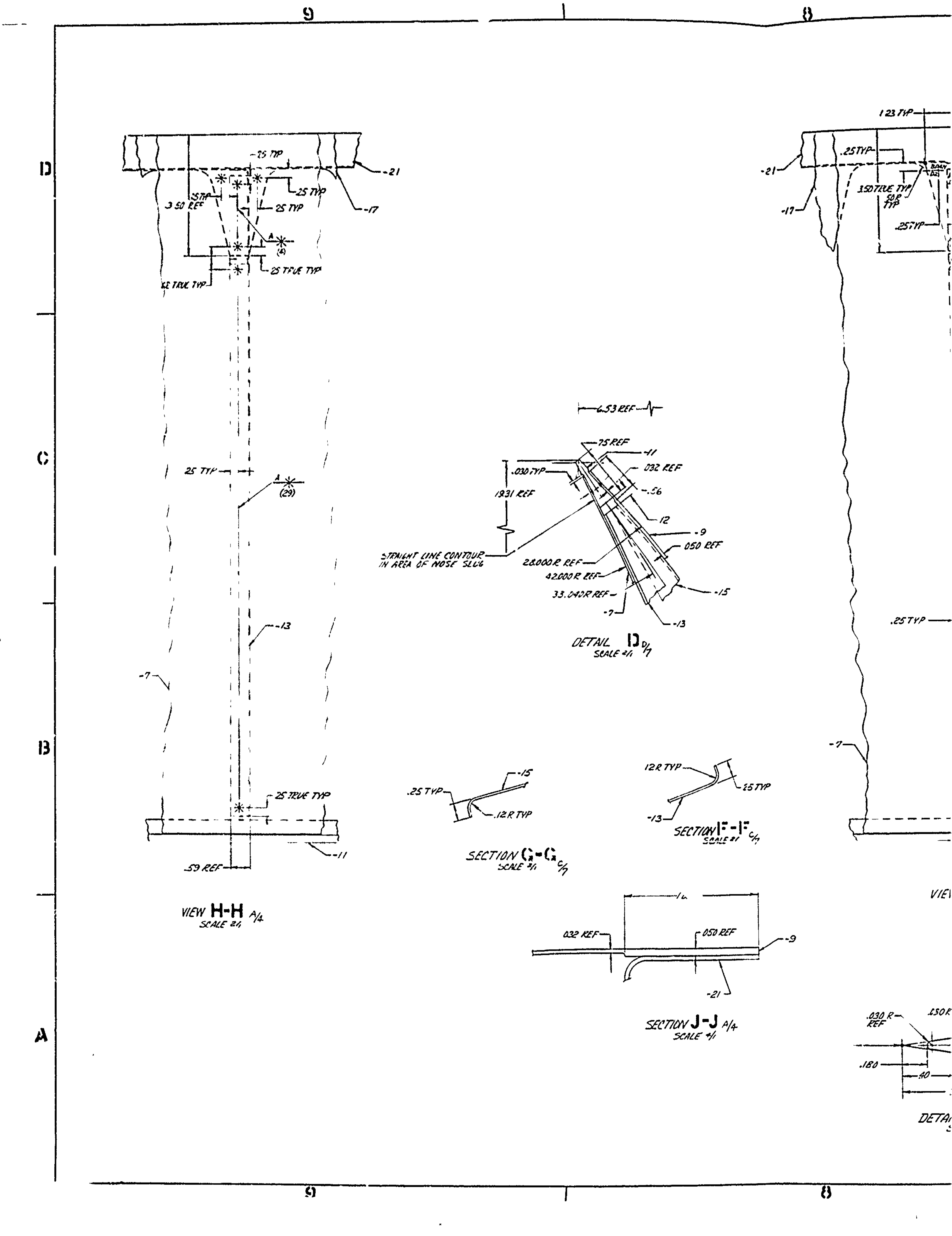
The test specimens were attached to a rigid fixture in a manner similar to an actual installation, using 3/16-inch bolts with one inch spacing.

The test load was distributed over 66 points of application to simulate air loads using a whipple tree system shown in Figures B-2 and B-3 (pages 123 and 124). The load was applied by eyebolts through the skin and ribs into steel blocks cushioned by pieces of asbestos blanket.

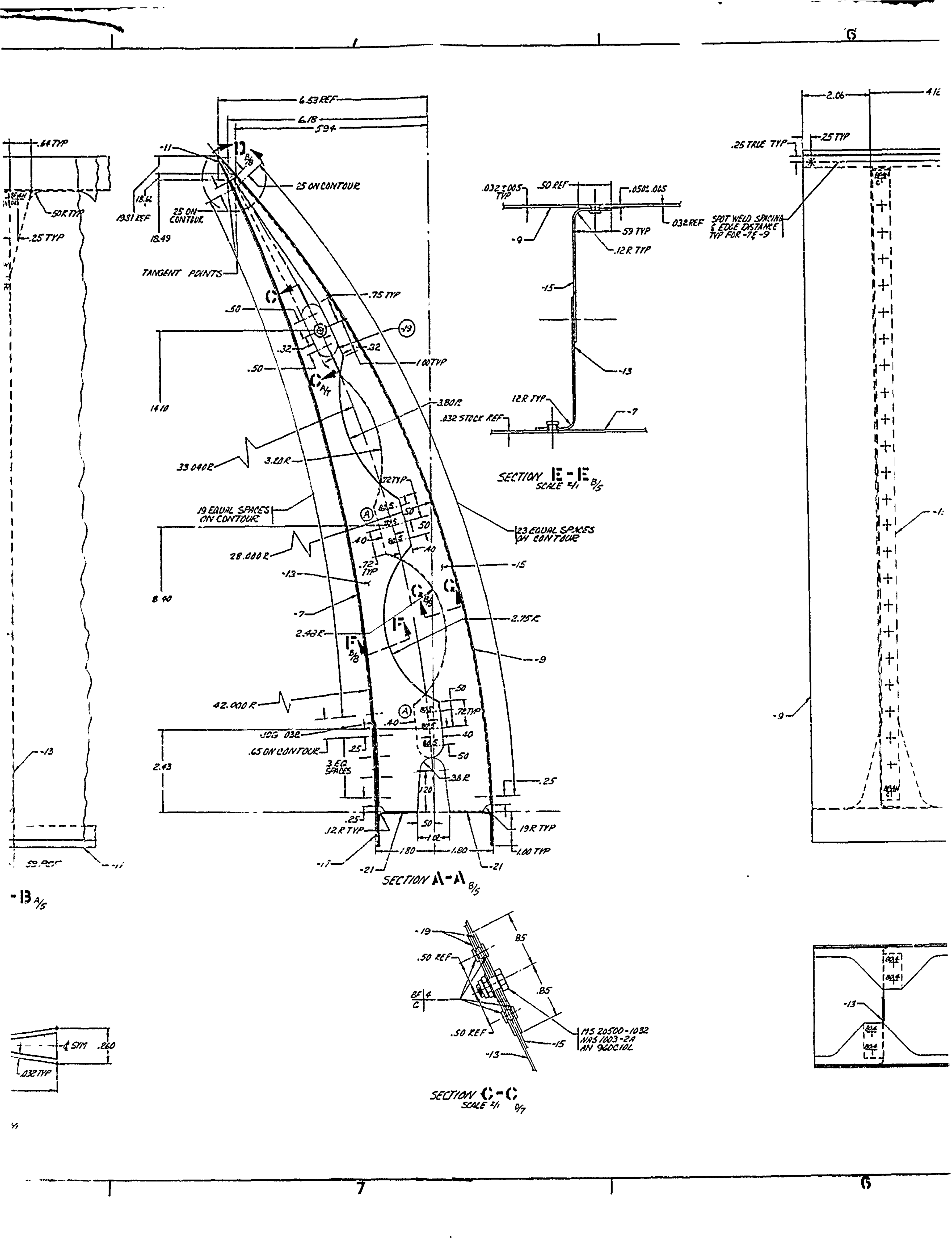
The maximum static load for all conditions, except the failing load, was 6650 pounds, which is limit load. The load was applied in 20 per cent increments and deflections taken. Permanent set was measured at 10 per cent load after each of the increments. Deflections were taken at the mid-point of the front edge and at the quarter points, i.e., at points halfway between the mid-point and the edges. Eight strain gages were placed as shown in Table B-1 (page 125) for the room temperature static test.

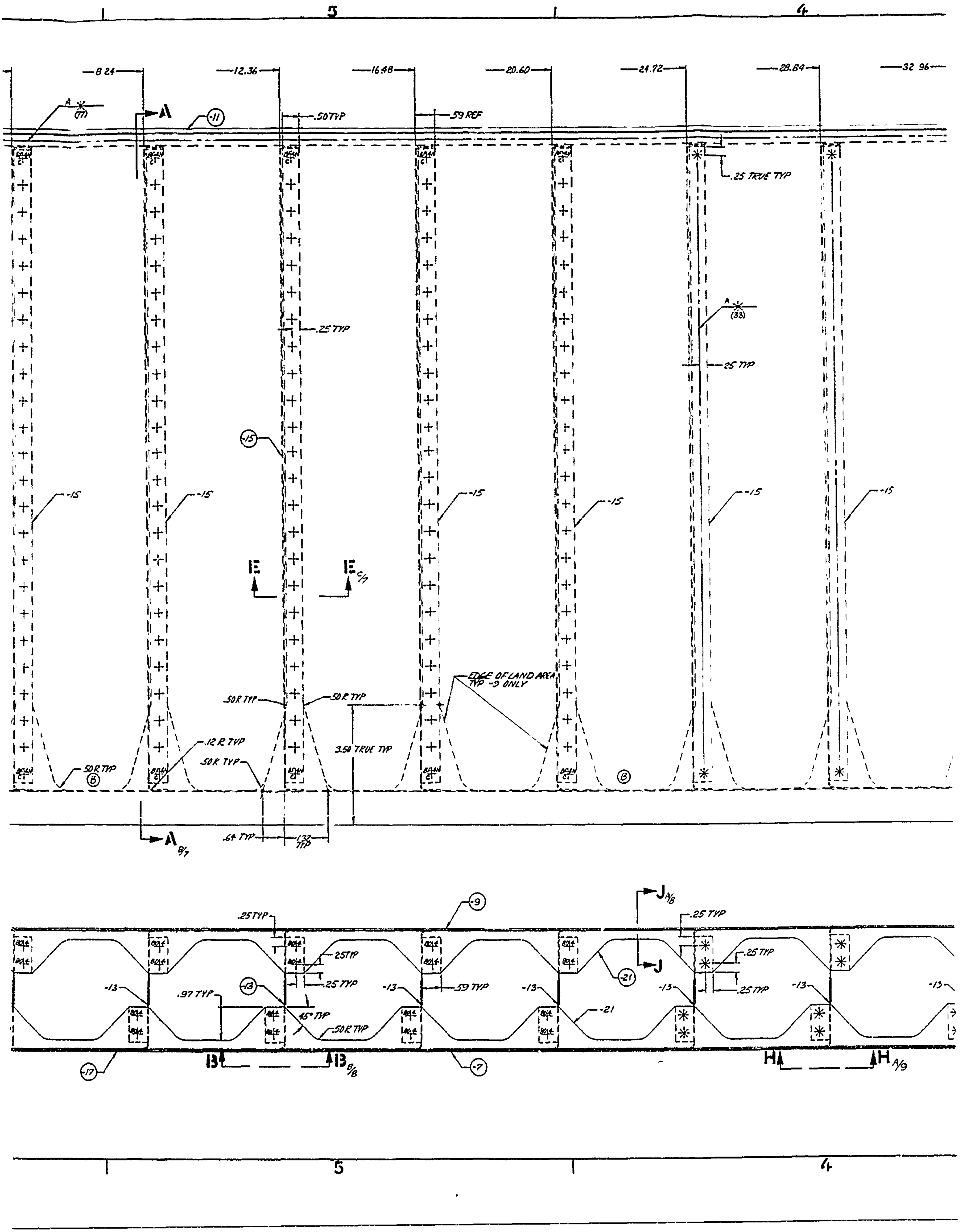
The complete static load sequence was run at room temperature, 200 F, 300 F, 400 F, 500 F, 600 F, 700 F, 800 F, and 900 F. A similar load sequencing was used during the failure test, which was conducted at 800 F after 900 F.

Figure B-1 - WING LEADING-EDGE ASSEMBLY;
Engineering Drawing 29-01007

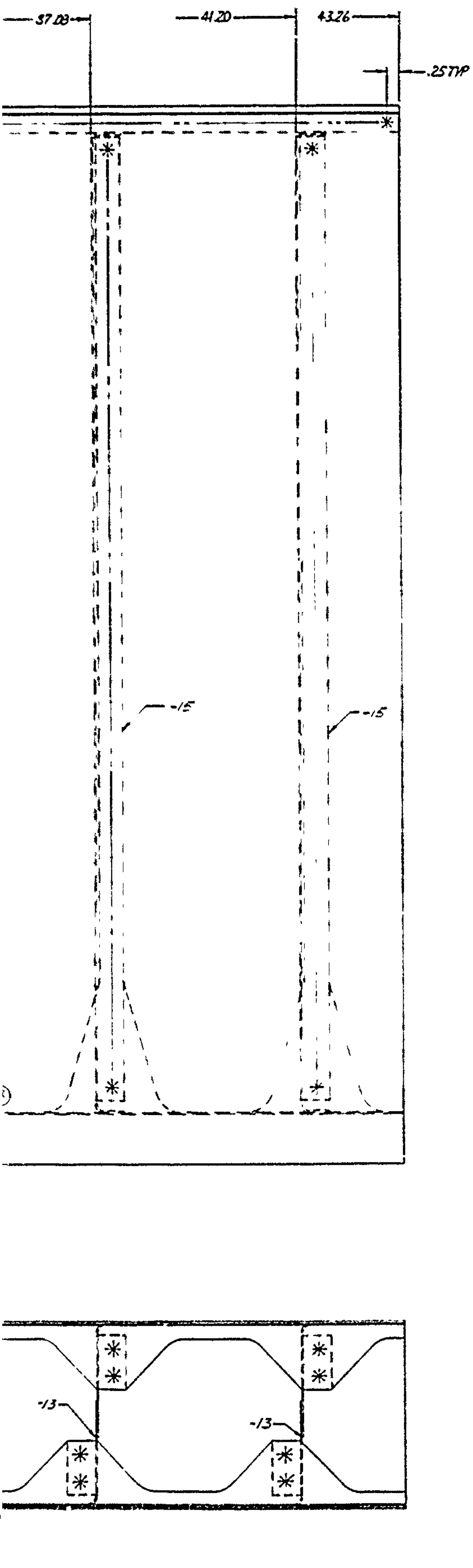


9
8
D
C
B
A
-21
-17
.25 TYP
3.50 REF
.25 TRUE TYP
-7
-13
-11
.59 REF
VIEW H-H A/4
SCALE 2/1
6.53 REF
.75 REF
.030 TYP
.032 REF
-.56
19.31 REF
STRAIGHT LINE CONTOUR IN AREA OF NOSE SLUG
28.000 R REF
42.000 R REF
33.040 R REF
.050 REF
-9
-15
DETAIL D D/7
SCALE 2/1
.12 R TYP
SECTION G-G C/7
SCALE 4/1
SECTION F-F C/7
SCALE 4/1
SECTION J-J A/4
SCALE 4/1
1.23 TYP
.030 R REF
.180
.40


SECTION A-A B/5
SECTION E-E B/5
SCALE 2/1
SECTION C-C
SCALE 2/1 D/7
6.53 REF
6.18
5.94
.25 ON CONTOUR
TANGENT POINTS
19 EQUAL SPACES ON CONTOUR
23 EQUAL SPACES ON CONTOUR
33.040 R
28.000 R
42.000 R
3.80 R
3.20 R
2.75 R
2.43 R
.65 ON CONTOUR
3 EQ SPACES
.032 STOCK REF
SPOT WELD SPACING & EDGE DISTANCE TYP FOR -7 & -9
.25 TRUE TYP
MS 20500-1032
NAS 1003-2A
AN 960C10L
.50 REF
¢ SYM
.260
.032 TYP
7
6



5
4
8.24
12.36
16.48
20.60
24.72
28.84
32.96
A
-11
.50 TYP
.59 REF
.25 TRUE TYP
.25 TYP
-15
E
E C/7
EDGE OF LAND AREA TYP -9 ONLY
.50R TYP
.12 R TYP
3.50 TRUE TYP
.64 TYP
.132 TYP
A B/7
J A/8
J
-9
.25 TYP
-13
-21
.97 TYP
.59 TYP
45° TYP
.50R TYP
B
B B/8
-17
-7
H
H A/9



3 ALL FASTENERS INSTALLED PER CONVAIR 22-00011
2 WELD PER MIL-W-6858, EXCEPT PENETRATION TO BE 35-70%
1. THIS PART DESIGNED FOR DYNAMIC ETCHING PER CONVAIR 0-05039
NOTES:

2

REVISIONS

EFF ON	INCORP	LTR	DESCRIPTION	ZONE	DATE	APPROVAL
EWO 0082		A	IN SECT A-A REMOVED .196 .191 HOLE (2 PLACES) ADDED 60 ℄ (2)	B/4 C/7	4/23	[illegible]
EWO 0082		B	IN MAIN VIEW REMOVED RIVETS & SPOT WELDS THRU SKIN AT SPAR	B/3 B/4 B/5 B/6	4/1/	[illegible]

D

C

29-01007 B 1

B

-25	-23	-1	PART NO.	OPP / DASH NO	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MATL SPECIFICATION	SEE FINISH SPECIFICATION(S)	ZONE	INSP CLASS	CALC UNIT WT
		11	AN 960C10L		WASHER									
		11	NAS1003-2A		BOLT									
		11	MS20500-1032		NUT									
✓	✓		AN 427M4		RIVET									
✓	✓		NAS508M4		RIVET									
		✓	NAS508M5		RIVET									

Figure B-1

1

29-01007
SHEET 1 OF 1 B
AUTH EWO 0082

-25	-23	-1	PART NO.	OPP / DASH NO	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MATL SPECIFICATION	SEE FINISH SPECIFICATION(S)	ZONE	INSP CLASS	CALC UNIT WT
		1		-25	SUB ASSY									
		1		-23	SUB ASSY							A/4		
1	1			-21	ANGLE	.032 x 2.2 x 45.4	TITANIUM ALY	SOL HT	SHT+H	4AL 3MO 1V		D/7		
11	11			-19	DOUBLER	.032 x .7 x 1.7						A/6		
	1			-17	DOUBLER	.032 x 3.5 x 45.4						A/6		
11				-15	RIB	.032 x 3.5 x 20.9						C/5		
	11			-13	RIB	.032 x 3.8 x 19.9	TITANIUM ALY	SOL HT	SHT+H	4AL 3MO 1V		A/5		
		1		-11	EDGE	.25 x .75 x 45.4	COMM PURE TI, AMS 4921			OR TI ALY 6AL-4V SPEC 0-01022		D/5		
1				-9	SKIN	.063 x 21.3 x 45.4	TITANIUM ALY	SOL HT	SHT+H	4AL 3MO 1V		A/5		
	1			-7	SKIN	.032 x 20.7 x 45.4	TITANIUM ALY	SOL HT	SHT+H	4AL 3MO 1V		A/5		

REQUIREMENTS PER ASSEMBLY

LIST OF MATERIAL

A

USED ON	CALC UNIT WT	QTY REQD	FINAL ASSY	DASH NO	END RECORD NO.	SERIAL NO	NEXT ASSY	USED ON	CALC UNIT WT	QTY REQD	FINAL ASSY
			-1				TEST			1	

APPLICATION

RIVET CODE PER NAS 523
F=MFD HEAD FAR SIDE
N=MFD HEAD NEAR SIDE
DIAMETER IN 32NDS
BASIC CODE
NON-STD INSTL ONLY
D=DIMPLE
NO OF DIMPLED SHEETS
C=COUNTERSINK
LENGTH DASH NO.
BASIC CODE
BB=ANNULAR 100°-NAS 520M
BJ=ANNULAR 82°-[illegible]

MANUFACTURING STANDARDS
UNLESS OTHERWISE NOTED ON FACE OF DRAWING
DIMENSIONS IN INCHES
TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR ±1/2°
ALL MACHINED SURFACES ✓ PER MIL-STD-10
INSTALL RIVETS PER 0-05035 AND FLAT HEAD SCREWS PER 0-[illegible]
SPOTFACE AND COUNTERBORE CORNER RADIUS .03 [illegible]
HT TR OF ALLOY PER MIL-H-6088, HT TR STEEL PER MIL-H-6875

[illegible]	Carpenter	11/4/59
	[illegible]	11/4/59
GOVT		
CHECKER		
STRESS		
MATERIAL		
TOOLING		
STR ENGR	[illegible]	11/4/59
WEIGHTS		
DESIGN		
DFTSMN	Ke Pender	11/4/59

LEADING EDGE ASSY 4AL-3MO-1V TITANIUM ALLOY

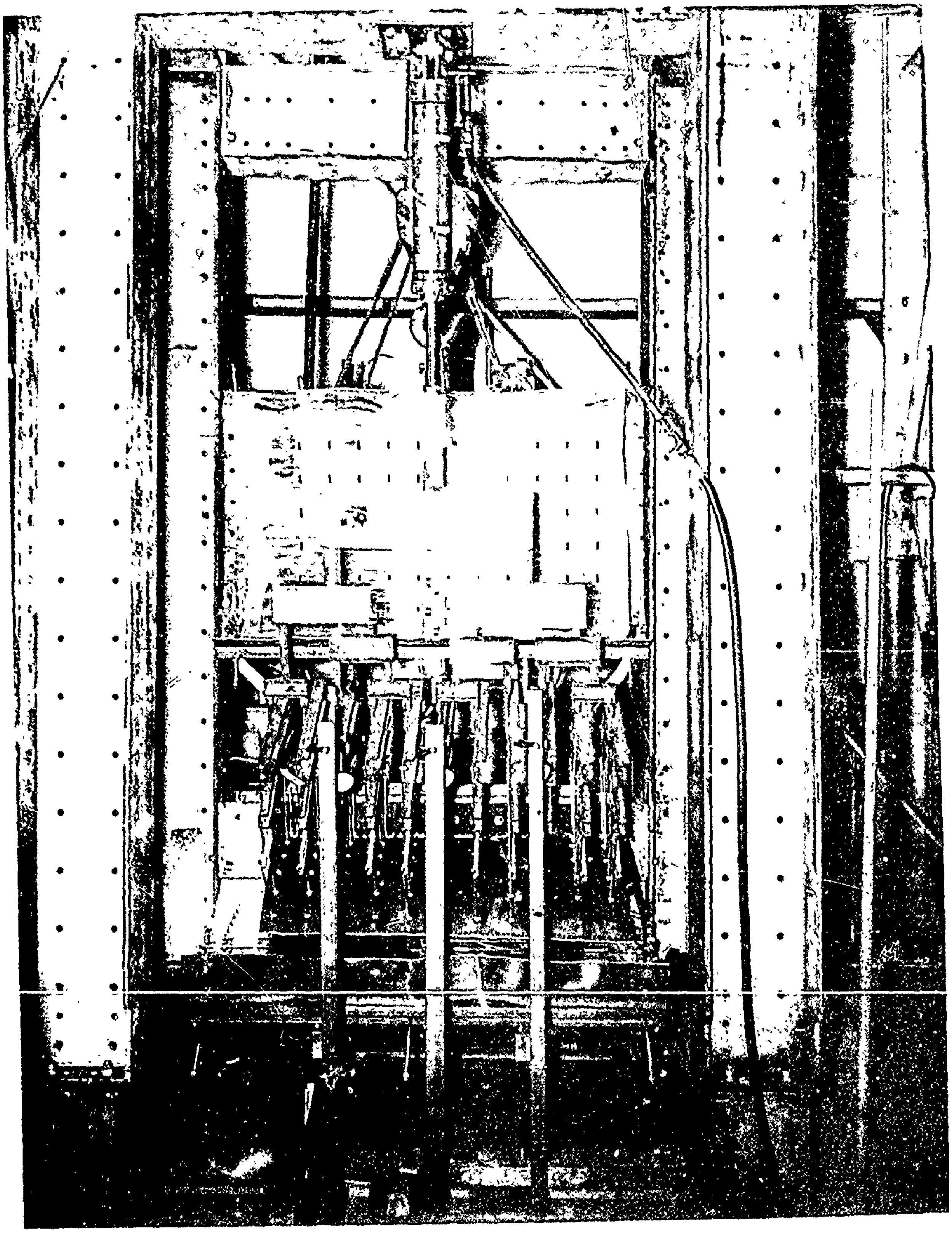
SCALE 1/1 & NOTED REF

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

DWG SIZE J 29-01007
SHEET 1 OF 1

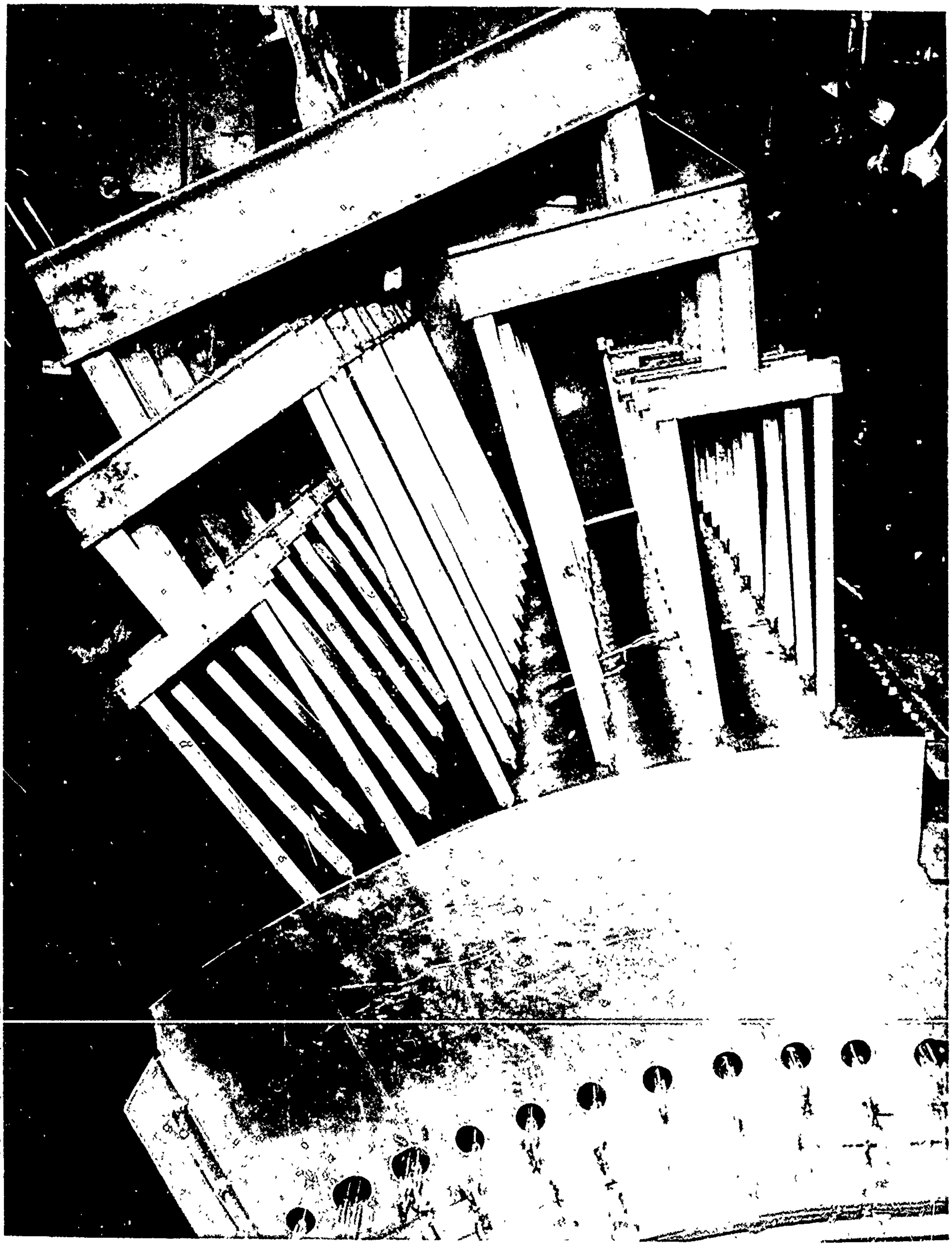
357 (Rev 5-58) FORM 8-3043A

2



Convair Print 60715

Figure B-2 – FRONT VIEW OF TEST SET UP; With Oven Open

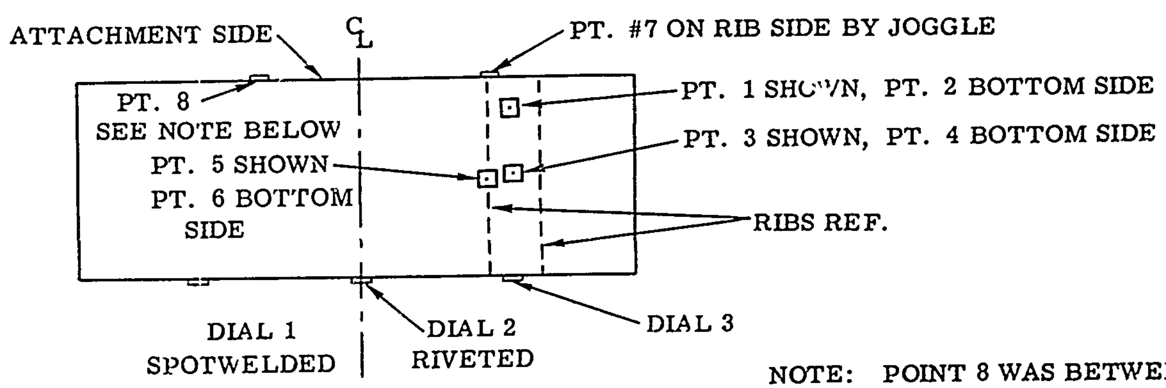


Convair Print 60714

Figure B-3 – SIDE DETAIL OF TEST SET UP; Showing Load Attachment Points.

TABLE B-1 - ROOM-TEMPERATURE STRAIN GAGE DATA - STATIC TEST OF WING LEADING-EDGE ASSEMBLY

Loading %	Loading Pounds	E psi	Stress Pt.1 psi	Stress Pt. 2 psi	Stress Pt. 3 psi	Stress Pt.4 psi	Stress Pt. 5 psi	Stress Pt. 6 psi	Stress Pt.7 psi	Stress Pt.8 psi
10	665	15.5×10^6	← Zero Reference →							
20	1330		0	- 310	+ 233	- 78	+ 310	- 465	- 155	- 1318
10	665		C	0	+ 78	- 155	- 155	0	0	0
40	2660		+ 155	- 620	+ 388	- 78	+ 1162	- 1628	- 465	- 5040
10	665		C	0	+ 78	- 155	- 233	- 78	+ 155	- 388
60	3990		- 620	- 2330	+ 698	- 155	+ 2095	- 2790	- 1085	- 9620
10	665		- 78	0	+ 78	- 155	- 155	- 78	0	- 1085
80	5320		- 1001	- 3250	+ 1160	- 155	+ 2950	- 3800	- 1550	-14880
10	665		0	+ 155	+ 78	- 78	- 155	0	- 78	- 1628
100	6650		- 1475	- 4120	+ 1318	- 388	- 3800	- 4575	- 2560	-21450
10	665	15.5×10^6	- 78	+ 310	+ 78	- 543	- 310	- 233	- 310	- 2480



TOP VIEW

NOTE: POINT 8 WAS BETWEEN TWO SPOT WELDS

III. 2. Test Procedure: (Cont'd)

The fatigue test load was 2/3 of limit load (4433 lbs.). This load was applied and removed about 33 times per minute. Loadings were applied 2500 times at room temperature, 200 F, 400 F, and 600 F. At 800 F, the loadings were applied 150,000 times. All loads were applied hydraulically using a hydraulic cylinder and pump.

The loading cylinder was placed in a calibrated Baldwin Lima Hamilton standard universal testing machine prior to test. Pressure was applied to the cylinder by the hand pump. A pressure vs load curve was thereby obtained. By using the same pressure gage and cylinder, the loads could be duplicated accurately during subsequent testing.

Heat was applied to the specimen by means of quartz heat lamps in a contoured, reflective oven, Figure B-2 (page 123). The temperature was controlled by a Research, Inc. heat programmer. Four channels of heating were used: two above and two underneath the specimen. A channel consists of a lamp bank, a controller, and a feedback thermocouple attached to the specimen under the lamp bank. The accuracy of the temperature is dependent only on the accuracy of the thermocouple.

3. Test Loads:

Test load for the static test was design limit load which is defined in Convair Report S-Gen-84 "Titanium Development Program" as 6650 pounds with a uniform distribution. This was based on condition 1610 from Convair Report ZS-8-136 "Static Test Load Summary 106A."

Fatigue load was 66.6% of limit load.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

IV. TEST RESULTS

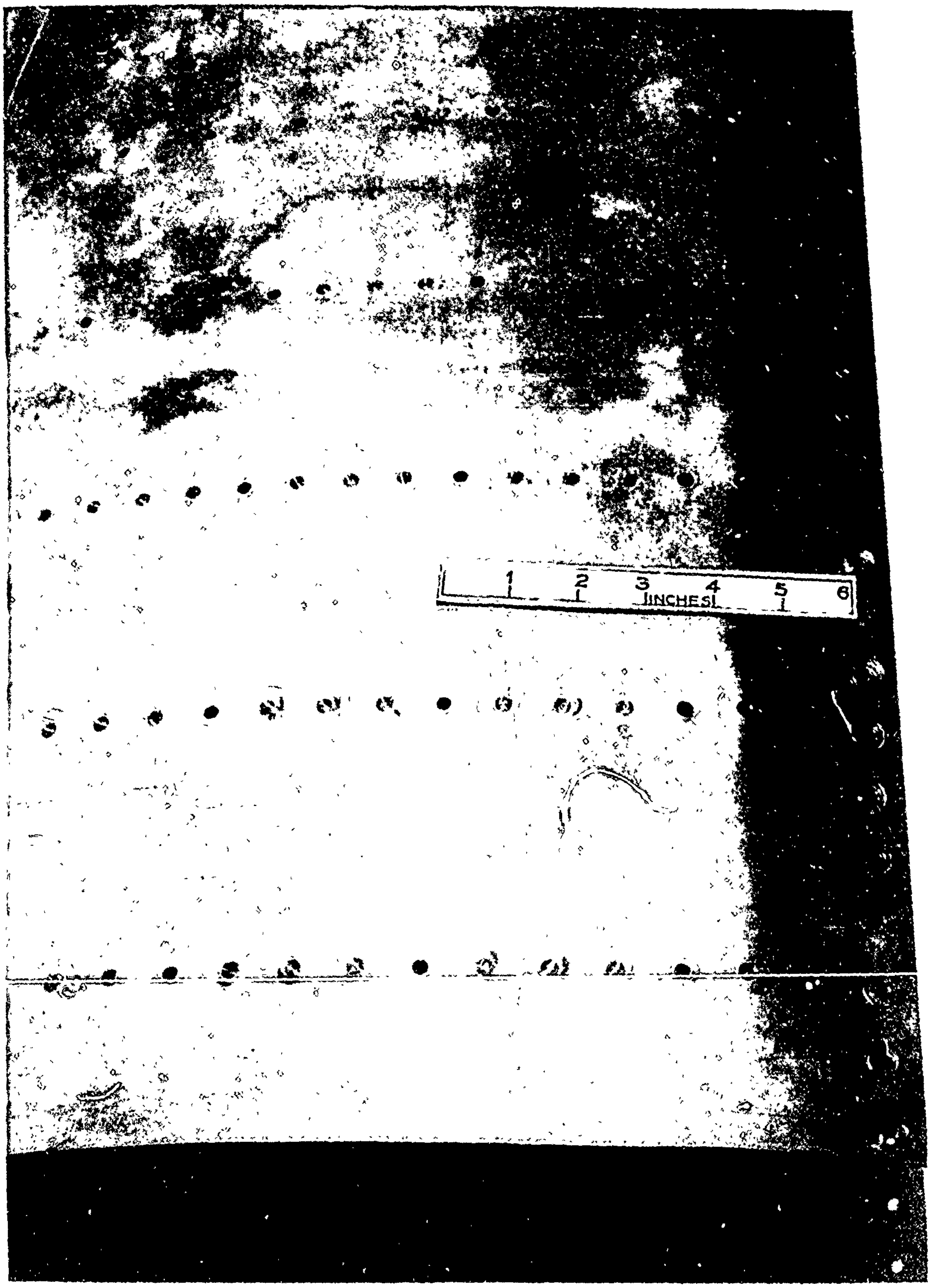
The static test Wing Leading Edge Assembly failed at 12,600 pounds which is 189.5% of limit load or 126.3% of design ultimate. Failure occurred in the upper skin which failed as a column, pulling out spotwelds, popping rivet heads, and bulging outward, Figures B-4 and B-5 (pages 128 and 129).

Strain gage readings taken during the room temperature static test are to be found in Table B-1 (page 125).

Deflection and set curves for the various test temperatures are shown in Figures B-6 through B-16 (pages 130 through 140). The data from the midpoint were used. This point approximates the average of the three. The quarter point falling in the middle of the riveted section was about 5% higher, the spotwelded, about 5% less.

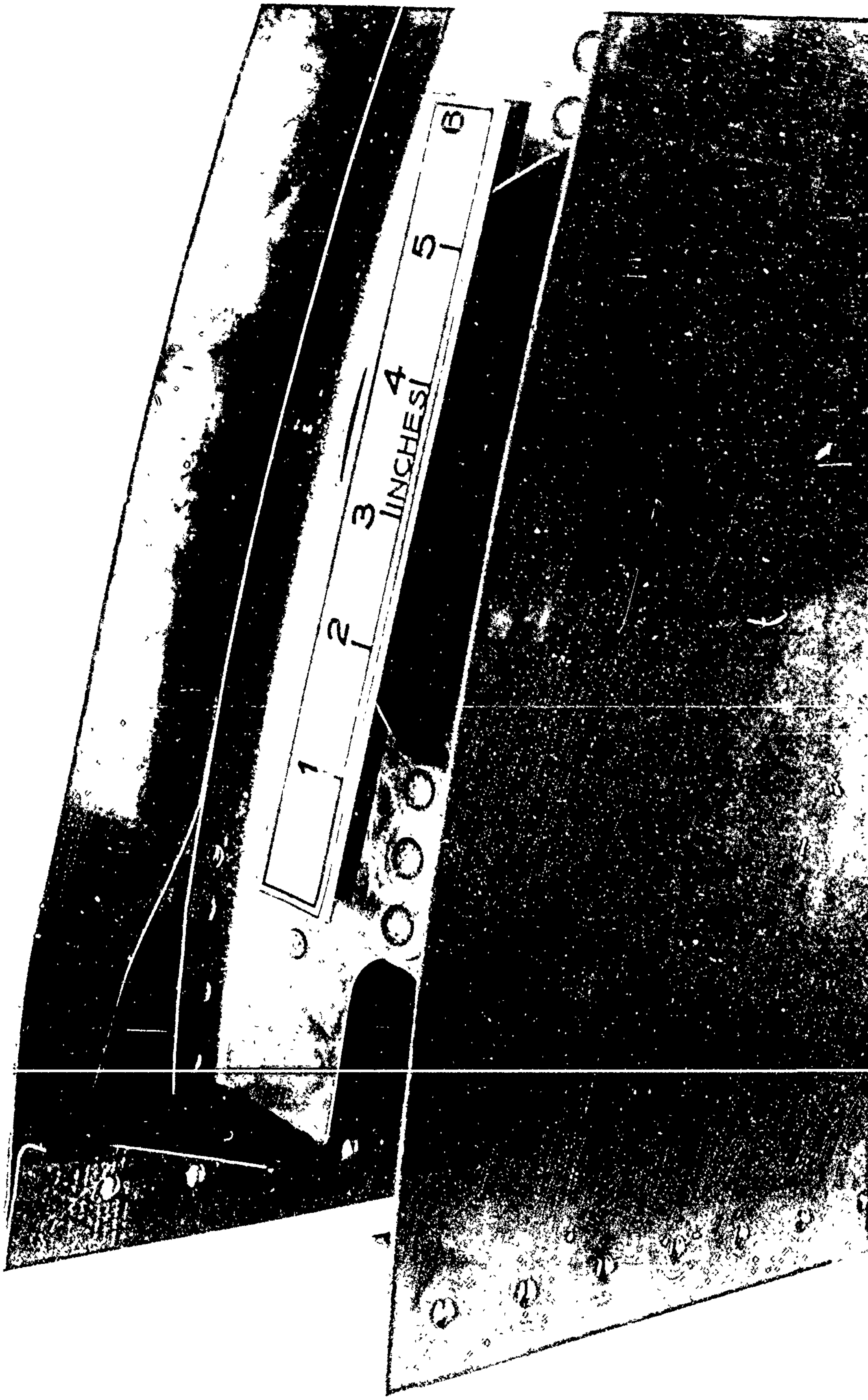
The fatigue test Wing Leading Assembly withstood a total of 160,000 cycles of 2/3 limit load. However, the spotwelded half suffered considerable damage. The first spotweld failures occurred at 29,855 cycles. The failure was heard at that time, but damage could not be seen. At 72,000 cycles, the failure of the spotwelds could be seen. They were mostly internal structure welds. By 160,000 cycles, there was extensive internal damage as well as damage to the skin as shown in Figures B-17 and B-18 (pages 141 and 142).

The first rivet head popped in the skin at 55,338 cycles. At 160,000 cycles, the riveted half had lost several rivet heads in the upper skin as shown in Figure B-19 (page 143). There was also some damage to the ribs next to the spotwelded half as shown at the right in Figures B-17 and B-18.



Convair Print 61646

Figure B-4 — WING LEADING-EDGE ASSEM; Top View of Specimen Showing Rivet Failures.



Convair Print 61647

Figure B-5 — WING LEADING-EDGE ASSEM; End View of Specimen Showing Spotweld Failures.

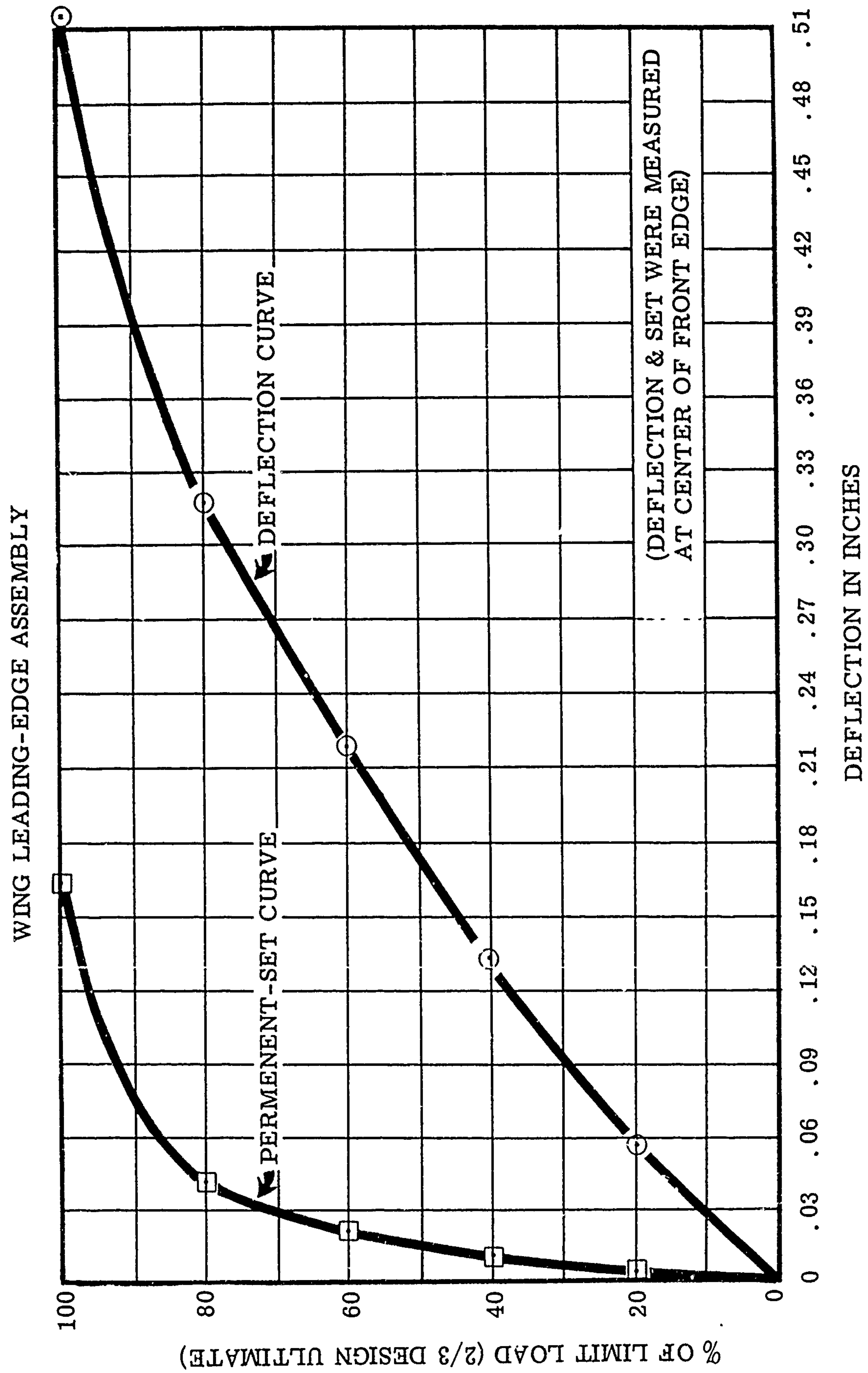


Figure B-6 — DEFLECTION AND PERMANENT SET AT ROOM TEMPERATURE.

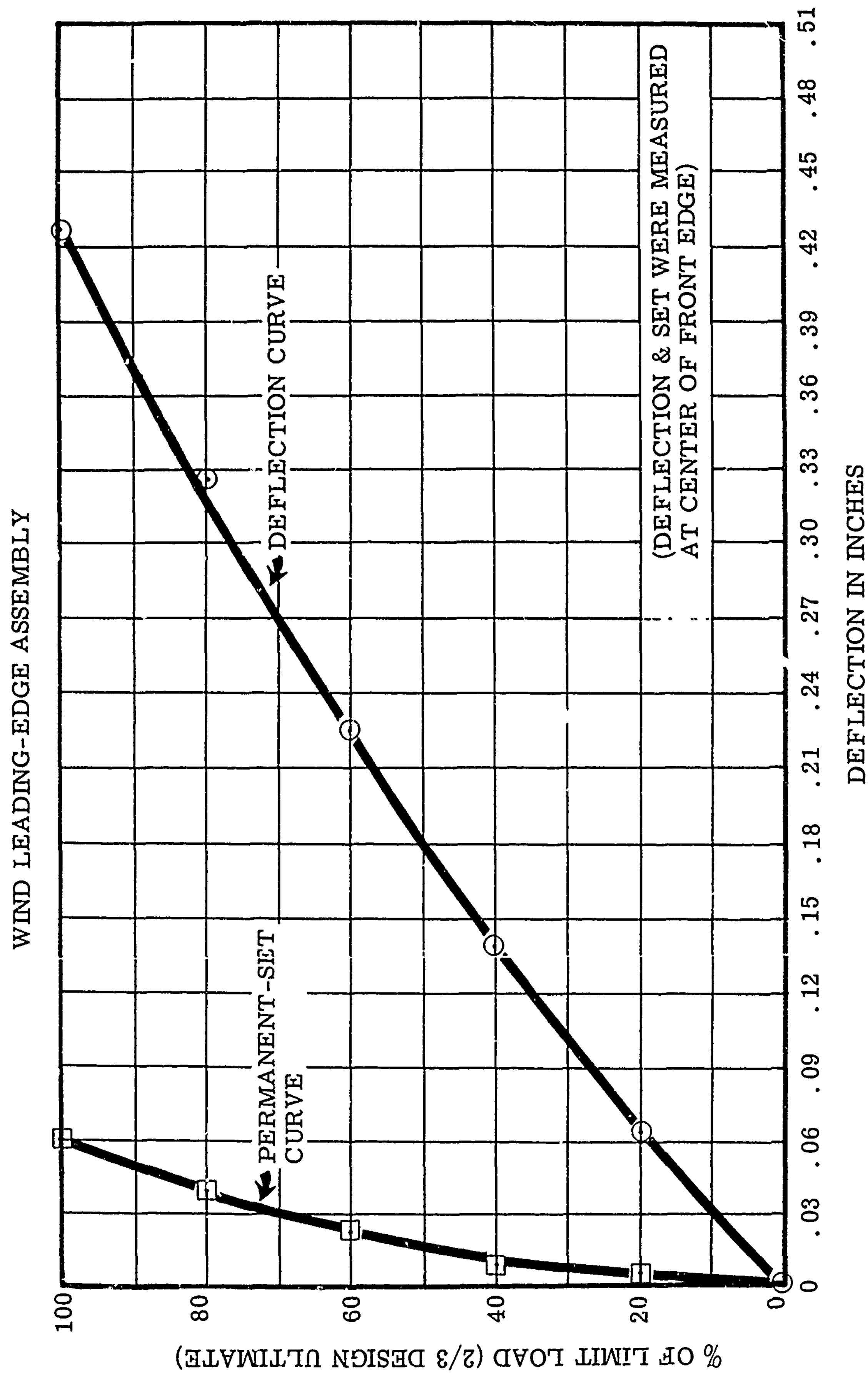


Figure B-7 — DEFLECTION AND PERMANENT SET AT 200F.

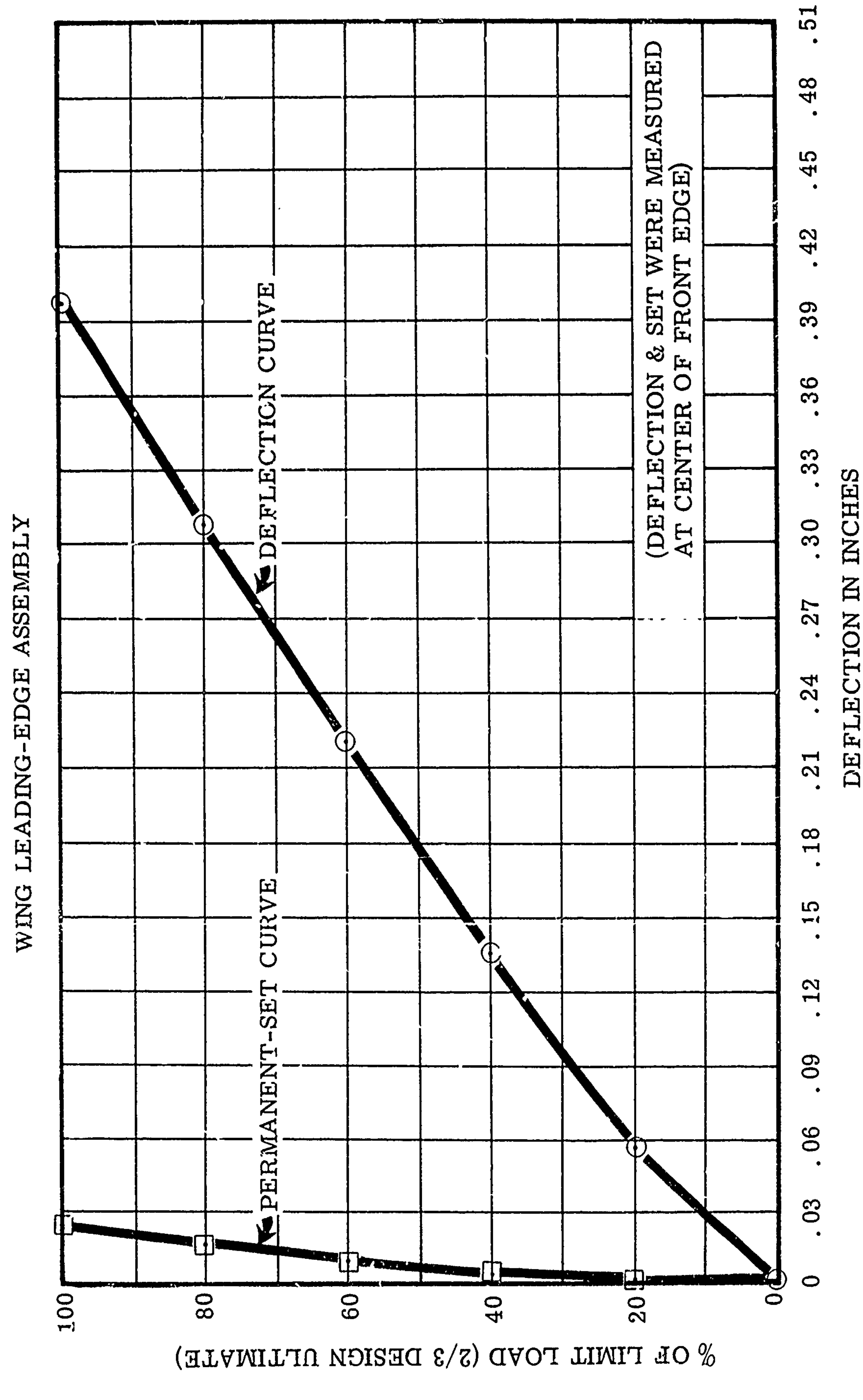


Figure B-8 — DEFLECTION AND PERMANENT SET AT 300F.

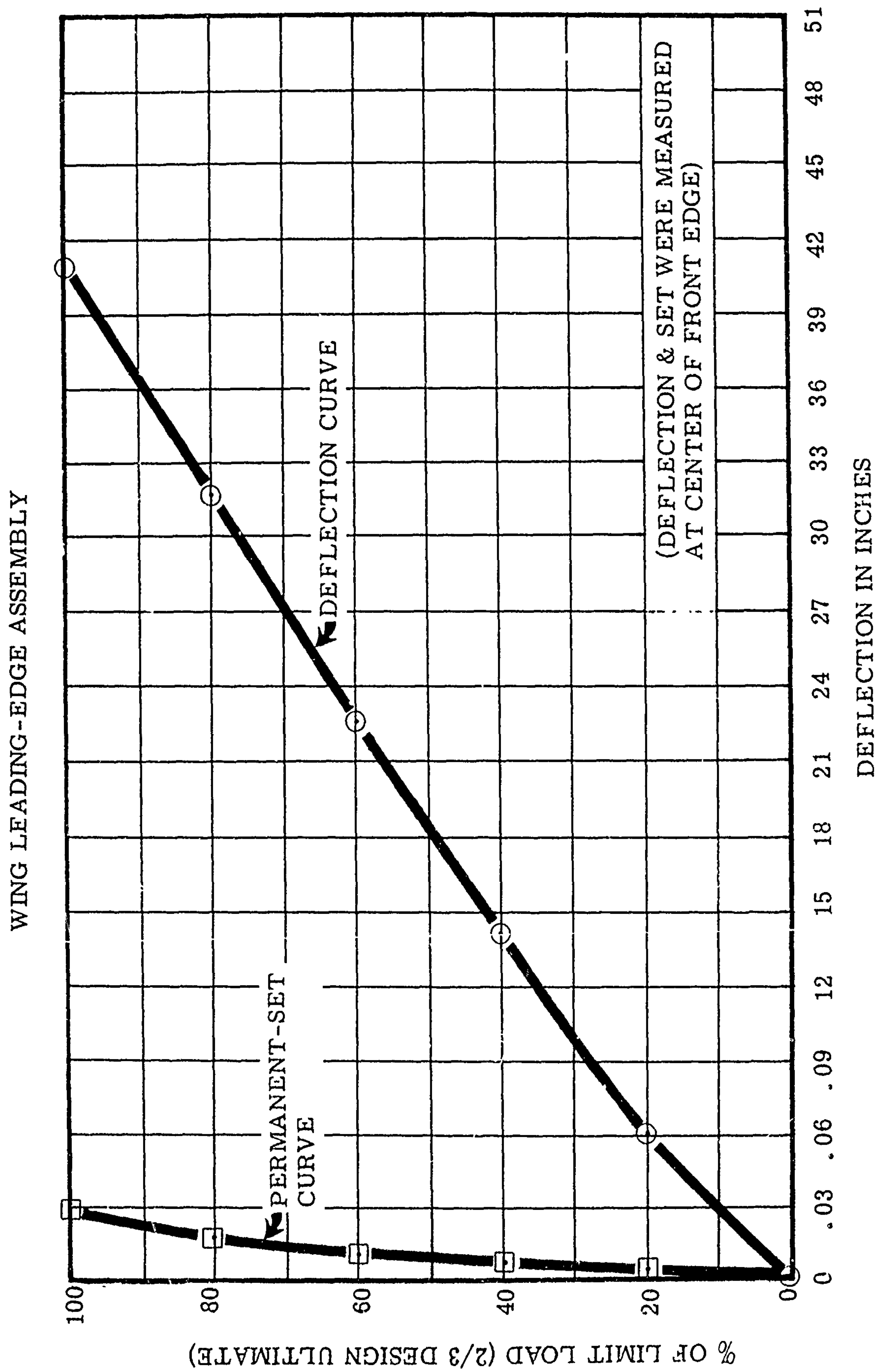


Figure B-9 — DEFLECTION AND PERMANENT SET AT 400F.

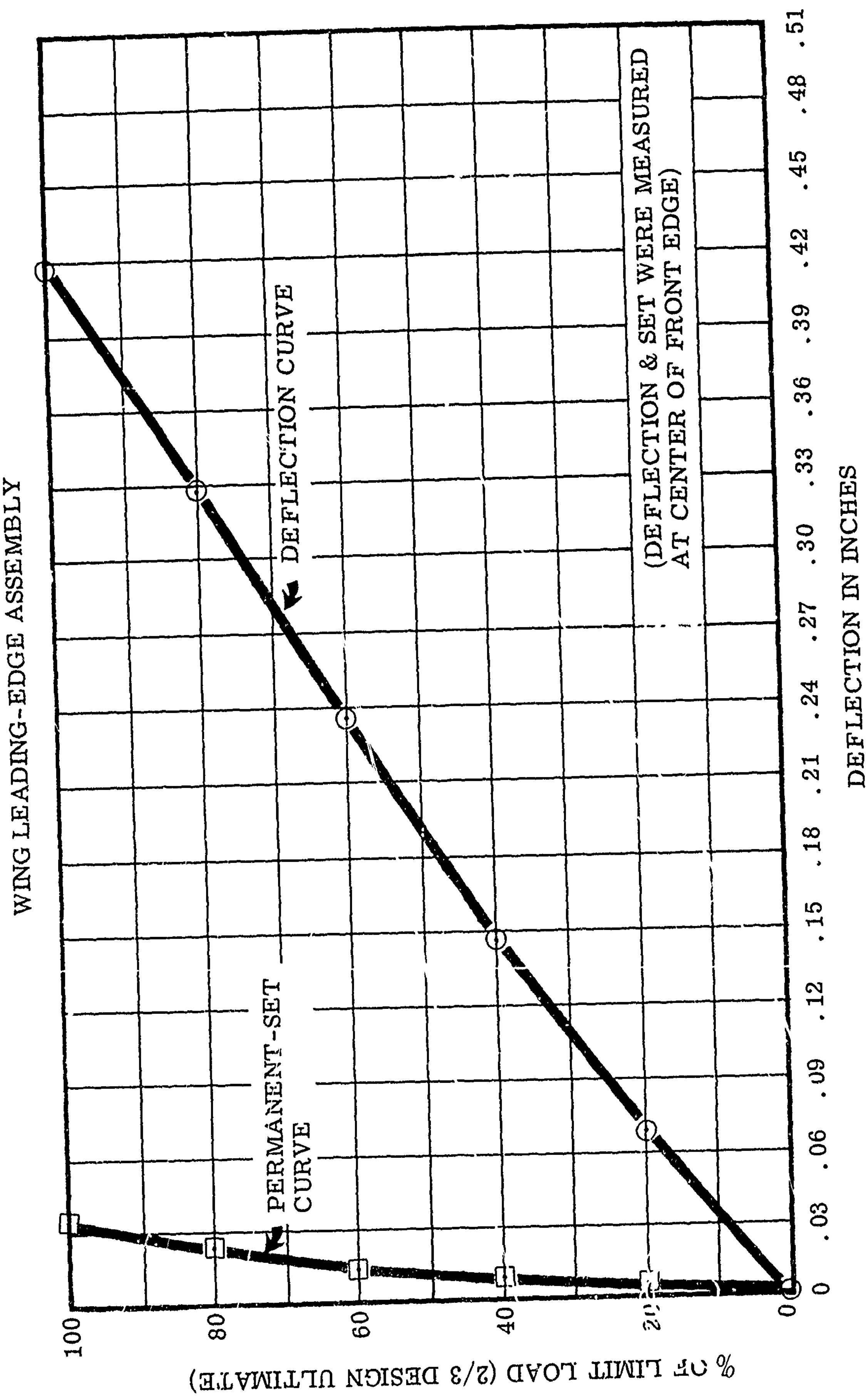


Figure B-10 — DEFLECTION AND PERMANENT SET AT 500F.

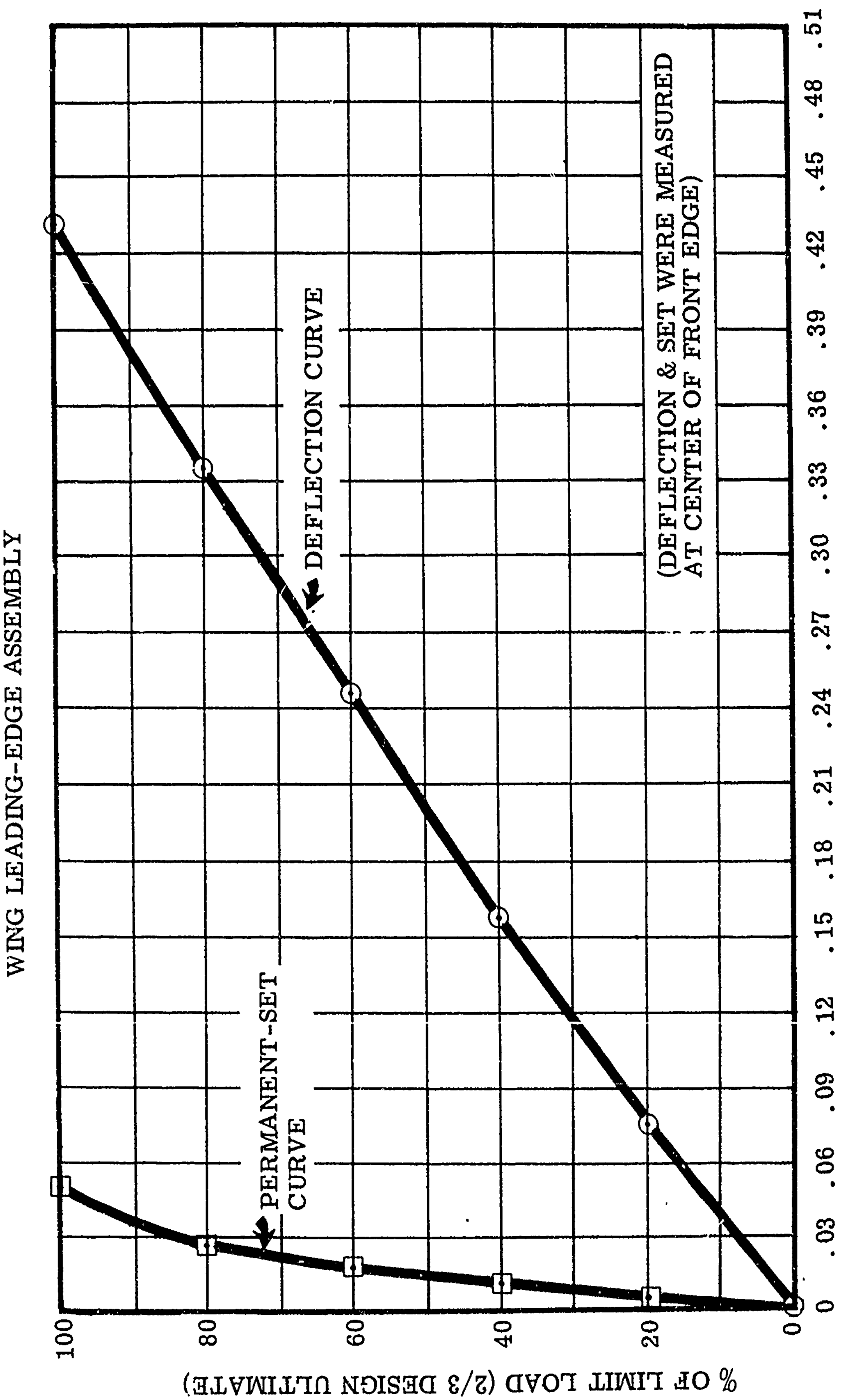


Figure B-11 — DEFLECTION AND PERMANENT SET AT 600F.

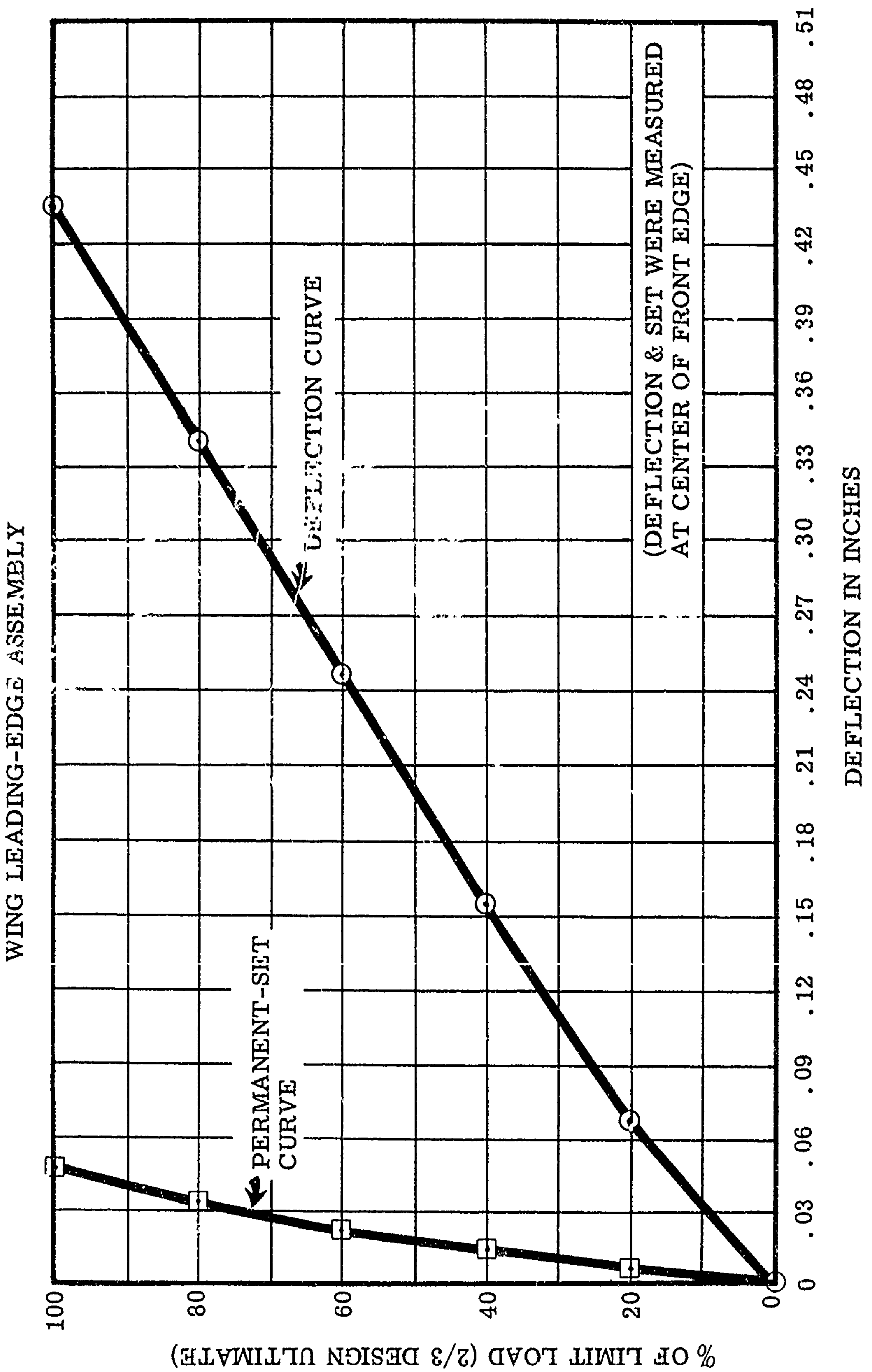


Figure B-12 — DEFLECTION AND PERMANENT SET AT 700F.

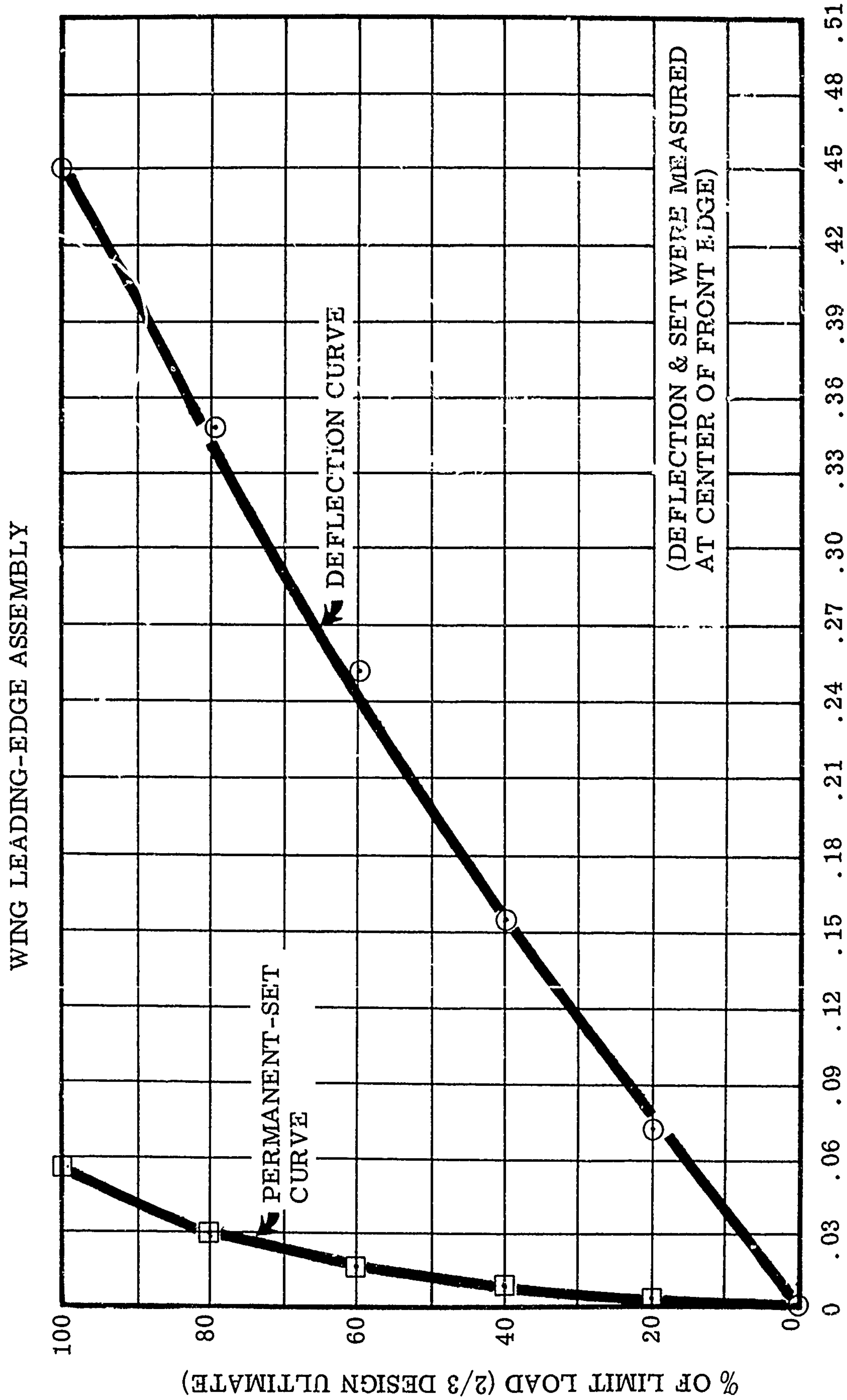


Figure B-13 — DEFLECTION AND PERMANENT SET AT 800F.

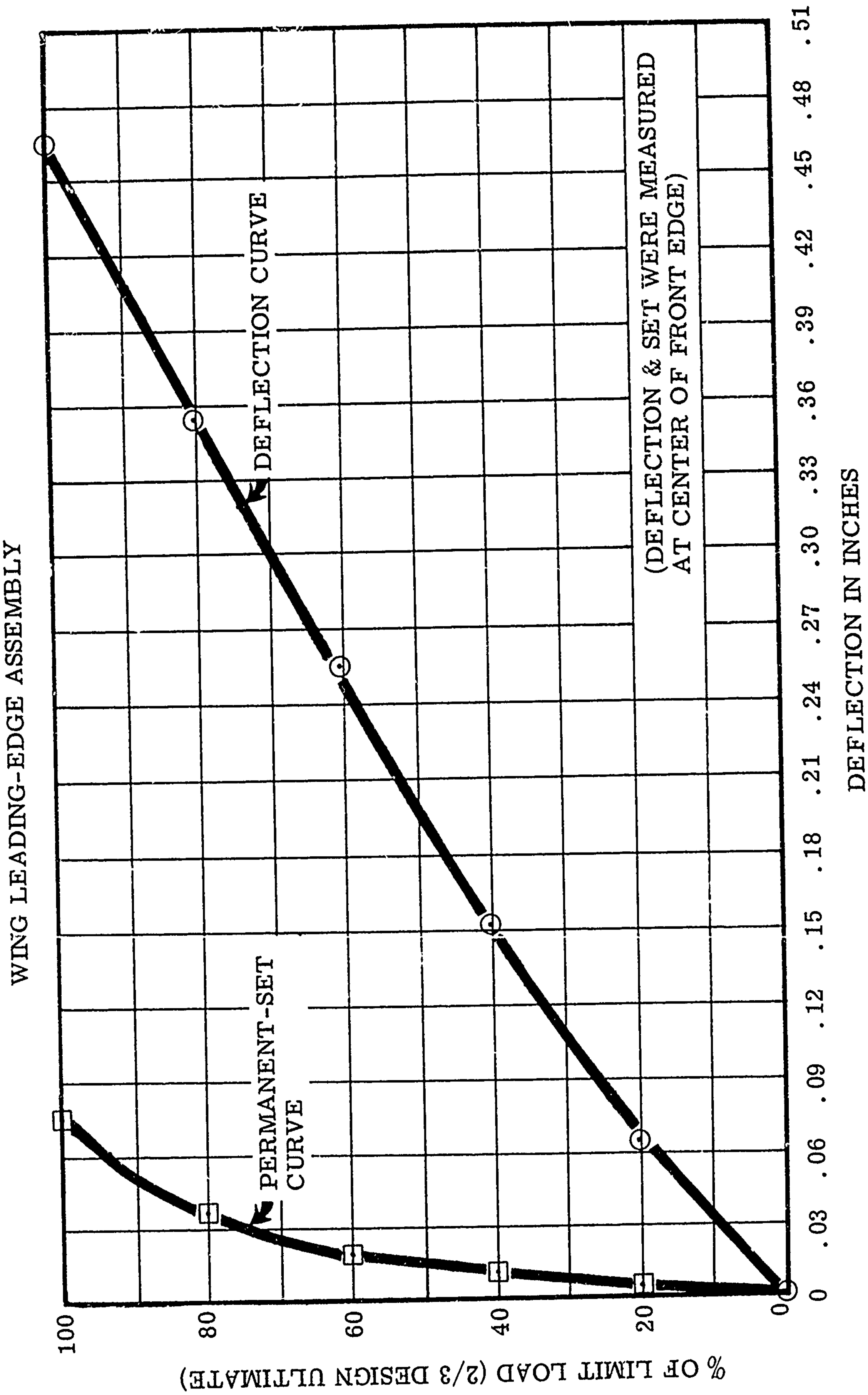


Figure B-14 — DEFLECTION AND PERMANENT SET AT 900F.

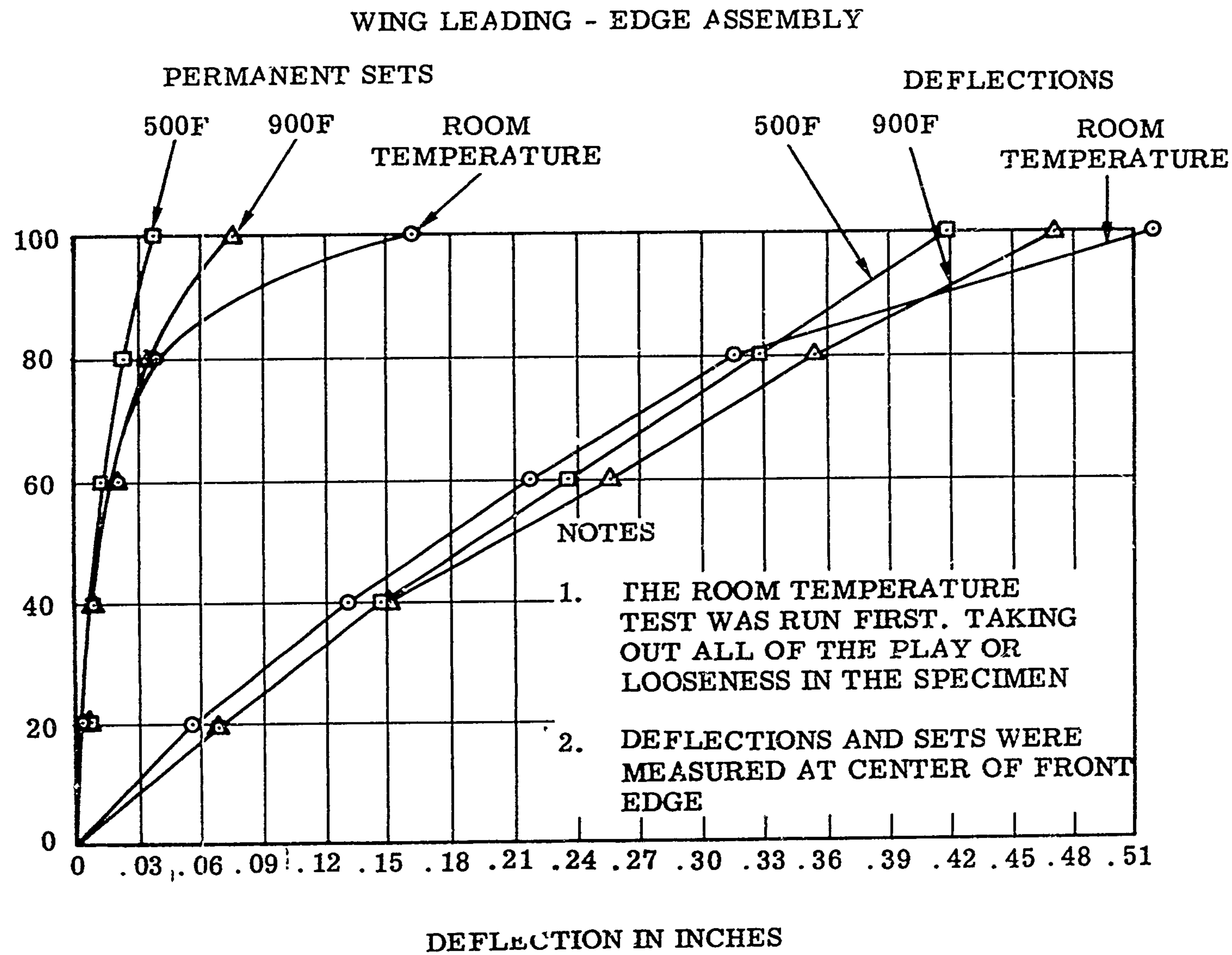


FIGURE B-15. DEFLECTIONS AND PERMANENT SETS; At Room Temperature, 500F, And 900F

CONVAIR, SAN DIEGO

WING LEADING-EDGE ASSEMBLY

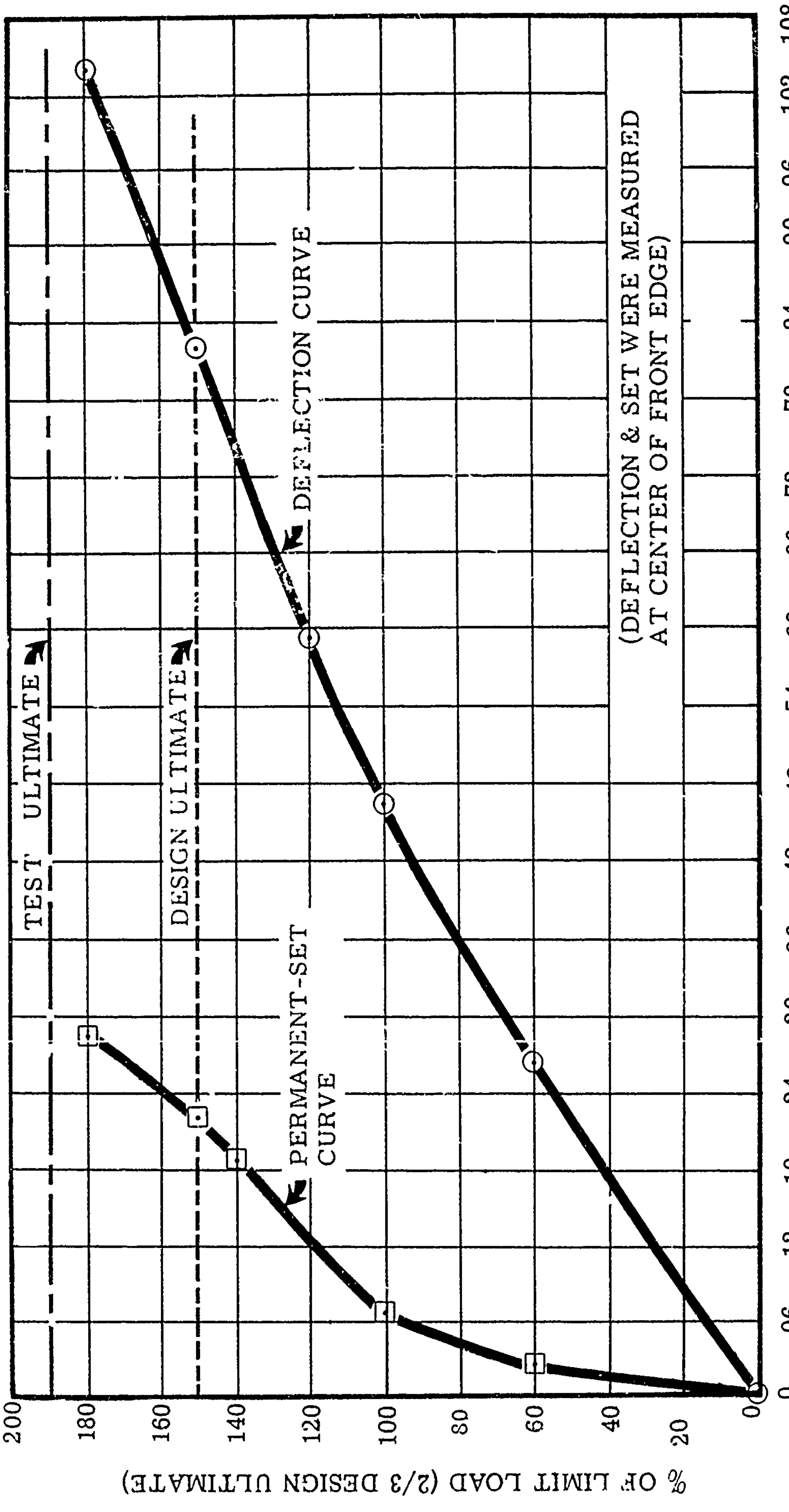
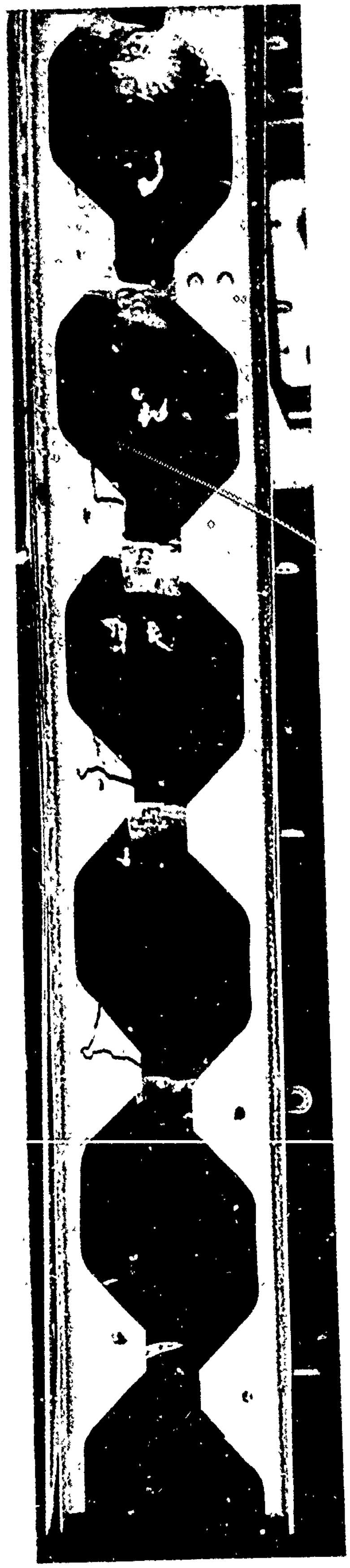


Figure B-16 — DEFLECTION AND PERMANENT SET DURING FAILURE TEST AT 800F.

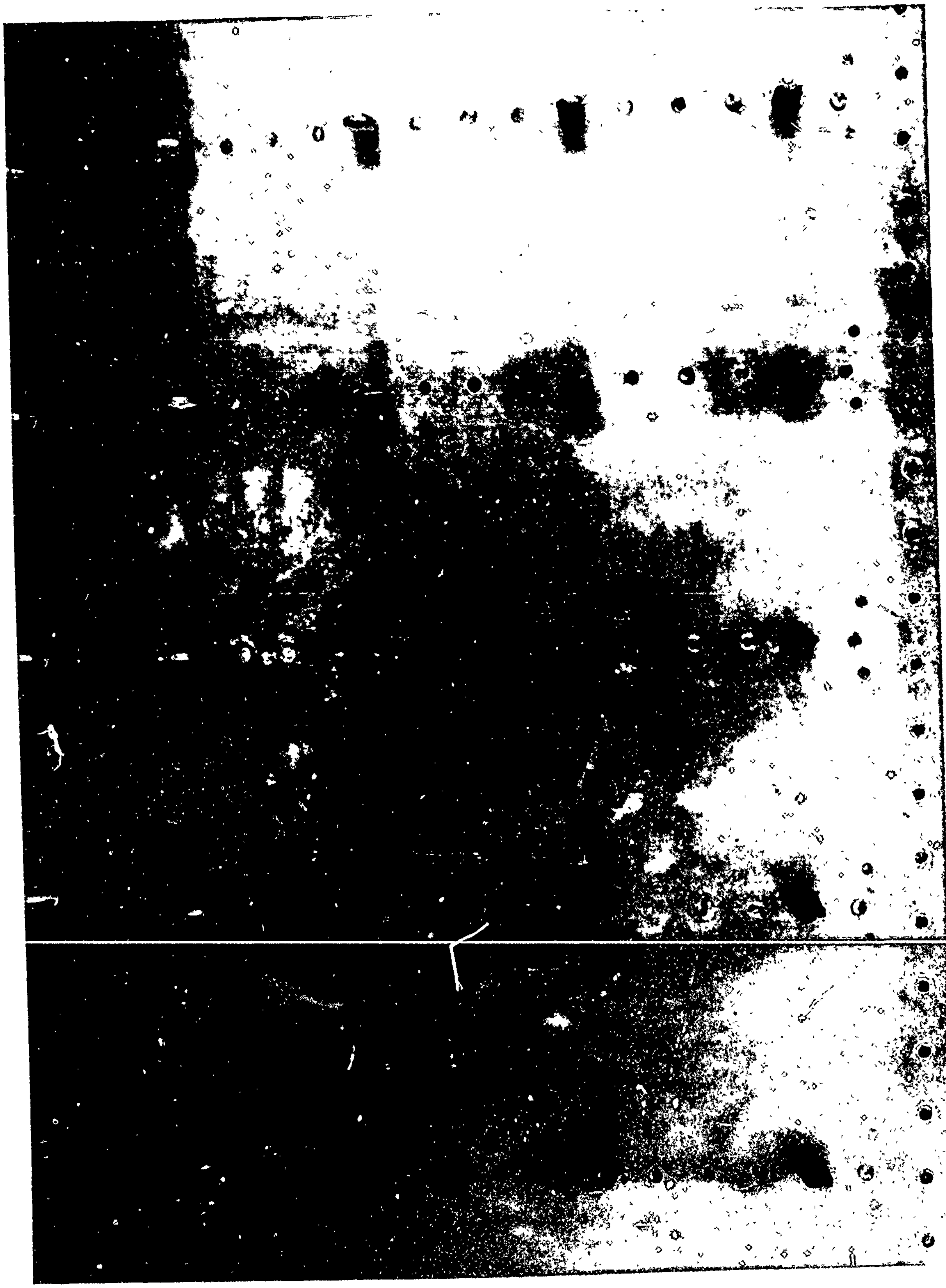
Convair Print 63965

Figure B-17 — SPOT WELDED SECTION OF WING LEADING-EDGE ASSEMBLY; Oblique View Showing Fatigue Failures.



Convair Print 63966

Figure B-18 — SPOT WELDED SECTION OF WING LEADING-EDGE ASSEMBLY:
Rear View Showing Fatigue Failures.



Convair Print 63964

Figure B-19 — RIVETED SECTION OF WING LEADING-EDGE ASSEMBLY; Top View Showing Rivet Head Failures

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

V. SUMMARY OF RESULTS

1. The load carrying characteristics of the Wing Leading Edge Assembly, as determined by the deflection and set curves, are not materially affected by temperatures up through 900 F, although deflections increased with temperature.

2. The ultimate strength of the Wing Leading Edge Assembly was 126.3% of design ultimate load.

3. The spotwelded section failed first, with failure progressing to the riveted side.

4. After 160,000 cycles of 66.7% limit load, the 29-01007 Leading Edge Assembly would still withstand the load.

5. The riveted portion was in good condition except for several popped rivet heads and cracks in the rib adjacent to the spotwelded portion.

6. The spotwelded portion had many internal failures and was gradually transferring more and more of its load through the skins into the riveted section, causing the failures in the adjacent riveted rib as mentioned above.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

B. WING LEADING EDGE SECTIONS - STATIC AND FATIGUE TESTS

VI. CONCLUSIONS AND DISCUSSION

The leading edge assembly which was fabricated from titanium for the structural tests weighed approximately 17.28 pounds. This is almost the identical weight of the presently used aluminum structure on the F-106 (calculated to be 16.1 pounds). The titanium skin was chemically milled between the ribs so that the weight of the specimen would approach the weight of the original design.

The condition that the specimen was tested to is a 7g limit, steady state pull up, at subsonic speed, at sea level. Temperature was not a design parameter. The specimen showed a margin of safety of 26.3 even though it was tested at 800 F. The fatigue life of the specimen far exceeded any reasonable design requirements. With these facts in mind, it can be reasonably assumed that a substantial weight saving could have been experienced had the original design been based on titanium. Leading edge designs in the near future will be influenced by aerodynamic heating generated by Mach 3.0 and above. Titanium as a material for leading edges has been demonstrated to be a very useful material under these operating conditions.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

C. DUCT-ENGINE BLEED AIR - STATIC, FATIGUE AND BURST TESTS

TABLE OF CONTENTS

LIST OF TABLES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

C. DUCT-ENGINE BLEED AIR - STATIC, FATIGUE AND BURST TESTS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

C. DUCT-ENGINE BLEED AIR - STATIC, FATIGUE AND BURST TESTS

I. INTRODUCTION

Six titanium alloy ducts similar to the F-106 engine bleed air ducts were manufactured by three methods, two specimens by each method. One of each type was subjected to static tests at 800 F and the other, to fatigue tests at 800 F. After completion of the above tests, each duct was burst-tested at room temperature.

II. SUMMARY

The program objective was to determine the structural integrity of air ducts, made from titanium alloy by three different methods. Since all specimens met or exceeded initial test requirements, the objective of the program was accomplished.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

C. DUCT-ENGINE BLEED AIR - STATIC, FATIGUE AND BURST TESTS

III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING

1. Test Specimens:

Six engine bleed air ducts were manufactured from Ti-4Al-3Mo-1V titanium alloy. These specimens simulated the engine bleed air ducts used in the Convair F-106 interceptor. The production ducts are manufactured from type 321 or 347 corrosion resistant steel, using fusion and seam welded construction.

The three manufacturing methods used on the titanium test specimens were:

a. Fusion butt welded with seam welded end flanges, Figure C-1 (page 153).

b. Seal welded, Figure C-2 (page 155).

c. Riveted and brazed, Figure C-3 (page 157).

It is to be noted that all specimens had fusion butt welds in some areas.

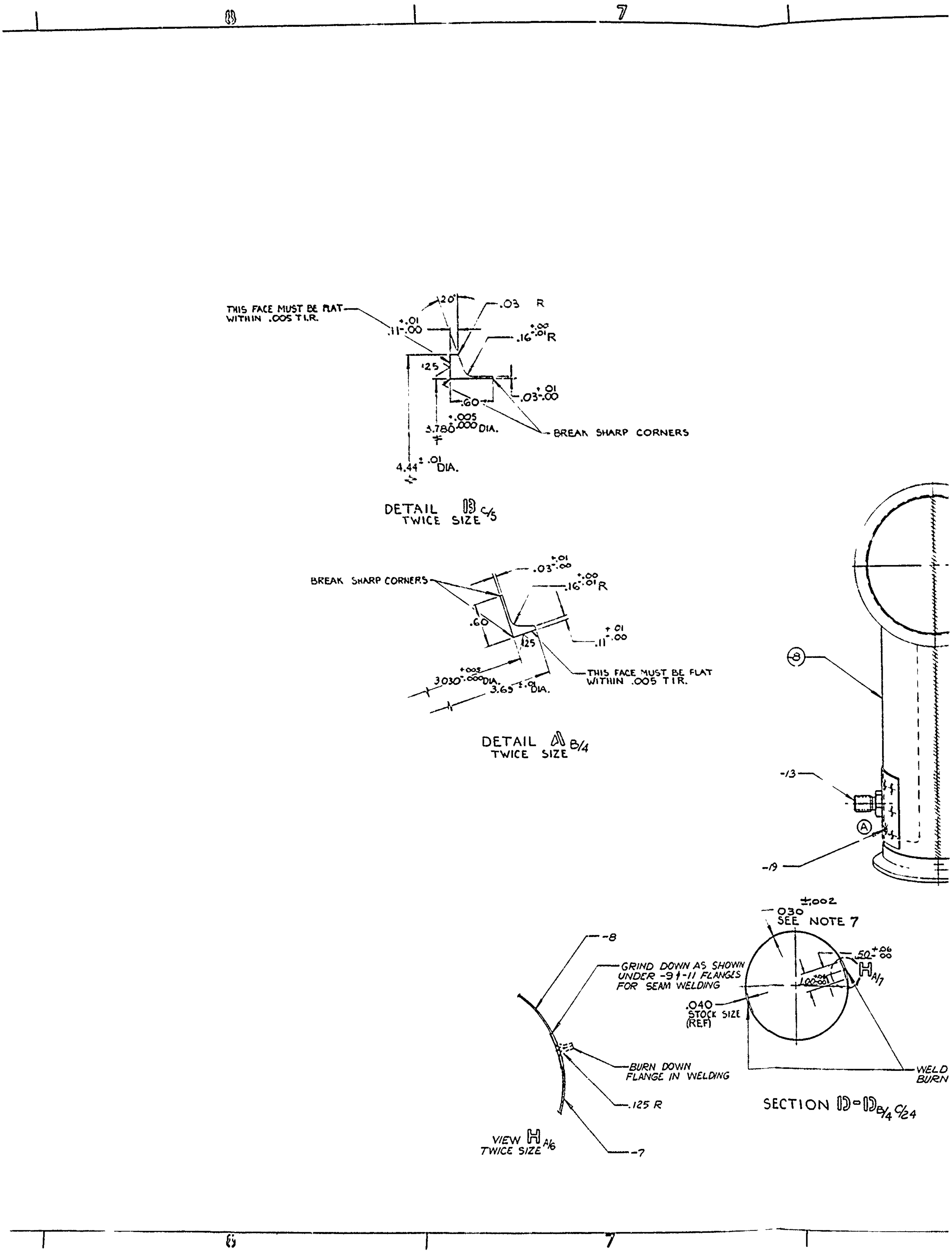
Details of the specimen manufacture are discussed in Volume IV, this report.

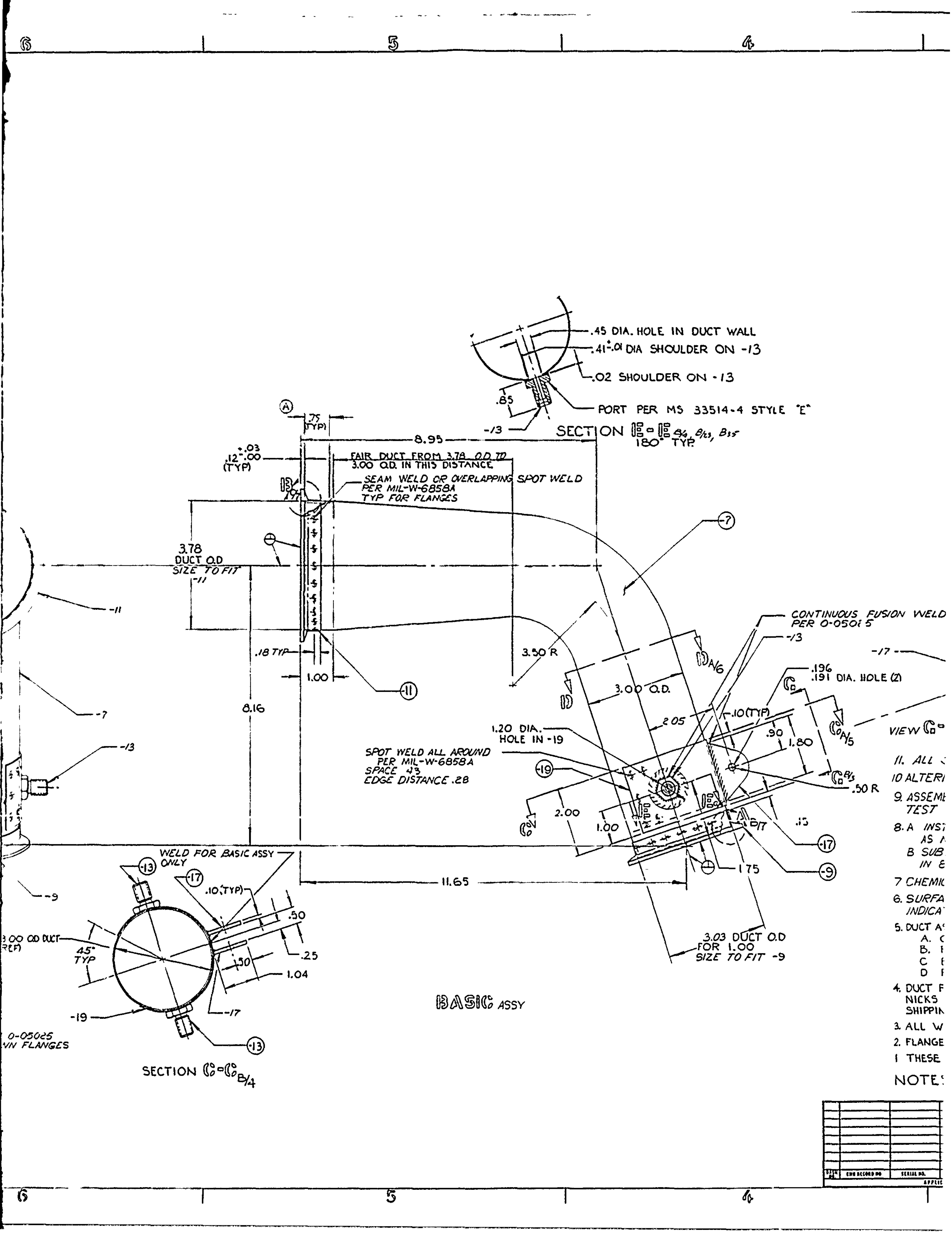
The test ducts were assembled using solid end caps. Sealed tubes were attached to the cap and inserted into the ducts in order to reduce the internal volume, Figure C-4 (page 159).

The caps were held in place with Marmon clamps and sealed with asbestos and steel gaskets, Figure C-5 (page 160).

A preliminary leak test was accomplished by submerging the duct in water and applying 90 PSIG internal air pressure. Leaks in the duct were repaired prior to test. Difficulty was experienced in obtaining a satisfactory

Figure C-1 - ENGINE-BLEED AIR DUCT; Butt Welded Assembly
Engineering Drawing 29-01005, Sheet 1 of 3


8
7
THIS FACE MUST BE FLAT WITHIN .005 T.I.R.
20°
.03 R
.16 R
.125
.60
BREAK SHARP CORNERS
3.780 DIA.
4.44 ±.01 DIA.
DETAIL B C/5
TWICE SIZE
BREAK SHARP CORNERS
.03
.16 R
.60
.125
.11
THIS FACE MUST BE FLAT WITHIN .005 T.I.R.
3.030 DIA.
3.65 DIA.
DETAIL A B/4
TWICE SIZE
-8
-13
A
-19
.030 ±.002
SEE NOTE 7
-8
GRIND DOWN AS SHOWN UNDER -9 + -11 FLANGES FOR SEAM WELDING
.040 STOCK SIZE (REF)
BURN DOWN FLANGE IN WELDING
.125 R
-7
VIEW H A/6
TWICE SIZE
SECTION D-D B/4 C/24
WELD
BURN
8
7



6
5
4
.45 DIA. HOLE IN DUCT WALL
.41±.01 DIA SHOULDER ON -13
.02 SHOULDER ON -13
.85
PORT PER MS 33514-4 STYLE "E"
-13
SECTION E-E
180° TYP
.75 (TYP)
8.95
.12 +.03 -.00 (TYP)
FAIR DUCT FROM 3.78 O.D. TO 3.00 O.D. IN THIS DISTANCE
SEAM WELD OR OVERLAPPING SPOT WELD PER MIL-W-6858A TYP FOR FLANGES
3.78 DUCT O.D SIZE TO FIT -11
-11
-7
-13
-9
.18 TYP
1.00
3.50 R
8.16
11.65
CONTINUOUS FUSION WELD PER 0-0502 5
-13
-17
3.00 O.D.
.196 .191 DIA. HOLE (2)
.10 (TYP)
2.05
.90
1.80
1.20 DIA. HOLE IN -19
SPOT WELD ALL AROUND PER MIL-W-6858A SPACE .43 EDGE DISTANCE .28
.50 R
2.00
1.00
.15
1.75
3.03 DUCT O.D FOR 1.00 SIZE TO FIT -9
VIEW C
WELD FOR BASIC ASSY ONLY
.10 (TYP)
.50
.25
.50
1.04
3.00 OD DUCT (REF)
45° TYP
-19
-17
0-05025 ...N FLANGES
SECTION C-C B/4
BASIC ASSY
11. ALL
10 ALTER
9. ASSEM TEST
8. A INST AS B SUB IN
7 CHEMI
6. SURFA INDICA
5. DUCT A A. B. C D
4. DUCT F NICKS SHIPPIN
3. ALL W
2. FLANGE
1 THESE
NOTES

REVISIONS

LTR	DESCRIPTION	ZONE	DATE	APPROVAL
A	ADDED INFORMATION TO DESCRIBE CHEM-MILLING AT ENDS OF DUCT HALVES	C5 B6	15160	[illegible]
B (O.D.)	IN L/M-RIVETS NAS508M WAS AN[illegible] AN427M WAS AN427M[illegible] IN L/M REMOVED -19(1) FROM -3 ASSY ADD -37(1) TO -3 ASSY. SHTS 1,2,3 COMPRISE COMPLETE "B" CHG. DIST RWK. (NO PARTS MADE)			[illegible]

. . . WELD

. . . AGED CONDITION

. . . ?-19 C-0.038 (6AL 4V) COND (A)

. . . ESSURE TEST AS SHOWN IN

. . . AMPS PER B-23400 NOTE 2 EXCEPT

. . . GASKET FOR 94-16009-002 GASKET

. . . SQUARE WITHIN .015 TOTAL

. . . E FOLLOWING PRESSURES AND TEMPERATURES:

. . . 800° F

. . . 800° F.

. . . 800° F

. . . ROOM TEMPERATURE (REPEATED LOAD TEST)

. . . REE FROM BURRS AND

. . . FOR STORAGE AND

. . . E REMOVED ONLY UPON INSTALLATION.

. . . OTHERWISE NOTED.

. . . THIN .005 TIR AFTER WELDING.

. . . RSIONS OF B 23028-3

PART NO	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MATL SPECIFICATION	ZONE	INSP CLASS
NAS508M		RIVET							
AN427M		RIVET							
B-23028-19		FLANGE						C/34	
B-23028-11		FLANGE						C/34	
	-37	DOUBLER	.040x20x.95	COML PURE TI	A	A	AMS 4901	B/35	A
	-35	STIFFENER	.063x.4x3.9	CRES 321 OR 347	A	A	QQ-S-763 [illegible]	B/30	A
	-33	PLATE	.190x3.3x3.2	CRES 321 OR 347	A	A	QQ-S-763 [illegible]	B/23	A
	-31	PLATE	.190x3.9x3.9	CRES 321 OR 347	A	A	QQ-S-763 [illegible]	C/3	A
	-29	DUCT HALF	.030x2.5x14.7	TI ALY	SOL HT	SHT AGE	4AL-3MO-1V	C/32	A

Figure C-1 Page 153

29-01005
SHEET 1 OF 3 B
AUTH EWO 0082

PART NO	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MATL SPECIFICATION	ZONE	INSP CLASS
	-27	DUCT HALF	.030x12.5x14.1	TI ALY	SOL HT	SHT AGE	4AL 3MO-1V	C/33	A
	-25	DUCT	.030x6.4x1.8	TI ALY	SOL HT	SHT AGE	4AL-3MO-1V	D/24	A
	-24 -23	DUCT HALF	.040x4.8x6.4	TI ALY	SOL HT	SHT AGE	4AL-3MO-1V	C/2?	A
	-21	DUCT	.030x6.4x9.5	TI ALY	SOL HT	SHT AGE	4AL 3MO-1V	B/25	A
	-19	DOUBLER	.040x2.0x3.5	COML PURE TI	A	A	AMS 4901	B/5	A
	-17	PLATE	1/8x1.4x1.6	COML PURE TI			AMS 4901	B/3	A
	-15	STIFFENER	.063x.4x3.2	CRES 321 OR 347			QQ-S-763 [illegible]	A/9	A
	-13	FITTING	3.4 OD x .9	COML PURE TI			AMS 4921	A/5	A
	-11	FLANGE	5/8x4.5x4.5	COML PURE TI			AMS 4901	B/5	A
	-9	FLANGE	5/8x3.7x3.7	COML PURE TI	A	A	AMS 4901	B/4	A
-8	-7	DUCT HALF	.040x12.2x15.8	TI ALY	SOL HT	SHT AGE	4AL-3 MO-1V	C/4	A

REQUIREMENTS PER ASSEMBLY: -5 -3 -1

LIST OF MATERIAL

RIVET CODE PER NAS 523

MANUFACTURING STANDARDS UNLESS OTHERWISE NOTED ON FACE OF DRAWING. DIMENSIONS IN INCHES

DUCT-ENGINE BLEED AIR, 4.31 TITANIUM BUTT WELDED

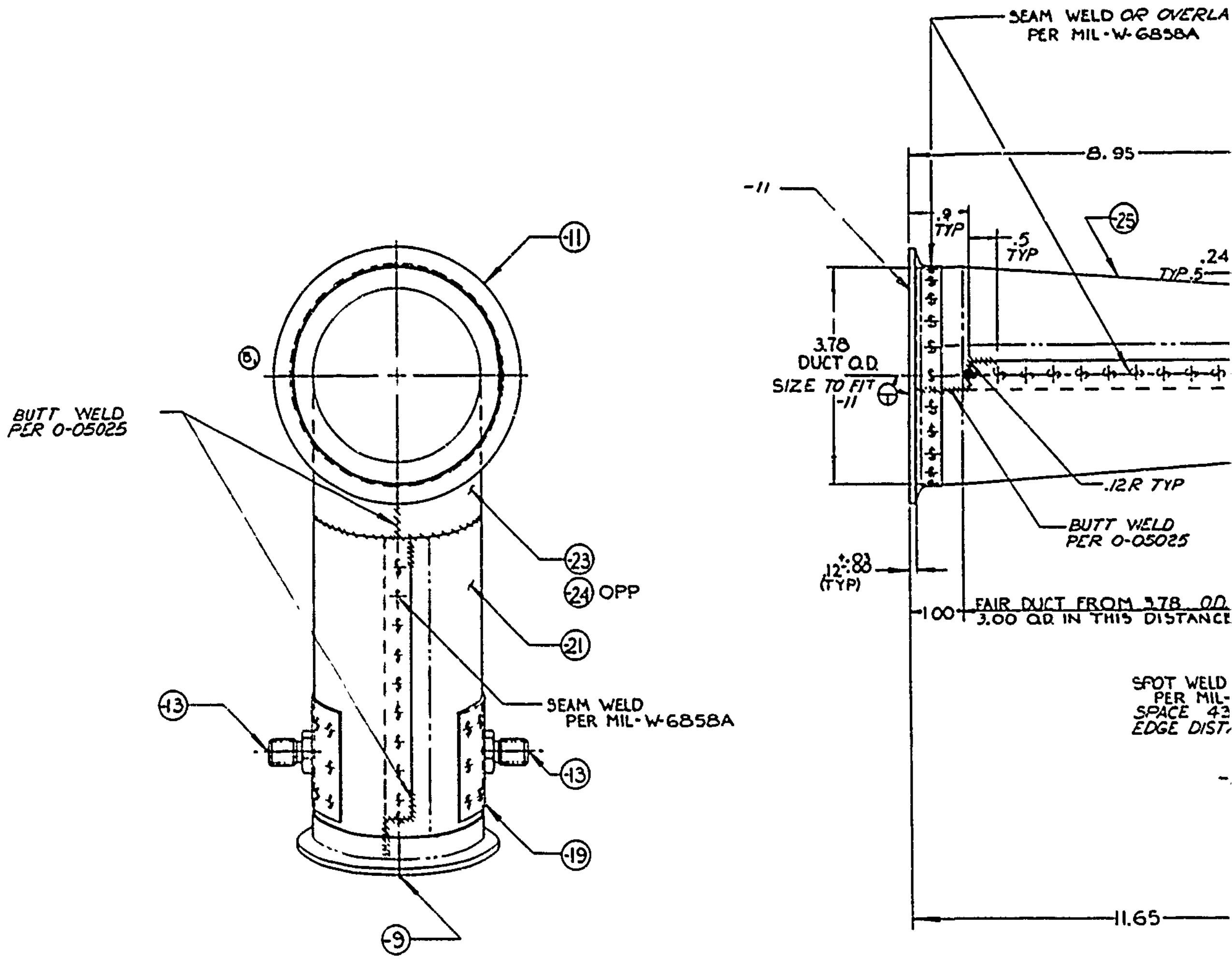
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

J 29-01005

SCALE ½ NOTED

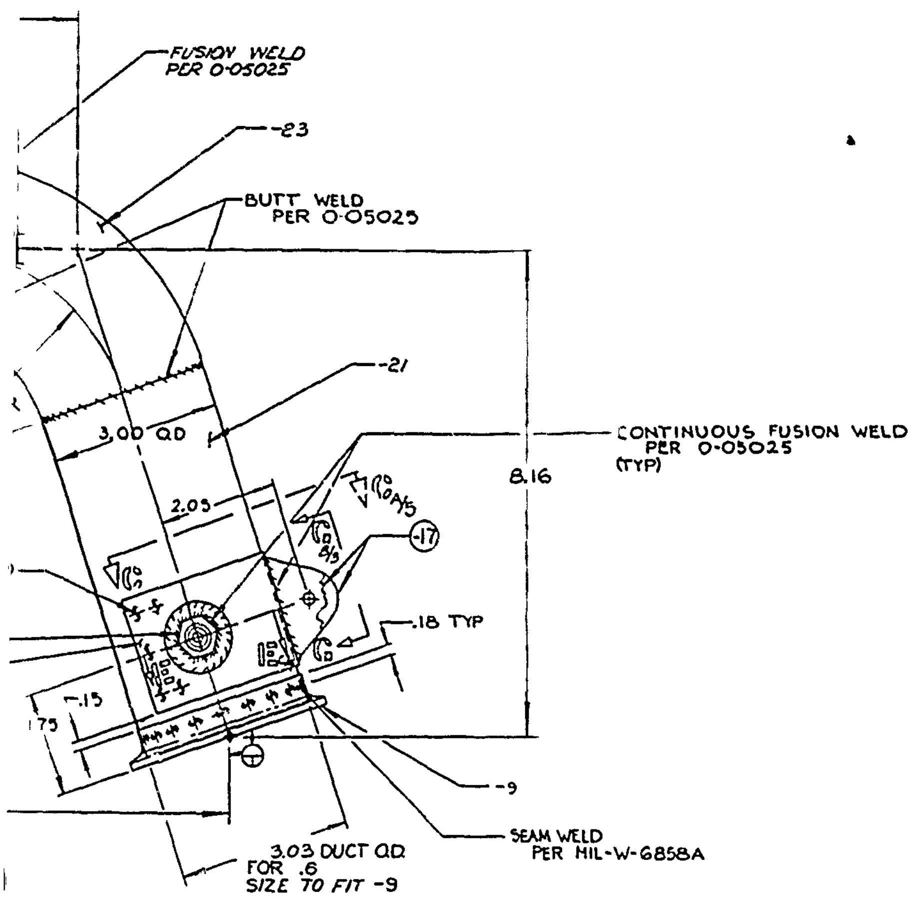
APPLICATION

Figure C-2 - ENGINE-BLEED AIR DUCT; Seam Welded Assembly
Engineering Drawing 29-01005, Sheet 2 of 3


SEAM WELD OR OVERLA
PER MIL-W-6858A
8.95
-11
.9
TYP
.5
TYP
25
.24
TYP .5
3.78
DUCT O.D.
SIZE TO FIT
-11
.12R TYP
BUTT WELD
PER 0-05025
.12 +.03 -.00
(TYP)
1.00
FAIR DUCT FROM 3.78 OD
3.00 OD IN THIS DISTANCE
SPOT WELD
PER MIL-
SPACE
EDGE DIST
11.65
-11
BUTT WELD
PER 0-05025
-23
-24 OPP
-21
SEAM WELD
PER MIL-W-6858A
-13
-13
-19
-9

23 22

WELDS



Figure

23 22

22 21

REVISIONS

LTR	DESCRIPTION
B,	IN END VIEW - REMOVED PICTURE OF ONE LAP JOINT TO CORRECT PICTURE. DEP AUG (NO PHOTO MADE) SHT 1, 2, 3 COMPRISE COMPLETE "B" DWG

D

C

...OUS FUSION WELD
...-05025

29-01005 B 2

B

...A

Figure C-2 Page 155

29-01005
SHEET 2 OF B
ARTE EWO 0082

A

LIST OF MATERIAL

DUCT–ENGINE BLEED AIR, 431 TITANIUM SEAM WELDED

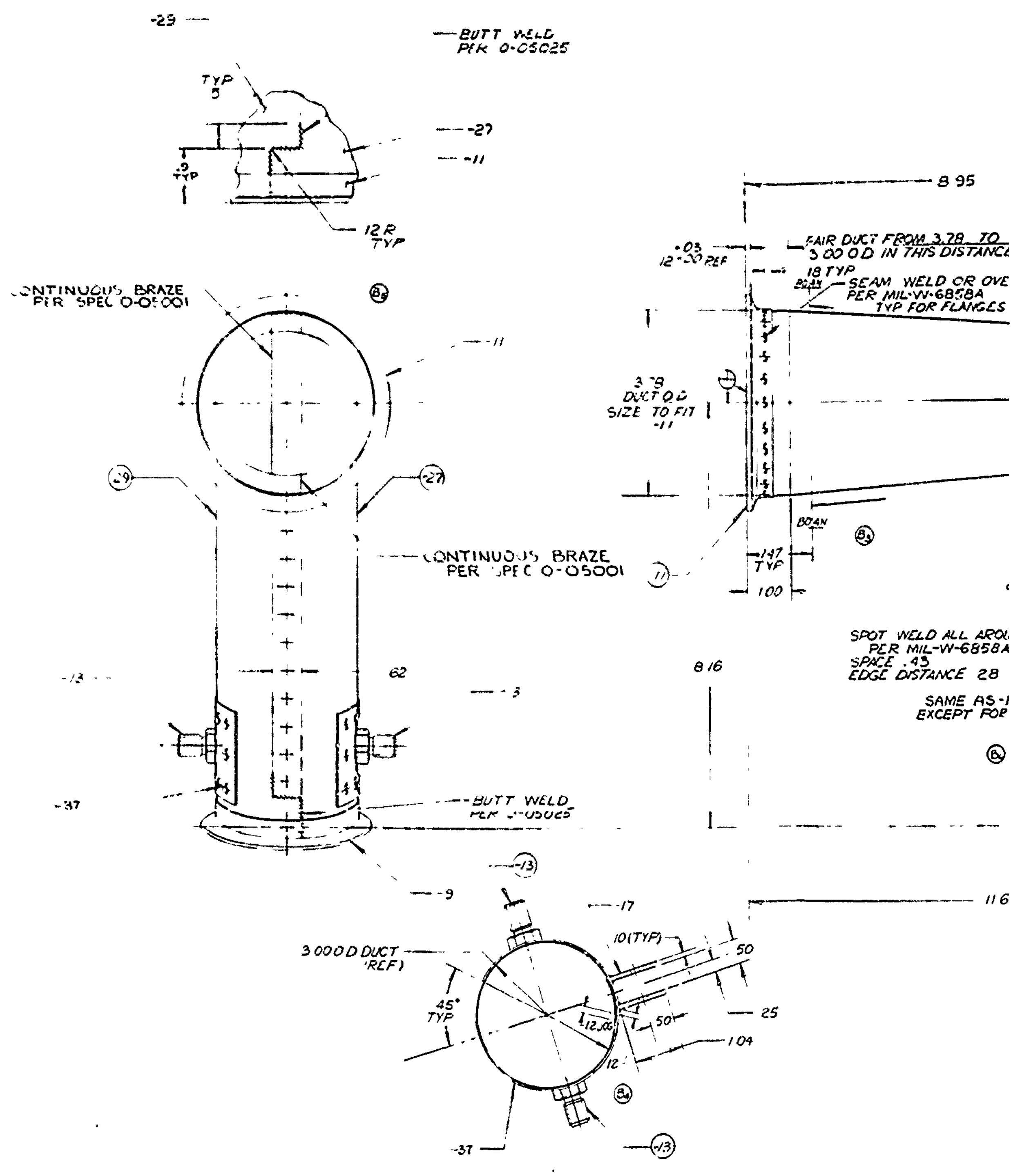
SCALE 1/1 & NOTED

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

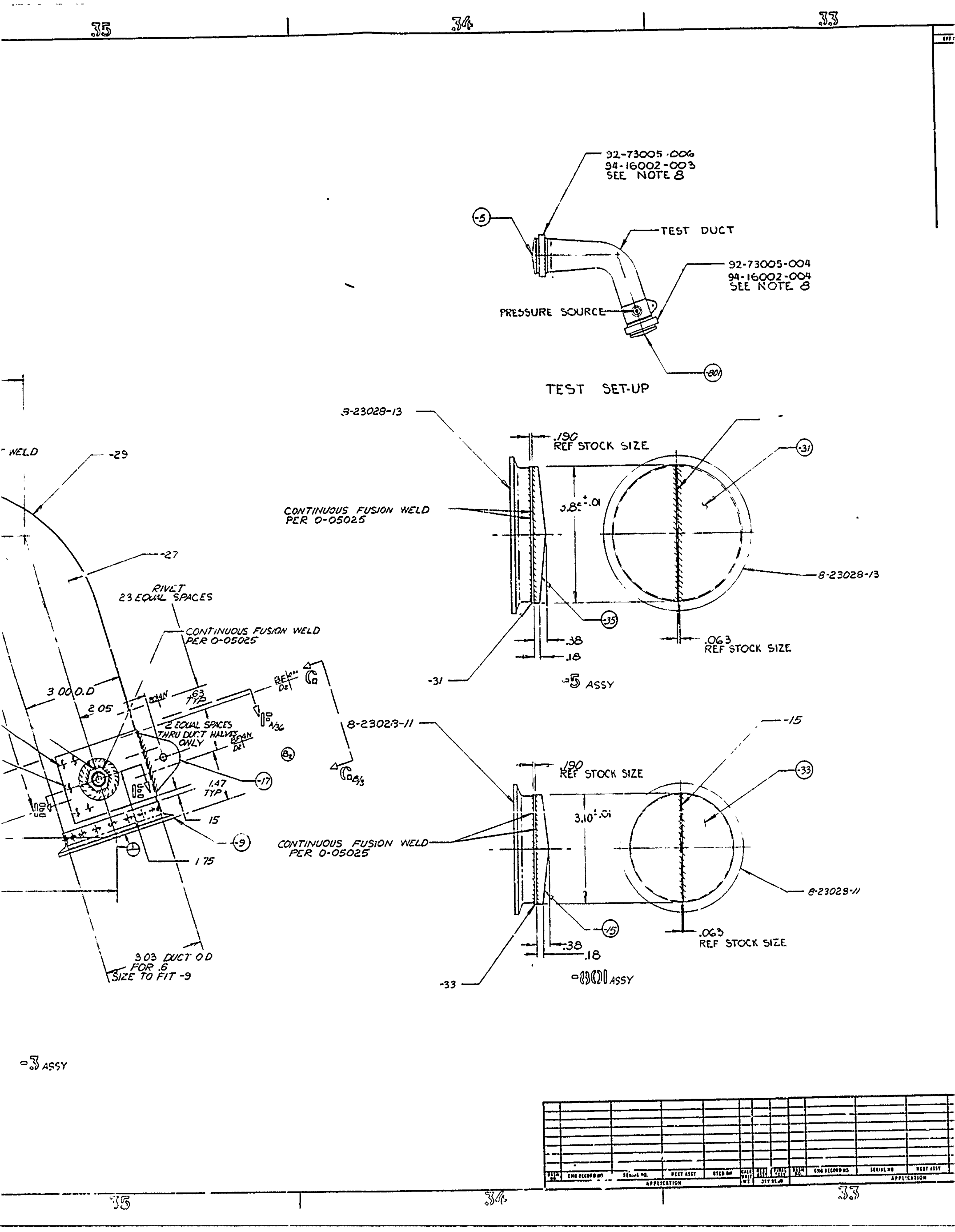
J 29-01005
SHEET 2 OF

22 21

Figure C-3 - ENGINE-BLEED AIR DUCT; Brazed Assembly
Engineering Drawing 29-01005, Sheet 3 of 3



SECTION B-B 8/35



35
34
33
92-73005-006
94-16002-003
SEE NOTE 8
-5
TEST DUCT
92-73005-004
94-16002-004
SEE NOTE 8
PRESSURE SOURCE
801
TEST SET-UP
8-23028-13
.190
REF STOCK SIZE
-31
CONTINUOUS FUSION WELD
PER 0-05025
3.85 ±.01
8-23028-13
35
.38
.18
.063
REF STOCK SIZE
-31
-5 ASSY
WELD
-29
-27
RIVET
23 EQUAL SPACES
CONTINUOUS FUSION WELD
PER 0-05025
3.00 O.D
2.05
.63
TYP
2 EQUAL SPACES
THRU DUCT HALVES
ONLY
1.47
TYP
-17
15
-9
1.75
3.03 DUCT OD
FOR .6
SIZE TO FIT -9
8-23023-11
-15
.190
REF STOCK SIZE
-33
3.10 ±.01
CONTINUOUS FUSION WELD
PER 0-05025
8-23023-11
-15
.38
.18
.063
REF STOCK SIZE
-33
-801 ASSY
-3 ASSY
APPLICATION
APPLICATION

32

31

REVISIONS

SYM	DESCRIPTION	ZONE	DATE	APPROVAL
B_2	CHG RIVET SYMBOLS "BF" WAS "HW", "BO" WAS "HX"	B 36		
B_3	CHG RIVET SYMBOLS "BO" WAS "HX"	C-36		
B_4	IN SECT F-F REVISED JOGGLE SCHEDULE SEE F/D	9 36		
B_5	IN END VIEW REVISED JOGGLE PICTURES	C-37		
B_6	REPLACED -19 WITH -37	B-35		
	SHTS 1,2,3 COMPRISE COMPLETE "B" CHG. DISP RWK-(NO PARTS MADE) KNNG			

D

C

29-01005 B 3

B

Figure C-3 Page 157

29-01005
SHEET 3 OF B
AUTH EWO 0082

A

REQUIREMENTS PER ASSEMBLY | PART NO. | DESCRIPTION | STOCK SIZE | MATERIAL | MATL SPECIFICATION | SEE FINISH SPECIFICATIONS | ZONE

LIST OF MATERIAL

DUCT-ENGINE BLEED AIR, 431 TITANIUM BRAZED

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

SIZE J DWG 29-01005
SHEET 3 OF

SCALE 1/1 & NOTED

APPLICATION

30

Convair Print 65693

Figure C-4 — ENGINE-BLEED AIR DUCT; Disassembled View of Test Specimen.

Convair Print 65695

Figure C-5 — ENGINE-BLEED AIR DUCT; View of Assembled Test Specimen.

III. 1. Test Specimens: (Cont'd)

seal at the cap. It was necessary to polish the duct flanges, on a flat surface, using coarse and then fine emery paper. The cap and duct flange were then lapped together.

2. Test Procedure:

One specimen of each type was static tested and the other was fatigue tested.

The static and fatigue tests were run at 800 F in a steel box oven. The oven had three resistance wire heating elements supported approximately 1/2 inch from the surface of the specimen, Figure C-6 (page 162). The oven was wrapped with insulation and placed in a second steel container in order to contain the specimen in the event of an explosive failure.

Thermocouples were spot welded to the surface of the specimen in three locations. Each thermocouple controlled the heating element adjacent to it. The power was controlled by, and the temperature recorded by, a three-channel Brown Controller and Recorder. The 800 F test temperature was reached in two hours and the specimen soaked at that temperature for an additional two hours prior to the start of the test.

Test pressures were obtained with bottled, dry nitrogen and controlled by means of a gas regulator and a calibrated bourdon tube pressure gage. A schematic diagram of the pressurization system is shown in Figure C-7 (page 163).

A pair of bourdon tube pressure switches, counter, and relay were wired to automatically cycle the pressure from 15 PSIG to the maximum pressure for the fatigue test. The cycle rate was maintained at 40 cycles per minute. A schematic diagram of the cycling system is shown in Figure C-8 (page 164).

Burst tests were conducted on all specimens after completion of the static and fatigue tests. The burst tests were conducted at room temperature using hydraulic oil and a motor driven pump as the pressurization sources.

Convair Print 65692

Figure C-6 – ENGINE-BLEED AIR DUCT; Specimen Installed in Oven. Note Nitrogen Inlet Coil for Preheating Gas.

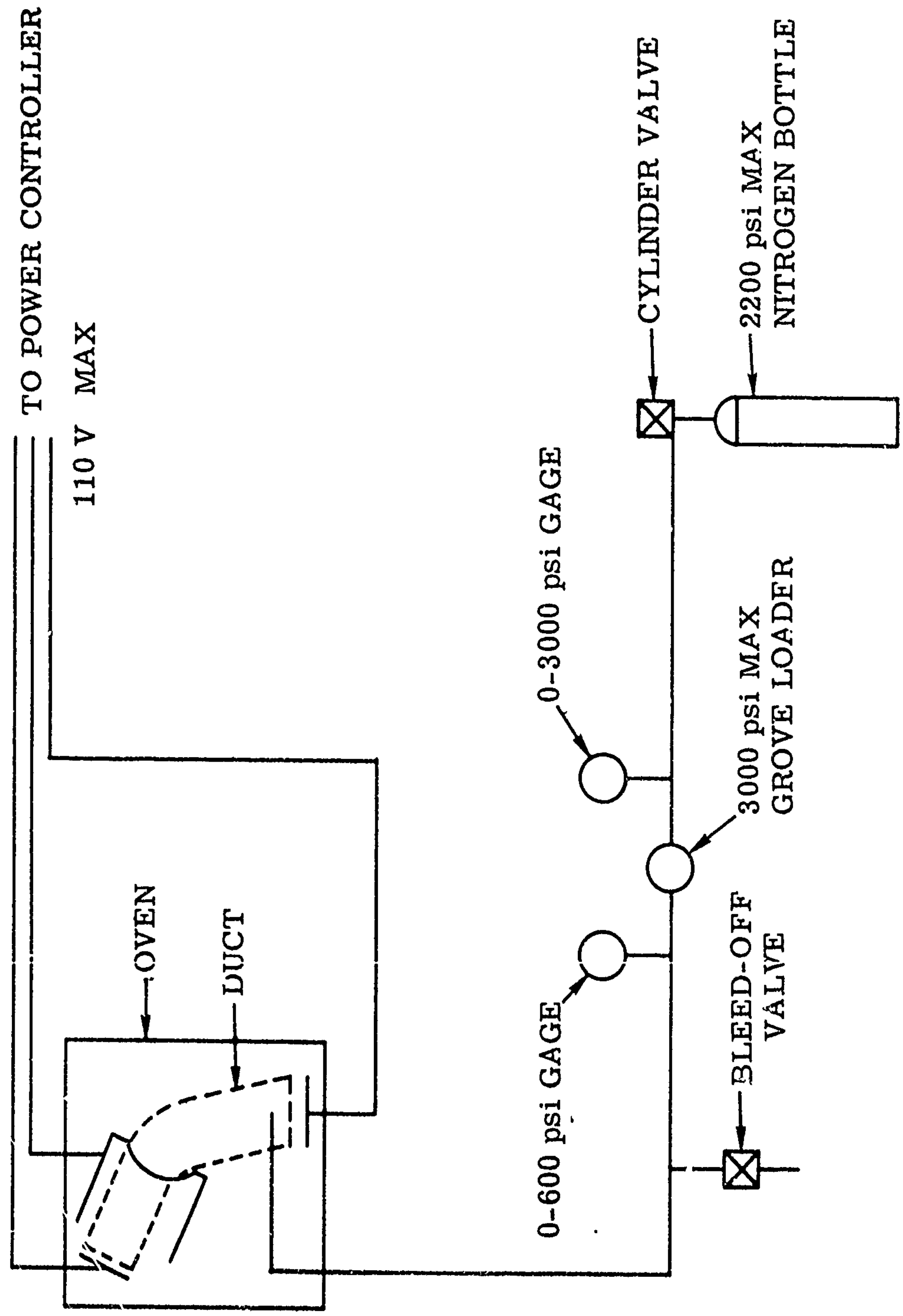


FIGURE C-7. ENGINE-BLEED AIR DUCT; Schematic Diagram Of Pressurization & Heating Systems - Static Test

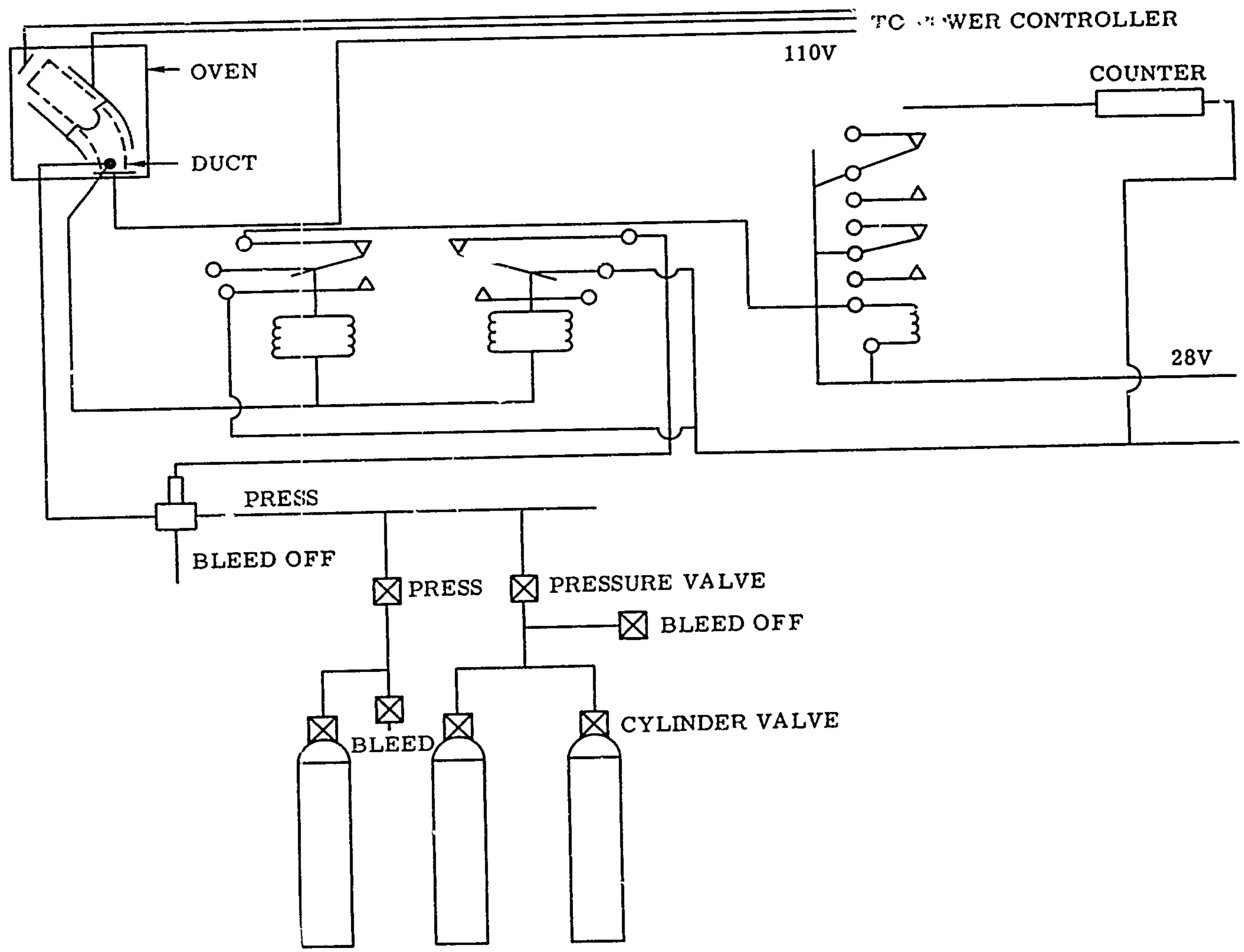


FIGURE C-8. ENGINE-BLEED AIR DUCT; Schematic Diagram Of Pressurization Cycling & Heating System - Fatigue Test

III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING (Cont'd)

3. Test Loads:

The static tests were conducted in the following order on one duct of each type:

a. 245 PSIG at 800 F for 3 minutes

b. 370 PSIG at 800 F for 3 minutes

c. 550 PSIG at 800 F for 1 minute

The fatigue tests were conducted in the following order on the other duct of each type:

a. Static Proof 245 PSIG at 800 F for 3 minutes

b. Static Proof 370 PSIG at 800 F for 3 minutes

c. 100,000 cycles 245 PSIG at 800 F

d. 120,000 cycles 310 PSIG at 800 F

e. 30,000 cycles 370 PSIG at 800 F

In the burst test, each specimen was subjected to an increasing hydraulic pressure at room temperature to duct failure. In some cases, a high flow was required at high pressure in order to compensate for end cap leakage.

4. Test Results and Discussion:

All of the bleed air ducts satisfactorily completed the test schedule specified on the specimen drawings (reference Figures C-1 through C-3). It is to be noted that the fatigue test was changed from room temperature to 800 F.

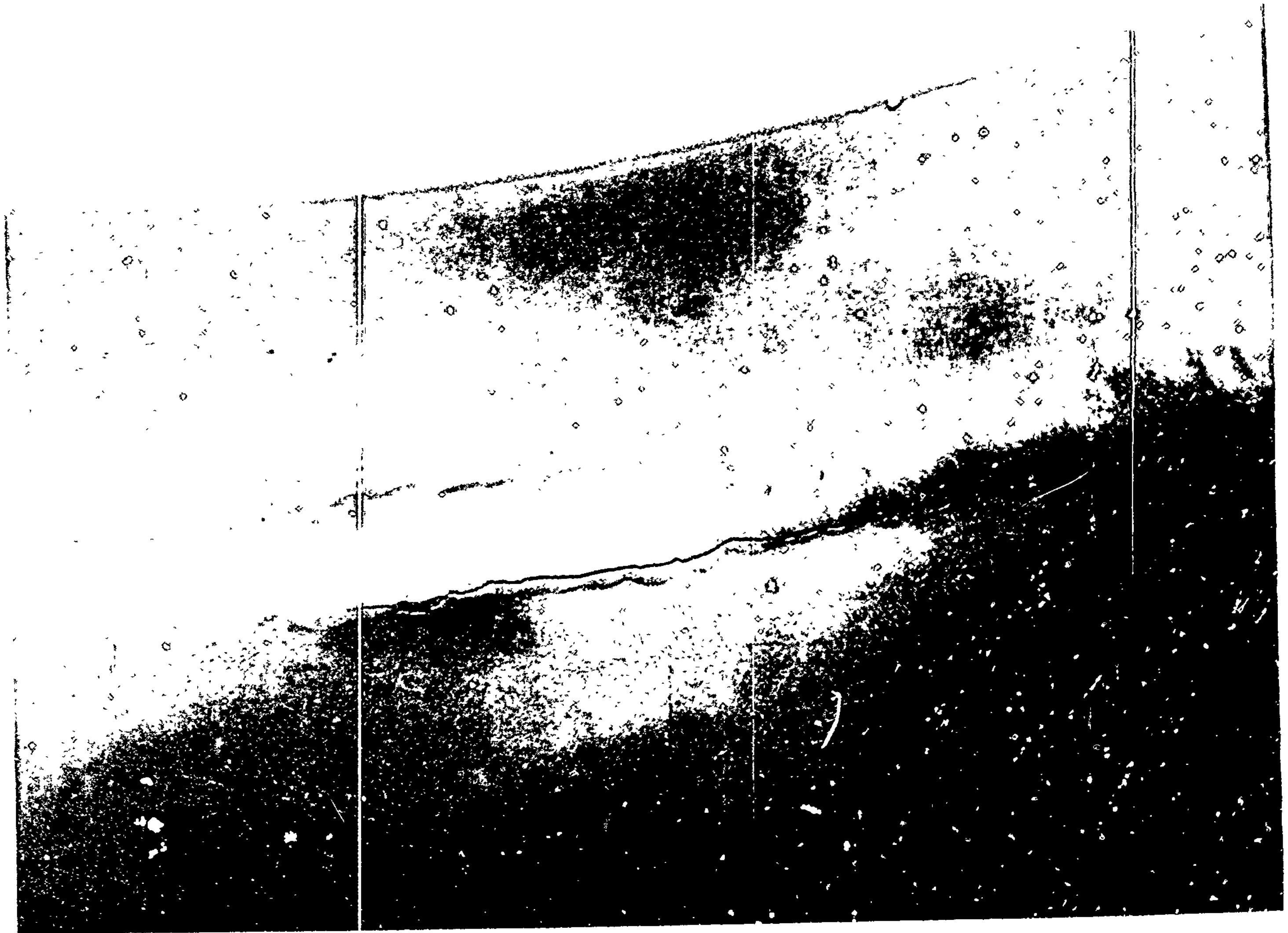
All but one specimen failed in the hydraulic burst test at room temperature. Typical burst failures occurred in the portions of the ducts that had been joined by fusion welds. The burst test results are presented in Table C-1 (page 166). Photographs of the specimen failures are shown in Figures C-9 through C-14 (pages 167 through 172).

TABLE C-1 - TITANIUM ENGINE-BLEED AIR DUCT ASSEMBLY; BURST TEST RESULTS

Duct Type	Specimen Drawing	Assembly Type Previous Test	Burst Pressure (psi)	Remarks
Basic	Figure C-1	Butt Fusion Weld Fatigue	340	3" long crack in longitudinal weld near large end. See Figure C-9.
Basic	"	" Static	200	Split on longitudinal weld. See Figure C-10
-1	Figure C-2	Seam Welded Fatigue	---	No Failure - Reached 1140 psi and cap leaks equalled hydraulic pump flow output.
-1	"	" Static	1100	See Figure C-11.
-3	Figure C-3	Riveted and Brazed Fatigue	740	Cracked but sustained 1200 psig at high flow. See Figure C-13.
-3	"	" Static	600	Repair Weld Cracked - would sustain higher pressure at high flow. See Figure C-14.

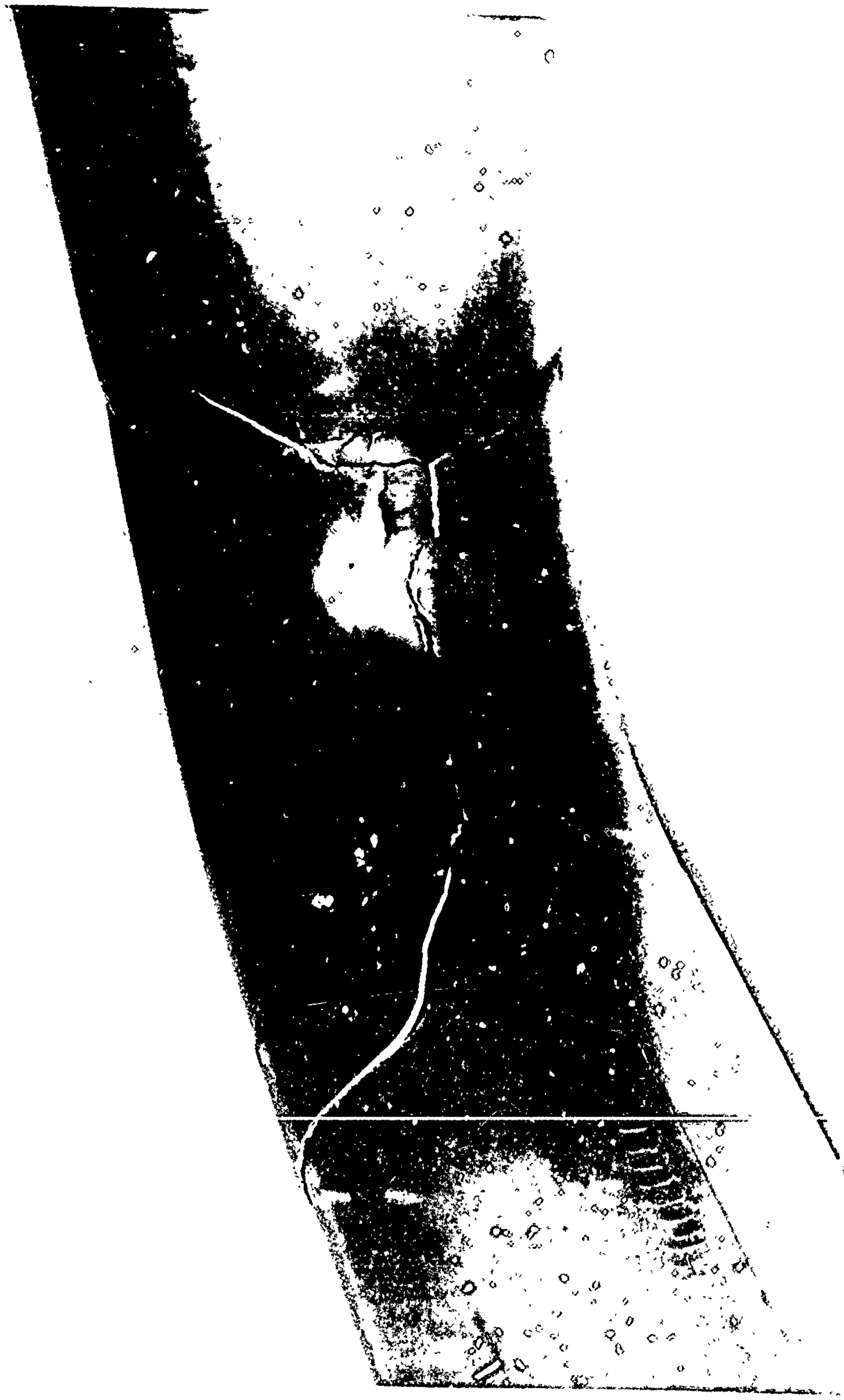
Convair Print 65698

Figure C-9 — ENGINE-BLEED AIR DUCT; Burst Test Failure of Butt, Fusion-Welded Fatigue Test Specimen.



Convair Print 65697

Figure C-10 — ENGINE-BLEED AIR DUCT; Burst Test Failure of Butt, Fusion-Welded Static Test Specimen.



Convair Print 65696

Figure C-11 — ENGINE-BLEED AIR DUCT; Burst Test Failure of Seam Welded, Static Test Specimen.

Convair Print 65694

Figure C-12 — ENGINE-BLEED AIR DUCT; Riveted and Brazed Test Specimen.

Convair Print 65697

Figure C-13 — ENGINE-BLEED AIR DUCT; Burst Test Failure of Riveted and Brazed Fatigue Test Specimen.

Convair Print 65700

Figure C-14 — ENGINE-BLEED AIR DUCT; Burst Test Failure of Riveted and Brazed Static Test Specimen.

III. 4. Test Results and Discussion: (Cont'd)

The 29-01005 basic specimens (all fusion welded - Figures C-9 and C-10) failed in the room temperature burst test at lower pressures than the same specimens sustained at 800 F. The static test specimen failed at 200 PSIG and the fatigue specimen failed at 340 PSIG. Both specimens failed in the longitudinal fusion welded seam. These apparent premature failures cannot be fully explained. It is possible that the elevated temperature permitted the stress to be more evenly distributed over the weld area, and the stress concentration points due to local discontinuities were more effective at room temperature. Secondly, it is possible that the temperature cycle caused a redistribution of the residual stresses.

The 29-01005-1 seam welded duct reached 1100 PSIG in the burst test, which is 200% of the burst value required by the drawing. The static specimen failed in the fusion welded elbow, Figure C-11. The fatigue specimen did not fail. The end cap leakage equaled the pump output flow at 1140 PSIG.

The 29-01005-3 riveted and brazed specimens both had small failures at 740 and 600 PSIG, respectively, and would sustain higher pressures at high flow. A photograph of this specimen type is shown in Figure C-12 (page 170) and enlarged photographs of the failures are shown in Figures C-13 and C-14 (pages 171 and 172).

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

C. DUCT-ENGINE BLEED AIR - STATIC, FATIGUE AND BURST TESTS

IV. SUMMARY OF RESULTS

1. All specimen types sustained the static or fatigue test schedules.

2. The seam welded specimens sustained the highest pressure in the burst tests.

3. The riveted and brazed ducts failed in excess of the required 555 PSIG burst pressure. One specimen failed in the fusion weld area.

4. The fusion welded specimens failed at a room temperature burst test pressure lower than the 800 F pressures applied in the static and/or fatigue tests.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

TABLE OF CONTENTS

LIST OF TABLES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

I. INTRODUCTION

Test panels, representative of typical shear panel applications in supersonic aircraft structures were tested. Flight conditions would be expected to impose combined shear loads and aerodynamic heating, up to 900 F.

The objectives were to conduct static and repeated load tests to:

Determine if the panels would withstand a predetermined stress level of 34,600 lbs/sq. in. at room temperature, 200 F and 100 F increments thereafter to 900 F.

Determine the change in deflection under load due to temperature variations from room temperature up to 900 F.

Determine the ultimate static failing strength of the panels at 800 F.

Obtain deflection normal to the panel surface when statically loaded at 800 F.

Determine the fatigue life of the panels at 800 F.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

II. SUMMARY

Static and repeated load tests were conducted on 23" x 23" flat and stiffened shear panels mounted in a rhomboid shear frame. Panels were tested at temperatures up to 900 F in order to determine the static strength, load-deflection characteristics, and fatigue life at elevated temperatures.

All panels withstood a predetermined shear stress of 39,200 lbs/sq. in. at temperatures up to 900 F. The panels were then statically and fatigue loaded to destruction at 800 F.

Static and fatigue failure results, along with load-deflection curves, are presented herein.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

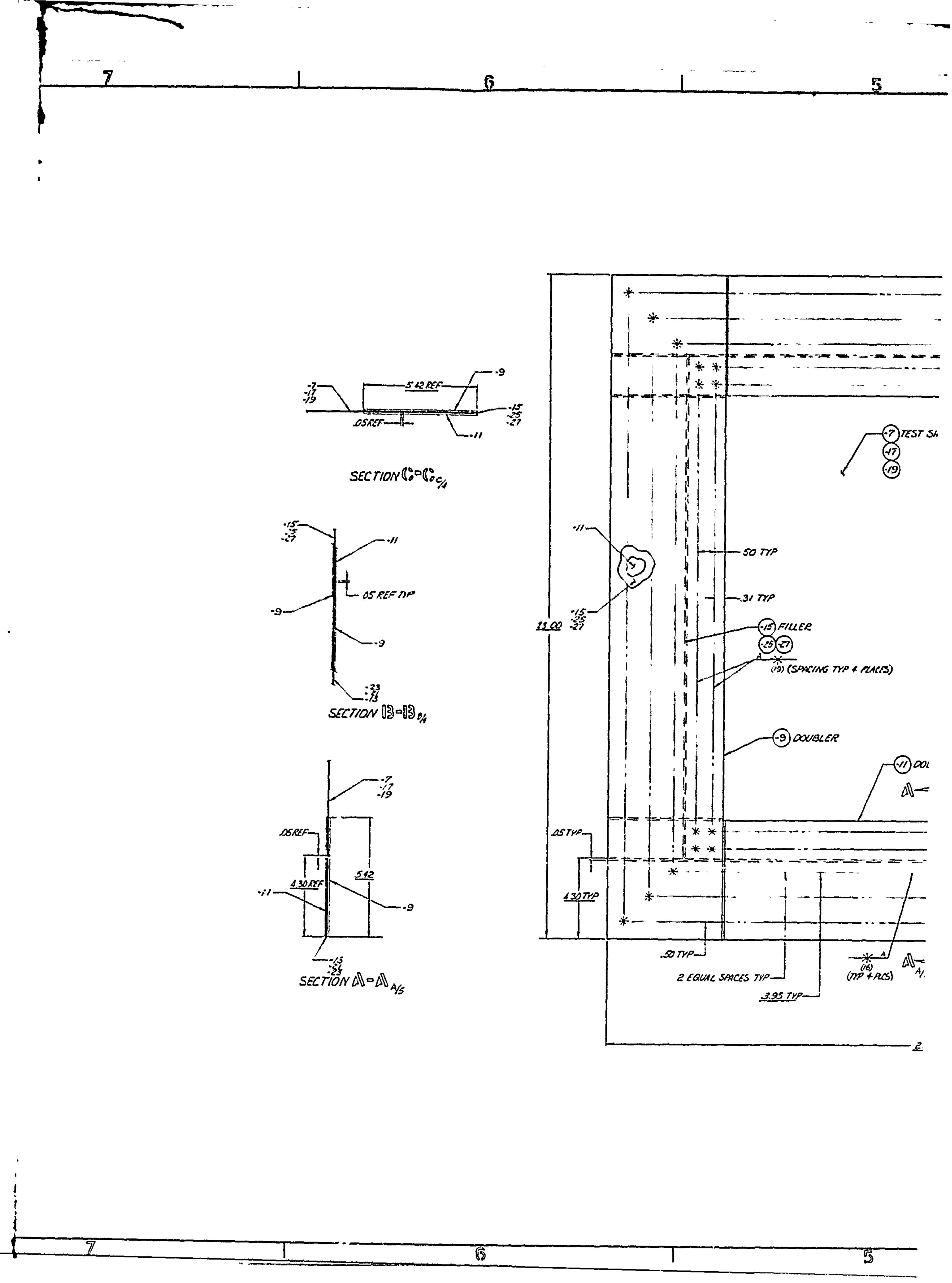
D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

III. TEST SPECIMENS

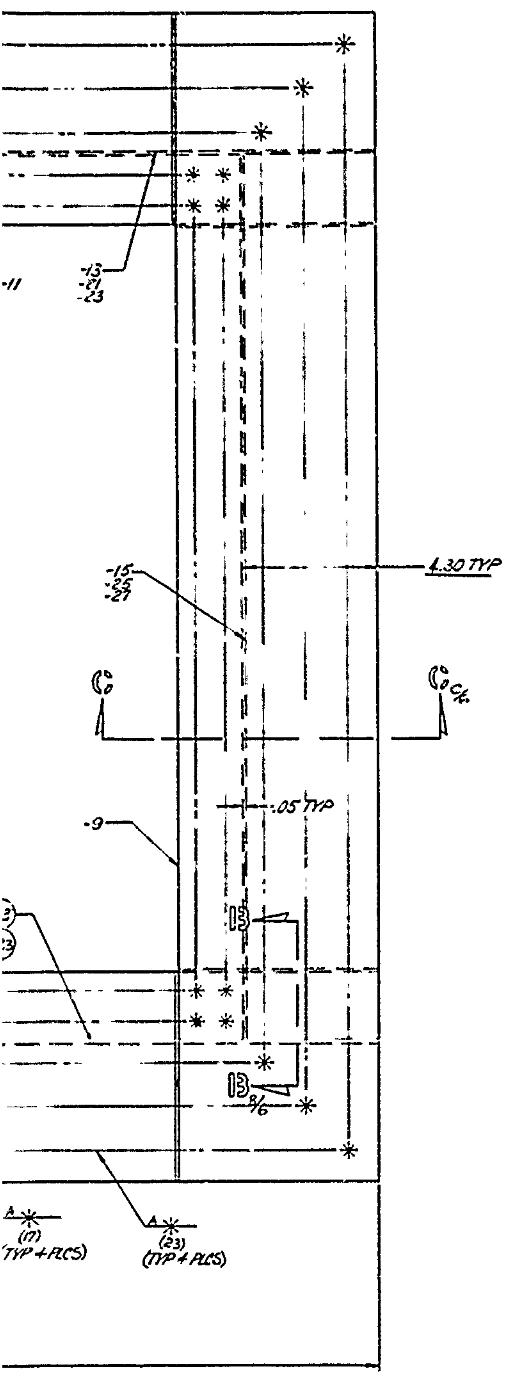
Two each of the following Ti-4Al-3Mo-1V titanium alloy shear panels were tested to destruction. One each was statically tested and one was fatigue tested.

Test Panel	29-01010-1, -3 & -5	(Figure D-1, page 183)
	29-01011	(Figure D-2, page 185)
	29-01013	(Figure D-3, page 187)
	29-01014	(Figure D-4, page 189)

Figure D-1 - SHEAR TEST PANEL - Engineering Drawing 29-01010



7
6
5
SECTION C-C C/4
5.42 REF
-9
-7
-17
-19
.05 REF
-11
-15
-25
-27
SECTION B-B B/4
-11
.05 REF TYP
-9
-9
-23
-13
SECTION A-A A/5
-7
-17
-19
.05 REF
4.30 REF
5.42
-11
-9
-15
-25
-7 TEST SH
-17
-19
-11
-15
-25
-27
11.00
.50 TYP
.31 TYP
-15 FILLER
-25 -27
(19) (SPACING TYP 4 PLACES)
-9 DOUBLER
-11 DOU
.05 TYP
4.30 TYP
.50 TYP
2 EQUAL SPACES TYP
3.95 TYP
(16) (TYP 4 PLCS)



1. WELD PER MIL-W-6858
NOTES:

DASH NO.	CHG RECORD NO	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO
																-5	
																-3	
																-1	

D

C

29-01010 1

B

A

Figure D-1 Page 183

29-01010
SHEET 1 of 1
AUTH 0082

-5	-3	-1	PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	HEAT TREAT INITIAL	HEAT TREAT FINAL	MATL SPECIFICATION	SEE FINISH SPECIFICATION	ZONE
2				-27	FILLER	.040 x 4.3 x 14.4	TITANIUM ALY	[illegible]	[illegible]	[illegible]		C/S
	2			-25	FILLER	.032 x 4.3 x 14.4						[illegible]
2				-23	FILLER	.040 x 4.3 x 23.0						[illegible]
	2			-21	FILLER	.032 x 4.3 x 23.0						[illegible]
1				-19	TEST SHEET	.040 x 14.4 x 14.4						[illegible]
	1			-17	TEST SHEET	.032 x 16.4 x 14.4						[illegible]
		2		-15	FILLER	.025 x 4.3 x 14.4						[illegible]
		2		-13	FILLER	.025 x 4.3 x 23.0						[illegible]
4	4	4		-11	DOUBLER	.040 x 5.5 x 12.1						[illegible]
4	4	4		-9	DOUBLER	.040 x 5.5 x 23.0						[illegible]
		1		-7	TEST SHEET	.025 x 14.4 x 14.4	TITANIUM ALY	SOL HT	SHT-A	4AL 3MO-1V		[illegible]

REQUIREMENTS PER ASSEMBLY — LIST OF MATERIAL

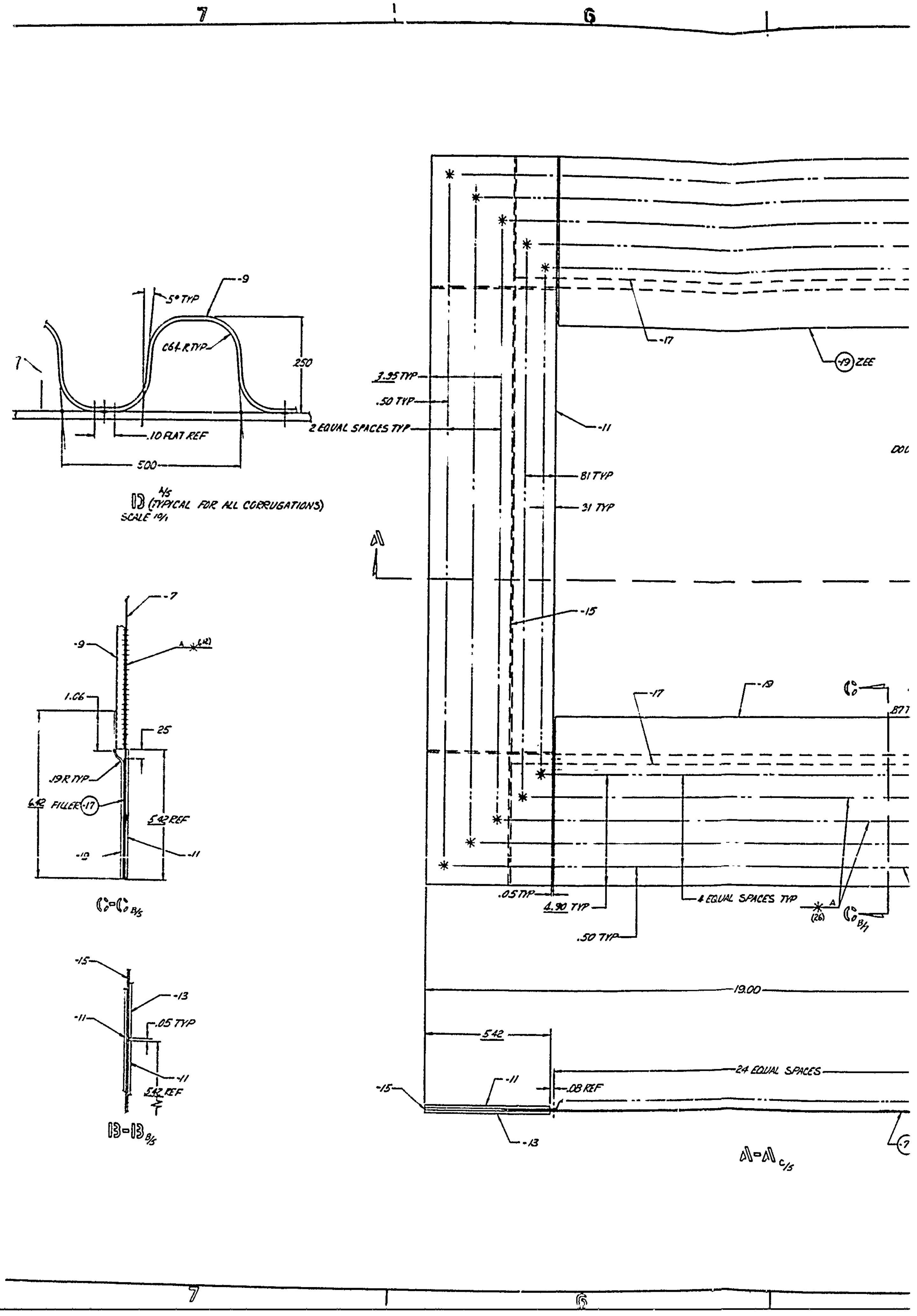
DASH NO.	NEXT ASSY	QTY
-5	TEST	1
-3	TEST	1
-1	TEST	1

TEST PANEL
SHEAR
TITANIUM ALLOY
4AL-3MO-1V

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

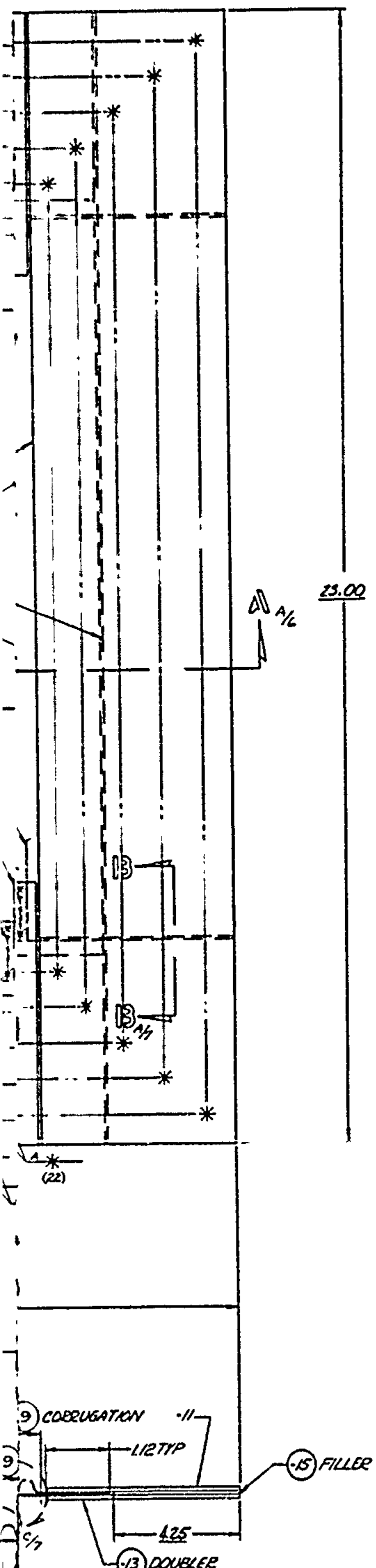
SIZE J DWG 29-01010
SCALE 1/1

Figure D-2 - CORRUGATED SHEAR TEST PANEL -
Engineering Drawing 29-01011


7
6
5° TYP
-9
.064 R TYP
.250
.10 FLAT REF
.500
B (TYPICAL FOR ALL CORRUGATIONS)
SCALE 10/1
-7
-9
1.06
25
.19 R TYP
6.42 FILLER -17
5.42 REF
-11
C-C B/5
-15
-13
-11
.05 TYP
-11
5.42 REF
B-B B/5
3.95 TYP
.50 TYP
2 EQUAL SPACES TYP
-17
-19 ZEE
-11
.81 TYP
.31 TYP
A
-15
-17
-19
.87
.05 TYP
4.90 TYP
4 EQUAL SPACES TYP
(26)
C B/7
.50 TYP
19.00
5.42
24 EQUAL SPACES
-15
-11
.08 REF
-13
A-A C/5

4 3

REVISIONS			
LTR	ZONE	ECO	DESCRIPTION



3. MAX HYDROGEN CONTENT 200 PPM AFTER ETCHING
2. -9 CORRUGATION CONFIGURATION SAME AS 29-01012-9 CORRUGATION
1. WELD PER MIL-W-6858 EXCEPT PENETRATION TO BE 10-80%

NOTES:

DASH NO.	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO.
																-7	
APPLICATION						QTY REQD		APPLICATION						QTY REQD			

4 3

REQUIREMENTS PER ASSEMBLY	PART NO.	DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MATL SPECIFICATION	FINISH SPECIFICATION	ZONE
2		-19	ZEE	040 x 6.6 x 12.1	TITANIUM ALY	SOL HT	SHT+A	4AL 3MO 1V		D/5
2		-17	FILLER	016 x 5.2 x 14.4						B/7
2		-15	FILLER	036 x 4.3 x 23.0						A/5
2		-13	DOUBLER	040 x 5.5 x 12.1						A/5
4		-11	DOUBLER	040 x 5.5 x 18.0						C/5
1		-9	CORRUGATION	016 x 12.2 x 22.1						A/5
1		-7	SKIN	020 x 14.4 x 23.0	TITANIUM ALY	SOL HT.	SHT+H	4AL -3MO -1V		A/5
-1										

LIST OF MATERIAL

Figure D-2 Page 185

29-01011
SHEET 1 OF 1
0082

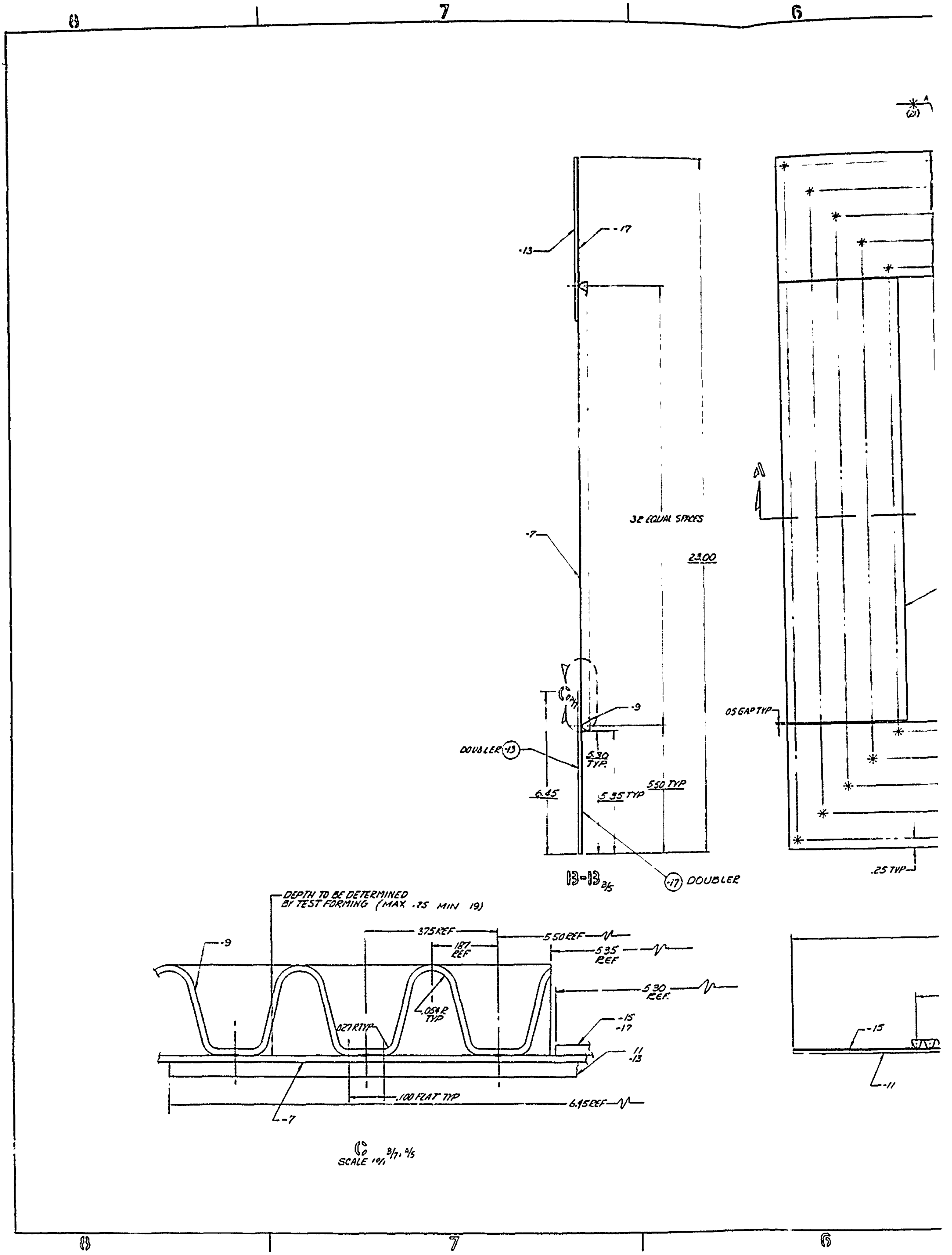
APPLICATION: NEXT ASSY TEST

TEST PANEL
CORRUGATED
SHEAR
TITANIUM ALLOY
4AL-3MO-1V

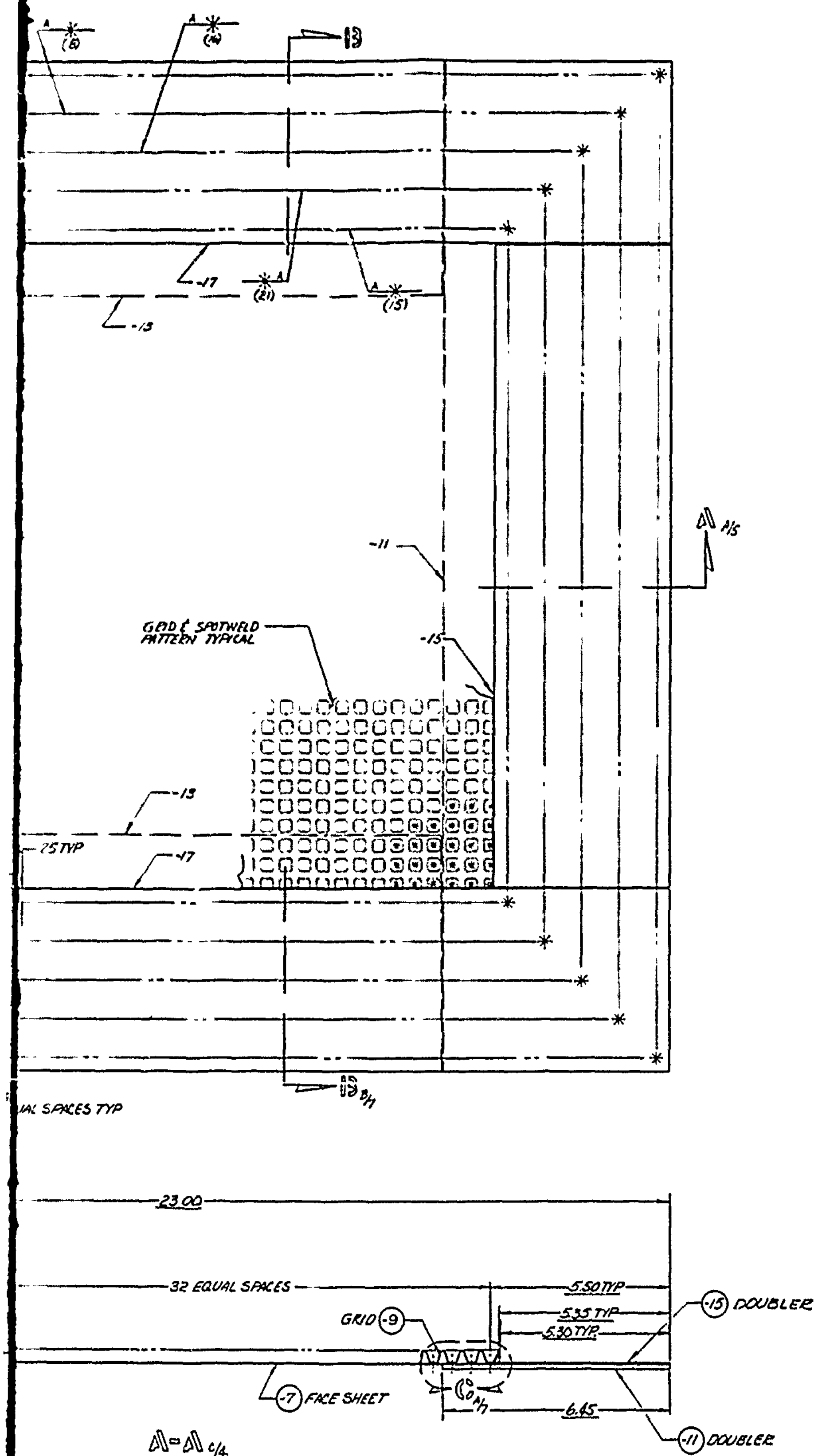
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

SIZE J
29-01011
SHEET 1 OF 1
SCALE ½ & NOTED

Figure D-3 - RIGIDIZED-GRID SHEAR TEST PANEL - Engineering Drawing 29-01013


8
7
6
-13
-17
-7
32 EQUAL SPACES
23.00
-9
05 GAP TYP
DOUBLER -13
5.30 TYP.
6.45
5.35 TYP
5.50 TYP
B-B 3/5
-17 DOUBLER
.25 TYP
DEPTH TO BE DETERMINED BY TEST FORMING (MAX .25 MIN .19)
-9
.375 REF
.187 REF
5.50 REF
5.35 REF
5.30 REF.
.054 R TYP
.027 R TYP
-15
-17
-11
-13
.100 FLAT TYP
6.45 REF
-7
-15
-11
C
SCALE 10/1 3/7, 3/5

5 | 4 | 3



2. MAX HYDROGEN CONTENT 200 PPM AFTER ETCHING
1. WELD PER MIL-W-6858
NOTES:

	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO.	SERIAL NO.
	APPLICATION				QTY REQD				APPLIC	

5 | 4 | 3

D

C

B

A

29-01013 1

Figure D-3 Page 187

29-01013
SHEET 1 OF 1
AUTH 0082

REQUIREMENTS PER ASSY	PART NO.	OPP / SHN DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL	FINAL	MATL SPECIFICATION	SEE FINISH SPECIFICATIONS	ZONE	INSP CLASS	CALC UNIT WT
2		-17	DOUBLER	.040 x 5.3 x 23.0	TITANIUM ALY	SOL HT	SHT-H	4AL-3MO-1V		4/6		
2		-15	DOUBLER	.040 x 5.3 x 11.4		"	"			8/7		
2		-13	DOUBLER	.063 x 6.5 x 10.1	TITANIUM ALY	SOL HT	SHT-H	4AL-3MO-1V		4/4		
2		-11	DOUBLER	.063 x 6.5 x 23.0						4/5		
1		-9	GRID	.016 x 4.3 x 13.4						4/5		
1		-7	FACE SHEET	.020 x 23.0 x 23.0	TITANIUM ALY	SOL HT	SHT-H	4AL-3MO-1V				
-1												

COND OR HT TR (ESN) SEE MFG STDS BLOCK

LIST OF MATERIAL

TEST

APPLICATION

RIVET CODE PER NAS 523

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED

DIMENSIONS IN INCHES

SHEAR PANEL, RIGIDIZED GRID-TITANIUM ALLOY 4AL-3MO-1V

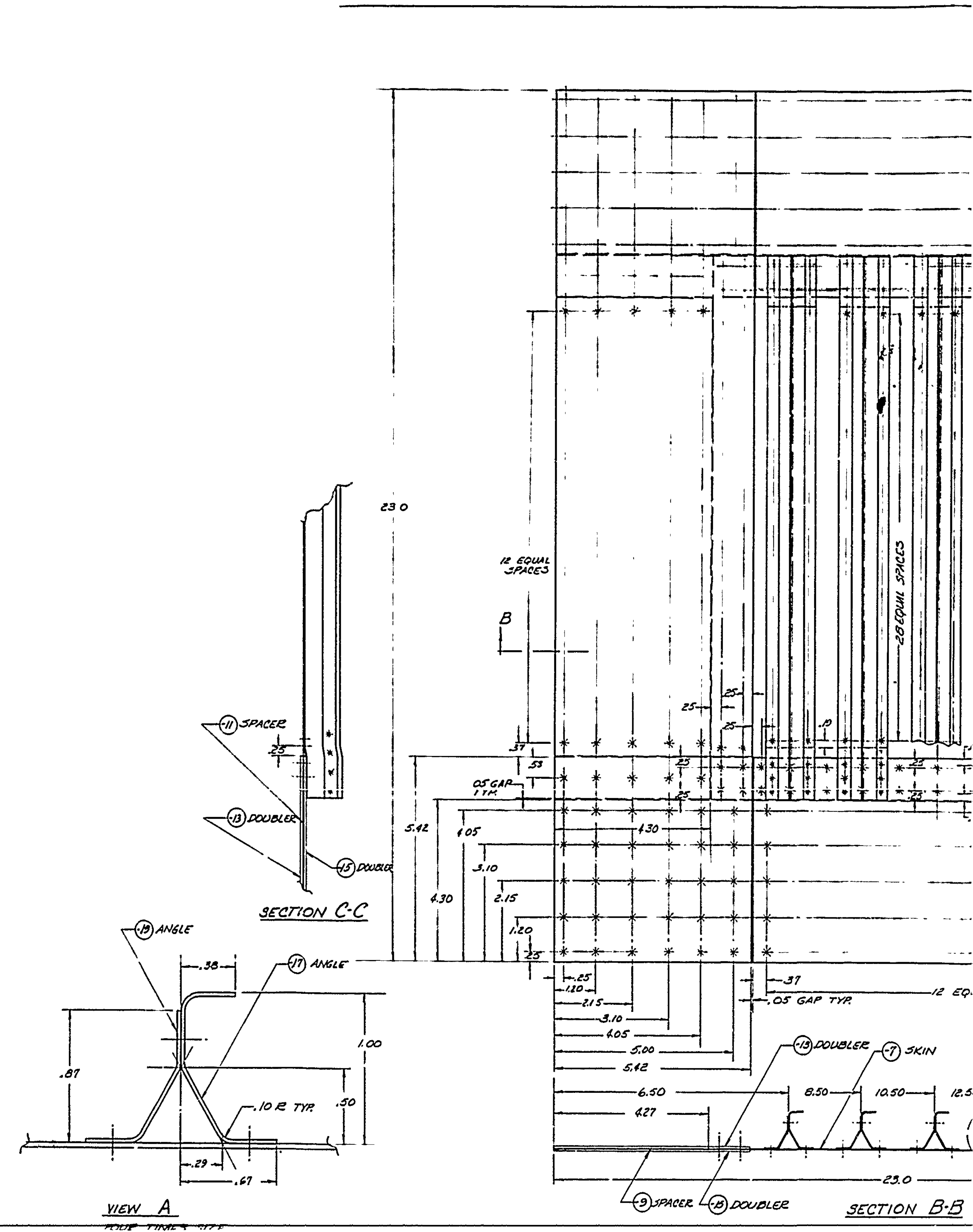
SCALE 1/1 & NOTED

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

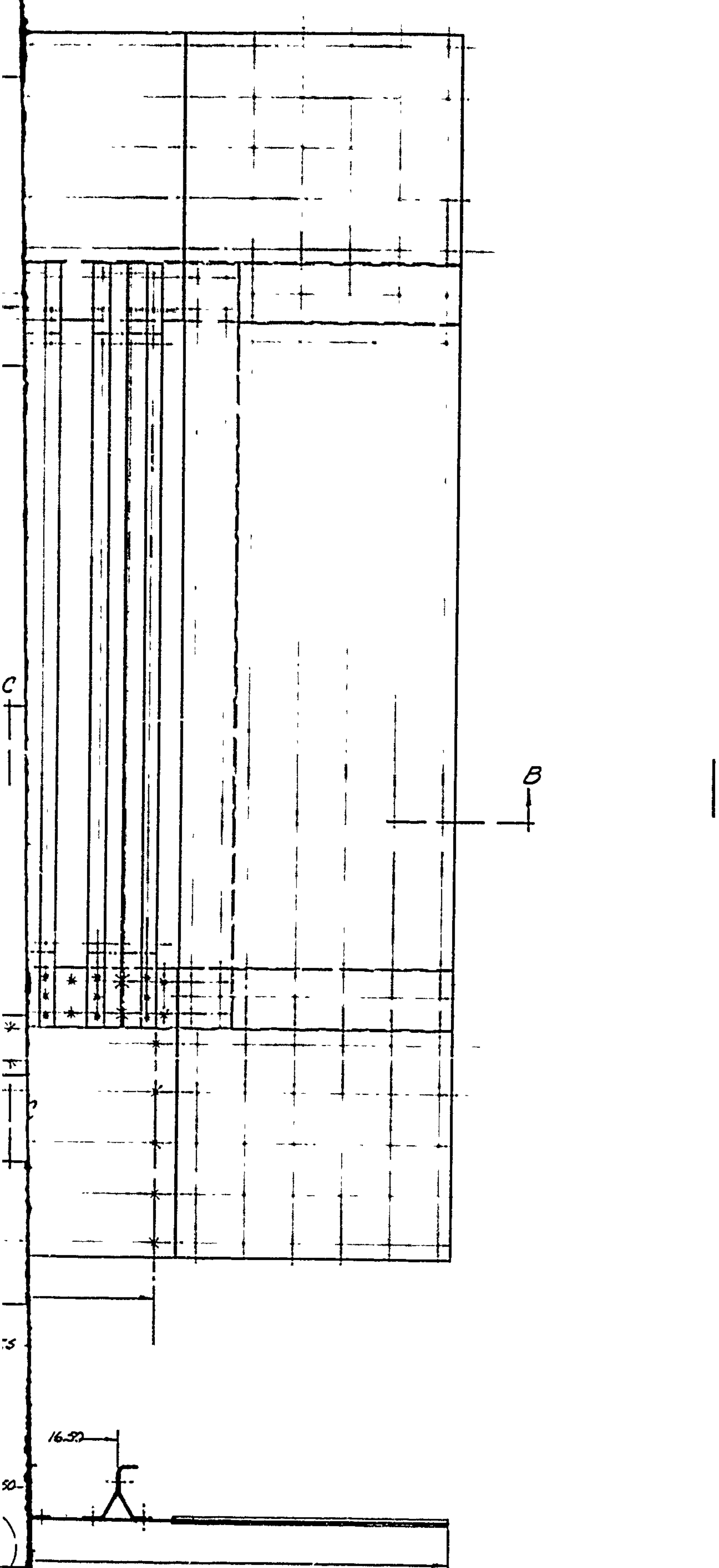
DWG SIZE J 29-01013
SHEET 1 OF 1

FORM 6-904

Figure D-4 - SHEAR TEST PANEL - Engineering Drawing 29-01014



23.0
12 EQUAL SPACES
B
28 EQUAL SPACES
(-11) SPACER
(-13) DOUBLER
(-15) DOUBLER
SECTION C-C
.05 GAP TYP
5.42
4.05
3.10
2.15
1.20
4.30
.37
.53
.25
.19
(-19) ANGLE
(-17) ANGLE
.38
1.00
.87
.50
.10 R TYP.
.29
.67
VIEW A
.05 GAP TYP.
12 EQ
5.00
6.50
4.27
8.50
10.50
(-13) DOUBLER
(-7) SKIN
(-9) SPACER
(-15) DOUBLER
SECTION B-B



3. HYDROGEN CONTENT NOT TO EXCEED 200
PPM AFTER ETCHING
2. SPOTWELD PER MIL-W-6858
1. SPOTWELD PATTERNS SHOWN ARE TYPICAL
SYMETRICALLY AROUND ASSEMBLY
NOTE:

DASH NO.	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT NO.	NEXT ASSY	FINAL ASSY	DASH NO.	CHG RECORD NO.	SERIAL NO.	NEXT ASSY
APPLICATION								APPLICATION			

REVISIONS

SYM	DESCRIPTION	ZONE	DATE	APPROVAL

D

C

29-01014

B

Figure D-4 Page 189

29-01014
SHEET 1 OF 1
APPL ENO 0082

REQUIREMENTS PER ASSEMBLY	PART NO.	OPP / DASH NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL	FINAL	MATL SPECIFICATION	SEE FINISH SPECIFICATION(S)	ZONE	INSP CLASS	CALC UNIT WT
6		-19	ANGLE	.025×1.5×14.3	TITANIUM ALLOY	SOL HT	SHT+A	4 AL 3MO 1V				
6		-17	ANGLE	.025×2×14.3								
4		-15	DOUBLER	.040×3.5×11.1								
4		-13	DOUBLER	.040×3.5×23.0								
2		-11	SPACER	.032×6.3×23.0								
2		-9	SPACER	.032×6.3×14.3								
1		-7	SKIN	.032×14.3×14.3	TITANIUM ALLOY	SOL HT	SHT+A	4 AL 3MO 1V				
-1												

LIST OF MATERIAL

A

TEST PANEL-
SHEAR
TITANIUM ALLOY
4 AL-3MO-1V

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

DWG SIZE J 29-01014
SHEET 1 OF 1
SCALE FULL & NOTED

357

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

IV. TEST SET-UP

1. Load and Deflection:

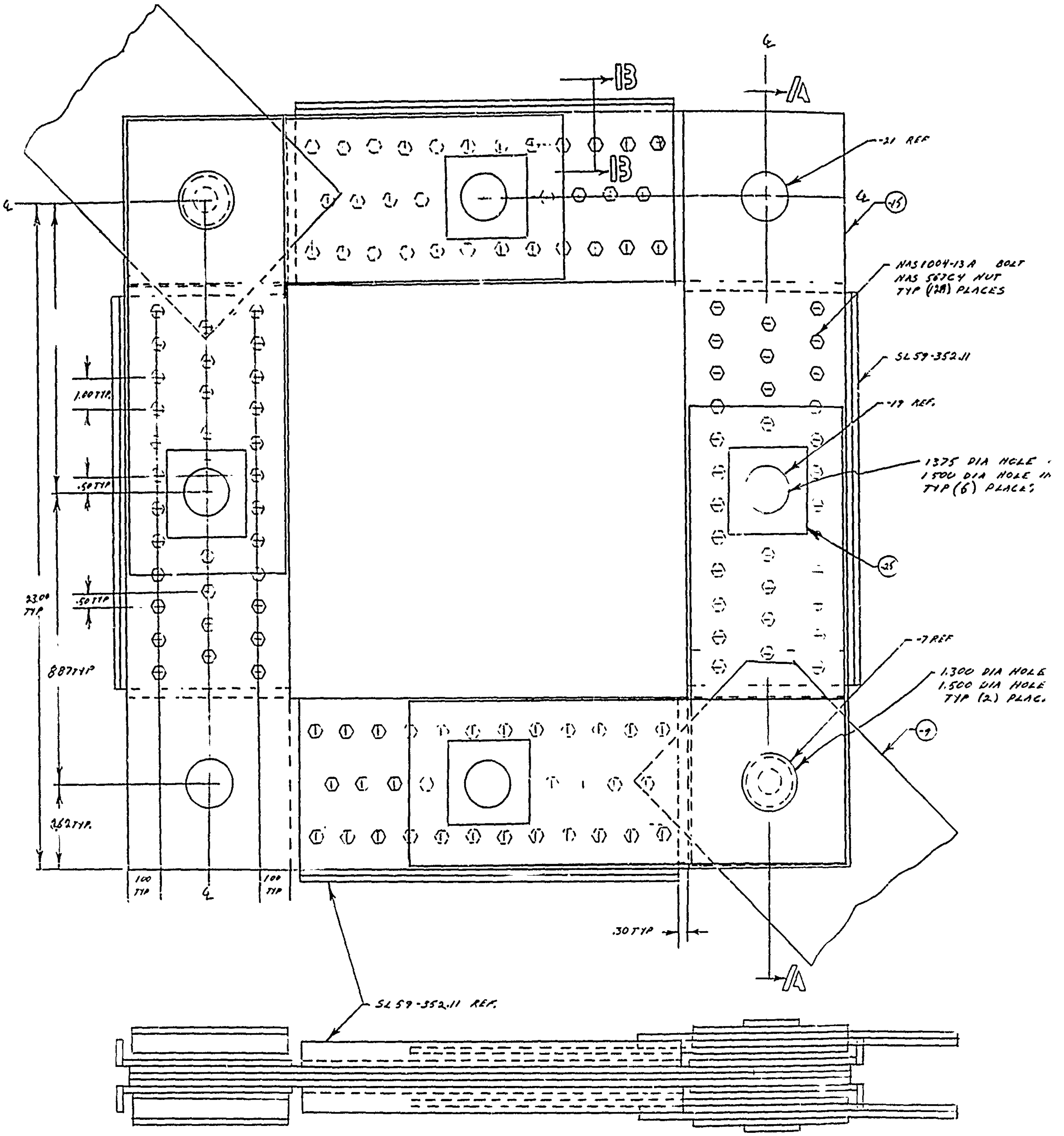
The specimens were mounted in a rhomboid shear frame as shown in Figures D-5, D-6 and D-7 (pages 193 ,195 and 196). In order to produce, as nearly as possible, pure shear in the specimen, the sides of the frame were designed to allow less than 0.003" deflection at center span. Load was applied to the shear frame by a hydraulic actuator and was monitored by a Baldwin-Lima-Hamilton SR-4 load cell. Diagonal deflection in the direction of load as well as deflection of the panel normal to the surface was measured by dial indicators. Deflection point locations are shown in Figure D-8 (page 197).

2. Heating:

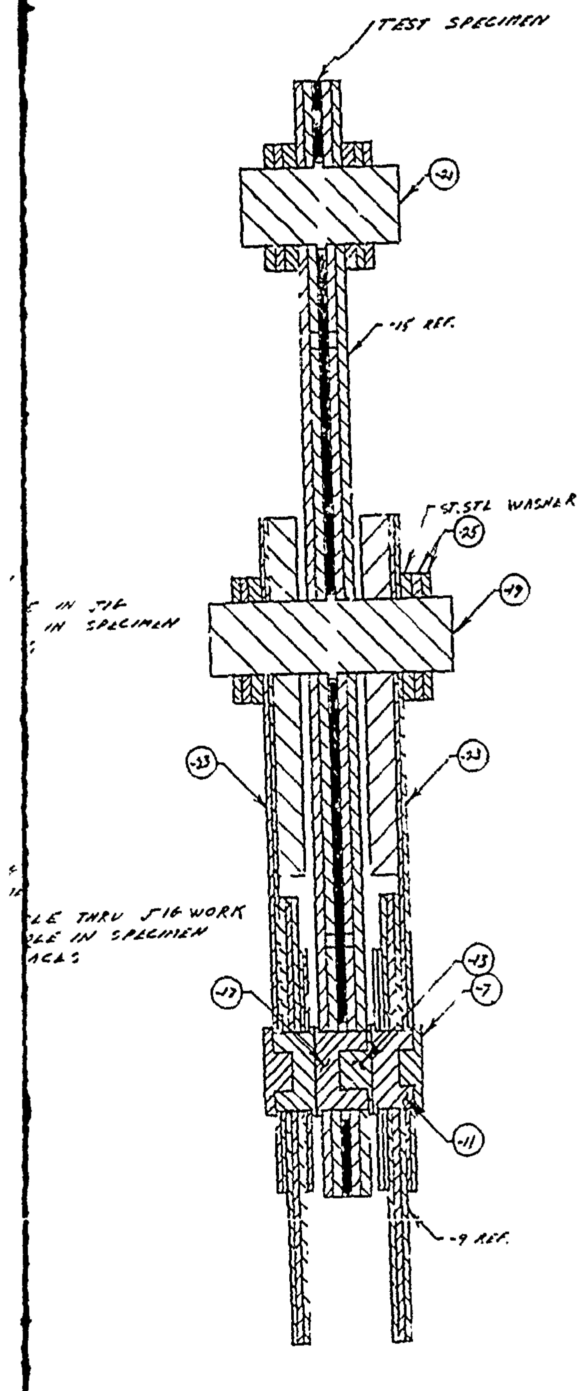
Heat was applied by tubular infrared lamps mounted at two inch centers and having a maximum heating capacity of 530 BTU/min/sq. ft. (see Figure D-9). Power to the lamps necessary to produce the correct steady-state temperature was controlled by a Research, Incorporated heat programmer utilizing thermocouple numbers 1 and 2 as control thermocouples. (See Figure D-8 for thermocouple location.)

Heat was applied to the top and bottom of the shear frame. However, the specimen was heated on the bottom unstiffened side only. The two bottom lamp banks used to heat both the panel and frame are shown in Figure D-9 (page 198). The specimen and frame were placed over the bottom lamp bank, Figure D-10 (page 199), and a lamp bank was placed over the top to heat the frame only. The specimen and jig work were completely enclosed in a stainless steel oven to minimize heat loss and edge cooling effects. Figure D-11 (page 200).

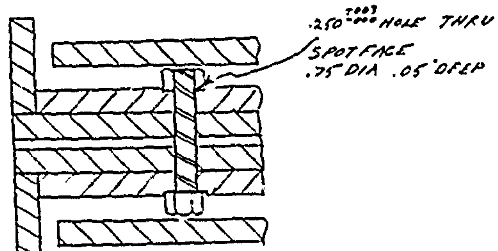
Figure D-5 - TEST FRAME FOR SHEAR TEST PANEL -
Engineering Drawing SL 59-532.7



B
A
-21 REF
-15
NAS1004-13A BOLT
NAS 567C4 NUT
TYP (128) PLACES
SL59-352.11
-19 REF.
1375 DIA HOLE
1.500 DIA HOLE
TYP (6) PLACES
-25
-7 REF
1.300 DIA HOLE
1.500 DIA HOLE
TYP (2) PLAC.
-9
1.00 TYP.
.50 TYP
23.00 TYP
.50 TYP
887 TYP
3.62 TYP.
.100 TYP
.30 TYP
SL59-352.11 REF.



SECTION A-A



SECTION B-B

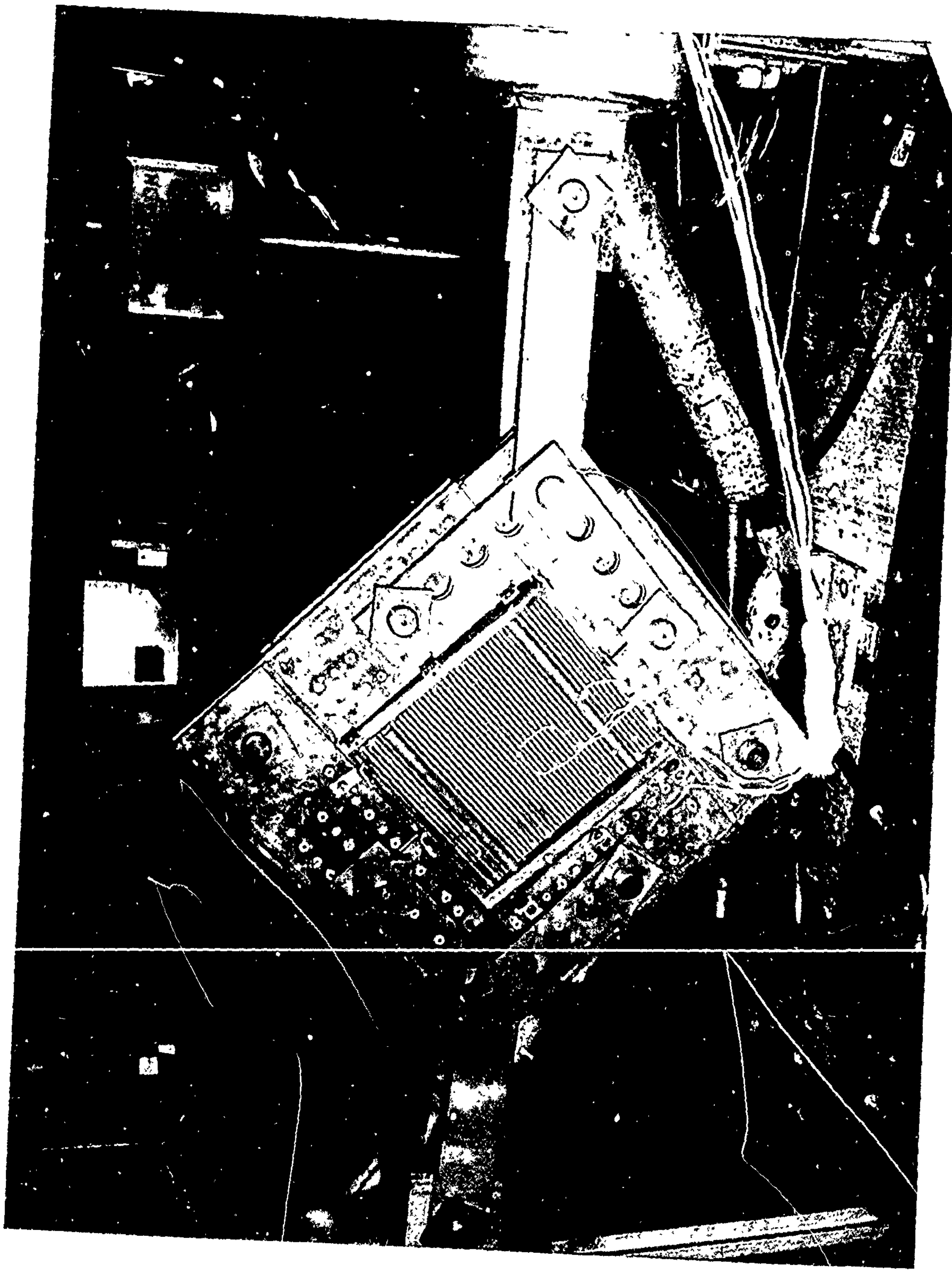
NO REQ.	PART NO	OPP DASH	SHN NO	DESCRIPTION	STOCK SIZE	MATERIAL
4			-27	SPACER	3/4 × 5.00 × 7.00	STAINLESS STL
32			25	NUT	1/4 × 40 × 4.0	HAYNES N-155 STL
128	NAS679C4			NUT - HI TEMP		A 286 STL
128	NAS1004-13A			BOLT - HI TEMP		A 286 STL
8	SL59-352.11		-	FRAME	1/4 × 6.50 × 11.90	HAYNES N-155 STL
16			-23	LOAD LINK	3/16 × 5.00 × 14.00	INCONEL X
4	SL59-352.7			LOAD LINK		
2			-21	PIN CORNER	1.50 DIA × 3.38	INCONEL X
4			-19	PIN CENTER	1.50 DIA × 6.37	INCONEL X
2			-17	PIN - FEMALE INBD	1.50 DIA × 1.22	INCONEL X
8			-15	FRAME	3/16 × 5.25 × 23.00	HAYNES N-155 STL
2			-13	PIN MALE INBD	1.50 DIA × .88	INCONEL X
4			-11	PIN - FEMALE - OUTBD	1.50 DIA × 1.44	INCONEL X
12			-9	LOAD STRAP	3/16 × 6.0 × 18.0	INCONEL
4			-7	PIN - MALE - OUTBD	1.50 DIA × 1.00	INCONEL X

SHEAR FRAME
HI-TEMP.

KEA 1/2 11/12/59 J.K.HEARY

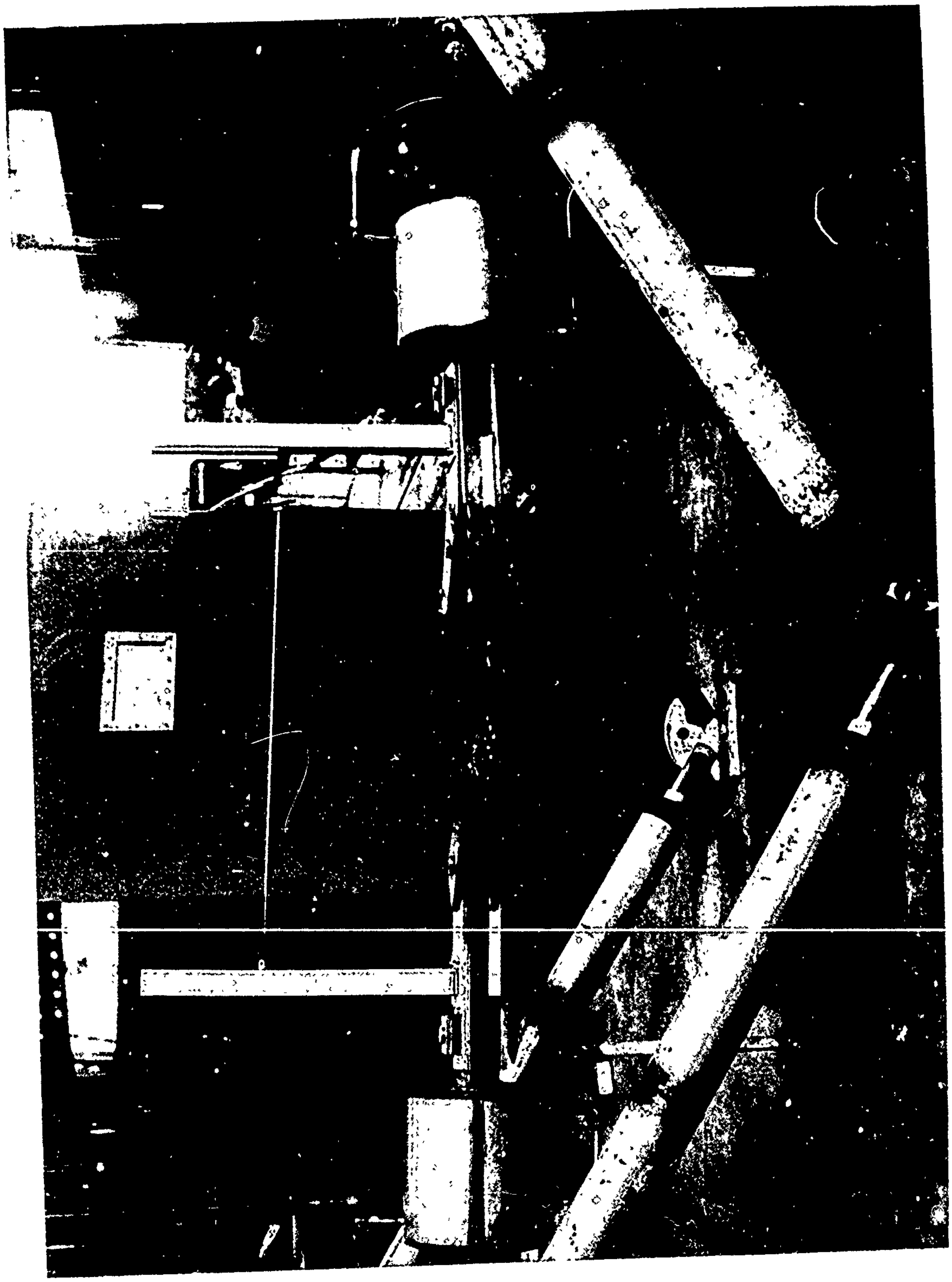
5898
6020 SL 59-532.7

Figure D-5



Convair Print 58363

Figure D-6 — SHEAR FRAME; Test Panel.



Convair Print 55342

Figure D-7— SHEAR FRAME TEST ARRANGEMENT; General View.

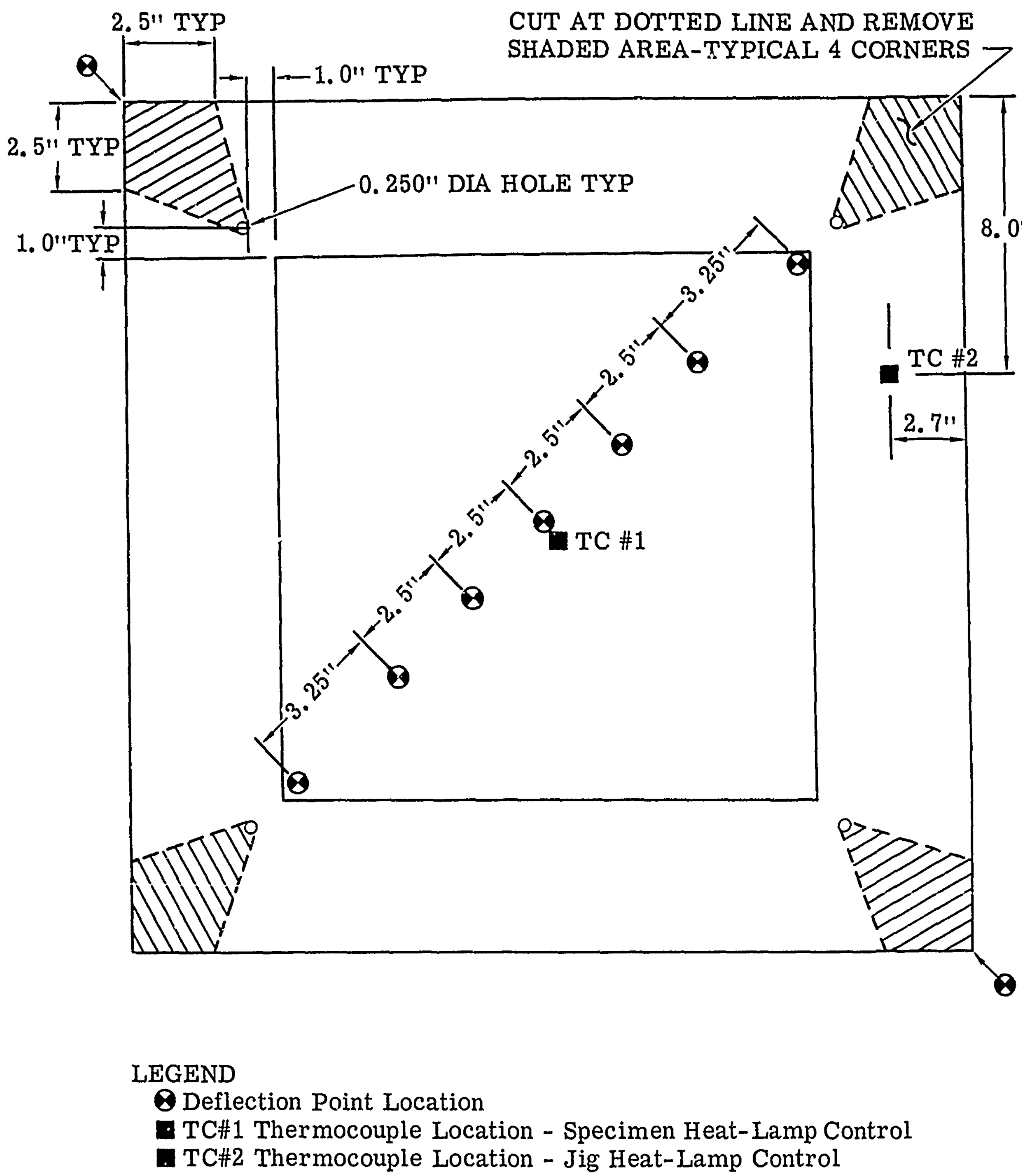
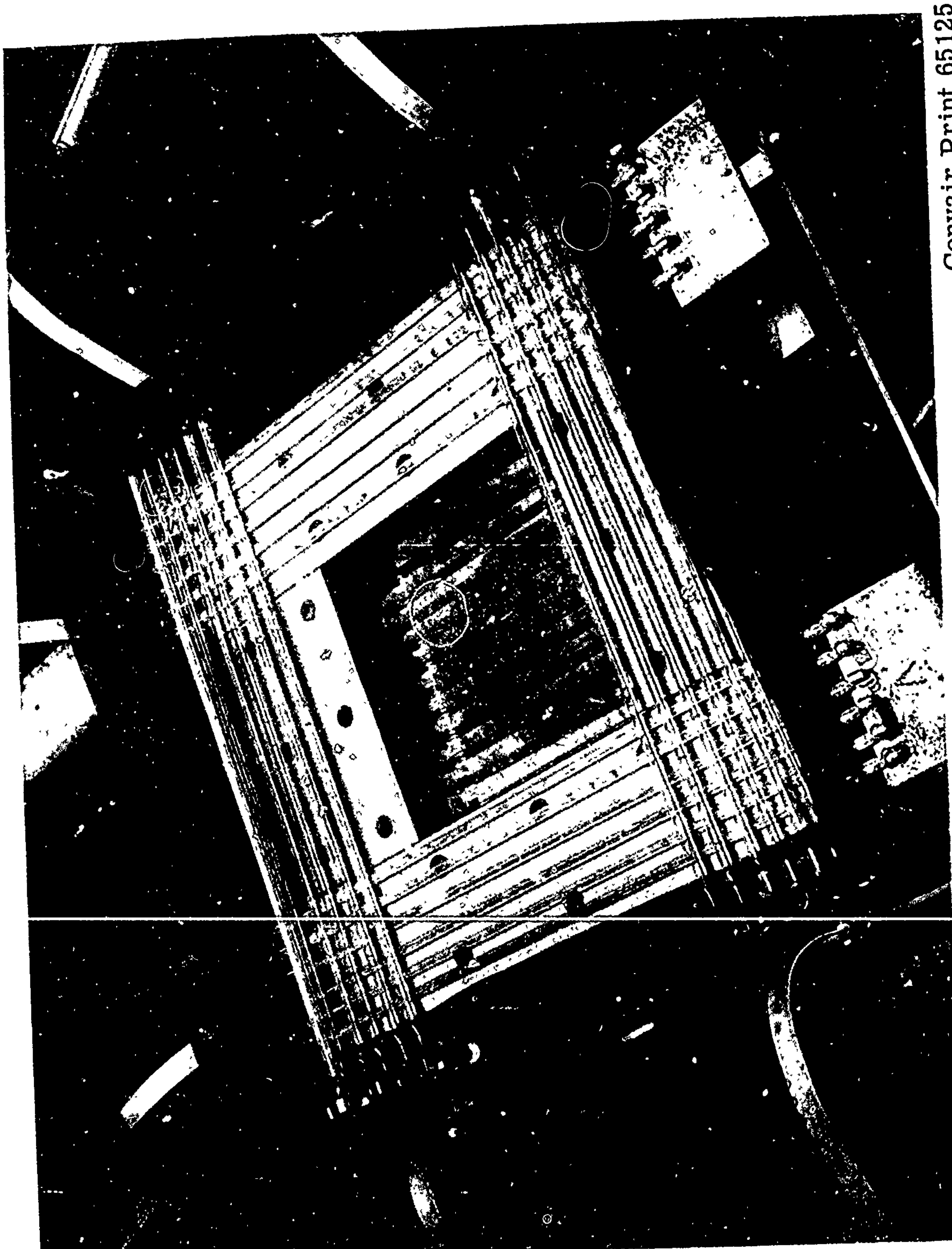
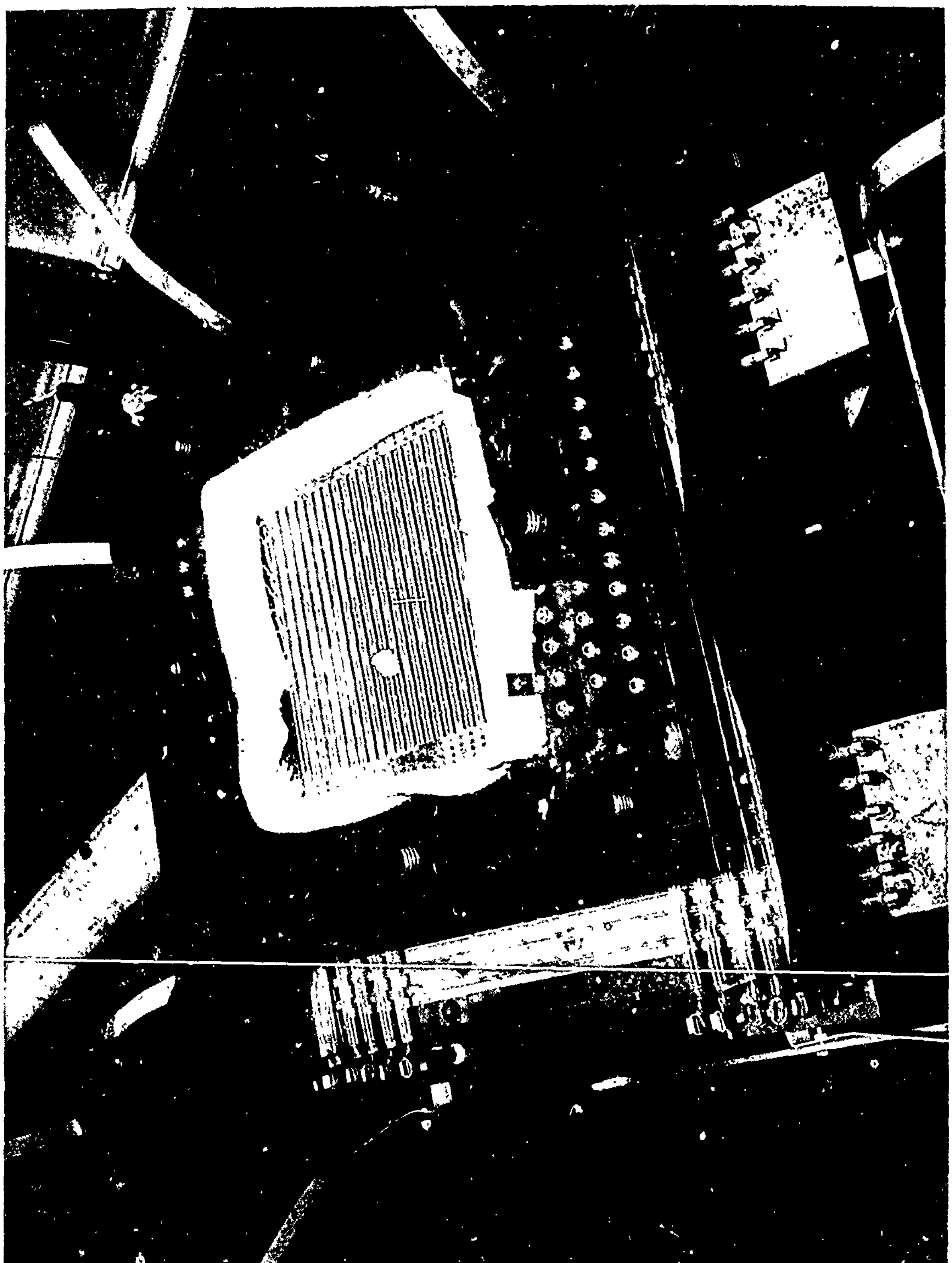


Figure D-8— DEFLECTION POINT AND THERMOCOUPLE LOCATION.



Convair Print 65125

Figure D-9 — INFRARED LAMP BANK; Bottom View.



Convair Print 62126

Figure D-10 — SPECIMEN INSTALLATION OVER LAMP BANK

Convair Print 65392

Figure D-11— INFRARED OVEN AND TEST ARRANGEMENT; For Elevated-Temperature Tests.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

V. TEST PROCEDURE

1. Static Tests:

a. Room Temperature -

Load was applied in increments until a calculated shear stress of 34,600 lbs/sq. in. was obtained. Load was reduced to a tare of 2500 pounds after each increment in order to determine permanent set. Deflections were recorded at each increment.

b. Elevated Temperature -

The specimen and jig work were heated at a rate of 18 F/min. Preliminary testing indicated that this heat rate maintained a temperature differential between specimen and jig work of less than 50 F. Load was applied at 200 F and at each 100 F increment thereafter through 900 F. At each temperature increment, load was applied and deflections recorded in the same manner as was done at room temperature.

After completion of tests at 900 F, temperature was reduced to 800 F at a rate of 18 F per minute. The specimen was then loaded in increments to failure with deflections recorded at each increment.

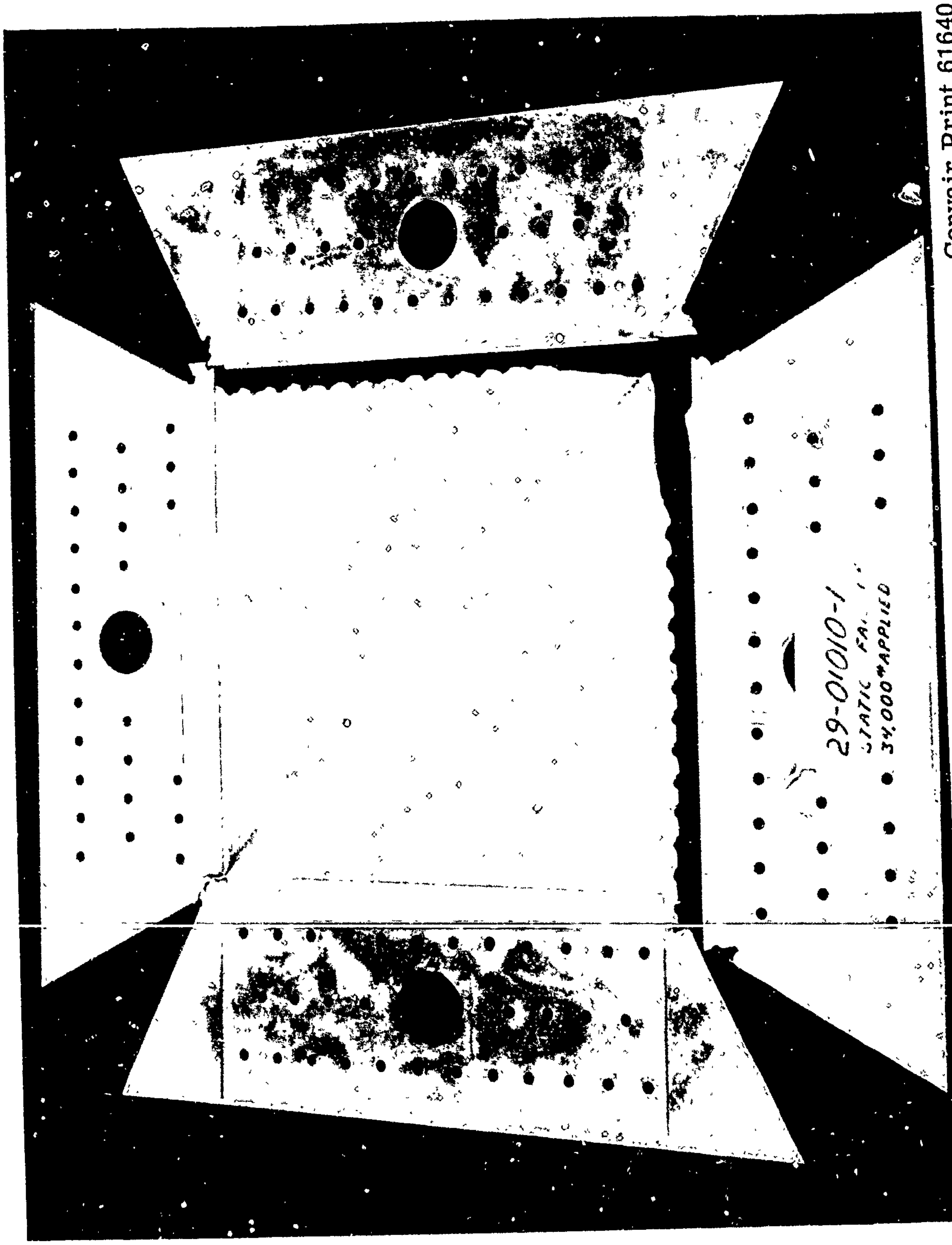
2. Fatigue Tests:

The specimen and jig work were maintained at 800 F and load was applied at an approximate rate of 30 cycles per minute.

Throughout the repeated load tests, the magnitude of load, as indicated by the SR-4 load cell, was monitored and recorded on a Sanborn oscillographic recorder. Applied loads test conditions and results are shown in Table D-1 (page 202) and Figures D-12 through D-34 (pages 203 through 225).

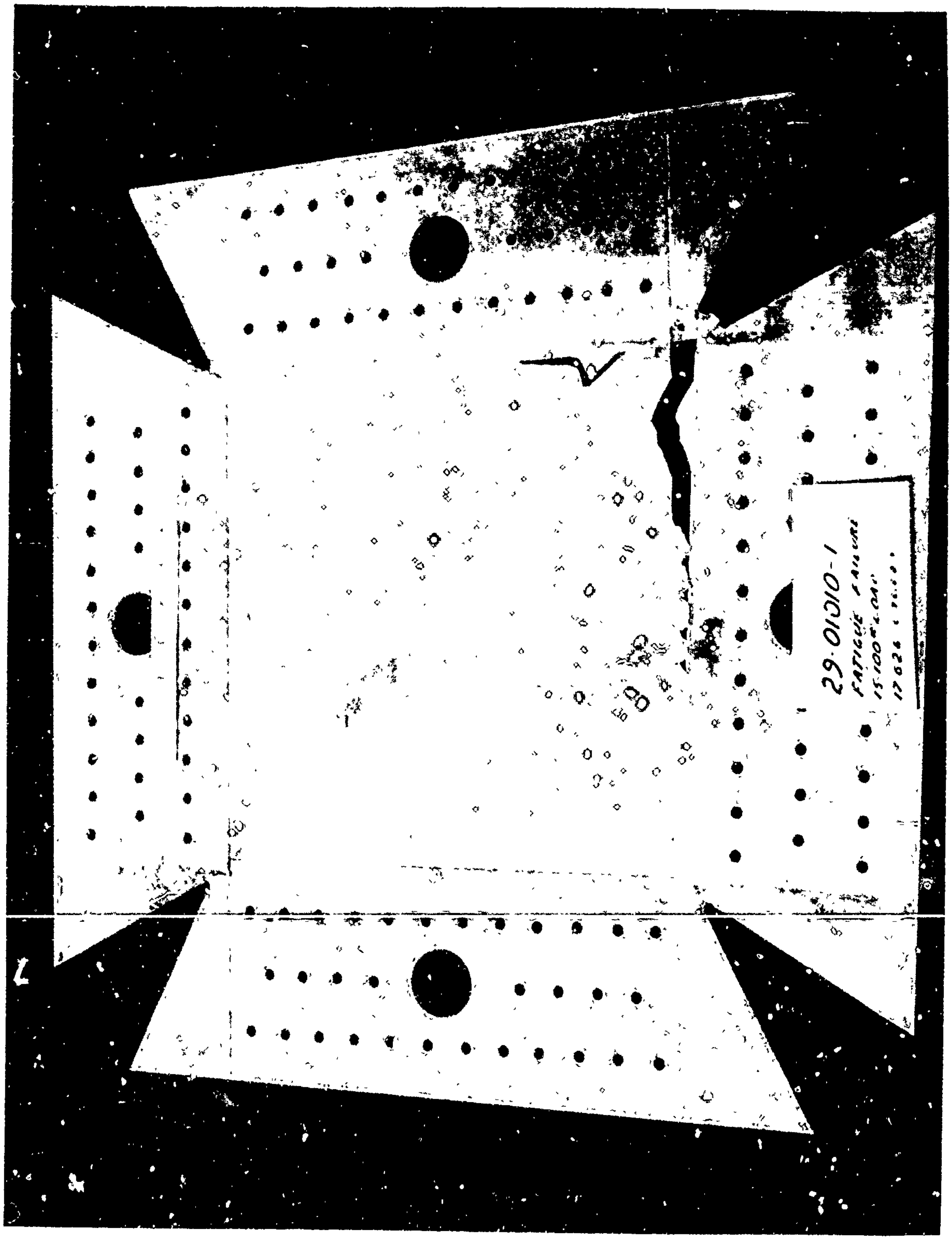
TABLE D-1-SHEAR PANELS - TEST CONDITIONS AND RESULTS

DRAWING NUMBER ①	TYPE OF TEST ②	NUMBER OF CYCLES ③	TEMPERATURE (F) ④	SKIN THICKNESS (IN) ⑤	CORRUGATION THICKNESS (IN) ⑥	EFFECTIVE THICKNESS (IN) ⑦	EFFECTIVE WIDTH (IN) ⑧	APPLIED LOAD (LBS) ⑨	SHEAR STRESS (LB/IN²) ⑩	FIGURE SHOWING DEFLECTION ⑪	FIGURE SHOWING FAILURE ⑫	PANEL WEIGHT (LBS) ⑬	REMARKS
29-01010-1	STATIC DEFLECTION		AMB - 900	.025	—	.025	14.5	0-	—	—	—	.605	
29-01010-1	STATIC TO FAILURE		800	.025	—	.025	14.5	38,000	—		12	.605	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS
29-01010-1	FATIGUE TO FAILURE	17,626	800	.025	—	.025	14.5	16,900	—		13	.605	CRACK PROPAGATED FROM CORNER RESULTING IN A SECONDARY STATIC SHEAR FAILURE
29-01010-3	STATIC DEFLECTION	—	AMB - 900	.032	—	.032	14.5	0-20,000	30,500	14		.775	
29-01010-3	STATIC TO FAILURE	—	800	.032	—	.032	14.5	50,000	—		15	.775	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS
29-01010-3	FATIGUE TO FAILURE	16,013	800	.032	—	.032	14.5	22,200	—		16	.775	CRACK PROPAGATED FROM CORNER RESULTING IN A SECONDARY STATIC SHEAR FAILURE
29-01010-5	STATIC DEFLECTION	—	AMB - 500	.040	—	.040	14.5	0-25,000	30,500	17		.968	
29-01010-5	STATIC TO FAILURE	—	800	.040	—	.040	14.5	62,000	—		18	.968	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS
29-01010-5	FATIGUE TO FAILURE	6,093	800	.040	—	.040	14.5	27,600	—		19	.968	CRACK PROPAGATED FROM CORNER RESULTING IN A SECONDARY STATIC SHEAR FAILURE
29-01011	STATIC DEFLECTION		AMB - 500	.020	.016	.025	12.0	0-15,000	35,200	20		1.760	
20-01011	STATIC TO FAILURE	—	800	.020	.016	.025	12.0	54,100	—		21 & 22	1.760	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS AT EDGE
29-01011	FATIGUE TO FAILURE	14,059	800	.020	.016	.025	12.0	24,000	—		23 & 24	1.760	SHEAR FAILURE ALONG SPOT WELDS BETWEEN CORRUGATIONS
29-01013	STAIC DEFLECTION		AMB - 700	.020	.016	.030	10.5	0-15,000	33,600	25		1.160	
29-01013	STATIC TO FAILURE	—	800	.020	.016	.030	10.5	50,700	—		26 & 27	1.160	DIAGONAL TENSION FAILURE IN SKIN & RIGID RED GRID
29-01013	FATIGUE TO FAILURE	28,756	800	.020	.016	.030	10.5	22,500	—		28 & 29	1.160	SHEAR FAILURE ALONG ROW OF SPOT WELDS AT EDGE
29-01014	STATIC DEFLECTION	—	AMB - 700	.032	—	.032	14.5	0-25,000	38,200	30		1.530	
29-01014	STATIC TO FAILURE	—	800	.032	—	.032	14.5	62,000	—		31 & 32	1.530	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS AT EDGE
29-01014	FATIGUE TO FAILURE	6,627	800	.032	—	.032	14.5	27,600	—		33 & 34	1.530	SHEAR FAILURE ALONG FIRST ROW OF SPOT WELDS AT EDGE AND BETWEEN STIFFENERS



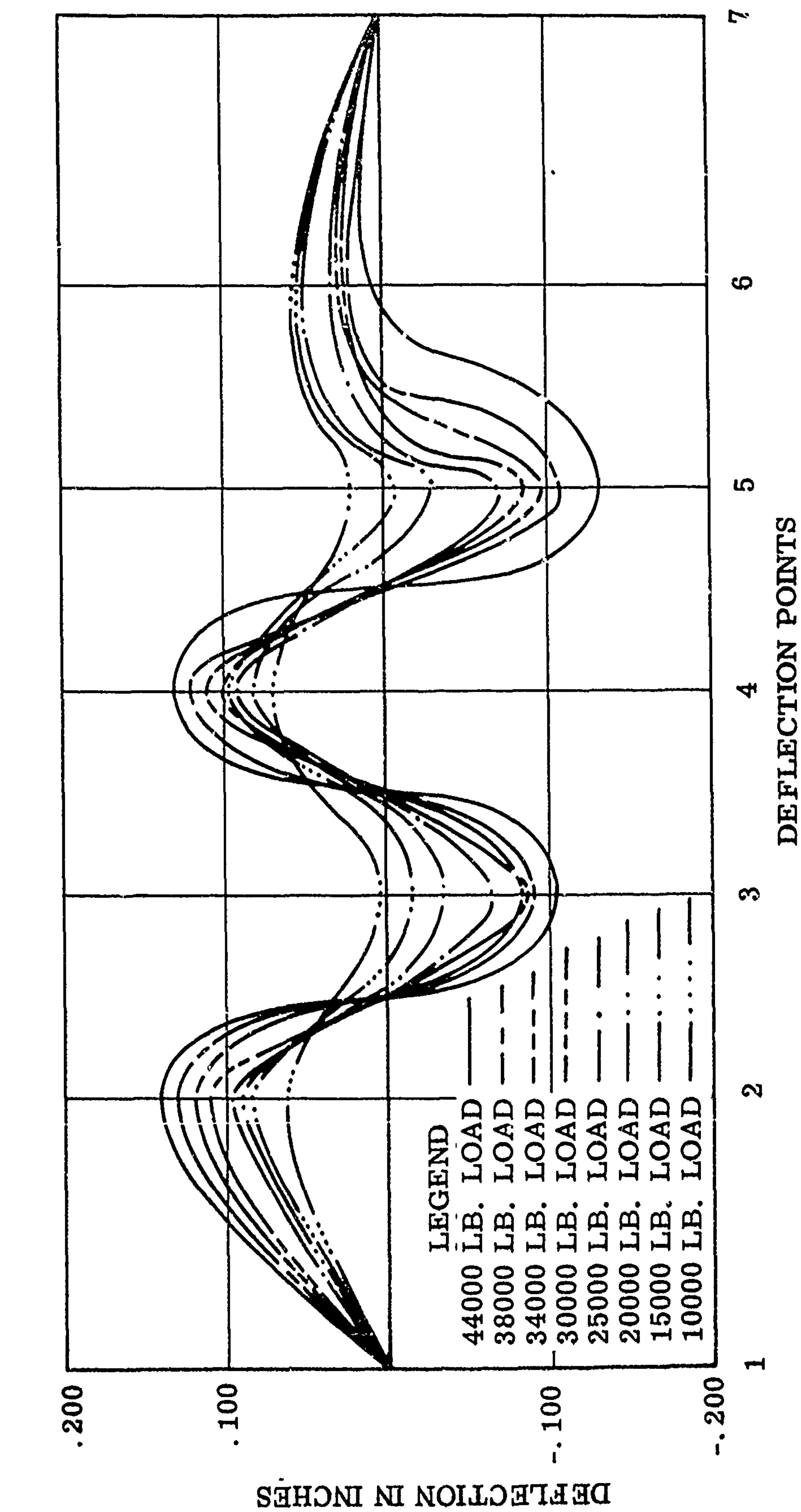
Convair Print 61640

Figure D-12 – STATIC FAILURE OF TEST PANEL 29-01010-1.



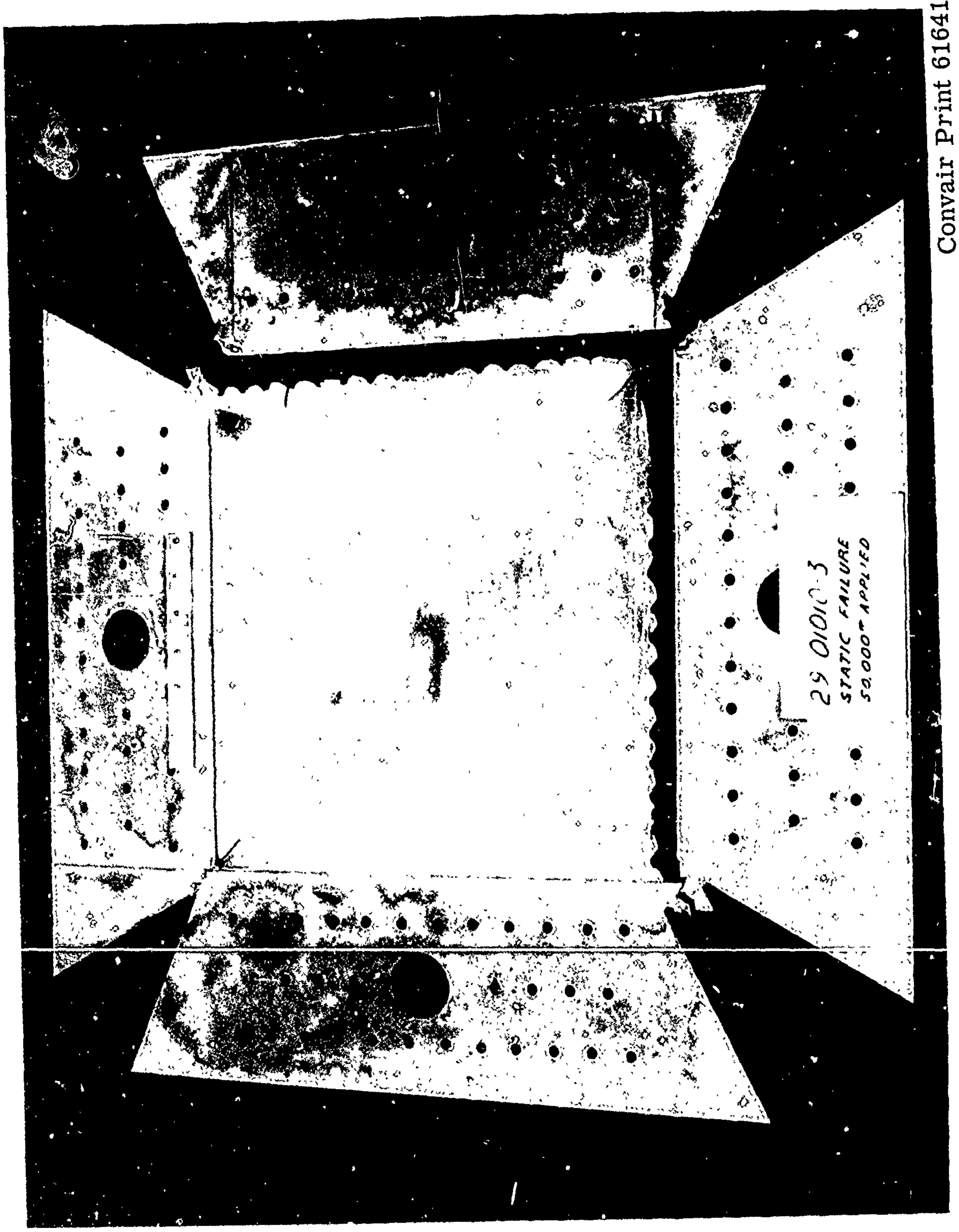
Convair Print 61639

Figure D-13 — FATIGUE FAILURE OF TEST PANEL 29-01010-1.



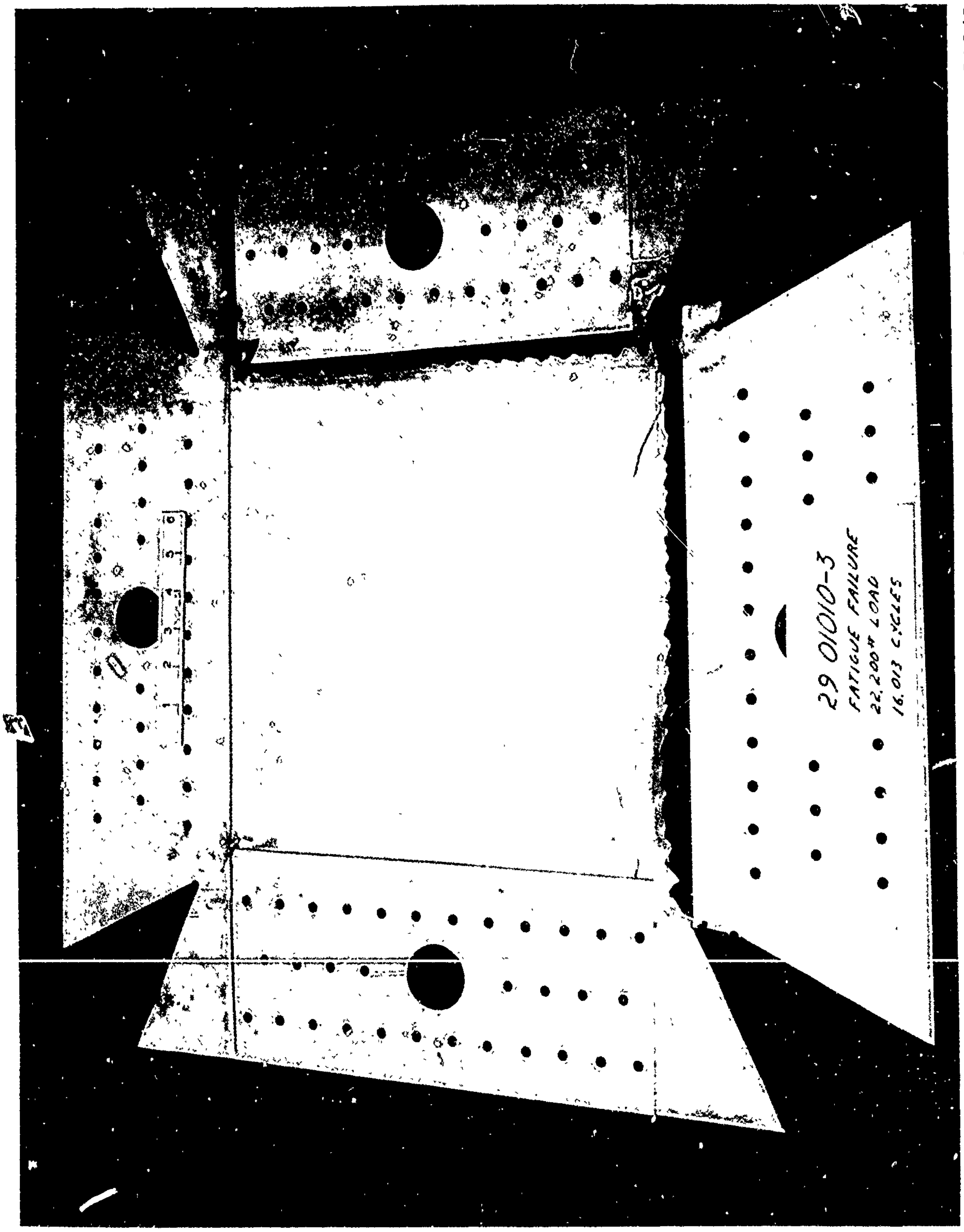
NOTE: SEE FIGURE #8 FOR DEFLECTION POINT LOCATION

Figure D-14 29-01010-3 UNSTIFFENED SHEAR PANEL; Load Versus Deflection



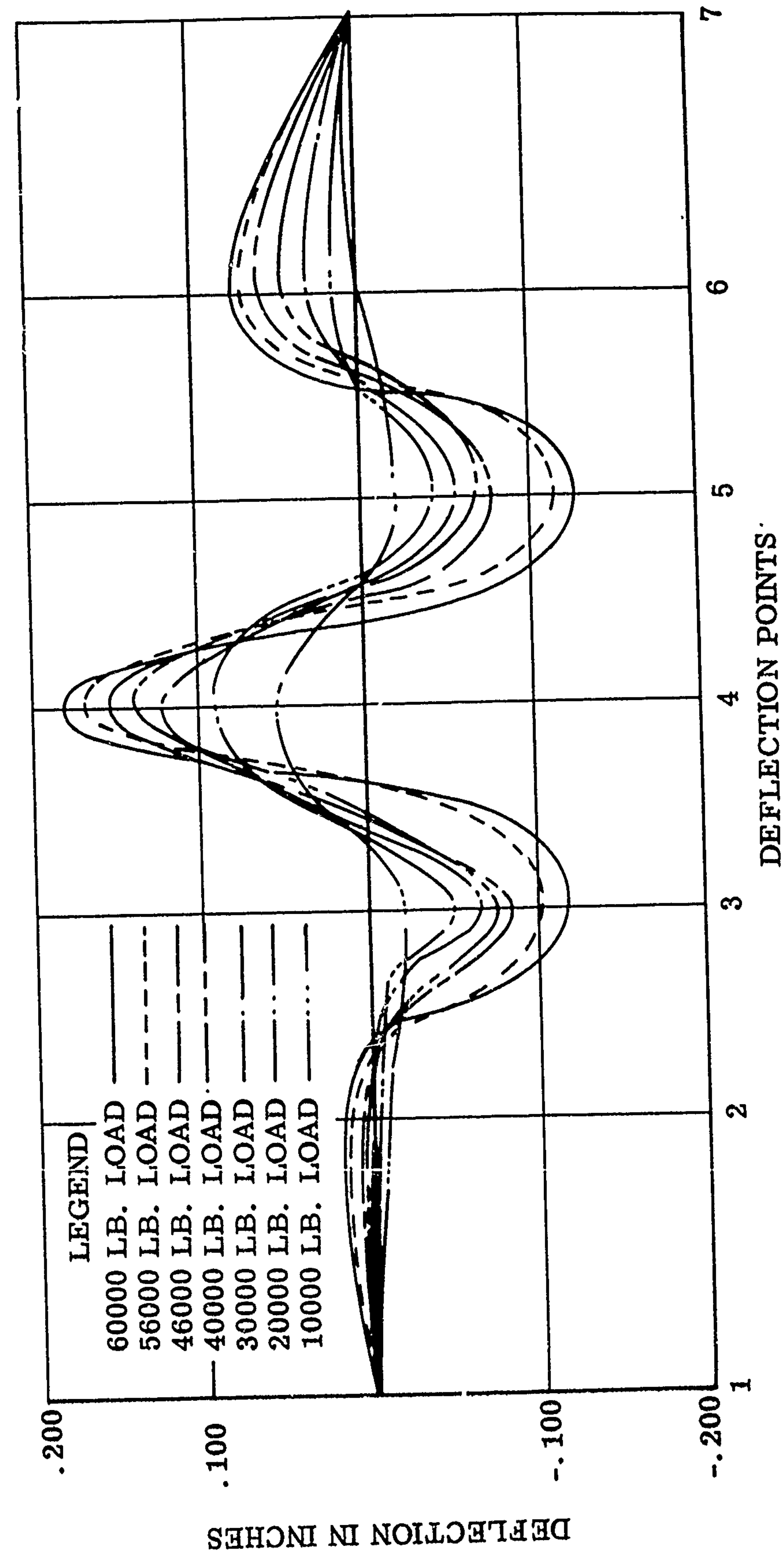
Convair Print 61641

Figure D-15 — STATIC FAILURE OF TEST PANEL 29-01010-3.



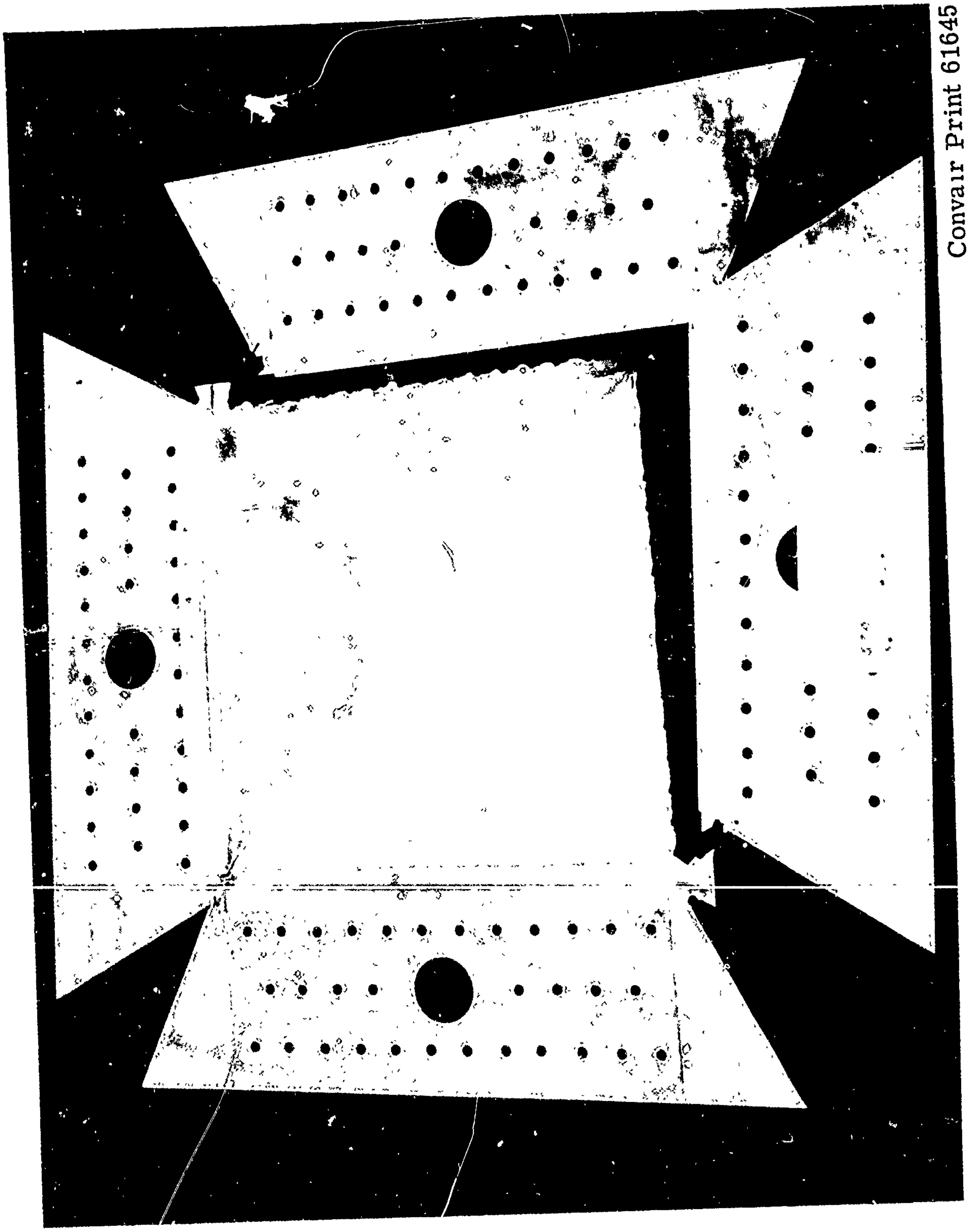
Convair Print 61642

Figure D-16 — FATIGUE FAILURE OF TEST PANEL 29-01010-3.



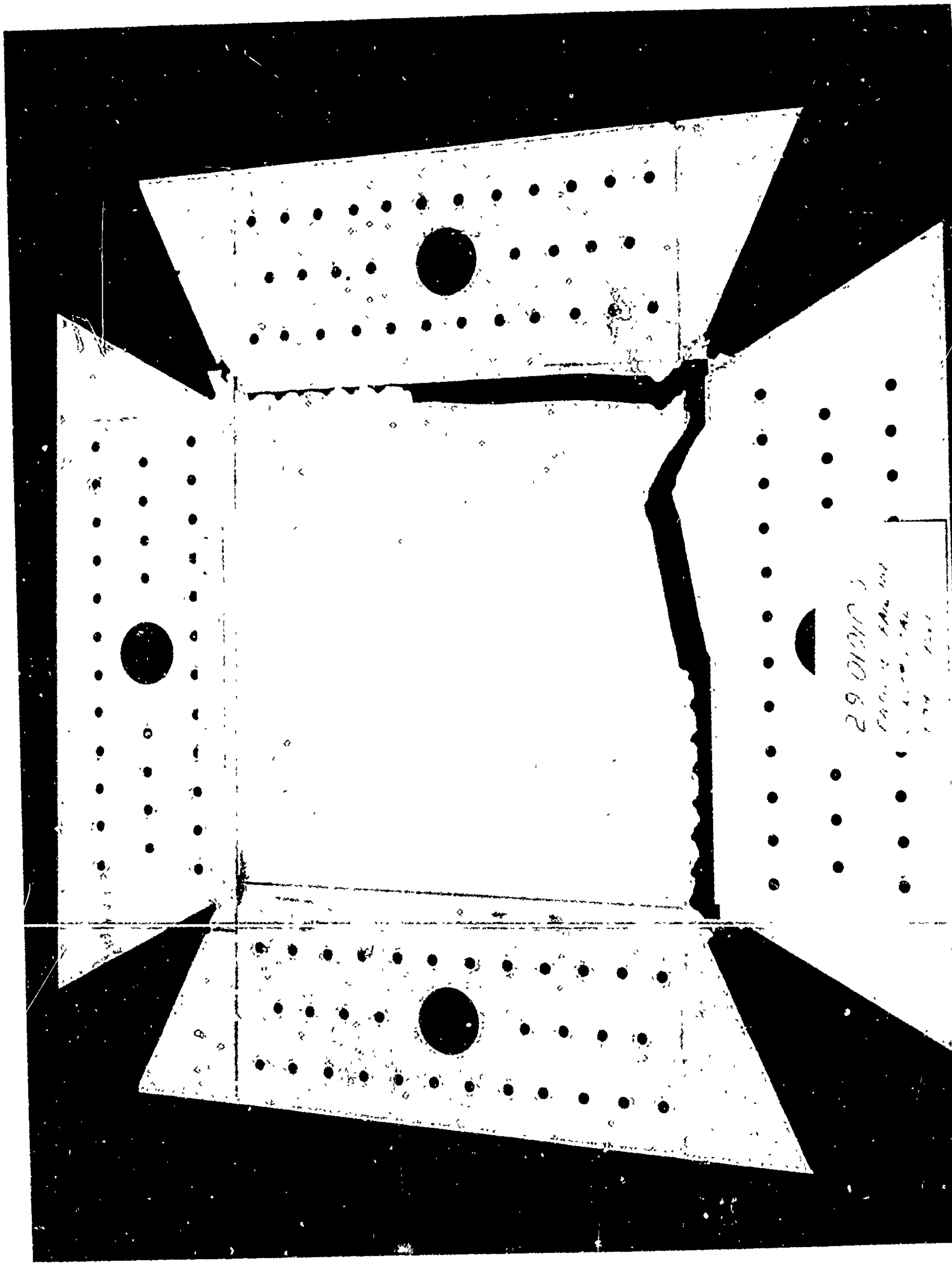
NOTE: SEE FIGURE #8 FOR DEFLECTION POINT LOCATION

Figure D-17 29-01010-5 UNSTIFFENED SHEAR PANEL; Load Versus Deflection



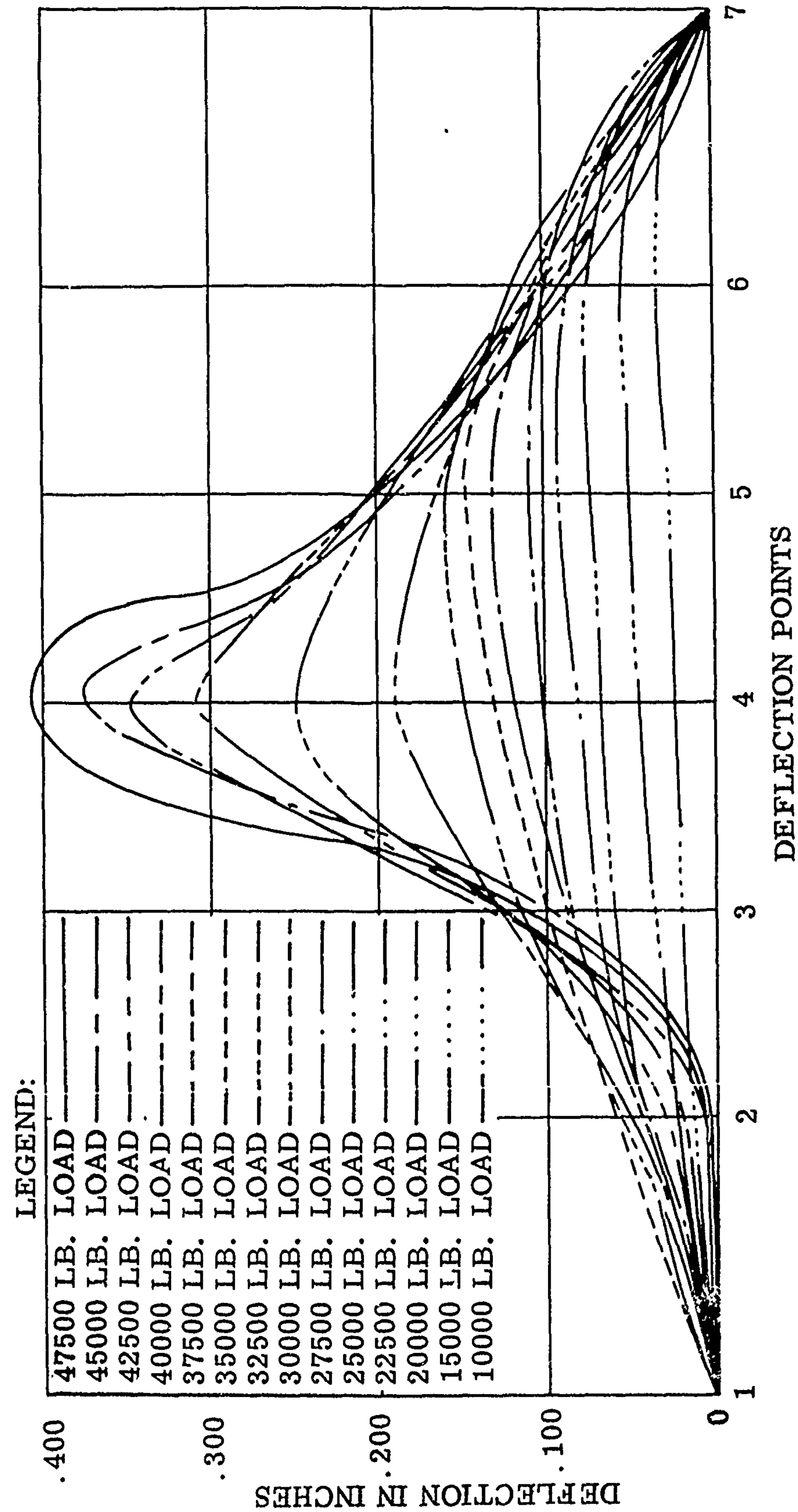
Convair Print 61645

Figure D-18 — STATIC FAILURE OF TEST PANEL 29-01010-5.



Convair Print 61644

Figure D-19 — FATIGUE FAILURE OF TEST PANEL 29-01010-5.



NOTE: SEE FIGURE #8 FOR DEFLECTION POINT LOCATION

Figure D-20 29-01011 SHEAR PANEL - CORRUGATED; Load Versus Deflection

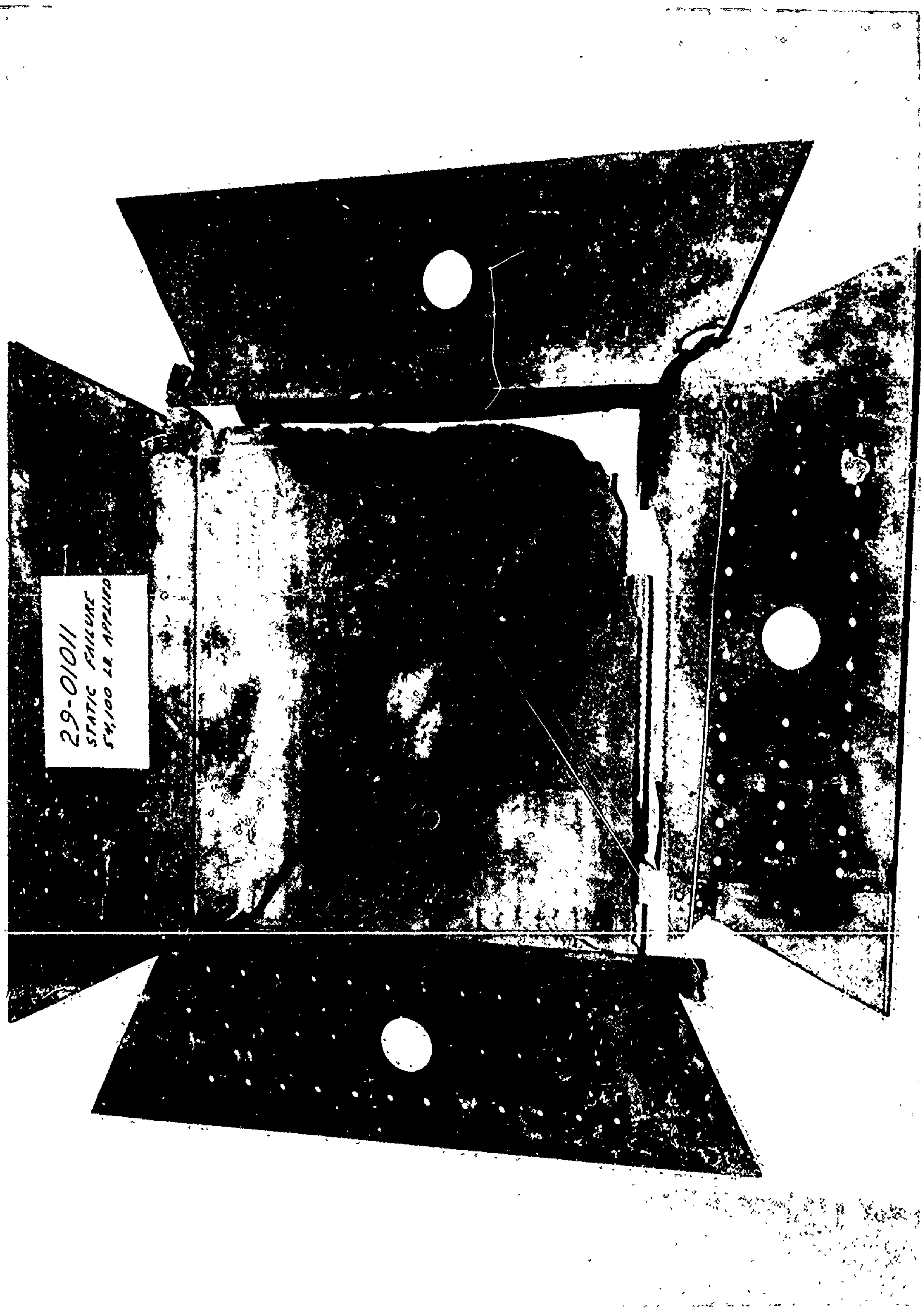
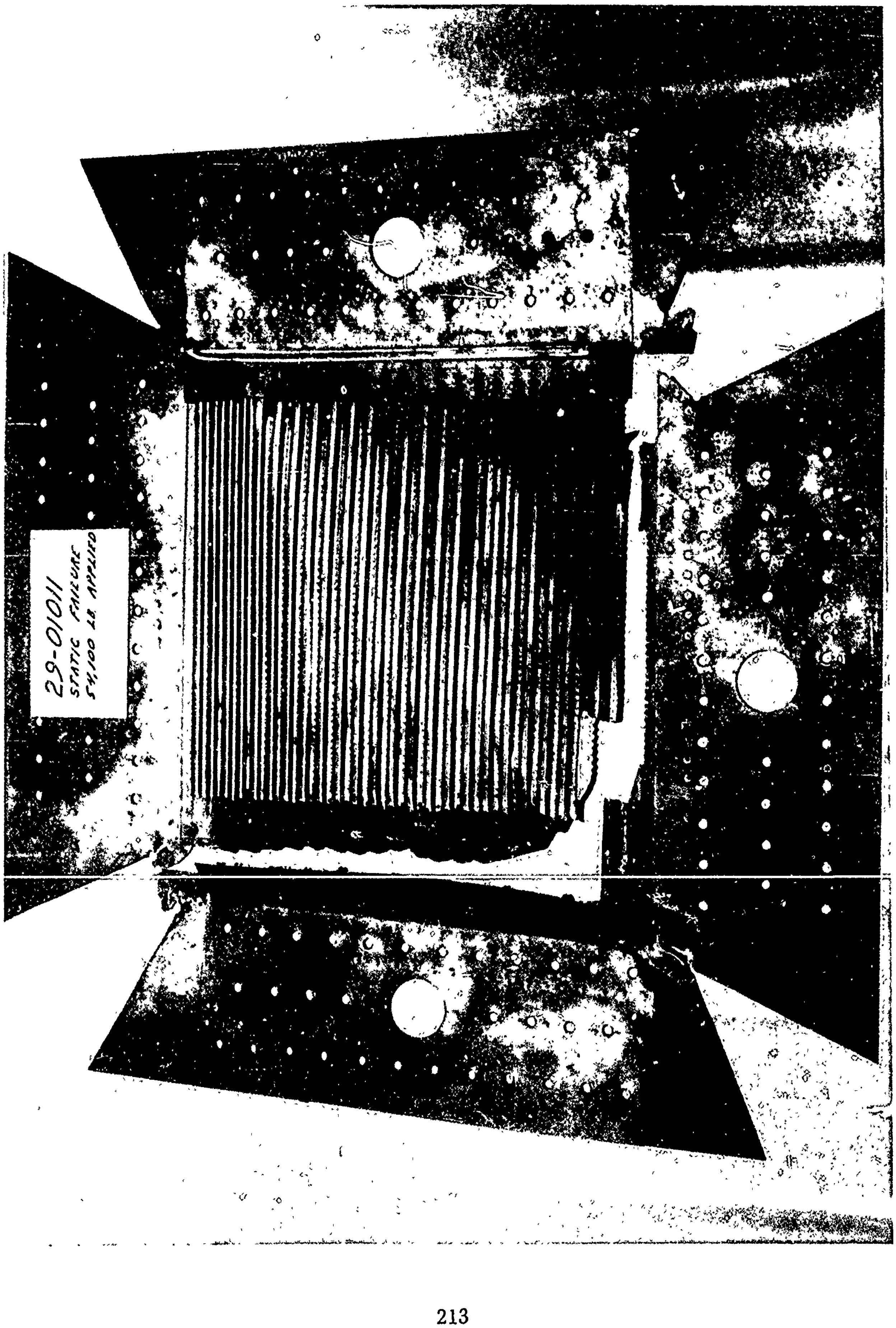


Figure D-21 — STATIC FAILURE OF 29-01011 PANEL; Unstiffened Side.

Convair Print 65080

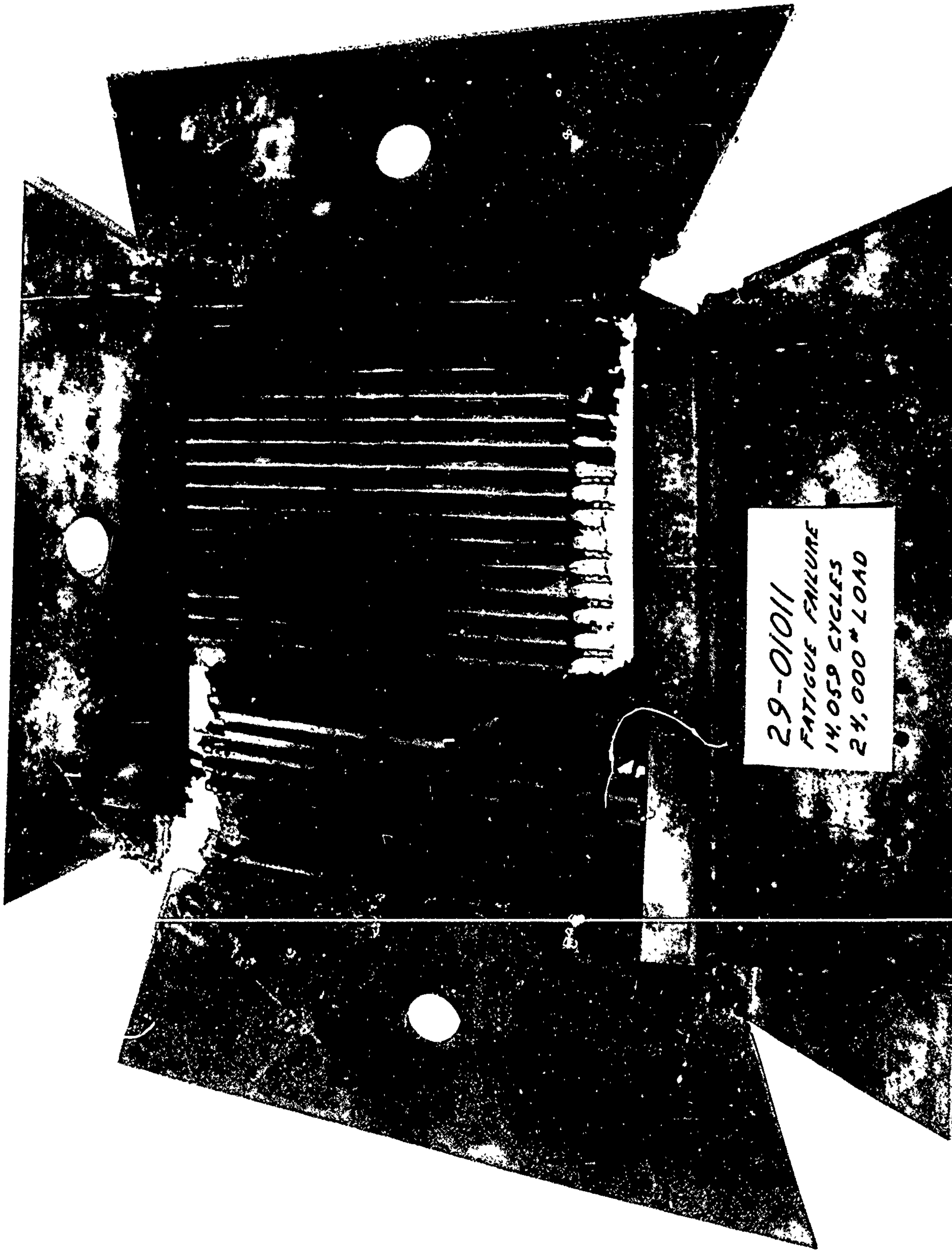


Convair Print 65079

Figure D-22 — STATIC FAILURE OF 29-01011 PANEL; Stiffened Side.

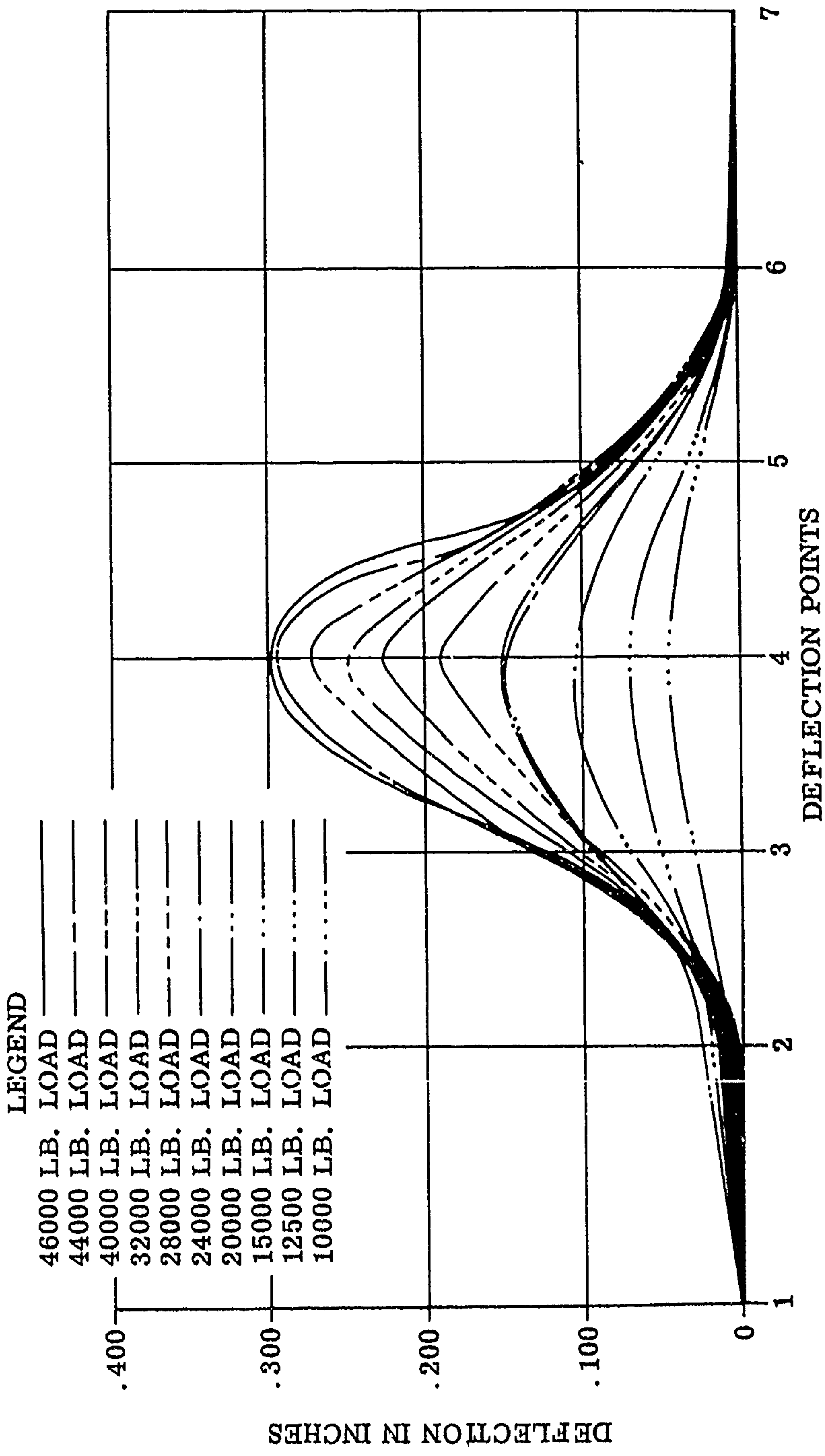
Convair Print 66372

Figure D-23 — FATIGUE FAILURE OF 29-01011 PANEL; Unstiffened Side.



Convair Print 66373

Figure D-24 — FATIGUE FAILURE OF 29-01011 PANEL; Stiffened Side.



NOTE: SEE FIGURE #8 FOR DEFLECTION POINT LOCATION

Figure D25 29-01013 TEST PANEL - RIGIDIZED GRID; Load Versus Deflection

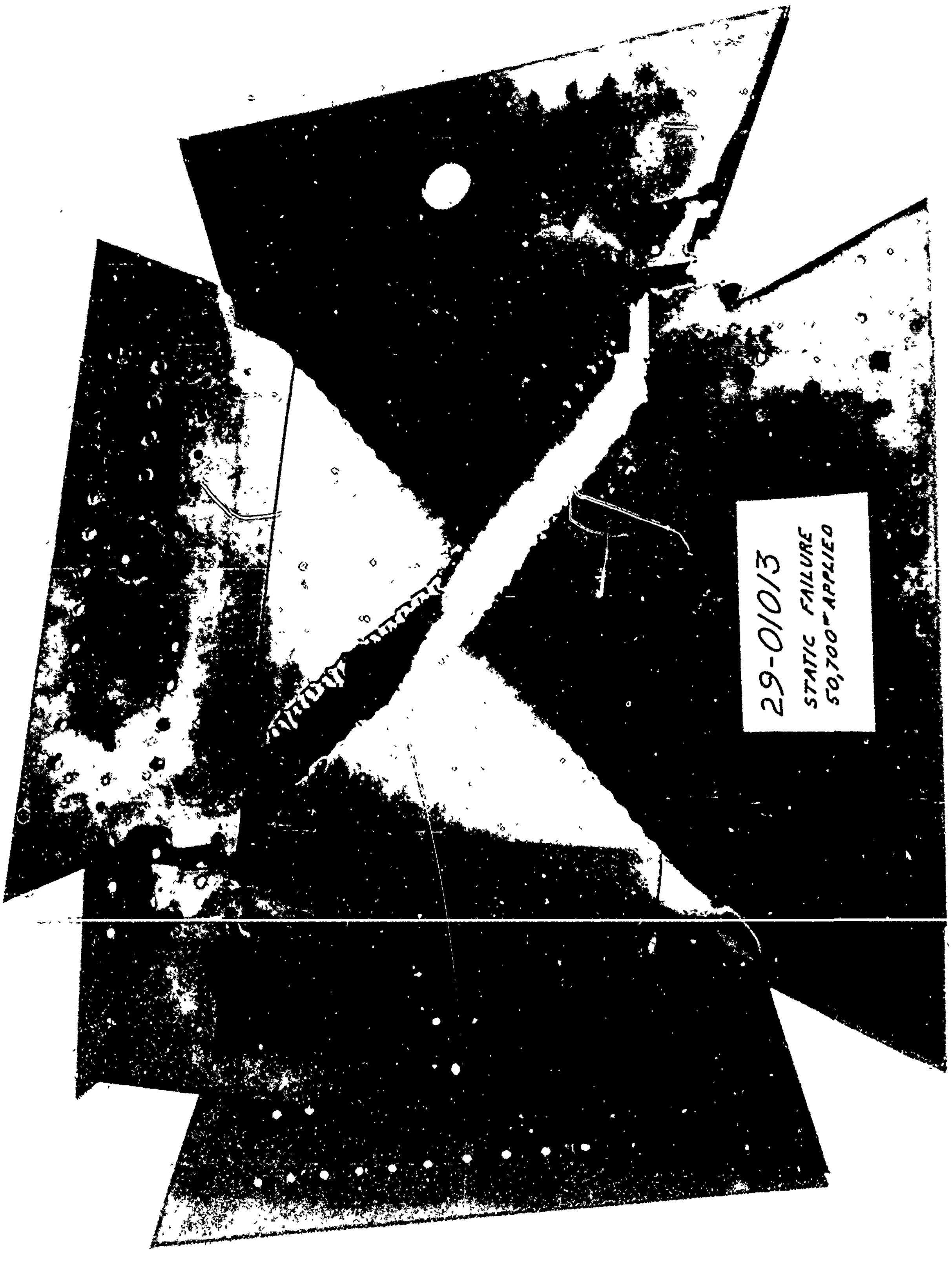


Figure D-26 — STATIC FAILURE OF 29-01013 PANEL; Unstiffened Side.

Convair Print 66370

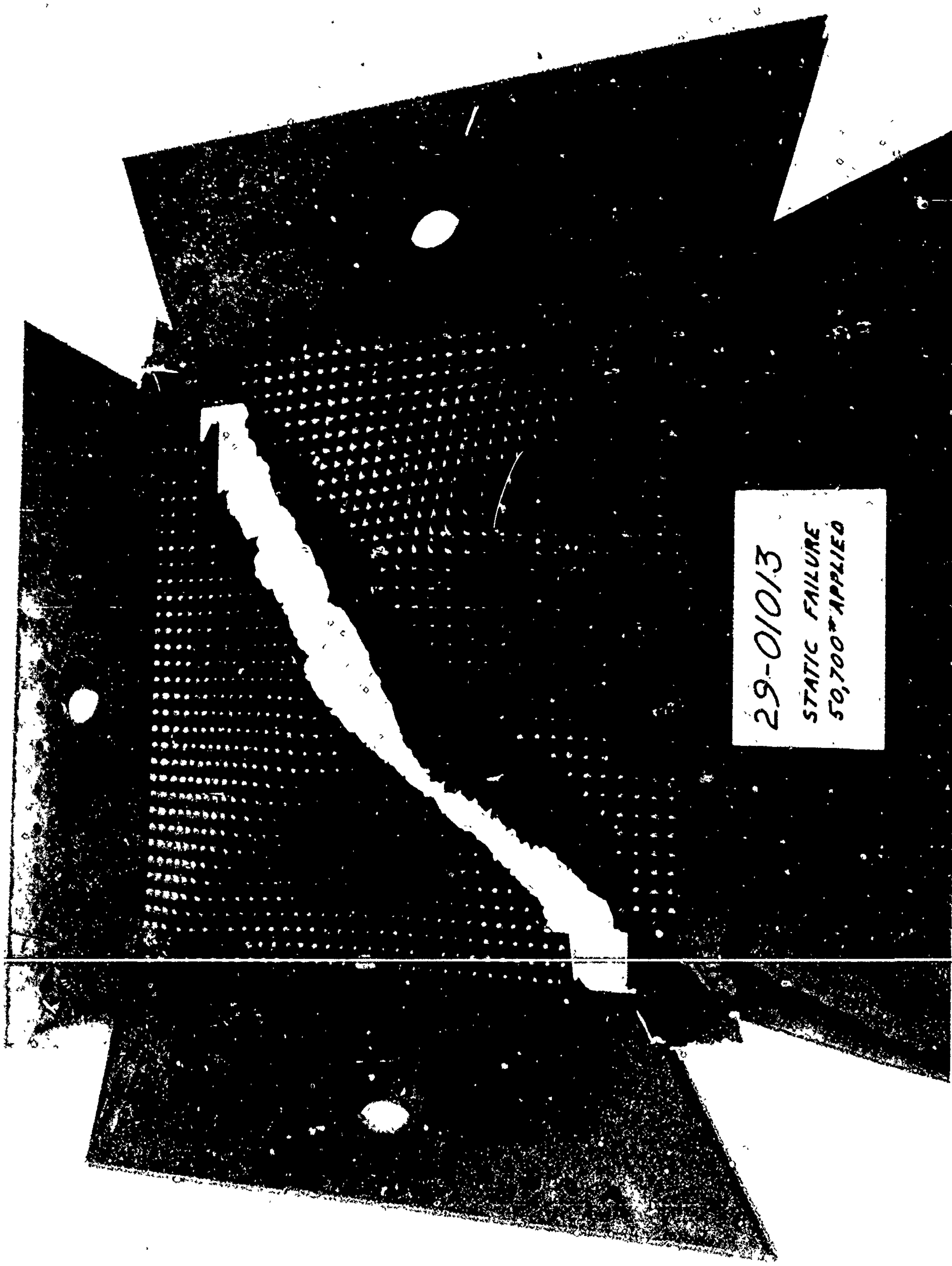
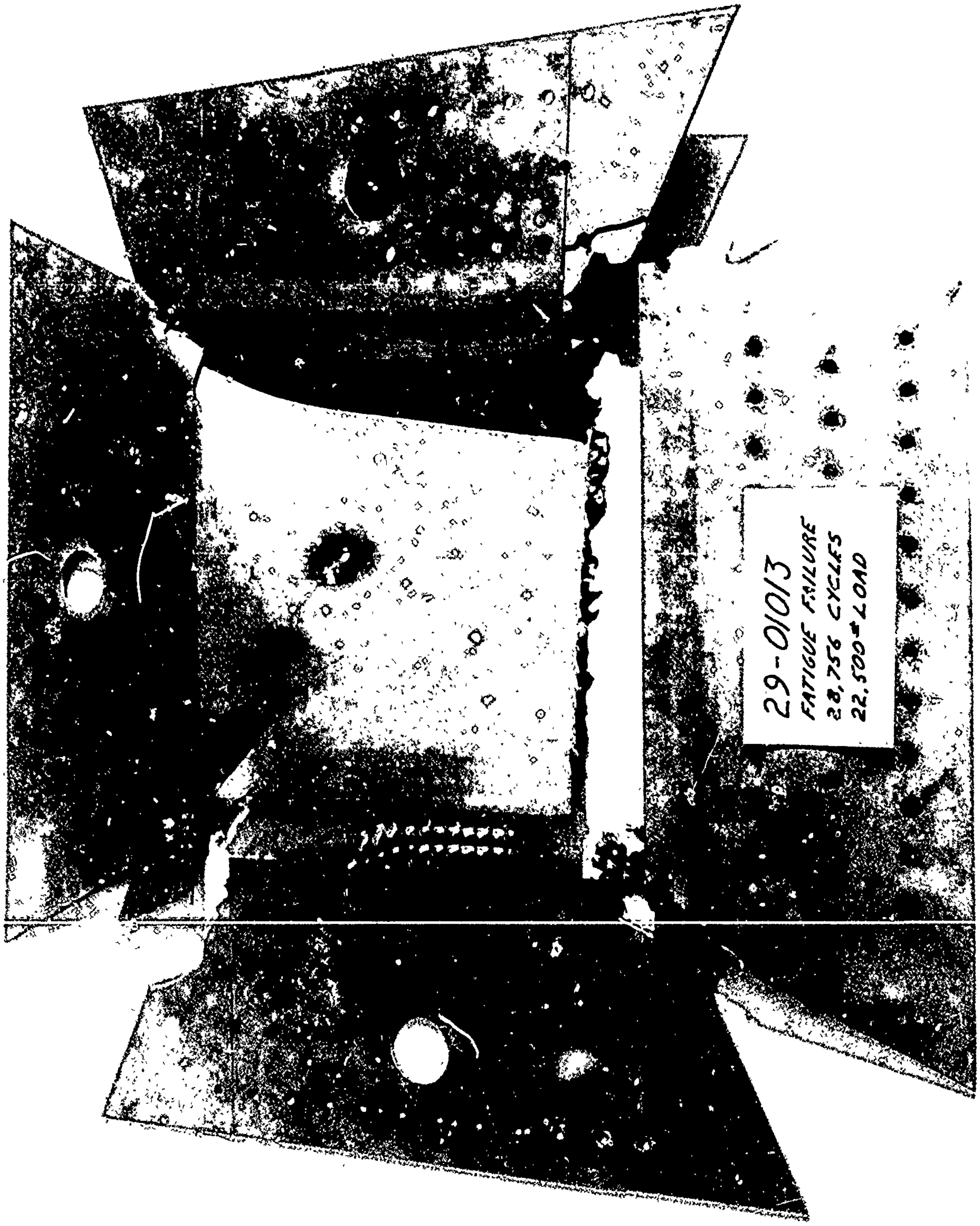


Figure D-27 — STATIC FAILURE OF 29-01013 PANEL. Stiffened Side. Convair Print 66369



Convair Print 66371

Figure D-28 — FATIGUE FAILURE OF 29-01013 PANEL; Unstiffened Side.

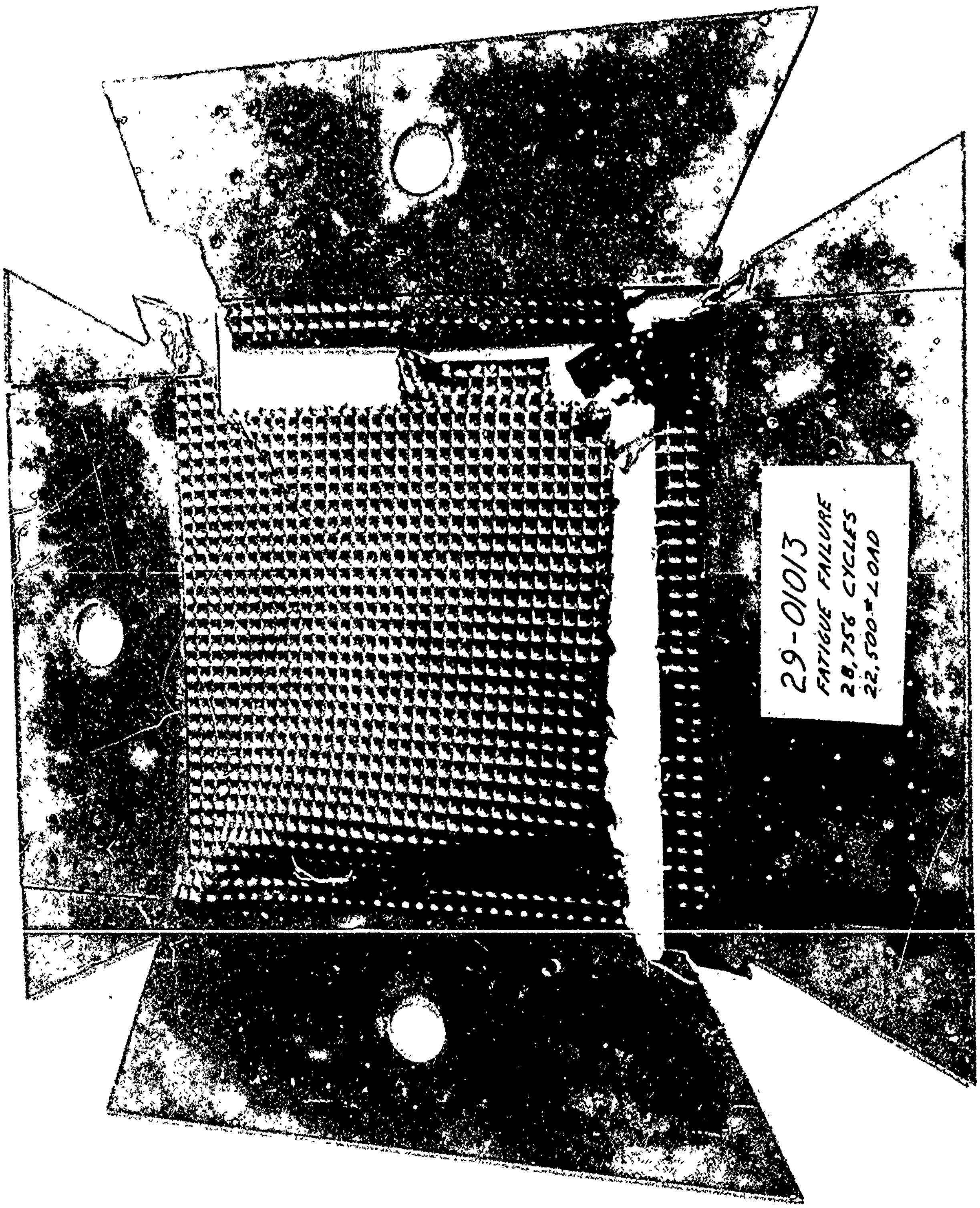
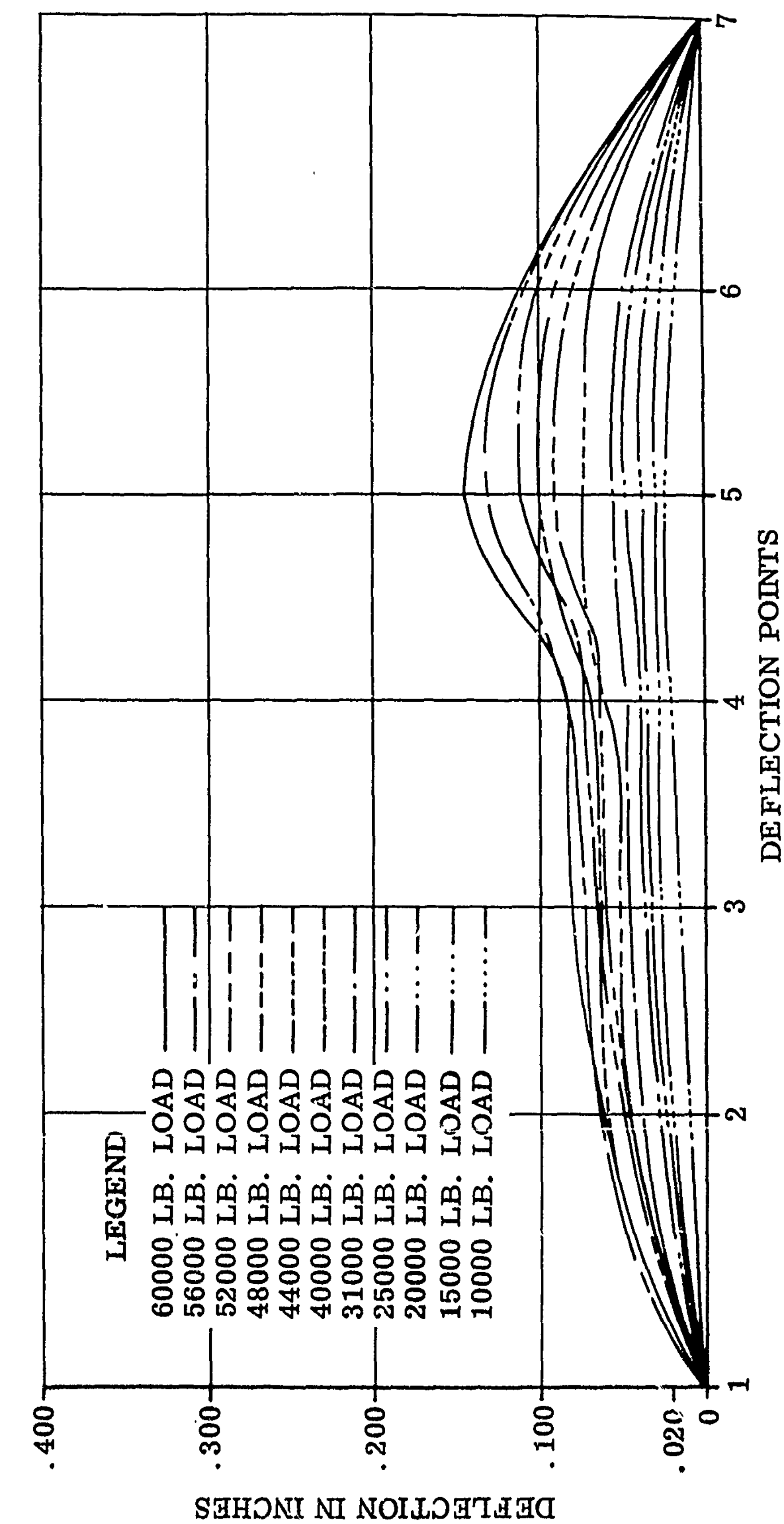


Figure D-29 — FATIGUE FAILURE OF 29-01013 PANEL; Stiffened Side.

Convair Print 66368



NOTE: SEE FIGURE #8 FOR DEFLECTION POINT LOCATION

Figure D-30 SHEAR PANEL 29-01014; Load Versus Deflection

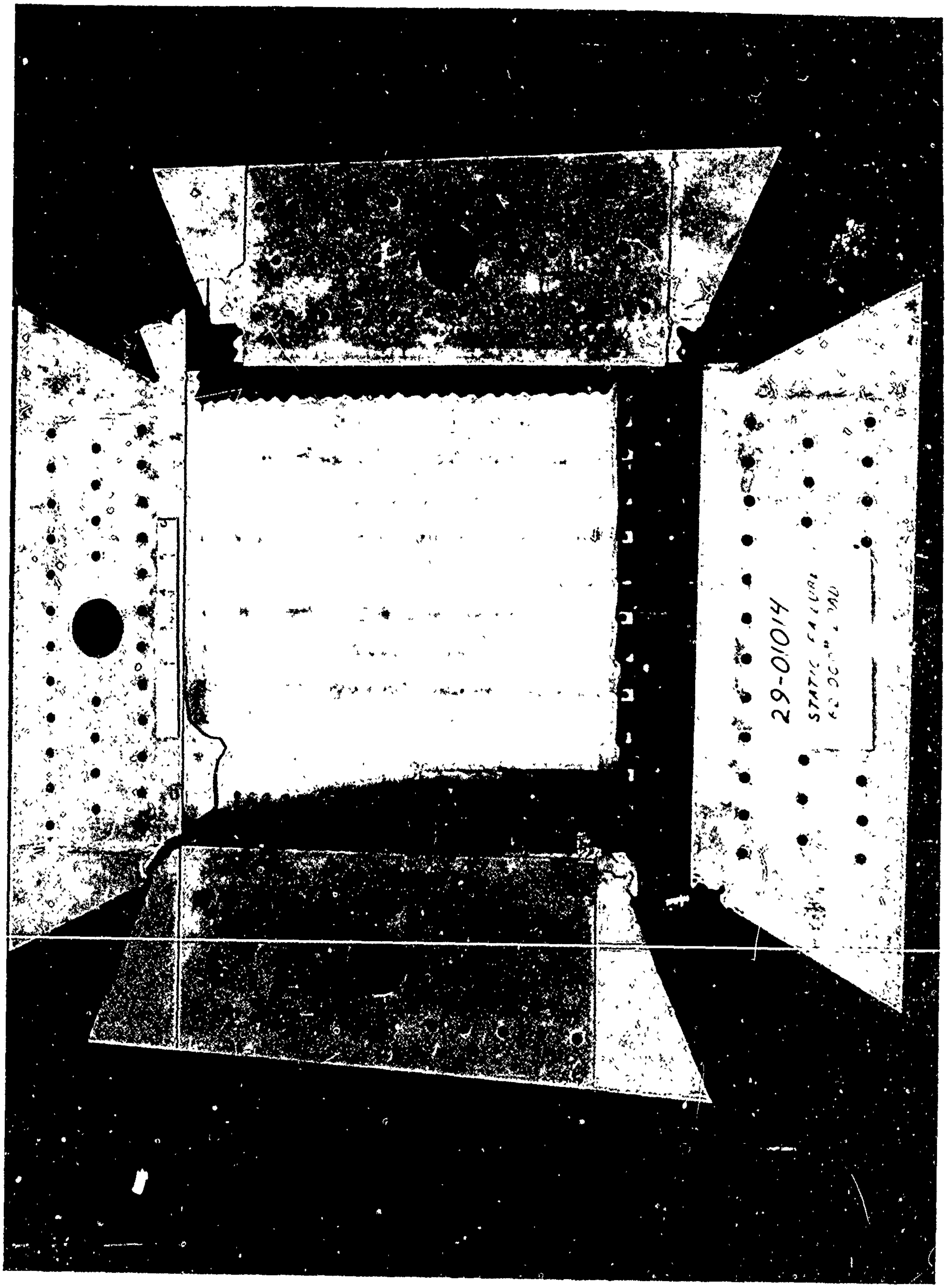
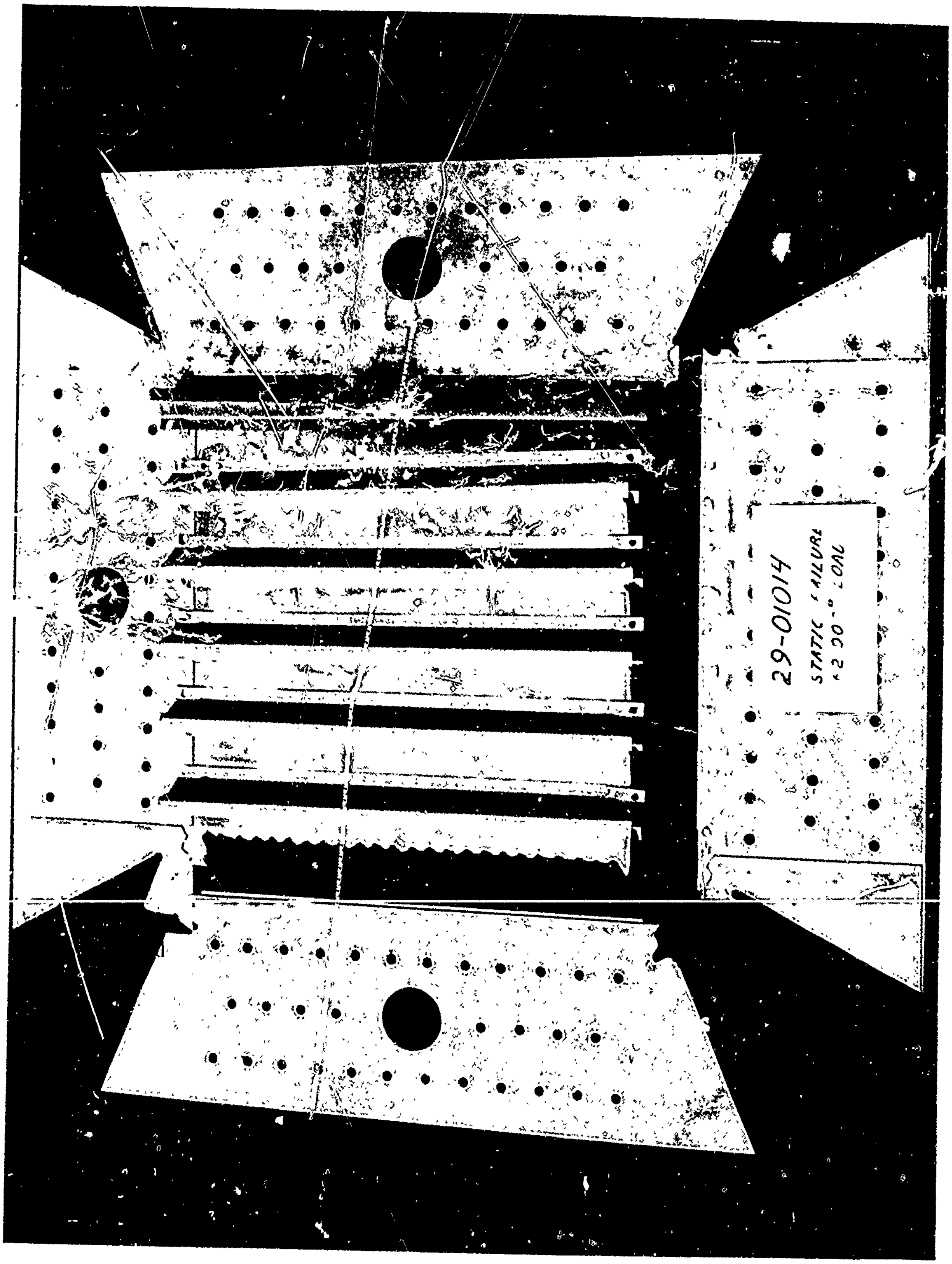
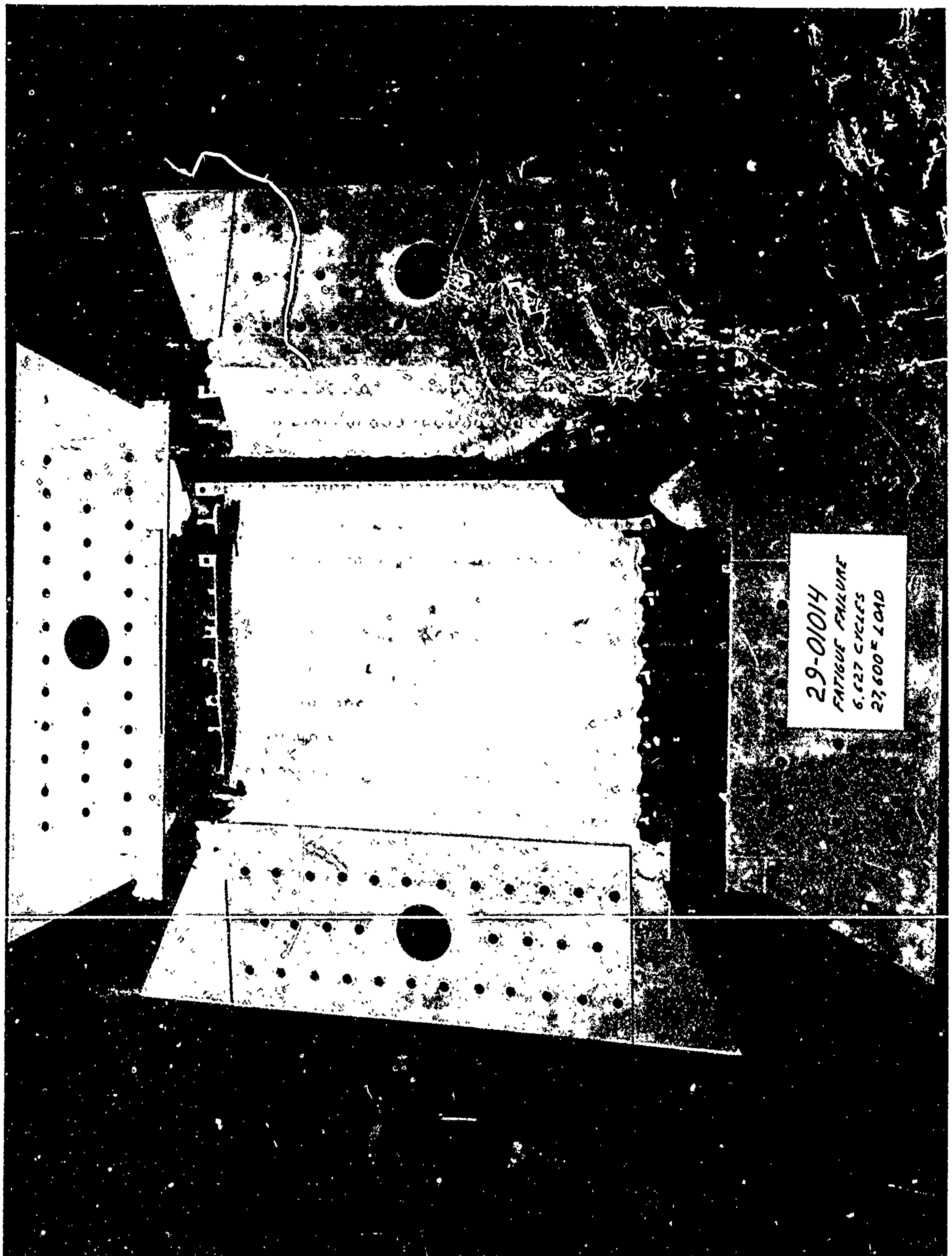


Figure D-31 — STATIC FAILURE OF 29-01014 PANEL; Unstiffened Side. Convair Print 62926



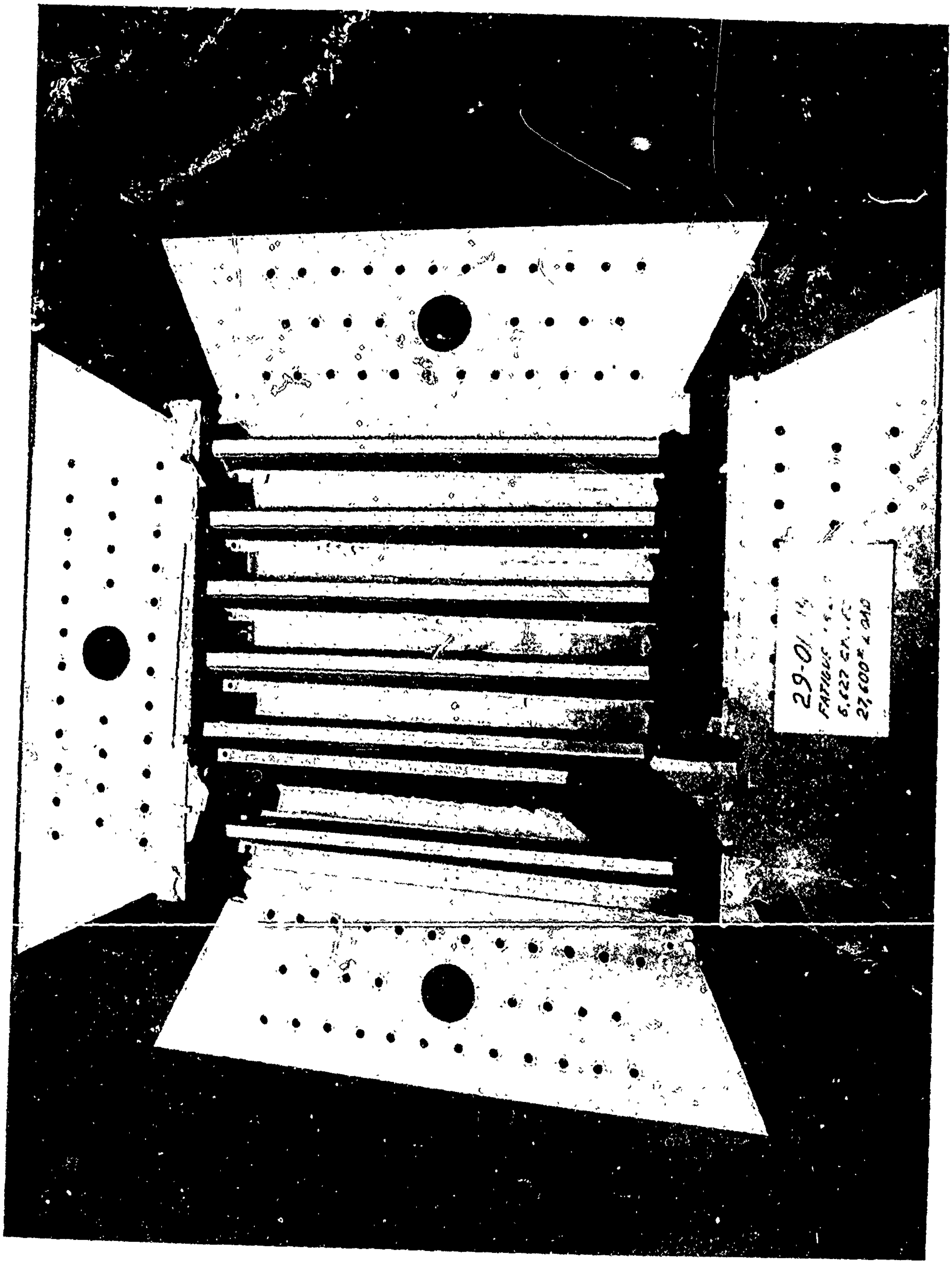
Convair Print 62925

Figure D-32 — STATIC FAILURE OF 29-01014 PANEL; Stiffened Side.



Convair Print 62928

Fgiure D-33 – FATIGUE FAILURE OF 29-01014 PANEL; Unstiffened Side.



Convair Print 62927

Figure D-34 — FATIGUE FAILURE OF 29-01014 PANEL; Stiffened Side.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE
STATIC AND FATIGUE TEST

VI. TEST LOADS

1. Static Tests:

All panels were loaded to the same stress level at room temperature, 200 F and at each 100 F increment thereafter through 900 F. This stress level equals 75% design limit stress at 900 F (design limit stress at 900 F equals 46,100 PSI.

2. Fatigue Tests:

The magnitude of the applied fatigue load was 4/9 of the ultimate failing load as determined by previous static tests.

VII. TEST RESULTS

1. Static Tests:

The ultimate static loads as well as references to failure photographs and load-deflection data are presented in Table D-1 (page 202).

2. Fatigue Tests:

Applied load, number of cycles and references to failure photographs are presented in Table D-1.

VIII. DISCUSSION

As shown in Table D-1 the 29-01014 stiffened panel withstood the greatest load (62,000 pounds). In addition, this panel had the least normal deflection under load (reference Figure D-30). However, the fatigue life of the 29-01014 panel was noticeably less than that of the other stiffened panels.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

IX. CONCLUSIONS

All specimens withstood an applied shear stress of 39,200 lbs/sq. in. at room temperature, 300 F and 100 F increments thereafter through 900 F.

Variations of deflection due to temperature variations were considered negligible and are therefore not presented.

Ultimate static failing load, deflection under load, fatigue life and weights of panels are presented in tabular form in this report.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

D. SHEAR PANEL - ELEVATED-TEMPERATURE STATIC AND FATIGUE TEST

X. STRUCTURAL DISCUSSION

The titanium shear panel load is given as

$$P = \frac{\tau\, tw}{.707}$$

The shear stress τ is the pertinent unknown for a given ultimate applied static load in each panel; w, the effective width of the panel, is taken as the distance between the inboard rows of the spot welds or 12.78 inches in each of the six shear panels tested. The small bent effect of the sheet and doublers, at the corners, is neglected. The following table shows the result of the static portion of the tests, all of which were run at a temperature of 800 F.

Panel No.	Specimen	Shear Load (lbs) P 2	"q" (lbs/in) Shear Load/ 12.78	"t" (ins.)	"τ" (lbs/ sq. in.) qt
1	29-01010-1	24000	1878	.025	75,100
2	29-01010-3	35350	2766	.032	86,400
3	29-01010-5	43800	3427	.040	85,700
4	29-01011-1	38250	2993	.020 + .016	83,100
5	22-01013-1	35820	2803	.020 + .016	77,900
6	22-01014-1	43800	3427	.032	107,100

The average ultimate shear stress for the first five panels is 81,600 lbs/sq. in. This compares favorably with the ultimate allowable shear stress (at test temperature) of 76,000 lbs/sq. in. Ref: Properties of Ti-4Al-3Mo-1V - Titanium Metals Corporation of America, 233 Broadway, New York. Panel No. 6 failed at a very high calculated stress because of the heavy stiffeners which acted as a vieren deel truss and reacted some of the applied load.

X. STRUCTURAL DISCUSSION (Cont'd)

Panel No. 5 actually failed in static tension. In this specimen the rigidized grid reacts shear, but is much too flexible in tension, in a diagonal direction, to help the face sheet react the applied load. The tension stress at rupture in the face sheet was 50,700:(1.414)(12.78)(.020) (140,000 lbs/sq. in.) The allowable ultimate tensile stress at this temperature is 147,000 lbs/sq. in. It seems probable that the spot welding necessary for this type of construction reduced the parent metal allowable to 95% of the unwelded material allowable.

It is interesting to note that this alloy of titanium acts very similarly to the stainless steels. The ultimate shear stress is approximately 57% of the ultimate tensile stress at room temperature. This percentage drops slightly to approximately 51% at 800 F. The aluminums and the chrom-moly steels shear strengths are approximately 60% of the ultimate tensile strengths, at room temperature, however, this percentage seems to increase slightly with increase in temperature.

From the graphs of the deflections, it is seen that the first three panels were in tension field from the tare load; however, at ultimate load the deflections were not greater than plus/minus .15 inch. These three specimens had several deflection nodes, while the rigidized panels had only one. The corrugated panel (Panel No. 4) seems to be shear resistant up to a shear flow of approximately 1650 lbs/inch, at which time one large buckle appeared. The deflection at the center of the panel was over .40" at ultimate load. The rigidized grid is similar to Panel No. 4 in that only one buckle appeared. It grew with increase in load to a maximum deflection of .30 inch. The specimen did not seem to be shear resistant at the tare load. Panel No. 6 was shear resistant up to a shear flow of 2995 lbs/in. An unsymmetrical buckle then appeared and remained to failure. The deflections were small (less than .15 inch at failure). The cost weight-wise of Panel No. 6 is prohibitive unless there are large compressive loads that would necessitate the heavy stiffeners.

The fatigue tests show that much data is missing, if fatigue life is to be predicted accurately. The tests were not conclusive and fell short of expectations. The notch factors due to the spot welding needs much investigating.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

TABLE OF CONTENTS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

,. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

I. INTRODUCTION

Test specimens represented typical wing or fuselage compression panels of supersonic aircraft structures which would, under flight conditions, be subjected to combined compressive load, pressurization, and aerodynamic heating.

The objectives of this test were:

To determine the effect of limit load and pressure on the specimens when applied at room temperature, 200 F and 100 F increments thereafter to 800 F.

To determine the ultimate compressive load that the specimen would withstand when pressurized to design limit pressure and maintained at a constant temperature of 800 F.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

II. SUMMARY

Static compression load and pressurization were conducted on 26" x 31-1/2" 4Al-3Mo-1V titanium alloy stiffened panels. Panels were heated by infrared lamps from the unstiffened side, pressurized to limit pressure from the stiffened side and loaded axially in compression. All specimens withstood limit load and pressure at room temperature, 200 F and each 100 F increment through 900 F. The panels were then maintained at 800 F, pressurized to limit pressure and axially loaded to failure.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

III. TEST SPECIMENS

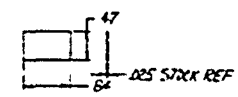
The test specimens were 26-1/2" x 31" stiffened compression panels fabricated from Ti-4Al-3Mo-1V titanium alloy. The following specimens were tested to failure:

Test Part 29-01009 - Figure E-1 (page 239)

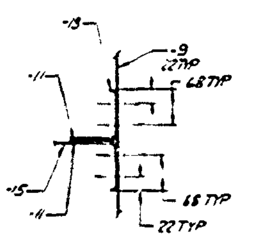
Test Part 29-01012 - Figure E-2 (page 241)

Test Part 29-01008 - Figure E-3 (page 243)

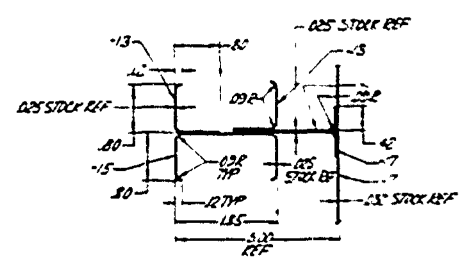
Figure E-1 - COMPRESSION SHEAR TEST PANEL -
Engineering Drawing 29-01009



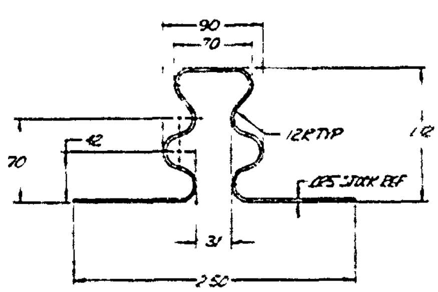
DETAIL -17
SCALE 1/1



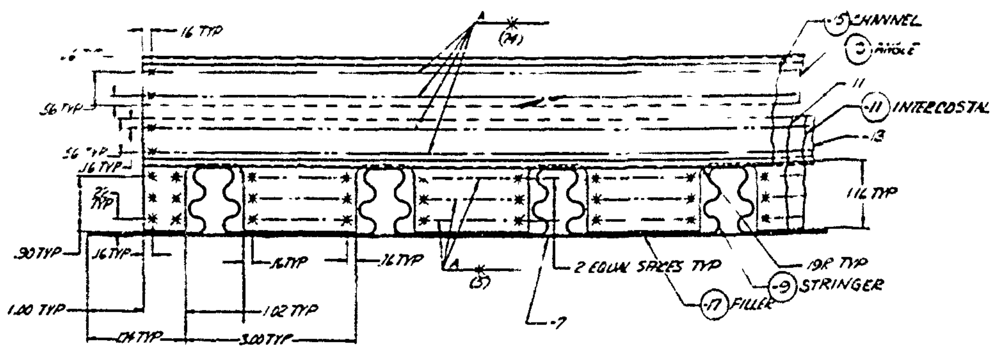
SECTION C-C A/5
SCALE 1/1



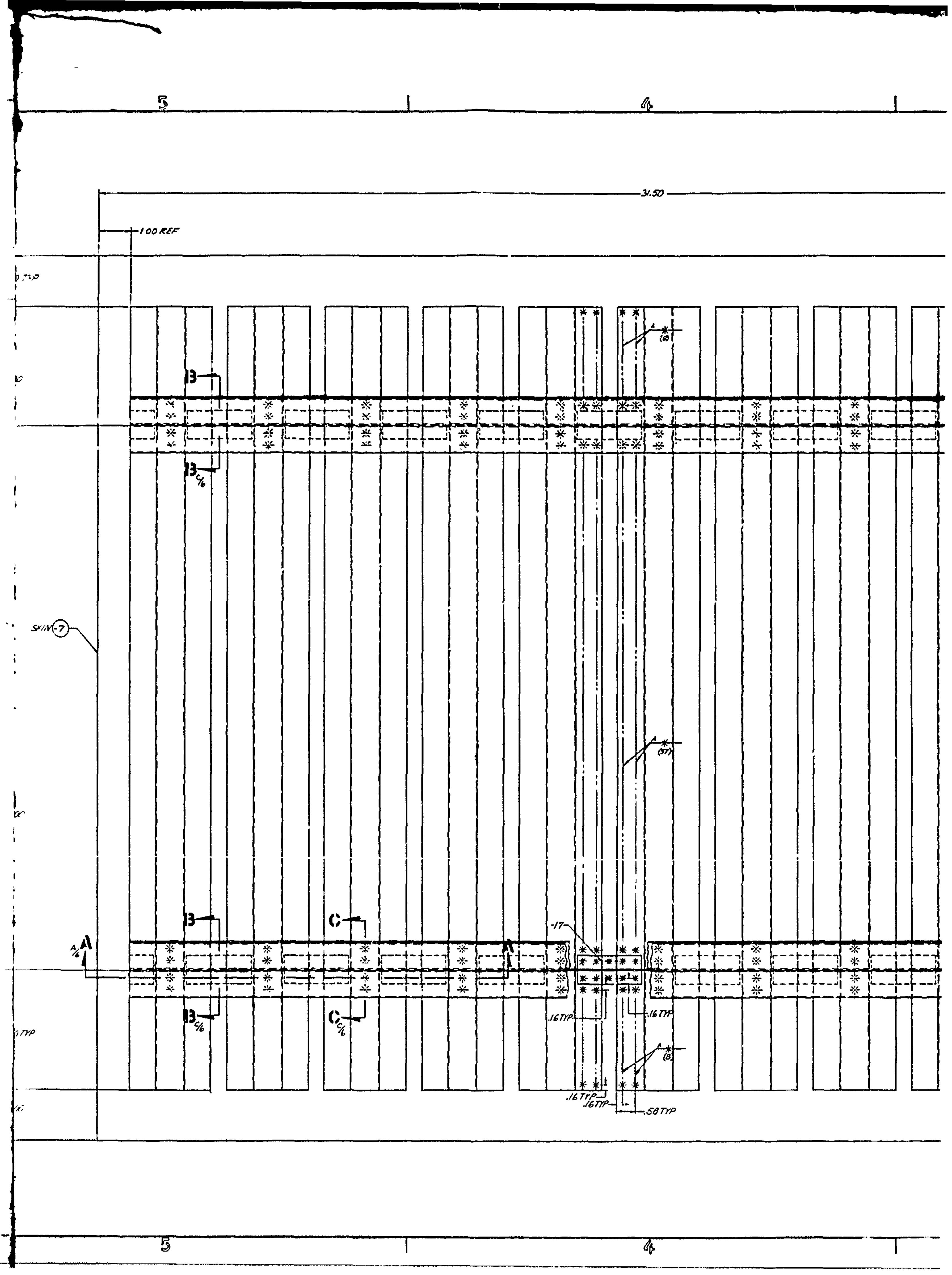
SECTION B-B
SCALE



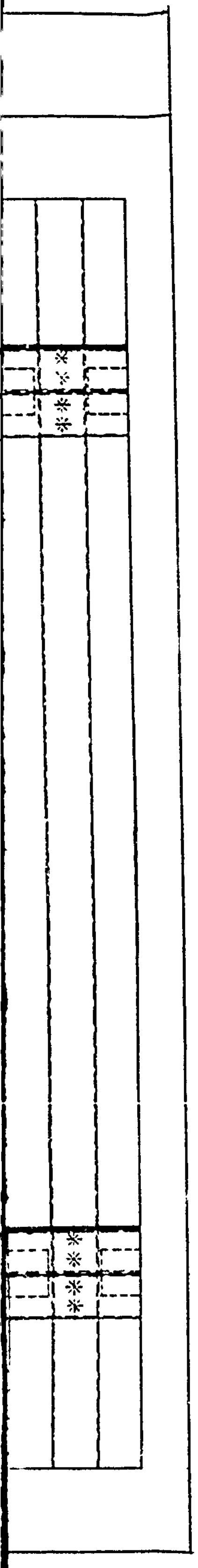
DETAIL -9



SECTION A-A A/5
SCALE 1/1



5
4
31.50
1.00 REF
SKIN-7
-17-
.16 TYP
.58 TYP



EFF ON	INCORP	STN	DESCRIPTION	ZONE	DATE	APPROVAL	EFF ON	INCORP	STN					

REVISIONS

2			-19	SC
18			-17	FI
	1		-15	CH
	2		-13	AI
	2		11	IN
10			-9	S
1			-7	SH
-1	-19	PART NO	OPP	SHN

REQUIREMENTS PER ASSEMBLY — DASH NO

1. WELD PER MIL-W-[redacted], EXCEPT PENETRATION TO BE 40-60%

NOTES:

DASH NO	ENG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO	ENG RECORD NO	SERIAL NO	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO	ENG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY
																-1			TEST				1

APPLICATION — QTY REQD

RIVET CODE
F=MFD HEAD FAR SIDE
N=MFD HEAD NEAR SIDE
DIAMETER IN 32NDS
BASIC CODE
NON-STD INSTL ONLY
D=DIMPLE
NO OF DIMPLED SHEETS
C=COUNTERSINK
LENGTH DASH NO
BASIC CODE

REVISIONS

EFF ON	INCORP	SYM	DESCRIPTION	ZONE	DATE	APPROVAL

Figure E-1 Page 239

29-01009
SHEET 1 OF 1
LTR 0082

Requirements per assembly -19	Requirements per assembly -1	Part No	Dash No.	Description	Stock Size	Material	Initial cond	Final cond	Matl Specification	Zone
	2		-19	SUB-ASSY						
	18		-17	FILLER	025 x 5 x 9	TITANIUM ALY	SOL HT	SHT+A	4AL-3MO-1V	A/5
1			-15	CHANNEL	025 x 3.4 x 275					A/5
2			-13	ANGLE	025 x 1.6 x 295					A/5
2			-11	INTERCOSTAL	025 x 2.3 x 295					A/5
	10		-9	STRINGER	025 x 5.5 x 230					A/5
	1		-7	SKIN	032 x 26.0 x 31.5	TITANIUM ALY	SOL HT	SHT+A	4AL-3MO-1V	B/5

LIST OF MATERIAL

APPLICATION: NEXT ASSY TEST; QTY REQD 1

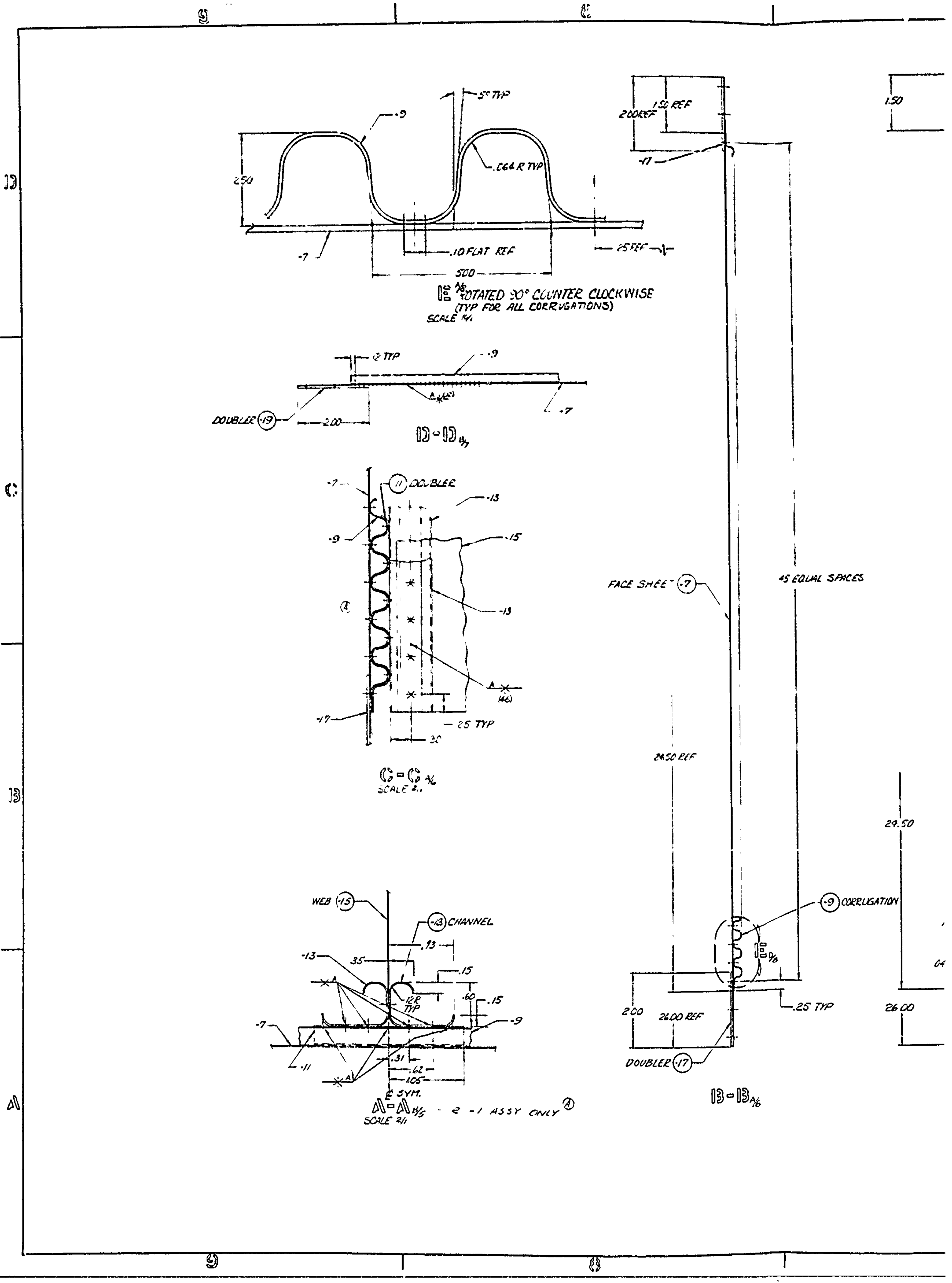
TEST PANEL
4Al-3MO-1V
TITANIUM ALLOY

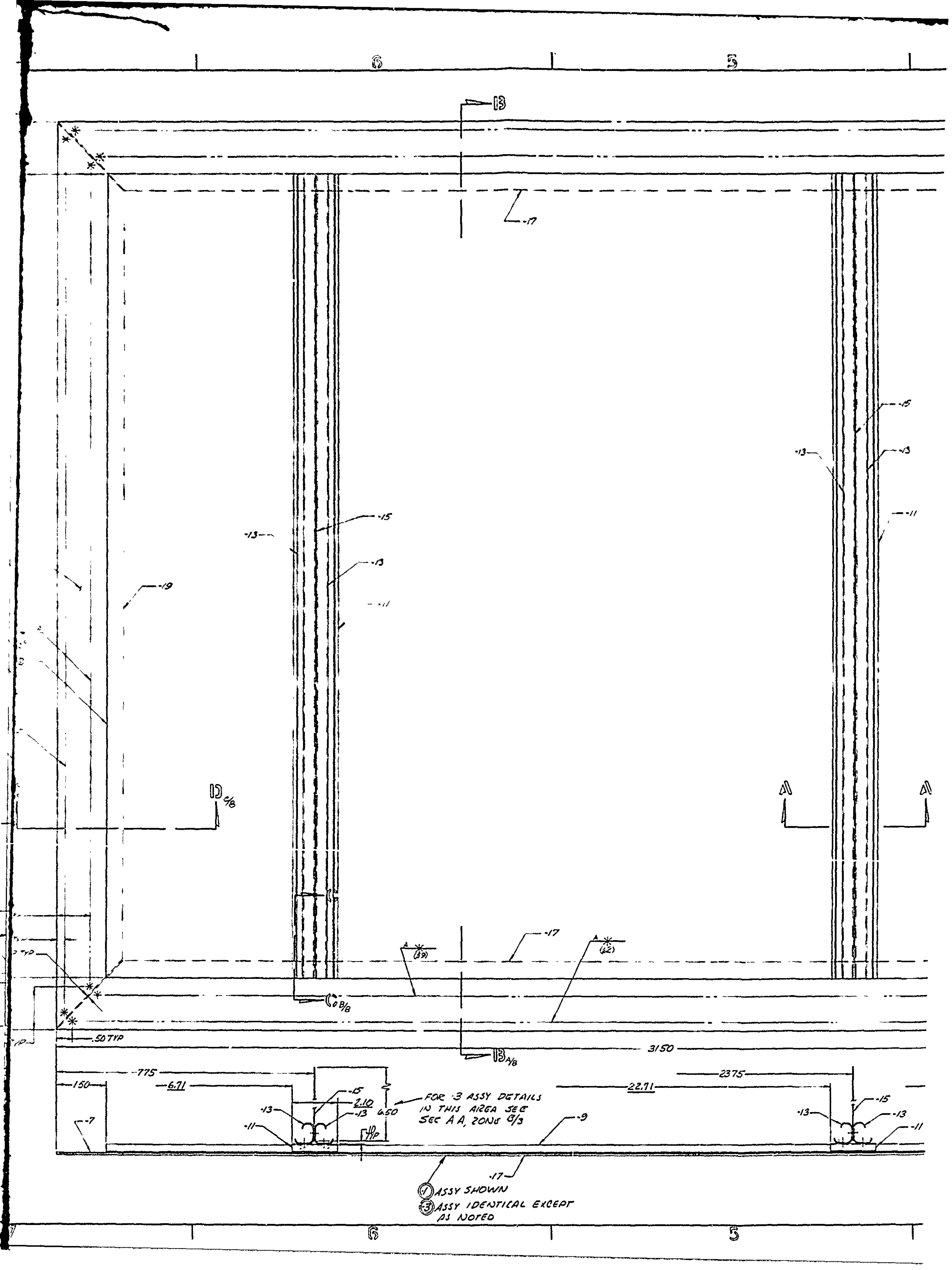
SCALE 1/2 VOIDED

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

SIZE J DWG 29-01009
SHEET 1 OF 1

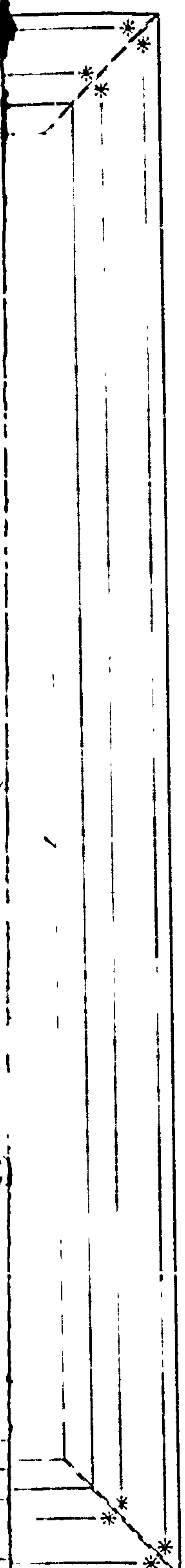
Figure E-2 - COMPRESSION TEST PANEL; Uninterrupted Corrugation - Engineering Drawing 29-01012

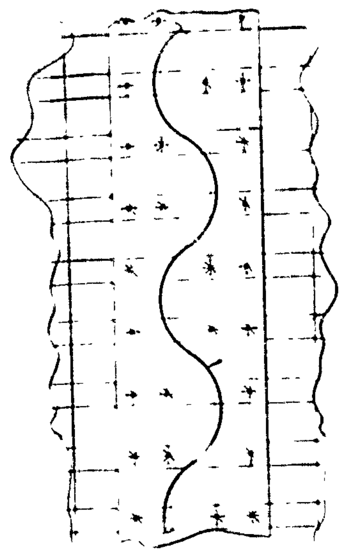

5° TYP
-9
.064 R TYP
250
-7
.10 FLAT REF
.25 REF
500
E-E ROTATED 90° COUNTER CLOCKWISE (TYP FOR ALL CORRUGATIONS)
SCALE 4/1
.12 TYP
-9
DOUBLER -19
2.00
-7
D-D
-7
-11 DOUBLER
-13
-9
-15
-13
-17
.25 TYP
.30
C-C
SCALE 2/1
WEB -15
-13 CHANNEL
-13
.35
.13
.15
.12R TYP
.60
.15
-7
-9
-11
.31
.62
1.05
℄ SYM.
A-A
SCALE 2/1
-2 -1 ASSY ONLY
2.00 REF
1.50 REF
-17
FACE SHEET -7
45 EQUAL SPACES
24.50 REF
-9 CORRUGATION
2.00
26.00 REF
.25 TYP
DOUBLER -17
B-B
1.50
24.50
26.00

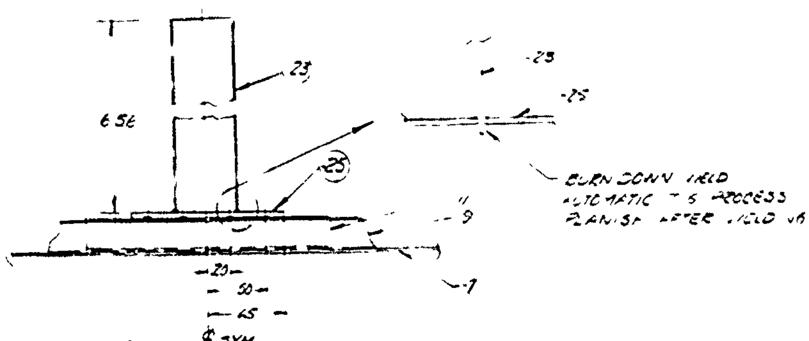

6
5
-17
-15
-13
-13
-13
-11
-19
-11
-17
.50 TYP
3150
775
2375
150
6.71
22.71
2.10
6.50
-7
-9
-11
-13
-15
-17
FOR -3 ASSY DETAILS IN THIS AREA SEE SEC A A, ZONE G/3
-1 ASSY SHOWN
-3 ASSY IDENTICAL EXCEPT AS NOTED

REVISIONS

SYM	DESCRIPTION	ZONE	DATE	APPROVAL







(A)
SEC A-A FOR -3 ASSY ONLY
SCALE 2/1

(A) 4. -3 ASSY IS IDENTICAL TO -5 ASSY EXCEPT AS SHOWN
3. MAX HYDROGEN CONTENT 200 PPM AFTER ETCHING
2. -9 & -11 CORRUGATION CONFIGURATION SAME AS 29-01011-9 CORRUGATION
1. WELD PER MIL-W-6858, EXCEPT PENETRATION TO BE 40-80%
NOTES:

-3	-21	-1	PART NO	DASH NO	DESCRIPTION
				25	CAP
2				-23	WEL
2				-21	SUB
		1		-19	DOL
2		2		-17	DOU
2		2		-15	WEL
		2		-13	CHA
		4		-11	DOL
2	2			-9	COR
1	1			-7	FAC
1		1			

REQUIREMENTS PER ASSEMBLY

DASH NO	CHG RECORD NO	SERIAL NO	NEXT ASSY	USED ON	DASH NO	CHG RECORD NO	SERIAL NO	NEXT ASSY	USED ON	DASH NO	CHG RECORD NO	SERIAL NO	NEXT ASSY	USED ON
										-3			TEST	
										-1			TEST	

APPLICATION

RIVET CODE PER
F = MFD HEAD FAR SIDE
N = MFD HEAD NEAR SIDE
DIAMETER IN 32NDS
BASIC CODE
NON-STD SUSTL ONLY
D = DIMPLE
NO OF DIMPLED SHEETS
C = COUNTERSINK
LENGTH DASH NO
BASIC CODE

REVISIONS					
EFF ON	GROUP	SYM	DESCRIPTION	ZONE	DATE	APPROVAL
		A	CREATE -3 ASSY & REVISE SPOTWELD SEQUENCE		3/6/[illegible]	

29-01012 A1

Figure E-2 Page 241

29-01012
SHEET 1 OF 1 A
AUTH EWO 0082

-3	-21	-1	PART NO.	DASH NO	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND OR HT TR(ALT)	FINAL	MATL SPECIFICATION	SEE FINISH SPECIFICATIONS	ZONE
2				-25	CAP	.040×1.3×23.0	TITANIUM ALLOY			B120 VCA		
2				-23	WEB	.020×6.6×46.0	TITANIUM ALLOY			B120 VCA		
		1		-21	SUB-ASSY							
2		2		-19	DOUBLER	.032×2.0×26.0	COMM PURE TI	ANNEAL		AMS 4901 B		C/9
2		2		-17	DOUBLER	.032×2.0×31.5	COMM PURE TI	ANNEAL		AMS-4901 B		A/8
		2		-15	WEB	.032×6.5×23.0	TITANIUM ALY	SOL HT	SHT+A	4AL-3MO-1V		A/9
		4		-13	CHANNEL	.032×1.8×23.0						A/9
2	2			-11	DOUBLER	.016×2.1×28.5						C/8
1	1			-9	CORRUGATION	.016×28.5×37.4						A/8
1		1		-7	FACE SHEET	.020×26.0×31.5	TITANIUM ALY	SOL HT	SHT+H	4AL-3MO-1V		C/8

REQUIREMENTS PER ASSEMBLY — LIST OF MATERIAL

APPLICATION: -3 / -1 — NEXT ASSY: TEST / TEST

RIVET CODE PER NAS 523

MANUFACTURING STANDARDS UNLESS OTHERWISE NOTED ON FACE OF DRAWING DIMENSIONS IN INCHES

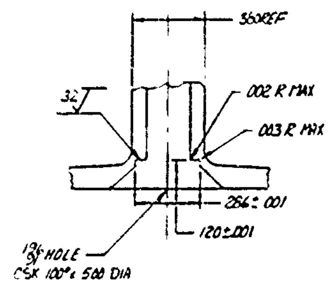
TEST PANEL CORRUGATION UN-INTERRUPTED 4AL-3MO-1V TITANIUM ALLOY

SCALE 1/1 & NOTED

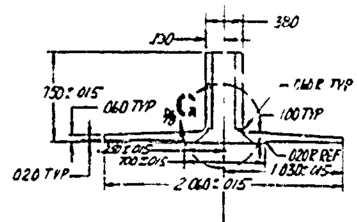
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

J 29-01012
SHEET 1 OF 1

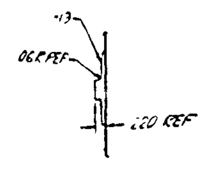
Figure E-3 - COMPRESSION TEST PANEL; Corrugation -
Engineering Drawing 29-01008



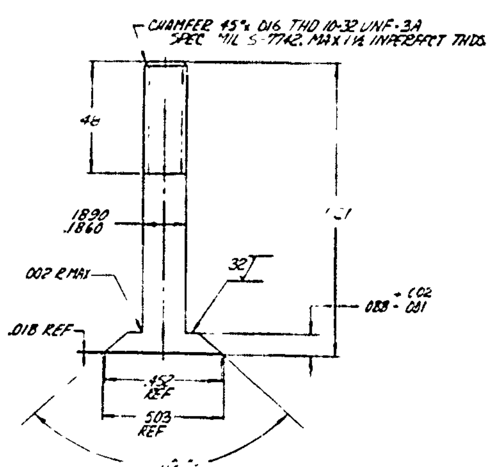
DETAIL G 4/1
SCALE 4/1



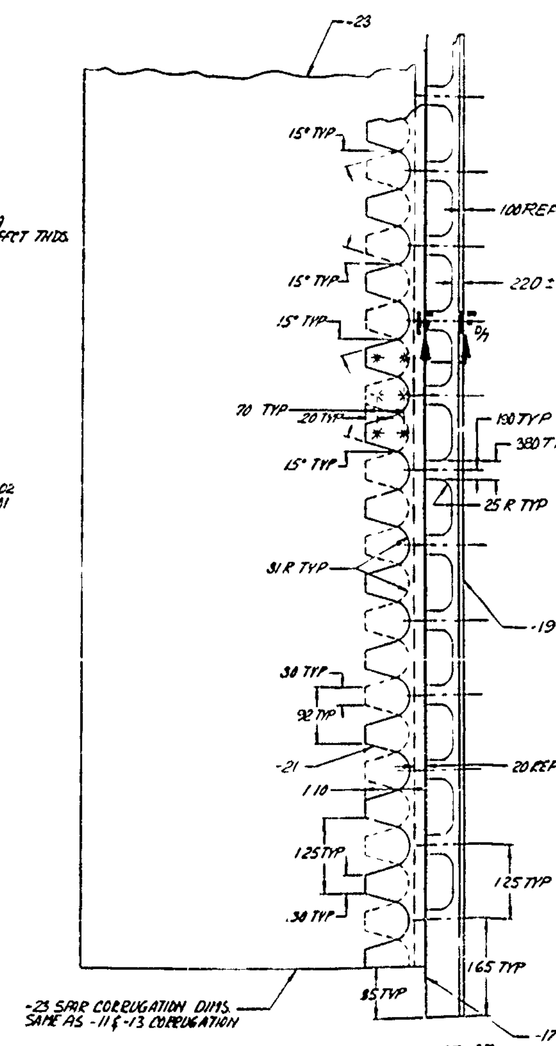
DETAIL -19
SCALE 4/1



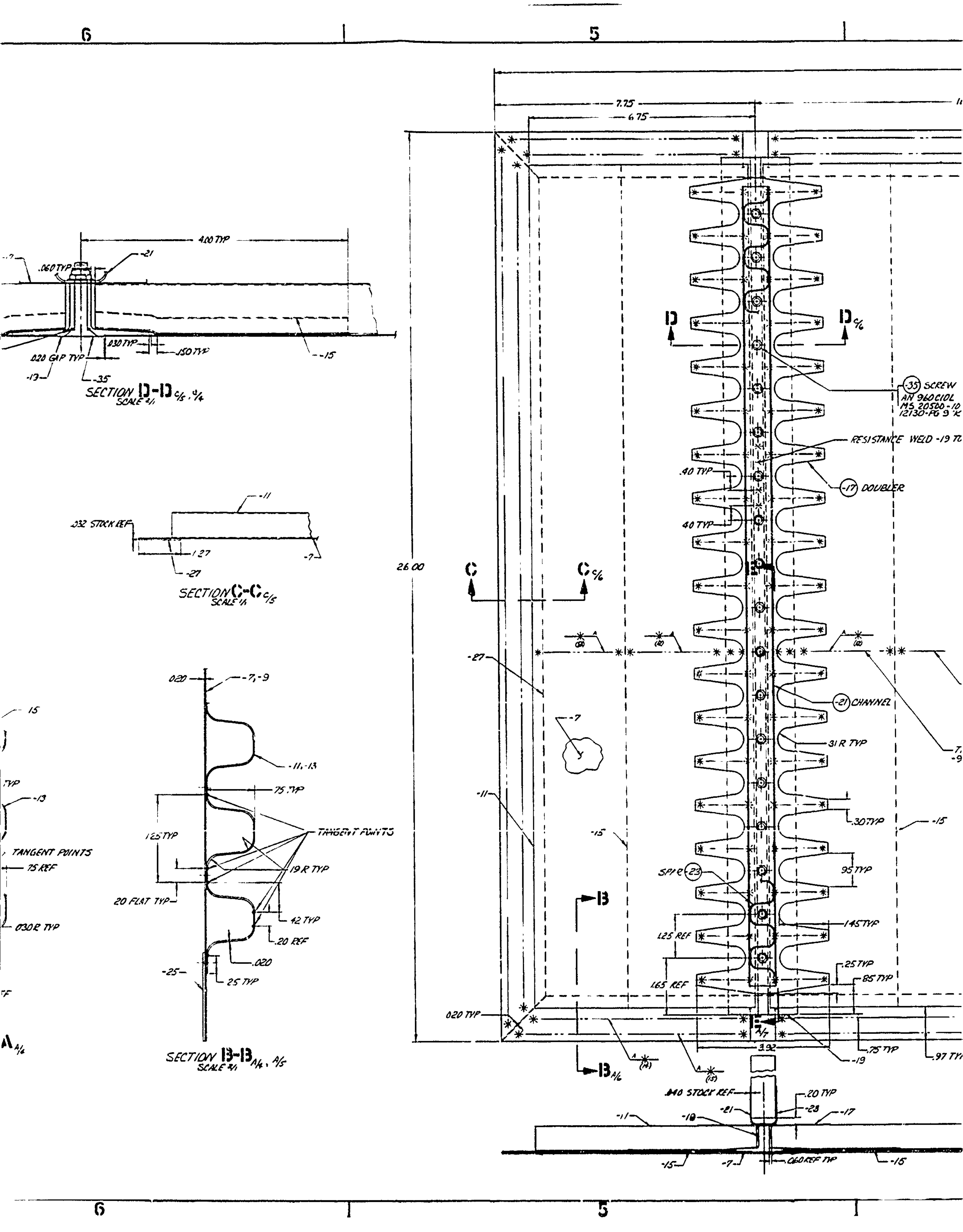
SECTION F-F 4/1
SCALE 1/1



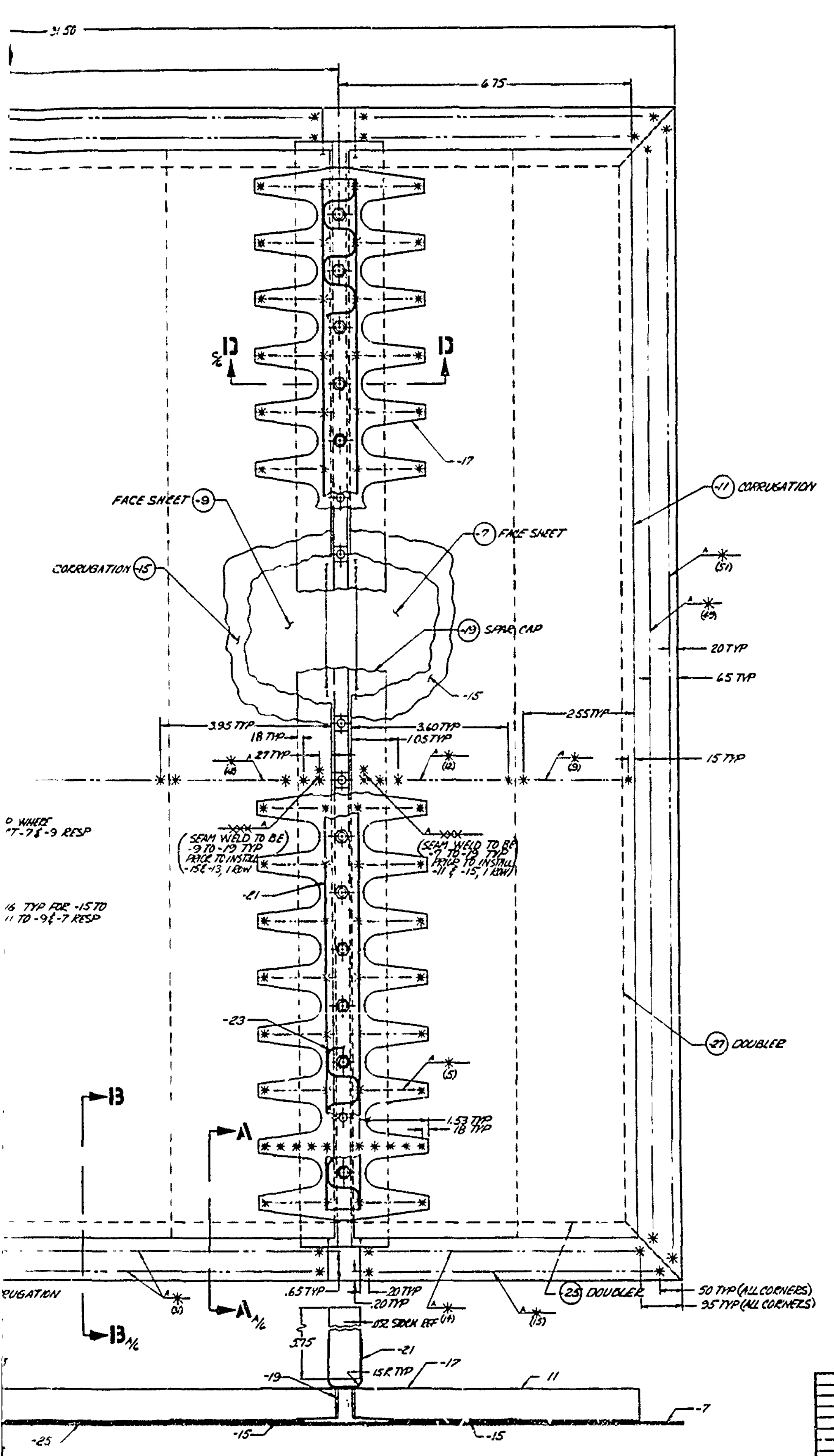
DETAIL -35
SCALE 4/1



SECTION E-E A/5
SCALE 1/1



6
5
4.00 TYP
.060 TYP
-21
.030 TYP
.150 TYP
.020 GAP TYP
-13
-35
-15
SECTION D-D c/5, a/4
SCALE 2/1
-11
.032 STOCK REF
1.27
-27
-7
SECTION C-C c/5
SCALE 1/1
.020
-7, -9
15
-13
-11, -13
.75 TYP
1.25 TYP
TANGENT POINTS
TANGENT POINTS
.75 REF
.19 R TYP
.20 FLAT TYP
.42 TYP
.030 R TYP
.20 REF
.020
-25
.25 TYP
SECTION B-B A/4, A/5
SCALE 3/1
7.75
6.75
26.00
D
D c/6
(35) SCREW
AN 960C10L
MS 20500-10
12130-PG 9 K
RESISTANCE WELD -19 TO
.40 TYP
(17) DOUBLER
.40 TYP
C
C c/6
-27
(21) CHANNEL
-7
.31 R TYP
-11
.30 TYP
-15
-15
SPR (23)
.95 TYP
B
1.25 REF
.145 TYP
.25 TYP
1.65 REF
.85 TYP
.020 TYP
3.92
.75 TYP
-19
.97 TYP
B A/6
.040 STOCK REF
.20 TYP
-21
-23
-17
-11
-19
-15
-7
.060 REF TYP
-15
6
5



7 HEAT TREAT PER SPEC 0-05034

⚠6 ROUGH MACHINE TO MAX 50 BEFORE HEAT TREAT

⚠5 COML PART. HARRISON MANUFACTURING CO. BURBANK

4 MF MEANS MAKE FROM

3 ALL FASTENERS INSTALLED PER CONVAIR 22-00011

2 -19 DESIGNED FOR DYNAMIC ETCHING PER CONVAIR

1 WELD PER MIL-W-6858 EXCEPT PENETRATION TO BE 3

NOTES:

APPLICATION

4 3

29-01008

Req. per Assembly	Part No.	Dash No.	Description	Stock Size	Material	Initial Cond.	Final Cond.	Matl. Specification	Zone
	12130-PG-9 △A		K SEAL						
36	MS 20500-1032		NUT						
36	AN 960 C 10L		WASHER						
36		-35	SCREW	MF N 5664120					B/1
2		-27	DOUBLER	.032 x 1.3 x 26.0	TITANIUM ALY	SOL HT	SHT + A	4AL 3MO-1V	B/3
2		-25	DOUBLER	.032 x 1.3 x 3.75					A/3
1		-23	SPAR	.032 x 3.8 x 23.9					B/5
1		-21	CHANNEL	.020 x 2.8 x 22.8		SOL HT	SHT + A	4AL 3MO-1V	B/6
2		△A -19	SPAR CAP	.75 x 2.1 x 24.5		SEE NOTE 7		6AL-4V SPEC Q C1022	C/4
2		-17	DOUBLER	.032 x 4.0 x 23.3		SOL HT	SHT + A	4AL 3MO-1V	C/5
4		-15	CORRUGATION	.010 x 3.8 x 28.9					C/4
1		-13	CORRUGATION	.025 x 15.6 x 44.3					A/4
2		-11	CORRUGATION	.025 x 6.6 x 46.3					D/3
1		-9	FACE SHEET	.025 x 15.3 x 26.0					C/4
2		-7	FACE SHEET	.025 x 7.4 x 26.0	TITANIUM ALY	SOL HT	SHT + A	4AL 3MO 1V	C/3
-1									

LIST OF MATERIAL

Figure E-3 Page 243

29-01008
SHEET 1 OF 1
EWO 0082

TEST PANEL
CORRUGATION
4AL 3MO 1V
TITANIUM ALLOY

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

J 29-01008
SCALE ½ & NOTED
SHEET 1 OF 1

APPLICATION: TEST

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

IV. TEST SET-UP

The specimens were loaded in compression by a Baldwin-Southwork, 400,000 pound, universal test machine. The vertical sides of the specimens were clamped in the test fixture in a manner which prevented long column buckling at the edges. This clamping action, however, reacted a negligible amount of vertical load from the skin. The test fixture was designed so that air pressure was applied to the stiffened side of the panel during loading. In addition, the fixture provided support for the specimen sub-structure. Normal skin deflection at the geometric center of the panel, as well as vertical movement of the compression heads of the machine were measured by dial indicators. These deflections were taken in an attempt to predict the failure or indicate local buckling before failure occurred.

Installation was as follows:

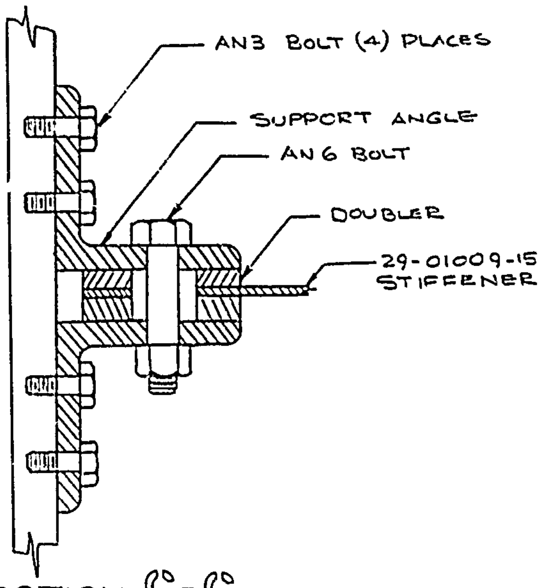
1. <u>29-01009 Test Panel</u>:

A load block applied a compressive load to the -9 stringers and the -7 skin as shown in Figure E-4 (page 247), section B-B. The -13 and -15 stiffeners were supported at the end through slotted holes as shown in Figure E-4, sections A-A and C-C. This can also be seen in the installation photograph, Figure E-5 (page 249). The supporting holes were slotted so that only shear load would be reacted to the fixture.

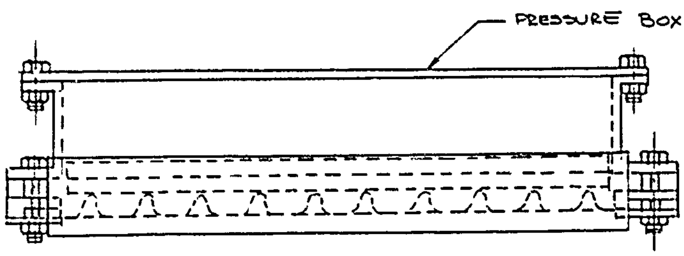
2. <u>29-01012 Test Panel:</u>

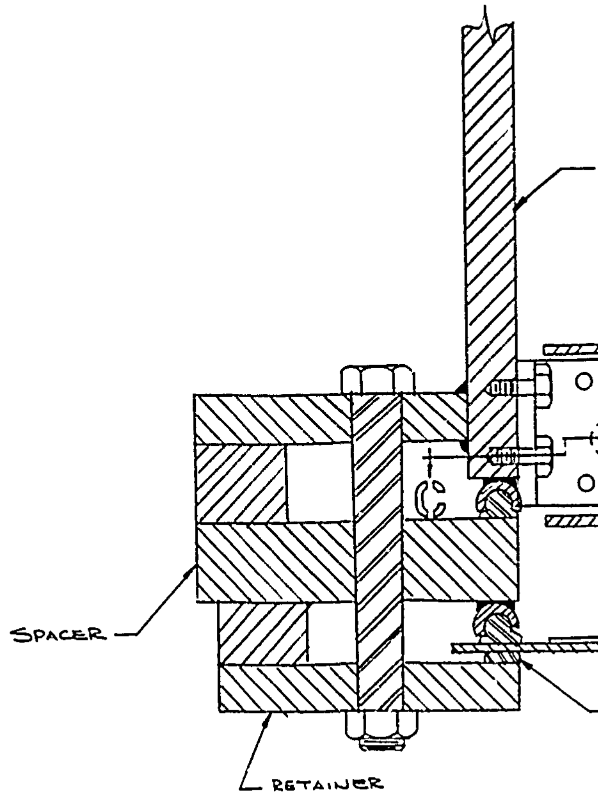
The specimen was mounted as shown in Figure E-6 (page 251). The -23 web was attached to the test fixture as shown in Figure E-6, sections A-A and C-C and also in Figure E-7 (page 253). The specimen was first mounted so that all of the compressive load was applied to the -7 skin as shown in Figure E-6, section D-D. However, since the skin was not of sufficient section to distribute the load into the center of the panel, local buckling occurred at the loaded edges as shown in Figure E-8 (page 254). After the specimen was removed from the jig, a crack was observed in the -23 web as also shown in Figure E-8. A repair was made by spot welding

Figure E-4 - INSTALLATION FOR COMPRESSION TEST
PANEL 29-01009 - Engineering Drawing 30488

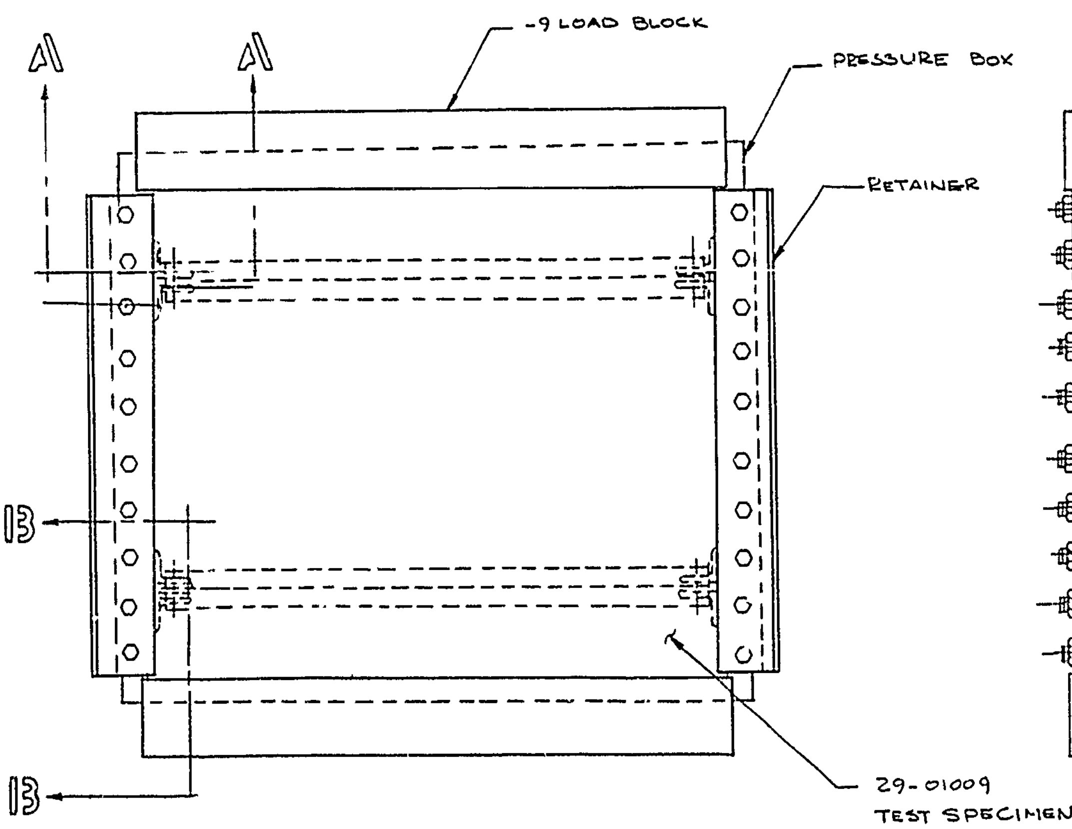


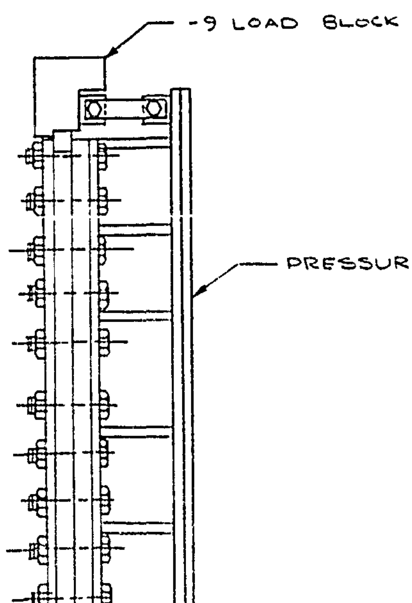
SECTION C-C
FULL SCALE

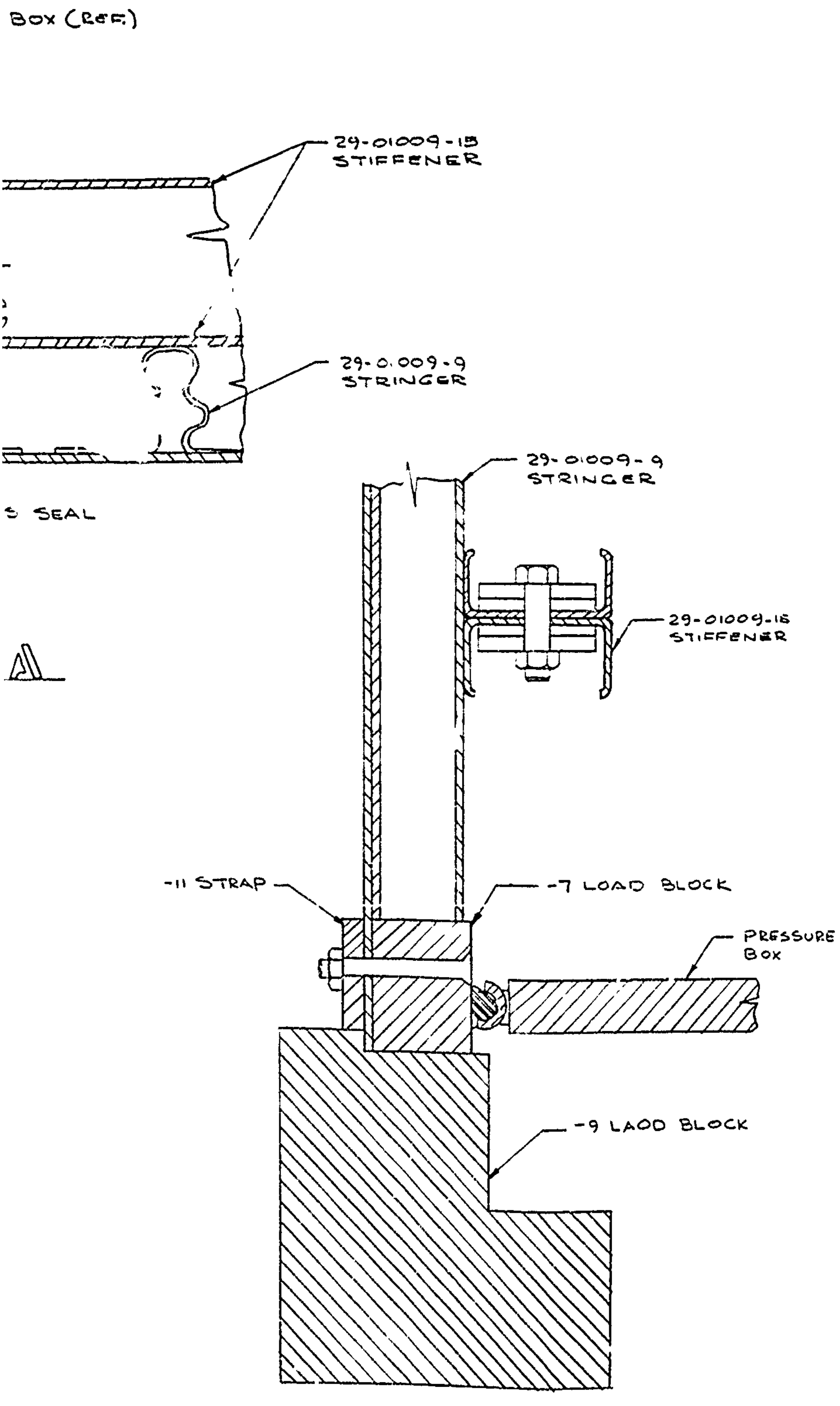




SECTI
FUL







SECTION B-B
FULL SCALE

MACHINE INSTRUCTIONS

1. MACHINE LOADED ENDS OF 29-01009-9 STRINGER FLAT AND PARALLEL.
2. MACHINE LOADING SURFACES OF -7 LOAD BLOCK FLAT AND PARALLEL.
3. INSTALL 29-01009 PANEL IN TEST FIXTURE WITH EXCEPTION OF -9 LOAD BLOCK.
4. WITH SPECIMEN INSTALLED, MACHINE LOADED SURFACE OF -11 STRAP, 29-01009-7 SKIN AND -7 LOAD BLOCK FLAT AND PARALLEL.
5.

Figure E-4 Page 247

STRUCTURAL TEST
CONVAIR SAN DIEGO
A DIVISION OF GENERAL DYNAMICS

SPECIMEN INSTALLATION
29-01009

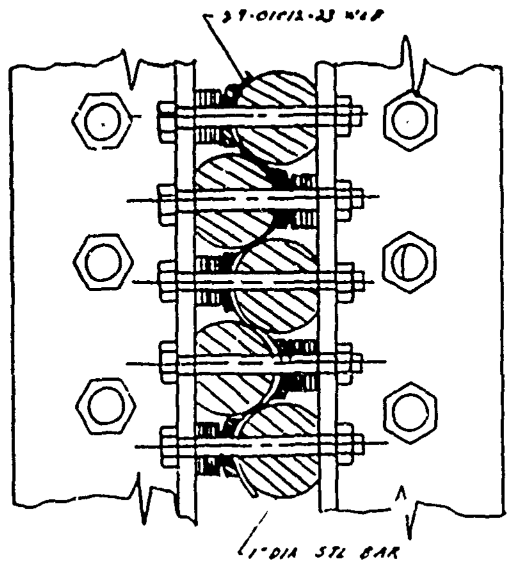
MODEL	SCALE	DATE	DRAWN BY
DODTSRP	1/2 NOTED	12/20/60	J. WILSON T NEARY

SO
WO
DRAWING NO 30488

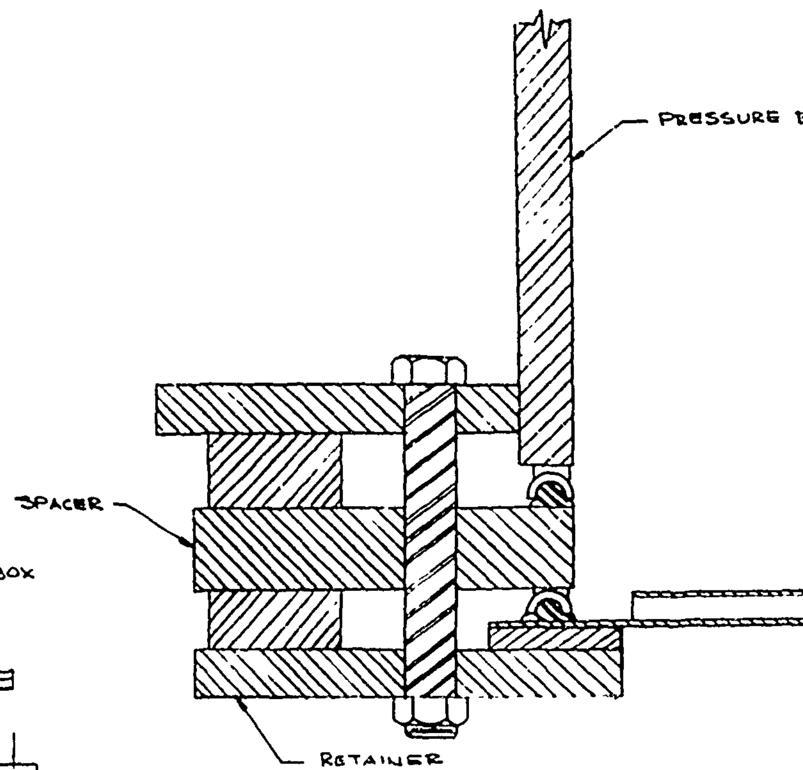
Convair Print 63517

Figure E-5 — SPECIMEN INSTALLATION 29-01009 PANEL; Showing Stiffener Attachment.

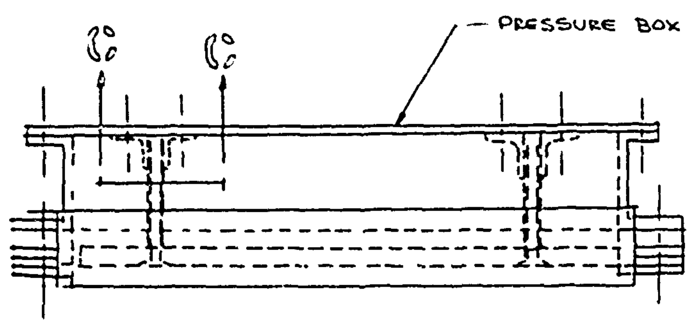
Figure E-6 - INSTALLATION FOR COMPRESSION TEST
PANEL 29-01012 - Engineering Drawing 30489

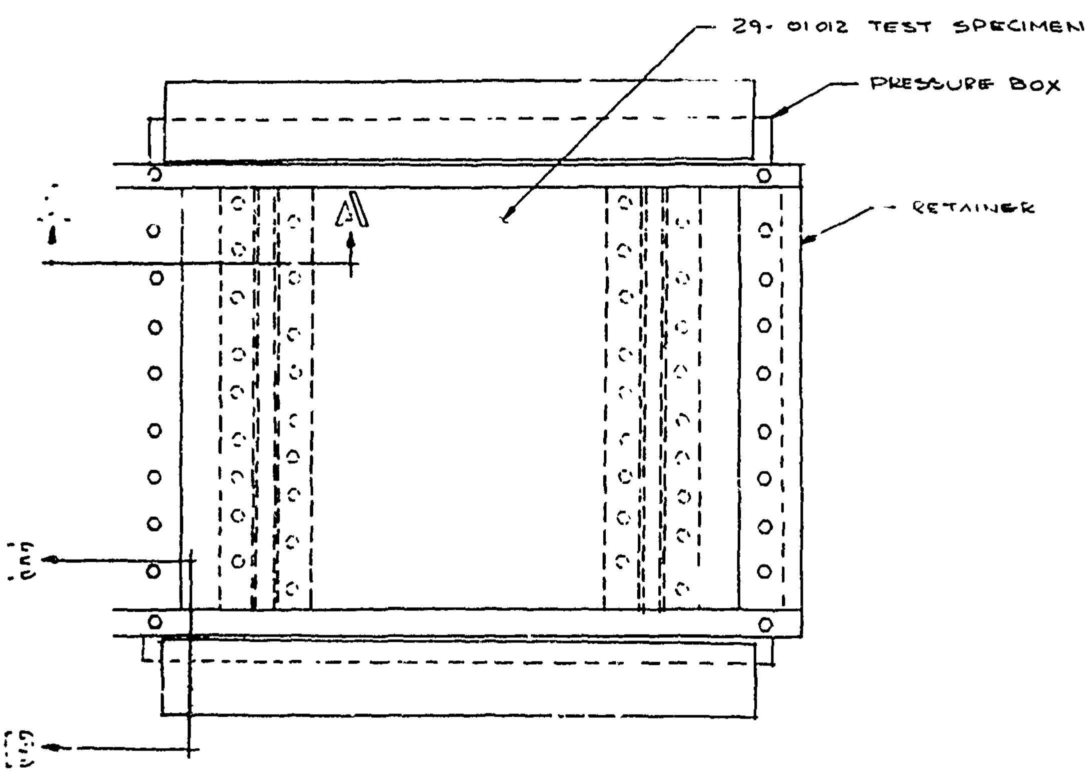


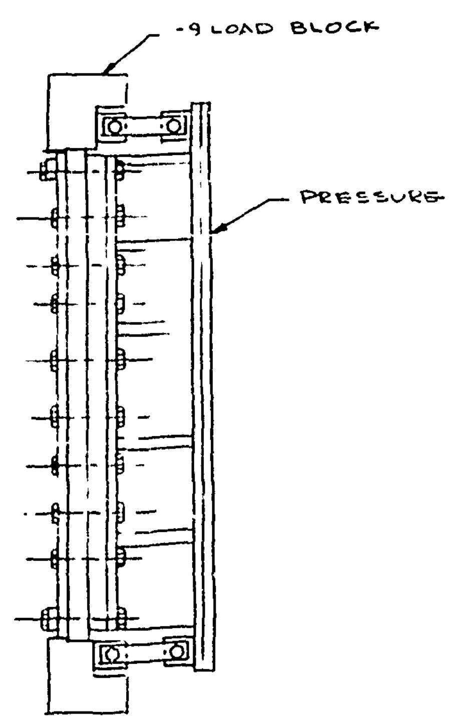
VIEW C-C
FULL SCALE

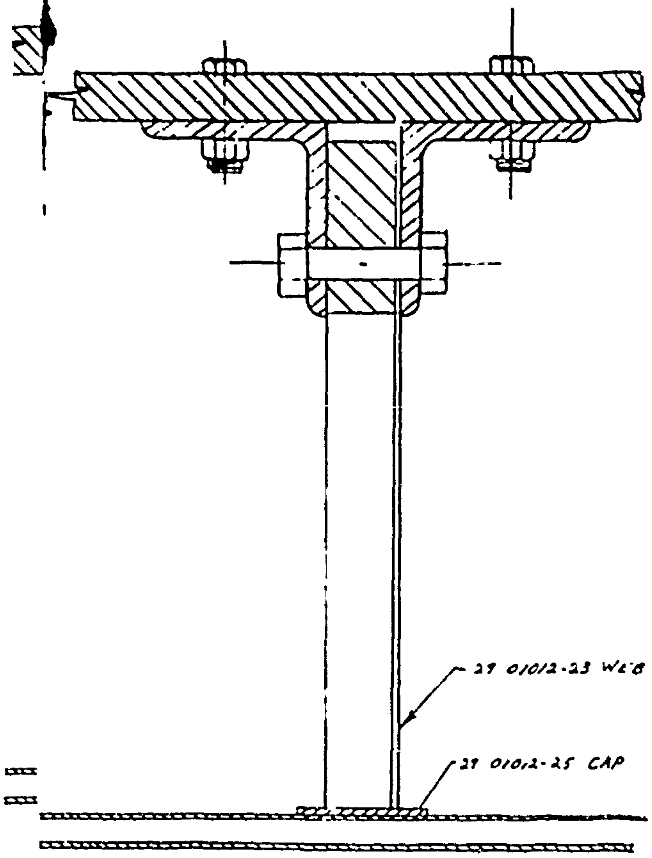


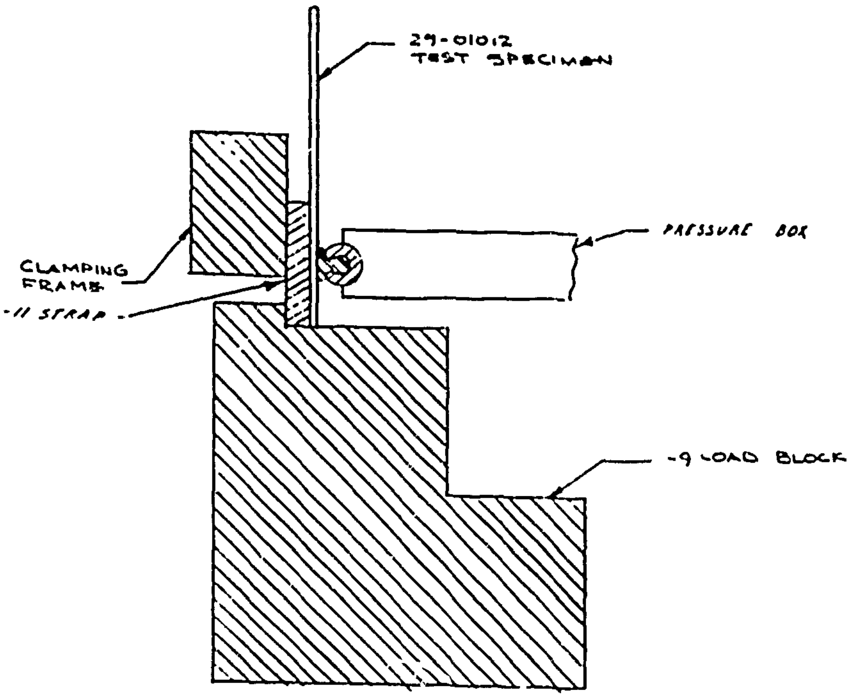
SECTIO
FULL S







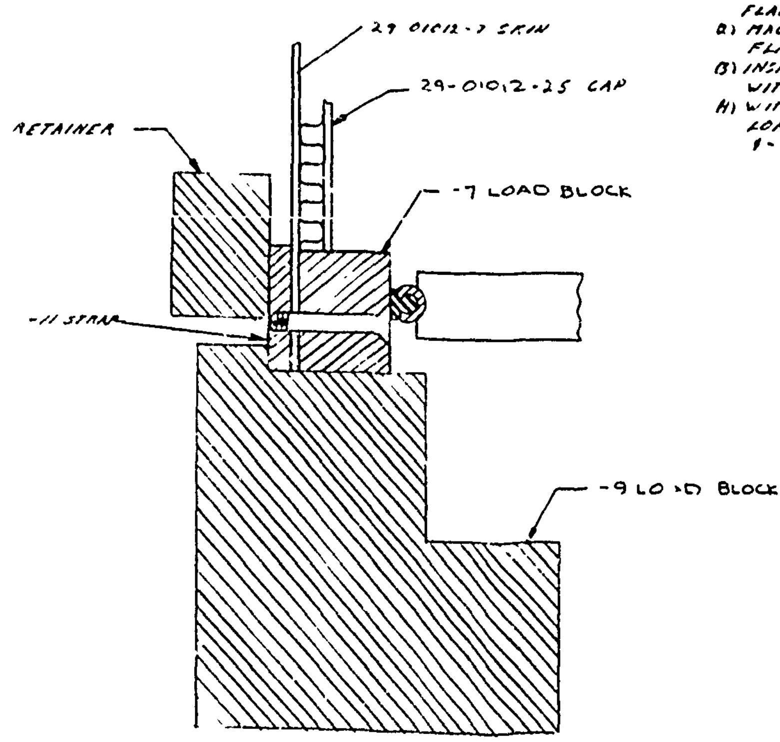




SECTION D - D
FULL SCALE

MACHINE INSTRUCTIONS

1) MACHINE LOADED END OF 29 01012-25 CAP FLAT & PARALLEL
2) MACHINE LOADED SURFACES OF -7 LOAD BLOCK FLAT & PARALLEL
3) INSTALL 29 01012 PANEL IN TEST FIXTURE WITH EXCEPTION OF -9 LOAD BLOCK
4) WITH SPECIMEN INSTALLED, MACHINE COMMON LOADED SURFACE OF 29 01012-7 SKIN, -7 STRAP & -7 LOAD BLOCK FLAT & PARALLEL



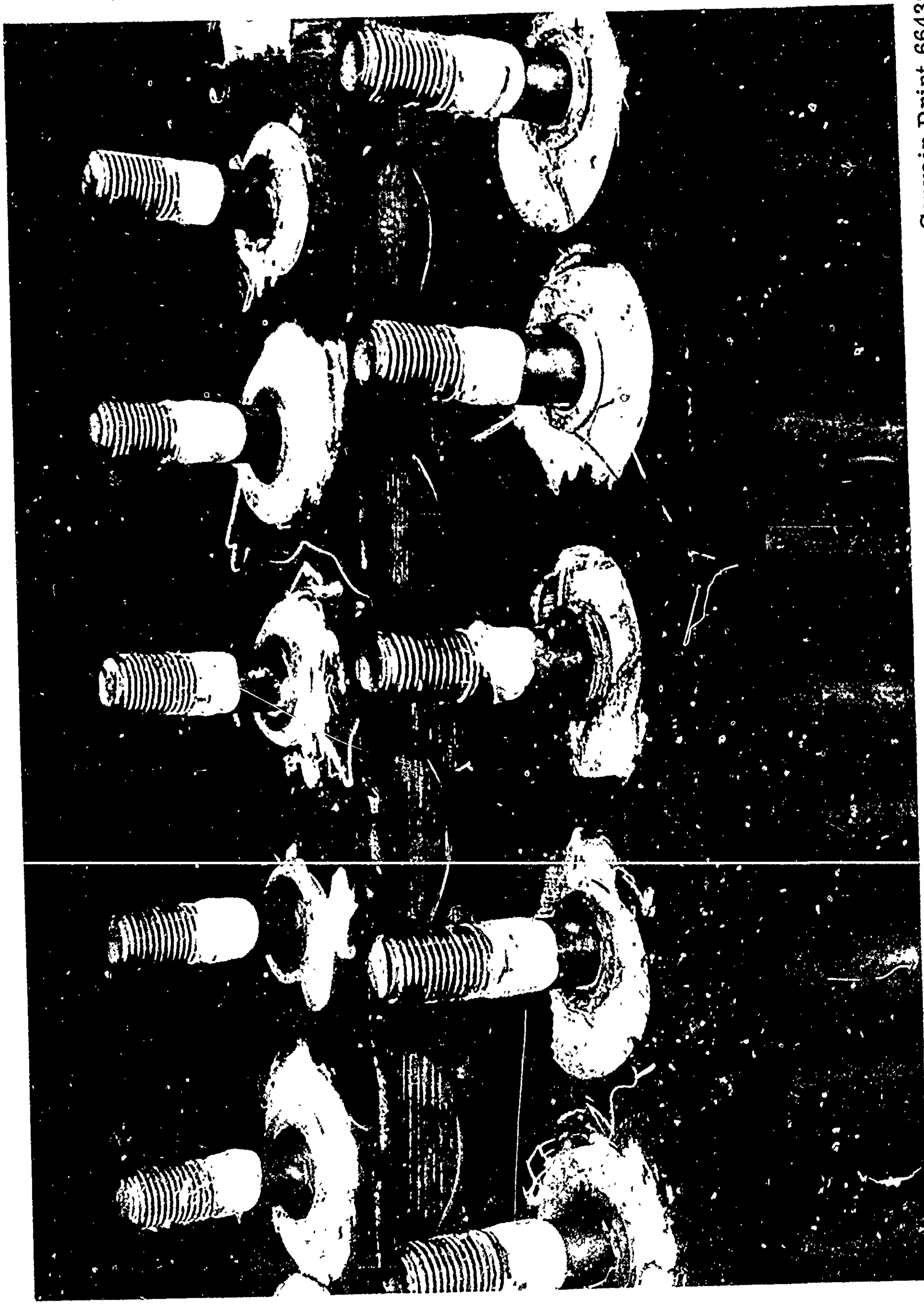
SECTION B - B
FULL SCALE

STRUCTURAL TEST
CONVAIR - SAN DIEGO
A DIVISION OF GENERAL DYNAMICS

SPECIMEN INSTALLATION
29-01012

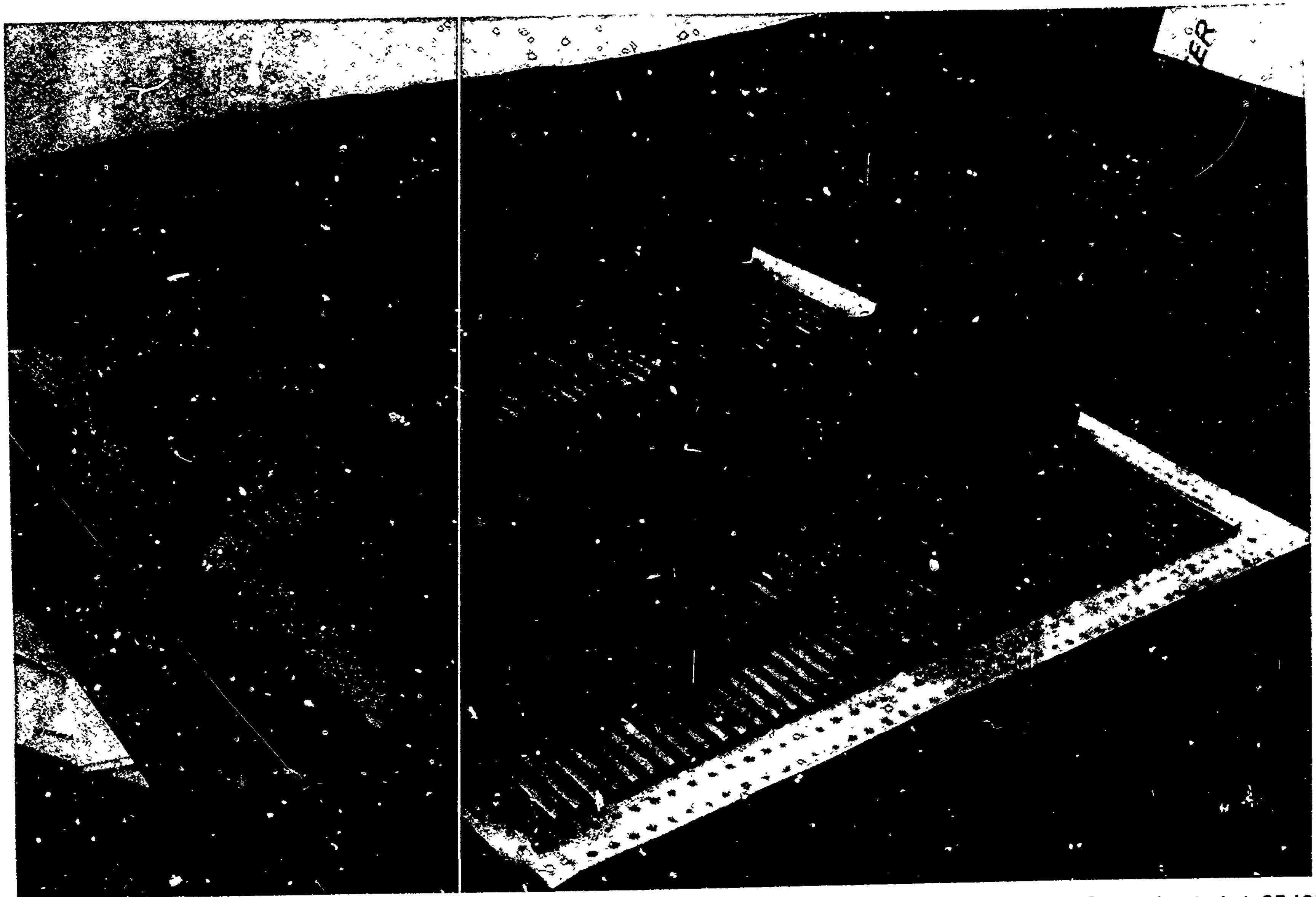
DRAWING NO.
30489

FIGURE E.6



Convair Print 66439

Figure E-7 — SPECIMEN INSTALLATION OF 29-01012 PANEL; Showing Stiffener Attachment.



Convair Print 65487

Figure E-8 — PRELIMINARY FAILURE OF 29-01012 PANEL; Local Skin Buckling.

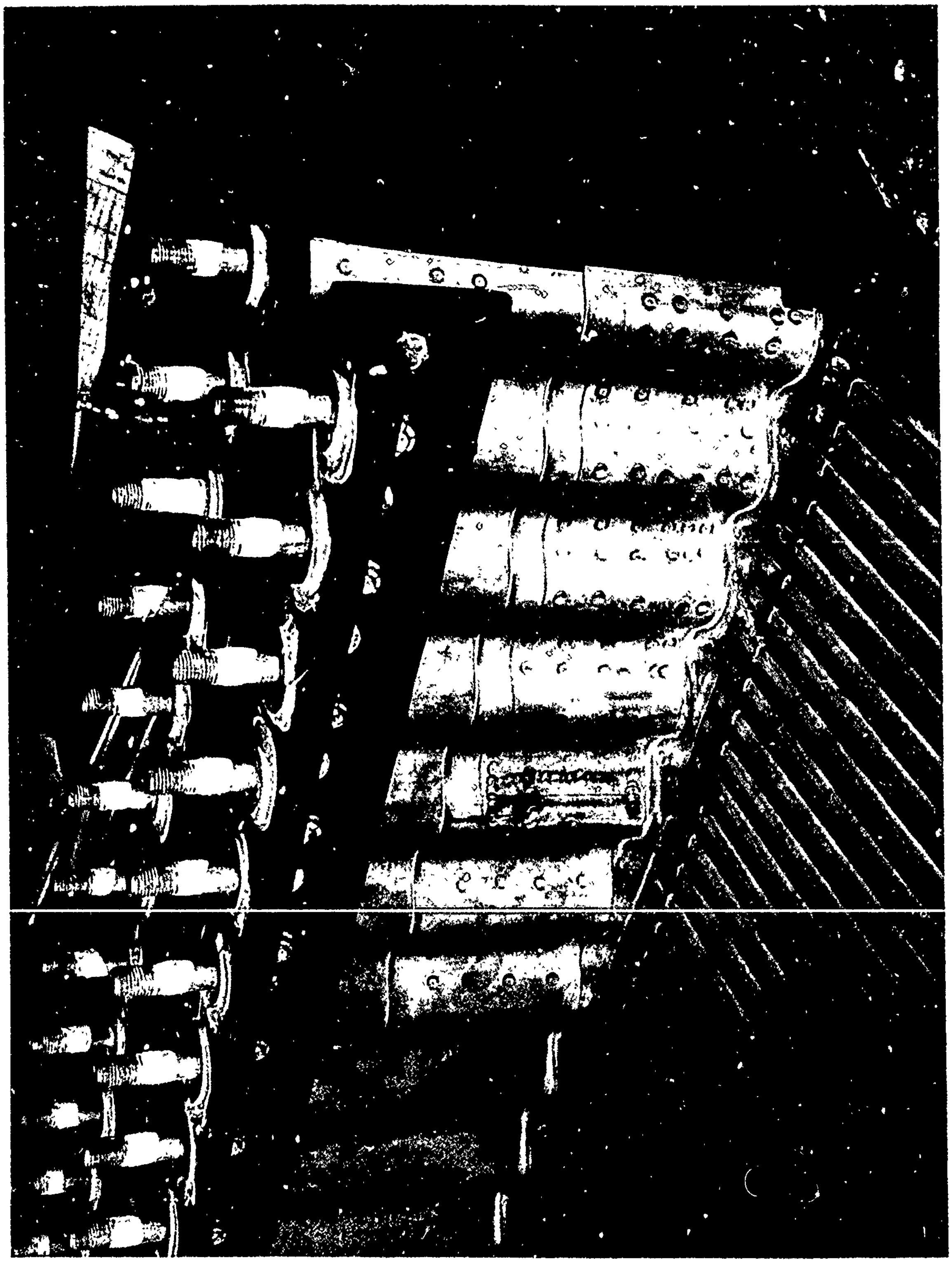
IV. 2. 29-01012 Test Panel: (Cont'd)

an .020" doubler on both sides of the web as shown in Figure E-9 (page 256). The -7 skin was straightened and a .090" thick frame was welded along the edge. The repaired specimen was remounted in the fixture and a load block added to apply a compressive load to the -25 cap as shown in Figure E-6, section B-B. In addition, a retaining bar was placed against the skin at the loaded ends to prevent column buckling (see Figure E-6, section B-B).

3. 29-01018 Test Panel:

The specimen was mounted in the test fixture as shown in Figures E-10 and E-11 (pages 257 and 259). The -21 web was attached to the load fixture as shown in Figure E-10, sections A-A and C-C. Figures E-12 and E-13 (pages 260 and 261) show the specimen and test fixture as mounted in the compression heads.

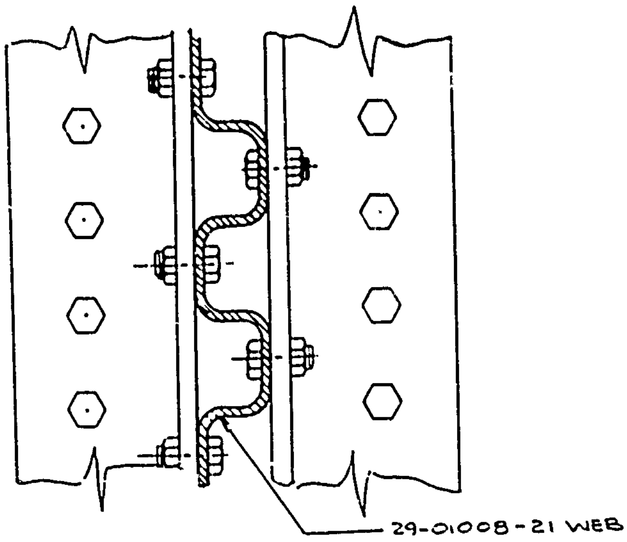
Thermocouples were mounted on the heated side of the panel at three locations as shown in Figure E-14 (page 262). Heat was applied to the unstiffened side of the panel by tubular, quartz, infrared lamps having a maximum heating capacity of 700 BTU/min./sq. ft., Figure E-15 (page 263). The lamp bank produced a constant thermal flux over the entire heated surface of the specimen. No attempt was made to heat the test fixture or compensate for edge cooling and chimney effect, caused by natural convection inside the lamp bank. Power to the lamps necessary to produce the correct specimen temperature was controlled as a time-temperature function by a Research, Incorporated heat programmer, utilizing thermocouple No. 2 as the control thermocouple. See Figure E-14 for thermocouple locations.



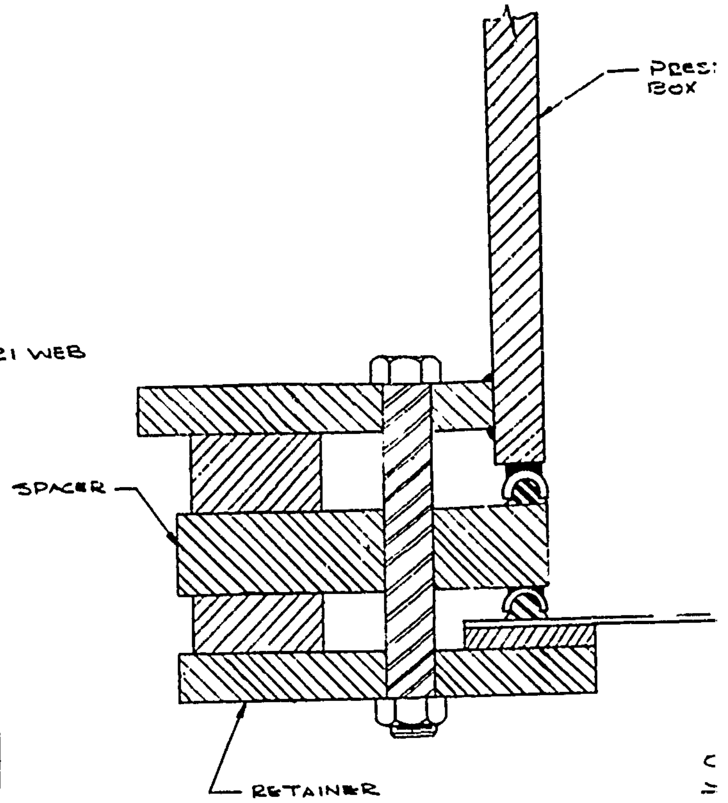
Convair Print 66438

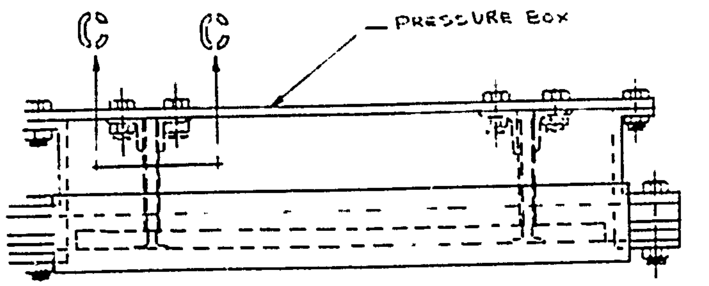
Figure E-9 — SPOT WELDED DOUBLER; Used to Repair Crack in Web of 29-01012 Panel.

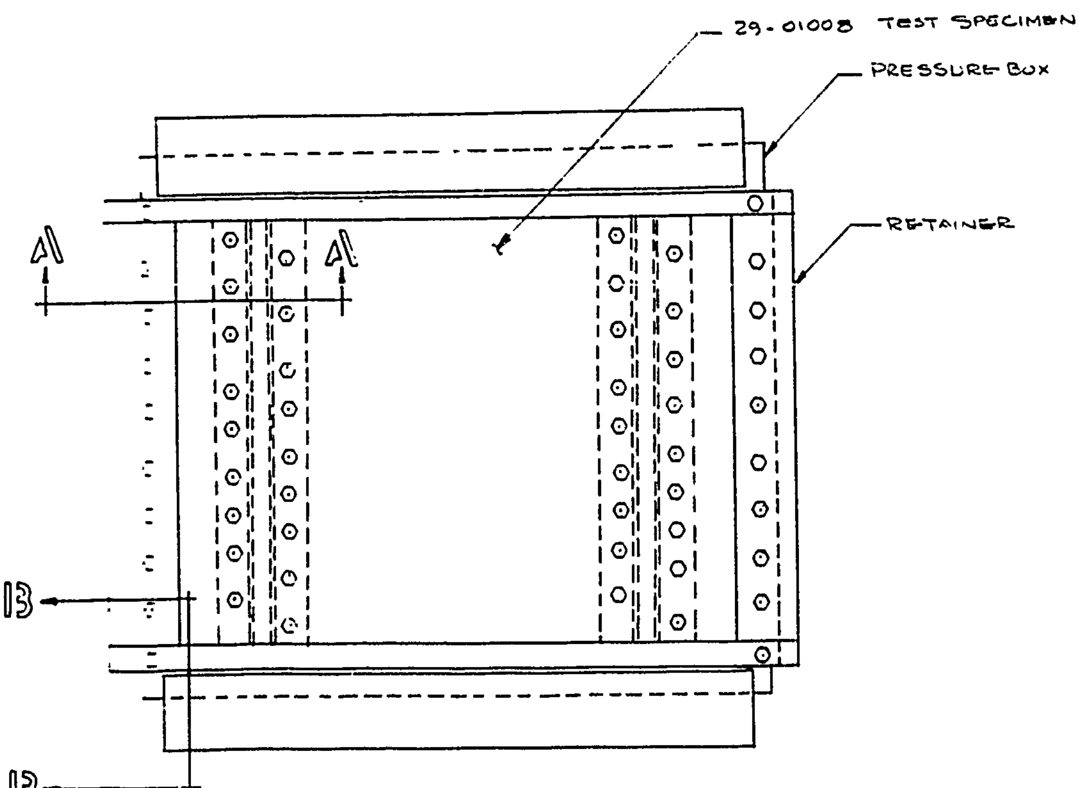
Figure E-10 - INSTALLATION OF COMPRESSION TEST PANEL 29-01008
Engineering Drawing 30487

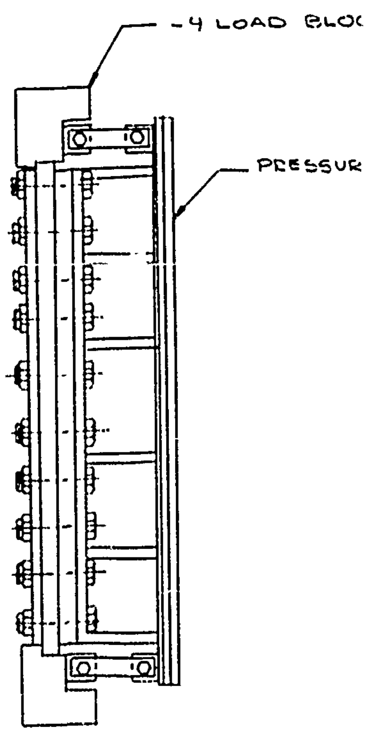

29-01008-21 WEB

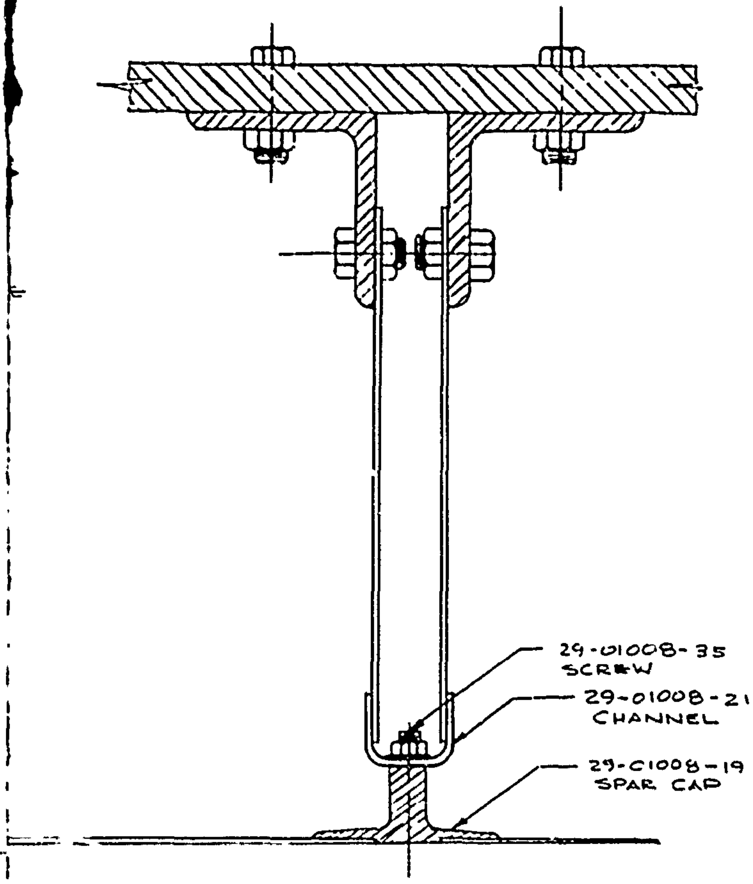
VIEW C-C


BOX
SPACER
RETAINER

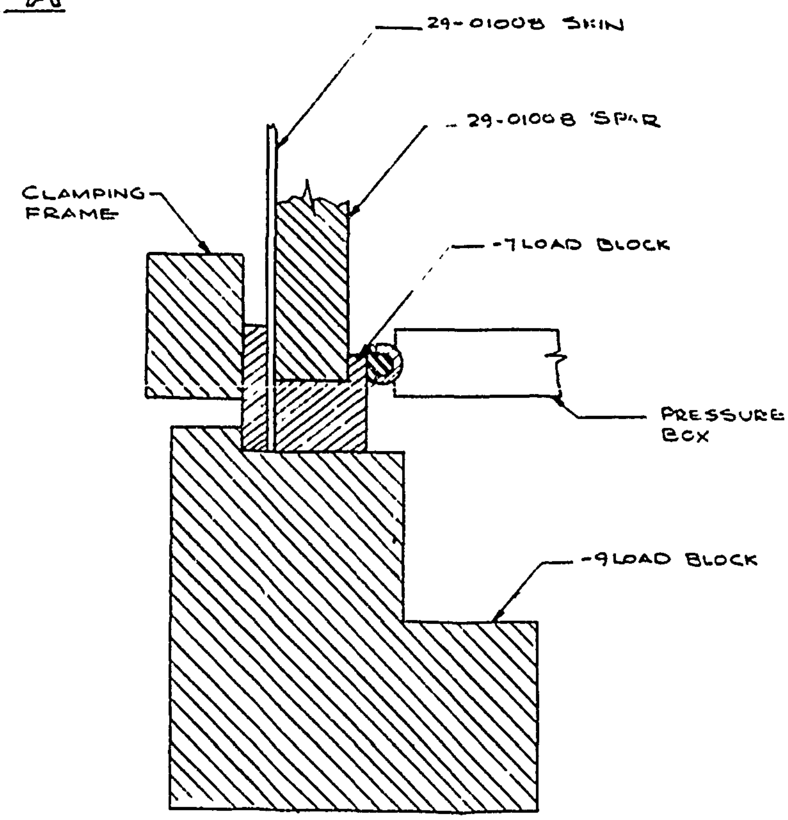

C
C
PRESSURE BOX


29-01008 TEST SPECIMEN
PRESSURE BOX
RETAINER
A
A
B
B


-4 LOAD



SECTION A-A
FULL SCALE



SECTION B-B
FULL SCALE

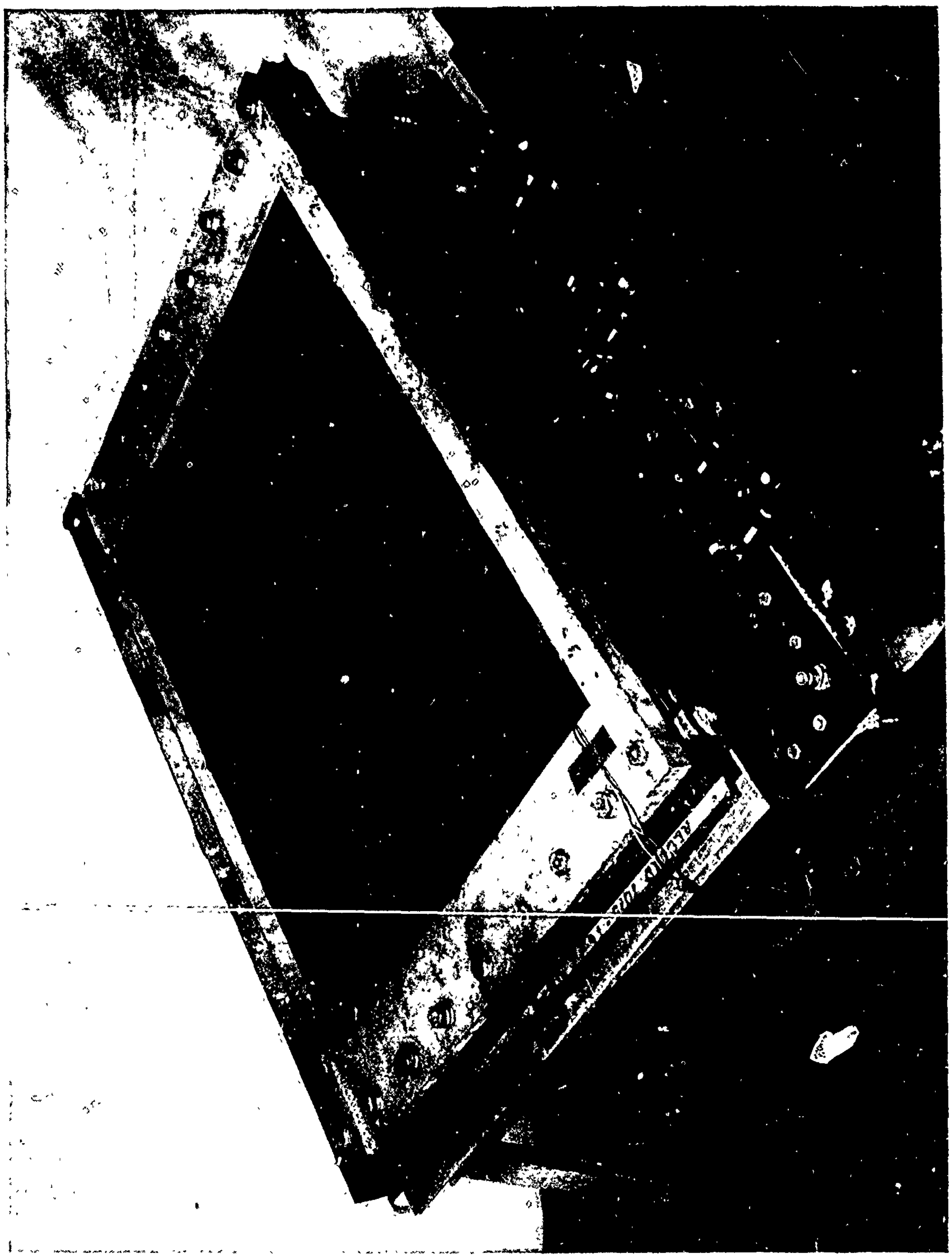
MACHINE INSTRUCTIONS

1. MACHINE LOADED ENDS OF 29-01008-19 SPAR CAP FLAT AND PARALLEL.
2. MACHINE LOADING SURFACES OF -7 LOAD BLOCK FLAT AND PARALLEL.
3. INSTALL 29-01008 PANEL IN TEST FIXTURE WITH EXCEPTION OF -7 LOAD BLOCK.
4. WITH SPECIMEN INSTALLED, MACHINE LOADED SURFACE OF -11 STRAP, 29-01008-7 SKIN 29-01008-9 SKIN, AND -7 LOAD BLOCK FLAT AND PARALLEL.

STRUCTURAL TEST
CONVAIR - SAN DIEGO
SPECIMEN INSTALLATION
29-01008
DRAWING NO
30487

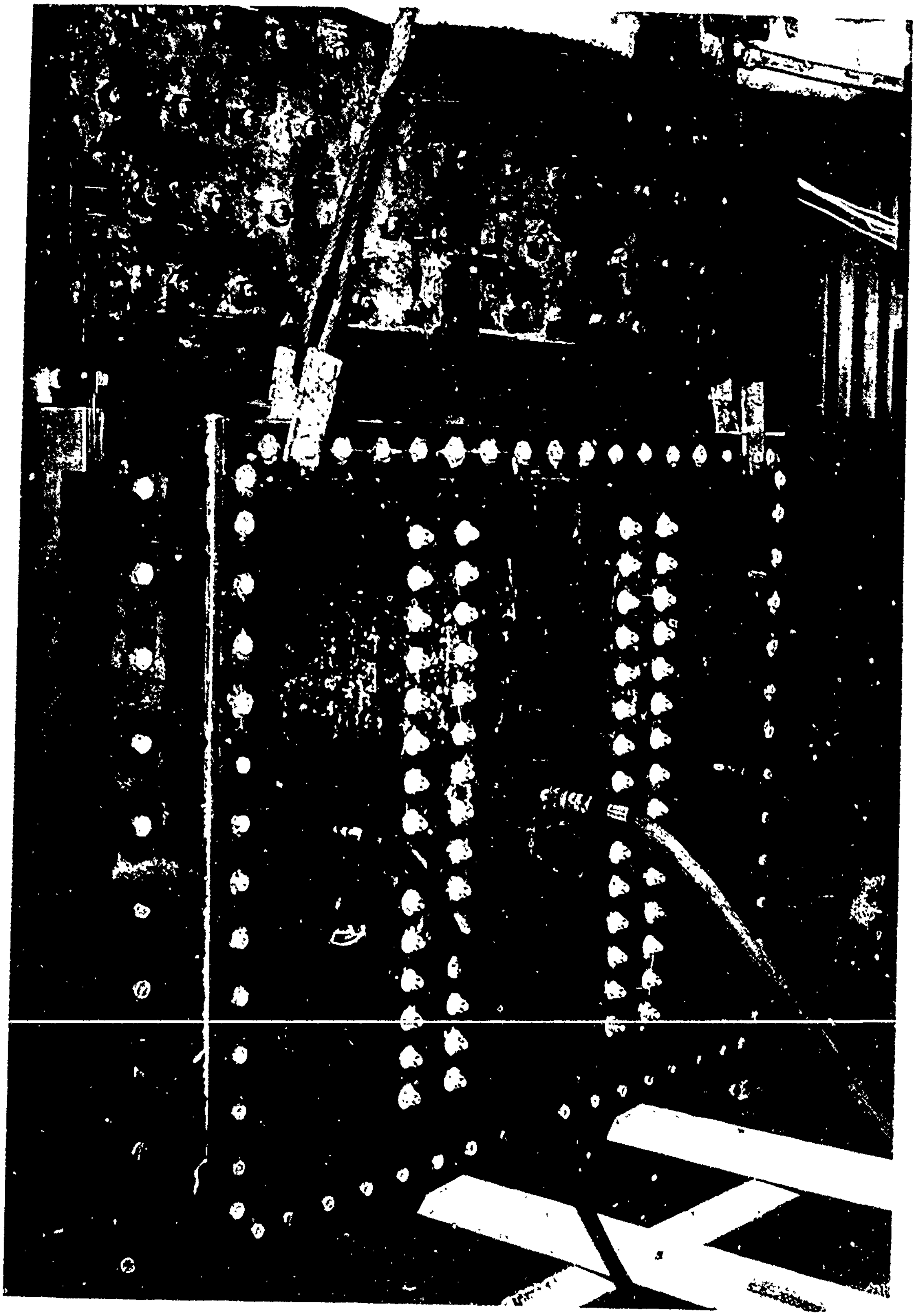
FIGURE E10

67127-1



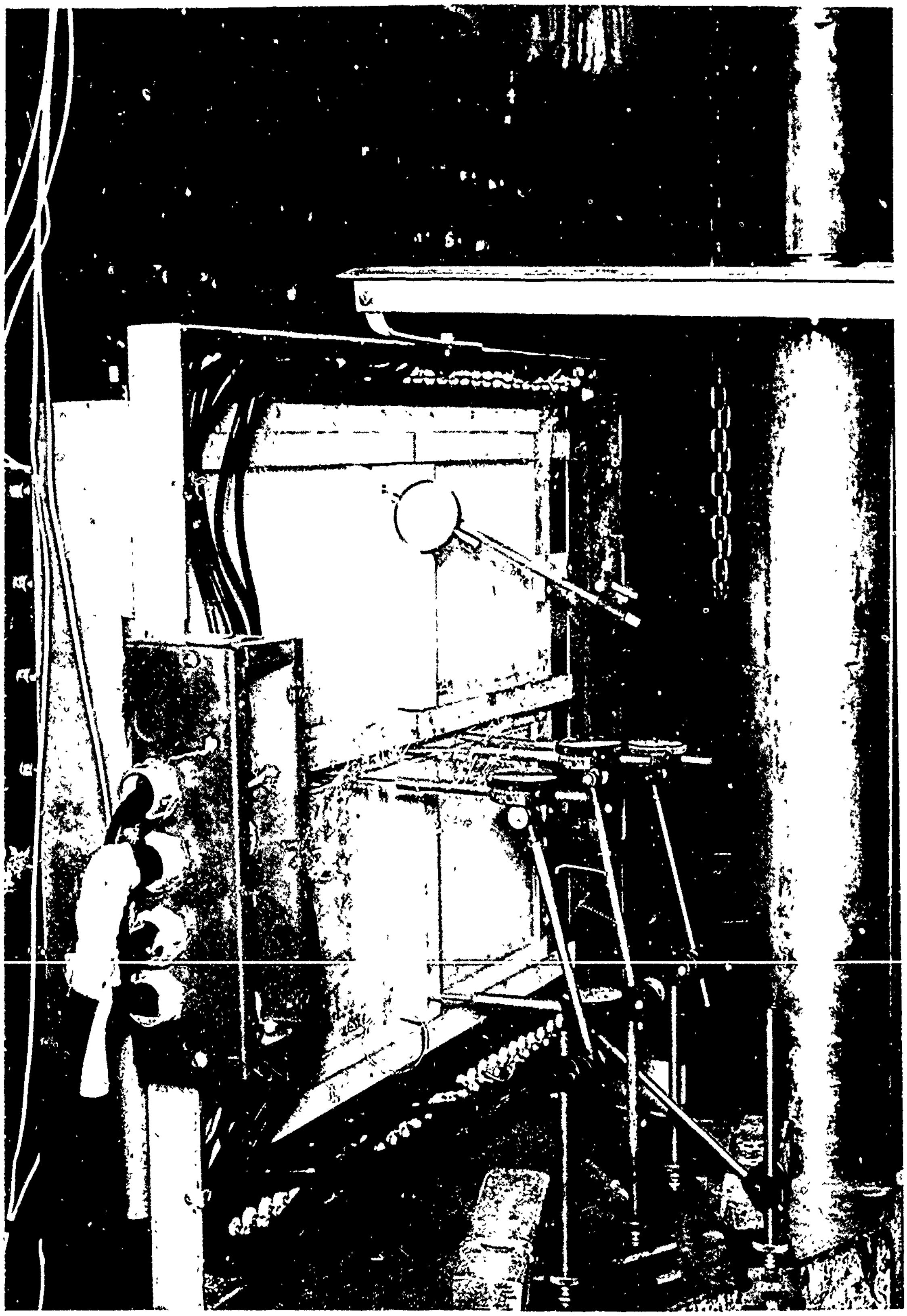
Convair Print 66376

Figure E-11 — SPECIMEN INSTALLATION; 29-01009 Panel.



Convair Print 58696

Figure E-12 – SPECIMEN AND TEST FIXTURE; Mounted In Compression Heads of Test Machine.



Convair Print 58697

Figure E-13 — PANEL TEST SET UP; A General View.

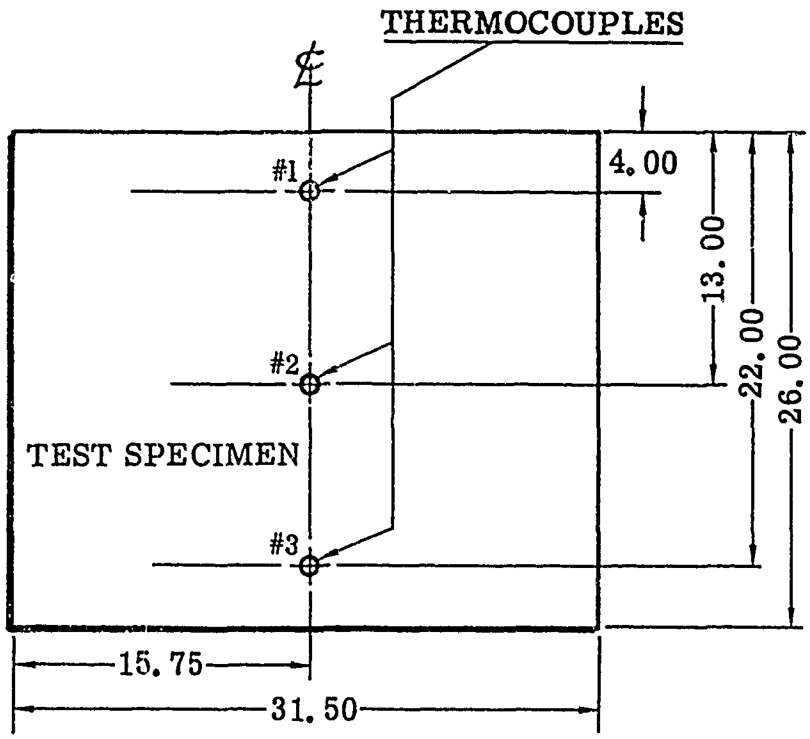
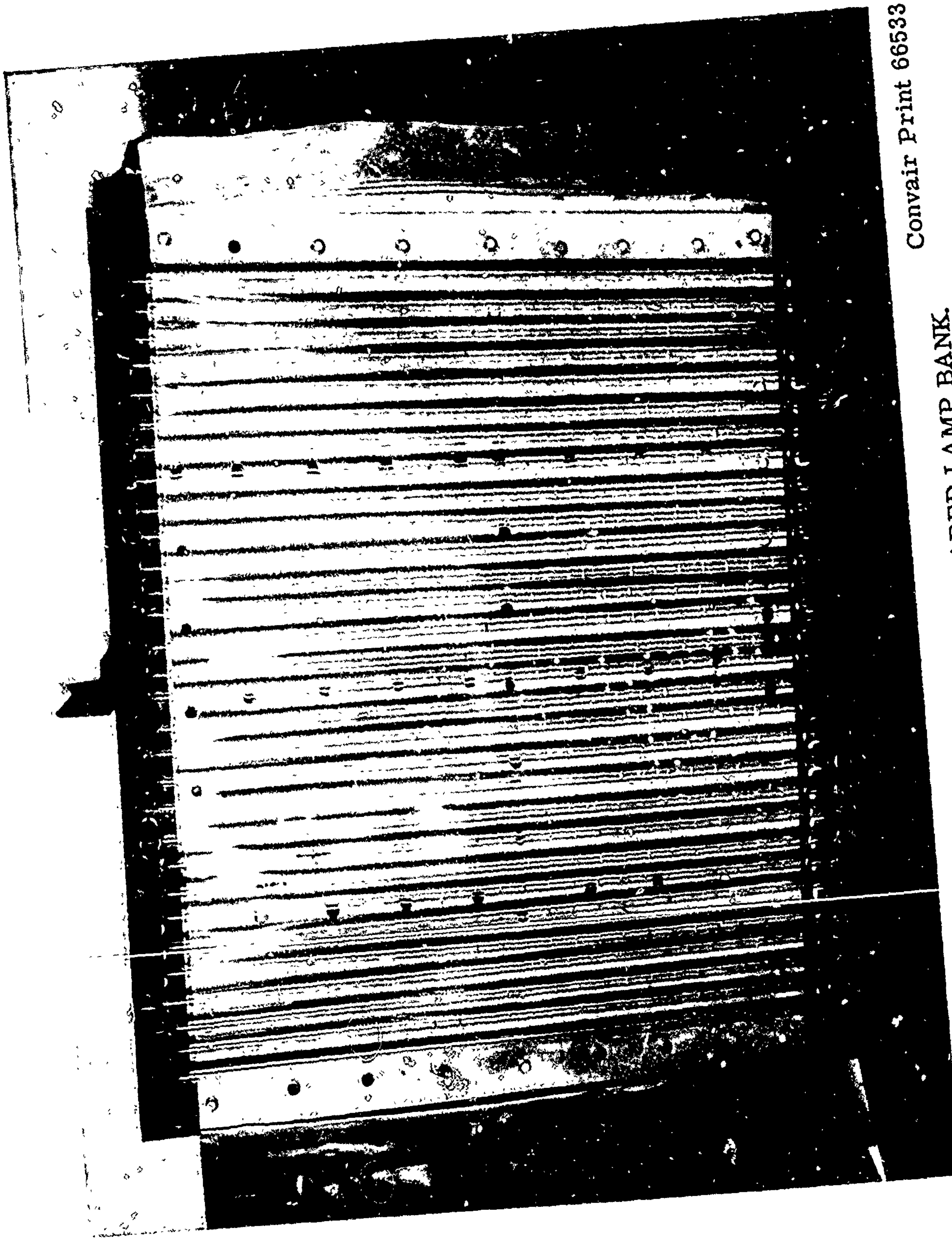


Figure E-14– COMPRESSION TEST PANEL; Showing Locations of Thermocouples.



Convair Print 66533

Figure E-15 — INFRARED LAMP BANK.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

V. TEST PROCEDURE

The following procedure was followed for all specimens tested:

Limit load and pressure were applied at room temperature, 200 F, and at increments of 100 F thereafter through 800 F.

With a temperature of 800 F maintained and limit pressure applied, load was increased until failure occurred.

VI. TEST LOADS

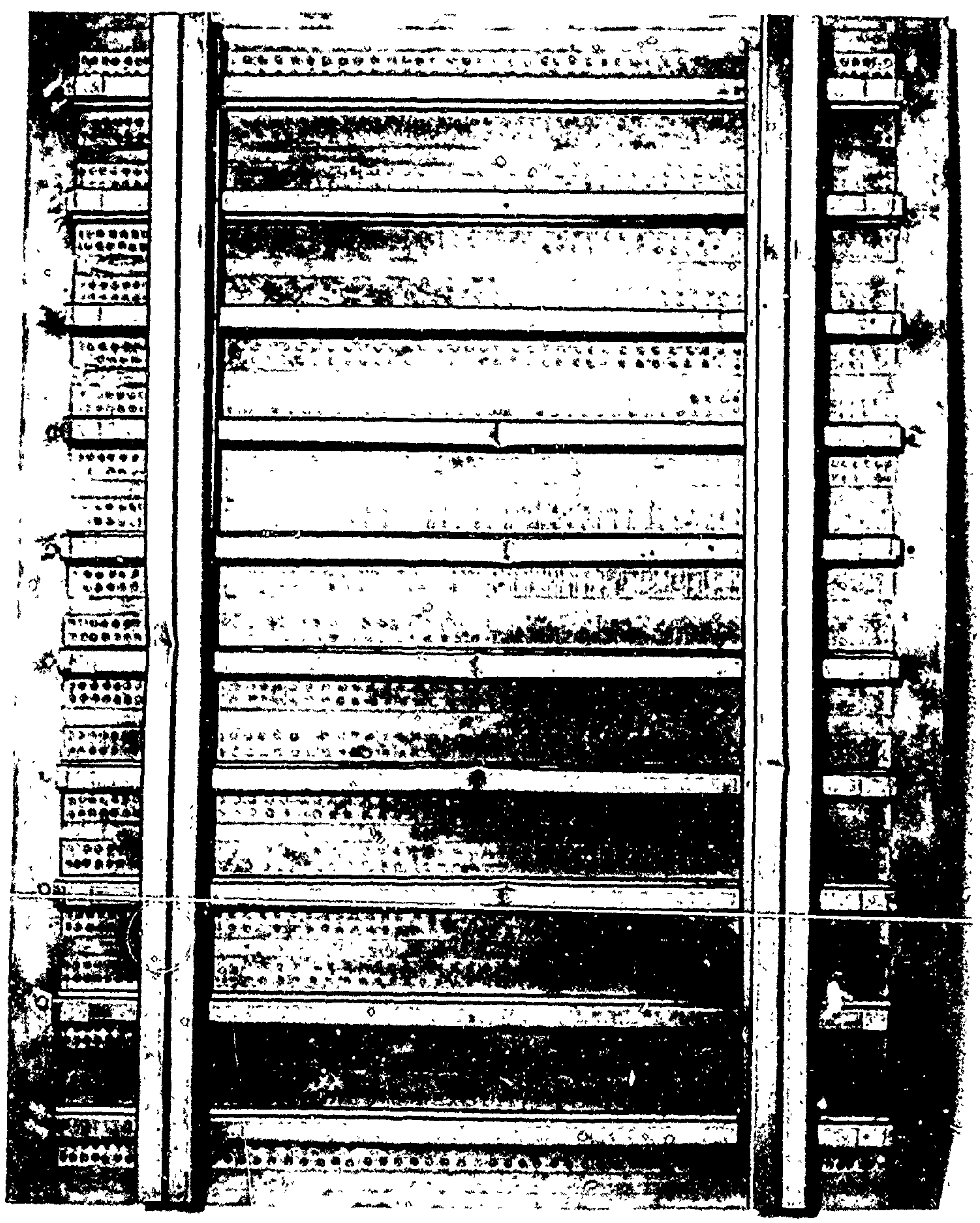
The following design limit loads and pressures at 800 F were calculated prior to testing:

Specimen No.	Design Limit Pressure (PSIG)	Design Limit Load (lb)
29-01009	10	28,000
29-01012	4	36,700
29-01008	10	37,800

VII. TEST RESULTS

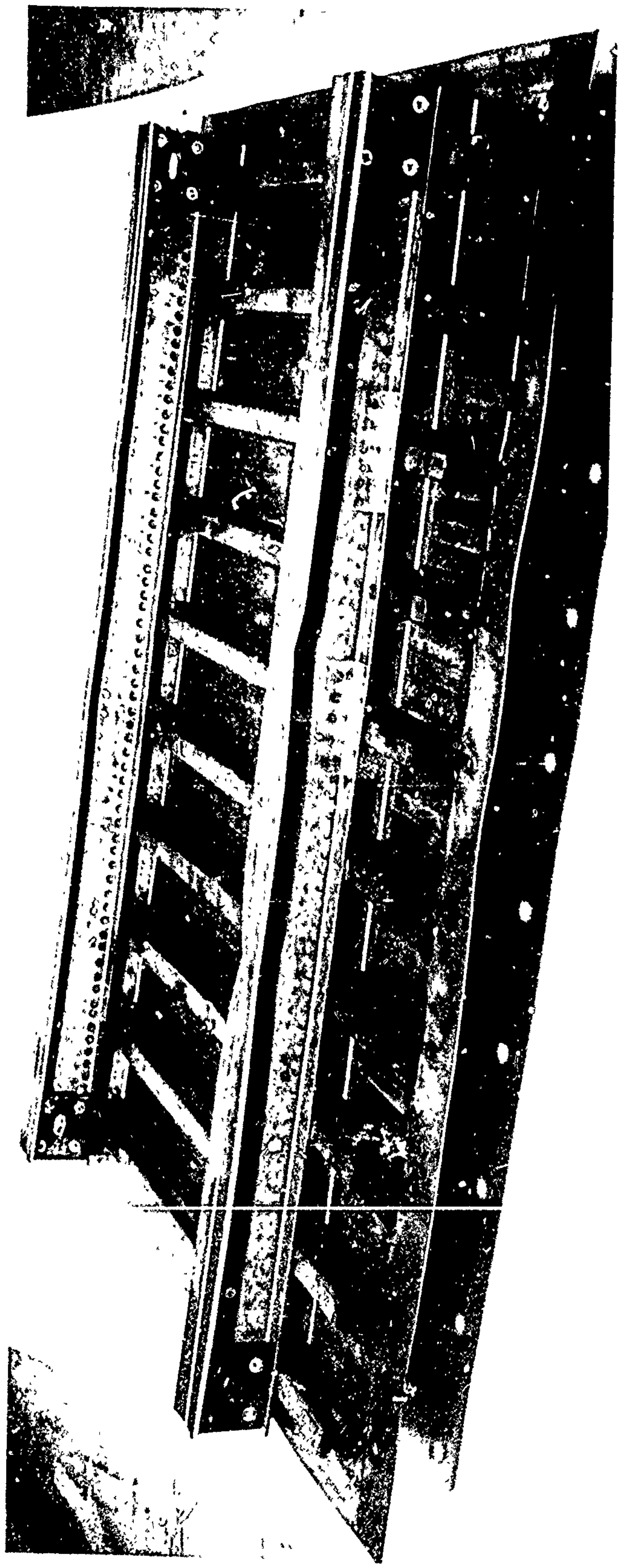
1. 29-01009 Test Panel:

The 29-01009 panel failed with limit pressure of 10 psi applied and a compressive load of 79,000 pounds. Failure is shown in Figures E-16 and E-17 (pages 266 and 267). The failure was due to compressive buckling of the -7 stringers and also the -13 and -15 stiffeners.



Convair Print 63550

Figure E-16 — STATIC FAILURE OF 29-01009 PANEL; Top View, 10 psi at 79,000 lbs & 800F.



Convair Print 63551

Figure E-17 — STATIC FAILURE OF 29-01009 PANEL; Oblique View, 10 psi at 79,000 lbs & 800F.

VII. TEST RESULTS (Cont'd)

2. <u>29-01012 Test Panel:</u>

After the initial repair was made, the specimen failed with limit pressure of 4 PSIG applied and a compressive load of 72,000 pounds. The primary failure was due to compressive buckling of the -7 skin, Figure E-18 (page 269), followed by a secondary failure of the weld between the -23 web and -25 caps, Figure E-19 (page 270). See Figure E-20 (page 271) for an over-all view showing general location of the weld failure.

3. <u>29-01008 Test Panel:</u>

The 29-01008 panel failed with limit pressure of 10 PSI and a compressive load of 36,500 pounds. Failure was due to compressive buckling of the -19 spar followed by a secondary tension failure in the -35 attaching screws. See Figures E-21 and E-22 (pages 272 and 273).

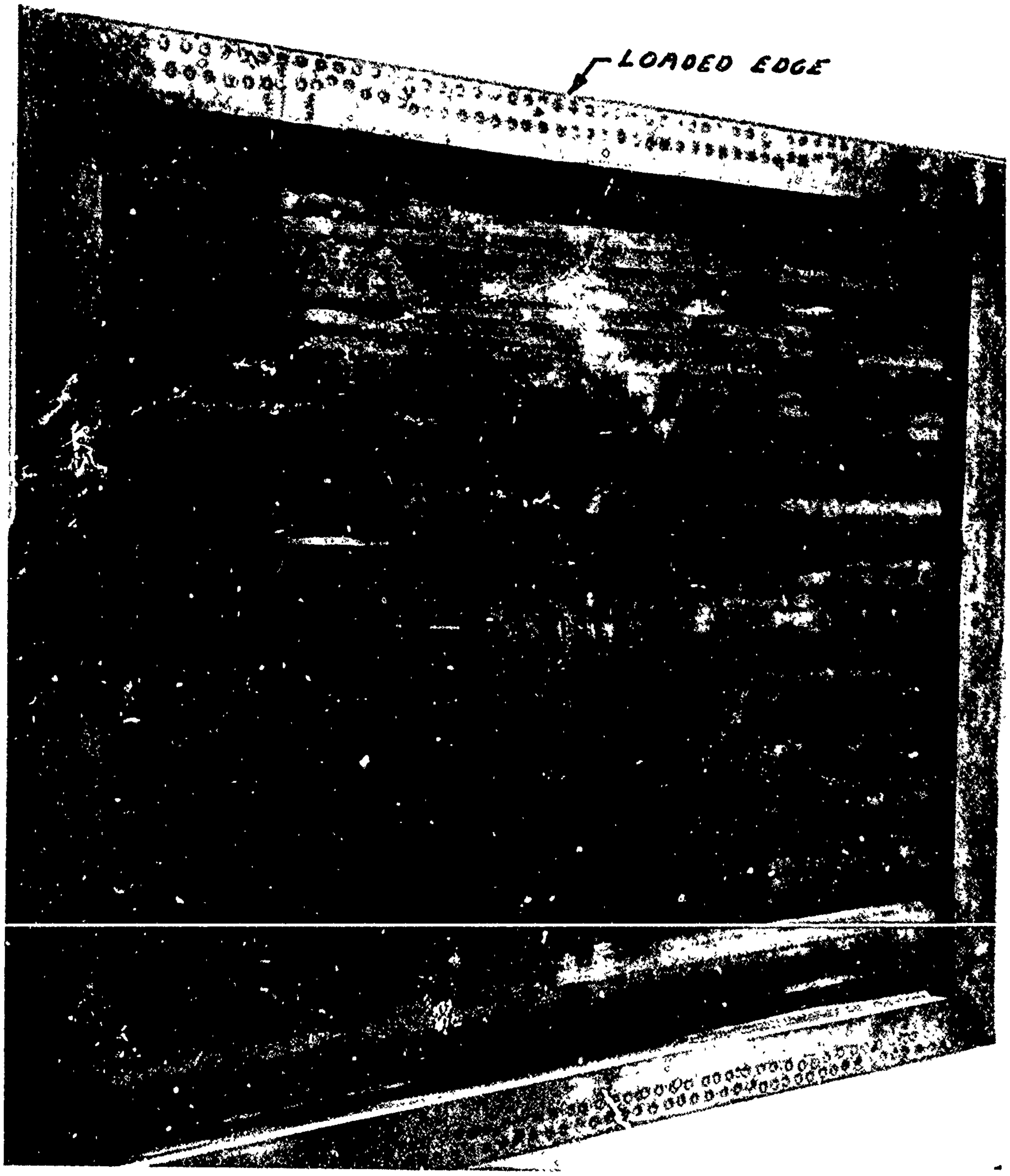
VIII. DISCUSSION

Panel deflection and compression head movement, as determined by dial indicators, did not indicate any local buckling or failure prior to the ultimate failure of the panel. Test data indicated that the effect of temperature upon deflection of the panel when loaded to limit load was negligible. Therefore, this deflection data is not presented in this report.

IX. CONCLUSIONS

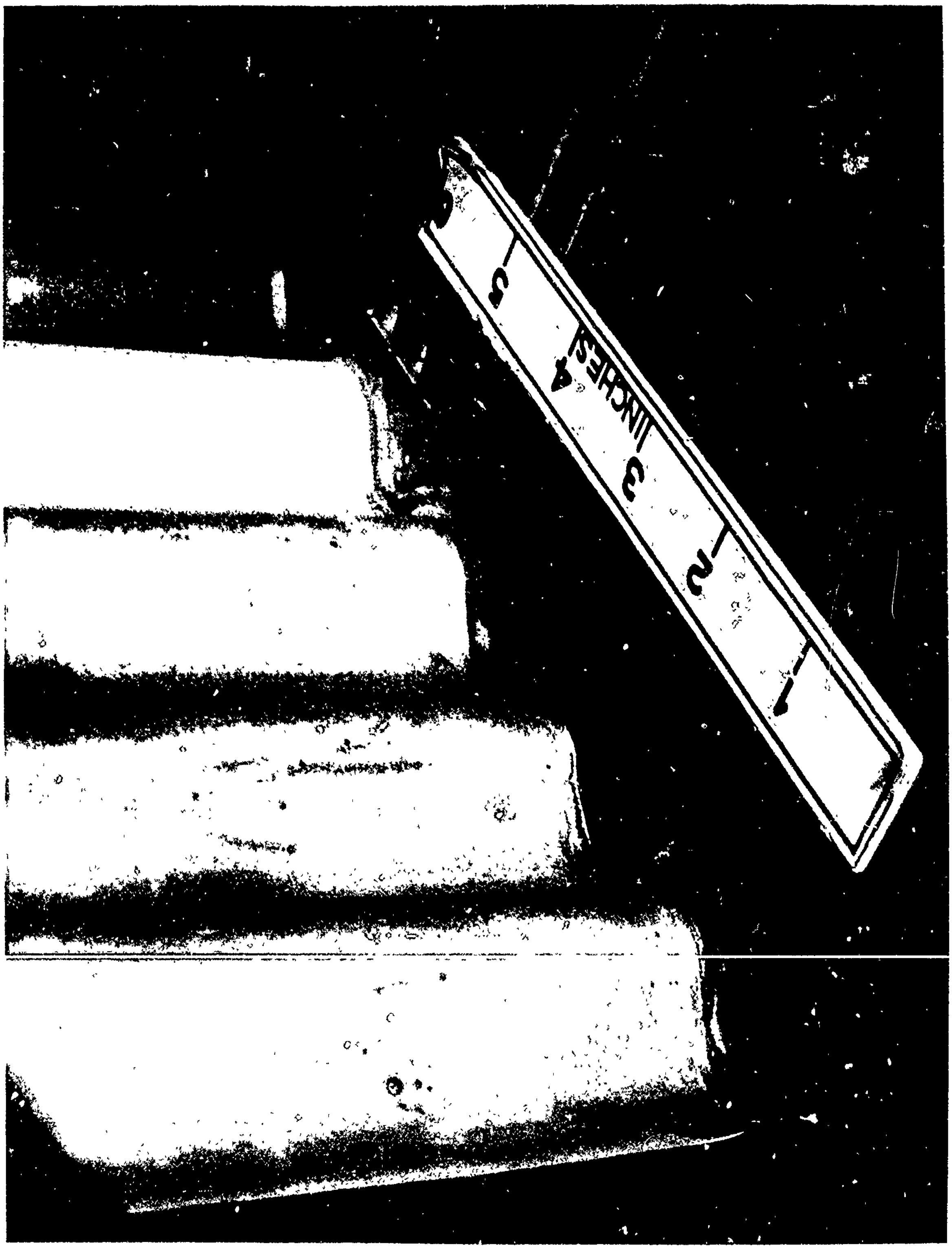
The specimens withstood design limit load and pressure at room temperature, 200 F, and increments of 100 F thereafter through 800 F. No failure was evident.

All panels failed at loads exceeding design ultimate.



Convair Print 66534

Figure E-18 – STATIC FAILURE OF 29-01012 PANEL;
Due to Skin Buckling, 4 psi at 36,000 lbs & 800F.

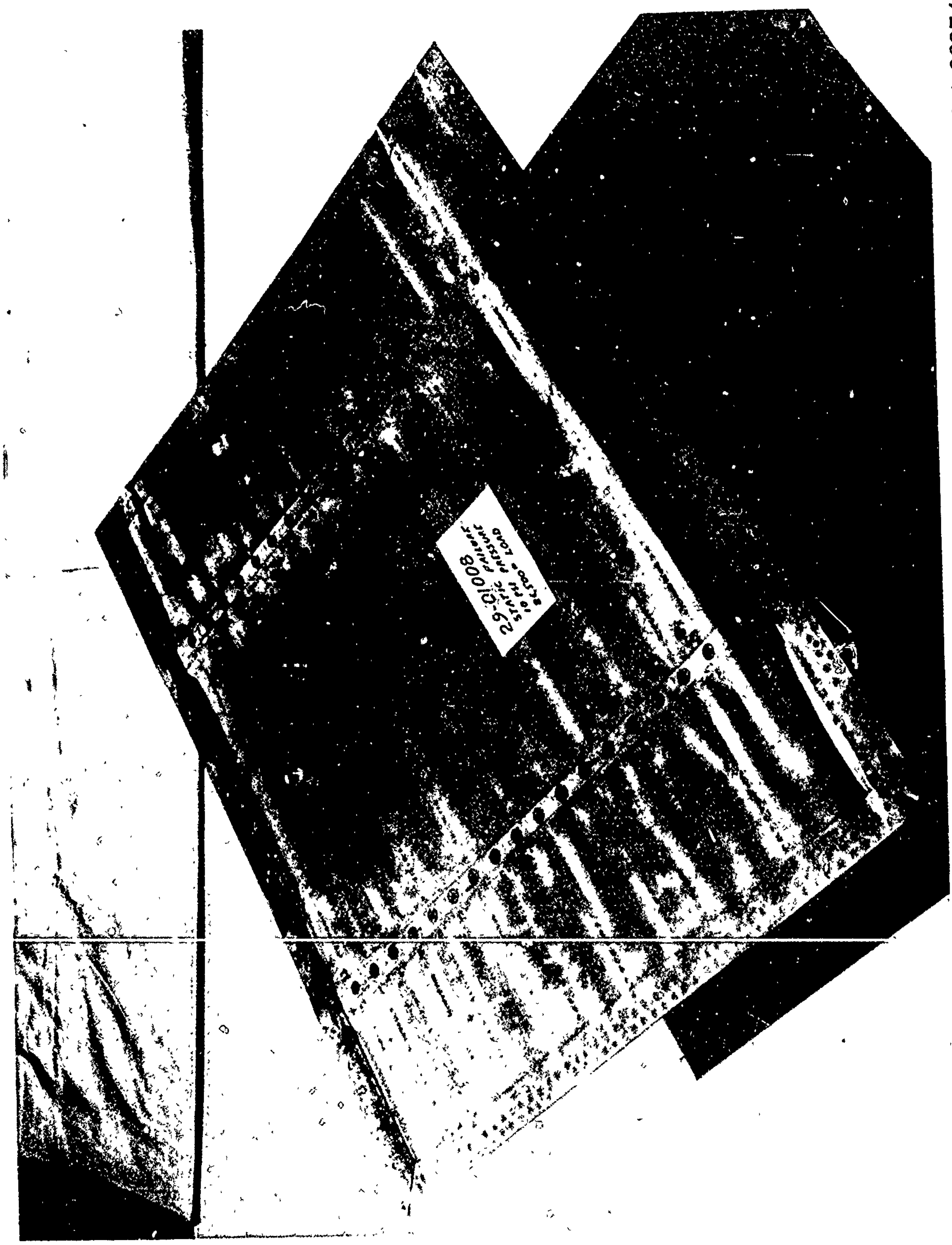


Convair Print 66531

Figure E-19 -- STATIC FAILURE OF 29-01012 PANEL; Due to Weld Failure, 4 psi at 72,000 lbs & 800F.

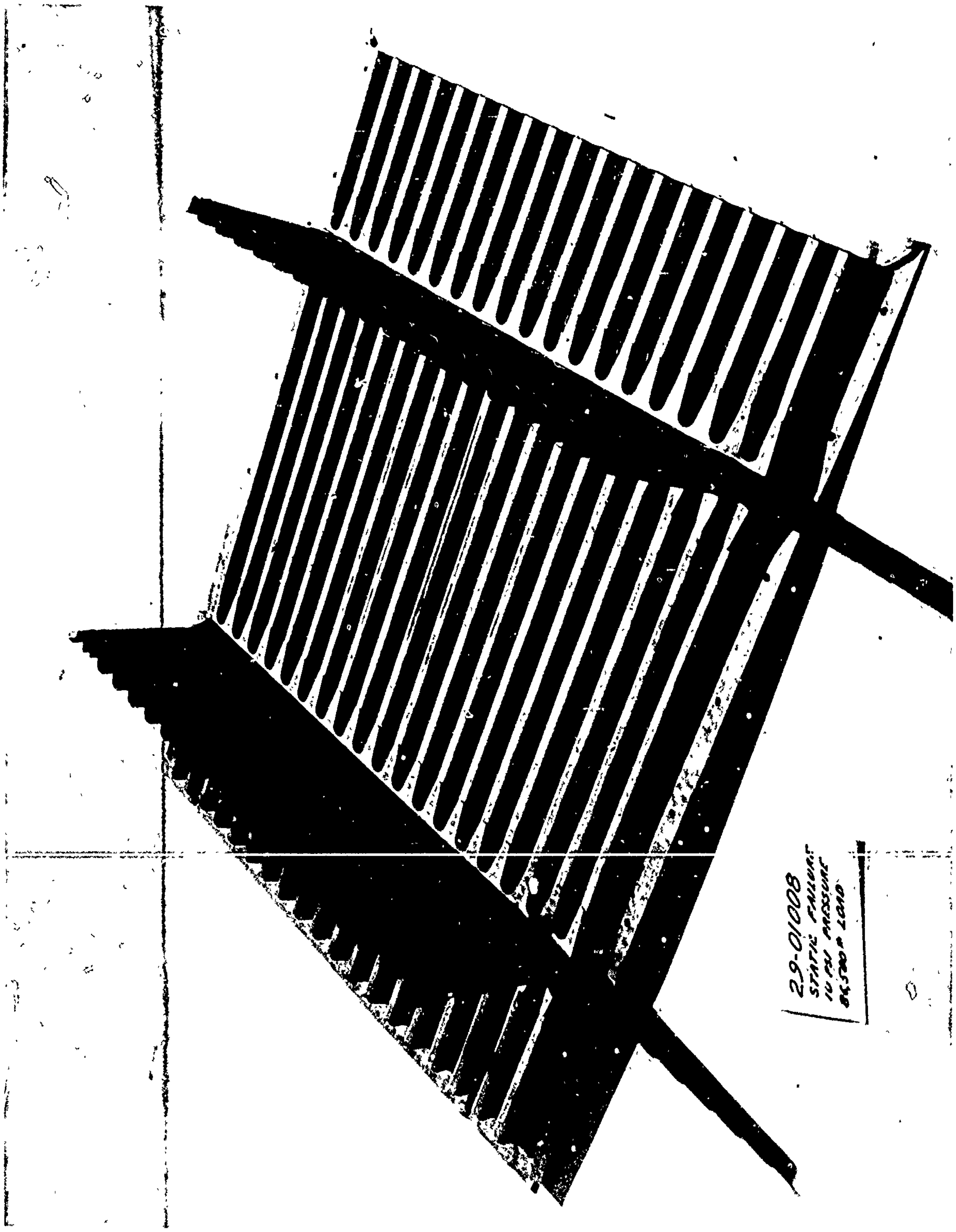
Convair Print 66532

Figure E-20 — STATIC FAILURE OF 29-01012 PANEL; 4 psi at 72,000 lbs & 800F.



Convair Print 66374

Figure E-21 — STATIC FAI RE OF 29-01008 PANEL; Spar and Skin Buckling, 10 psi at 86, 00 lb & 800F.



Convair Print 66375

Figure E-22 — STATIC FAILURE OF 29-01008 PANEL; 10 psi at 86, 500 lbs & 800F.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

E. COMPRESSION PANEL - ELEVATED-TEMPERATURE STATIC TEST

X. STRUCTURAL DISCUSSION

The results of the compression test specimens and the method of test set-ups make it difficult to determine which is the most efficient panel design. The panel failing loads and weights are given below. All ultimate tests were run at 800 F.

Panel No.	Specimen	Compression Load (lbs.)	Pressure Load (lbs/sq. in.)	Weight (lbs.)
1	29-01008	86,500	10	13.6
2	29-01009	79,000	10	10.7
3	29-01012	72,000	4	8.3

In Panels 1 and 3 the pressure load is reacted by the corrugated spar webs in tension. These loads are beamed to the spar webs by the face sheet corrugations and the face sheets. This test set-up resulted in stresses due to pressure which are 90 degrees removed from the primary compression load stresses. In these two panels the pressure is partially stabilizing the structure, however, this effect is negligible at ultimate load. In contrast, the pressure load on Panel No. 2 is directly adding to the stresses on the inboard leg of the stringer material. At failure of the -9 stringers in crippling, 72% of the load was due to primary compression and 28% was from bending due to pressure. This type of panel is probably best for resisting compression loads. Intercostaling of the skin is somewhat difficult at the stringer spacing shown, and the production costs are probably a little higher.

In Panel No. 3 design and production would be difficult at rib stations or bulkheads where the cross members must have continuity through the sine wave spar webs. Intercostling of the skin would probably be accomplished by the skin corrugations in bending, which would seem to be too flexible for good design.

X. STRUCTURAL DISCUSSION (Cont'd)

Panel No. 1 has most of the disadvantages of Panel No. 3. In addition to a weight penalty, the only desirable feature of Panel No. 1 is the ability to remove the skins and corrugations from the sub structure by means of screws or other fasteners.

1. Discussion of Stress and Allowables:

In Panel No. 2 the -9 stiffener and its effective skin has the following calculated properties:

$A = .1749$ sq. in.

$\bar{Z} = .386$ in. (from inside skin surface)

$I = .0327 \text{ in}^4$

The compressive load/stiffener = 7900 lbs.

The bending mom./stiffener = 770 in.-lbs.

Then,

$$f_c = \frac{7900}{.1749} \pm \frac{777\,(1.12 - .386)}{.0327}$$

$$= 62{,}800 \text{ lbs/sq. in.}$$

(Outboard element of -9 stiffener)

The allowable calculator from the formula $K\,E\,(t/6)^2$ gives very close results, if the element is considered fixed at the ends and simply supported at the edges. This assumption sets $K = 3.62$.

Then,

$$F_c = 3.62\,(13.4 \times 10^6)\,(.025/.70)^2 = 61{,}900 \text{ lbs/sq. in.}$$

("E" at 800 F)

X. 1. Discussion of Stress and Allowables: (Cont'd)

In Panel No. 3 the radius of gyration, ρ, of the skin is

$$\frac{t}{\sqrt{12}} = .00777 \text{ in.}$$

$$\frac{L'}{\rho} = \frac{.5}{[2\,(.00777)]} = 32.2$$

(For c = 4; or fully fixed at each corrugation)

Then,

$$F_c = F_{cy}\left[1 - \frac{F_{cy}\left(\frac{L'}{e}\right)^2}{4\pi^2 E}\right]$$

(Johnson formula with F_{cy} substituted for F_{co})

$$F_c = 119,000\left[1 - \frac{119,000\,(32.2)^2}{4\pi^2\, 13.4 \times 10^6}\right] = 91,000 \text{ lbs/sq. in.}$$

(Note: All values at 800 F)

Assuming that -25 plate and 1 inch of -23 web is effective at F_{cy} stress levels, then the calculated compression load carrying ability of 29-01012 panel is: 28.5 (.020) 91,000 + 2 (.040) 1.3 (119,000) + 2 (.020) 1.0 (119,000) = 69,040 lbs.

This calculation compares favorably with the ultimate compression load of 72,000 pounds that failed the panel.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

F. TAIL CONE STATIC AND FATIGUE TESTS

TABLE OF CONTENTS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

F. TAIL CONE - STATIC AND FATIGUE TESTS

I. INTRODUCTION

The Fuselage Tail Cone is a conversion to Ti-4Al-3Mo-1V alloy of the F-102A Interceptor, Part No. 8-73490, Tail Cone Assembly. The original part contained 2024-T81 clad aluminum alloy, type 321 stainless steel, commercially pure titanium, and some titanium alloy.

The objectives of the program were to determine:

The load carrying characteristics of a titanium fuselage tail cone assembly at various temperatures through 900 F.

The fatigue strength of the assembly at 800 F.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

F. TAIL CONE - STATIC AND FATIGUE TESTS

II. SUMMARY

A titanium Fuselage Tail Cone Assembly was tested statically to limit load and in fatigue at several loads from 66.6% limit load to design ultimate at temperature.

In the static test, load was applied in 20 per cent steps up to limit load at room temperature, 200 F, 300 F, 400 F, 500 F, 600 F, 700 F, 800 F, and 900 F with no apparent failures.

The fatigue test consisted of 2,500 cycles each at room temperature, 200 F, 400 F, and 600 F; and 100,000 cycles at 800 F at 66.6% limit load, 50,000 cycles at limit load, 25,000 at 1-1/4 limit load and 17,375 at 150% limit load (design ultimate), at 800 F with some minor structural failures.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

F. TAIL CONE - STATIC AND FATIGUE TESTS

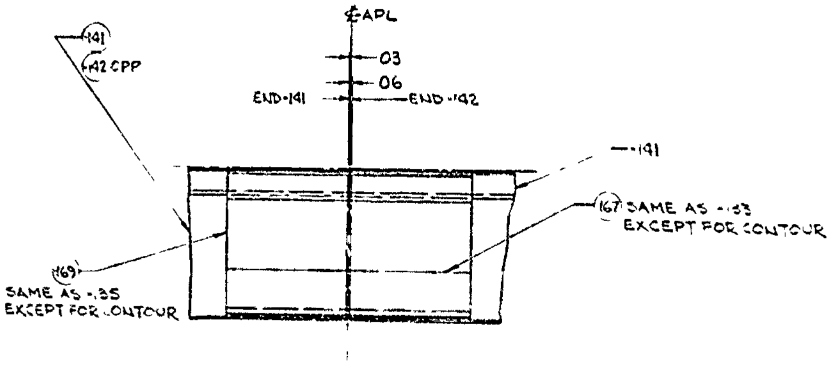
III. TEST SPECIMEN

The test specimen was manufactured according to Engineering Drawings 29-01001 and 29-01002, Figures F-1 and F-2 (pages 285 and 287).

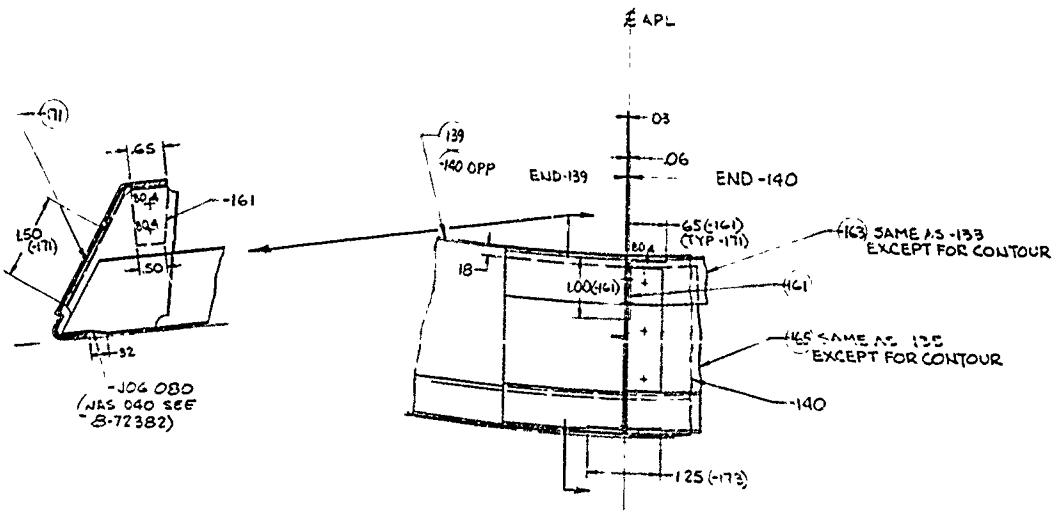
The specimen was made entirely from Ti-4Al-3Mo-1V alloy except for the fairing tips which were spun from type 321 stainless steel.

Figure F-1 - FUSELAGE TAIL CONE ASSEMBLY -
Engineering Drawing 29-01001

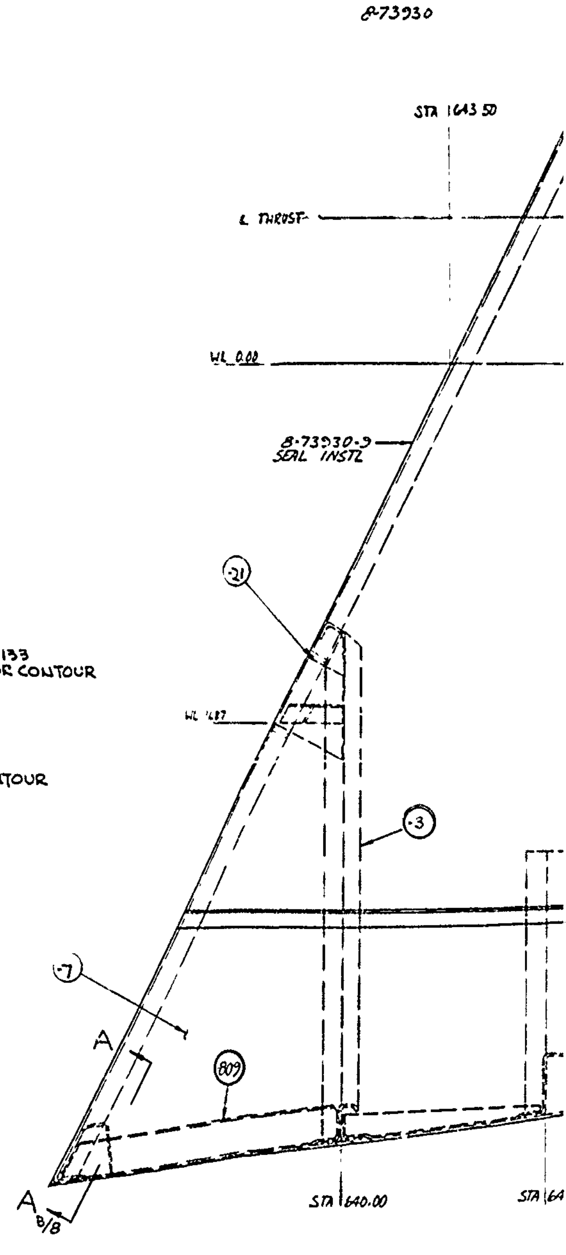
8 7

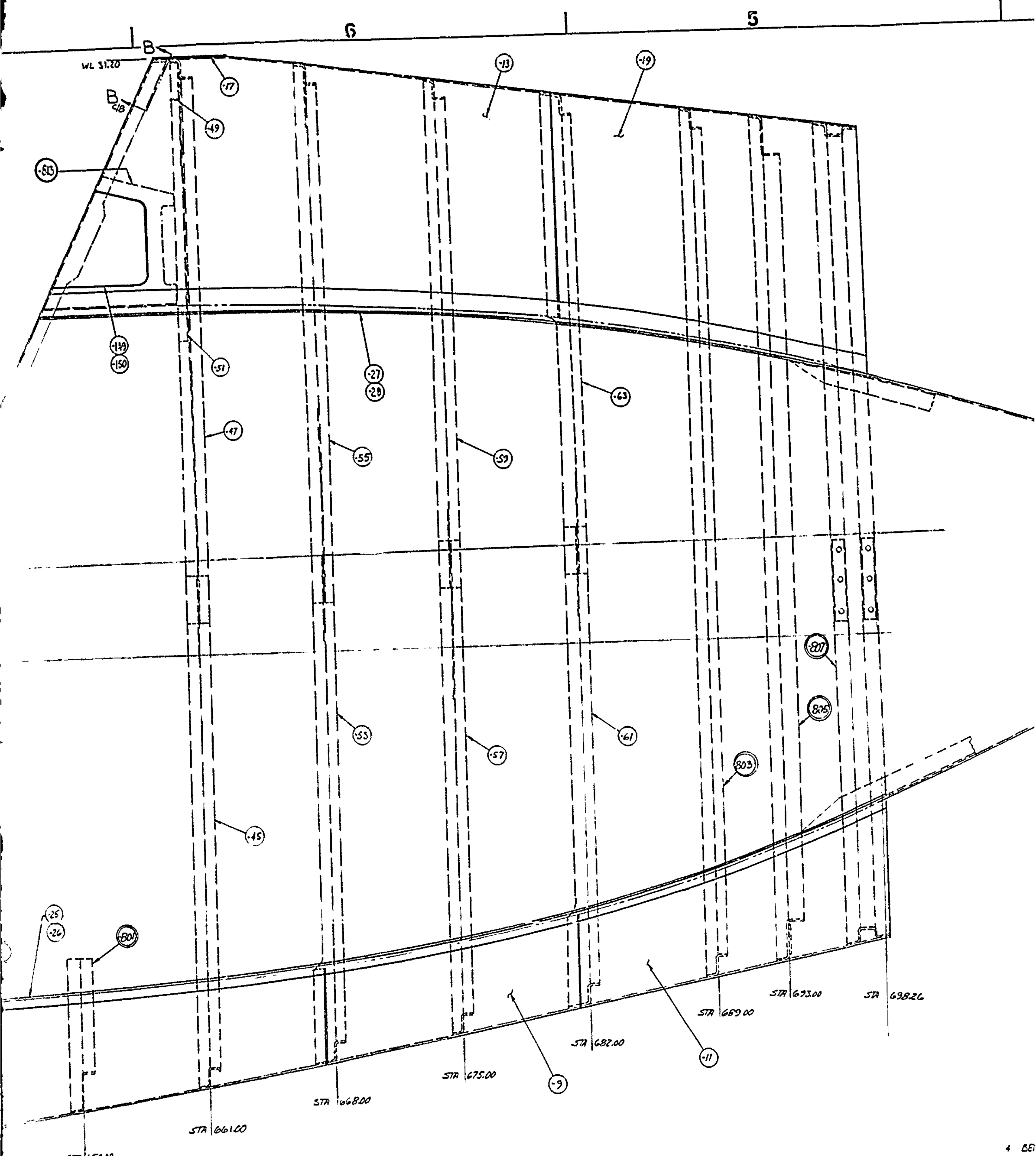


VIEW B-B D/6
SEE SPLICE AT WL 0.00 (8-73351)
FOR ATTACHMENTS



VIEW A-A A/7
SEE SPLICE AT WL 0.00 (8-73351)
FOR ATTACH NOT SHOWN





4. BE
3. SC
NOTES

4 | 3 | 2

REVISIONS

LTR	ZONE	DESCRIPTION	DATE	APPROVED

Dash No.		Ref. Drawing	Dash
-813	INSTL SAME AS	8-73694	-1 & -2 EXCEPT AS NOTED
-811		8-73351	-BASIC
-809		8-72382	-BASIC
-807		8-72380	-BASIC
-805		8-72379	-805
-803		8-72378	-BASIC
-801		8-72373	-BASIC
-5		8-72372	-BASIC
-3		8-72371	-BASIC
BASIC	INSTL SAME AS	8-73490	-1 EXCEPT AS NOTED
-159	DETAIL IS IDENTICAL TO	8-73695	-29 EXCEPT FOR MATERIAL
-157			-27
-155			-25
-153			-21
-151			-19
-149			-17
-147			-9
-145		8-73695	-7
-143		8-73694	-13
-141		8-73351	-19
-139			-17
-137			-15
-135			-13
-133		8-73351	-11
-131		8-72382	-17
-129			-15
-127			-13
-125			-11
-123			-9
-121		8-72382	-7
-119		8-72380	-33
-117			-31
-115			-29
-113			-27
-111			-25
-109			-23
-107			-21
-105			-19
-103			-17
-101			-15
-99			-13
-97			-11
-95			-9
-93		8-72380	-7
-91		8-72379	-51
-89			-49
-87			-47
-85			-45
-83			-43
-81			-41
-79			-39
-77			-37
-75			-35
-73		8-72379	-33
-71		8-72378	-13
-69			-11
-67			-9
-65		8-72378	-7
-63		8-72377	-9
-61		8-72377	-7
-59		8-72376	-9
-57		8-72376	-7
-55		8-72375	-9
-53		8-72375	-7
-51		8-72374	-15
-49			-11
-47			-9
-45		8-72374	-7
-43		8-72373	-7
-41		8-72372	-11
-39		8-72372	-9
-37		8-72372	-7
-35		8-72371	-15
-33			-13
-31			-11
-29		8-72371	-9
-27		8-73490	-17
-25			-15
-21			-23
-19			-19
-17			-31
-13			-25
-11			-11
-9			-9
-7	DETAIL IS IDENTICAL TO	8-73490	-7 EXCEPT FOR MATERIAL

2. THE ABOVE TABLE IS THE CROSS INDEX BETWEEN DASH NOS OF THIS DWG & DASH NOS OF RESP. PRODUCTION PARTS. FOR DETAILS & ASSY SEE THE PRODUCTION DWG.

1. FOR RIVET SIZE, TYPE, & LOCATION SEE PRODUCTION DWG. RIVET MAT'L TO BE MONEL, NOT PLATED.

NOTES:

...TS MUST BE AS SMALL AS POSSIBLE
... ARE SAME AS PRODUCTION.

DASH NO	CHG RECORD NO	SERIAL NO	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO	CHG RECORD NO	SERIAL NO	NEXT ASSY	USED ON	CALC UNIT WT	NEXT ASSY	FINAL ASSY	DASH NO	CHG RECORD NO	SERIAL NO

APPLICATION — QTY REQD

Sym	Revisions – Description	Zone
A	ADDED -140, -142, -161, -163, -165, -167, -169, -171 VIEW A-A & VIEW B-B	B/8, C/8
	ENAGY 12-3-59	

Opp	Dash No	Description	Stock Size	Remarks
	-171	FILLER	.040 x .7 x 1.5	SEE VIEW A-A
	-169	ANGLE	.040 x 3.2 x 4.3	SEE VIEW B-B C/8
	-167	ANGLE	.040 x 1.6 x 4.3	
		SEAL INSTL		
	-1			
	813	DOOR INSTL - TAILCONE UPPER		
	811	BLKHEAD - STA 643.50 AFT CANTED		
	-165	ANGLE	.040 x 3.2 x 4.3	SEE VIEW A-A B/8
		FAIRING		
-160	-159	ANGLE	.051 x 1.6 x 2.8	
	-157	DOUBLER	.051 x 4.0 x 4.9	
	-155	FILLER	.016 x 7.0 x 10.0	
-154	-153	DOUBLER	.040 x 6.1 x 3.7	
-152	-151	PAN	.051 x 9.6 x 10.7	
-150	-149	DOOR	.040 x 5.6 x 6.7	
		FITTING		
-148	-147	ANGLE	.051 x 1.2 x 4.4	
-146	-145	ANGLE	.051 x 1.6 x 2.8	
	-143	DOOR	.025 x 1.1 x 3.4	
-142	-141	CHANNEL	.040 x 35.8 x 29.6	
-140	-139	CHANNEL	.040 x 36.1 x 29.0	
	-137	STRAP	.072 x .5 x 10.1	
-136	-135	ANGLE	.040 x 3.2 x 4.3	
-134	-133	ANGLE	.040 x 1.6 x 4.3	
	-131	CLIP	.032 x 1.2 x 1.8	
	-129	GUSSET	.032 x 2.8 x 3.6	
-128	-127	ANGLE	.032 x 1.9 x 9.8	
-126	-125	GUSSET	.032 x 2.8 x 3.6	
	-123	ANGLE	.032 x 1.8 x 8.0	
	-121	CHANNEL	.032 x 2.2 x 8.0	
	-119	STRAP	.040 x .6 x 3.4	
	-117	ZEE	.050 x 2.6 x 4.6	
	-115	ZEE	.040 x 2.6 x 4.6	
	-113	STRAP	.050 x .8 x 50.0	
	-111	STRAP	.050 x .9 x 13	
	-109	STRAP	.050 x 1.2 x 44.0	
	-107	STRAP	.050 x .8 x 17.0	
	-105	STRAP	.080 x .7 x 26.0	
	-103	STRAP	.050 x 7 x 11.0	
	-101	STRAP	.040 x 7 x 29.9	
	-99	STRAP	.050 x .7 x 68.5	
	-97	STRAP	.050 x .7 x 65.5	
	-95	FRAME	.040 x 4.1 x 66.3	
	-93	FRAME	.040 x 4.1 x 66.3	
-92	-91	GUSSET	.032 x 3.5 x 7.5	
-90	-89	ANGLE	.040 x 1.3 x 7.5	
-88	-87	ANGLE	.050 x 1.6 x 28.2	
-86	-85	STRAP	.050 x .5 x 33.0	
-84	-83	STRAP	.050 x .5 x 8.8	
-82	-81	STRAP	.080 x .5 x 12.0	
	-79	ANGLE	.040 x 1.3 x 33.1	
	-77	ANGLE	.040 x 1.3 x 30.6	
	-75	ZEE	.050 x 3.0 x 68.6	
	-73	ZEE	.050 x 3.0 x 68.4	
	-71	STRAP	.025 x .5 x 16.4	
	-69	STRAP	.032 x .9 x 16.4	
	-67	FRAME	.025 x 2.3 x 76.0	
	-65	FRAME	.025 x 2.3 x 76.0	
	-63	FRAME	.025 x 2.9 x 78.3	
	-61	FRAME	.025 x 2.9 x 76.7	
	-59	FRAME	.025 x 2.3 x 82.0	
	-57	FRAME	.025 x 2.3 x 80.0	
	-55	FRAME	.025 x 2.3 x 85.0	
	-53	FRAME	.025 x 3.2 x 81.0	
	-51	STRAP		
	-49	ANGLE	.025 x 2.5 x 18.5	
	-47	FRAME	.025 x 2.4 x 87.0	
	-45	FRAME	.025 x 2.4 x 84.5	
	-43	FRAME	.032 x 3.6 x 45.0	
	-41	STRAP	.051 x .5 x 5.3	
-40	-39	GUSSET	.040 x 2.7 x 4.9	
	-37	FRAME	.032 x 3.4 x 47.4	
	-35	STRAP	.040 x .5 x 4.0	
	-33	STRAP	.025 x .5 x 4.0	
	-31	FRAME	.025 x 2.8 x 67.5	
	807	INTERCOSTAL INSTL CANTED STA AFT		ZONE B/7
	807	FRAME INSTL STA 698.26		B/5
	806	FRAME INSTL STA 693.00		B/5
	805	FRAME INSTL STA 689.00		B/5
	-27	FRAME INSTL STA 654.00		B/7
	-5	FRAME INSTL STA 647.00		
	-3	FRAME INSTL STA 640.00		ZONE B/7
-30	-29	CLIP	.032 x 2.1 x 2.5	
-28	-27	ANGLE	.032 x 2.1 x 46.3	
-26	-25	ANGLE	.032 x 2.0 x 66.1	
	-163	ANGLE	.040 x 1.6 x 4.3	SEE VIEW A-A B/8
	-21	GUSSET	.025 x 2.5 x 3.0	
	-19	SKIN	.020 x 17.0 x 48.0	
	-17	SKIN	.020 x 6.0 x 13.5	
	-161	ANGLE	.040 x .7 x 1.7	SEE VIEW A-A B/8
	-13	SKIN	.020 x 29.0 x 56.0	
	-11	SKIN	.020 x 17.8 x 44.0	
	-9	SKIN	.020 x 18.2 x 44.0	
	-7	SKIN	.032 x 38.0 x 52.0	

BASIC -813 -811 -809 -807 -805 -3 -1 — REQUIREMENTS PER ASSY

PART NO. | OPP | DASH NO | DESCRIPTION | STOCK SIZE | MATERIAL | MATL SPECIFICATION | ZONE

LIST OF MATERIAL

SEE FINISH SPECIFICATIONS 8-00004, 8-00009

RIVET CODE PER NAS 523

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED — DIMENSIONS IN INCHES

STRUCTURE ASSY - TAIL CONE, TEST

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

DWG J 29-01001

SHEET 1

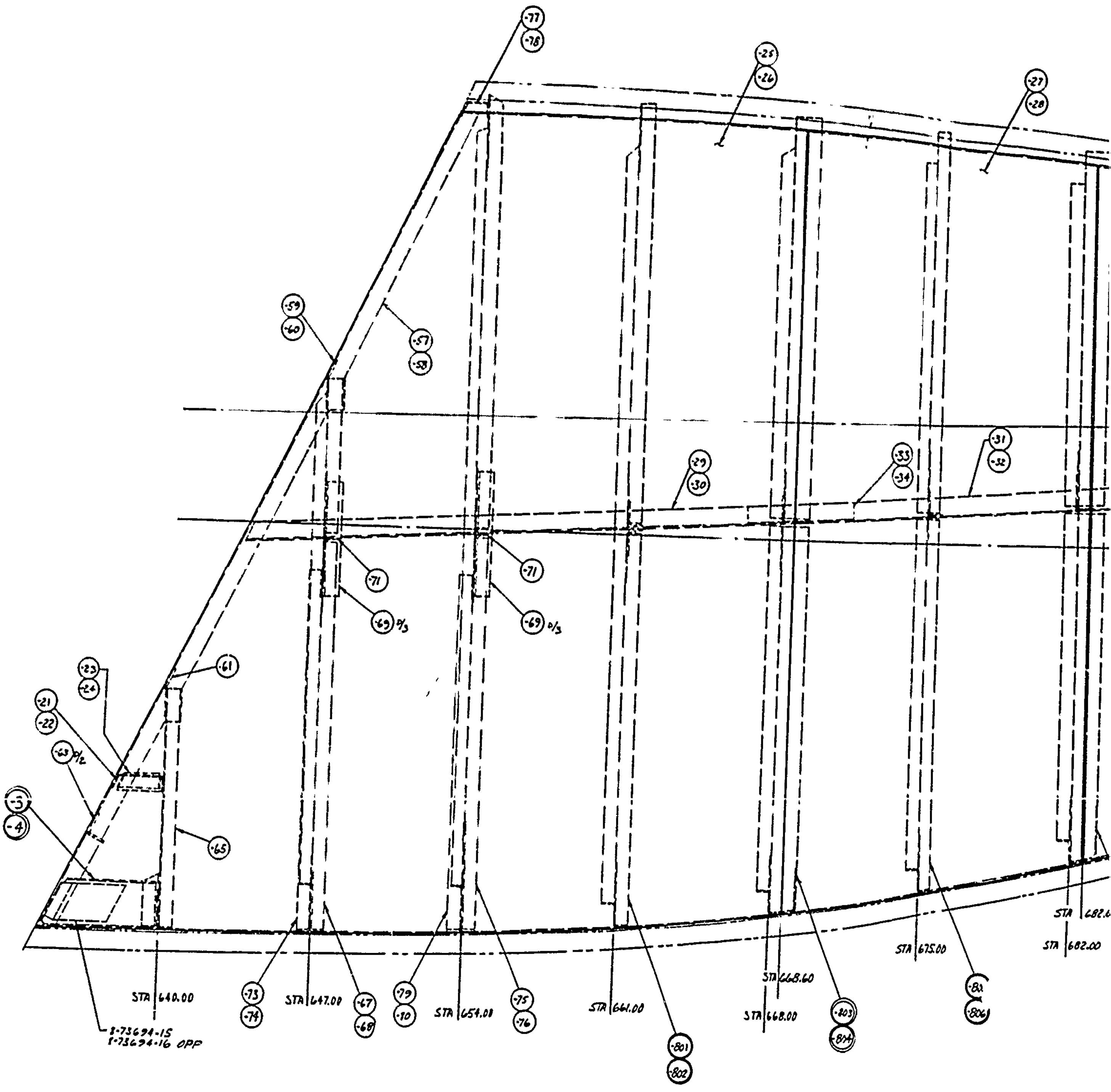
Figure F-1

Page 285

29-01001 SH 1 of 1 A

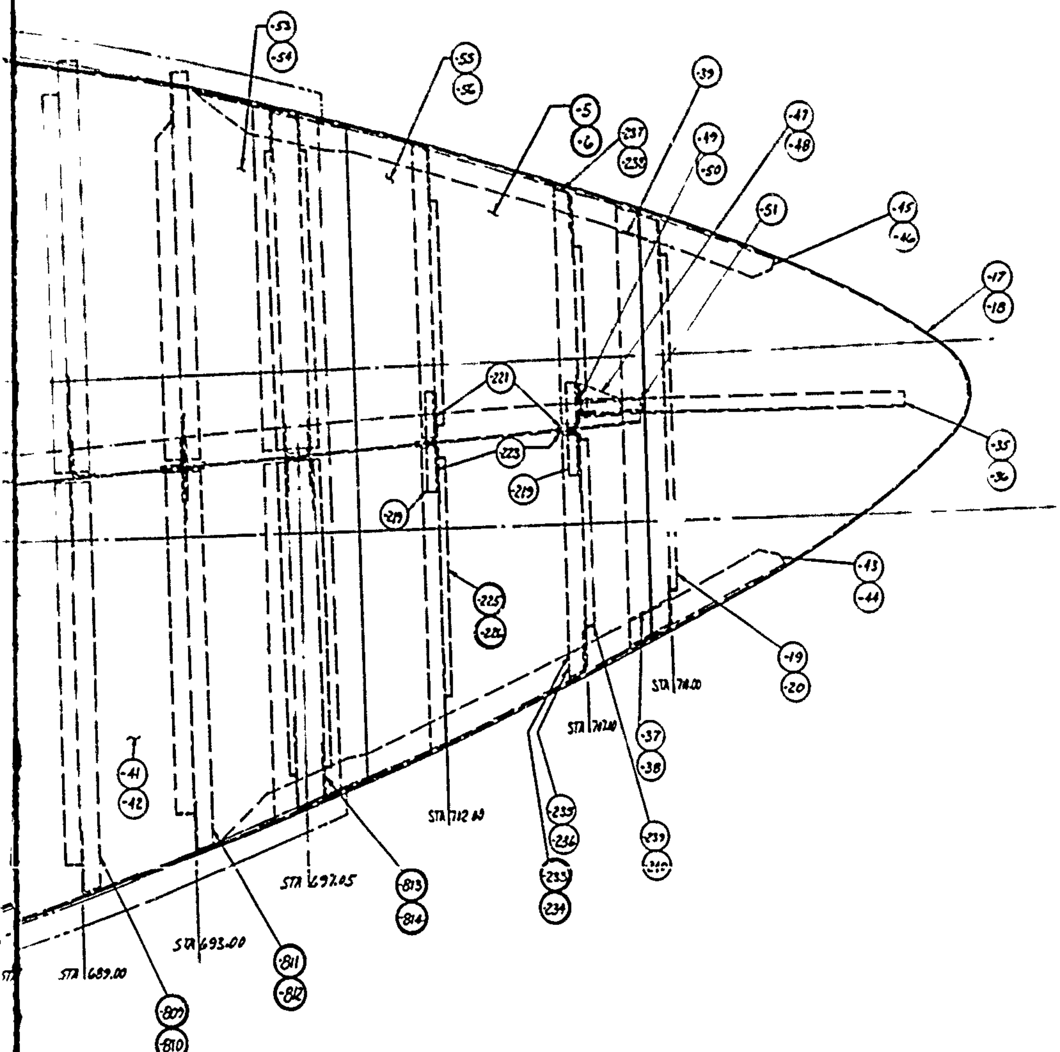
EWO 1986

Figure F-2 - FAIRING INSTALLATION; Fuselage Tail Cone Assembly - Engineering Drawing 29-01002


STA 640.00
STA 647.00
STA 654.00
STA 661.00
STA 668.00
STA 668.60
STA 675.00
STA 682.00
1-73694-15
1-73694-16 OPP

6

5



-7 DETAIL IS IDENTIC

4. THE ABOVE TABLE IS T
OF RESP PRODUCTION

3. SCREWS BOLTS

2. FOR RIVET SIZE, T
RIVET MATL TO

1. BEND RADII OF AL

6

3

234-233		226	225	214	213	212	211	210	209	208	207	206	205	204	203	202	201	-6	-5	-4	-3	-2	-1	PART NO.	MP DASH NO	SUB DASH NO	DESCRIPTION	STOCK SIZE	MATER
																									240	239	FORMER	.020 x 11.0 x 16.3	
1	1																								238	237	ANGLE	.020 x 5.3 x 15.0	
1	1																								236	235	ANGLE	.020 x 5.5 x 15.0	
1	1																					1	1		234	233	SPOTWELDED ASSY (STA 707.00)		
		1	1																						232	231	ANGLE	.020 x 6.3 x 17.5	
		1	1																						230	229	ANGLE	.020 x 6.3 x 14.8	
		1	1																						228	227	FORMER	.020 x 17.0 x 20.0	
																						1	1		226	225	SPOTWELDED ASSY (STA 702.00)		
																						2	2			223	ANGLE	.025 x .8 x 1.8	
																						2	2			221	ANGLE	.025 x .8 x 1.8	
																										219	ANGLE	.025 x 1.0 x 3.0	
1	1	1	1																					P-73759-11			BLOCK		
				4	4																			P-73759-8					
				2	2																			P-73759-7					
				2	2																			P-73759-9			BLOCK		
				12	12																				218	217	CLIP	.040 x 1.1 x 2.7	
				1	1																				216	215		x 1.1 x 2.7	
				1	1																				214	213		x 1.0 x 2.8	
				1	1																				212	211		x 1.0 x 2.8	
				1	1																				210	209		x 2.0 x 4.9	
				1	1																					207		x .7 x 3.0	
				1	1																				206	205	CLIP	[illegible] x 2.0 x 4.5	
				1	1																				204	203	CHANNEL	.025 x 2.4 x 10.2	
				1	1																				202	201	CHANNEL	.025 x 2.4 x 9.7	
				1	1																				200	199	CHANNEL	.032 x 2.4 x 9.4	
				1	1																				198	197	FORMER	.032 x 2.5 x 18.0	
				1	1																				196	195	FORMER	.032 x 3.5 x 22.4	
				1	1																				194	193	FORMER	.025 x 2.8 x 24.0	
						1	1																		192	191	STIFF	.040 x 1.4 x 10.0	
						1	1																		190	189	FORMER	.025 x 2.8 x 18.7	
						1	1																		188	187	CLIP	.050 x 1.0 x 1.9	
						1	1																		186	185	CLIP	.050 x 1.0 x 1.9	
						1	1																		184	183	STIFF	.025 x 1.8 x 10.8	
						1	1																		182	181	STIFF	.025 x 1.8 x 10.0	
						1	1																		180	179	CLIP	.050 x .8 x 1.6	
								1	1																	177	CHANNEL	.025 x .9 x 3.2	
								1	1																	175	CHANNEL	.025 x .9 x 2.2	
								1	1																	173	CLIP	.032 x .6 x 1.8	
								1	1																172	171	ANGLE	.025 x 1.1 x 2.6	

REQUIREMENTS PER ASSY

-19 EXCEPT FOR MATERIAL
BETWEEN DASH NOS OF THIS DWG & DASH NOS
TAILS & ASSY SEE THE PRODUCTION DWG.
TES ARE SAME AS PRODUCTION, SEE PROD. DWGS.
SEE PRODUCTION DWGS.
NOT PLATED
BE AS SMALL AS POSSIBLE.

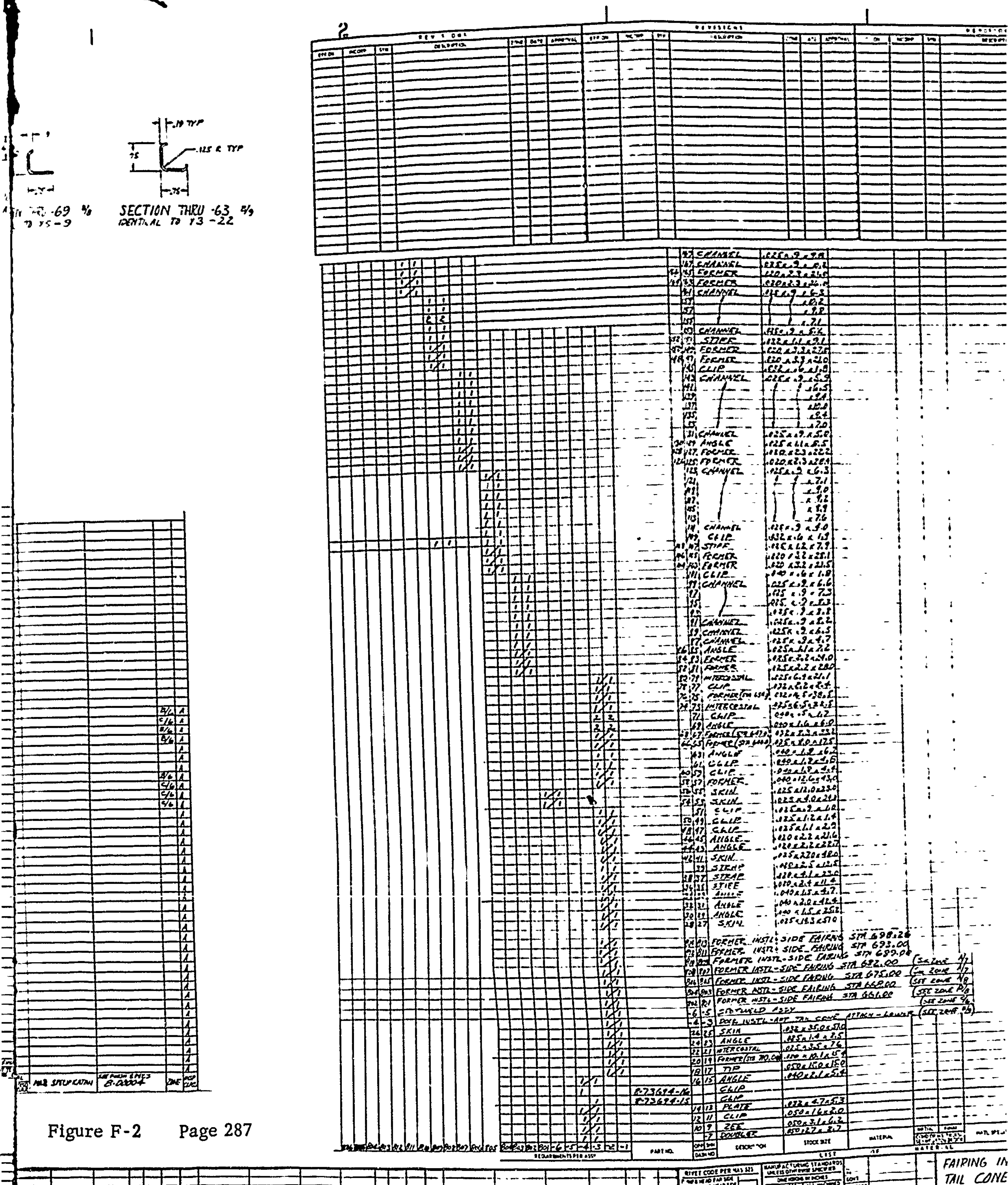


Figure F-2 Page 287

OPP	SHOWN	DESCRIPTION	STOCK SIZE
	167	CHANNEL	.025 x .9 x 7.8
	167	CHANNEL	.025 x .9 x 8.1
166	165	FORMER	.020 x 2.3 x 26.0
	163	FORMER	.020 x 2.3 x 26.0
	161	CHANNEL	.025 x .9 x 6.3
	159		x 10.2
	157		x 9.8
	155		x 7.1
	153	CHANNEL	.025 x .9 x 5.5
152	151	STIFF	.032 x 1.1 x 3.1
150	149	FORMER	.020 x 2.3 x 27.5
148	147	FORMER	.020 x 2.3 x 26.0
	145	CLIP	.032 x .6 x 1.8
	143	CHANNEL	.025 x .9 x 5.9
	141		x 6.5
	139		x 9.1
	137		x 10.0
	135		x 8.4
	133		x 7.0
	131	CHANNEL	.025 x .9 x 5.0
130	129	ANGLE	.025 x 1.1 x 8.5
128	127	FORMER	.020 x 2.3 x 22.2
126	125	FORMER	.020 x 2.3 x 28.4
	123	CHANNEL	.025 x .9 x 6.3
	121		x 7.1
	119		x 9.0
	117		x 9.2
	115		x 8.9
	113		x 7.6
	111	CHANNEL	.025 x .9 x 5.0
	109	CLIP	.032 x .6 x 1.9
108	107	STIFF	.032 x 1.2 x 7.9
106	105	FORMER	.020 x 2.2 x 23.1
104	103	FORMER	.020 x 2.2 x 21.5
	101	CLIP	.040 x .6 x 1.8
	99	CHANNEL	.025 x .9 x 6.6
	97		.025 x .9 x 7.3
	95		.025 x .9 x 8.3
	93		.025 x .9 x 8.8
	91	CHANNEL	.025 x .9 x 8.2
	89	CHANNEL	.025 x .9 x 6.5
	87	CHANNEL	.025 x .9 x 4.7
86	85	ANGLE	.025 x 1.1 x 7.2
84	83	FORMER	.025 x 2.2 x 24.0
82	81	FORMER	.025 x 2.2 x 28.0
80	79	INTERCOSTAL	.025 x 6.4 x 21.1
78	77	CLIP	.032 x 2.2 x 2.4
76	75	FORMER (STA 654)	.032 x 2.5 x 30.5
74	73	INTERCOSTAL	.025 x 6.5 x 32.5
	71	CLIP	.040 x .5 x 4.2
	69	ANGLE	.050 x 1.6 x 6.0
68	67	FORMER (STA 647.9)	.032 x 2.3 x 23.1
66	65	FORMER (STA 640)	.025 x 8.0 x 12.5
	63	ANGLE	.040 x 1.2 x 6.2
	61	CLIP	.040 x 1.2 x 4.5
60	59	CLIP	.040 x 1.2 x 4.4
58	57	FORMER	.040 x 12.6 x 43.0
56	55	SKIN	.025 x 12.0 x 23.0
54	53	SKIN	.025 x 4.0 x 21.0
	51	CLIP	.025 x .2 x 1.0
50	49	CLIP	.025 x 1.2 x 1.4
48	47	CLIP	.025 x 1.1 x 2.2
46	45	ANGLE	.020 x 2.2 x 21.6
44	43	ANGLE	.020 x 2.2 x 22.7
42	41	SKIN	.025 x 27.0 x 48.0
	39	STRAP	.080 x 2.5 x 12.5
38	37	STRAP	.020 x 4.1 x 23.0
36	35	STIFF	.020 x 2.4 x 11.4
34	33	ANGLE	.040 x 1.5 x 4.7
32	31	ANGLE	.040 x 2.0 x 42.4
30	29	ANGLE	.040 x 1.5 x 35.2
28	27	SKIN	.025 x 14.3 x 51.0
214	213	FORMER INSTL - SIDE FAIRING STA 698.26	
212	211	FORMER INSTL - SIDE FAIRING STA 693.00	
210	209	FORMER INSTL - SIDE FAIRING STA 687.00	
208	207	FORMER INSTL - SIDE FAIRING STA 682.00	(SEE ZONE A/7)
206	205	FORMER INSTL - SIDE FAIRING STA 675.00	(SEE ZONE A/7)
204	203	FORMER INSTL - SIDE FAIRING STA 668.00	(SEE ZONE A/8)
202	201	FORMER INSTL - SIDE FAIRING STA 661.00	(SEE ZONE B/8)
-6	-5	SPOTWELD ASSY	(SEE ZONE C/6)
-4	-3	DOOR INSTL - AFT TAIL CONE ATTACH - LOWER	(SEE ZONE B/6)
26	25	SKIN	.032 x 35.0 x 57.0
24	23	ANGLE	.025 x 1.4 x 2.5
22	21	INTERCOSTAL	.025 x 3.5 x 7.6
20	19	FORMER (STA 710.0)	.020 x 10.1 x 15.4
18	17	TIP	.050 x 15.0 x 15.0
16	15	ANGLE	.040 x 2.1 x 5.4
P-73694-16		CLIP	
P-73694-15		CLIP	
14	13	PLATE	.032 x 4.7 x 5.3
12	11	CLIP	.050 x 1.6 x 2.0
10	9	ZEE	.050 x 3.1 x 6.2
	-7	DOUBLER	.050 x 2.7 x 2.7

REQUIREMENTS PER ASSY | PART NO. | OPP DASH NO | SHOWN DASH NO | DESCRIPTION | STOCK SIZE | MATERIAL | MATL SPECIFICATION

LIST OF MATERIAL

8-00004
8-00003

RIVET CODE PER NAS 523

MANUFACTURING STANDARDS UNLESS OTHERWISE SPECIFIED

FAIRING INSTL - TAIL CONE AFTERBODY, TEST

CONVAIR

29-01 002

29-01 002

D

C

B

A

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy·Assemblies

F. TAIL CONE - STATIC AND FATIGUE TESTS

IV. TEST PROCEDURES

The test specimen was attached to a steel plate by four bolts, simulating an actual installation.

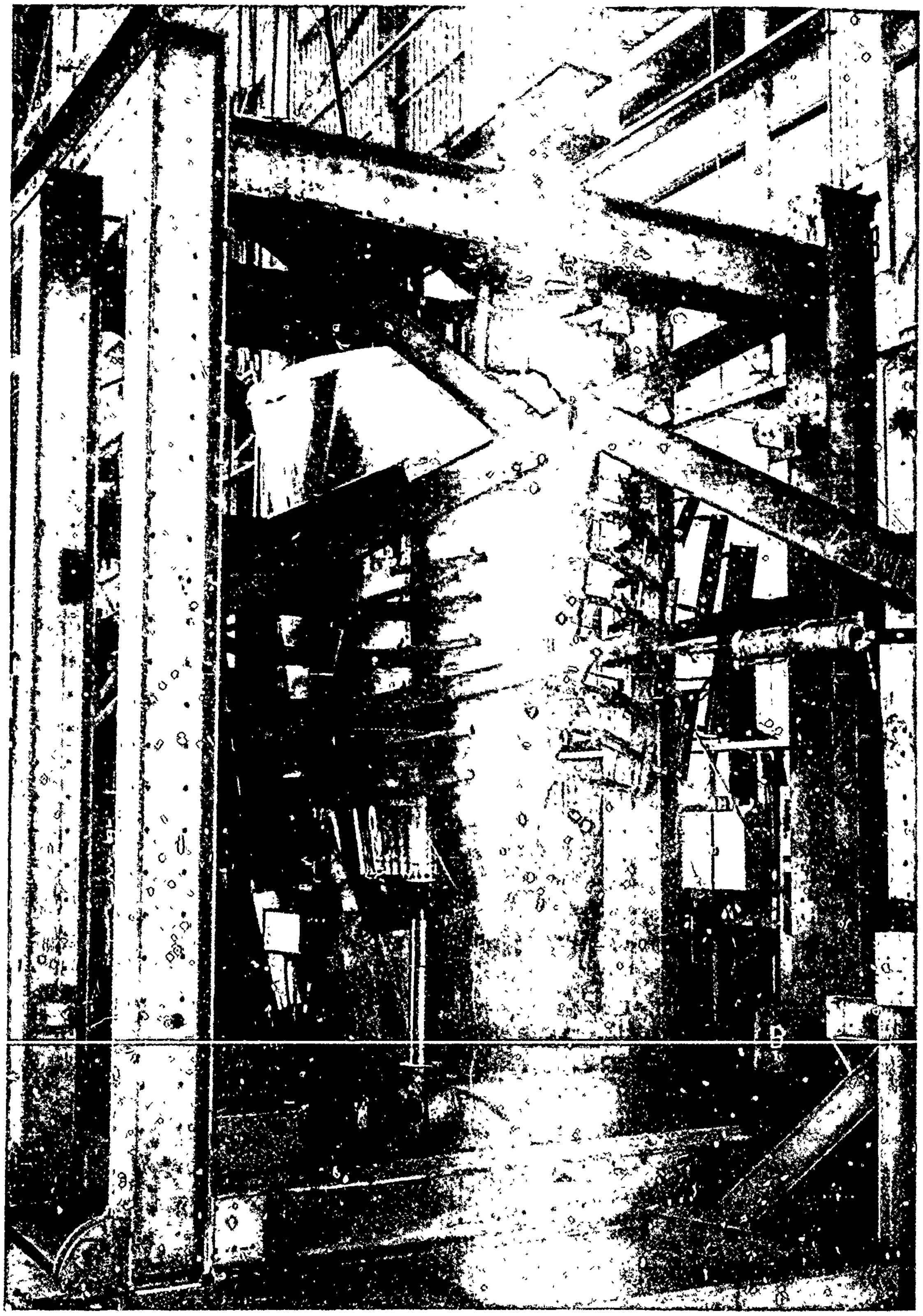
Test loads were applied through 108 points uniformly distributed over the surface of the specimen as shown in Figure F-3 (page 290). The loads were applied to the specimen skin by eyebolts through the skin into 1/2" x 1" steel blocks cushioned by pieces of asbestos blanket.

The static test load (limit load) was applied in 20 per cent increments and deflections taken. Permanent set was measured at 10 per cent load after each increment. Deflections were taken at four points on the skin. These points were 3-1/2" forward of the exit nozzle: one at each end of the flight vertical and horizontal axes. The purpose was to detect diameter changes. The complete load sequence was run at room temperature, 200 F, 300 F, 400 F, 500 F, 600 F, 700 F, 800 F and 900 F.

The first fatigue test load was 2/3 limit load. This load was applied 2,500 times at each of the following temperatures: room temperature, 200 F, 400 F, and 600 F. The same load was then applied 100,000 times at 800 F. Full limit load was applied 50,000 times at 800 F. 125% limit load (83.3% design ultimate) was applied 25,000 times at 800 F. 150% limit load (design ultimate) was applied 17,375 times at 800 F.

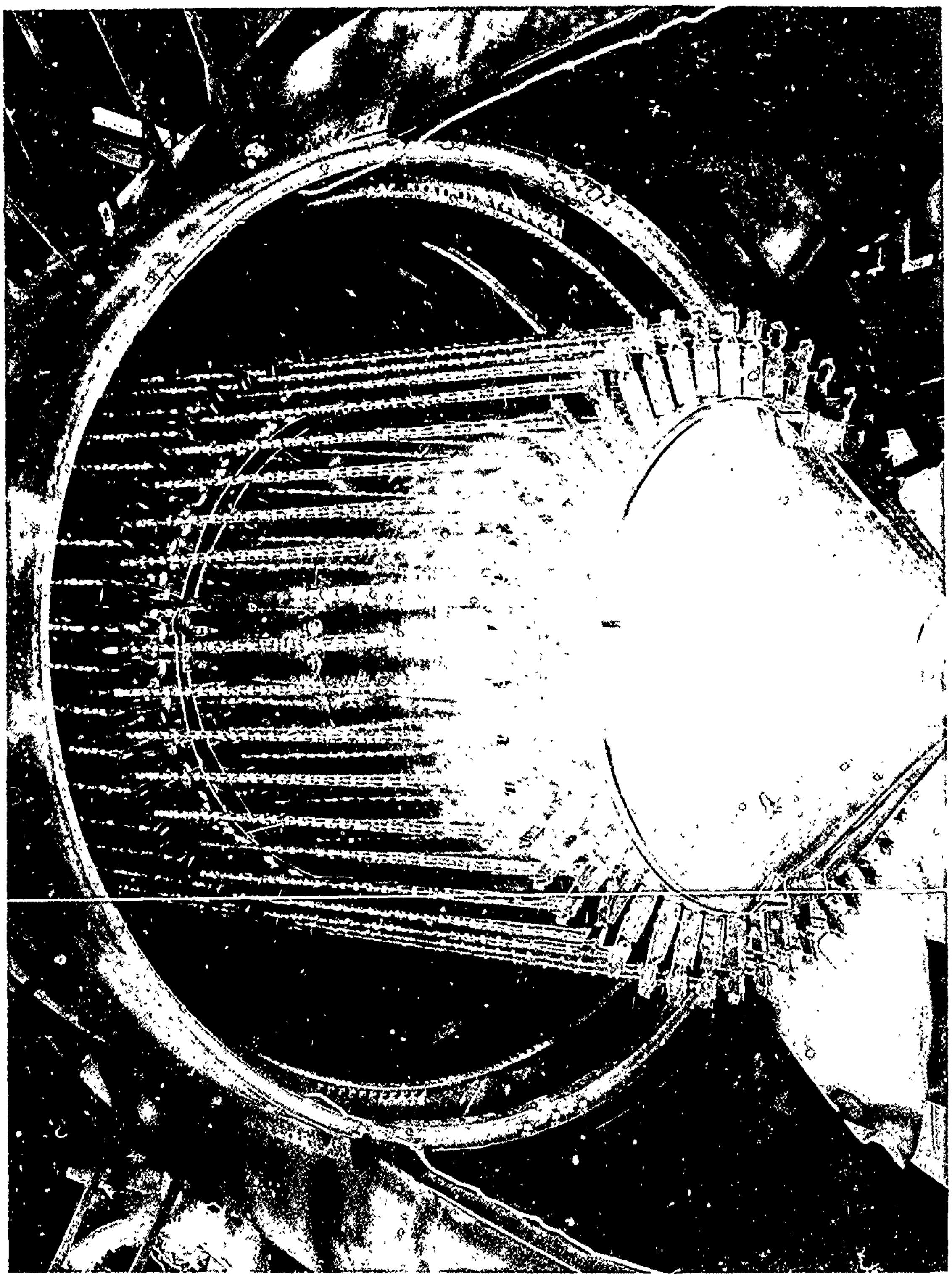
During the fatigue test, limit load was applied at the rate of 50 times per minute. Full limit load was applied at 30 times per minute, 125% limit load at 25 times per minute, and 150% limit load (design ultimate) at 20 times per minute.

Heat was applied by a conical oven within the specimen, simulating heat from a jet engine, as shown in Figure F-4 (page 291). The specimen was covered with an asbestos blanket, Figure F-5 (page 292), to reduce heat loss and help maintain an even temperature distribution. Quartz infrared lamps were used to provide heat. They were controlled by a Research, Incorporated heat programmer. Four channels of heating were



Convair Print 65546

Figure F-3 — FUSELAGE TAIL CONE IN TEST FIXTURE;
With Whippletrees Attached.



Convair Print 65547

Figure F-4 — VIEW LOOKING UP INTO TAIL CONE; Showing Heat Lamp Oven in Place.

Convair Print 65545

Figure F-5 – OVERALL VIEW SHOWING ASBESTOS BLANKET COVERING IN PLACE.

IV. TEST PROCEDURES (Cont'd)

used: one each at the top and bottom and two sharing the center portion. A channel consists of a lamp bank, a controller, and a thermocouple attached to the specimen under the lamp bank. The accuracy of the temperature is dependent only on the accuracy of the thermocouple.

V. TEST LOADS

Load for the static test was design limit load which is defined in Convair Report S-GEN-84 "Titanium Development Program" as a combination of maneuver shear and moment and internal pressure (condition 3).

Fatigue load was 66.6% of limit load for the first 110,000 cycles and was raised subsequently on instructions from Convair Structures Group in order to obtain failures in the specimen structure.

VI. TEST RESULTS AND DISCUSSION

The deflection and set data from the static test may be found in Figures F-6 through F-23 (pages 294 through 311). There was no apparent damage after the static test.

During the fatigue test, the Fuselage Tail Cone Assembly withstood a total of 202,375 cycles of loads which ran from 2/3 limit load to 150% limit load (design ultimate) at 800 F. The assembly would still carry the load, although three internal ribs had failed and another was about 80% failed. The three failed ribs are shown in Figure F-24 (page 312), and the partially failed one in Figure F-25 (page 313). Figure F-26 (page 314) shows their relative locations.

Several cracks started in the skin adjacent to rivets near the nozzle end of the Tail Cone during the 125% limit load testing at 800 F. These are shown in an over-all view in Figure F-27 (page 315). Figures F-28, F-29, and F-30 (pages 316, 317 and 318) show details of these cracks; left, middle, and right, respectively, as compared to Figure F-27. The cracks were located in a lightly loaded area (48 pounds per load point) while diametrically opposite there were no cracks with up to 101 pounds per load point. An investigation showed that the cracked skin had a hydrogen content of about 190 PPM. This was about the highest of all skins used on the Tail Cone. The load points adjacent to these cracks were then moved

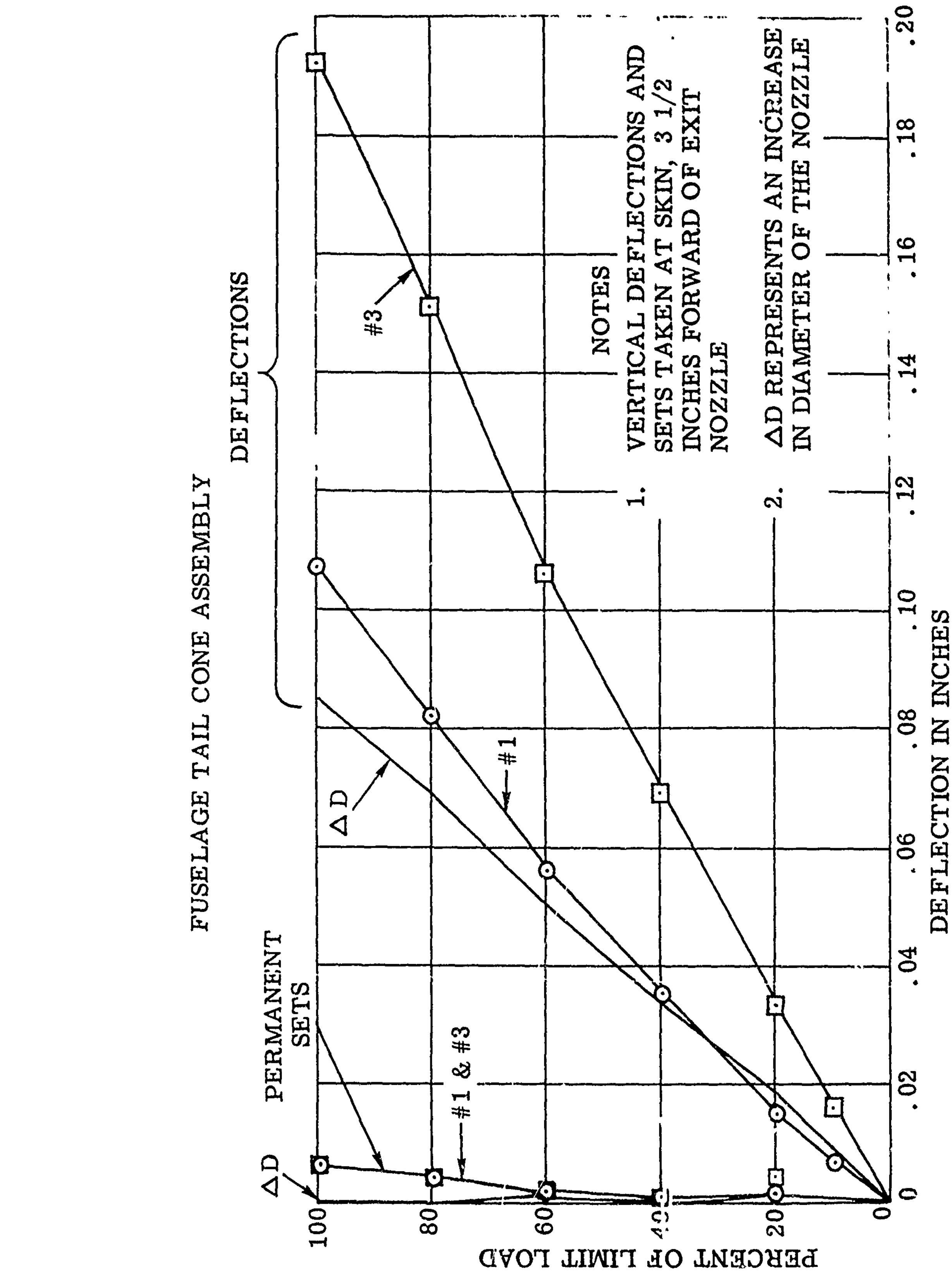


Figure F-6 ROOM-TEMPERATURE STATIC TEST RESULTS

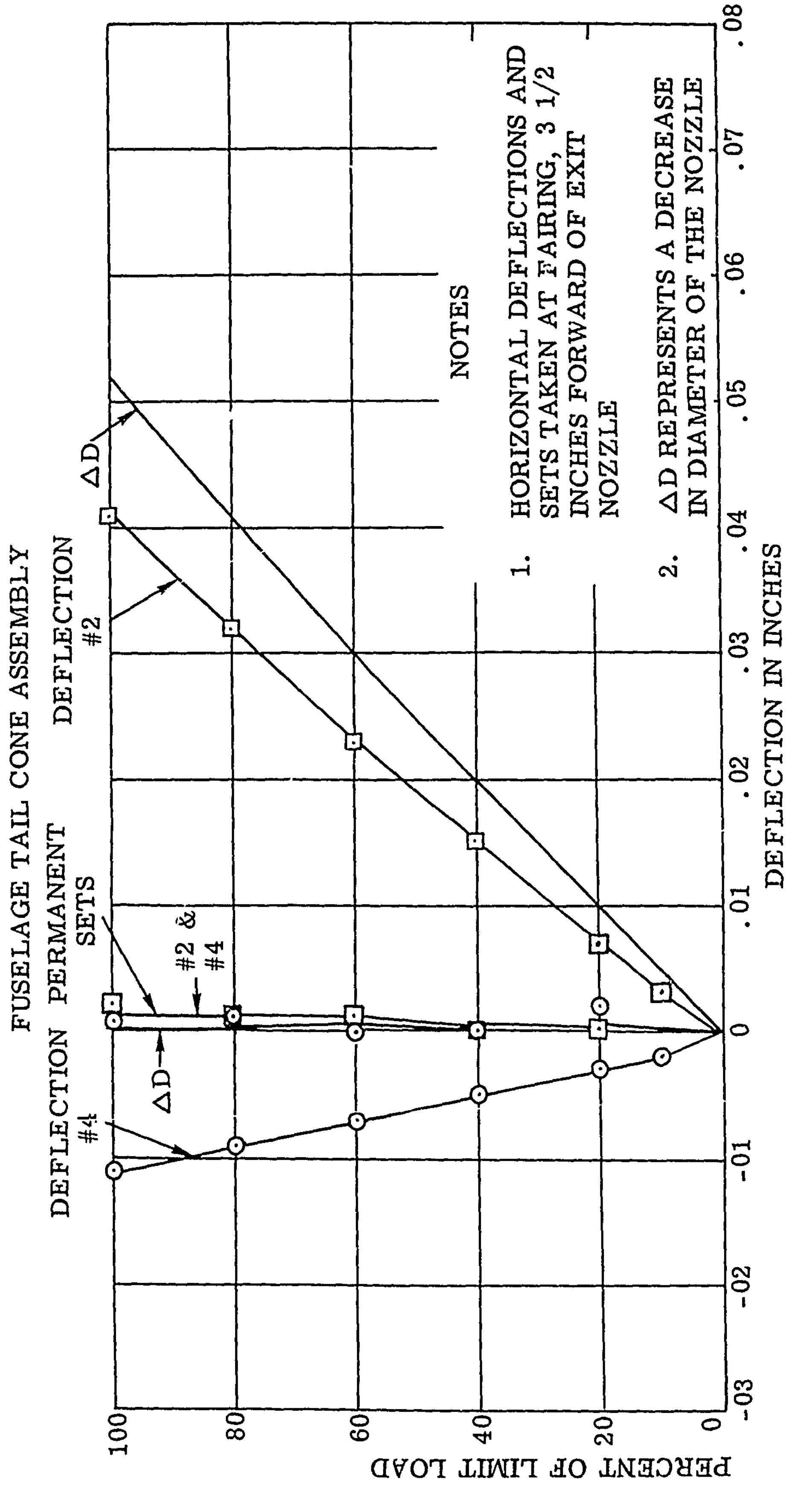


Figure F-7 ROOM-TEMPERATURE STATIC TEST RESULTS

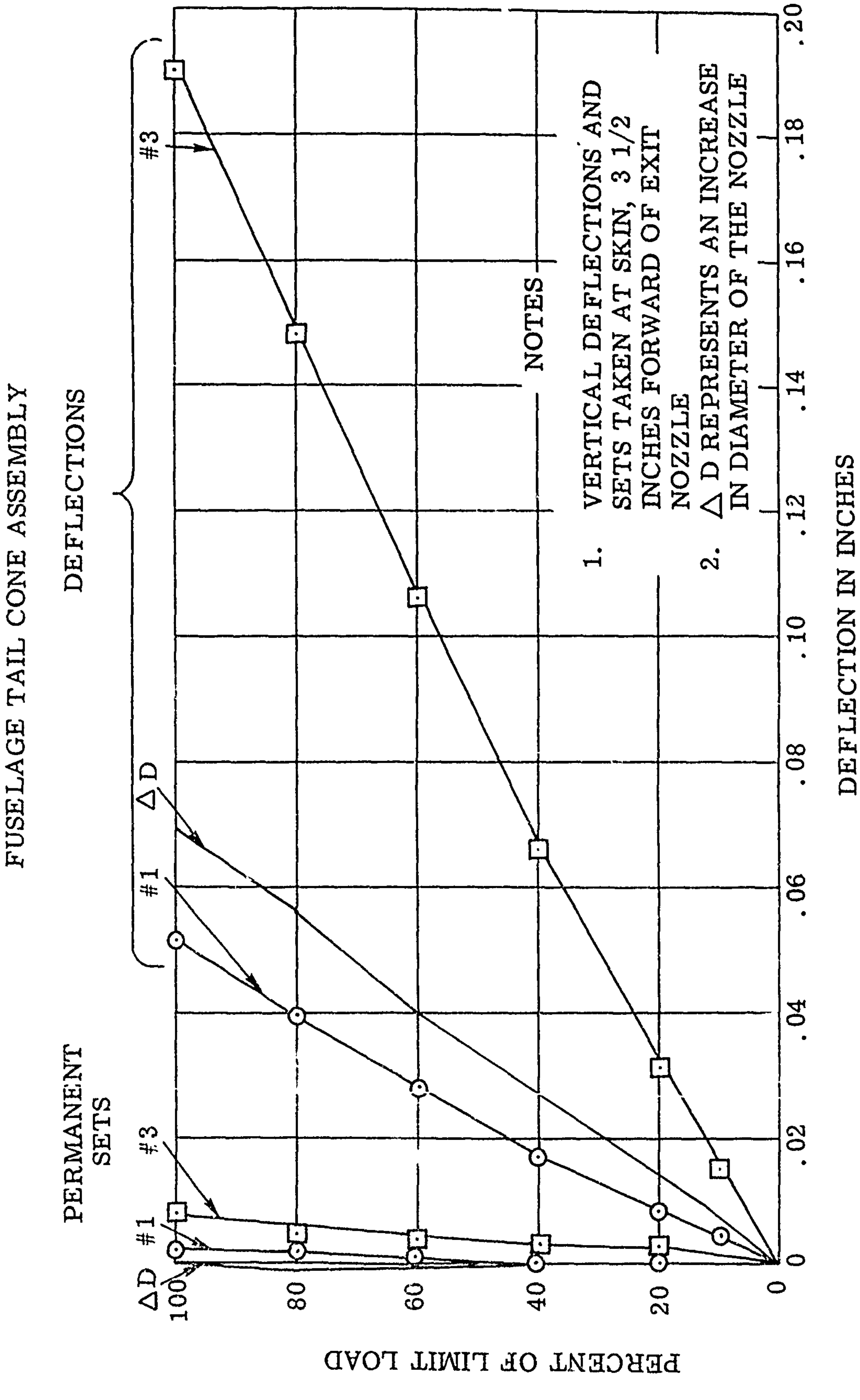


Figure F-8 200°F STATIC TEST RESULTS

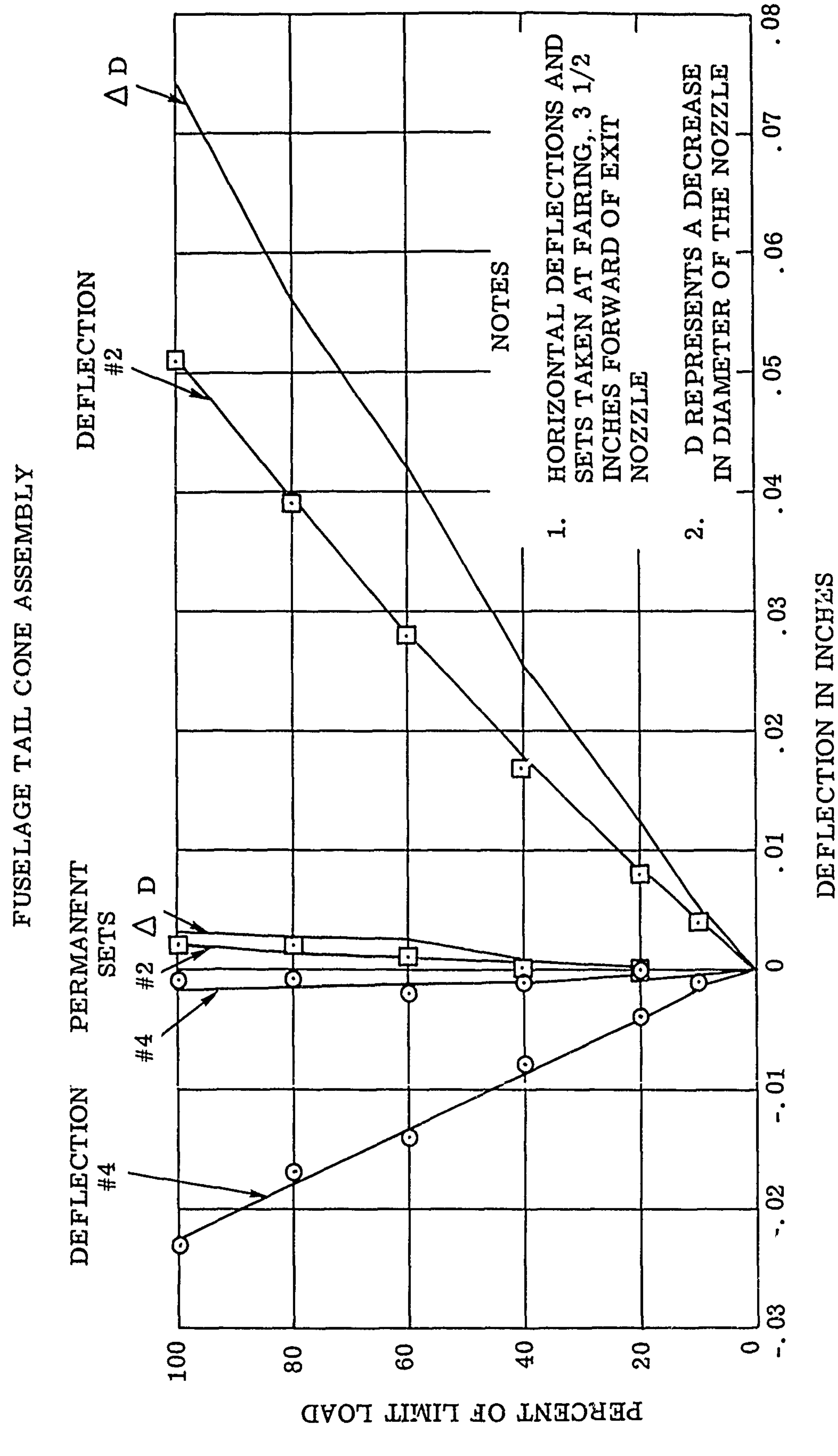


Figure F-9 200°F STATIC TEST RESULTS

FUSELAGE TAIL CONE ASSEMBLY

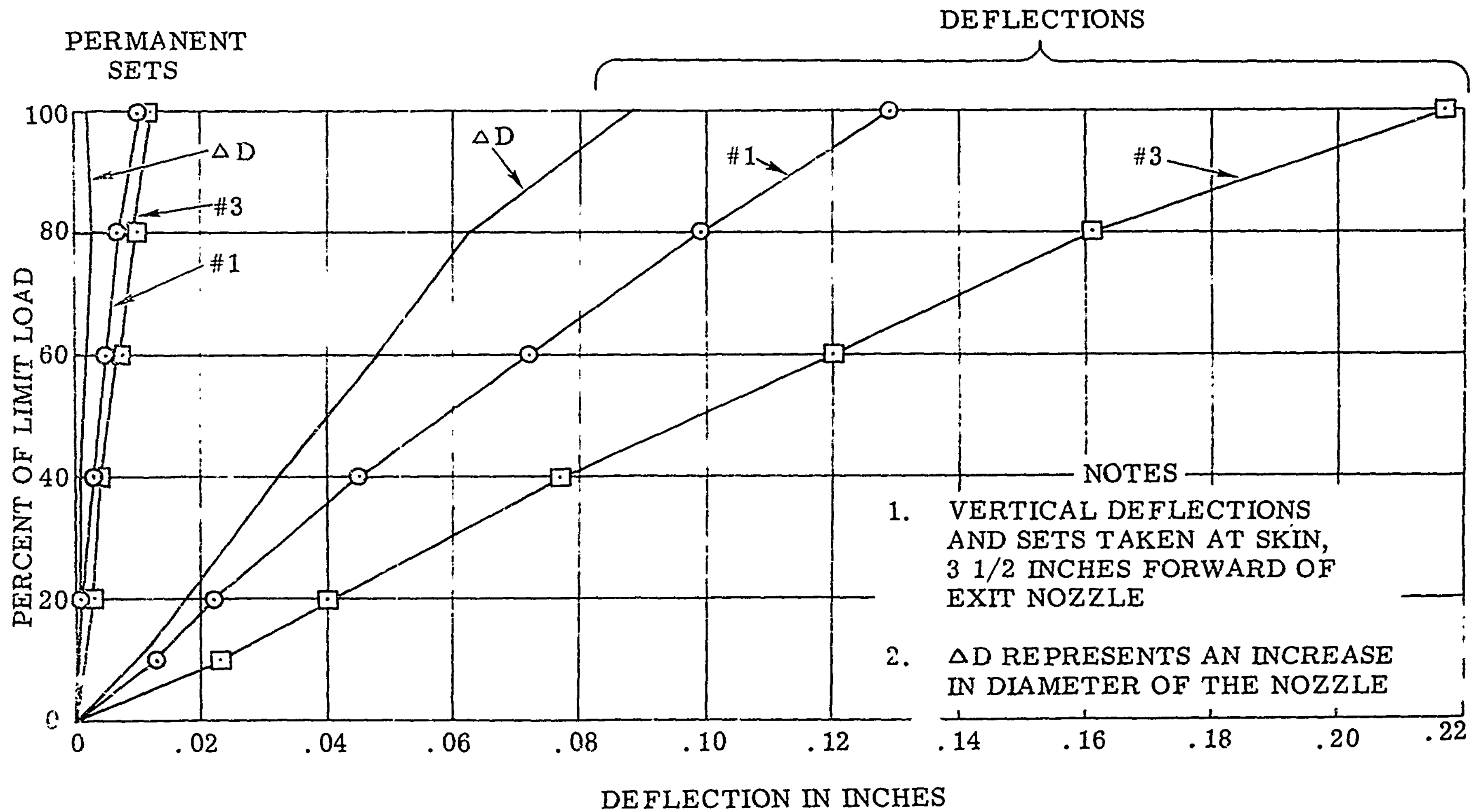


FIGURE F-10. 300°F STATIC TEST RESULTS

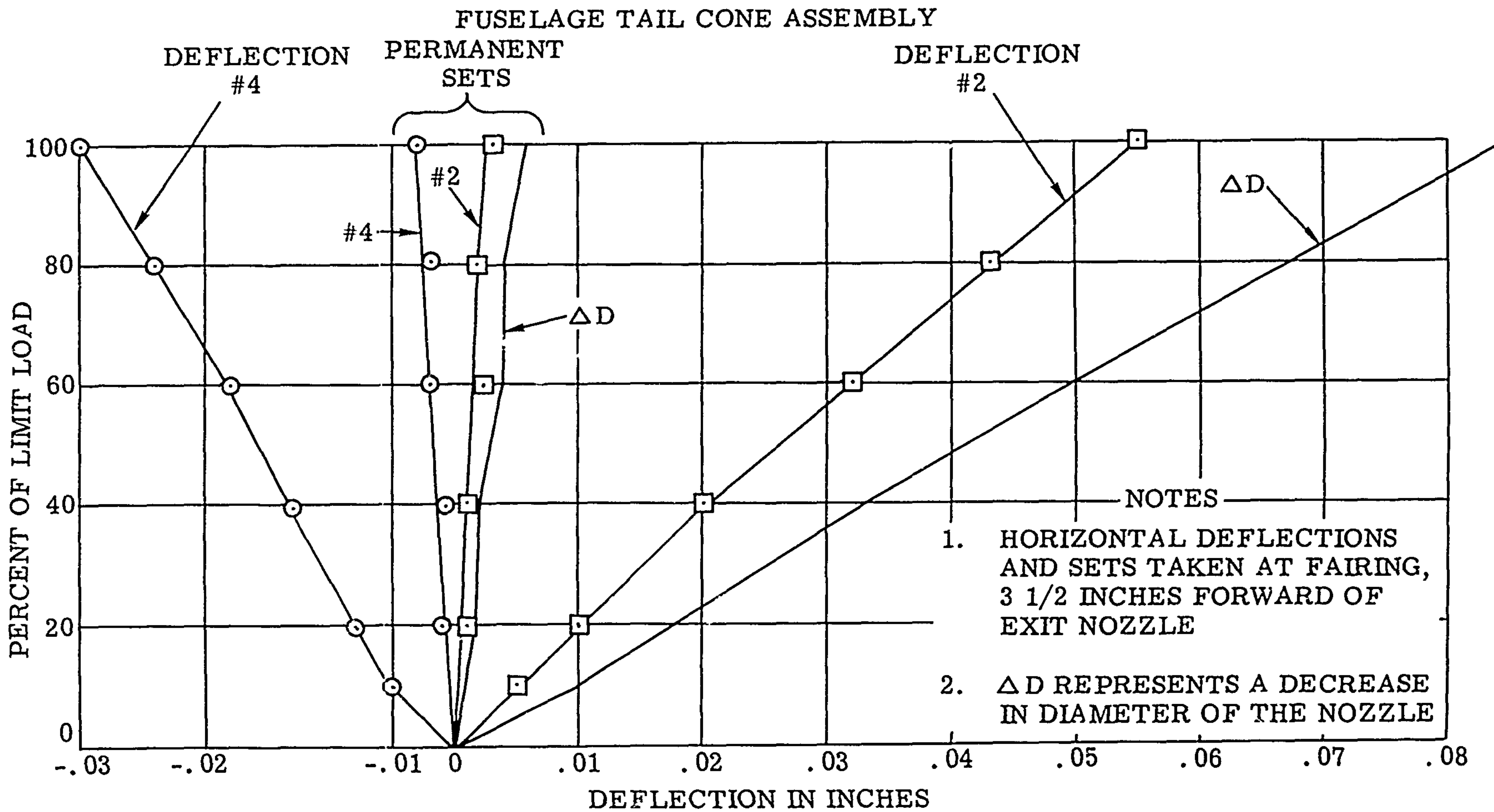


FIGURE F-11. 300°F STATIC TEST RESULTS

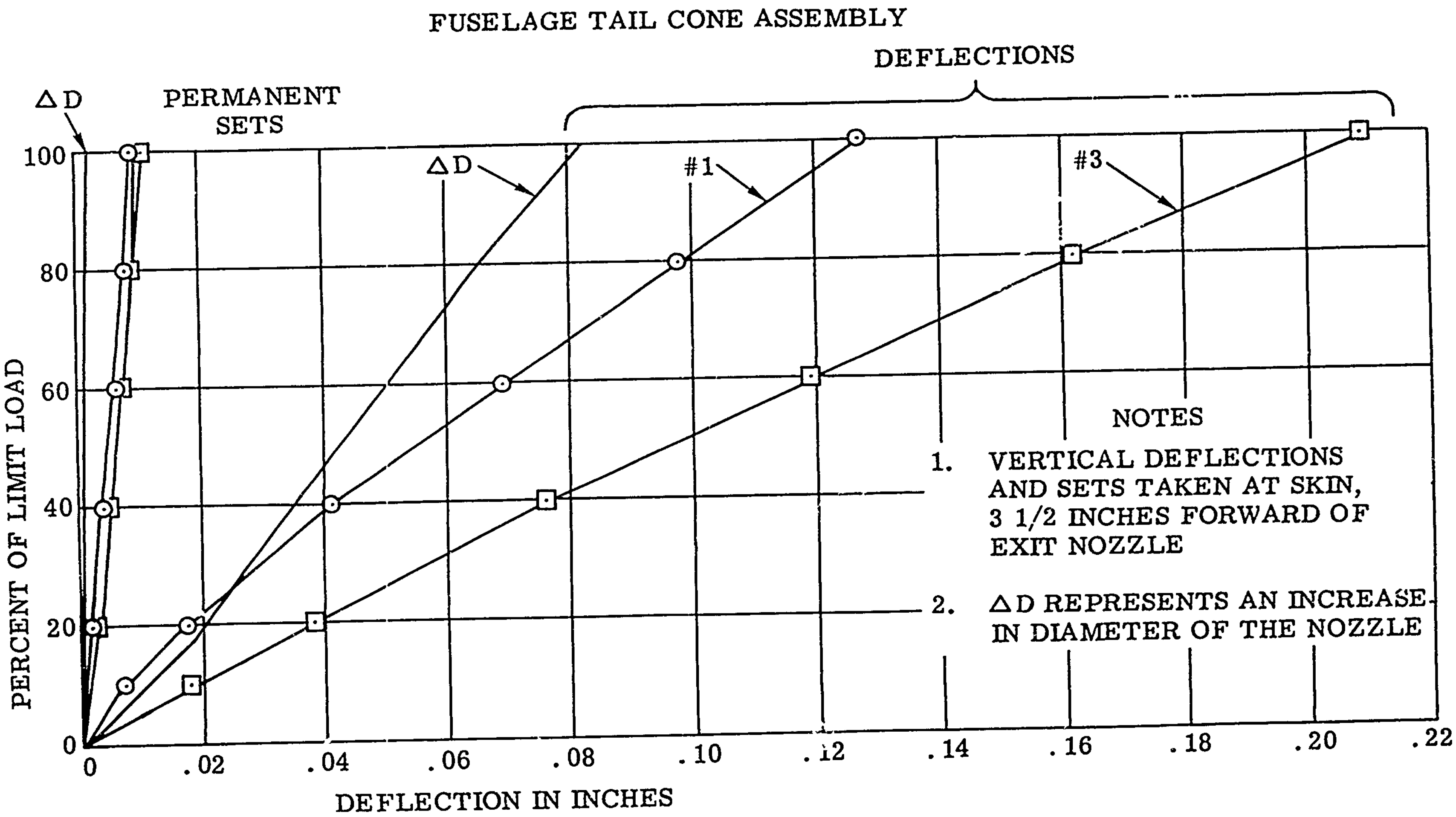


FIGURE F-12. 400°F STATIC TEST RESULTS

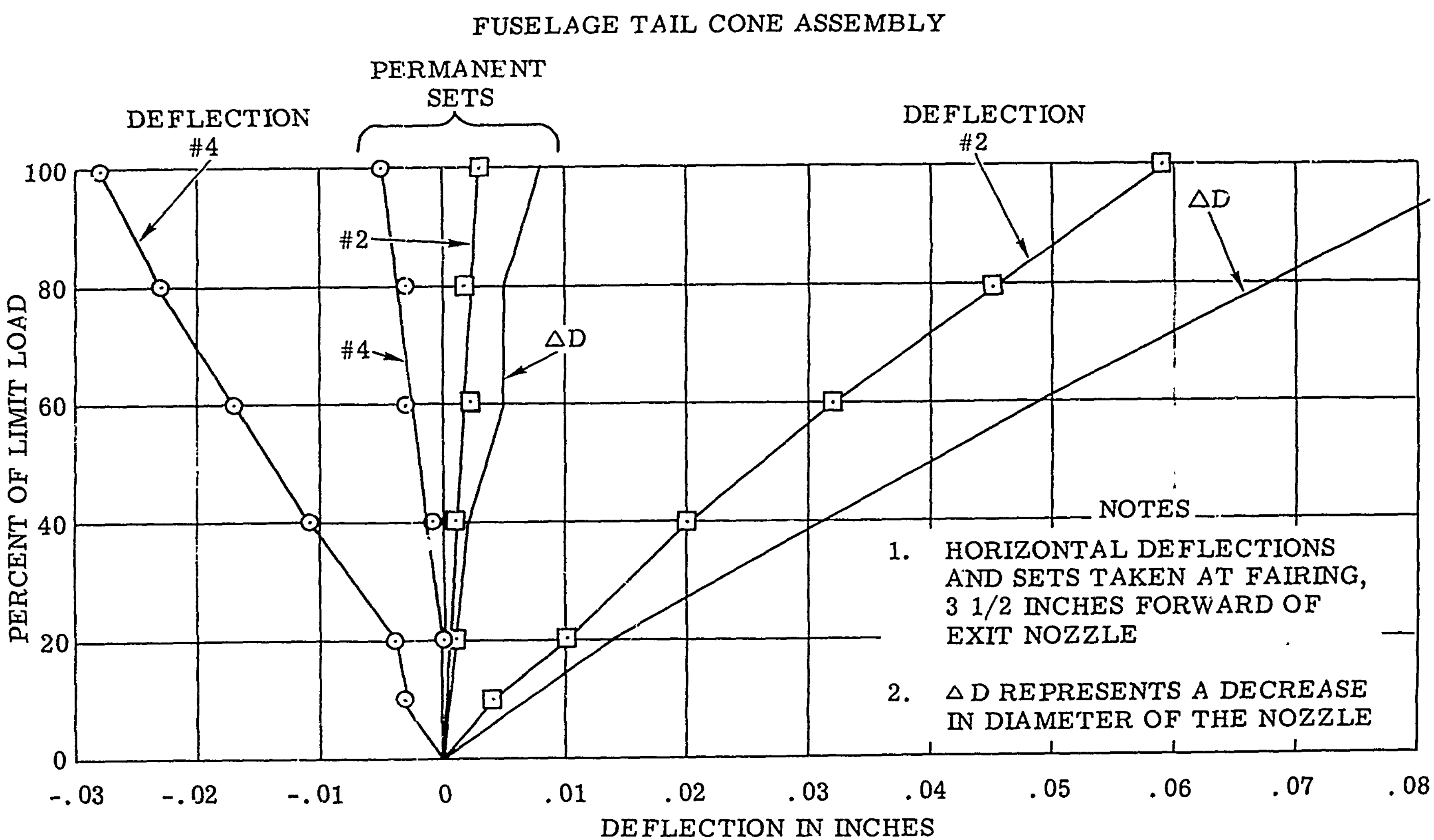


FIGURE F-13. 400F STATIC TEST RESULTS

FUSELAGE TAIL CONE ASSEMBLY

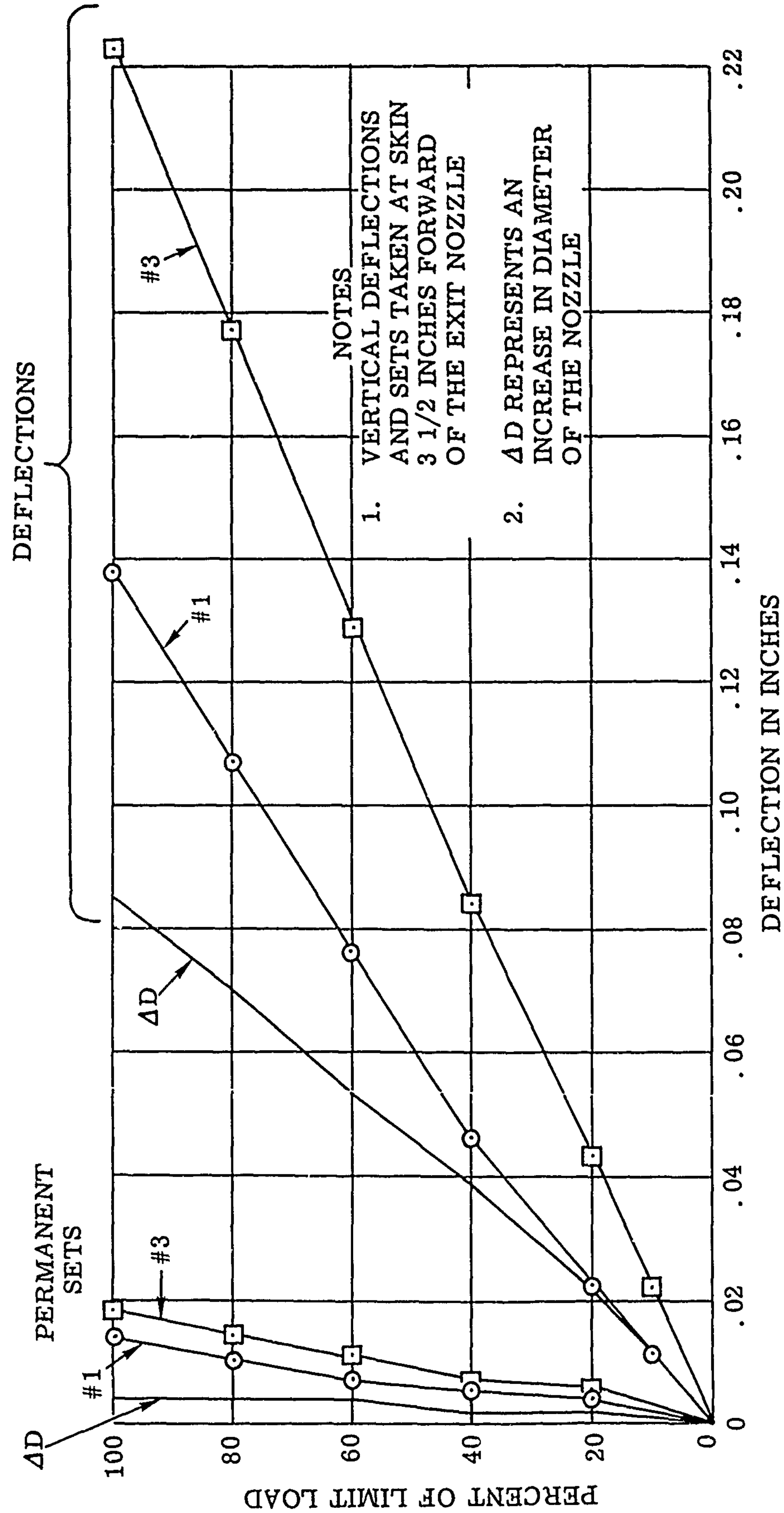
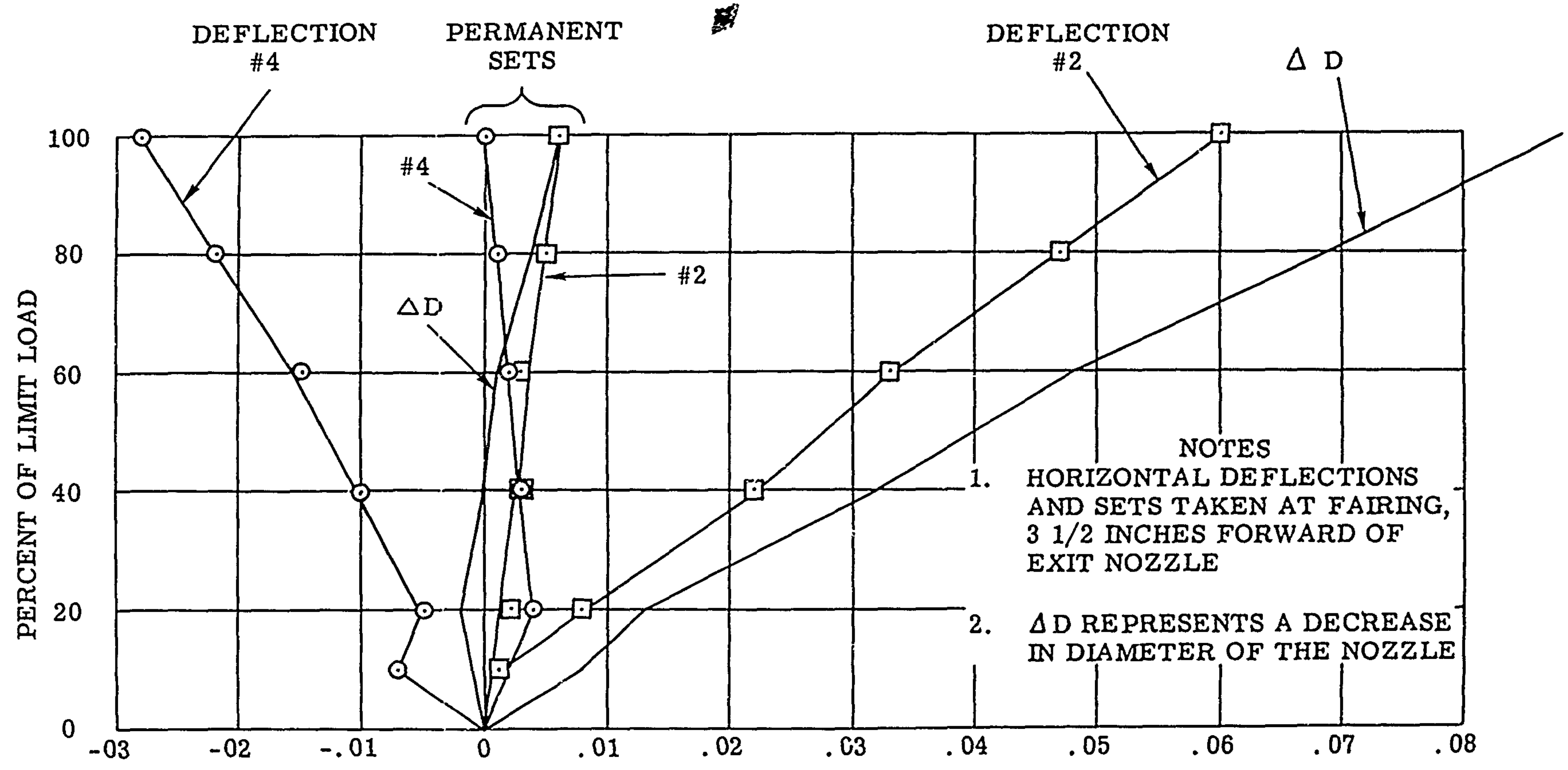


FIGURE F-14. 500°F STATIC TEST RESULTS



FUSELAGE TAIL CONE ASSEMBLY

FIGURE F-15. 500° F STATIC TEST RESULTS

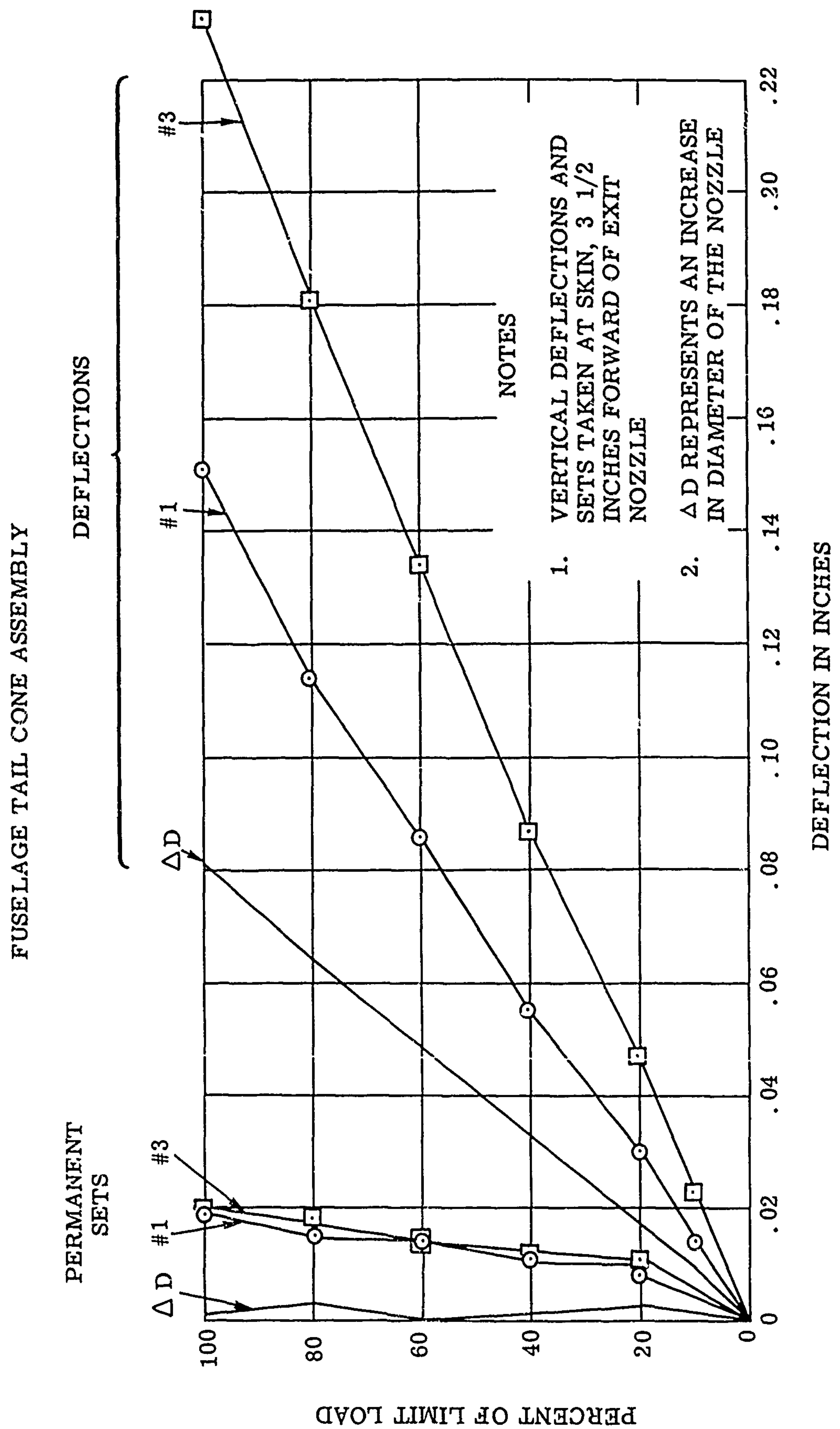


Figure F-16 600°F STATIC TEST RESULTS

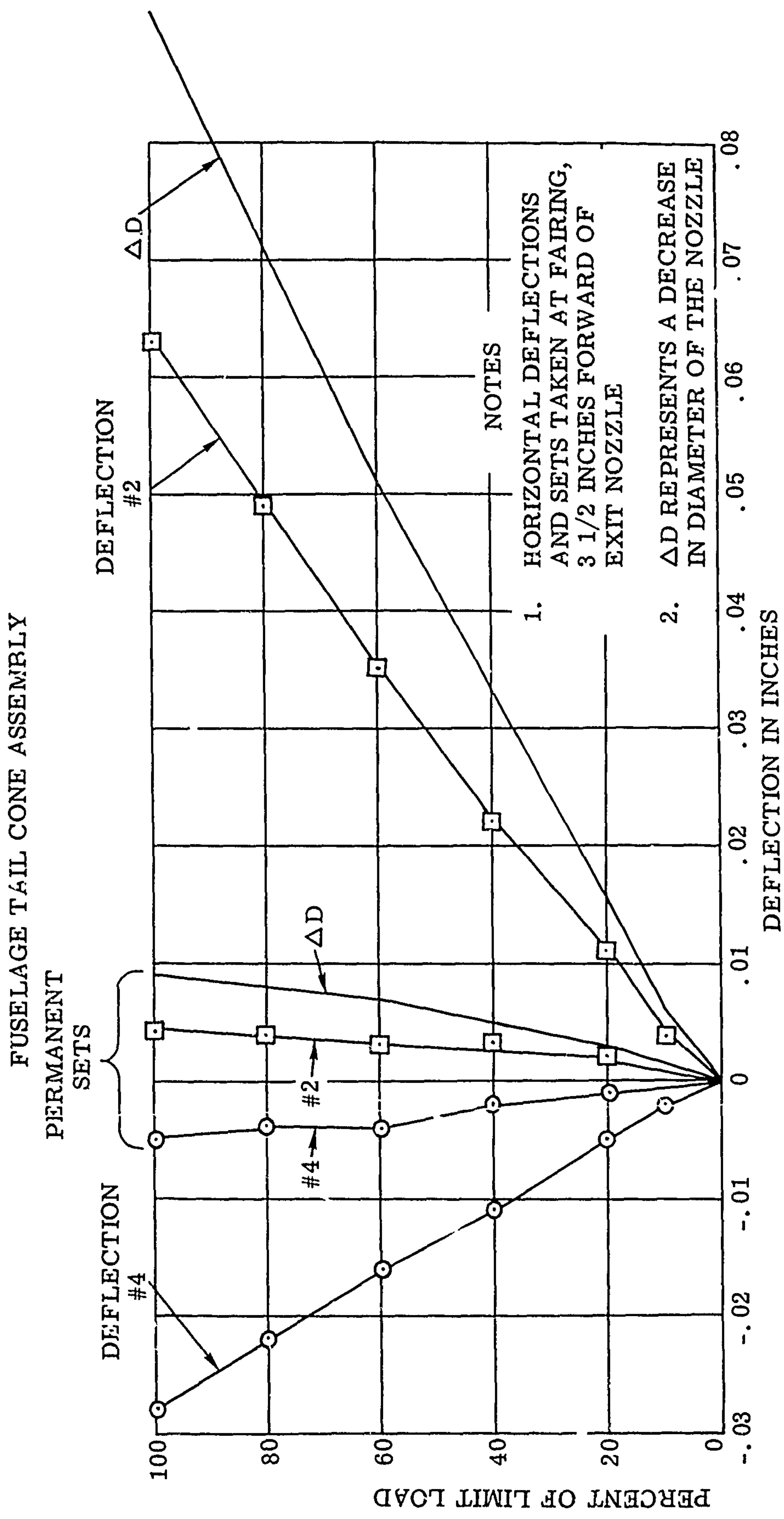


FIGURE F-17. 600°F STATIC TEST RESULTS

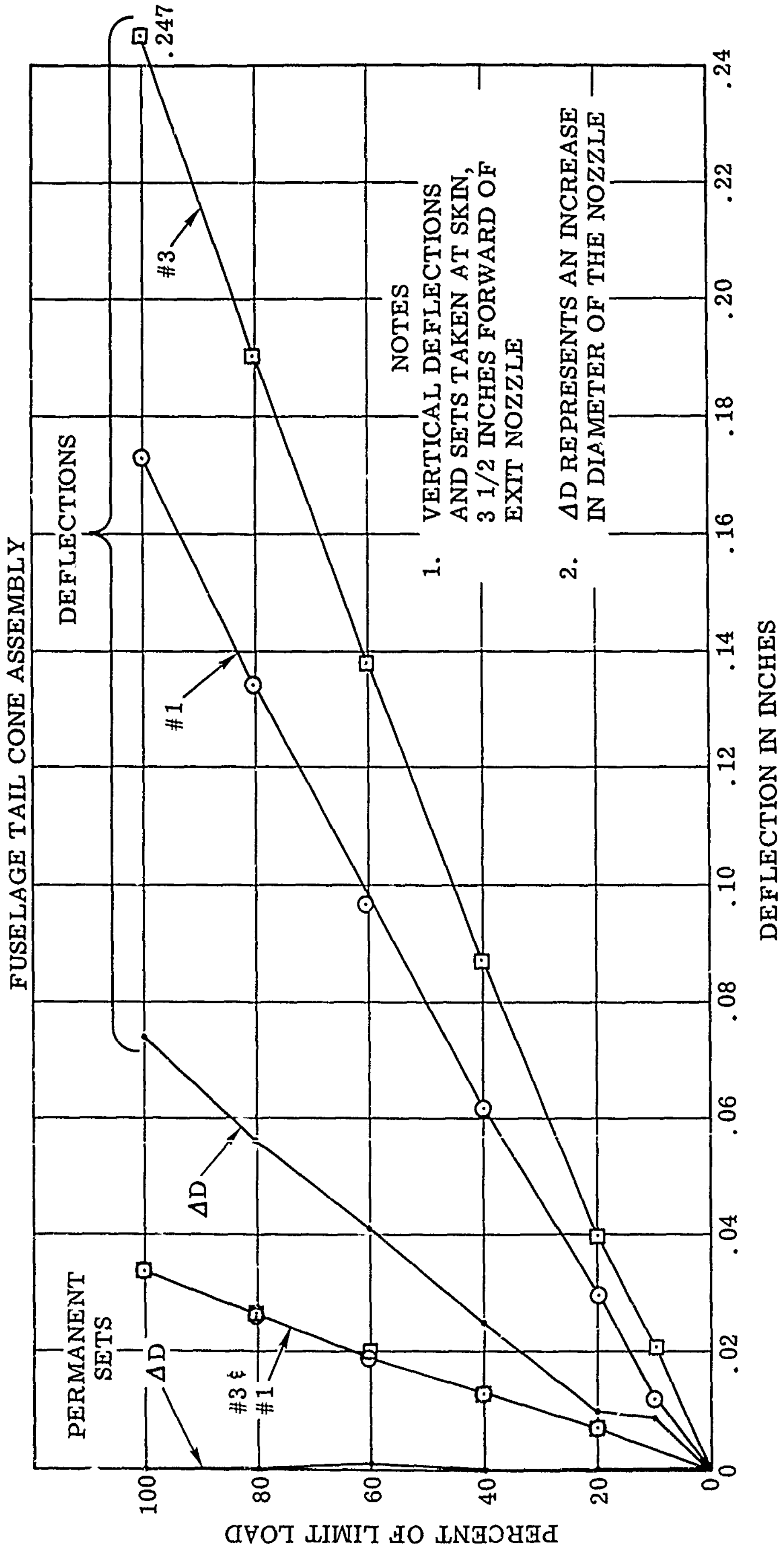


FIGURE F-18. 700°F STATIC TEST RESULTS

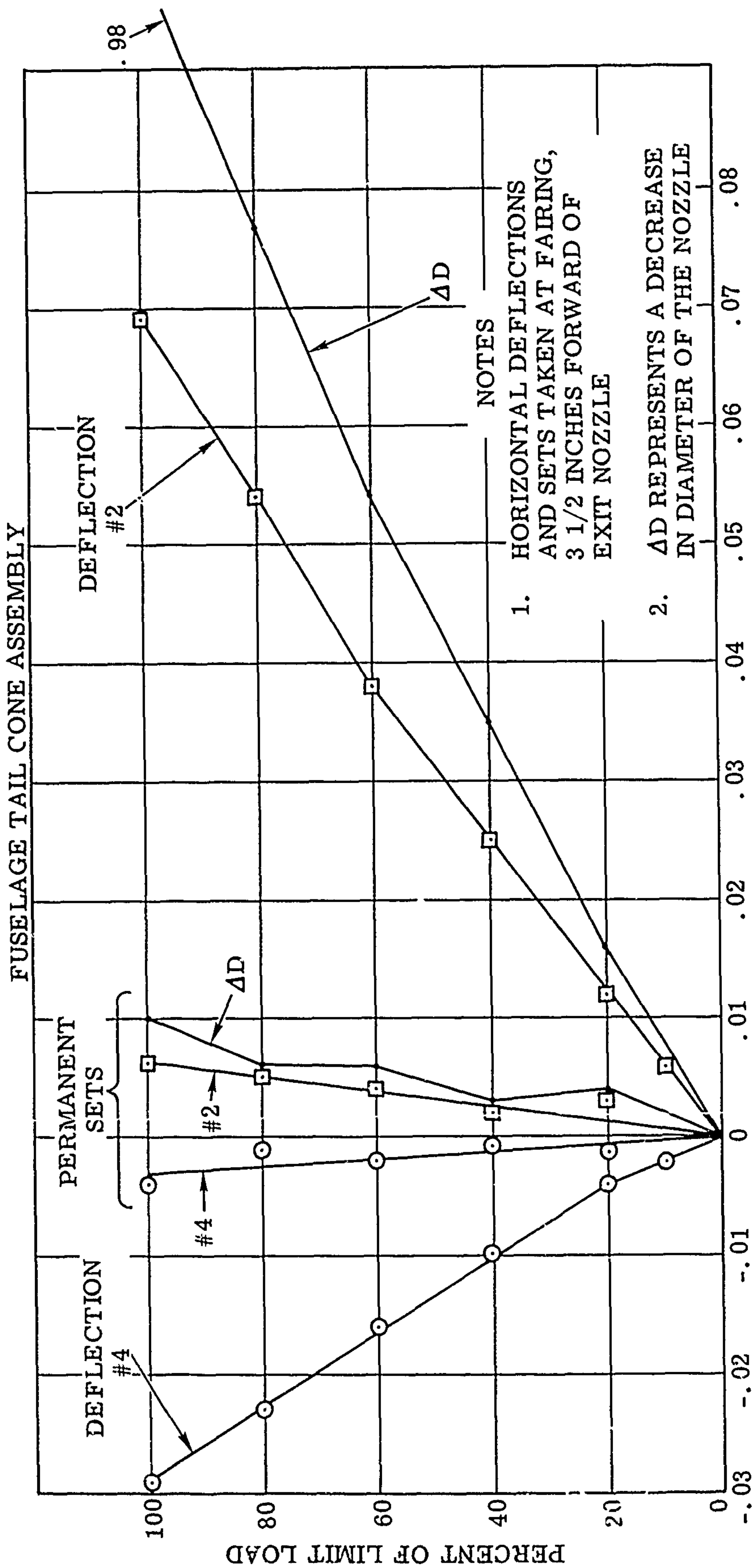


FIGURE F-19. 700°F STATIC TEST RESULTS

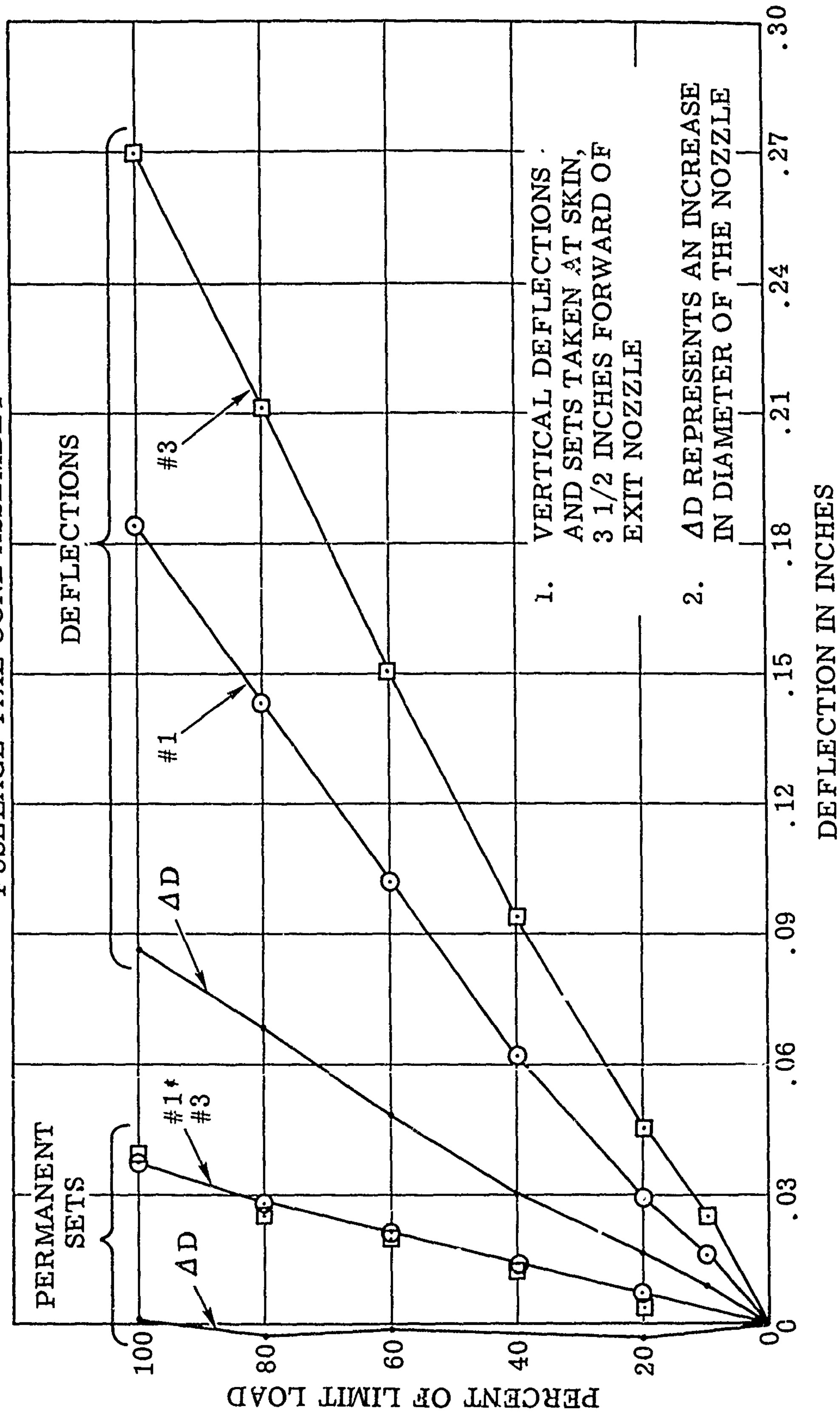


FIGURE F-20. 800°F STATIC TEST RESULTS

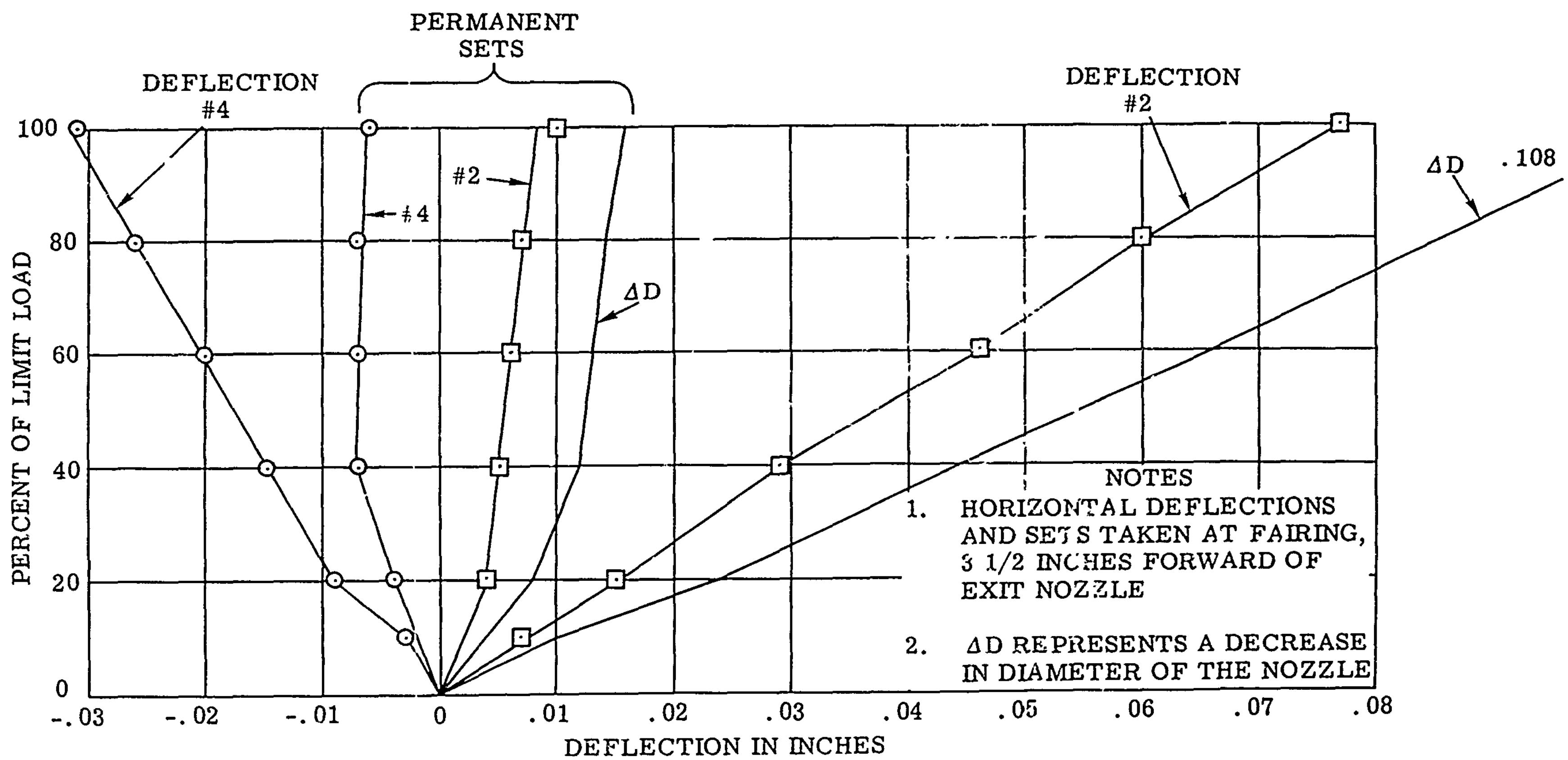


FIGURE F-21. 800°F STATIC TEST RESULTS

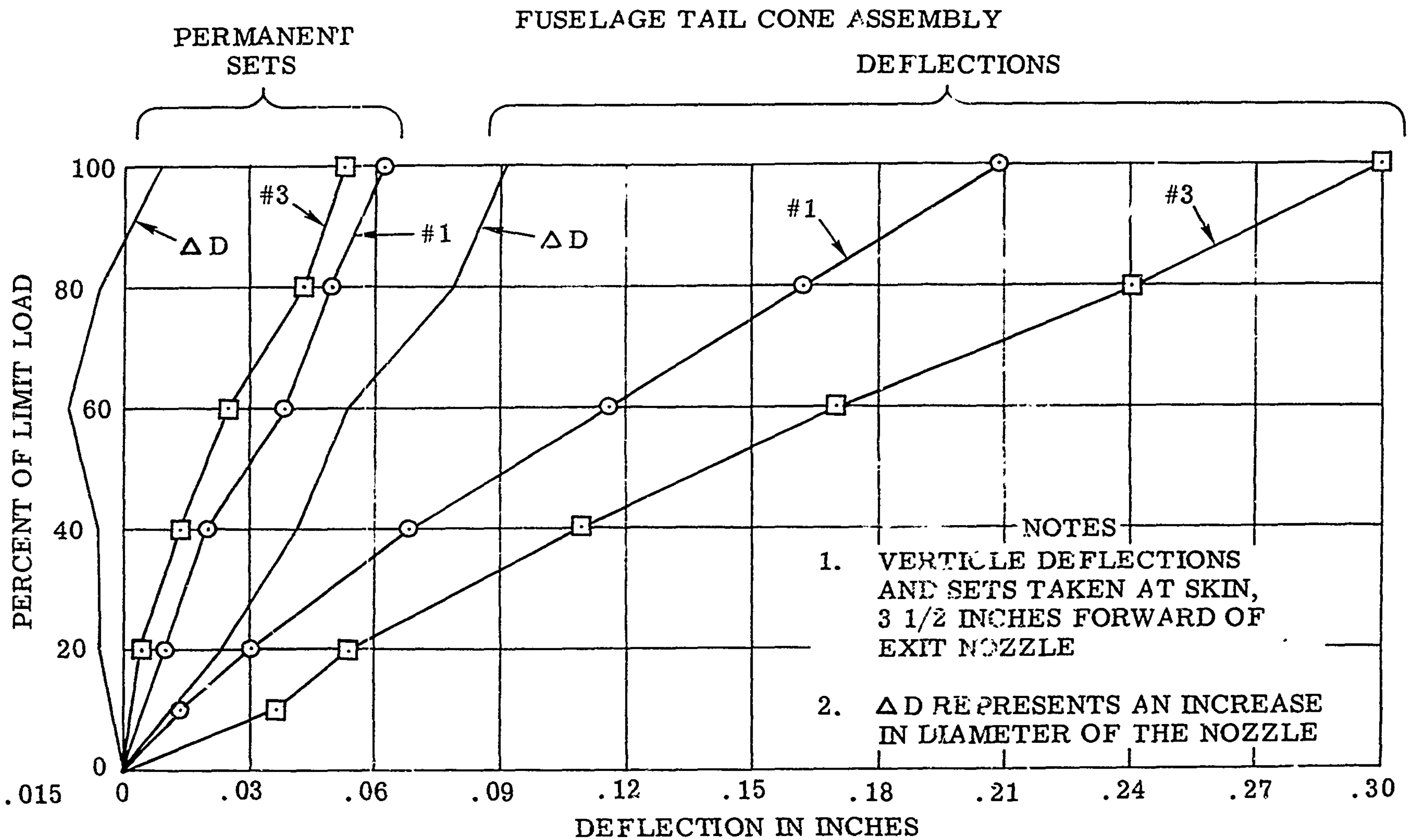


FIGURE F-22. 900°F STATIC TEST RESULTS

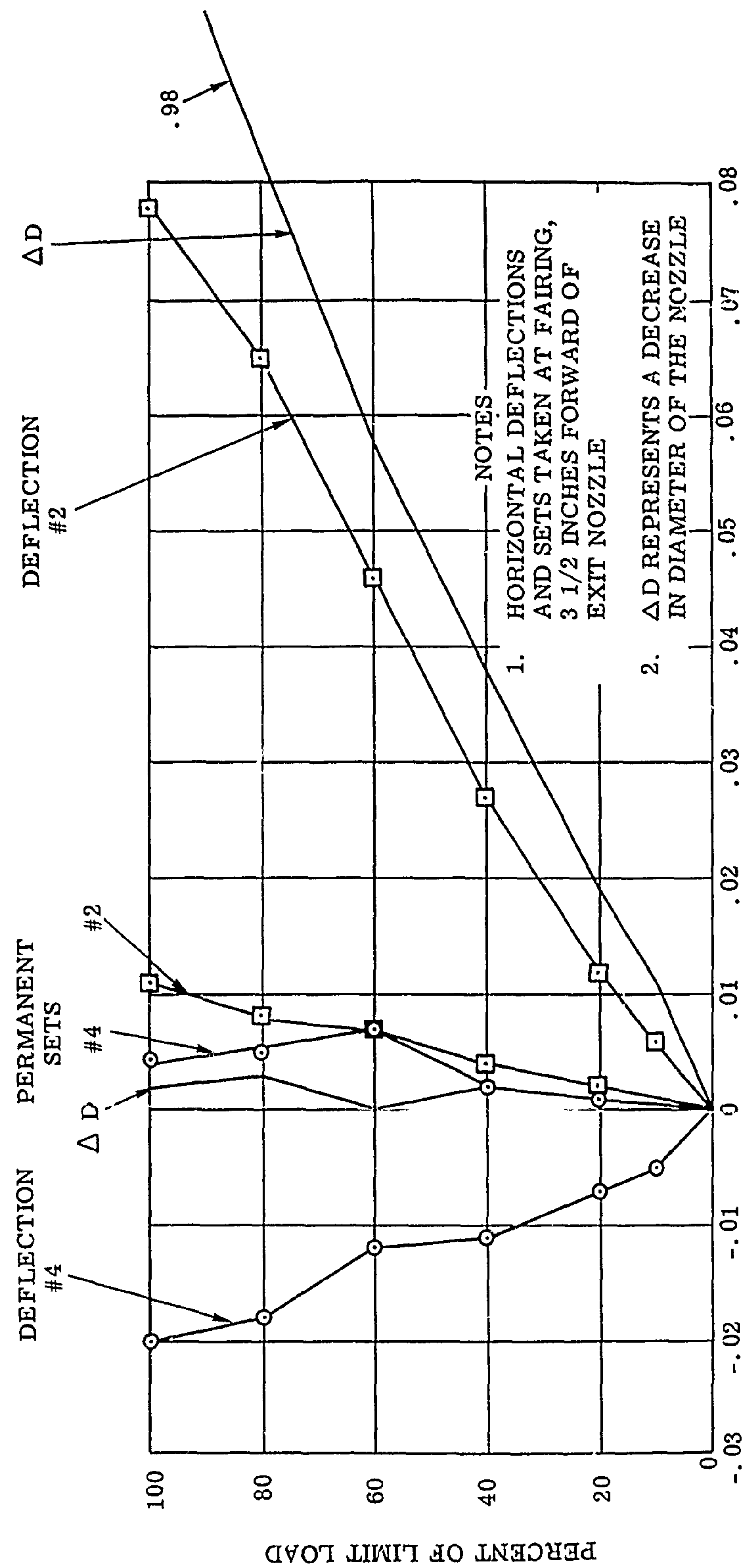
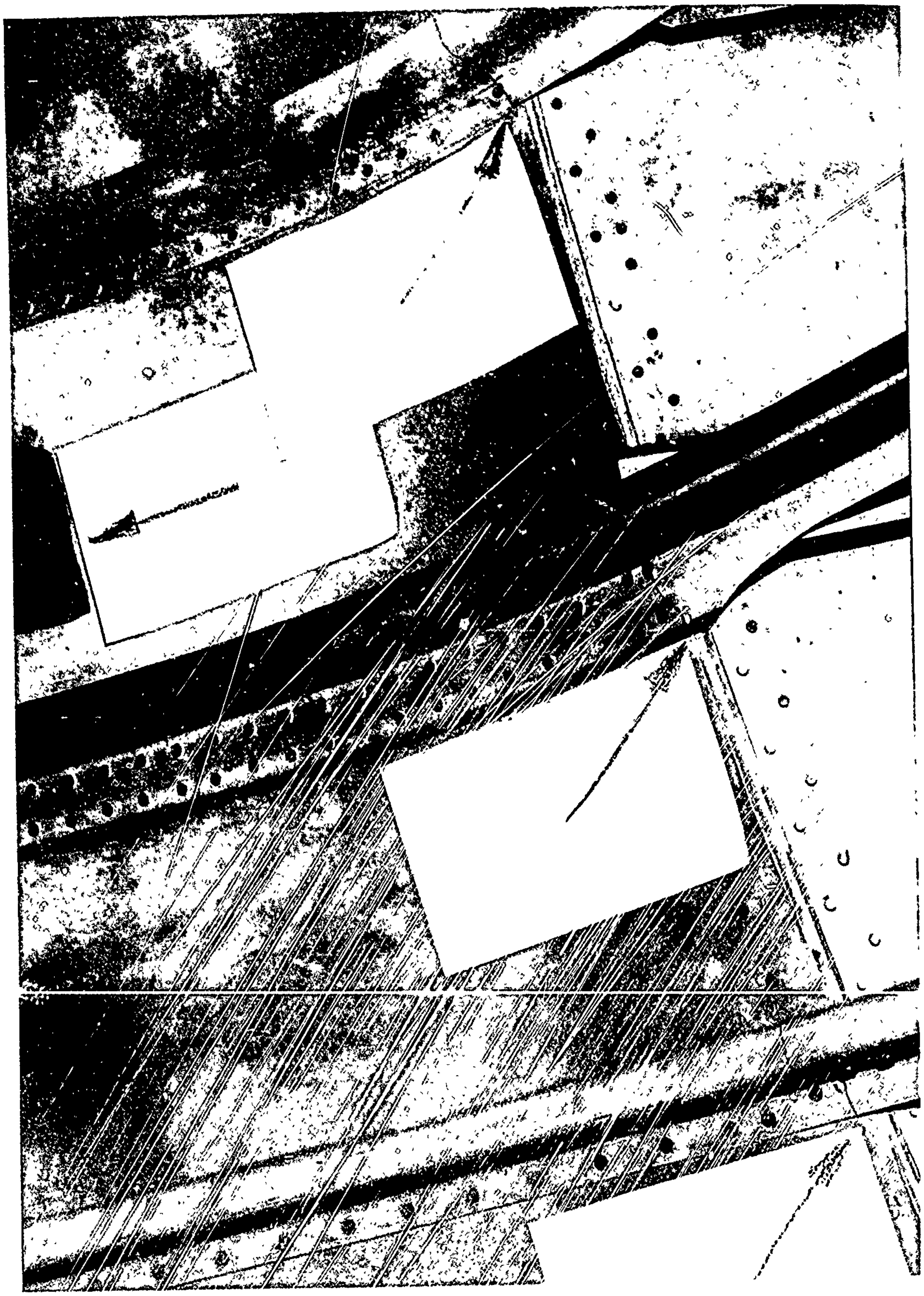


FIGURE F-23. 900°F STATIC TEST RESULTS

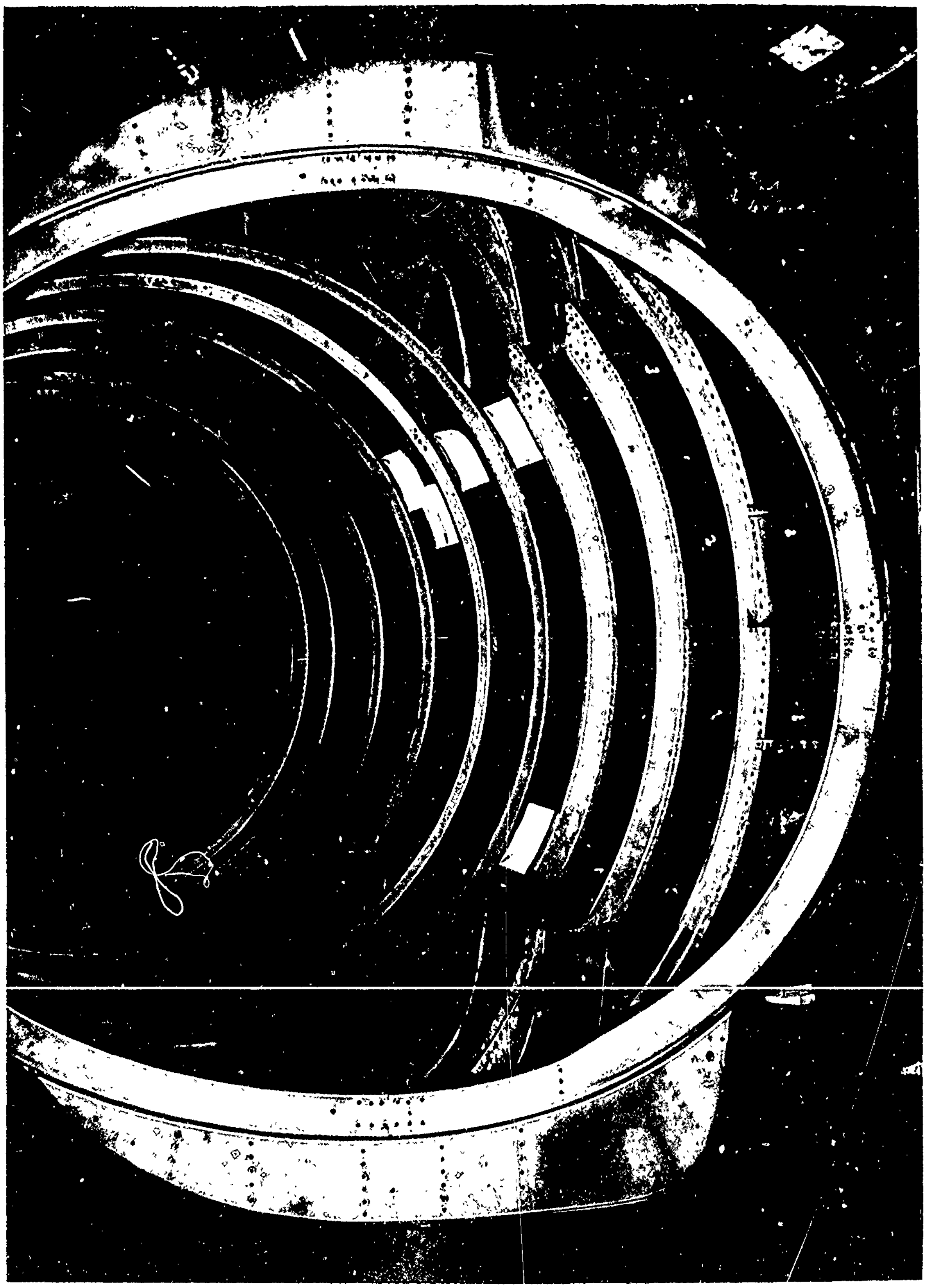


Convair Print 65612

Figure F-24 – DETAIL VIEW SHOWING THE THREE FAILED RIBS AND TORN OUT SECTION.

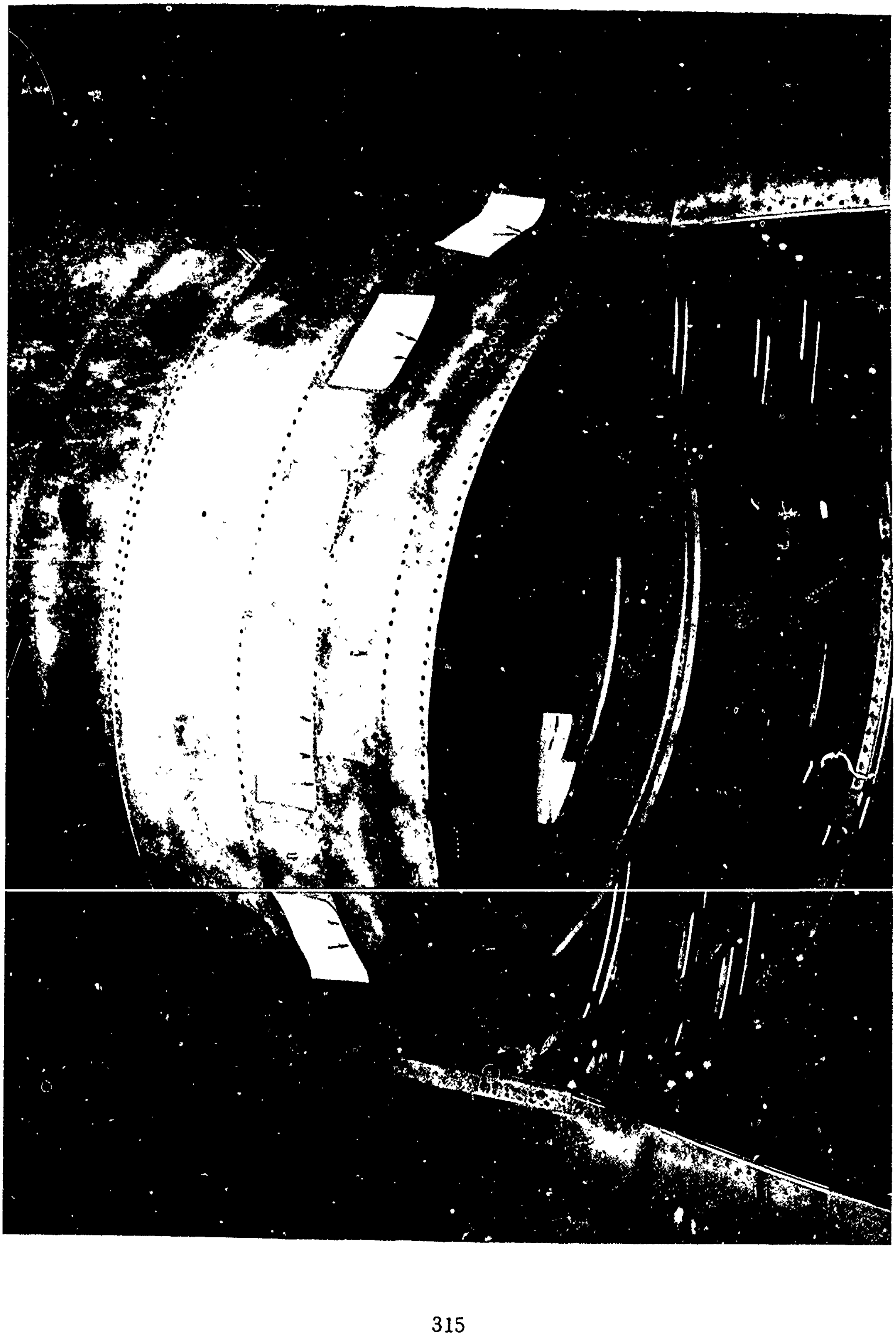
Convair Print 65613

Figure F-25 – DETAIL VIEW SHOWING PARTIALLY FAILED RIB.



Convair Print 65950

Figure F-26 — OVERALL VIEW SHOWING RELATIVE LOCATIONS OF FAILED RIBS AND TORN OUT SECTION.

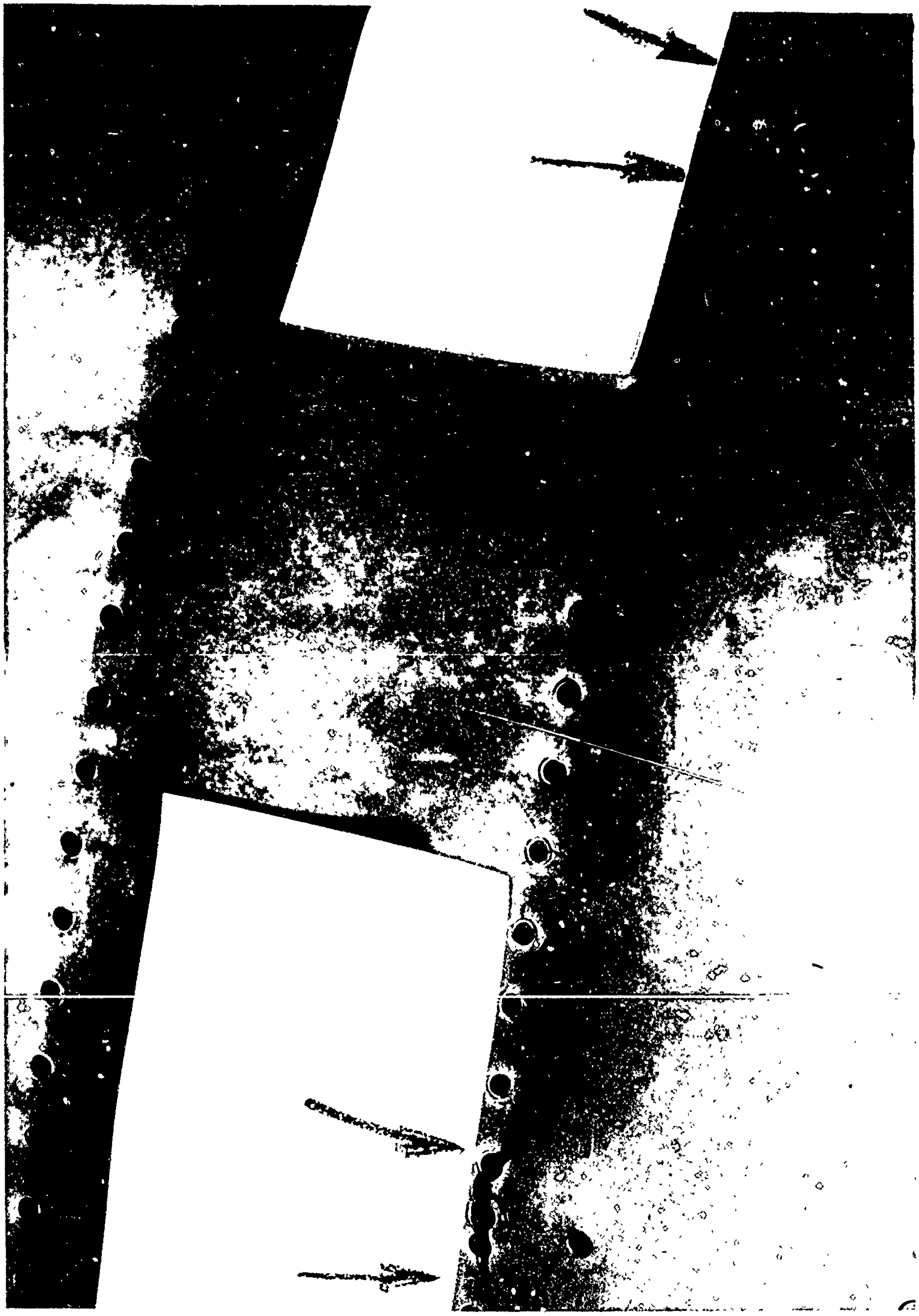


Convair Print 65951

Figure F-27 — OVERALL VIEW SHOWING SKIN CRACKS AND THEIR LOCATION RELATIVE TO THE FAILED RIBS AND TORN OUT SECTION.

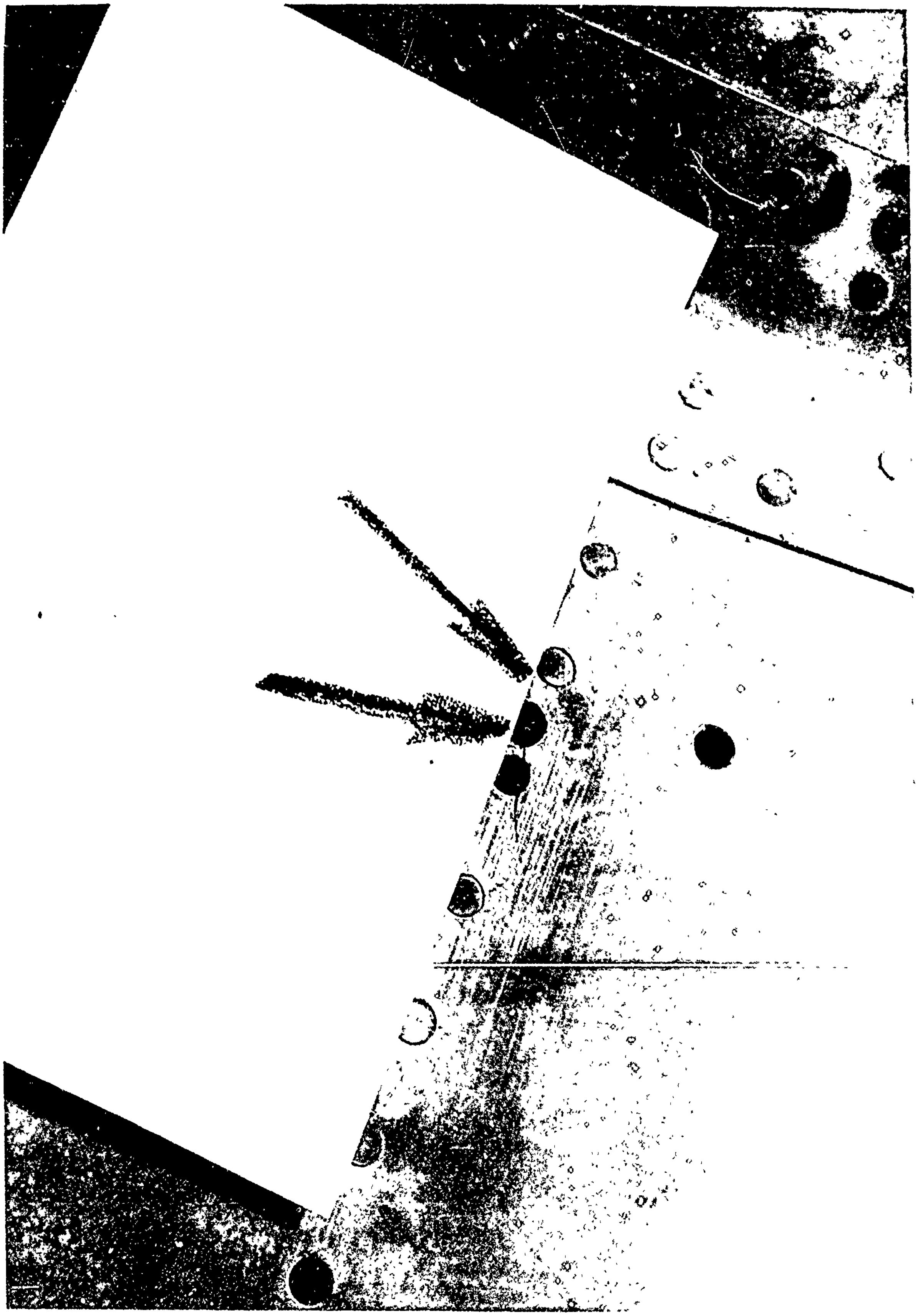
Convair Print 65614

Figure F-28 — DETAIL VIEW SHOWING SKIN CRACKS; Original Load-Point Holes are Away From Rivet Pattern, Relocated Holes are Between Rivets.



Convair Print 65615

Figure F-29 — DETAIL VIEW SHOWING SKIN CRACKS; Original Load-Point Holes are Away From



Convair Print 65616

Figure F-30 — DETAIL VIEW SHOWING SKIN CRACKS; Original Load-Point Holes are Away From Rivet Pattern, Relocated Holes are Between Rivets.

VI. TEST RESULTS AND DISCUSSION (Cont'd)

to the rib where holes were drilled between rivets putting the load directly into the rib itself and testing continued.

After a total of 202,375 cycles, one of the loading blocks (1/2" x 1") pulled out a 2-1/2" x 3" piece of skin. This skin failure is shown in detail in Figure F-24. Figures F-26 and F-27 show its location relative to the other failures. Testing was discontinued at this point.

VII. CONCLUSIONS

1. The load carrying characteristics of the Fuselage Tail Cone Assembly, as determined by the deflection/set curves, are not materially affected by temperatures up through 900 F although deflections did increase slightly with temperature.

2. The Fuselage Tail Cone Assembly withstood 202,375 cycles of load, including 17,375 at design ultimate at 800 F, without major structural failure.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

TABLE OF CONTENTS

LIST OF TABLES

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

LIST OF FIGURES

TITANIUM DEVELOPMENT PROGRAM

LIST OF FIGURES (Continued)

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

I. INTRODUCTION

The type of test structures reported herein were skin and stringer combinations which represent sections of an airframe wing skin. Three different test configurations of these structures were fabricated. Each of the test structures represented varying degrees of difficulty of fabrication and strength. This report presents the results of testing the three configurations of skin and stringer combinations as edge compression members. Flight parameters for a type of future aircraft were duplicated, as closely as possible. These flight parameters are axial compressive load, internal pressure and temperature.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

II. SUMMARY

Three configurations were selected for evaluation of Titanium Alloy B-120 VCA as fabricated in typical wing structure. The three specimens were designed to be representative of typical plate stringer geometry. Each specimen consisted of three continuous 18.0 inch bays subjected to edge compression and internal pressure.

The analysis to predict their strength assumed each bay to act as a simple beam column having an end column fixity equal to 1.0. The material properties used in the analysis were based on available typical processing results obtained from Convair data for room temperature. The elevated temperature effects were derived by using a percentage deterioration factor estimated from data in DMIC Report 110.

The ultimate strength test loads have been correlated with the analytical method and the test data fitted on the design curves reasonably well.

The test unit strength-weights of the configurations tested based on the weight per square foot for a load of 10,000 pounds per chord inch are: 3.0 lbs/sq. ft, 3.29 lbs/sq. ft., and 2.52 lbs/sq. ft. for the -1, -3, and -5 specimens, respectively. These values do not reflect the fact that the -1 carried 4.7 PSIG at failure, the -3 carried 4.9 PSIG and the -5 carried 0 PSIG at failure. The theoretical strength-density for a 10,000 pound load per chord inch in combination with 9 PSIG pressure is 3.8 lbs/sq. ft, 4.67 lbs/sq. ft., and 3.09 lbs/sq. ft. for the -1, -3, and -5 specimens, respectively.

From a strength-weight standpoint the -5 specimen appears to be superior and its relative weight decreases as the internal pressure increases. The -3 specimen appears to be the least efficient and its relative weight increases as the pressure increases.

The 3.09 lbs/sq. ft. is equivalent to an aluminum panel operating at a gross average stress of 46,700 PSI which indicates that the titanium structure is essentially as efficient at 600 F as the aluminum is at room temperature for the load intensity compared.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

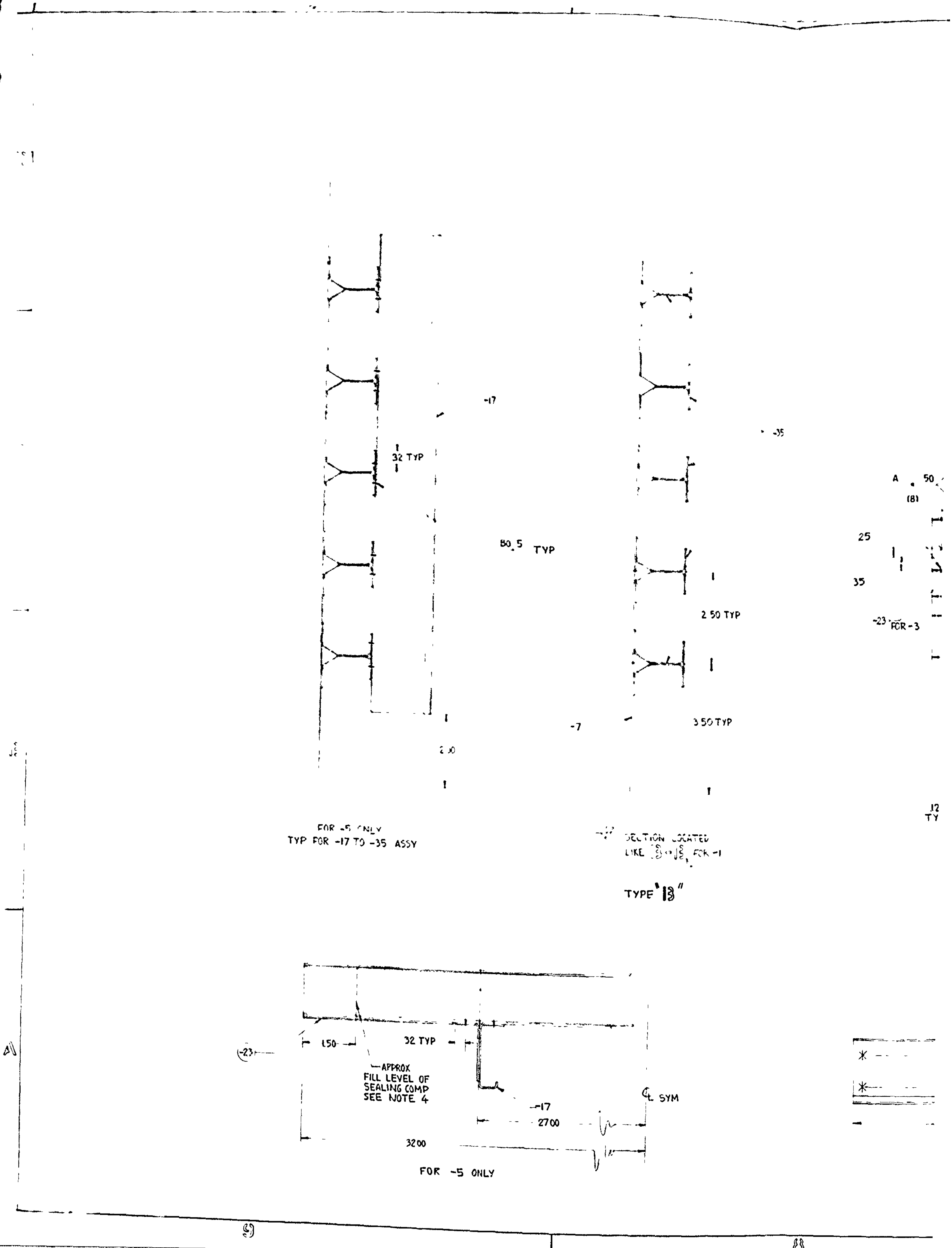
III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING

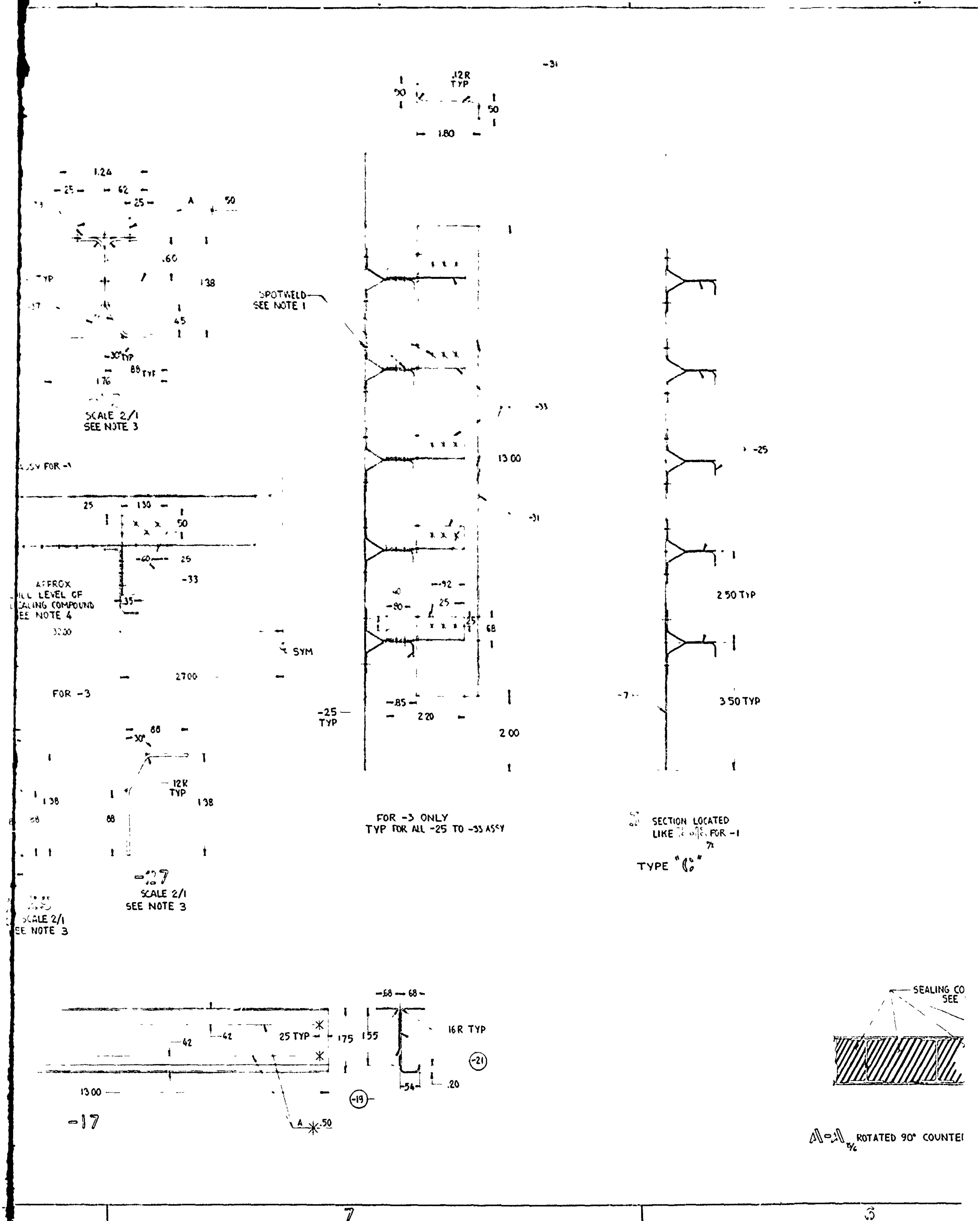
1. Test Specimens:

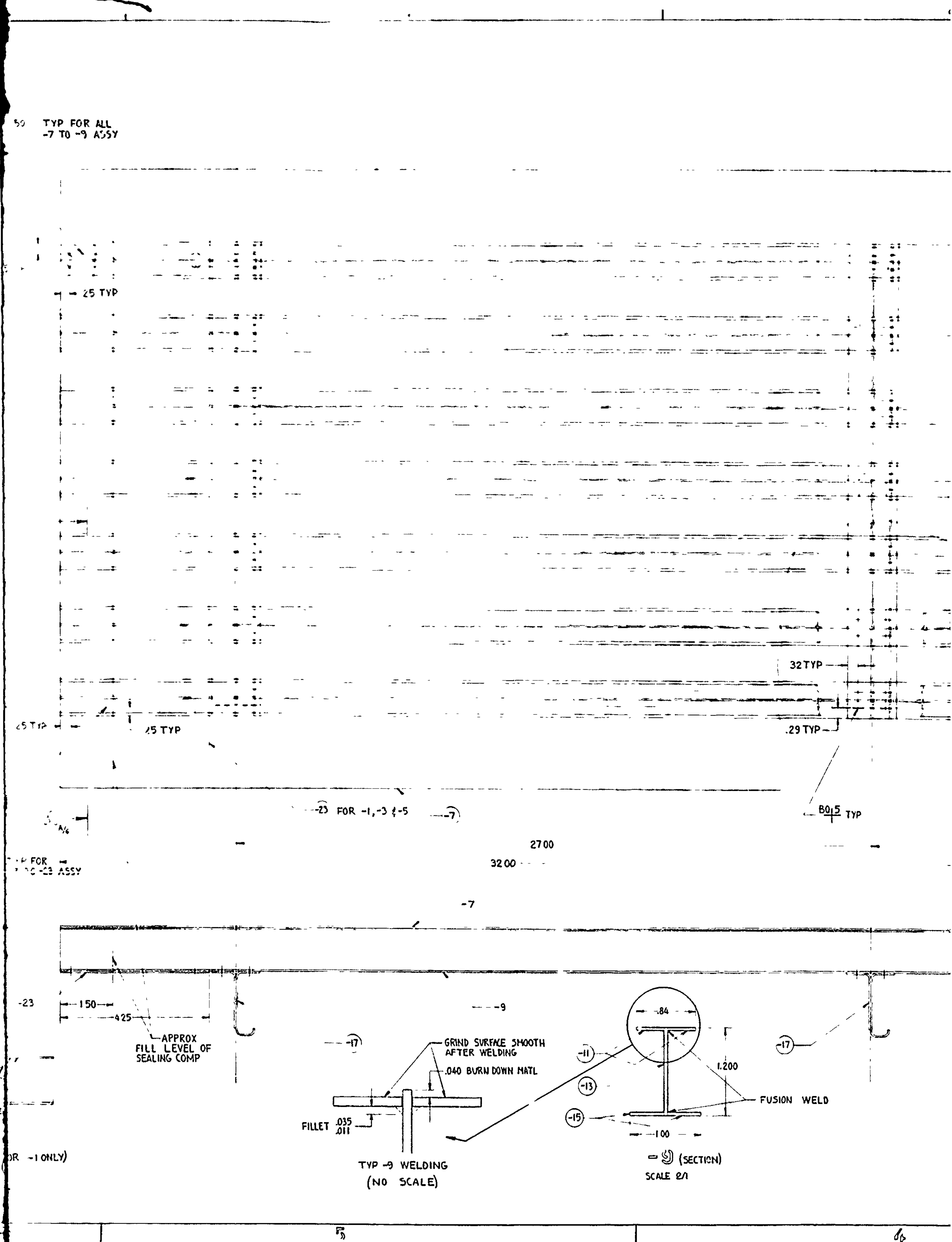
Three skin and stringer combination specimens were fabricated of the same thickness skin but with three different stringer shapes. The material used for all parts was Titanium alloy B-120 VCA. All of the specimens were of the same length. The three stringer shapes were "I", "J". and "Y" sections. The "I" section stringer was fabricated by fusion welding the top and bottom flanges to the web section. The shape was then spotwelded to the specimen skin. The "J" section was fabricated in two sections. One section was constructed similar to the shape of a channel section but of unequal flange width. The other section was constructed similar to a channel section. These two parts were made into an assembly by spotwelding the two parts back-to-back. The section was then spotwelded to the skin. The "Y" section was constructed from three parts. Two of the parts were constructed from the same shape by welding two sections back-to-back. These two sections were the same shape as the channel used for the "J" section. The third part of this stringer shape was a doubler cap spotwelded to the lower flanges of the "Y" section. This assembly was then spotwelded to the specimen skin. The specimen containing the fusion welded "I" section contained seven stringers, constructed on 2.00 inch centers, and was designated as -1 specimen on the manufacturing drawing shown in Figure G-1 (page 327). The finished test specimen is shown in Figure G-2a (page 329). The specimens containing the "J' and "Y" sections contained five stringers, constructed on 2.50 inch centers and were designated -3 and -5 specimens, respectively, on the manufacturing drawing shown in Figure G-1. The finished test specimens are shown in Figures G-2b and G-2c, respectively, (page 329).

At four locations along the length of the specimens structural shapes were spotwelded to the back flanges of the stringers. These structural shapes represented wing rib caps and were used to react pressure loads on the structure as well as restrain the skin and stringers from buckling. These rib cap shapes were located symmetrically about the center of the specimens and on 18.00 inch centers.

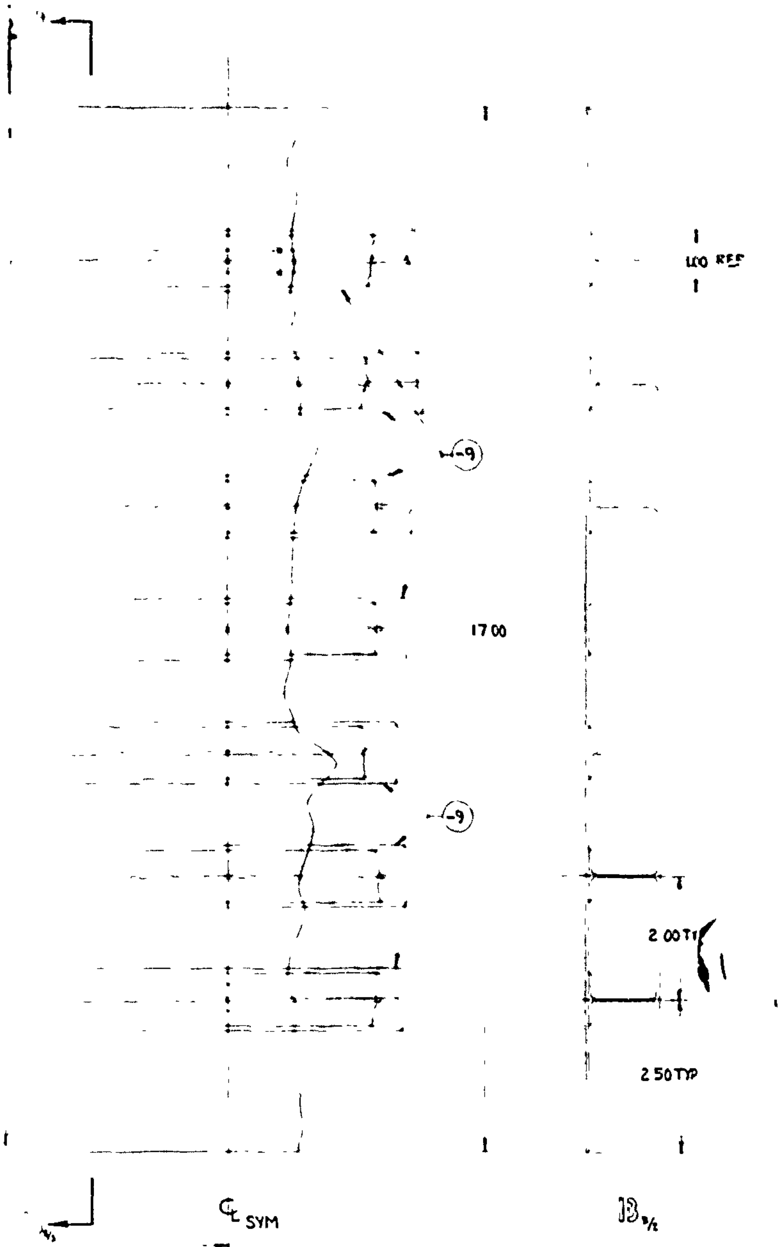
Figure G-1 - PANEL - PLATE STRINGER; Engineering Drawing 29-01015


-17
32 TYP
80.5 TYP
-35
2.50 TYP
3.50 TYP
-7
FOR -5 ONLY
TYP FOR -17 TO -35 ASSY
SECTION LOCATED
TYPE "B"
A 50
(8)
25
35
-23 FOR -3
-23
1.50
32 TYP
APPROX
FILL LEVEL OF
SEALING COMP
SEE NOTE 4
℄ SYM
-17
27.00
32.00
FOR -5 ONLY

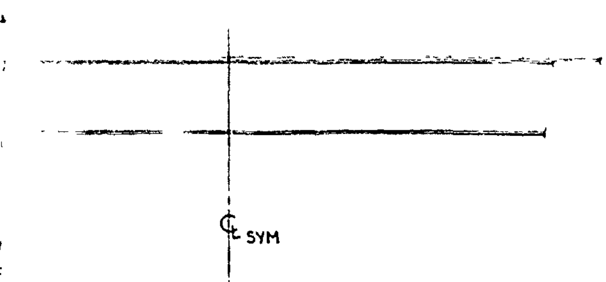

SCALE 2/1
SEE NOTE 3
SPOTWELD
SEE NOTE 1
APPROX
FILL LEVEL OF
SEALING COMPOUND
SEE NOTE 4
SYM
FOR -3
12R
TYP
SCALE 2/1
SEE NOTE 3
-25
TYP
FOR -3 ONLY
TYP FOR ALL -25 TO -35 ASSY
2 50 TYP
3 50 TYP
SECTION LOCATED
FOR -1
TYPE
16R TYP
25 TYP
-17
SEALING CO
SEE
ROTATED 90° COUNTE
7
3

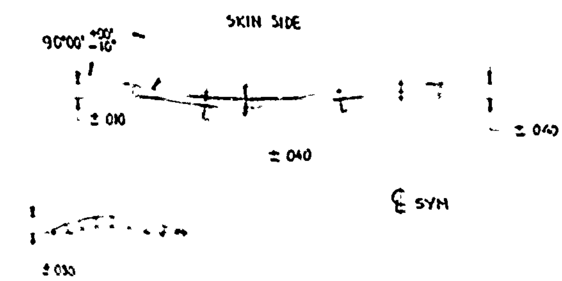


TYP FOR ALL
-7 TO -9 ASSY
.25 TYP
32 TYP
.25 TYP
.25 TYP
.29 TYP
-23 FOR -1,-3 & -5
-7
B0.5 TYP
2700
3200
-7
-23
150
425
APPROX
FILL LEVEL OF
SEALING COMP
-9
-17
GRIND SURFACE SMOOTH
AFTER WELDING
.040 BURN DOWN MATL
FILLET .035 .011
TYP -9 WELDING
(NO SCALE)
.84
-11
-13
1.200
FUSION WELD
-15
1.00
-9 (SECTION)
SCALE 2/1
-17
(FOR -1 ONLY)



TYPE "A"





ALLOWABLE PANEL DISTORTION DIAGRAM
(NO SCALE)

✱ SYMBOL DENOTES SPOTWELD

80|5 SYMBOL DENOTES NAS 508M, UNIVERSAL HEAD BARE MONEL RIVETS, 5/32 DI

BASIC SECTION	MATL	QTY
TYPE "A"	AGED Ti 3Al 13V 11Cr (B120 VCA)	1
TYPE "B"	" " "	1
TYPE "C"	" " "	1

6 TRIMMING & GRINDING OF -1, -3, & -5 TO BE PERFORMED UNDER TEST LA

5. DISTORTION OF PANEL AFTER STRAIGHTENING NOT TO EXCEED LIMITS SHOWN

4. USE DC Q3-0121 COMPOUND AS SEALANT FOR -1, -3, -5 ENDS

3. ADD 6.00 IN TO EACH END OF -9, -25, & -35 SUB-ASSYS TO PROVIDE GRIP F

2 FUSION WELD PER CONVAIR SPEC 0-05025.

1. SPOTWELD PER MIL-W-6858A EXCEPT RADIOGRAPHIC EXAMINATION NOT REQ'D FOR CLASS "A" WELDS.

NOTES:

HOW
IDE
WN
ICAL EXCEPT

DASH NO	CHG RECORD NO.	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	QTY REQD		DASH NO	CHG RECORD NO	SERIAL NO.	NEXT ASSY	USED ON	CALC UNIT WT	QTY	
	APPLICATION								APPLICATION						

ILL RIVETS, 5/32 DIA

	QTY
(B120VCA)	1
	1
	1

PERFORMED UNDER TEST LAB DIRECTION

TO EXCEED LIMITS SHOWN IN DIAGRAM

-3 -5 ENDS

SUB-ASSYS TO PROVIDE GRIP FOR STRAIGHTENING

EXAMINATION

-45	-5	-25	-3	-17	-9	-1	PART NO.	FIND NO.	DESCRIPTION	STOCK SIZE	MATERIAL	INITIAL COND	FINAL COND	MAT'L SPECIFICATION	SEE FINISH SPECIFICATION	ZONE
																C/6
5								-39	STRIP	.040 X 1.3 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7
10								-37	CHANNEL	.040 X 2.2 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7
	5							-35	STRINGER SUB ASSY							D/7
			20					-33	CLIP	.063 X 2.0 X 2.2	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7
			4					-31	ZEE	.063 X 2.2 X 13.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7
		5						-29	CHANNEL	.040 X 2.6 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/8
		5						-27	ANGLE	.040 X 2.2 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7
			5					-25	STRINGER SUB ASSY							C/6
	2		2			2		-23	STRIP	.060 X 6.3 X 17.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		B/5
				1				-21	CHANNEL	.063 X 3.10 X 13.0	Ti ALY 13V 11Cr 3Al	SHT	AGED			A/7
				1				-19	ANGLE	.063 X 2.20 X 13.0	Ti ALY 13V 11Cr 3Al	SHT	AGED			A/7
	4					4		-17	RIB CAP SUB ASSY							A/6
					14			-15	STRIP	.063 X .50 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		A/5
					7			-13	STRIP	.060 X 1.50 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		A/5
					14			-11	STRIP	.040 X .50 X 76.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		A/5
						7		-9	STRINGER SUB-ASSY							A/4
	1		1			1		-7	SKIN	.050 X 17.0 X 64.0	Ti ALY 13V 11Cr 3Al	SHT	AGED	B 120 VCA		D/7

REQUIREMENTS PER ASSEMBLY

LIST OF MATERIAL

Page 327

Figure G-1

29-01015

SHEET 1 OF 1

PANEL-
PLATE STRINGER

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO CALIFORNIA

J 29-01015

SCALE 1/4

Figure 2a
PANEL 29-01015-1
Convair Print 65755

Figure 2b
PANEL 29-01015-3
Convair Print 65757

Figure 2c
PANEL 29-01015-5
Convair Print 65759

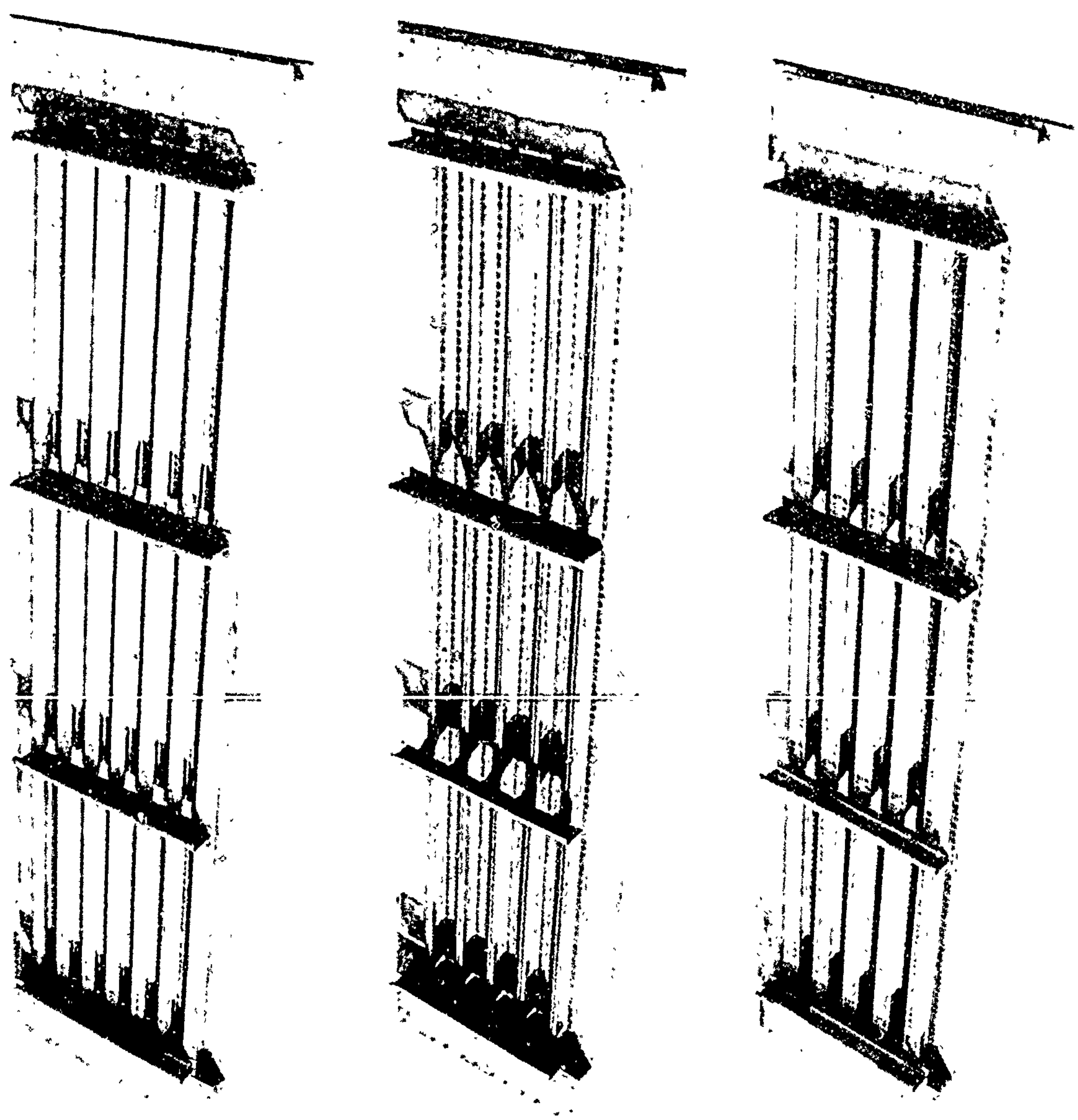


Figure G-2 — TEST SPECIMENS; Viewed from the Stringer Side.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

III. DESCRIPTION OF TEST SPECIMENS AND METHOD OF TESTING (Cont'd)

2. Test Program:

Each of the test specimens was subjected to a specific test program. This program contained the parameter of pressure and temperature and axial compressive load representative of those to be encountered in high speed flight. The test program is outlined in Table G-1, below.

Condition	Temperature	Pressure (PSIG)	Axial Compressive Load (lbs)		
			-1	-3	-5
I	Room Temp.	9	79,500	57,700	126,000
II	200 F	9	73,300	51,300	113,334
III	400 F	9	73,300	51,300	113,334
IV	600 F	9	73,300	51,300	113,334
V	800 F	9	60,700	45,300	96,667
VI	900 F	9	60,700	45,300	96,667
VII	600 F	9*	Failure	Failure	Failure

* During the test of the -5 specimen to failure, the internal pressure was reduced to 0 PSIG.

During each of the above test conditions the axial compressive load was increased in 20% increments up to the load shown. For the test to failure the load was increased in 20% increments to the load shown and then in 10% increments to failure.

3. Test Setup and Methods:

a. Axial Compressive Load -

The specimens were tested in a 400,000 pound Baldwin Southwark Universal Test Machine. The compressive load was applied by the loading head of the machine and reacted by the fixed head of the machine. The

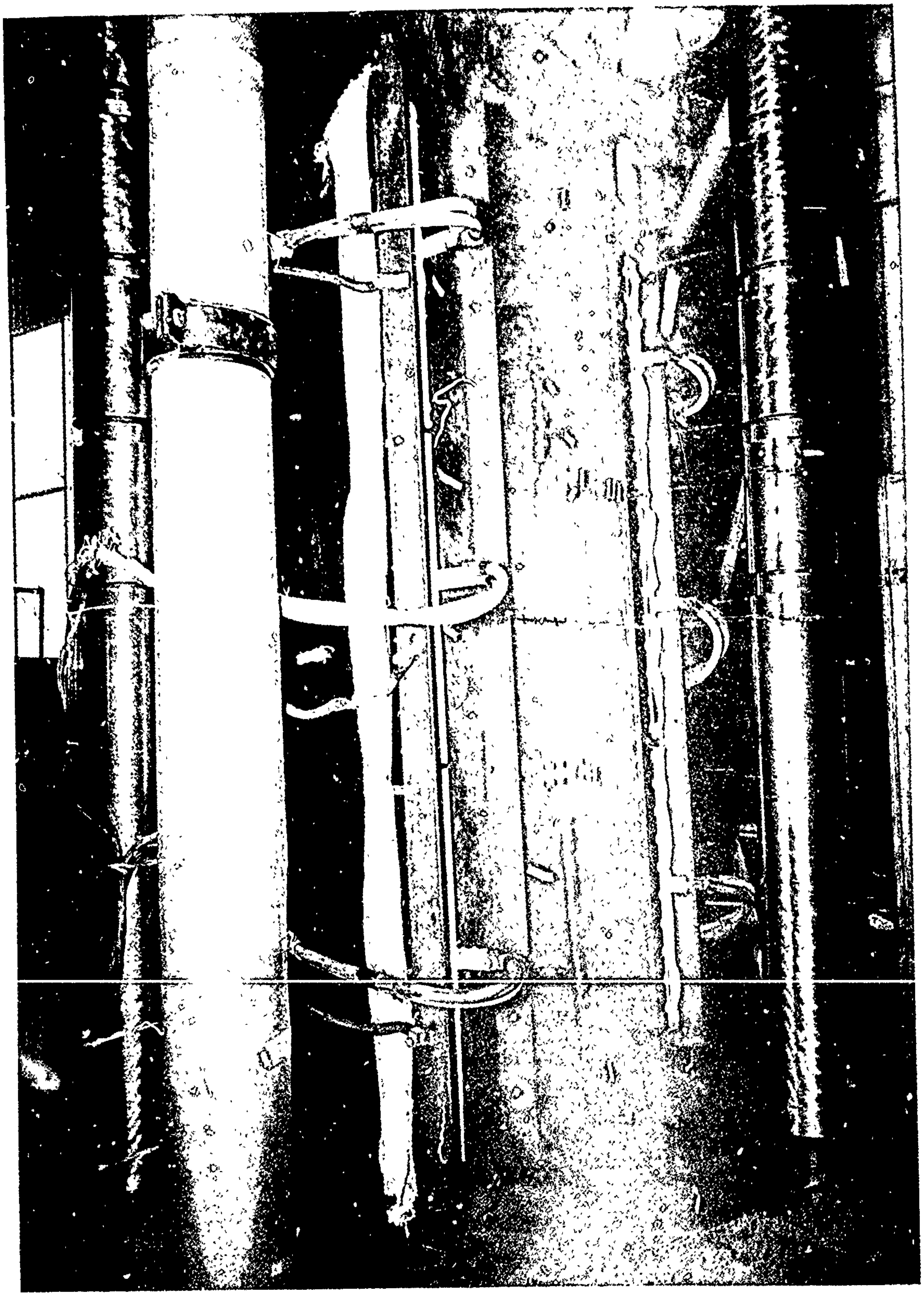
III. 3. a. Axial Compressive Load - (Cont'd)

reaction head of the testing machine was adjusted flat and parallel to the loading head within plus/minus .001 inch. The specimens also had the stringer ends of the assemblies ground flat and parallel within plus/minus .001 inch. For setup work the specimens and test fixture were supported by the test machine columns. However, during testing the specimens were held in the test machine by the load on the ground ends of the specimens. The test assembly in the test machine is shown in Figures G-3 and G-4 (pages 332 and 333).

b. Pressure Load -

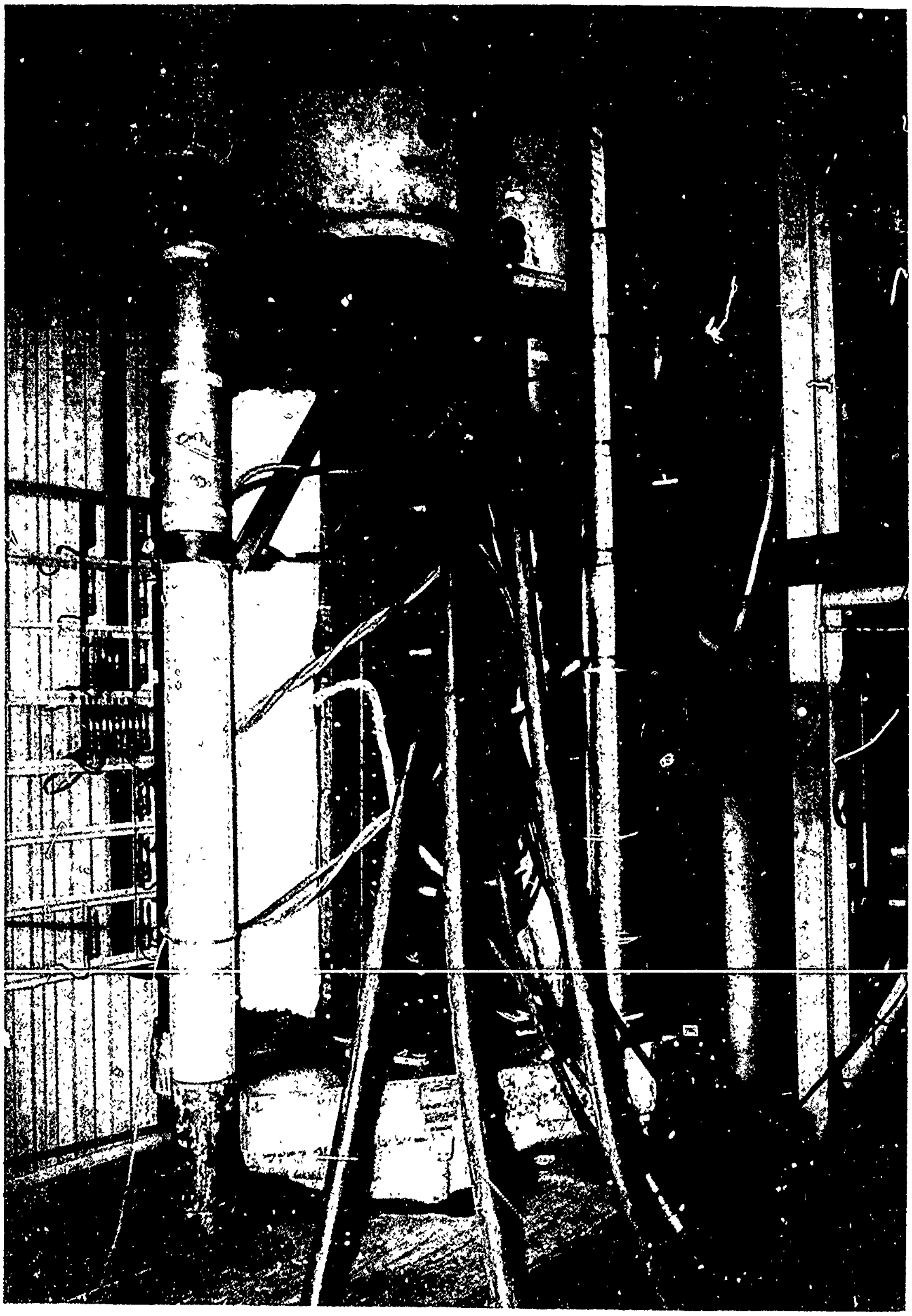
To apply internal pressure simulating pressurization of a wing fuel tank, a special test fixture pressure box was constructed. The pressure box was constructed of 8.00 inch steel channel sections. The ends of the pressure box were set in from the ends of the side members. These ends were set in so that the end seal on the box was 4.00 inches from the end of the specimen. This pressure box was mounted on the specimen in a manner that allowed pressure to be applied to the stringer side of the specimen. To react the pressure load the specimens were tied to the pressure box through the rib caps on the back of the stringers. The method of attaching these rib caps is shown in Figures G-5 and G-6 (pages 334 and 336). This type of attachment allows the pressure to be reacted by tension in the tieback straps. To minimize the effect of these straps carrying part of the compressive load into the pressure box, the straps were made of thin layers of stainless steel. To react the pressure load on the edge of the specimen skin a special retainer was constructed. The retainer was constructed of 6.00 inch channel sections and matched the pressure box. The retainer was mounted on the skin side of the test assemblies and connected to the pressure box by bolts through the flange of the pressure box. This bolt attachment was outside the area of the specimen and, therefore, made no direct connection to the test specimen.

The assembly of the pressure box and retainer resulted in a clamping action on the specimen skin. This clamping action was adjusted to produce a light fit between the skin and the fixture. In addition to reacting the skin pressure load the clamping of the skin also prevented local buckling at the edge of the skin by affording a straight ridge guide. Also, since the attachment of the two fixture parts was a light fit the test specimen was allowed to develop the full compressive strain with only an infinitesimally small amount of strain being fed into the fixture through friction. In



Convair Print 67670

Figure G-3 – TEST SPECIMEN AND FIXTURE ASSEMBLY IN THE TEST MACHINE; View From The Treated Side.



Convair Print 67672

Figure G-4 — TEST SPECIMEN AND FIXTURE ASSEMBLY IN THE TEST MACHINE; Viewed From The Back of The Pressure Box.

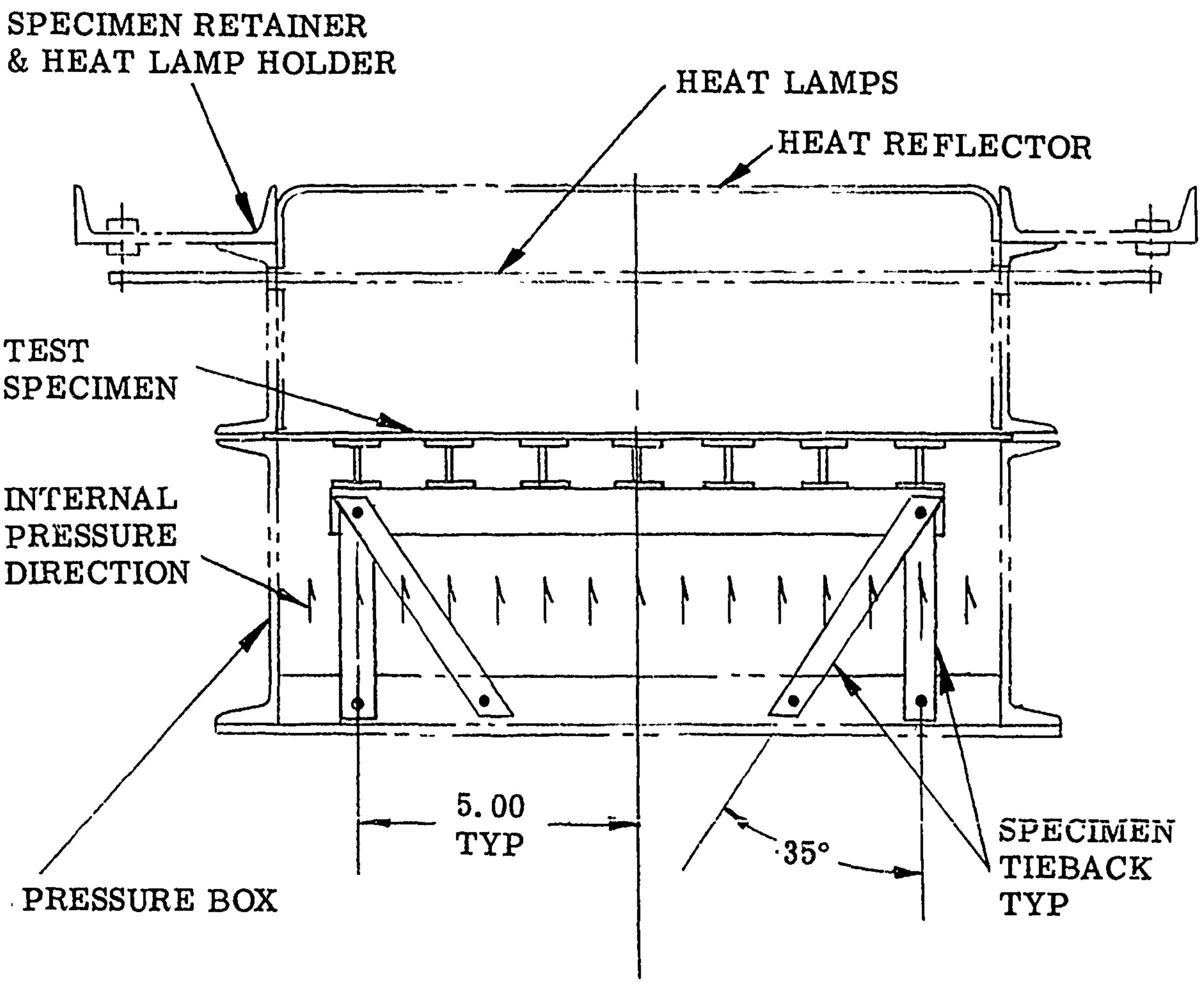


Figure G-5a— TYPICAL TEST SET UP; Cross Section.

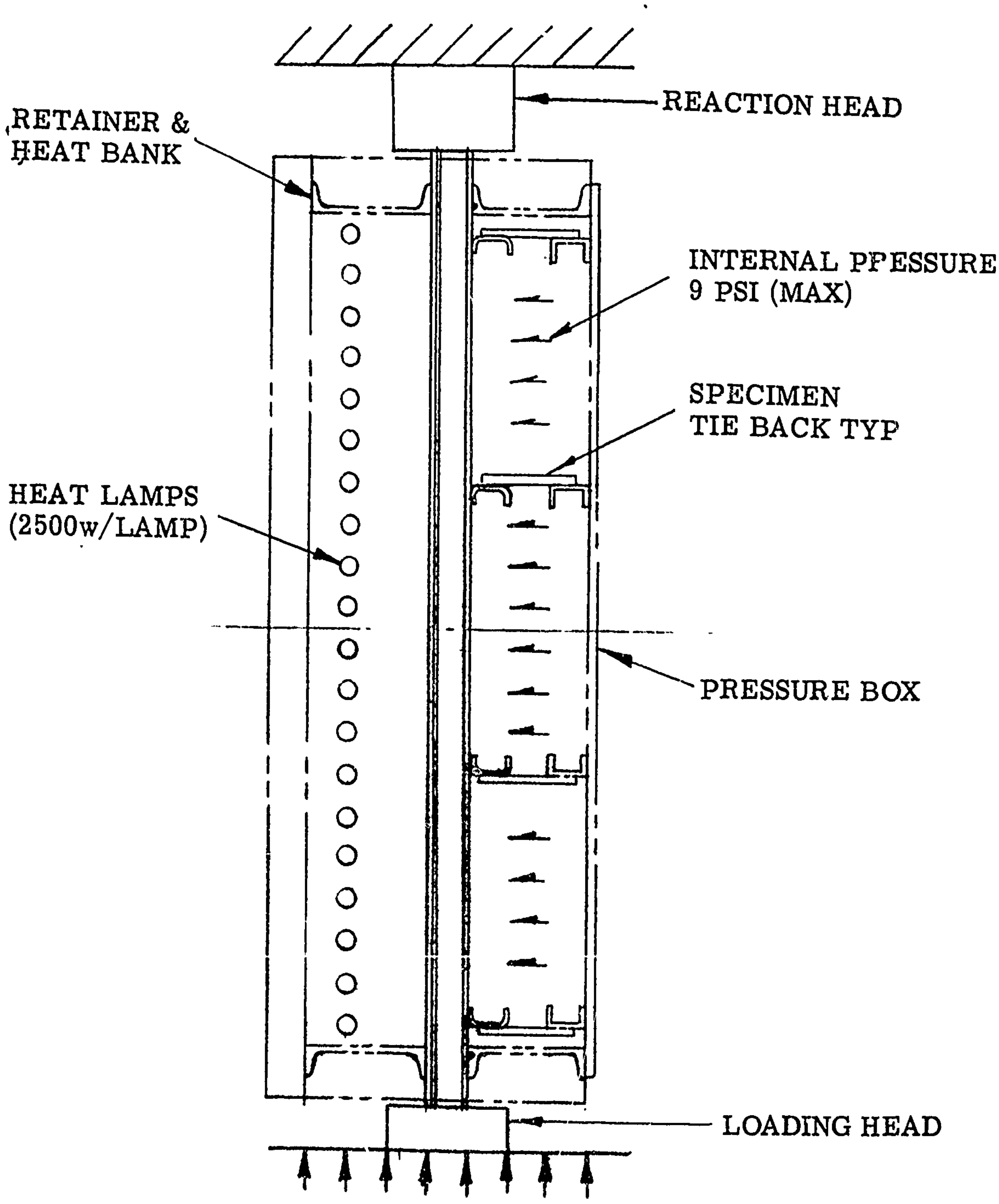
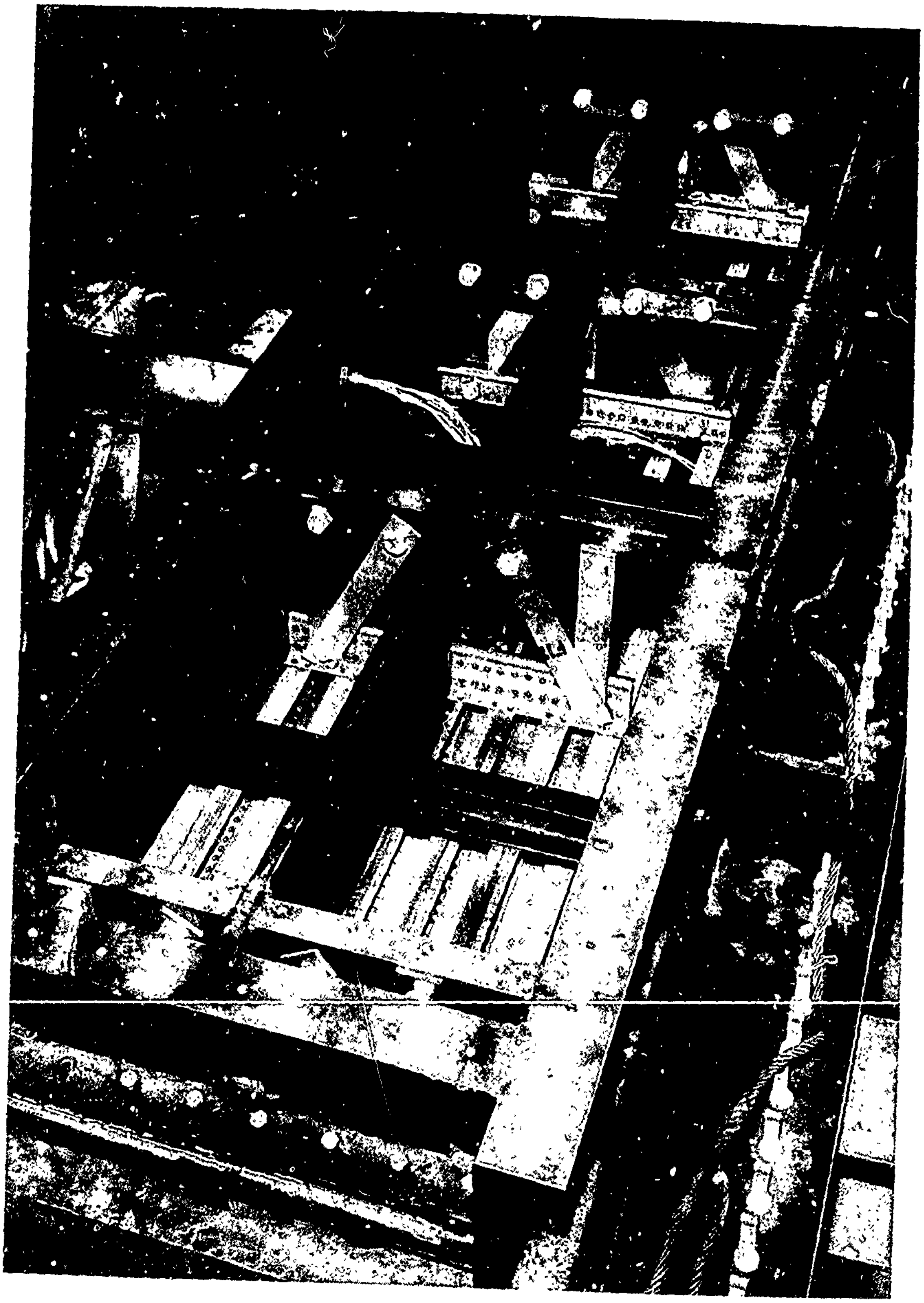


Figure G-5b – TYPICAL TEST SET UP; Side View.



Convair Print 66584

Figure G-6 — TYPICAL TIEBACK STRAP INSTALLATION; For Reacting Pressure Load.

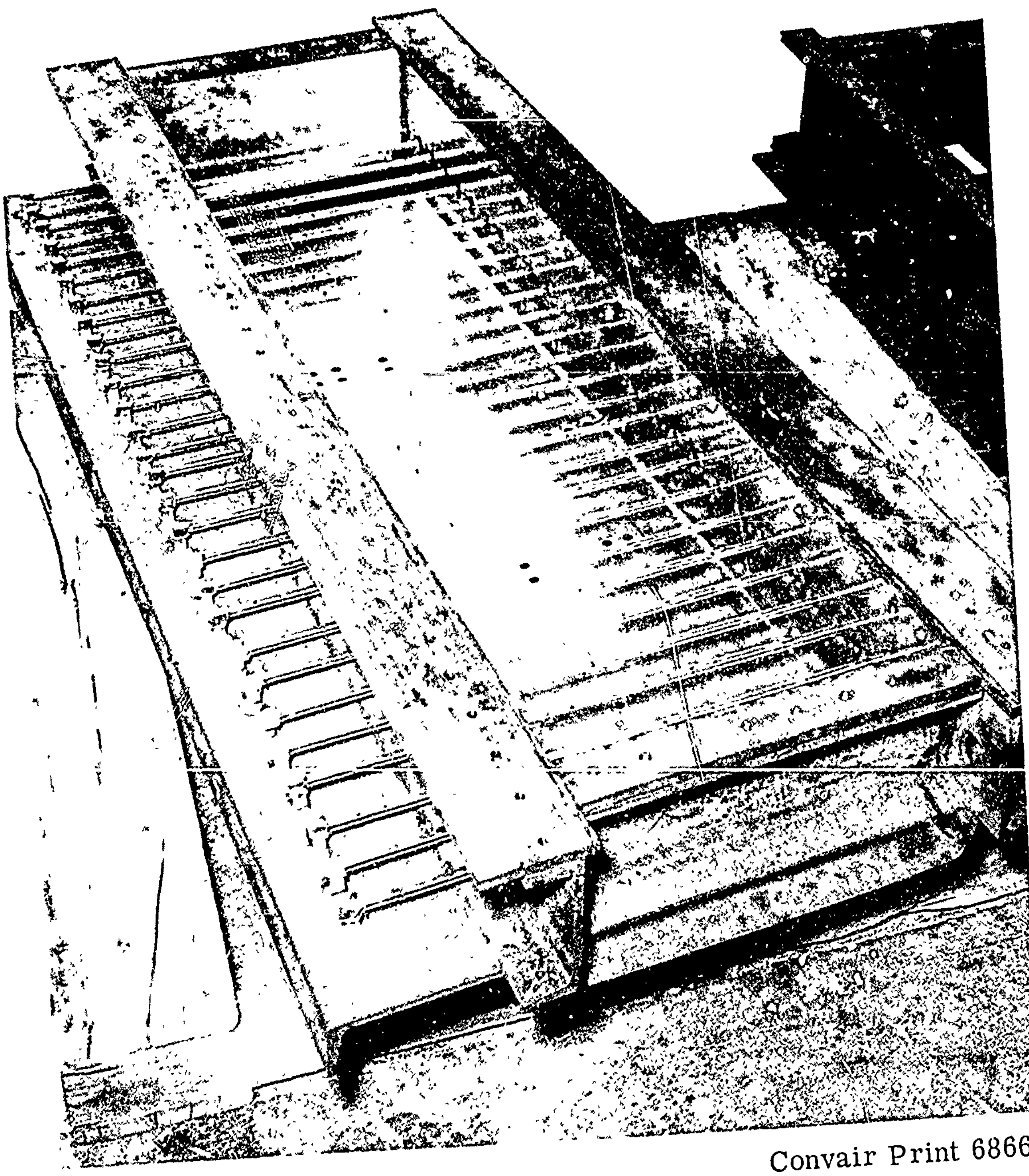
III. 3. b. Pressure Load - (Cont'd)

addition to the light fit, the flat surfaces of the pressure box and retainer flanges were machined to produce a narrow contact area between the fixture and the specimen. This contact area was 3/16 inch wide and extended the full length of the fixture as well as across the full width of the ends. The resultant effect of the machining was a reduction of the contact areas.

During the test of the -1 specimen the distance between the contact areas on the fixture was 16.00 inches. This width allowed the same spacing between the edge stringer and the pressure box as existed between the stringers. For the test of the -3 and -5 specimens special bars were attached to the pressure box and retainer which reduced the distance between the contacts to 15.00 inches. These spacer bars also had the machined contact areas the same as the pressure box flange. By reducing the distance between the contact areas, the effective width of the fixture was reduced. This reduction allowed the same spacing between the edge stringer and the box as between the stringers for the -3 and -5 specimens.

c. Heat Source -

The flat skin side of the specimens only was heated during testing. Heating was accomplished by using the special pressure box retainer as a mounting for the heating devices. The heating devices were twenty-eight 2500 watt infrared heat lamps. The heat lamps were built into the pressure box retainer by welding two 6.00 inch steel channel sections to the top of the retainer. This channel section then provided a mounting for the heater clips and buss bars. The heat lamps were extended through holes, located on 2.00 inch centers, in the web of the retainer channels. Gold plated stainless steel reflectors were mounted around the inside of the retainer. Gold plated reflectors were also used across the open side of the retainer to enclose the heat lamps and produce a partial oven effect. Figure G-7 (page 338) shows the heat lamps as well as the reflectors installed in the retainer. The top and bottom of the retainer were not sealed to produce a complete oven effect. These ends were left open so the chimney effect of the heating could be reduced by venting some of the hot gases that accumulated at the top of the oven when the whole assembly was vertical in the test machine.



Convair Print 68662

Figure G-7 — SPECIAL PRESSURE BOX RETAINER; Showing the Installation of the Heat Lamps and Gold-Plated Reflectors.

III. 3. c. Heat Source - (Cont'd)

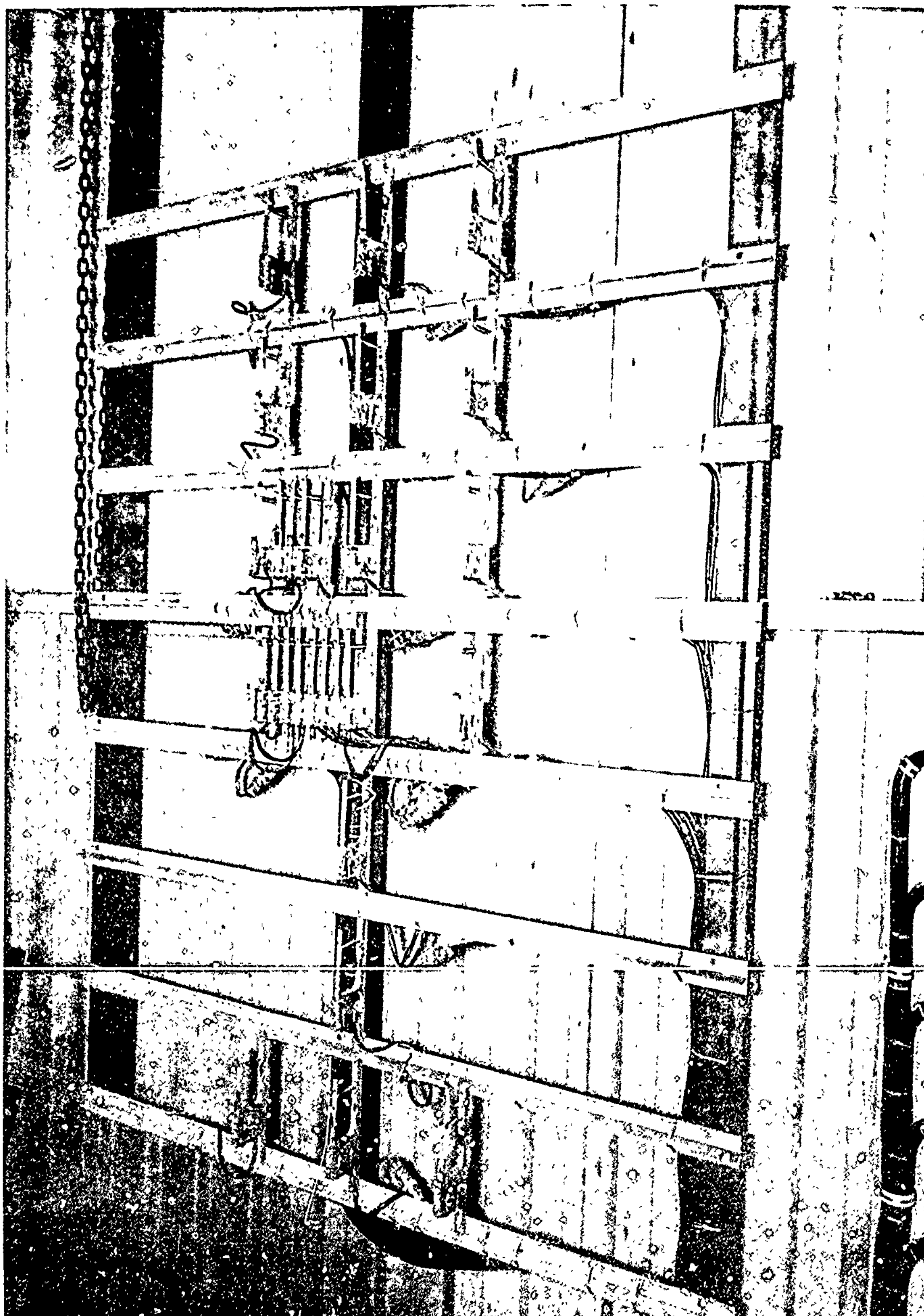
The heat lamps were divided into three bays for control purposes. Each heat bay covered one-third of the total effective test area. The temperature of the specimen was controlled by controlling the electric power to the heaters. To control this power the heat lamps were connected to three control channels of a twelve channel Research, Inc. Heat Control Programmer. In the center of each of the three heat bays a thermocouple was spotwelded to the test specimen skin. This thermocouple was spotwelded to the skin between the stringers so that the heat sink effect would be negligible. The thermocouple was then connected to the heat programmer to provide a control feedback voltage. The control voltage was summed with a voltage representing the desired temperature. The resultant different voltage or error signal was then used to control the power output of three channels of 480 KVA ignitron power controllers. The heat lamps in each of the control bays provided a uniform heat flux over the entire surface of the heat bay. No attempt was made to apply uniform temperature over the heat bay.

d. Instrumentation -

Each of the test specimens was instrumented with thermocouples for measuring the temperature distribution across the test panel, deflection wires for determining the deflection of the panel normal to the compressive load, and strain gages to determine the strain distribution as well as indicate the start of buckling. The locations and numbers of each type of instrumentation are presented as follows:

e. Deflections -

Twenty-seven deflection wires were attached to the -1 specimen and twenty-five wires were attached to the -3 and -5 specimens. Ten of the deflections were reference points and measured deformation of the test fixture. The remaining deflection locations determined the deflections along the length as well as across the width of the specimens. Each of the deflection wires was connected to a cantilever beam strain gaged deflection indicator. The deflection indicators are shown in Figure G-8 (page 340). In addition, the movement of the loading head of the test machine was recorded. This deflection was indicated on a 1.00 inch travel dial indicator. All deflections except the dial indicator were recorded on a remote indicator. The locations of the deflection points are shown in Figures G-9 and G-10 (pages 341 and 342).



Convair Print 67671

Figure G-8 – DEFLECTION BEAM SET UP; Adjacent to the Test Machine.

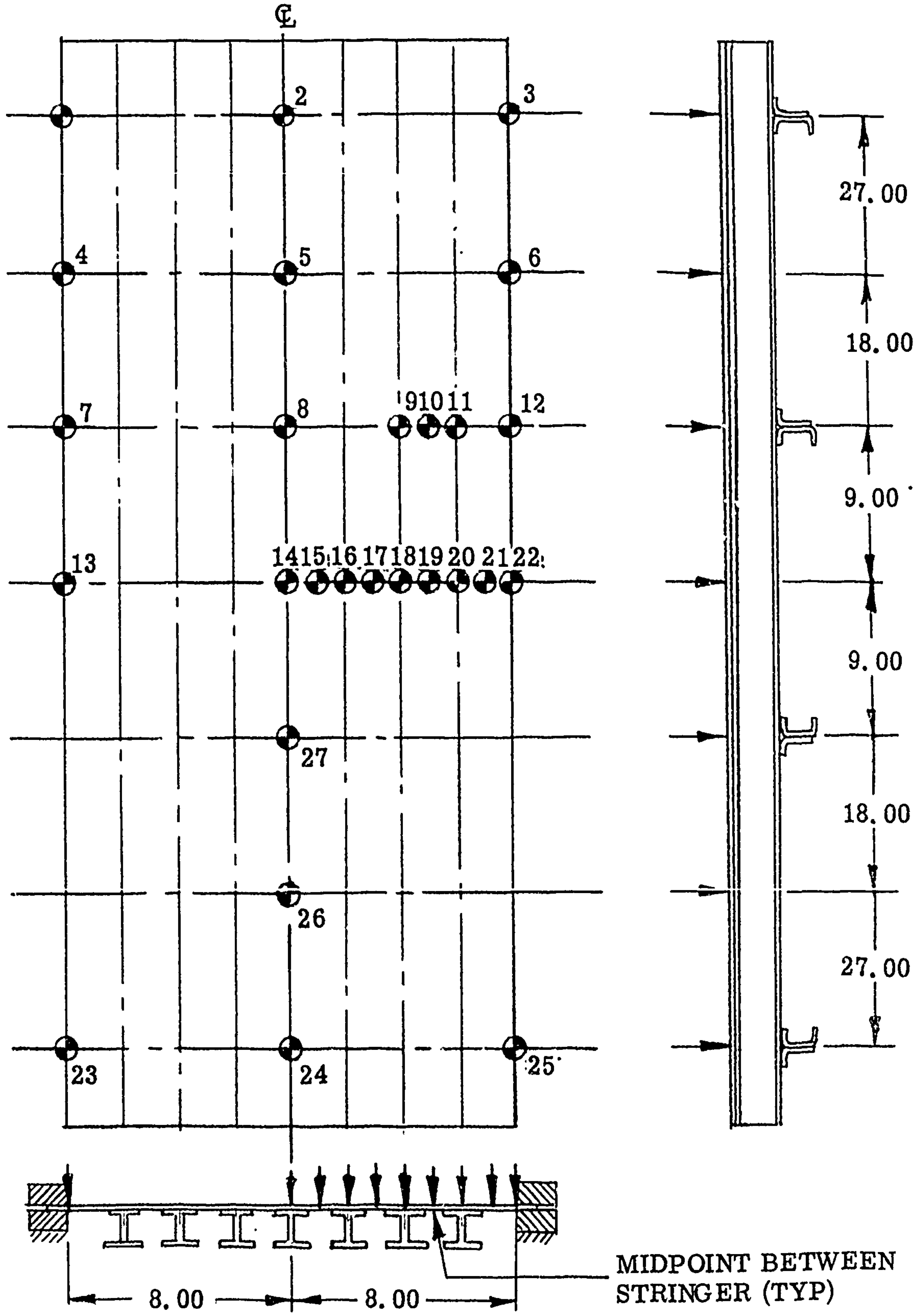


Figure G-9 – DEFLECTION LOCATIONS; 20-01015-1 Panel.

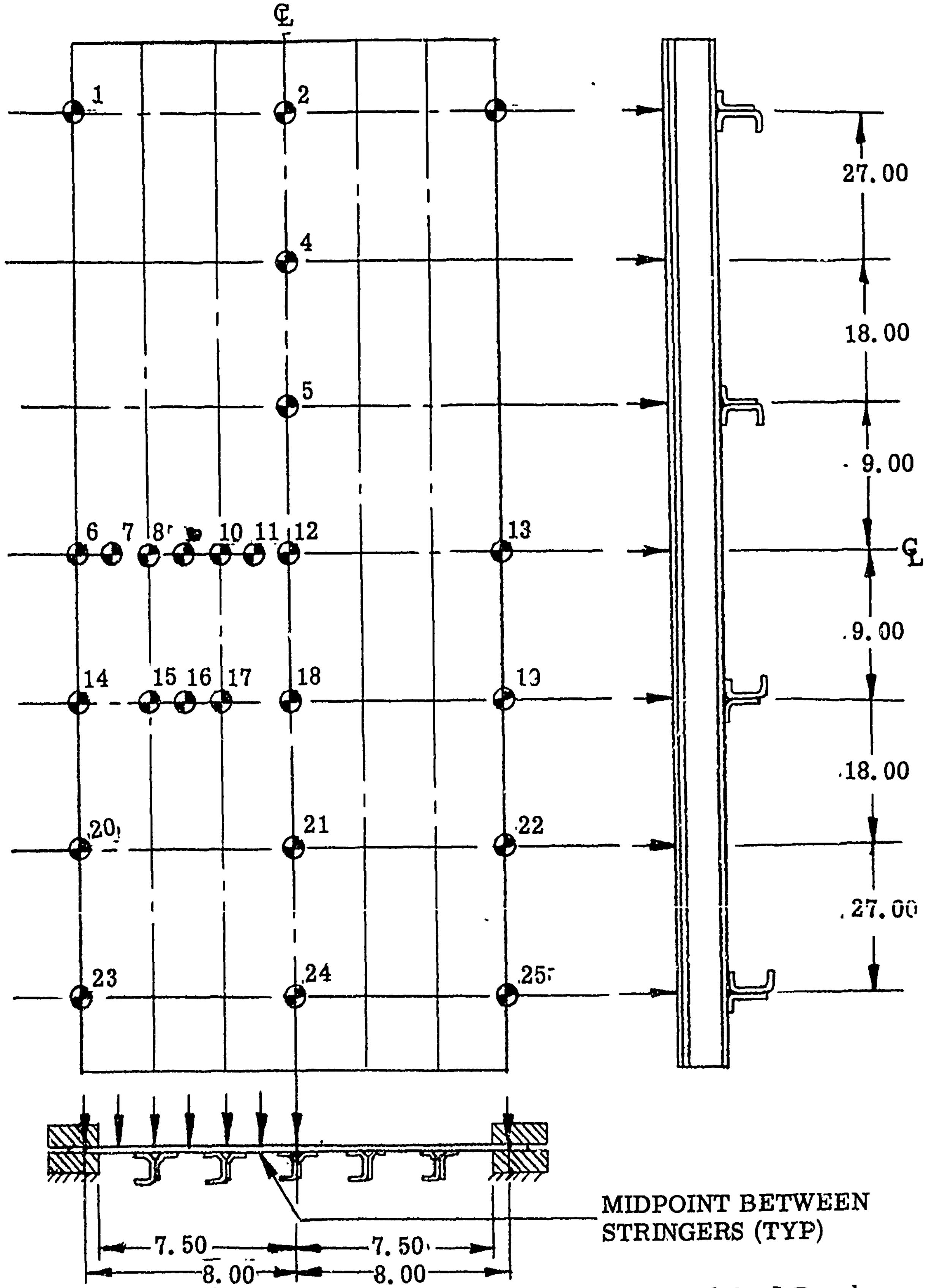


Figure G-10 — DEFLECTION LOCATIONS; 29-01015-3 & -5 Panels.

III. 3. Test Setup and Methods: (Cont'd)

f. Thermocouples -

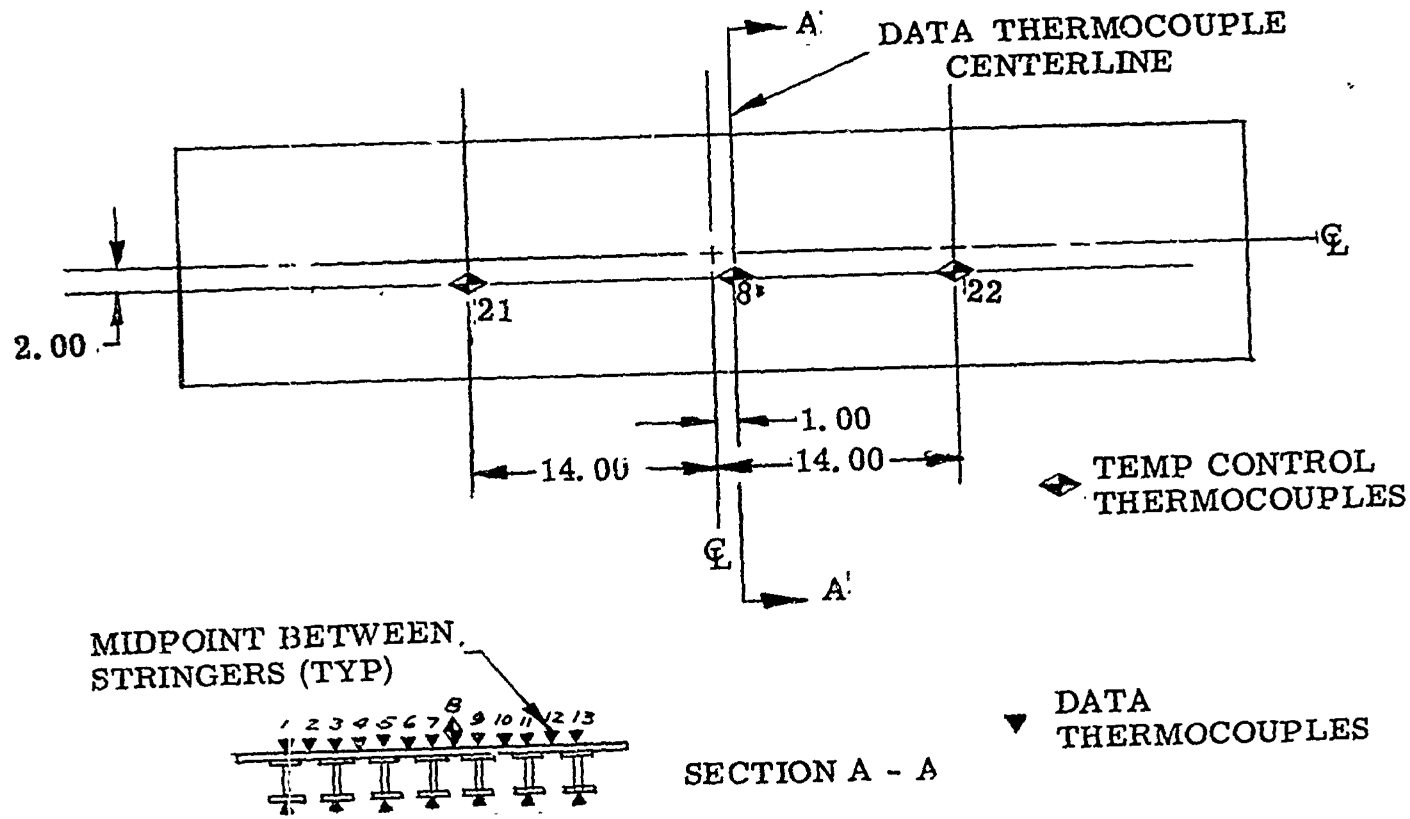
Chromel-alumel thermocouple wires were attached to each of the test specimens; i.e., twenty on -1 and fourteen on -3 and -5. These thermocouples were resistance spotwelded to the specimen to form a split junction. This type of junction is formed by spotwelding each wire individually to the skin at a maximum distance of 1/16 inch apart. The thermocouple therefore contains two junctions; i.e., one junction of Chromel-Titanium and the other junction of Titanium-Alumel. Since the titanium sheet is used as a connecting part of the electric circuit the effect of the two junctions resolves to the output of a Chromel-Alumel junction. This type of thermocouple installation provides the most accurate temperature of the skin surface since the skin is part of the electric circuit. Each of the thermocouples was connected to a 150 F reference junction and then connected to a remote indicator. The locations of the thermocouples on each specimen are shown in Figures G-11 and G-12 (pages 344 and 345).

g. Strain Gages -

Ten strain gages were attached to each of the test specimens. The strain gages were attached by resistance spotwelding. Five of the strain gages were attached to the specimen skin on the centerline of the stringers. For the -1 and -5 specimens the second five were attached to the back flange of the stringer on the centerline. The -3 specimen stringer back flange was shaped in the form of the bottom of a "J". Therefore, the second five strain gages were attached to the bottom leg of the "J" section .20 inches from the centerline of the stringer. The locations of these gages are shown in Figures G-13, G-14 and G-15 (pages 346, 347 and 348). Each of the strain gages was wired as a single legged bridge and was connected to a remote indicator.

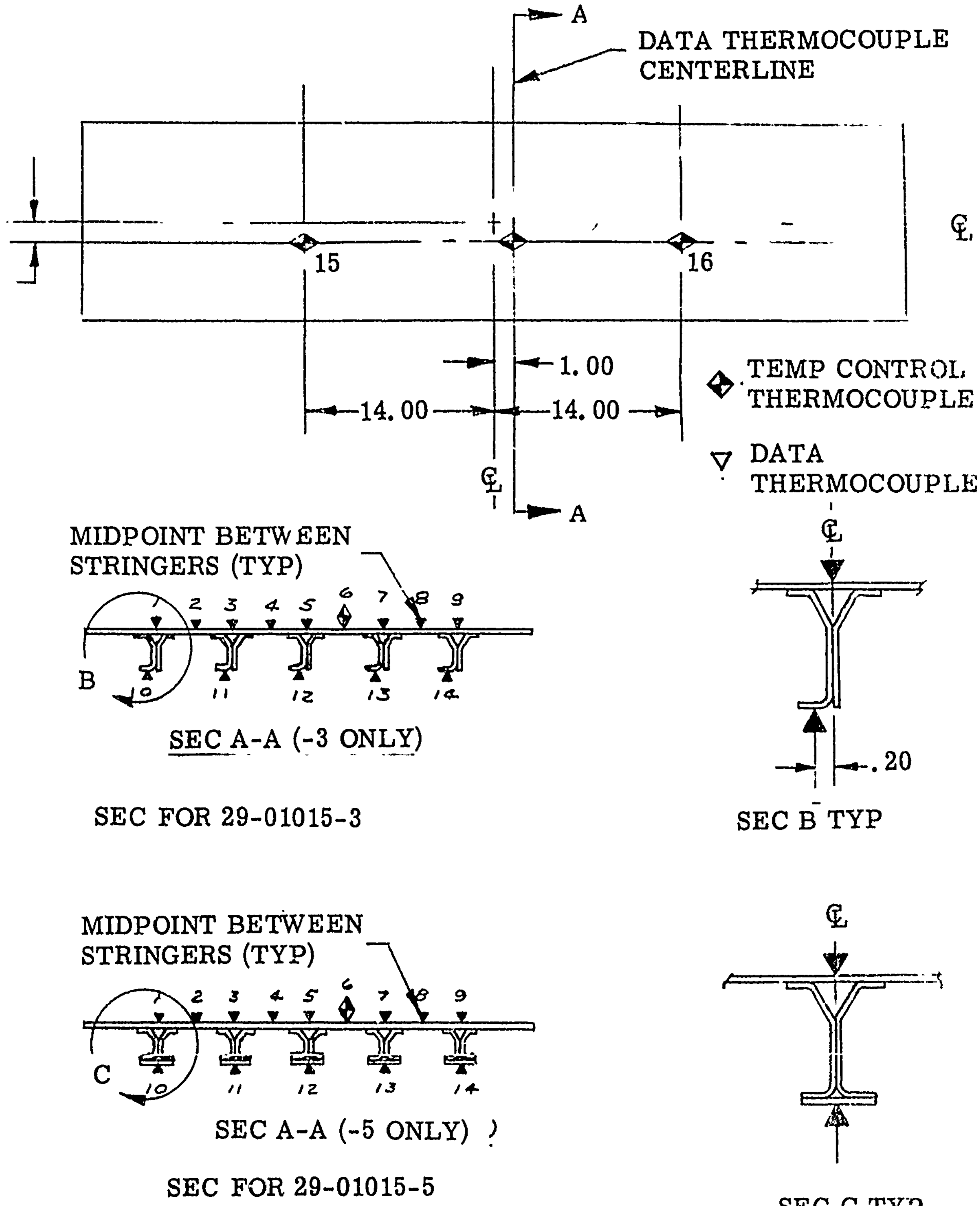
h. Data Recording -

All instrumentation was connected to a remote recorder. This recorder was the Data Acquisition and Interpretation System (DAISY I) shown in Figure G-16 (page 349, 350). This recording system has the capability of recording 400 channels of data simultaneously with a maximum sampling rate of four samples per second for each of the 400 channels. The data gathered by this system was digitized and placed on tape for readout after completion of the test. After completion of the test the data from each instrumentation device was plotted from the tape on an X-Y plotter.



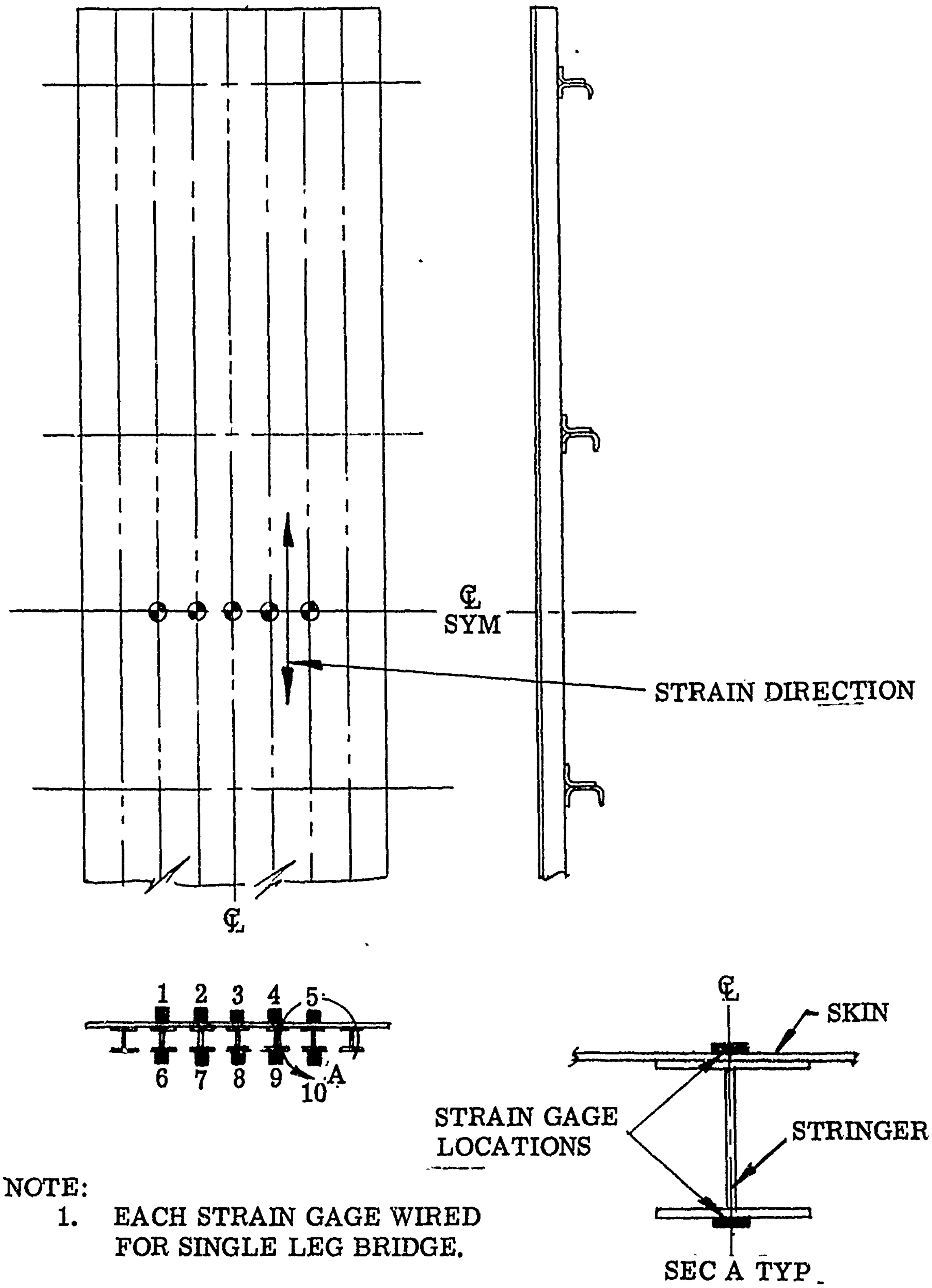
NOTE:
1. THERMOCOUPLES ON STRINGERS TO BE LOCATED ON CENTERLINE OF STRINGER WEB.
2. MIDPOINT DATA THERMOCOUPLES LOCATED ON CENTER OF STRINGER SPACING.
3. ALL THERMOCOUPLES TO BE CHROMEL-ALUMEL WIRE.
4. JUNCTION TO BE SPLIT-WELDED JUNCTION.
5. MAXIMUM SPACING BETWEEN WIRES - 0.06 IN.

Figure G-11 — THERMOCOUPLE LOCATIONS; 29-01015-1 Panels.



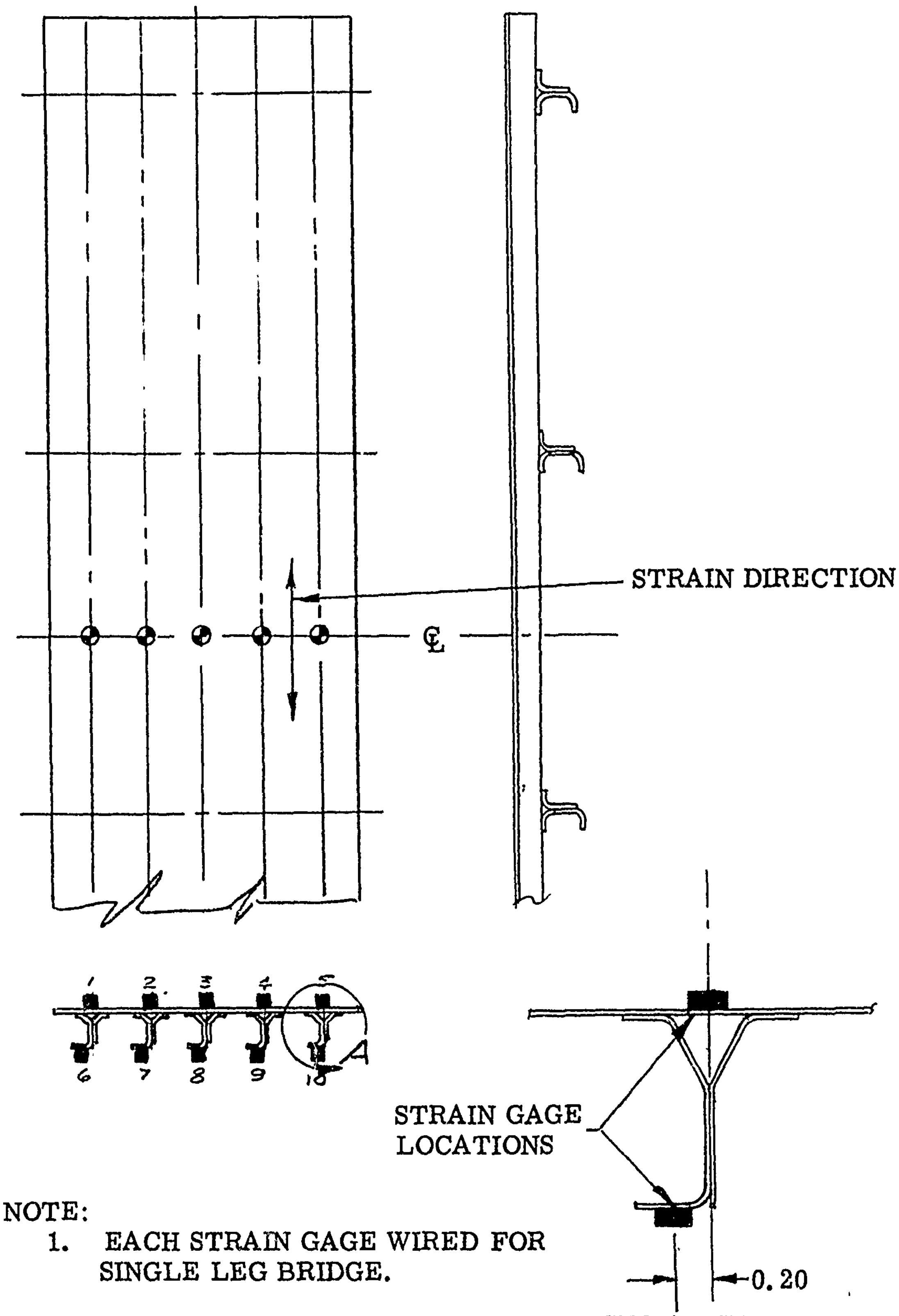
NOTE:
1. FOR INSTALLATION NOTES SEE FIGURE

Figure G-12 – THERMOCOUPLE LOCATIONS;
29-01015-3 & 29-01015-5 Panels.



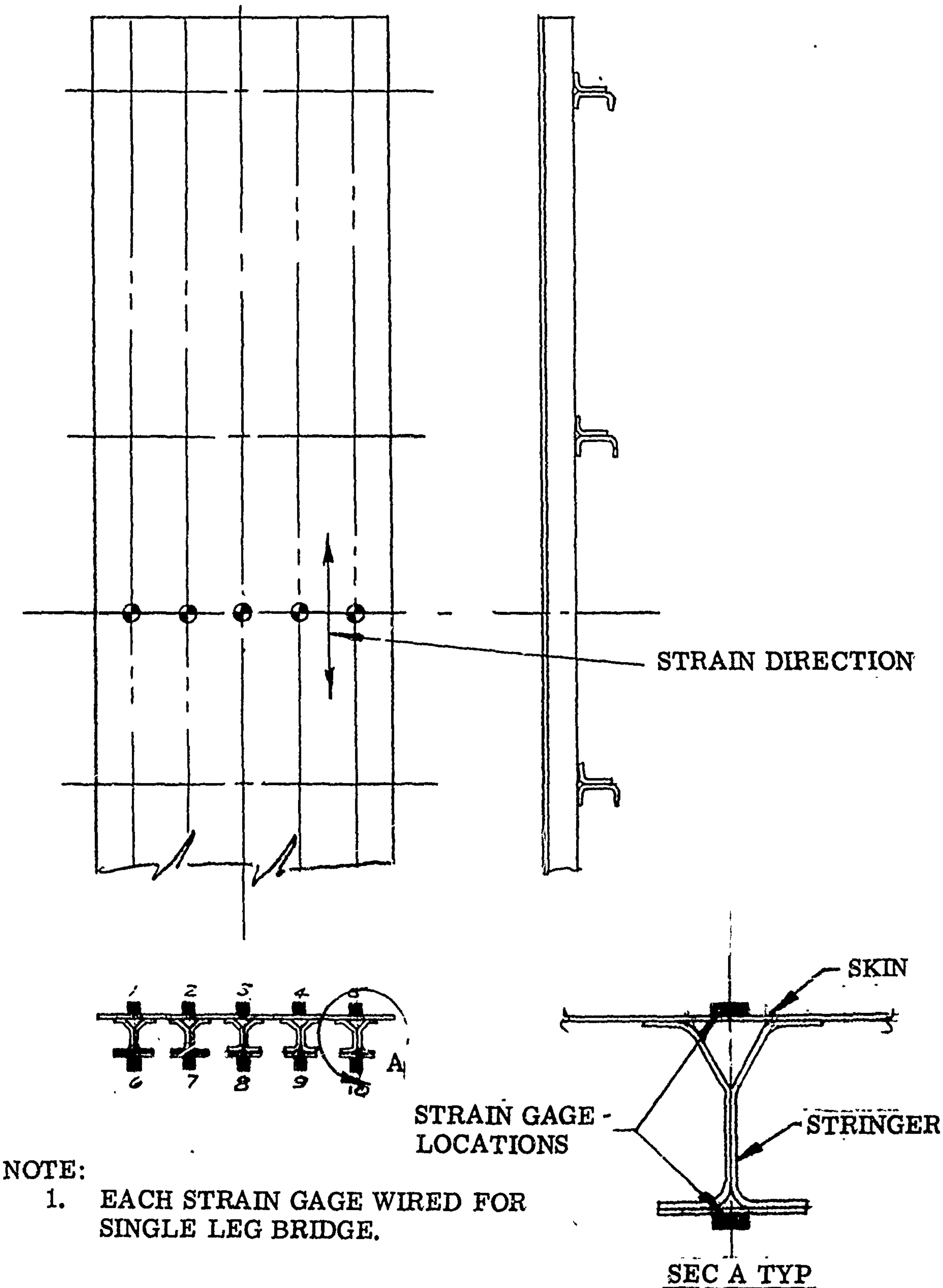
NOTE:
1. EACH STRAIN GAGE WIRED FOR SINGLE LEG BRIDGE.

Figure G-13 — STRAIN GAGE LOCATIONS; 29-01015-1 Panels.



NOTE:
1. EACH STRAIN GAGE WIRED FOR SINGLE LEG BRIDGE.

Figure G-14 STRAIN GAGE LOCATIONS; 29-01015-3 Panels



NOTE:
1. EACH STRAIN GAGE WIRED FOR SINGLE LEG BRIDGE.

Figure G-15 — STRAIN GAGE LOCATIONS; 29-01015-5 Panels.

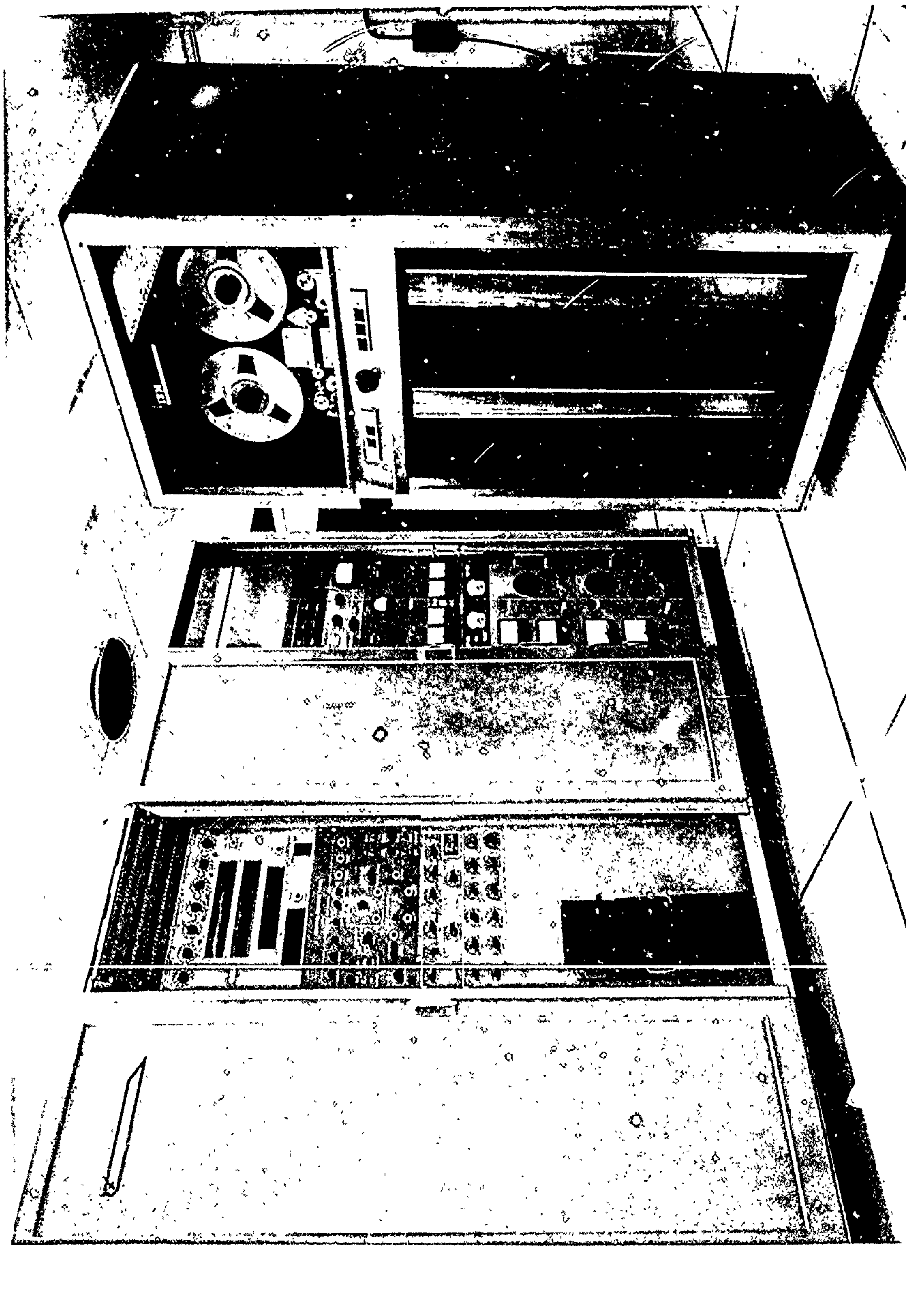
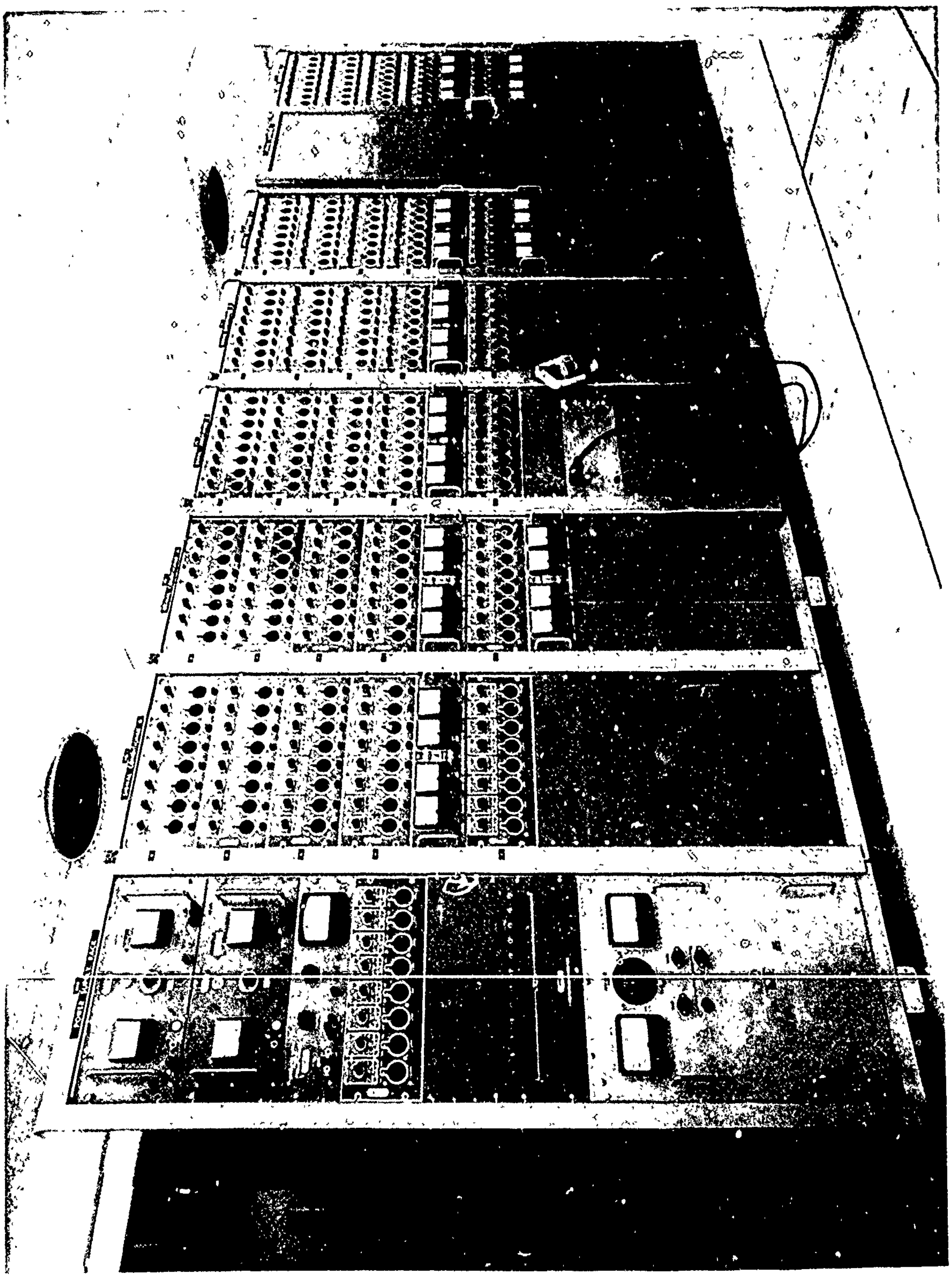


Figure G-16a — DAISY I, TAPE UNIT AND CONTROLS.

Convair Print 48692



Convair Print 48694

Figure G-16[illegible] — DAISY I, PART OF SIGNAL CONDITIONERS.

TITANIUM DEVELOPMENT PROGRAM

Volume V - Structural Evaluations of Titanium Alloy Assemblies

G. PLATE STRINGER COMPRESSION PANELS

IV. DISCUSSION OF TEST RESULTS

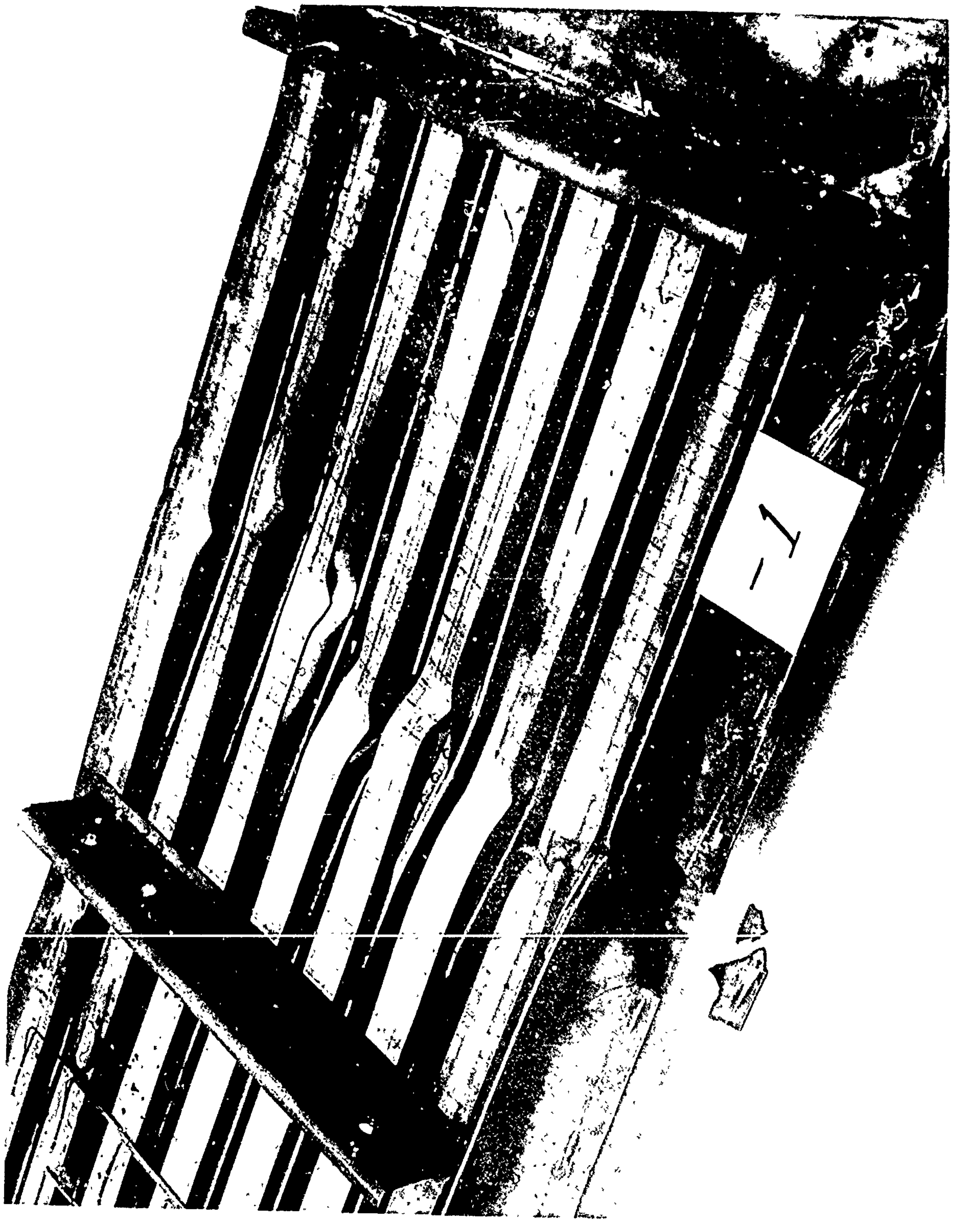
1. Specimen 29-01015-1:

The test specimen sustained all of the imposed test conditions up to 900 F without adverse effects. The temperature was then returned to 600 F. The test load was then increased in increments toward failure. When the load reached 100,000 pounds the internal pressure leakage became excessive and resulted in a gradual loss of pressure. As the test load was increased the pressure loss became greater and resulted in a linear drop in pressure to 4.9 PSIG at failure. The test specimen failed at 149,000 pounds compressive load. The specimen failure occurred in the approximate center of the lower bay. Failure occurred as a result of the buckling of the stringer inner flange. In addition, four of the seven stringers showed shear failures of the stringer webs. The details of this failure are shown in Figure G-17 (page 352).

The results of this test were projected onto the Stress Ratio Diagram shown in Figure G-18 (page 353). The loss of internal pressure was taken into account in projecting these results. The test points on the diagram indicate that the specimen exceeded design expectations with a margin of safety of plus .146.

2. Specimen 29-01015-3:

This test specimen sustained all of the imposed test conditions up to 900 F without adverse effects. When the specimen was loaded to failure excessive pressure leakage started at approximately 75,000 pounds load. As the test load was increased beyond this point, the internal pressure leakage increased until failure occurred. At failure the internal pressure was 4.9 PSIG. The test specimen failed at 122,000 pounds compressive load. The specimen failure occurred in the approximate center of the upper bay. Failure occurred as a result of buckling of the stringer inner flange and shear of the stringer web. This failure is shown in Figure G-19 (page 354). After the test unit was failed a manufacturing defect was observed. This defect was the lack of 7.0 inches of spotweld directly



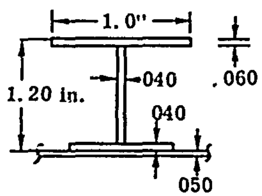
Convair Print 68199

Figure G-17 — FAILURE OF PANEL 29-01015-1; Showing Stringer Back Flange Buckling and Shear Failure of Stringer Web.

A/ LOCAL BUCKLING - REFERENCE NACATN 3782 p. 29
INNER FLANGE AND WEB CRITICAL

$$\sigma_{cr} = \frac{K_w \pi^2 E_c \cdot}{12\,(1-V_e^2)} \quad \frac{t_w^2}{b_w^2} \qquad t_w/t_f = .04/.06 = .667 \qquad b_f/b_w = .48/1.05 = .457$$

$$K_w = 5.40$$



$$\sigma_{cr} = \frac{5.4\pi^2 E_c \cdot \overline{04}^2}{12\,(1-.3^2)\,\overline{1.05}^2} \quad .00707E_c$$

Temperature	E_c	σ_{cr}
R.T.	17.5×10^6	124000 psi
600°	16.0×10^6	113000 psi
900	14.8×10^6	104500 psi

B/ COLUMN ALLOWABLE

$$F_c = F_{cc}\left(1 - \frac{F_{cc}\, l^1/e^2}{4\pi^2 E}\right) \qquad \text{USE } F_{cc} = \sigma_{cr.}; \quad l^1 = 18$$

Temperature	E_c	F_c
R.T.	17.5×10^6	98000 psi
600	16.0×10^6	89400 psi
900	14.8×10^6	82500 psi

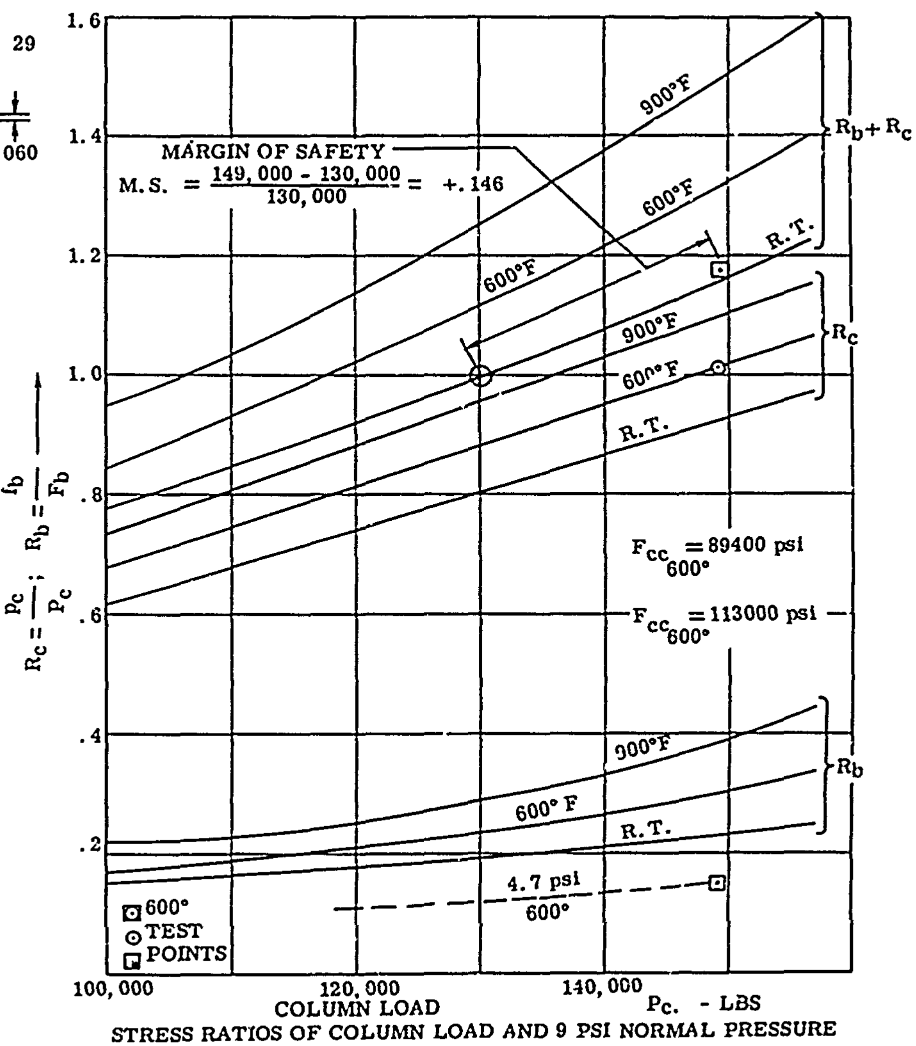
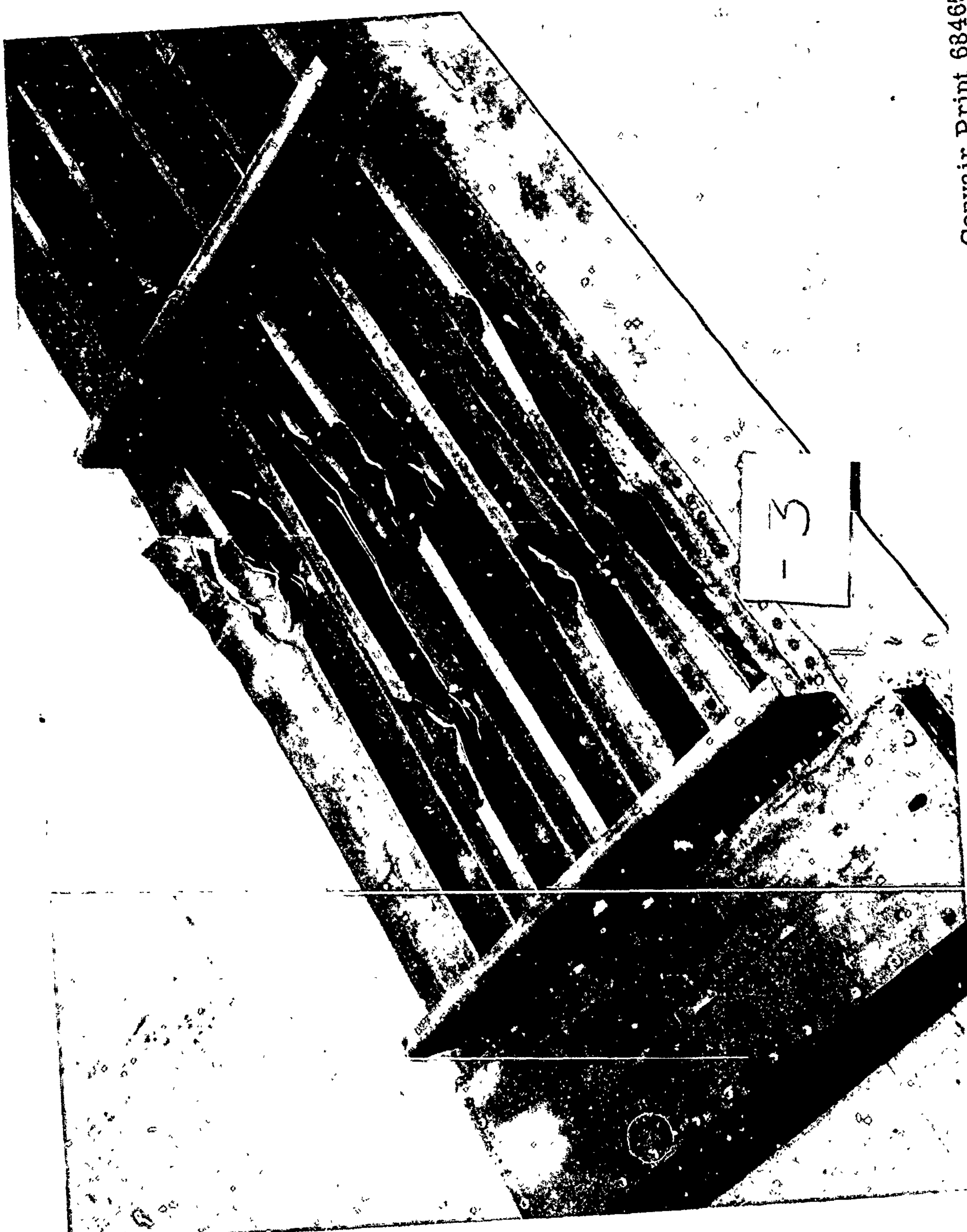


Figure G-18 PANEL DESIGN ALLOWABLES; Panel 29-01015-1



Convair Print 68465

Figure G-19 — FAILURE OF PANEL 29-01015-3; Showing Stringer, Web and Back Flange Failures.

IV. 2. Specimen 29-01015-3: (Cont'd)

under the rib cap attachment between the center and the upper bays. These spotwelds were the stringer to skin attachment. The stringer that was not spotwelded was adjacent to the center stringer. The failure of the specimen occurred in this region. However, since the failure did not occur directly through the center of the unspotwelded section, the effect of the lack of spotwelds is unpredictable.

The results of this test were projected onto the Stress Ratio Diagram shown in Figure G-20 (page 356). The loss of pressure was also taken into account in this projection. The test points on the diagram indicate that the specimen exceeded design expectations with a margin of safety of plus .185.

3. Specimen 29-01015-5:

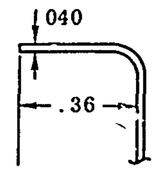
This specimen sustained all of the required conditions. During the failure test on this specimen no internal pressure was applied. The test specimen failed at 198,800 pound compressive load. This specimen failure occurred in the approximate center of the upper bay. Failure occurred as a result of buckling of the skin and shear failure of the stringer web. As a result of these failures the stringer inner flange also failed. The details of this failure are shown in Figure G-21 (page 357). The results of this test were also projected onto the Stress Ratio Diagram in Figure G-22 (page 358). The test points on this diagram indicate that this panel also exceeded design expactations with a margin of safety of plus .073.

4. Discussion:

During the tests of each compression specimen deflections normal to the skin was recorded. These deflections included the deflection of the specimen as well as the movement of the fixture and the test machine relative to the deflection indicator rack. The deflection data was reduced to remove all the extraneous deflections and leave only the true deflections relative to the test fixture. After data reduction the deflection data proved to be small and within the range of test data scatter. Since this data was small and showed no trends relative to the test temperature, this data is not recorded in this report.

A. LOCAL BUCKLING

INNER FLANGE CRITICAL



$$\sigma_{cr.} = KE_c\left(\frac{t}{b}\right)^2$$

$$= .64 \times \left(\frac{.040}{.36}\right)^2 E = .00790E_c$$

Temperature	E_c	σ_{cr}
R.T.	17.5×10^6	138000 psi
600°	16.0×10^6	126000 psi
900°	14.8×10^6	117000 psi

B. COLUMN ALLOWABLE

$$F_c = F_{cc}\left(\frac{1 - F_{cc}\,(l^1/e)^2}{4\pi^2 E}\right) \qquad F_{cc} = \sigma_{cr.};\ l^1 = 18\text{ in.}$$

$$e^2 = .2105$$

Temperature	E_c	σ_{cr}
R.T.	17.5×10^6	95500 psi
600°	16.0×10^6	87200 psi
900°	14.8×10^6	81000 psi

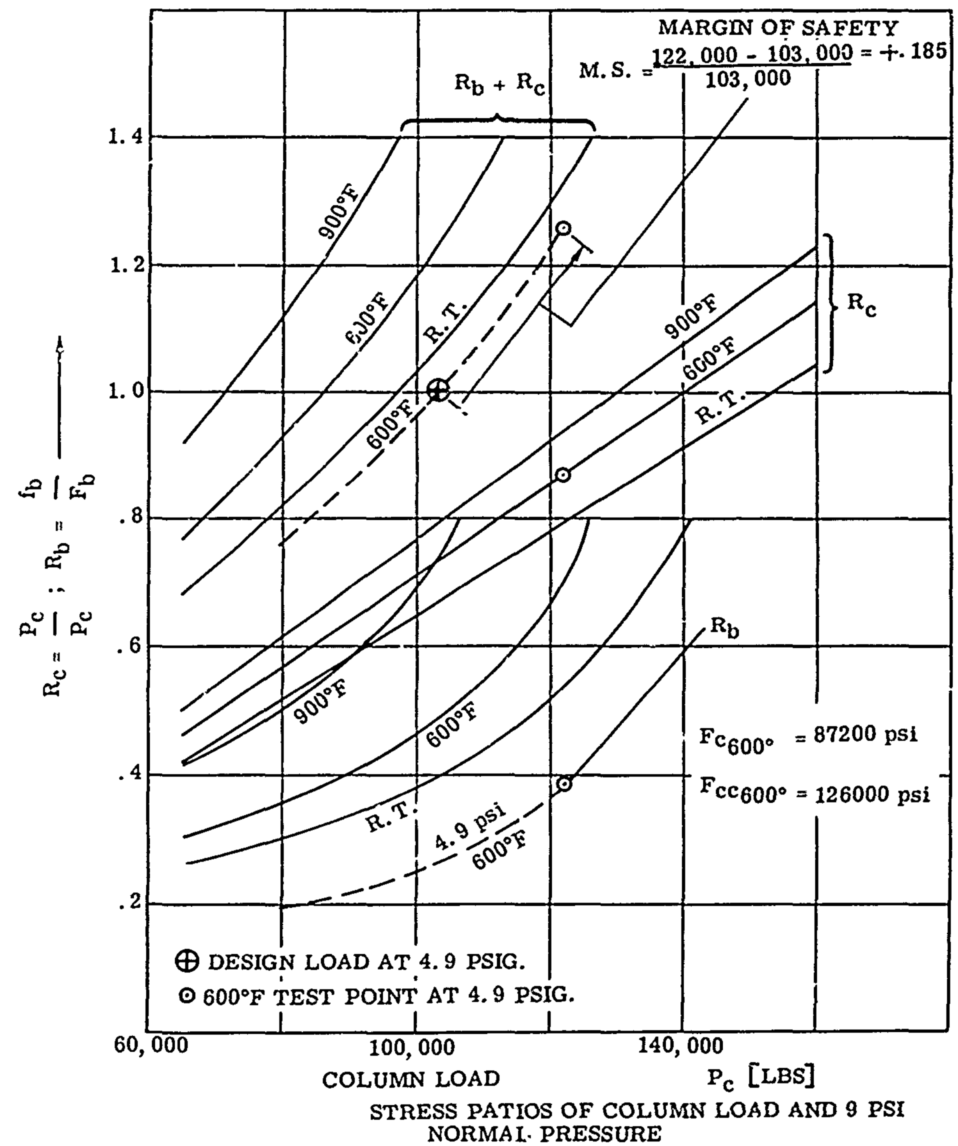
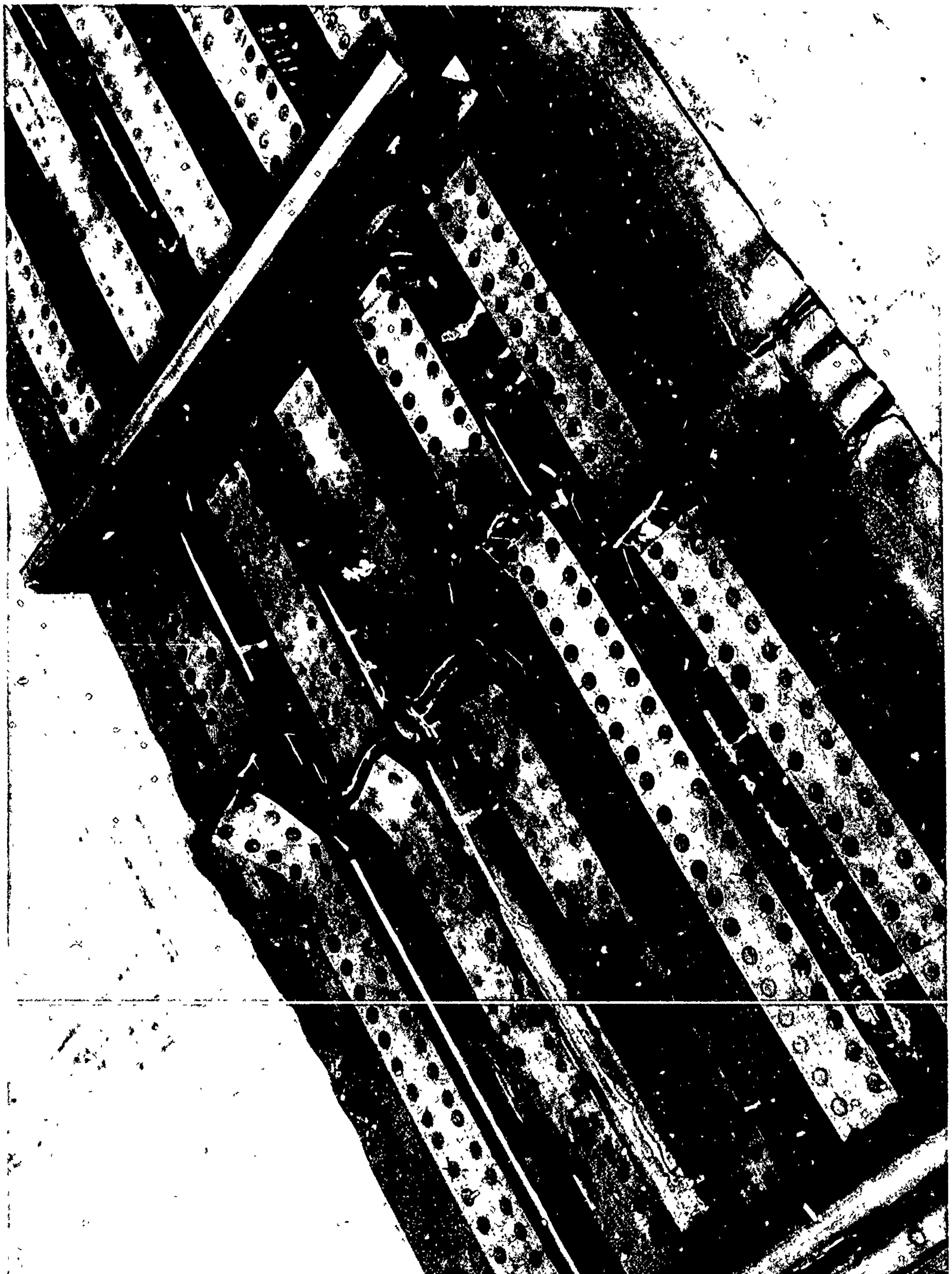


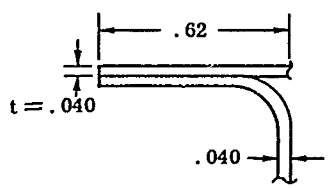
Figure G-20. Panel Design Allowables;
Panel 29-01015-3



Convair Print 68661

Figure G-21 — FAILURE OF PANEL 29-01015-5; Showing Buckled Skin and Back Flanges, As Well As Shear Failures of Webs.

A. LOCAL BUCKLING
INNER FLANGE CRITICAL



$$\sigma_{cr} = KE_c\left(\frac{t}{b}\right)^2$$

$$= .64 \times \left(\frac{.06}{.58}\right)^2 E = .00685E_c$$

TEMPERATURE	E_c	σ_{cr}
R.T	17.5×10^6	120000 psi
600°	16.0×10^6	109500 psi
900°	14.8×10^6	101300 psi

$b = .62 - 040 = .58$
$K = .64$
$t_e = .040 + \frac{04}{2} = .06$

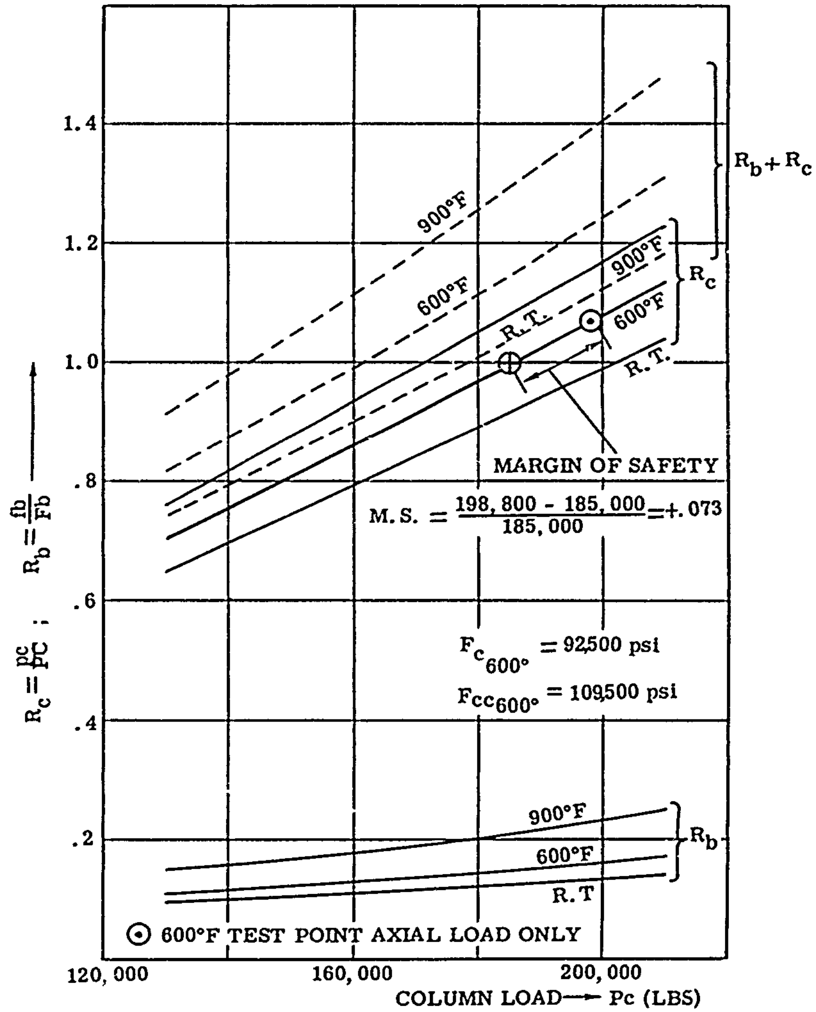
B. COLUMN ALLOWAB: F

$$F_c = F_{cc}\left[1 - \frac{F_{cc}\,(l^1/e)^2}{4\pi^2 E}\right]$$

$F_{cc} = \sigma_{cr}$; $l^1 = 18$

$C^2 = .362$

TEMPERATURE	F_c
R.T	10100 psi
600°	92500 psi
900°	85500 psi



STRESS RATIOS OF COLUMN LOAD AND 9 PSI NORMAL PRESSURE

Figure G-22 PANEL DESIGN ALLOWABLES; Panel 29-01015-5

IV. 4. Discussion: (Cont'd)

The strain gages located on the stringer sections showed that all stringers on all specimens were loading evenly and uniformly up to the point where a stringer strain started decreasing disproportionately indicating an imminent failure. The strain indicated by the strain gages compared closely to the analytic strain based on the compressive modulus as determined by coupons from the test assemblies. Figure G-23 (page 360) shows the average strain versus applied compressive load for each specimen during the failure tests at 600 F. By taking into account the change of the compression modulus (E_c) with temperature the modulus calculated from the indicated strain is within 8.2% of the theoretical adjusted value, Figure G-24 (page 361). Table G-2, below, shows the percentage difference between these values.

Table G-2

STRAIN GAGE INDICATED MODULUS VS. COUPON MODULUS

Specimen Dash No.	Arbitrary Load lbs.	Specimen Gross Area	Strain in/in $x10^{-6}$	Indicated E_c	Coupon E_c @ 600 F	% Diff.
-1	102,620	1.81	3866	14,600,000	15,900,000	-8.2
-3	90,600	1.71	3227	16,400,000	15,600,000	+5.2
-5	128,000	2.11	4035	15,000,000	15,200,000	-1.33

The thermocouples located on the skin and the inner stringer flanges showed that the temperature transport properties of the three stringer configurations were approximately the same up to 600 F. At 600 F the temperature differences start diverging indicating that beyond this point the stringer conductivity shape factor is becoming more effective in determining the transport properties. The skin temperature over the stringer centerline versus the difference between this temperature and the inner flange temperature are shown in Figure G-25 (page 362). The graphs of this figure indicate that anyone of the three types of stringers will conduct approximately the same amount of heat to the inner structure up to 600 F. Therefore, the selection of a stringer design cannot be determined by the temperature transport properties of these configurations.

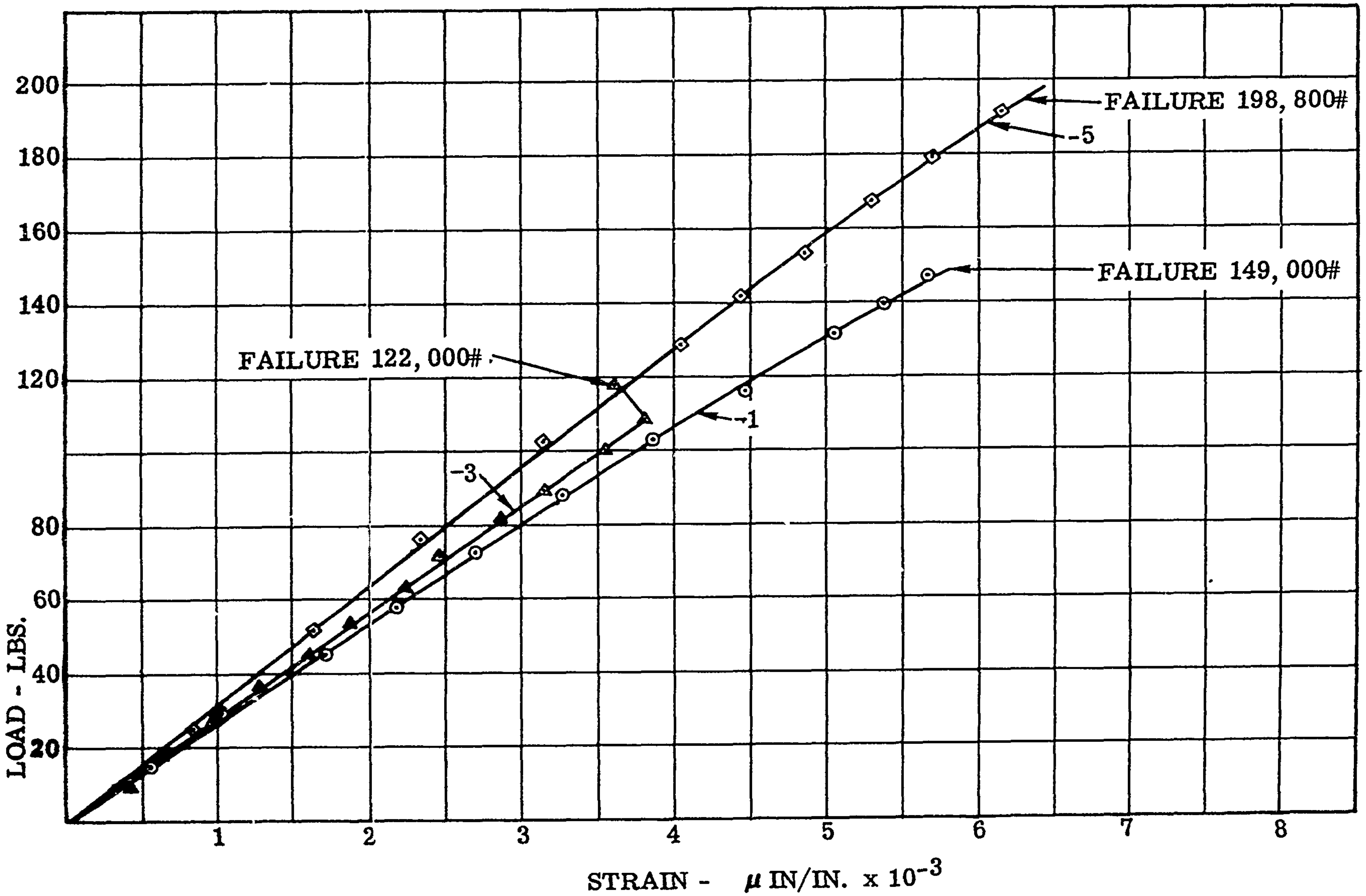


Figure G-23 AVERAGE STRAIN VS. APPLIED COMPRESSIVE LOAD FOR ALL SPECIMENS

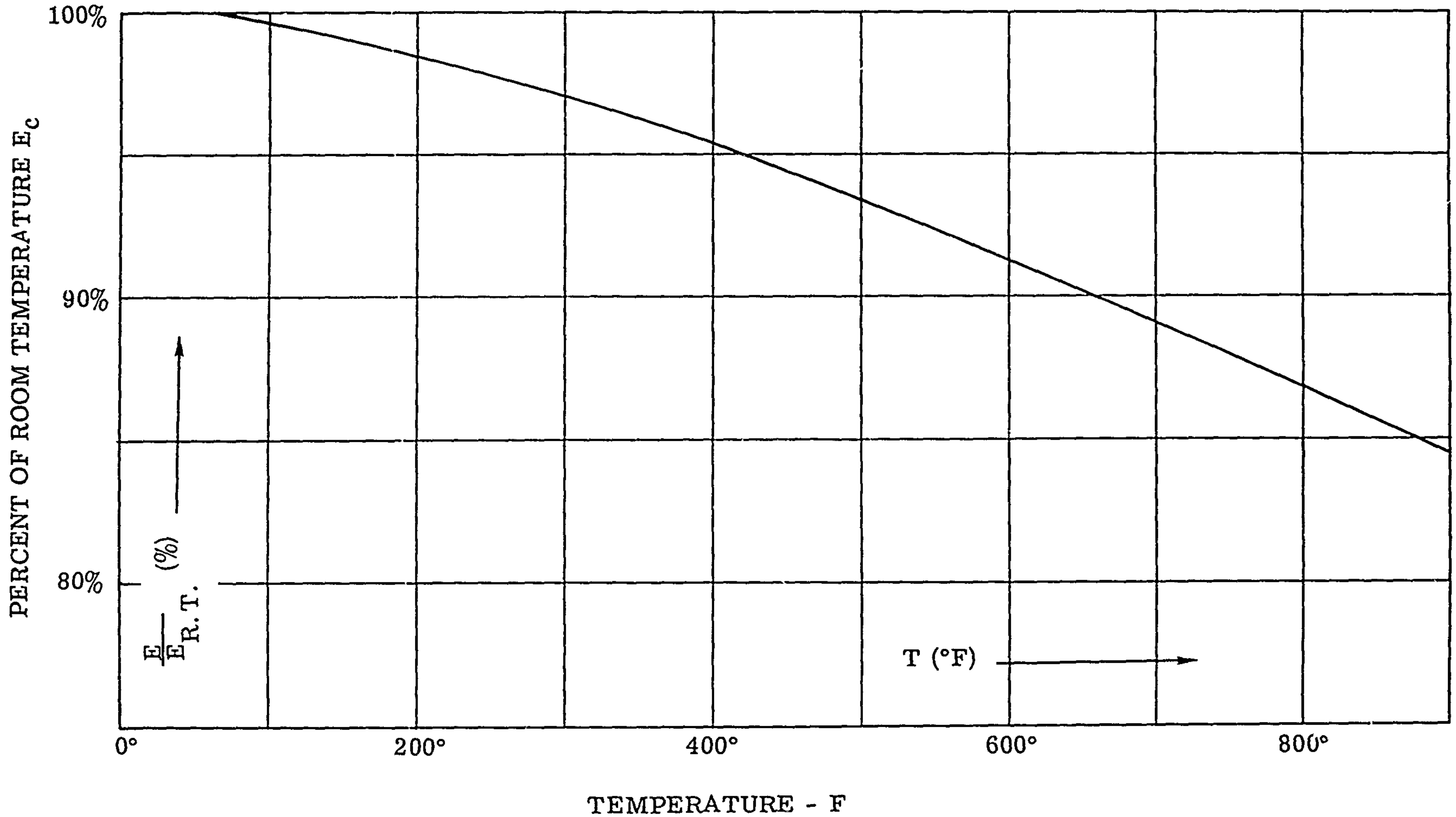


Figure G-24 PREDICTEI TEMPERATURE EFFECT ON MODULUS OF ELASTICITY; Ti Alloy B-120 VCA, $E_c = 17.5 \times 10^6$ PSI

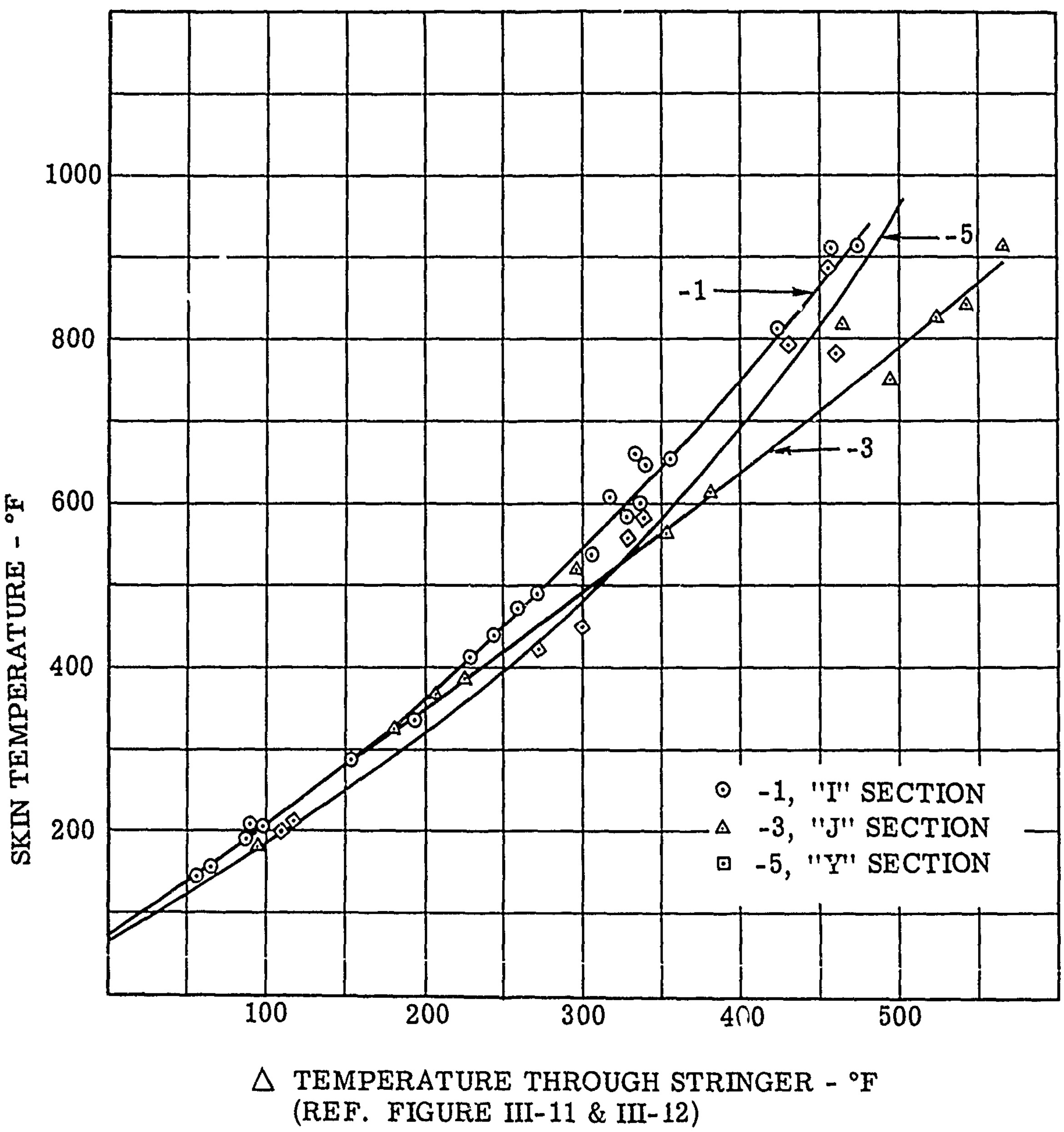


Figure G-25 SKIN TEMPERATURE VS. STRINGER INTERNAL-FLANGE TEMPERATURE

CONVAIR - SD

TITANIUM DEVELOPMENT PROGRAM

DISTRIBUTION LIST

TITANIUM DEVELOPMENT PROGRAM

DISTRIBUTION

MILITARY

Armed Services Technical Information Agency (ASTIA)
Arlington Hall Station
Arlington 12, Virginia - (10 copies)

Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio
Attn: ASRCTF - (6 copies and 1 reproducible)

Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio
Attn: WCLS - Aircraft Lab Project Officer

Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio
Attn: WCRT - Materials Lab Project Officer

Air Force Logistics Command
Wright-Patterson Air Force Base, Ohio
Attn: LMKP (Mr. T. E. Grant)

Assistant Secretary of Defense
Supply and Logistics
Washington 28, D.C.
Attn: Mr. N.D. Tweed

A.M.C. Ballistic Missile Center
Attn: LBTR Mr. F. Becker
A.F. Unit
P.O. Los Angeles 45, California

Director Naval Research Laboratories
Attn: Code 2021
Washington 25, D.C.

Commanding Officer
Ordnance Materials Research Office
Watertown Arsenal
Attn: N. L. Reed, Asst. Director
Watertown 72, Mass.

DEPARTMENT OF DEFENSE TITANIUM ALLOY SHEET ROLLING PROGRAM - MATERIALS ADVISORY BOARD PANEL

CHAIRMAN:

Dr. W.J. Harris, Jr.
Executive Director
Materials Advisory Board
National Academy of Sciences
2101 Constitution Avenue
Washington 25, D.C.

PANEL MEMBERS:

Dr. George Gerard, Asst. Director
Research Division
New York University
New York 53, N.Y.

Mr. P.J. Hughes
Lockheed Aircraft Corporation
Structural Research Laboratory
Marietta, Georgia

Dr. R.I. Jaffee
Nonferrous Physical Metallurgy Div.
Batelle Memorial Institute
505 King Avenue
Columbus 1, Ohio

Mr. Paul Maynard, Metallurgist
North American Aviation, Inc.
Columbus, Ohio

Mr. A.R. Mead, Metallurgical Engr.
Grumman Aircraft Engineering Co.
Bethpage, Long Island, N.Y.

Dr. D.J. McPherson, Asst. Mgr.
Metals Research Department
Armour Research Foundation
Illinois Institute of Technology
10 West 35th Street
Chicago 16, Illinois

Associate Director
Metallurgical Research Laboratories
Syracuse University Research Institute
Syracuse, New York

Mr. Y.J. Elizondo
Engineering Department
Chance Vought Aircraft, Inc.
Dallas, Texas

Mr. Winston H. Sharp, Metallurgist
Engineering Department
Pratt & Whitney Aircraft Corporation
East Hartford 8, Connecticut

Mr. L.P. Spalding, Section Head
Materials - North American Aviation, Inc.
International Airport
Los Angeles 45, California

Mr. W.O. Sunafrank, Project Engineer
Department 23-2
Convair - Division of General Dynamics
Fort Worth, Texas

Mr. Robert Wichser, Chief Research Engineer
Republic Aviation Corporation
Farmingdale, Long Island, N.Y.

Dr. William Youden, Consultant
National Bureau of Standards
Washington 25, D.C.

CONVAIR - SD

DEPARTMENT OF DEFENSE TITANIUM ALLOY SHEET ROLLING PROGRAM - MATERIALS ADVISORY BOARD PANEL

MILITARY LIAISON:

Mr. S.V. Arnold
Physical Metallurgy Division
Watertown Arsenal Laboratory
Watertown, Massachusetts

Mr. H.J. Boertzel, BuAer
Department of the Navy
Washington 25, D.C.

Headquarters
Wright Air Development Center
Wright-Patterson Air Force Base, Ohio
Attn: Mr. Edward Dugger
Materials Laboratory

Chief, Materials Division
Office, Director of Research and Engineering
The Pentagon
Washington 25, D.C.

Chief, BuAer
Code Aer-AE-4
Department of the Navy
Washington, D.C.
Attn: Mr. N.E. Promisel, Head
Materials Branch
Airborne Equipment Division

PRODUCER REPRESENTATIVES:

Director of Research
Mallory-Sharon Titanium Corporation
Niles, Ohio

Mr. H.D. Kessler
Titanium Metals Corp. of America
P.O. Box 718
Toronto, Ohio

Mr. R.F. Malone, Supervisor
Pilot Production Research
Crucible Steel Company of America
Midland, Pennsylvania

Mr. T. Perry
Central Alloy District
Republic Steel Corporation
Massillon, Ohio

OTHERS:

Mr. Leslie R. Gould, Staff Metallurgist
National Academy of Sciences
Materials Advisory Board
2101 Constitution Avenue
Washington 25, D.C.

Mr. H.R. Ogden
Defense Metals Information Center
Batelle Memorial Institute
505 King Avenue
Columbus 1, Ohio

CORPORATIONS:

Aerojet-General Corporation
Attn: Kenneth F. Mundt,
Vice President, Manufacturing
6352 North Irwindale Avenue
Azusa, California

Aeronca Manufacturing Corporation
Attn: Mr. E.V. Gustafson,
Director of Engineering
Middleton, Ohio

AiResearch Manufacturing Company
Attn: Harris W. Young
Factory Manager
9851 Sepulveda Boulevard
Los Angeles 45, California

Allison Division
General Motors Corporation
Attn: Mr. L.E. Batchellor
Master Mechanic
Attn: Mr. E.D. Berlin
Exp. Process Dev.
P.O. Box 894
Indianapolis, Indiana (2 copies)

Battelle Memorial Institute
Attn: Defense Materials Information
Center
505 King Avenue
Columbus, Ohio

Bell Aircraft Corporation
Attn: R. W. Varrial, Manager
Production Engineering
P.O. Box 1
Buffalo 5, New York

Bell Aircraft Corporation
Attn: M.D. Ellett, Manager
Production Engineering
P.O. Box 482
Fort Worth 1, Texas

Bendix Products Division
Bendix Aviation Corporation
Attn: A.J. Walsh, Staff Assistant
401 Bendix Drive
South Bend, Indiana

Boeing Airplane Company
Attn: Fred P. Laudan
Vice President
Mfg. Hq. Office
P.O. Box 3707
Seattle 24, Washington

Boeing Airplane Company
Attn: Boyd K. Bucey, Assistant to
Vice President, Manufacturing
P.O. Box 3707
Seattle 24, Washington (2 copies)

Boeing Airplane Company
Wichita Division
Attn: W.W. Rutledge
Manufacturing Manager
Wichita, Kansas

Cessna Aircraft Company
Attn: Del Roskam, Vice President
Wichita, Kansas

Cessna Aircraft Company
Attn: R.L. Lair, Plant Manager
Prospect Plant
Wichita, Kansas

Chance Vought Aircraft, Inc.
Attn: Chief Librarian,
Engineering Library
Dallas, Texas

Cleveland Pneumatic Tool Company
Attn: Fred W. Olsen, Assist. to Vice
Pres., General Manager
3781 E. 77th Street
Cleveland 5, Ohio

CORPORATIONS: (Cont'd)

Continental Aviation and Engrg. Corp.
1470 Algonquin Street
Attn: Mr. James D. Finnucan, Vice President in Charge of Mfg.
Detroit, Michigan

Curtiss-Wright Corporation
Attn: Vice President of Manufacturing
Wood Ridge, New Jersey

Curtiss-Wright Corporation
Metals Processing Division
760 Northland Avenue
Attn: General Manager
Buffalo, New York

Curtiss-Wright Propeller Division
Fairfield Road
Attn: Mr. J.H. Sheets, Works Manager
Caldwell, New Jersey

Curtiss Wright Corporation
Wright Aeronautical Division
Attn: Mr. F.W. Mencik, Vice President of Manufacturing
Wood Ridge, New Jersey

Douglas Aircraft Company, Inc.
Attn: N.H. Shappel, Works Manager
3000 Ocean Park Boulevard
Santa Monica, California

Douglas Aircraft Company, Inc.
Attn: O.L. Rumble, Tooling Mgr.
3855 Lakewood Boulevard
Long Beach 8, California

Douglas Aircraft Corporation, Inc.
Attn: S.D. Truhan, Production Design Engineer
2000 N. Memorial Drive
Tulsa, Oklahoma

Fairchild Aircraft Division
Fairchild Engine & Airplane Corp.
Attn: A.D. Jairett, Manager of Tool Engineering and Mfg.
Hagerstown, Maryland

Flight Refueling, Inc.
Attn: Walter Venghaus, Manufacturing Manager
Friendship International Airport
Box 1701
Baltimore 3, Maryland

General Electric Company
P.O. Box 196, Building 100
Attn: Mr. Robert L. Grunewald, Manager, EOD Components
Cincinnati 15, Ohio

Glenn L. Martin Company
Attn: Chief Librarian, Engineering Library
Baltimore 3, Maryland

Goodyear Aircraft Corporation
1210 Massillon Road
Attn: Engineering Library Dept. 277 - Plant G
Akron, Ohio

Grumman Aircraft Engineering Corp.
Attn: William J. Hoffman Vice President - Manufacturing
Bethpage, Long Island, New York

Hiller Helicopters
Attn: Engineering Library
1350 Willow Road
Palo Alto, California

CORPORATIONS (Cont'd)

Hughes Tool Co., Aircraft Division
Attn: William W. Lampkin,
Director of Manufacturing
Florence Avenue at Teale Street
Culver City, California

Hughes Aircraft Company
Attn: J. Ferderber
2060 E. Imperial Highway
El Segundo, California

Hughes Aircraft Company
Attn: D. F. Davern
Chief Tool Engineer
Tucson, Arizona

Jack & Heintz, Inc.
Attn: Jack L. McGinnis
Assistant Works Manager
17600 Broadway
Cleveland 1, Ohio

Lear, Inc.
Attn: A.F. Haiduck, Executive Vice
President - Manufacturing
110 Ionia, N.W.
Grand Rapids, Michigan

Lear, Inc.
Lear Romec Division
Attn: W.T. Miles,
Production Manager
Abbe Road
Elyria, Ohio

Lear, Inc., Learcal Division
Attn: D.W. Dressel,
Factory Manager
3171 S. Bundy Drive
Santa Monica, California

Lockheed Aircraft Corporation
Attn: H. Caldwell, Mfg. Manager
P.O. Box 511
Burbank, California

Lockheed Aircraft Corporation
Attn: H. Fletcher Brown
Manufacturing Manager
Marietta, Georgia

Lycoming Division
AVCO Manufacturing Corporation
Attn: Mr. W.A. Panks
Superintendent, Mfg. Engrg.
Stratford, Connecticut

Marquardt Aircraft Company
16555 Saticoy Street
Attn: Mr. John D. Liefeld,
Director of Manufacturing
Van Nuys, California

Marquardt Aircraft Company
Box 670
Attn: Mr. Eugene L. Klein,
Chief Manufacturing Engr.
Ogden, Utah

McDonnel Aircraft Corporation
Attn: A.F. Hartwig, Chief
Industrial Engineer
Lambert
St. Louis Municipal Airport
St. Louis 3, Missouri

North American Aviation, Inc.
Attn: W. E. Fore, Plant Engineer
International Airport
Los Angeles 45,
California

CORPORATIONS (Cont'd)

Northrop Aircraft, Inc.
Attn: F.W. Lloyd, Vice. Pres. - Mfg.
1001 E. Broadway
Hawthorne, California

Parker Aircraft Company
Attn: Robert H. Davies, Vice Pres.
17352 Euclid Avenue
Cleveland 12, Ohio

Pratt & Whitney
United Aircraft Corporation
Attn: Mr. W.P. Gwinn
Hartford 3, Connecticut

Radioplane Company
Attn: F.D. Murphy, Manager
Engineering Adm. Department
8000 Woodley Avenue
Van Nuys, California

Rem-Cru Titanium, Inc.
Attn: Dr. W.C. Finaly
Midland, Pennsylvania

Republic Aviation Corporation
Attn: Adolph Kastelowitz, Chief,
Mfg. Engineering
Farmingdale, Long Island, N.Y.

Rohr Aircraft Corporation
Attn: Burt F. Raynes, Vice Pres. Mfg.
P.O. Box 878
Chula Vista, California

Ryan Aeronautical Company
Attn: Lawrence M. Limbach
Vice President, Manufacturing
2701 Harbor Drive
San Diego 12, California

Sikorsky Aircraft Division
United Aircraft Corporation
Attn: Alex Sperber, Factory Manager
North Main Street
Stratford, Connecticut

Solar Aircraft Company
Attn: J.A. Logan, Manager
Facilities Division
2200 Pacific Highway
San Diego 12, California

Solar Aircraft Corporation
Attn: William Dixon, Manager
Production Engineering Division
1900 Bell Avenue
Des Moines 5, Iowa

Sperry Gyroscope Company - Div. of
Sperry Rand Corporation
Attn: G.A. Richroath,
Vice Pres. of Manufacturing
Great Neck, New York

Temco Aircraft Corporation
Attn: V.N. Ferguson, Mfg. Manager
P.O. Box 6191
Dallas, Texas

Temco Aircraft Corporation
Engineering Library
Department 413D
P.O. Box 6191
Dallas, Texas

Temco Aircraft Corporation
Attn: E.F. Bushring
Plant Manager
P.O. Box 1056
Greenville, Texas

CORPORATIONS (Cont'd)

Thiokol Chemical Corporation
Reaction Motors Division
Attn: Contracts Department
Danville, New Jersey

Thompson Products, Inc.
Attn: Emil F. Gibian, Staff
Director, Ind. Engineering
23555 Euclid Avenue
Cleveland 17, Ohio

Titanium Metals Corporation
Attn: Mr. W. Minkler
233 Broadway
New York 17, New York

Westinghouse Electric Corporation
P.O. Box 228 ACT Division
Attn: Mr. E.C. Sedlack,
Works Manager
Kansas City, Missouri

Westinghouse Electric Corporation
Air Arm Division
Friendship International Airport
Attn: Mr. F.E. Tighe, Manager
Manufacturing Engineering
and Tools
Baltimore 27, Maryland

CONVAIR - A Division of General Dynamics Corporation, San Diego, Calif.

TITANIUM DEVELOPMENT PROGRAM - Vol. V., by G.D. Lindeneau, D.H. Love, J.K. Neary, et al. May 1961.
362 p. incl. illus. tables (Project 7-756) (ASD TR 61-7-756) (Contract AF33(600)34876)
Unclassified Report.

Typical airframe structures of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increments of 100 degrees from room temp. to either 800 F or 900 F. Riveted and resistance welds were evaluated on some. Others were fusion welded, or brazed. Parts were subjected to static and repeated loadings. All satisfactorily withstood static test loads.

UNCLASSIFIED

A. Bulkhead
B. Wing Leading Edge
C. Bleed Air Ducts
D. Shear Panels
E. Compression Panels
F. Tail Cone
G. Plate Stringer Comp. Panel

I. Lindeneau, G.D., Love, D.H., et al.
II. Convair, A Division of General Dynamics Corporation
III. Contract AF33(600) 34876
IV. ASD Project 7-576

UNCLASSIFIED

CONVAIR - A Division of General Dynamics Corporation, San Diego, Calif.

TITANIUM DEVELOPMENT PROGRAM - Vol. V, by G.D. Lindeneau, D.H. Love, J.K. Neary, et al. May 1961.
362 p. incl. illus. tables (Project 7-756) (ASD TR 61-7-756) (Contract AF 33(600)34876)
Unclassified Report.

Typical airframe structures of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increments of 100 degrees from room temp. to either 800 F or 900 F. Riveted and resistance welds were evaluated on some. Others were fusion welded, or brazed. Parts were subjected to static and repeated loadings. All satisfactorily withstood static test loads.

UNCLASSIFIED

A. Bulkhead
B. Wing Leading Edge
C. Bleed Air Ducts
D. Shear Panels
E. Compression Panels
F. Tail Cone
G. Plate Stringer Comp. Panel

I. Lindeman, G.D., Love, D.H., et al.
II. Convair, A Division of General Dynamics Corporation
III. Contract AF33(600) 34876
IV. ASD Project 7-576

UNCLASSIFIED

CONVAIR - A Division of General Dynamics Corporation, San Diego, Calif.

TITANIUM DEVELOPMENT PROGRAM - Vol. V, by G.D. Lindeneau, D.H. Love, J.K. Neary, et al. May 1961.
362 p. incl. illus. tables (Project 7-756) (ASD TR 61-7-756) (Contract AF 33(600)34876)
Unclassified Report.

Typical airframe structures of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increments of 100 degrees from room temp. to either 800 F or 900 F. Riveted and resistance welds were evaluated on some. Others were fusion welded, or brazed. Parts were subjected to static and repeated loadings. All satisfactorily withstood static test loads.

UNCLASSIFIED

A. Bulkhead
B. Wing Leading Edge
C. Bleed Air Ducts
D. Shear Panels
E. Compression Panels
F. Tail Cone
G. Plate Stringer Comp. Panel

I. Lindeman, G.D., Love, D.H., et al.
II. Convair, A Division of General Dynamics Corporation
III. Contract AF 33(600) 34876
IV. ASD Project 7-576

UNCLASSIFIED

CONVAIR - A Division of General Dynamics Corporation, San Diego, Calif.

TITANIUM DEVELOPMENT PROGRAM - Vol. V, by G.D. Lindeneau, D.H. Love, J.K. Neary, et al. May 1961.
Unclassified Report.

Typical airframe structures of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increments of 100 degrees from room temp. to either 800 F or 900 F. Riveted and resistance welds were evaluated on some. Others were fusion welded, or brazed. Parts were subjected to static and repeated loadings. All satisfactorily withstood static test loads.

UNCLASSIFIED

A. Bulkhead
B. Wing Leading Edge
C. Bleed Air Ducts
D. Shear Panels
E. Compression Panels
F. Tail Cone
G. Plate Stringer Comp. Panel

I. Lindeman, G.D., Love, D.H., et al.
II. Convair, A Division of General Dynamics Corporation
III. Contract AF 33(600) 34876
IV. ASD Project 7-576

UNCLASSIFIED

Under repeated load test, resistance welded fuselage frame and wing leading edge, although adequate, were not equal to those riveted. Repeated loading of resistance welded shear panels gave marginal results. Other components were satisfactory under repeated loads.

UNCLASSIFIED

V. Fabrication Branch
Manufacturing
Technology
Laboratory

UNCLASSIFIED

Under repeated load test, resistance welded fuselage frame and wing leading edge, although adequate, were not equal to those riveted. Repeated loading of re-slatance welded shear panels gave marginal results. Other components were satisfactory under repeated loads.

UNCLASSIFIED

V. Fabrication Branch
Manufacturing
Technology
Laboratory

UNCLASSIFIED

Under repeated load test, resistance welded fuselage frame and wing leading edge, although adequate, were not equal to those riveted. Repeated loading of resistance welded shear panels gave marginal results. Other components were satisfactory under repeated loads.

UNCLASSIFIED

V. Fabrication Branch
Manufacturing
Technology
Laboratory

UNCLASSIFIED

Under repeated load test, resistance welded fuselage frame and wing leading edge, although adequate, were not equal to those riveted. Repeated loading of resistance welded shear panels gave marginal results. Other components were satisfactory under repeated loads.

UNCLASSIFIED

V. Fabrication Branch
Manufacturing
Technology
Laboratory

UNCLASSIFIED